Soil Fertility Guide

Factors Affecting Plant Growth

Many factors influence plant growth, some of the most important ones are:

Climate

The daily and seasonal supply and distribution of moisture, heat, sunlight, wind, and frost provide varieties of regional and local climatic environments. Such environments directly influence the growth, quality, and maturity of crops. Also, indirectly they may affect the severity of many plant diseases and pest infestations.

At present, sufficiently accurate definition and delineation of local specific crop geolimatic environments is difficult and incomplete. There is, however, much that can be done to take advantage of favorable elements of the climate. Successful farmers can select plant species and varieties within species to suit the local climate. They can, at least to a degree, modify local field and soil climates by protective hedges, land drainage, tillage practices, and the use of crop residues or snow barriers to reduce the severity of winters to biennial and perennial plants. The application of many fertilizer, fungicide, and pesticide treatments can be adjusted to weather conditions.

Soil

Crop production capacity is greatly influenced by soil quality. Soil quality is determined by physical and chemical characteristics, some of which may or may not be economically controlled. Many of the physical proper- ties such as texture, slope, and soil depth, cannot be modified economically by the farmer. Yet, these factors determine the suitability of a soil for agricultural production. In general, for the cool moist climate of Atlantic Canada, the most desirable soils are friable, well-drained sandy loam or loams on relatively level to gently rolling topography.

Chemical characteristics that affect soil quality are: acidity, organic matter content and supply of essential plant nutrients. In general, if physical properties are satisfactory, the chemical properties can be modified by adequate use of agricultural limestone, manures, commercial fertilizers, green manure plow downs and other organic additives.

Micro-organisms

Soil micro-organisms (bacteria, yeasts, fungi, algae, protozoa, etc.) are present in soils that furnish them with food and water plus a suitable place to live. Their food is the energy material turned over to the soil in the form of plant and animal residues.

As soil micro-organisms decompose organic matter, they release its nitrogen, phosphorus, and other mineral nutrients in forms available to crops. In addition, the decomposing organic matter improves soil tilth, increases the moisture holding capacity, and lessens loss of soil.

Crop Sequence

Traditionally, farmers have been encouraged to adopt and follow crop rotations designed for their specific type of farm operation. Crop production programs were less intensive and only "key" crops in the rotation were fertilized. The main advantages claimed for crop rotations were better control of insects, diseases, and weeds, and better maintenance of soil structure.

Farmers are now encouraged to adopt different cropping systems on different soils for maximum production. Certain fields, which are particularly suited, may be used for cash crops. Other fields may need to be maintained in continuous forage production and still others may be used in a rotation of several crops. This enables more flexibility in the cropping program from year to year, as warranted by changing feed requirements, and changing cash crop opportunities. However, to successfully carry out such a program requires adequate fertilization of each crop, plant disease, insect and weed control measures, as well as provision of organic matter in soils used for continuous production of inter-tilled crops. The cropping program should, over the long term, maintain or improve the productive capacity of the soil.

Lime and Fertilizer

Most soils in the Atlantic Provinces are, by nature, very acid and low in available plant nutrients. Thus in planning a crop production program, agricultural limestone should be applied at the rate required to raise the soil pH to the optimum level for the crops which are to be grown, and the right kinds and amounts of commercial fertilizers and/or farm manures must be applied to supplement the essential plant nutrients in the soil.

Crop Management

In addition to the foregoing, a successful crop production program is influenced by soil preparation, seeding date, tillage, weed and pest control, time and placement of fertilizer applications, grazing practices, harvesting dates, etc.

The program must be designed to supply the requirements of each individual crop on each farm.

Soils and Climate

The Nature and Development of Soils

The soil is a natural body on the surface of the earth in which plants grow. All soils are composed of mineral and organic matter, water, and air in varying proporations.

Soils develop as a result of the interaction of climate (temperature and rainfall), unconsolidated rock material, organisms (plants, animals, and microorganisms), topography, and time. Climate is the major factor in soil development since it determines the rate of decomposition of minerals, the amount of leaching, and the kind of organisms that can thrive in an area. The other factors have a modifying influence on the effect of climate in soil formation.

The interaction of the soil-forming factors produces changes with soil depth which can be seen in a vertical section of **soil profile**. These changes result in the formation of layers, or **horizons**, extending downward one below the other, more or less parallel to the surface. Most soils have three main horizons called A, B and C from the surface downwards. The A horizon is the zone of maximum removal of materials by leaching. The B horizon is the zone of maximum accumulation of materials, and the C horizon is the relatively unaltered parent material. Some young soils lack a B horizon.

In the Atlantic region, generally the well-drained soils belong to the Podzolic order. Under forest they have relatively thin organic surface horizons, a light colored leached horizon (Ae) underlain by a darker colored horizon (B) which grades into the parent material (C). When cultivated, the Ae horizon is mixed with the organic surface horizons. Since the soil has depth and breadth as well as area, the horizon characteristics may vary horizontally as well as vertically. Within a chosen range of characteristics, there will be a number of soil individuals with horizons sufficiently alike that they are together called a soil series. Soil series are given names to indicate the area where they were first established, e.g. - Halifax series. To a person familiar with soils, the series name Halifax, for example, conveys a "concept" of topography, drainage, profile characteristics, and generalizations about plant nutrient status and crop productivity.

Kinds of Soil

There are two major kinds of soil material, mineral and organic. Organic soils are developed mainly from organic deposits and contain 30% or more organic matter. All others are considered as mineral soils.

In the Atlantic Provinces the greater proportion of soils are mineral. The materials, from which most of them developed, were deposited by glacial ice in the form of boulder till, sands, gravels, and fine-textured sediments that settled out in glacial lakes. The materials that make up the floodplains along river courses, and the marshlands and dykelands of the river estuaries are of more recent origin. These soils differ from the upland soils in being stone free, less leached, and usually better supplied with nutrients. They usually have not been in place long enough to develop horizons, except a surface layer.

The term "texture" as related to soils refers to the size of soil particles. Many soil properties are readily associated with the well known textural classes, sand, silt and clay. Particles from 2 to .05 mm in diameter are called sand, those from .05 to.002 mm are called silt, and those below .002 mm are called clay. (1 inch equals 25.4 mm).

Figure 1 shows the relation between the various textural classes which are called clay (C), silty clay (SiC), sandy clay (SC), silty clay loam (SiCL), clay loam (CL), sandy clay loam (SCL), silt loam (SiL), loam (L), sandy loam (SL), loamy sand (LS), sand (S), and silt (Si).

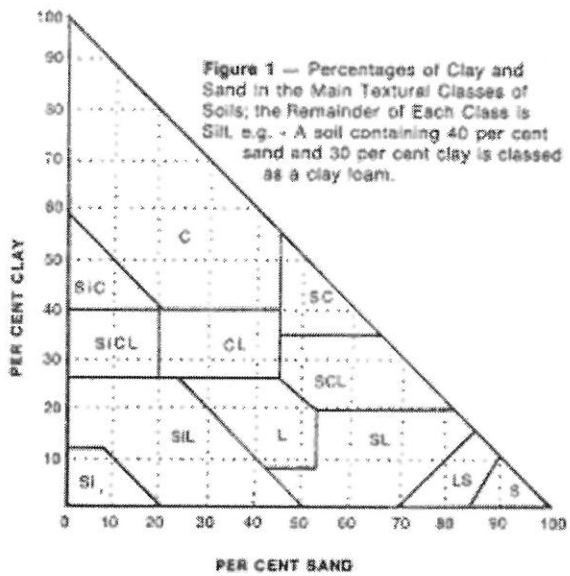

Figure 1 — Percentages of Clay and Sand in the Main Textural Classes of Soils; the Remainder of Each Class is Silt, e.g. - A soil containing 40 per cent sand and 30 per cent clay is classed as a clay loam.

Soil Survey and Classification of Atlantic Region Soils

The purpose of the soil survey is to make a systematic examination of soils in the field and laboratory, to prepare maps showing their location and distribution, to classify the soils, to describe their properties, and provide an inventory of this important natural resource. This information can be used to group soils of similar properties for various purposes.

Soil surveys have been completed for all of Prince Edward Island and Nova Scotia, three quarters of New Brunswick, and a part of Newfoundland. To date, over 12 million hectares (30 million acres) have been mapped. In addition, all of Prince Edward Island and parts of other provinces have, or are being surveyed in more detail. The index to soil surveys is shown in Figure 2 and 3.

NEW BRUNSWICK — NOVA SCOTIA — PRINCE EDWARD ISLAND
INDEX TO SOIL SURVEYS, JANUARY 1980.

Cartography by the Land Resource Research Institute,
Research Branch, Agriculture Canada, 1974.
Reprinted 1981.

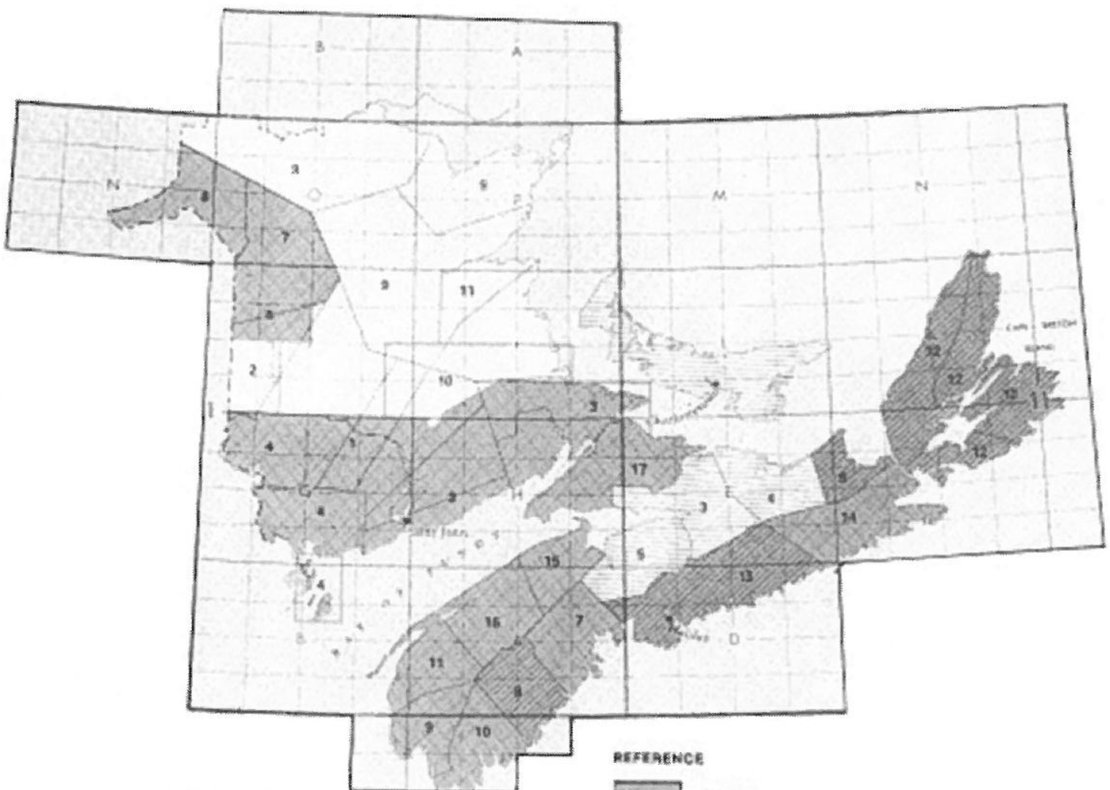

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Figure 2 -Soil Survey Map of Maritime Provinces

NOVA SCOTIA

REPORT NO.	COUNTY	SCALE	PUBLISHED
3	Colchester	1:126,720 1:50,000	1948
4	Pictou	1:126,720 1:50,000	1950
5	Hants	1:126,720 1:50,000	1954, 1979
6	Antigonish	1:126,720 1:63,360	1954 1979
7	Lunenberg	1:63,360	1958
8	Queens	1:63,360	1959, 1979
9	Yarmouth	1:63,360	1960
10	Shelburne	1:63,360	1961
11	Digby	1:63,360	1962
12	Cape Breton Island (Inverness, Victoria-Cape Breton, Richmond Counties)	1:84,480 1:100,000	1963 1980
13	Halifax	1:63,360 1:50,000	1963 1980
14	Guysborough	1:63,360	1963
15	Kings	1:63,360	1966
16	Annapolis	1:63,360	1968
17	Cumberland	1:63,360	1973

NEW BRUNSWICK

REPORT NO.	AREA	SCALE	PUBLISHED
1	Fredericton-Gagetown	1:95,040	1941
2	Woodstock	1:63,360	1944
3	Southeastern New Brunswick	1:126,720	1953
4	Southwestern New Brunswick	1:126,720	1953
5	Andover-Plaster Rock	1:63,360	1963
7	*Victoria	1:63,360	1974
8	*Madawaska	1:50,000	1980
9	**Central and Northeast New Brunswick	1:250,000	
10	**Chipman-Harcourt	1:50,000	
11	**Richibucto-Rogersville	1:50,000	

*Bilingual legend
Légende bilingue
**Report number not available

PRINCE EDWARD ISLAND

	SCALE	PUBLISHED
Prince Edward Island	1:126,720 1:75,000 1:10,000	1965

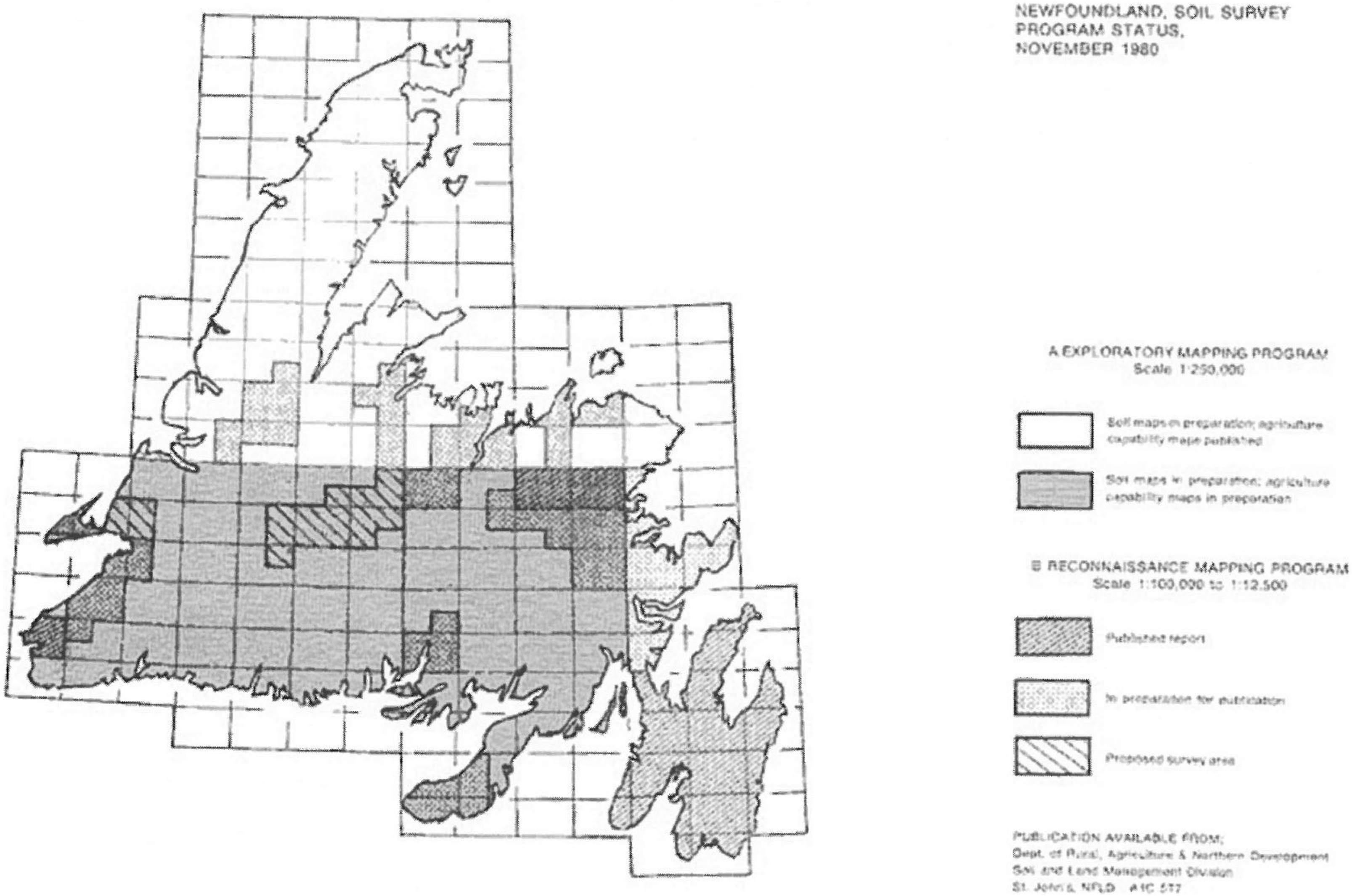


Figure 3 - Soil Survey Map of Newfoundland

Land Use Capability Classification of Soils

The suitability of soils for crop production is limited by such factors as slope, stoniness, susceptibility to erosion and flooding, inherent physical characteristics, shallowness, and wetness. Any one or a combination of these factors may determine most appropriate land use. The method now used in Canada to classify soils for use in agriculture, groups the soils into 7 classes. The soils in each class have the same degree of limitations and risks for crop use increase from Class 1 to Class 7. Class 1 soils soils have few or no limitations, and Classes I to 3 are suitable for the sustained production of cultivated field crops, but the range of crops in Class 3 is less than in Class 1. Class 4 soils are limited in use for cultivated field crops. Soils in Classes 5 and 6 are not suitable for cultivated crops. However Class 5 soils may be used for improved permanent pasture and Class 6 soils for rough pasture. Class 7 soils are too stony, steep, or wet for agriculture. They are better suited for forestry or wildlife. To obtain further information on the classification of soils consult your local department of Agriculture.

Climate in Relation to Crop Production

The climate of the Atlantic Provinces is classed as a modified continental type, influenced by the general easterly movement of air masses from the interior of the continent. The climate favours the production of a wide variety of crops, but at the same time places constraints on certain cropping systems. For example, winterkill produces a constraint on the production of winter wheat and forage legumes and insufficient heat units limit the production of corn. Local conditions determine which crops can be grown successfully in a specific area.

The average annual precipitation is about 1000 mm, but ranges from 900 to 1400 mm. Precipitation is highest along the south shores of Nova Scotia, Newfoundland, and New Brunswick. During the growing season, (May - September), rainfall averages about 400 mm, but is as high as 500 mm along the south shores of Nova Scotia and Newfoundland.

Precipitation is distributed fairly evenly throughout the year and generally adequate yields can be achieved without irrigation. However, in some years when rainfall is more sporadic, supplemental irrigation may be useful for some crops, particularly on excessively well-drained soils. In general, excessive moisture is a more serious problem than drought, particularly in spring and fall.

The average length of the frost free period is 120 to 130 days. It varies from 60 days in low-lying inland areas to 175 days in some coastal regions.

Heat units are frequently used as a combined index of the length of the growing season and temperature. Growing degree-days above 5.5"C (420F) and corn heat units are commonly used. Corn heat units range from below 1900 in northern New Brunswick, much of south eastern Nova Scotia, Cape Breton Island, and Newfoundland, to over 2500 units in parts of the Annapolis and Saint John River Valleys.

Growing degree-days are calculated on a daily basis by subtracting the base temperature (5.5"C) from the mean daily air temperature. For example, a day with a mean temperature of 10.5"C has 5 degree-days. Daily values are added to obtain weekly, monthly, or seasonal totals. Most crops will grow very slowly or not at all during periods when low temperatures result in few degree-days being accumulated.

In the Atlantic Provinces, degree-days normally begin to accumulate between April 20 and May 15, depending on location. In the fall, degree-days normally stop ac_ cumulating between October 11 and November 1. The average degree-days range from 1550 in parts of Nova Scotia, New Brunswick, and Prince Edward Island to 850 in northern Newfoundland.

For details on corn heat units, see "Heat Units for Corn in the Maritime Provinces" by A. Bootsma, A.D. Gates, and P.J. Smith, Atlantic Committee on Agrometeorology, Publication No. ACA79-1.

Limestone Needs

The Problem of Acid Soils

Most agricultural soils of Atlantic Canada are naturally acidic. The major causes of acidity are the type of material from which the soils were formed and the very high precipitation. In areas of Western Canada where annual precipitation is quite low, nutrients are not leached, soils are neutral to alkaline in reaction and are naturally quite fertile. In other areas the soils are developed from calcareous (limestone) materials and are naturally alkaline as well. In the Atlantic area, high precipitation of approximately 1000 mm results in severe leaching of elements such as calcium, magnesium, and potassium from the surface soil leaving it strongly acid and relatively infertile.

In strongly acid soils, aluminum and manganese are more soluble and can be present in toxic amounts in the solution which surrounds the soil particles and roots. Fertilizer efficiency is reduced in such soils and the activity of soil bacteria is drastically limited. Soil acidity is, therefore, a major limitation to crop production.

When soil samples are analysed in the laboratory, the degree of soil "acidity" or "alkalinity" is expressed in terms of "pH values". It is important to understand the meaning of this term.

What Is pH?

(1) The pH scale is divided into 14 divisions or pH units ranging from 0, which is extremely acid, to 14, which is extremely alkaline.

(2) Soil "pH" refers to the concentration or activity of hydrogen ions in the soil solution surrounding soil particles and plant roots.

(3) A pH of 7.0 means that the soil is neutral in reaction. Soils with a pH below 7.0 are acid and soils with a pH above 7.0 are alkaline.

(4) The pH of most cultivated mineral soils of the Atlantic Provinces falls in the range between 4.6 and 6.6.

While the pH of a soil refers to the concentration of hydrogen ions in that soil, it is the effect of the pH on the solubility and availability of many of the elements in the soil that is important rather than the actual concentration of hydrogen ions. Since the concentration of soluble salts in soil can affect pH measurements, 0.01 M CaCi, is used to eliminate this effect. In some laboratories, pH is deter- mined using the dilute CaCi, solution. This results in more consistent pH values of about 0.5 of a unit less than those determined in water.

Importance of Limestone in Crop Production

The addition of limestone is essential for the successful production of most crops in our soils. Although the overall effect of liming is to increase yields, there are 5 major functions which lime fulfills in the soil:

(1) It reduces toxic leves of soluble aluminum and manganese.

(2) It increases the efficiency of applied fertilizers (see Figure 4).

(3) It encourages the activity of soil bacteria thus releasing valuable nutrients such as nitrogen, phosphorus, and sulfur from organic components within the soil. In the case of

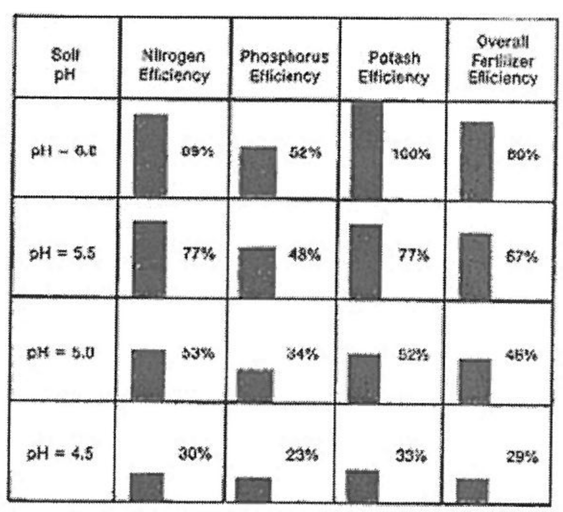


Figure 4 - Fertilizer Efficiency at Various Soil pH (water) Values. (Potato Councillor, September 1979, Page 8)

legumes, it also stimulates the nitrogen fixing bacteria in the root nodules.

(4) Through several processes, it stabilizes soil aggregates and renders the soil more resistant to erosion.

(5) It supplies calcium and magnesium for crops.

What Kind of Limestone and How Much?

There are two types of agricultural limestone available in the region, calcitic which contains calcium carbonate, and dolomitic which contains both calcium and magnesium carbonates. The type and amount of limestone required depends on the calcium and magnesium level within the soil and the requirements for the crops to be grown. Both will correct soil acidity.

In addition to the type of limestone to be applied, there are two other important considerations regarding the use of limestone:

1. Neutralizing Value - This refers to the effectiveness of limestone as compared to pure calcium carbonate. The higher the neutralizing value, the more soil acidity it will neutralize. In theory, the neutralizing value is 100 for calcitic limestone and 109 for dolomitic limestone. Due to some impurities, however, the values for commercially available limestone will be slightly less.

2. Rate of Reaction - Limestone reacts slowly with the soil and the rate at which it reacts depends mainly on the fineness to which it is ground, although calcitic limestones are somewhat more soluble than dolomitic limestones. Finely ground material begins to react immediately whereas very coarse material may react slowly over 2-3 years. Very coarse limestone, such as fertilizer filler or "grits", will take many years and are of no value in at- tempting to change soil acidity.

Under federal legislation, agricultural limestone must be labelled to indicate calcium and magnesium content, neutralizing value, and its fineness of grind (sieve size).

Table 1 - Limestone Required (tonnes/ha)* to Change the pH of the Plow Layer (18 cm**) of various soils.

Texture of Plow Layer	Desired pH	Soil pH (in water) before Liming 4.5	5.0	5.5	6.0
		tonnes/ha ***			
Clay loam	6.5	13	11	8	4
	6.0	11	8	4	0
	5.5	8	4	0	0
Loam	6.5	11	9	7	4
	6.0	9	7	4	0
	5.5	7	4	0	0
Fine Sandy loam	6.5	9	7	4	2
	6.0	7	4	2	0
	5.5	4	2	0	0
Sandy loam	6.5	7	5	3	2
	6.0	5	3	2	0
	5.5	3	2	0	0

* Values should be adjusted for different depths of plowing.
** 1 cm = 0.394 inches
*** 1 tonne/ha = 0.446 tons/acre

The rate of limestone application required to achieve a given soil pH will depend on three main factors: (1) the initial soil pH, (2) the texture of the soil, and (3) the organic matter content of the soil. The only reliable way to determine the rate of limestone required is by a Soil Test which is highly recommended. The rates of limestone required in some typical situations are given in Table 1.

The desirable pH range for most crops is shown in Figure 5. Information on the relative tolerance of a number of crops to soil acidity is given in Figure 5. In general, it is not advisable to lime to pH 7.0. Unnecessarily high liming rates may have adverse effects on the availability of phosphorus and certain trace elements.

How and When to Apply Limestone

Limestone can be applied whenever field conditions are suitable. For immediate response and maximum yields, limestone should be thoroughly mixed with the soil before the crop is seeded. Part of the requirement may be plowed down and the balance worked into the surface or it may all be applied on the surface as on permanent-type pastures. Liming sod is an ineffective manner of raising pH of the plow layer. Limestone applied on the surface of sod penetrates very slowly (up to 1.5 cm per year) and requires many years to correct the acidity throughout the plow depth. Frequent light applications are preferable to heavy rates on sod since the heavier rates result in localized areas of extremely high pH and may cause some depression in yield of sod crops.

Maximum benefit from limestone is obtained by applying moderate rates to large areas rather than using the same quantity to supply the full limestone requirements over smaller areas. Subsequent applications may be made during the next cycle of the rotation to bring the pH to the desired level.

In the humid Atlantic climate, leaching, acid rains, and crop removal of calcium and magnesium will slowly but steadily lower the soil pH and "maintenance applications" of lime are required. While maintenance applications should be based on periodic checks of soil pH, a general recommendation for sandy or silt loams is 500-600 kg/ha per year (100 kg/ha = 89 lb/acre). Heavy ferilization with acid forming fertilizers such as ammonium nitrate or diammonium phosphate will increase the requirement.

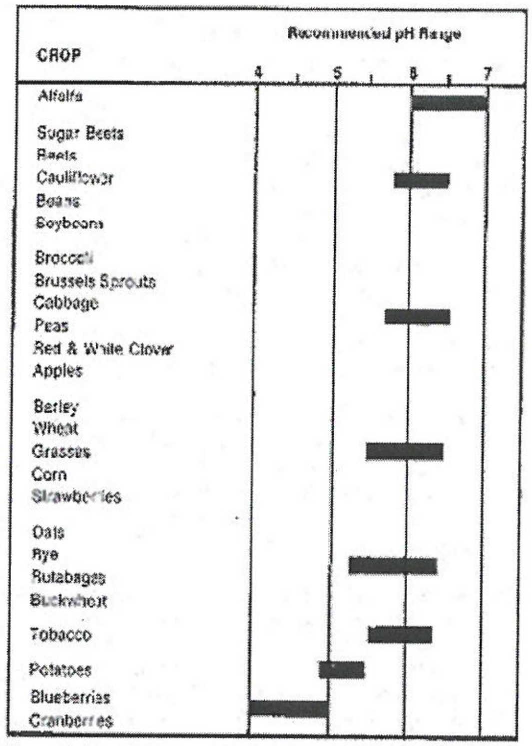


Figure 5 - Most Suitable pH (water) Ranges for Various Crops.

Limestone and Potato Production

Potatoes grow well in soils that range from pH 5.0 to over 7.0. However, occurrence of potato scab is more likely at high pH levels. Potatoes are, therefore, grown under more acid soil conditions than many other crops. Continuous cropping to potatoes, or frequent potato crops in the rotation, may encourage incidence of scab. Some varieties of potatoes are more susceptible to scab than others.

When scab susceptible varieties are grown continuously or in very short rotations, the soil pH should be between 5.0 and 5.4. In rotations where potatoes occur no more frequently than every third year, or where scab resistant varieties are grown, soil pH as high as 5.7 is satisfactory. With a combination of long rotations and scab resistant varieties, the soil pH can be as high as 6.0.

Soil pH of less than 5.7 is usually detrimental to crops such as grain and forage in the rotation. Limestone should be applied after the potatoes in the rotation. If potatoes follow potatoes and limestone is required, it should be applied and harrowed in immediately after harvest.

For a more detailed discussion on lime, see "Atlantic Soils Need Lime" prepared by the Atlantic Soil Fertility Committee.

Soil Management

Soil Drainage

Good soil drainage is essential for successful crop production. Soil micro-organisms as well as plant roots re- quire oxygen. When a soil is poorly drained, it remains saturated or nearly saturated with water for fairly long periods, thus limiting the supply of oxygen and restricting crop growth. In the Atlantic Provinces, poor soil drainage also results in cold, wet soils in spring, and poor trafficability for spring and fall tillage, seeding, and harvesting operations. This leads to serious delays in seeding, germination, and harvesting of spring seeded crops, with in- creases in crop disease, maturity related problems, soil compaction, and to higher equipment operating costs. Poor soil drainage contributes to poor winter survival of perennial legume and winter cereal crops.

Moisture moves through the soil at different rates depending on the size and distribution of pore spaces between soil particles. The greater the volume of large pore spaces, e.g. in sandy and gravelly soils, the faster water will drain out of a soil. In a fine textured (clayey) soil, the total pore space volume is small and the movement of moisture is slower than in sandy soils.

Soil particles have a natural tendency to cling together to form soil aggregates, a condition known as soil structure. Soil structure can be improved by judicious use of limestone, manures, fertilizer, crop sequence, and tillage practices. Development of an improved soil structure will increase the pore volume distribution in the soil and permit more rapid removal of surplus water.

In most instances, soil management practices alone are not sufficient to adequately control excess soil moisture. In such cases, use one or a combination of the following corrective measures:

(1) Open ditches to collect surface water or to intercept water flowing onto land from a high point.

(2) Tile drains to remove surplus water from within the soil and thus control the level of the water table in the soil. This is the most effective method of artificial drainage.

(3) Subsoiling is beneficial if an impervious layer exists in the soil at a reasonable depth. The impervious layer (hard- pan or clay-pan) is broken up by a deep tillage machine to permit more rapid movement of surplus water. Subsoiling will only be effective if carried out when the soil is fairly dry down to the depth of the subsoil tillage. This corrective measure is usually of a temporary nature.

The importance of well-drained agricultural soils in the Atlantic Provinces is emphasized by the fact that each province provides financial and technical assistance to farmers to install improved drainage systems.

For more information see "Farm Drainage in the Atlantic Provinces" by J. K. Higgins, Atlantic Agricultural Engineering Committee Publication No. 3.

Cropping Systems

There have been many recent advances in cropping practices, fertilization and pest control, however, a sound system of crop rotation is still essential: (1) to check or prevent an outbreak or spread of hard-to-control pests or diseases associated with certain crops; (2) to reduce soil erosion on certain soils or slopes by using perennial crops in a long rotation; (3) to introduce sod and other high organic matter residue tilled crops in rotation with low residue tilled crops to increase the return of organic matter and reduce compaction from heavy machinery; and (4) to compliment herbicide use for weed control.

A minimum of traffic on fields is most important to avoid compaction, especially when the soil is wet. For every operation on the field with tractor and equipment - one should consider - "is this trip necessary? Can it be avoided?"

Soil and Water Conservation

Soil conservation is the adoption of practices to protect the soil from loss or damage by wind or water and to maintain its ability to produce crops. Water conservation means the adoption of practices to regulate the quantity and quality of the water supply as required during the year.

Soil completely covered with vegetation is in an ideal condition to absorb moisture and to resist erosion provided the cover is continuous and the soil is well permeated with plant roots.

While it is not possible to have agricultural soils completely covered by vegetation at all times, soil conservation measures must be patterned on nature's own methods of soil protection. This means that crop production programs should be designed so that the land will be protected as much as possible by close growing crops such as grass and legume swards and winter cereals. On areas where intertilled crops are grown, the soil organic matter should be maintained at as high a level as is practical. Addition of organic matter is an important component of soil management. A cover of crop residue should be maintained wherever possible. For instance, cereal crop stubble should be left until the following spring or be stubble mulched in the fall using a chisel or disc plow rather than mold board plowing in the fall.

The presence of close growing crops or crop residues on the land surface reduces the rate of flow of "run-off" water and erosion. The presence of high levels of organic matter in the soil tends to bind the soil particles together and to increase both the rate of penetration and the moisture holding capacity of the soil.

Run-off and erosion may be reduced by carrying out plowing, other tillage operations, and planting crops across slopes. However, there are definite limits to the effectiveness of this practice of contouring due to length, steepness, and complexity of the slopes. It is most effective on slopes of about 2 to 7% but may be ineffective on steeper slopes or on complex or very long slopes, and becomes difficult on small fields.

To control erosion in extreme cases, properly designed and constructed grassed waterways, strip cropping, con- tour farming, or terracing may be used. These practices are not substitutes, however, for proper care to maintain soil structure and tilth.

Irrigation

Irrigation of agricultural crops is carried out for two reasons:

(a) To supplement the natural soil moisture during moisture deficient periods through the growing season by sprinkler, furrow, flood or drip systems.

(b) To protect sensitive crops from frost damage.

Irrigation facilities are used for relatively high value crops such as early vegetables, strawberries, and tobacco. The sprinkler type of irrigation system is the most common in the Atlantic Provinces. With this method, water is pumped from a stream, lake, or pond through pipes to sprinkler heads placed at regular intervals throughout the field. The gun type system is gaining in popularity for potatoes and tobacco.

A successful irrigation installation requires careful planning, for both a sufficient supply of good water and adequate capacity of the system.

Plant Nutrition

Essential Nutrient Elements

Plants need sixteen chemical elements each of which has one or more special functions in the growth and development of plants.

The essential elements may be classified as follows: , Major elements or macro nutrients are required in relatively large amounts, i.e., (i) carbon, hydrogen and oxygen, which are supplied by air and water, (ii) nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur, which come from the soil.

Trace elements or micro-nutrients are required in relatively small amounts, i.e., iron, manganese, zinc, copper, boron, molybdenum, and chlorine, all of which come from the soil.

A number of other elements such as sodium, cobalt and lead are also taken up by plants from the soil. Although a few of these have been found beneficial under some circumstances, plants will generally grow and develop normally without them.

Sources, Functions of Nutrients and Some Deficiency Symptoms

Carbon (C) is present in all animal and vegetable substances (organic compounds) making up about 45% of the dry matter. It is associated chiefly with hydrogen and oxygen in carbohydrates and fats, and with hydrogen, oxygen, and nitrogen in proteins. It enters the plant as carbon dioxide (CO_2)from the air.

Hydrogen (H) is present in practically all organic compounds. It enters the plant as a component of water, which is the carrier of other plant nutrients from the soil.

for potatoes. On fields testing very low in Mg, especially on high pH soils where only calcitic limestone has been used, some Mg in the fertilizer may be required.

On some soils where the pH is lower than 5.0, Mn and other elements may reach toxic levels. Under such conditions, dolomitic limestone should be applied. This will correct the toxicity and supply Mg requirements of the crop at the same time. Further details on potatoes can be found in "Atlantic Canada Potato Guide", Publications No. 700, prepared by the Atlantic Potato Committee.

Cole Crops: Cabbage, Broccoli, Cauliflower, and Brussels Sprouts

These crops are well adapted to the Atlantic Provinces. It is good practice to have the soil tested before planting to determine the specific fertilizer and limestone requirements. Fertilizers at planting or transplanting time may be banded or broadcast. In addition to spring fertilization, a side-dressing of N during the growing period is frequently beneficial. On soils of low pH, Mg may be beneficial.

Cole crops are susceptible to B and Mo deficiency. The most convenient method of applying B is with the fertilizer. A spray containing 1/2 kg B in 500 1 water can be applied to the plants. Starting beds for plants should also be fertilized, preferably with a fertilizer containing B.

Soil applications of Mo may be used at the rate of I to 2 kg sodium molybdate per ha. Sodium molybdate can also be applied in the transplanting water or as a spray at 150 g/500 litre or to the seed at 60-120 g/kg seed.

Transplanted crops may benefit from a starter solution, and this should be used according to the manufacturer's directions.

Berry Crops

(a) **Strawberries** - Production requires high quality (preferably certified) plants, and good soil fertility.

Soils selected for strawberry plantations should be well supplied with organic matter and relatively free from weeds. The soil should be tested, and, if necessary, limestone should be applied to adjust the soil pH to the range of 5.5 to 6.0. Also, sufficient P fertilizer should be applied and mixed with the soil to supply the P requirements of the crop. Nitrogen and K are applied after the plants have been set out if the soil is low in N and K.

A plant starter solution following the manufacturer's recommendations may be used, when the plants are set out.

About four or five weeks after planting, a 1-1-1 ratio fertilizer should be applied as a side-dressing and more N added during the last week of August.

The most profitable response can be expected from this fertilizer program if irrigation is provided as required.

(b) **Bush and Cane Fruits** - They perform well on soils which are high in organic matter, limed to pH 6.0, and well supplied with P.

To prepare soils for these crops, it is desirable to apply barn manure, hay, or straw or to plow down a green manure crop. These organic materials and an application of P fertilizer should be mixed with the soil.

No additional fertilizer is required during the first year. In succeeding years, manure combined with a 1-2-2 ratio fertilizer is recommended. If manure is not available, a higher rate of 1-2-2 fertilizer may be used.

(c) Highbush Blueberries - The highbush blueberry grows best at a pH of 4.3 to 4.8, which is more acid than that preferred by most plants. A naturally fertile soil, well supplied with organic matter and well tilled, is also a prime requirement for newly set plants.

If these conditions exist, there is no need to fertilize for the first few years. However if fertility is lacking, the necessary nutrients can be supplied by applying a light application of fertilizer just before bud breaks. When applying fertilizer, broadcast it within 15 to 25 cm of the plant and out as far as the roots extend. Do not apply nitrate forms of N. Ammonium sulfate or urea are good sources of N. Use ammonium sulfate when the soil pH is above 5.0 and urea when the soil pH is below 5.0.

Apples and Other Tree Fruits

A soil fertility program for mature orchards must not only supply the nutrient requirements of the fruit trees, but also support a good sward cover crop. Young orchards should be free of weed competition.

Orchards require a more or less constant supply of P, K, B, Zn, and sufficient N to give good, but not excessive terminal growth for the kind and variety of fruit. Too much and/or late applications of N may prolong growth, resulting in lower quality fruit and susceptibility to winter
Mulching with hay, straw, or manure will increase organic matter level where needed.

A reliable assessment of orchard fertility requirements may be obtained by means of regular tree leaf and soil analysis, and orchardists should make use of this service.

Tobacco

The production of quality flue cured tobacco requires careful observance of fertility and production practices.

Research in the Atlantic Provinces indicates that N, P, K, Mg, Gl, and B must be given careful consideration when fertilizing flue cured tobacco.

a) Nitrogen is very critical as it affects leaf size and yield and will also delay maturity if used in excess.

b) Phosphorus is essential for proper growth and development of the crop. High levels may hasten maturity where N levels are high.

c) Potassium fertilizer is necessary for proper growth; however, an excess may delay maturity.

d) Magnesium is required for plant growth. This element may be supplied in dolomitic limestone or in fertilizer.

e) Excess fertilization with Gl will adversely affect the burning quality of tobacco, yet 20-50 kg Gl/ha is necessary for plant growth. The level of Gl in tobacco fertilizers is regulated by the Fertilizers Act to provide the appropriate level of this element.

f) There is some evidence to indicate that low B levels in the soil may be related to premature breakage or "drop" of leaves. Boron fertilization should be done with extreme caution and application rates should not exceed 1.0 -1.5 kg/ha, to prevent a possible B toxicity.

The actual amount and analysis of fertilizer used should be based on the results of soil analysis and past management of the field concerned.

Tobacco fertilizer is banded at time of transplanting. Care must be taken to place the fertilizer below and to each side of the seeding.

Commercial Vegetables

(a) Asparagus plantings should be limited to the warmer high pH soils. An open, porous, well drained soil is desirable. Since this crop is grown on the same site for many years, careful soil preparation is important. Adequate limestone, P, and organic matter should be incorporated into the soil before planting or transplanting. Also it is extremely important that perennial weeds be controlled before planting.

(b) Beans can be grown in most areas in the Atlantic Provinces. The warmer, drier sections are preferred for commercial production. Beans grow well on sandy loam soils limed to pH 6.0. A high P, low N fertilizer is preferred. Avoid the use of excess B on beans.

(c) Carrots prefer deep fertile sandy loam soils free of rocks and other foreign matter (avoid the use of strawy manure) for maximum production. A mixed fertilizer high in P banded at seeding with a later application of N is advisable. The addition of B to some soils may be necessary.

(d) Corn may be grown in the warmer areas of the Atlantic Provinces. With good soil drainage, this crop will grow satisfactorily on most soil types. A mixed fertilizer banded at seeding with a later side-dressing of N is recommended. On soils low in Mg it may be necessary to add this element either as fertilizer or in dolomitic limestone.

(e) Cucumbers grow well under warm conditions. Ideal soils are sandy loams with southern exposures protected from the wind. Manure and a mixed fertilizer low in N and high in P at seeding, supplemented by a later application of N and K is recommended.

(f) Lettuce requires a cool climate, therefore many of the coastal areas are ideal. With a relatively short growing season and a limited root development, this crop requires a high level of fertility. Usually a complete fertilizer is applied at planting or transplanting then followed by one or two side-dressings of N.

(g) Peas are a cool season crop, well adapted to the Atlantic Provinces. Well drained soils are essential for favorable growth. Added fertilizers generally do not increase yields.

(h) Spinach must make rapid growth for good yield and highest quality. A fertile sandy loam soil is ideal. The use of B is advisable. Well limed soils with a pH of about 6.5 would be most satisfactory.

(i) Tomato The commercial production of this crop should be confined to the warmer inland areas. Light sandy loam soils with southern exposure are advisable. A mixed fertilizer high in P and low in N should be applied in the spring. At time of fruit set, additional N may be added. The use of starter solutions at transplanting is advisable.

(j) Turnips Another crop well adapted to the Atlantic area. Fertilizer broadcast or banded at time of planting. Usually no side-dressing of N is required. Best quality turnips make slow and continuous growth. Boron is usually added to the fertilizer, to prevent "brown-heart". This condition is caused by a deficiency of B.

(k) Pumpkins and Squash are best adapted to the warm areas of the Atlantic Provinces. Usually fertilizers are broadcast at time of planting. Usually one side-dressing of N and K is made when the vines begin to run. Manures are beneficial to this crop.

Further details on fertilization of field and vegetable crops can be found in: "Field Crop Guide", Publication 100, and "Vegetable Production Recommendations", prepared by the Atlantic Committee on Crops.

Lawns and Play Areas

An attractive lawn or play area turf requires a well limed soil which is adequately supplied with plant nutrients. Low pH and low soil fertility are common causes of poor lawn growth.

A good lawn or play area turf may be mowed 20-25 times during the season, thus a good lawn produces a very high yield of grass and a high level of fertility is required. Nitrogen is particularly important for good lawn growth. A uniform supply of N must be provided throughout the entire growing season. A deficiency is indicated by light green color of the turf grasses.

A complete fertilizer, preferably a 1:1:1 or 3:1:3 ratio, should be applied early in the spring which may be followed by one or two additional applications during the season for continuous growth.
Fertilizer burn may be prevented by applying the material with a lawn spreader when the grass is dry.

Small Gardens

Small garden areas should receive regular applications of well rotted manure, compost material, or peat moss to maintain the organic matter content of the soil. Agricultural limestone should be applied as the need is indicated by a soil test.

Garden flowers require smaller amounts of N and P and K. An annual application of a 1:2:2 or 1:1:1 ratio fertilizer will usually produce satisfactory results. Additional N should be used only when needed to maintain green color and growth.

Oxygen (0) is a component of most organic compounds and of water but is also essential as a free element. It enters the plant from both air and soil.

Nitrogen (N) is necessary for protein production by the plant, for proper growth of leaves, and for many of the critical functions (such as photosynthesis) performed by them. Inside the plant, N converts to amino acids, the building blocks for proteins. These amino acids are then used in forming protoplasm. Therefore, N is a necessary component in cell structure and functions since protoplasm is the site of cell division and plant growth. Nitrogen is necessary for enzymatic reactions in plants as all plant enzymes are proteins. It is a necessary component of several vitamins, e.g., biotin, thiamine, niacin and riboflavin. Nitrogen increases protein content of plants directly and this protein reaches a man's dinner table from plants directly or via animals, birds, or fish that have consumed protein-containing plants.

Adequate N produces a dark green color in the leaves, caused by a high concentration of chlorophyll. Nitrogen deficiency causes chlorosis (a yellowing) of the leaves from declining chorophyll. This yellowing starts first on older leaves, then shows on younger ones as the deficiency becomes more severe. Nitrogen deficient plants tend to be stunted, grow slowly, and produce fewer tillers than normal. Certain N-deficient crops may reach maturity earlier than plants with adequate N.

Nitrogen is taken up by plant roots as either nitrate or ammonium with some crops having a definite preference for nitrate. Insufficient N is a common yield limiting factor. It may be supplied by fertilizer chemicals such as ammonium nitrate (33.5% N), urea (46% N), monoammonium phosphate (11% N), diammonium phosphate (18% N), anhydrous ammonia (82% N), and aqua ammonia (20% N). Animal manures and the nitrogen-fixing bacteria associated with legumes (clover, alfalfa, peas, etc.) also supply large quantities of N.

Phosphorus (P) is essential for plant growth and is vital to early growth. No other nutrient can be substituted for it. The plant must have P to complete its normal crop production cycle. Phosphorus plays a role in photosynthesis, respiration, energy storage and transfer, cell division, cell enlargement and several other processes in the living plant. It promotes early root formation and growth and improves the quality of many fruits, vegetables and grain crops. Phosphorus is vital to seed formation and its content is higher in seeds than in any other part of the plant. It helps roots and seedlings develop more rapidly and helps plants survive winter rigors. Phosphorus hastens maturity and contributes to disease resistance in some plants.

Plants absorb most of their P as the primary orthophosphate ion (H_2PO_4). Other forms of P may be utilized by the plants but in much smaller quantities. The first sign of P deficiency is an overall stunted plant. Older leaves are affected before the younger ones. A purple or reddish color is often seen on deficient corn plants and some other crops, especially at low temperatures. With severe P deficiency, dead areas may develop on the leaves, fruits and stems.

The most common source of P outside of farm manures, is phosphate rock from which various fertilizers are made, e.g., superphosphate (20% P_2O_5), triple superphosphate (46% P_2O_5), monoammonium phosphate (48% P_2O_5), and diammonium phosphate (46% P_2O_5).

Potassium (K) is a vital plant nutrient and no other nutrient can replace it. Agronomic crops contain about the same amount of K as N, but more K than P. In many high yielding crops, K content exceeds N content. Potassium is absorbed by plants in the ionic form (K+). It is essential for plant growth, but its exact functions in plants are not well understood. Unlike N and P, K does not form organic compounds in the plant. When K is deficient, photosynthesis declines and plant respiration rate increases and thus plant's carbohydrate supplies are reduced. It is essential for protein synthesis. Potassium has an important role in stomatal functioning and helps the plant use water more efficiently by promoting turgidity to maintain internal pressure in the plant. Potassium is important in fruit formation, in translocation of heavy metals such as iron, and in ionic balance. It activates enzymes and controls their reaction rate. Potassium improves winterhardiness in crops and increases disease resistance in plants.

Potassium deficiency symptoms show up as scorching or firing along the margins of older leaves in most plants, especially grasses. The leaves may later turn brown and this condition may invade the entire leaf in severe cases. Deficient plants grow slowly and have poorly developed root systems. Stalks are weak, lodging is common and seed and fruits are small and shriveled. In grass/legume forages the legume will not presist in the mixture when K is deficient.

Muriate of potash (60% K_2O) is the most common fertilizer source. Potassium sulphate (50% K_2O), potassium nitrate (44% K_2O), and potassium magnesium sulphate or "Sulpomag" (22% K_2O), are other sources.

Calcium (Ca) is necessary for proper root and leaf development. It forms compounds which are part of cell walls and this strengthens plant structure. Calcium deficiency is generally associated with high soil acidity. Liming materials which are added to correct the acidity generally prevent further deficiencies of this nutrient. Calcium activates several enzyme systems and neutralizes organic acids in the plant. It also stimulates microbial activity, increases Mo availability and uptake of other nutrients. Wood ashes, marl, slag, sea shells, gypsum, and superphosphate are high in Ca content. Calcium deficiency results in poor root growth and the growing point dies.

Magnesium (Mg) an essential constituent of chlorophyll, is associated with P in seed information, and activates photosynthesis and certain enzyme reactions. Shortage of Mg results in interveinal yellowish, bronze or reddish color patches in old leaves which may later die and become brown or black. Insufficient Mg in herbage can cause a livestock disease called hypomagnesaemia or staggers. If dolomitic limestone is used for the correction of acidity, Mg shortage may be prevented. Where calcitic limestone is routinely used, a high Ca to Mg ratio in the soil may cause acute Mg deficiency which may be corrected by applying Mg in foliar spray or with fertilizers.

Sulfur (S) is an essential constituent of many proteins. Sulfur helps develop enzymes and vitamins, promotes nodule formation on legumes and is necessary for chlorophyll formation. Sulfur-deficient plants show a pale green color, generally appearing first on younger leaves but the entire plant can take on a pale green appearance. Deficiencies show up most often on sandy soils, low in organic matter in areas of moderate to heavy rainfall.

Although the plant S contents are close to the published critical levels, no responses have been observed in the region. Sources of S include precipitation and certain fertilizer materials, such as, potassium sulfate (17.6% S) and superphosphate (11.9% S). Periodic 8 trials will be necessary to determine whether S becomes limiting in future, especially due to the recent increased use of fertilizers which contain only traces of S.

Boron (S) is considered necessary for uptake and translocation of sugars, and is implicated in carbohydrate metabolism and seed and fruit development. A lack of B hinders the development of young rapidly growing tissues and causes squat bushy plants in certain crops. Boron deficiency also causes physiological disorders such as "brown heart" of turnips, "top yellowing" of alfalfa, "collar rot" of mangers, "black heart" of cauliflower, "stem crack" of celery, and "corky core", "internal core", or "drought spot" of apples. All of these disorders are common in this region, particularly on the more sandy soils, or on farms where manure is scarce or where an excess of lime materials have been applied. To prevent disorders, fertilizers containing B should be applied regularly for turnips, apples, cauliflower, brussels sprouts, broccoli, spinach, beets, and alfalfa. Certain crops like cabbage, carrots, tomatoes, and lettuce may benefit from light applications, but most other crops will obtain sufficient of this element from soil minerals, manures, or from residues of previous applications. If a deficiency is suspected in a growing crop, the condition may be corrected by a foliar spray. Sensitivity of various crops to B is shown in Table II.

Table II. - Sensitivity of Crops to Boron.

Very Sensitive (up to ½ kg B per ha Broadcast)	**Sensitive** (Up to 1 kg B per ha Broadcast or 0.5 kg in Drills)	**Tolerant** (Up to 2 kg B per ha Broadcast or 1 kg in Drills)	**Very Tolerant** (Up to 4 kg B per ha Broadcast or 2 kg in Drills)
Cucumbers	Barley	Carrots	Alfalfa
Snap Beans	Lima Beans	Celery	Apples
Strawberries	Oats	Corn	Beets
	Potatoes	Clover	Broccoli
	Rye	Lettuce	Brussels Sprouts
	Squash	Onions	Cabbage
	Timothy	Peas	Cauliflower
	Wheat	Peppers	Radish
		Spinach	Rutabaga
		Tomatoes	Turnips

Repeated applications of B can cause toxicity in sensitive crops such as cereals, snap beans, and strawberries. Some damage may result in the year following applications of more than 5 kg B/ha.

Several carriers of 8 are available for fertilizer mixing or for direct application. Borax (11% B) has largely been replaced with more concentrated compounds which are cheaper sources of the element. For example, "Solubor" containing 20-21% B is water soluble and may be used for foliar sprays. Some boron in fertilizer mixes is sold as 0.1 B, 0.2 B by percentage, or as may be otherwise required. This means, for example 100 kg of 0.2 B fertilizer mix contains 0.2 kg B.

Molybdenum (Mo) Two principal functions of Mo in plants are: (1) reduction of nitrate nitrogen, and (2) fixation of nitrogen. Cauliflower and other cole crops, are very sensitive to low Mo levels. "Whiptail" is a very specific symptom in cauliflower. Chlorosis, followed by tissue collapse, death of leaf margins, and eventually entire leaves or plants, are general symptoms on many crops. Other symptoms of Mo deficiency include: decreased protein content, deposition of brown substance on tissue, and decreased ascorbic acid in certain plant species.

The most promising method of preventing Mo deficiency is use of a commercially prepared seed treatment before planting. All cole crops should receive this treatment since it is convenient, cheap, and effective. Seed treatment will supply sufficient Mo for many crops to maturity.

Any later deficiency can be prevented by foliar sprays. Soil application in the fertilizer mix or in solution at rates of 0.4 kg/ha or 0.2 kg/ha by foliar spray are effective for 2 to 3 years. Unlike most trace elements, soil availability of this nutrient is increased by liming, and deficiencies are minimal on limed soils.

Chlorine (Cl) is the latest (1954) addition to the list of essential micro-nutrients. Its functions are unknown, and as yet deficiencies in the field are uncommon and unlikely since Cl makes up nearly 50% of muriate of potash. Tobacco has critical requirements for Cl, since either too little or too much affects both yield and quality. Applications of 30 to 50 kg 01/ha should produce good quality tobacco.

Copper (Cu) is necessary in several enzyme reactions. These are essential steps in most plant growth processes. Copper increases the utilization of ammonium nitrogen resulting in improved growth of plants. It is also believed to play some role in the formation of chlorophyll. It has been found deficient in this region in peat soils, and sandy mineral soils in certain counties. A reduction in yield is often the only indication of a deficiency. Copper sulphate (25% Cu) is the chief source added at rates of 25 to 50 kg/ha.

The residual effect from such applications can last for up to 5 years.

Iron (Fe) is necessary for the formation of chlorophyll and other enzyme reactions. Deficiency results in chlorosis of the young leaves and may be corrected by foliar sprays of iron chelate. Most Atlantic area soils are well supplied with Fe. Deficiency seldom occurs except on soils with a pH above 7 or 8.

Manganese (Mn) is necessary in a number of enzyme reactions. It is involved in the formation of chlorophyll and its absence causes chlorosis, usually with a specific pat- tern, such as "grey-speck" in oats. Deficiency is found generally in neutral or alkaline soils. Toxicity from excessive concentrations in the soil may cause stem-streak in potatoes and reduction of yields of other crops in highly acid soils. Liming to recommended pH levels prevents this difficulty.

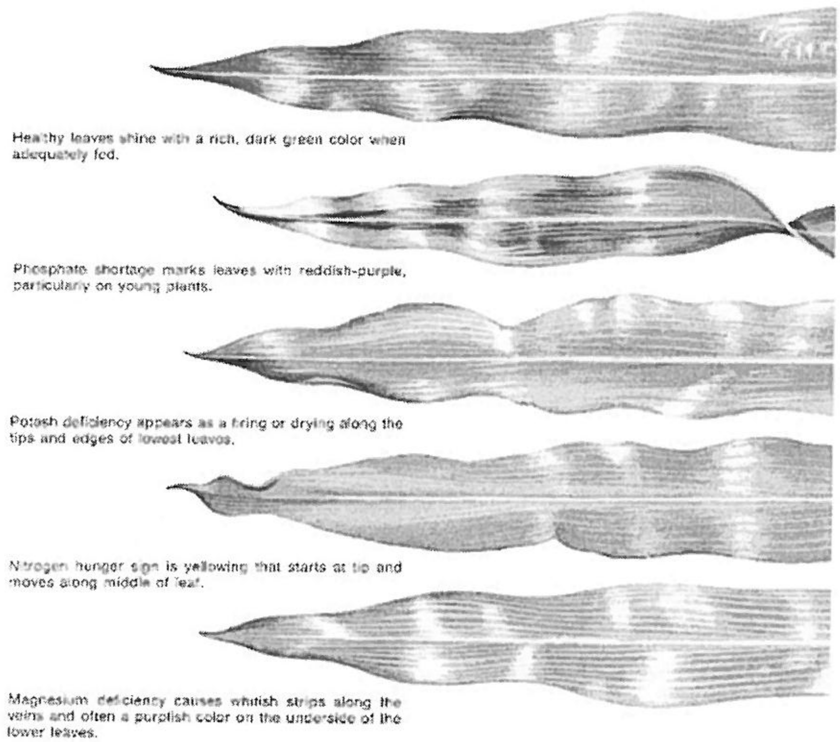
Zinc (Zn) is essential for promoting certain metabolic reactions and is associated with the plant hormone aux- in, which is responsible for elongation of stems. It is necessary for chlorophyll formation and carbohydrate production. Zinc is not readily translocated within the plant, so symptoms of deficiency first appear on the younger leaves. Deficiency results in leaf resetting and hrnn7inn a strined chlorosis in certain plants and in failure to produce seed. Corn is particularly susceptible to Zn deficiency in cold, wet soils which have a high P status. Zinc deficiency in corn is called "whitebud" because the young bud turns white or light yellow in early growth. Occasionally Zn deficiency has been noted in high pH sandy soils. Zinc deficiency can be controlled by applying a Zn compound, broadcast or with row fertilizer. Foliar application has also been used successfully.

Other Elements of Importance

Sodium (Na) stimulates the growth of certain plants such as beets and turnips under some conditions. However, it is not considered essential since plants can complete their growth cycle in its absence.

Cobalt (Co) has not been established as essential for plants, but is necessary for animals. Significant growth responses to Co have been demonstrated in pasture legumes in Australia in the past 15 years. When soils are deficient in this element, as in some areas of this region, crops grown on them are low and Go deficiency can occur in cattle or sheep consuming these crops. Cobaltized salt supplements for livestock are generally used to correct the deficiency.

Plant nutrient deficiency symptoms on corn leaves are shown in Figure 6.



Composition and Use of Manures and Fertilizers

Farm Manure

Farm manures provide a valuable source of organic matter and plant nutrients. Good conservation and efficient use of farm manures in the cropping program will reduce the requirements for purchased fertilizers.

Relatively large quantities of manures are produced on livestock farms. For efficient operation, manure must be handled easily and cheaply and in a manner to realize the maximum from its fertility value.

Composition and Value

The main value of farm manures is derived from their organic matter, N, P, K and trace element contents. Manures produced by different kinds of livestock under different conditions, vary considerably in content of plant nutrients and can substitute for appreciable amounts of manufactured fertilizer as shown in Table III.

Effect of Storage and Handling Methods on Nutrient Content

Nutrients in manure are best preserved by collecting as much urine as possible and preventing exposure to leaching rains. Aeration of liquid manures reduces odor problems but also causes depletion of N.

Manure should be incorporated into the soil as soon as possible after spreading, except for top-dressing of forages. This incorporation decreases nutrient losses, particularly of N which is susceptible to loss as ammonia, and minimizes chances of water pollution. The extra N saved by immediate incorporation amounts to approximately 25% of the N applied (Table 111). Manure should not be spread on frozen, sloping fields since such conditions favor runoff hazard. Rains will carry the manure away wasting a valuable resource and unnecessarily contaminating streams. Provincial Departments of Agriculture, Environment and/or Fisheries often have published guidelines which refer to safe buffer distances on a range of soil types and land slopes. For further details on the management of manures consult "Canada Animal Manure Management Guide", Agriculture Canada, Publication No. 1534.

Table III - Approximate Reductions in Fertilizer Application where Manure is Applied

Solid Manure	Liquid Manure	Subtract from Fertilizer Requirement				
tonnes per hectare*	cubic metres per hectare**	Nitrogen N(kg/ha) F & W	Spr	SprC***	Phosphate P_2O_5 (kg/ha)	Potash K_2O(kg/ha)
Cattle or Mixed Livestock Manure						
20	50	25	50	60	20	90
30	75	40	75	90	30	135
40	100	50	100	125	40	180
Swine Manure						
20	30	25	50	60	25	35
30	45	40	75	90	35	50
40	60	50	100	125	50	70
Poultry Manure						
4	10	20	45	60	25	22
10	25	50	110	140	60	44

* 66 bu manure = 1 metric tonne approximately. 10 tonnes/ha = 4.5 ton/acre.

** One cubic metre = 220 imperial gallons. One cubic metre per hectare = 90 gallons per acre.

*** F & W denotes fall and winter applied manure.
Spr denotes spring applied and not covered immediately including surface applications after seeding.
SprC denotes spring applied manure covered immediately after application.

Table taken from the Ontario Ministry of Agriculture and Food Publication 296, 1980 Field Crop Recommendations.

Further details on the nutrient content of various manures and on "Organic Gardening" can be found in "Vegetable Production Recommendations" Publication No. V24 -75, prepared by Atlantic Provinces Crop Protection and Vegetable Committees.

Commercial Fertilizers

The Contents of a Commercial Fertilizer

Fertilizer manufacturers must guarantee the analysis of all fertilizers. The total N must be expressed as per cent N, available P as percent P_2O_5, and soluble K (potash) as percent K_2O.

Commercial fertilizers contain one or more plant nutrients. Generally, fertilizers containing one or possibly two plant nutrients are known as fertilizer chemicals. Fertilizer chemicals are relatively pure compounds of standard composition with the plant nutrient as a component part of the compound. Fertilizer chemicals are identified by name and percentage of plant nutrient or nutrients, e.g. Ammonium nitrate - 33.5% N; Superphosphate - 20% P_2O_5; Triple superphosphate - 46% P_2O_5; Muriate of potash - 60% K_2O; Diammonium phosphate - 18% N and 46%P_2O_5.

Mixed fertilizers are mixtures of various fertilizer chemicals prepared to contain specified plant nutrients. The content (analyses) of mixed fertilizers is designated in whole numbers to express: (a) percentage of total nitrogen by the first number (b) percentage of phosphorus by the second number and (c) percentage of potash by the third number. For example, a 5 -10 -30 fertilizer contains 5%N, 10% P_2O_5, and 30% K_2O. If trace elements are sold as additives in mixed fertilizers, their presence and quantities must be guaranteed by the manufacturer as a percentage of the mixed fertilizer on an elemental basis.

(ii) Inspection and Control of Commercial Fertilizers The Fertilizer Act is administered by the Food Production and Inspection Branch of Agriculture Canada. This Act states that no person shall sell or import into Canada any mixed fertilizer unless it conforms to prescribed standards, is packaged and labelled as prescribed, and registered if so required.

Inspectors of the Food Production and Inspection Branch of Agriculture Canada check fertilizers to insure that labelling complies with the Fertilizer Act. The Inspectors also collect official samples to verity the guaranteed analysis of the fertilizer.

The Control and Inspection of Liming Materials

The Fertilizer Act, administered by the Food Production and Inspection Branch of Agriculture Canada ensures that liming materials meet labelled guarantees. All liming materials must have the minimum percent content Of elemental Ca and Mg indicated. Neutralizing value must be labelled in percent of the acid neutralizing capacity as compared to pure calcium carbonate, e.g. - neutralizing value - 95%. The particle size must be labelled as to the percent of material which will pass through a square screen size of 0.149 mm (100 mesh Tyler screen) and 1.68 mm (10 mesh Tyler screen).

(iv) Placement There is no single best method of applying fertilizers to all crops under all conditions. The main objective is to place the fertilizer so that it will be available to the plant when it is most needed. The "position" may be just as important as the analysis and amount. The best practice may be a combination of methods. Some of the common methods of applying fertilizers are:

(a) Banding the fertilizer 2.5 to 5 cm to the side and 2.5 to 5 cm below the seed is one of the most efficient methods of application for potatoes, corn and other row crops. Care must be taken to avoid contact with the seed especially with sensitive crops such as peas, beans or corn or where heavy applications are used. If large amounts are required, it may be desirable to split the application, e.g. Band a high P fertilizer at seeding time, and broadcast a high N and K fertilizer either before seeding or as a sidedressing or top dressing after seeding.

(b) Moderate amounts of some fertilizer materials may be applied in the drill with the seed of some crops, such as cereals. More caution is necessary when fertilizers contain urea and/or diammonium phosphate, as seedling damage is more likely to result due to ammonia release from these materials.

(c) Broadcasting or top-dressing without working into the soil is used on such crops as hay, pasture, and sod orchards. A fertilizer drill or a lime or fertilizer spreader may be used, or the fertilizer may be spread by hand.

(d) Broadcasting and working into the soil of part of the fertilizer may be desirable when high applications are required. However, broadcasting in general does not result in efficient use of fertilizer, particularly with row crops. Where soils are acid, broadcast applications allow maximum fixation of P by the soil making the P considerably less available to the crop.

(e) Side dressing is done when crops require additional fertilizer during the growing season. Continued wet weather may result in a shortage of nutrients and long season crops often benefit from N and, to a lesser extent, K fertilizers, applied in this way. Timing the application is important and should precede the period of rapid growth or development such as blossoming of beans or heading of cabbage and cauliflower. The fertilizer should be cultivated in immediately after application. It is preferable to use a cultivator with a side dressing attachment. It should be noted that N will move throughout the soil with moisture, but that P and to a great extent K will stay where they are placed.

(v) Fertilizers in Solution Fertilizers in solution or in suspension are widely used in many parts of North America, however, they have found little or no use in the Atlantic Region. Such solutions must be labelled with $N:P_2O_5:K_2O$guarantees as with dry granular products. Their effectiveness is similar to dry fertilizers. The chief advantages of fertilizer solutions lie in certain of their handling characteristics such as uniformity and flexibility of spreading and in their uniform consistency.

Dilute fertilizer solutions are often used when transplanting crops such as tomatoes or strawberries. Such solutions can provide a ready supply of nutrients, especially early in the season when soils are cold. They are often used on plants in beds, flats, or pots.

Foliar Applications

Leaves can absorb certain nutrients applied as a dust or spray. Most trace elements could be used efficiently in this manner. However, foliar applications of N, P, and K are seldom advisable as only small amounts can be applied without causing foliar damages.

Fertilizer Use and Environmental Concerns

During the past decade, increasing concerns have been expressed over the effects of man's activities on our environment - on our soils, our waters and the air we breathe. Agricultural practices and, in particular, fertilizer use and the potential entry of various nutrients into our water systems have been an area of valid concern.

Of the three major nutrients, N and P command greater interest. The many sources of fertilizer N are converted rapidly to soluble nitrate N. This form is not held by soil particles and is subject to leaching and downward movement within the soil whereby it may contaminate our wells and groundwater. Alternatively, it may be lost by runoff of surface waters and enter our streams and rivers. Phosphorus is held strongly by soil surfaces but is transported by soil particles and enters our waterways when soil erosion occurs. High nitrate -N levels (more than 10 ppm or 10 mg// in drinking water may make it unfit for human consumption and for infants in particular. Nitrogen and P enrichment of waters promote algal growth and subsequent depletion of oxygen supply and deterioration of water quality. The third major nutrient, K is held rather strongly by soil particles but nevertheless is subject to loss and entry into water systems but without apparent deleterious effects.

Sound land use and soil fertility practices can maximize efficiency of fertilizer use and minimize environmental concerns:

Keep soil erosion to a minimum through use of crop rotations, cover crops, and minimal production of intertilled crops on soils with significant slopes.

- Use limestone in the interest of increasing fertilizer efficiency and thereby reducing rates of application.
- Use soil testing services to determine fertilizer requirements for different crops in different soils.
- Apply fertilizers at recommended rates.
- Spring applications of fertilizers are preferable to fall applications.
- Follow recommendations on disposition of animal wastes with respect to storage, time and rate of application and do not apply to frozen soils with any significant degree of slope. (Detailed information in: Canada Animal Manure Management Guide, Agriculture Canada, Publication 1534, 1979).

Fertilization of Crops

Plant Nutrient Removal

Fertility of a soil is "the quality that enables it to provide nutrients, in adequate amounts and in proper balance, for the growth of specified plants, when other growth factors such as light, moisture, temperature, and the physical condition of the soil are favorable." For optimum crop production, adequate and balanced supply of plant nutrients is essential.

Erosion, leaching, and cropping are all responsible for the removal of plant nutrients from soils. Obviously, the relative amounts removed in each of these ways will vary from soil to soil and will depend on rainfall, soil texture (i.e. proportions of sand, silt, and clay), nature and amounts of nutrients present, and the cropping practices followed. Erosion losses are appreciable on steep slopes whereas removal by leaching occurs on level areas. Some nutrients such as N in the nitrate form are readily removed by leaching. Others, such as P are much more resistant to loss by leaching. Since water moves through coarse textured (sandy) soils more readily than through fine textured clayey soils, leaching losses are usually greater in the former. Since different crops have different nutrient requirements, removal by cropping will vary with the crops. Some indication of the extent of this variation is given in Table IV.

Table IV - Estimated Removal of Plant Nutrients by Various Crops

Crop	Yield Tonnes/ha	Kg/Ha Nitrogen (N)	Phosphorus (P)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)
Alfalfa Hay	9	213	22	228	132	27
Timothy hay	9	94	18	134	20	11
Red Clover hay	9	170	18	128	121	29
Oat grain	3	56	10	13	8	4
Oat straw	4	27	4	56	8	9
Barley grain	3	57	12	13	2	3
Barley straw	3	23	3	36	11	3
Wheat grain	3	62	13	17	1	8
Wheat straw	3	19	2	28	6	3
Apples	9	18	2	31	2	11
Potatoes (Tubers)	27	106	16	146	3	9
Carrots (Roots)	9	43	9	57	11	4
Turnips (Roots)	44	94	9	161	27	9
Cabbage	44	157	13	108	27	9
Corn	9	112	17	168	17	17

Nutrient Requirement of Crops

Grassland

Improved grassland production is essential for livestock farming in the Atlantic provinces. Benefits will result from the use of recommended varieties of grasses and legumes. Up-to-date experimental information combined with the experience of successful farmers also indicates that improvement of grassland production requires agricultural limestone and commercial fertilizers. Barnyard manures provide plant nutrients and may be used satisfactorily for either hay or pasture production. Every effort should be made to conserve the fertility present in manure and to ensure that it is applied to the fields with the least possible loss. Light, frequent applications are more beneficial than heavier applications at less frequent intervals. On the average livestock farm, manure alone will not supply sufficient fertility for optimum yields of grasses and legumes, but it may be used effectively along with commercial fertiliers.

Pasture

Fertilizer and limestone recommendations should be based on soil tests. They are designed to produce highest economic yields when accompanied by good management.

(a) Fertilizing in the Seeding Year

Apply recommended rates of limestone and fertilizer, since restricting fertility at this stage leads to weak establishment and poor stands.

Response obtained from fertilizing forages is greatly increased by liming the soil to a desirable pH before seeding. Information from research shows that forage yields are almost doubled when fertilizer is applied to a soil with a pH of 6.2 compared to fertilizing acid soil with a pH of 5.4.

Apply dolomitic limestone, as recommended by soil test, to raise the pH to 6.2 and mix thoroughly into the seedbed. For best results, apply limestone in fall.

Phosphorus is particularly important in the seeding year to ensure good root development and seedling establishment. Use a high P fertilizer at seeding, especially if your soil is low in P.

Legume seedlings may need some N to promote growth until they become modulated and can fix their own N. Grass seedlings need N to promote their growth for the entire establishment season.

Potassium is particularly important in the fall to encourage root development, storage of food reserves and development of cold hardiness.

Boron should be applied in the seeding year to aid in legume establishment. Apply recommended amounts, as excess applications may retard or even kill the seedlings. Do not apply B again for at least 2 or 3 years unless deficiency symptoms occur.

(b) Fertilizing Established Stands

Forage stands which do not receive adequate fertilization will become unproductive, thin out rapidly and revert to a less productive native sward. To maintain established forage stands:

- Fertilize annually and generously with K, which is an essential nutrient in maintaining all forage stands.
- While P is most essential in the seeding year, a small amount may also be required annually in the maintenance fertilizer.
- Nitrogen is required in maintenance fertilizer for pure grass stands or mixtures with less than 40% legume. Apply fertilizer containing N in early spring and again in early summer.

Where manure is applied, reduce the rate of fertilization according to the kind of manure and rate of application. Animal manure is an excellent fertilizer, and a good soil conditioner. It contains the three major plant nutrients and it can be utilized to realize savings in fertilizer costs. Samples of dairy cattle manure have been found to contain 5 kg N, 3 kg P and 6 kg K per tonne.

Further details on pastures can be found in: "Pasture Production and Utilization in the Atlantic Provinces", AFCC Bulletin No. 135.

May and Siliage

In general, species grown for hay or grass silage have similar limestone and fertility requirements as those grown for pasture. In view of the fact that hay and/or silage crops are harvested once or twice during the season whereas pasture growth is desired during the entire grazing season, there may be differences in fertilizer practices to meet these different conditions.

For crops consisting chiefly of legumes such as alfalfa, red clover, alsike clover, or birdsfoot trefoil, fertilizers used should be high in P and K and low in N. Legumes have the ability to fix nitrogen from the atmosphere and provide most of their requirements for this nutrient.

Hay crops with a predominant grass sward require high levels of N, and K applied in early spring, and a 3-1-3 ratio fertilizer is recommended. For aftermath growth, on fields well supplied with P, but low in N and K, a 1-0-1 ratio fertilizer may be applied after each grazing or crop removal to supply sufficient quantities of N and K.

Cereal Crops: Oats, Barley, Wheat and Rye

The ideal soil fertility program is one that stimulates rapid, vigorous growth early in the growing season followed by the development of strong straw, well filled kernels, and early, uniform maturity.

If the N supply is too high, a very heavy, rank growth may occur followed by poorly filled kernels, delayed maturity, and reduced yields due to increased disease and/or lodging. Lodged crops are difficult to harvest, and if planted as a companion crop will hinder the establishment of the grass and legume seedlings. Application of fungicides may help control diseases and allow higher production from higher levels of N.

Soil tests along with information on past soil treatments, crop yields, and other management practices provide a sound basis for fertilization of cereal crops.

In general, early planted spring cereal crops require higher N fertilizer than those planted later in the season. With spring planted cereals, all of the fertilizer is generally applied at the time of seeding, except in some intensive management systems where part of the N is applied at later stages. Care must be taken when drilling fertilizer with the seed to avoid seedling damage especially if the fertilizer contains urea and/or diammonium phosphate. However, in the case of winter cereals (winter wheat and winter rye) seeded in September, a mixed fertilizer is applied with the seed, as for other cereals, followed by an additional application of N as early as possible the next spring. For high levels of production of high protein wheat additional N application may be required.

Corn

Corn, a high yielding annual crop, is important as a livestock feed in the Maritime provinces. With increasing experience at growing corn, the continuing introduction of new earlier maturing corn hybrids, and a number of different options of harvesting and storage methods to choose from, more growers are looking to both silage and grain corn as home-grown animal feed sources. The kind and amount of fertilizer required for corn will depend on the fertility status of the field, the cropping program, and whether or not farm manure is to be used along with the fertilizer. Corn production is becoming highly specialized and most satisfactory fertilizer recommendations can be made only if soil analysis results are available. All of the fertilizer necessary for corn can usually be applied at the beginning of the season. Banding of a fertilizer high in P, such as, diammonium phosphate will promote early rapid growth, essential for maturity.

Further details on corn production can be found in: "Field Crop Guide", Publication 100, prepared by the Atlantic Committee on Crops.

Potatoes

Potatoes are generally grown on acid soils with a pH of about 5.0 to 5.4 to discourage scab development on the tubers. Some russet varieties however are scab resistant and are grown successfully on higher pH soils.

Under acid soil conditions, the efficiency of P whether applied as fertilizers or already in the soil is relatively low. However, as soil test levels increase from previous applications the need for large yearly applications of P declines. Application rates should be based on soil testing. The uptake of P tends to be inhibited due to excess amounts of chlorine.

Applications of K, especially potassium chloride, in excess of about 100 kg/ha will strongly depress tuber specific gravity and thus reduce quality usually without any yield benefit. Potassium applications should be based on soil testing and it high rates are required, broadcasting part of the K in the fall will be of benefit.

As a rule, N applied in excess of 130 kg/ha will produce little or no yield increase, and will tend to lower tuber specific gravity, delay maturity, and increase the susceptibility to skinning and bruising. Normally there is no advantage to splitting N applications. However, if N is applied after planting, it should be done when the plants are 12-15 cm high. Later applications may reduce yields.

Fertilizers for potatoes are usually applied in a band at planting. However, on soils testing high or high plus, broadcasting most or all of the fertilizer prior to planting can save considerable time. Application of some N and P in a band helps get plants off to a good start.

Although responses to Mg may occur on soils testing very low in Mg, the routine addition of Mg in potato fertilizers does not appear warranted. Occasional responses to Mg have been encountered on sandy soils of pH lower than 5. Required routine applications of dolomitic limestone should provide sufficient Mg

Fertilizer Recommendation Tables - 2006 Revision

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Soil Acidity and Liming

To correct soil acidity, ground limestone should be broadcast and worked into the soil at rates determined by soil test. The accompanying table shows the soil pH values below which lime is recommended and the "target" soil pH to which soils should be limed for different crops. In Ontario most crops grow quite well at pH values higher than the target pH to which lime is recommended.

Coarse and Medium Textured Mineral soils (sands, sandy loams, loams and silt loams)

	Soil pH Below Which Lime is Recommended	Target Soil pH*
All crops not listed below	6.1	6.5
Corn, soybeans, winter rye, grass hay and pasture, turf, tobacco, established tree fruits and grapes	5.6	6.0
Potatoes	5.1	5.5
Blueberry, cranberry, rhododendron, azalea	No lime recommended	

Fine Textured Mineral Soils (clays and clay loams)

	Soil pH Below Which Lime is Recommended	Target Soil pH*
Alfalfa, cole crops, rutabagas	6.1	6.5
All crops not listed above or below	5.6	6.0
Corn, rye, grass hay and pasture, tobacco, established tree fruits and grapes, potatoes	5.1	5.5
Blueberry, cranberry, rhododendron, azalea	No lime recommended	

Organic Soils (peats and mucks)

	Soil pH Below Which Lime is Recommended	Target Soil pH*
All crops not listed below	5.1	5.5
Blueberry, cranberry, rhododendron, azalea	No lime recommended	

* Where a crop is grown in rotation with other crops requiring a higher pH (for example corn in rotation with wheat or alfalfa) it is recommended that the soil be limed to the higher pH.

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