Orchard Soil Management and Apple Nutrition

in Eastern Canada

BY M. B. DAVIS AND H. HILL

Illustrations by Arthur Kellett

DIVISION OF HORTICULTURE—EXPERIMENTAL FARMS SERVICE

M. B. Davis, Dominion Horticulturist

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TABLE OF CONTENTS

ORCHARD SOIL MANAGEMENT AND APPLE NUTRITION IN EASTERN CANADA

Since the publication in 1941 of Technical Bulletin No. 32 "Apple Nutrition", the value of foliage symptoms as a means of diagnosing certain nutritional deficiencies has been amply demonstrated. This present bulletin, which is a revision of the original publication, contains a more complete section on cultural practices and the maintenance of soil organic matter.

ORCHARD SOIL MANAGEMENT

Orchard management should consist of a planned system for maintaining the productive capacity of the soil for the life of the orchard and for future use. Effectiveness of a given system as measured by yield alone should be judged over a period of years and not by immediate response since practices which result in eventually impairing the productive capacity of soils may initially give high yields.

General Soil Requirements

Profitable production and long life of trees is probably dependent on a suitable natural physical condition of the soil above all other soil factors. The soil should possess adequate depth for free root penetration; a condition which is also generally associated with good aeration and drainage. Trees on soils characterized by an impervious subsoil at comparatively shallow depths are shallow rooted and characteristically short-lived. If the root system is restricted in depth the tree will be in distress during a period of drought when the upper soil becomes very dry. Poorly drained soils do not allow proper soil aeration and active tree roots remain only above a water soaked layer. Colour of the subsoil is a reliable index of drainage and aeration qualities. Yellow or grey mottling of the subsoil is a good indication of inadequate drainage and the depth of mottling corresponds rather closely to the depth of good drainage.

In addition to the required natural soil characteristics mentioned above, management must be such that:

(1) Soil erosion is minimized.

(2) The soil is capable of storing or holding sufficient moisture to meet crop requirements.

(3) A balance supply of plant nutrients is available to the trees.

Soil Erosion Control

Orchard sites may be particularly subjected to erosion unless properly managed since a deliberate choice is made of sloping land for such sites to ensure good water and air drainage and the land is occupied continuously for a long period of time. In addition, land that is too steep and rough to be used satisfactorily for growing grains or cultivated row crops is often planted to fruit trees and careful management must be followed if the trees are to be grown successfully and erosion controlled. While severe erosion in the form of gullying is evident and spectacular, more insidious sheet and wind erosion which removes the fertile top soil over a longer period of time occurs more frequently and is often unsuspected.

The most effective means of checking soil erosion is the maintenance of a thick vegetative ground cover. Permanently sodded orchards are much less subject to erosion than clean cultivated orchards and, of the latter, orchards which are cover cropped annually suffer much less from erosion than where systematic cover cropping is not followed. In any orchard, regardless of the system of cultural management adopted, natural drainageways of waterways for surface water should be maintained in sod. Such waterways should be fertilized sufficiently to maintain a dense plant cover. Cover crop residues are valuable in holding winter snows and in preventing good top soil from being lost by run-off in the spring.

Apple trees require little cultivation and after the trees are well established satisfactory growth and production, as well as control of erosion, can be effected in the great majority of cases by maintaining a grass sod. Under the sod mulch system it would be only in rare cases where contour planting and terracing would be necessary to control run-off. The sod mulch system is therefore to be preferred on orchards situated on markedly rolling land or on steep slopes subject to erosion.

However, if for some reason a grower prefers to cultivate an orchard with such topography, contour planting, which allows for cultivation across the slope and along the contours, may be necessary. Such a system is designed to bring about absorption by the soil of the greatest quantity of rainfall by preventing abnormal run-off and, by conducting excess water off at low velocity, reduce or prevent soil erosion. On non-contoured, non-sodded orchards other conservation methods, such as sod stripping or mulching, should be substituted for the standard clean cultivation method. In areas where there is serious erosion the maintenance of a straw or other plant material mulch over the entire area has been found to be effective. This system would eliminate any competition for moisture that might exist if the area was sodded and by the elimination of labour costs for mowing or cultivation it might be found economical to produce the mulch material on parts of the farm not used for fruit production.

Nature and Functions of Soil Organic Matter

The two other aims of soil management previously mentioned are the maintenance of a soil capable of supplying sufficient moisture to meet crop requirements and of making available a balanced supply of plant nutrients. These two aims are primarily affected by the organic-matter content of the soil.

The main source of soil organic matter is plant material, such as dead roots, leaves, stems and fruit. The term "humus" is applied to an advanced stage in the decomposition of soil organic matter by micro-organisms, but the term organic matter will be applied to all plant residues whether fresh or well decomposed.

Organic matter modifies the structure, texture and therefore the moisture-holding capacity of soils. The moisture-holding capacity of a soil is proportional to its organic matter content. Trees growing on soils of high organic matter content are less likely to suffer from lack of moisture during summer droughts due to the ability of these soils to retain soil moisture against such needs. Organic matter promotes biological activity in the soil as a result of increased aeration and it functions as a storehouse of nitrogen and mineral plant nutrients, causing them to be gradually released for the use of the trees as its decomposition takes place. Chemical fertilizers may be employed as a source of nitrogen and mineral elements, but they do not serve to maintain the proper physical condition of the soil and therefore lasting production capacity is dependent upon the maintenance of adequate amounts of organic matter.

Organic Matter and Fertility Maintenance Under Different Systems of Management

The two systems of cultural management most generally employed are clean cultivation with cover crop and grass sod mulch. During the last ten to fifteen years the sod mulch system has gradually gained in favour because of the greater ease and economy with which organic matter may be maintained, and the realization that severe soil erosion has occurred in clean cultivated orchards situated on rolling land or steep slopes. One of the chief advantages of the sod mulch system is the assurance that the soil organic matter will be maintained. It is recognized that in permanent grassland the organic content of the soil is high. Additions are constantly being made to the soil from decomposing vegetation and eventually reach a point where the additions equal the removal by decomposition.

At Ottawa an experiment was started in 1938 on a relatively level site with a light sandy loam soil to determine the levels of soil organic matter maintained over a period of years under different systems of management. Determinations were made when the plots were laid down and again in 1945.

Three treatments are being carried on;

No. 1 involves clean cultivation until late June, then a cover crop, generally of Crown millet, and a complete fertilizer. The millet is cut when in bloom, allowed to lie where cut and disked into the soil in the spring.

No. 2 treatment consists of a grass sod mulch. The sod is a mixture of orchard grass, timothy and blue grass. It is mowed three times a year, the mowings being allowed to lie or forked in under the trees. In addition, during the seven years of the experiment 8 tons of straw per acre have been applied, which means about 6½ tons of actual dry matter, plus of course the dry matter from the grass cuttings. The fertilizer employed has been a 9-5-7.

No. 3 treatment has consisted of clean cultivation, cover crop, 4-8-10 fertilizer and a total of 120 tons of manure per acre during the seven-year period, estimated as equal to 30 tons of dry matter.

As indicated in the following table the clean cultivation, cover crop plot has actually lost 0·54 per cent of the original organic matter despite the turning under of a good green manure crop annually, while the sod mulch plot has gained 0·44 per cent and the clean cultivation, manure and cover crop plot has just about held its own, with a slight gain of ·09 per cent.

Plot	Treatment	1938 % Organic Matter	1945 % Organic Matter	Increase or Decrease
I	Clean cultivation, cover crop, 9–5–7 fertilizer	3·63	3·09	−0·54
II	Grass sod mulch, 9–5–7 fertilizer	3·54	3·98	+0·44
III	Clean cultivation, cover crop, 4–8–10 fertilizer, barnyard manure	4·61	4·72	+0·09

After the mulch layer has become established it also acts as a storehouse of nitrogen and mineral nutrients, gradually making them available to the trees as decomposition progresses. The following data in respect to total nitrogen and available mineral elements in the soil were obtained from the same experiment.

—	Plot I			Plot II			Plot III		
	1938	1945	Difference	1938	1945	ence	1938	1945	Difference
% nitrogen	0·144	0·106	−0·037	0·138	0·150	+0·012	0·184	0·200	+ 0·016
Exchangeable calcium	0·161	0·074	−0·087	0·190	0·188	−0·002	0·272	0·236	− 0·036
Exchangeable magnesium	0·013	0·005	−0·008	0·012	0·013	+0·001	0·014	0·019	+ 0·005
Exchangeable potassium	0·012	0·019	+0·007	0·013	0·033	+0·019	0·012	0·019	+ 0·007
Soluble phosphoric acid	340	195	− 144	216	431	+ 214	506	531	+ 24
Total phosphoric acid	0·250	0·240	−0·010	0·240	0·286	+0·046	0·266	0·326	+ 0·060

The clean cultivation, cover crop (Plot I) has decreased in total nitrogen, exchangeable calcium, magnesium, total and soluble phosphorus. When additional organic matter was supplied in the form of manure (Plot III) total nitrogen, magnesium and phosphorus were increased. In the grass sod mulch plot, total nitrogen increased, calcium and magnesium were maintained and substantial increases occurred in soluble and total phosphorus. Potassium was increased in all plots, with the greatest increase occurring in the sod mulch plot.

Other investigators, notably Wander and Gourley (2) from Ohio, have reported that larger amounts of available potassium are present under a mulch than in clean cultivation and the same authors have shown that the phosphorus content of leaves and fruit are increased by mulching (3).

In cultivated orchards with relatively level topography and therefore not so subject to erosion the main problem is to maintain soil structure, organic matter and fertility over the long period of time the land is occupied. While decomposition of organic matter at a rate sufficient to meet the nutritional requirements of the tree is desirable, cultivation may burn up organic matter at a wasteful rate and necessary replacement requires constant attention. It has been shown that on a light-textured soil even the annual use of a cover crop was not sufficient to maintain organic matter. However, under cultivation the main source of replacement is the annual use of cover or green manure crops. A plant for cover crop purposes should have certain desirable characteristics, namely:

(1) It should germinate quickly and grow rapidly.

(2) It should be a strong grower, so that it will supply substantial amounts of organic matter and provide a dense cover to prevent frost from penetrating deeply into the ground.

(3) It should stand fairly erect so that it will hold the snow well in winter.

(4) It should be a plant which can be easily handled in the orchard.

(5) In districts where there is danger of making the soil too dry by late growth, a cover crop should be chosen which will be killed by early frosts.

(6) It should be comparatively shallow rooted since deep rooted grasses and legumes compete with the tree for moisture.

There are several plants which possess the above desirable characteristics and some are much more satisfactory in certain regions than others because of climatic conditions:

Sudan Grass.—In those districts where dry conditions prevail during the summer, Sudan grass sown at the rate of 30 pounds per acre should be satisfactory. "This crop germinates well in hot weather, forms a thick ground cover, and is a good smother crop for weeds" (1).

Crown Millet or Empire Millet.—In eastern Ontario and Quebec these two rapid growing, vigorous plants are very satisfactory when sown at the rate of 25 and 30 pounds per acre respectively. Under dry conditions Crown millet is to be preferred since it does not use the quantity of soil moisture required by the Empire type.

Mixed Grains.—A mixture of barley, 1½ bushels; field peas, ¾ bushel and vetches, ½ bushel, has been employed to advantage in Nova Scotia.

Buckwheat.—Another cover crop often used is buckwheat, which is sown at the rate of ½ to 1 bushel per acre. The seed is cheap and the crop provides a good ground cover which smothers weeds.

Alfalfa and Sweet Clover.—These plants are not considered satisfactory as green manure crops on account of insufficient growth by the time they should be turned under.

Soybeans.—This plant appears to be a good leguminous green manure crop, although sometimes it is difficult to obtain a good stand and it does not offer too efficient opposition to weed growth. It should be sown at 1½ to 2 bushels per acre.

Domestic Rye.—Domestic rye seeded at 10 to 15 pounds per acre makes a vigorous, dense ground cover. However, if seeded too early in the season it may compete with the trees for moisture. When disking it in the spring it is well to apply a light application of nitrogen to prevent competition for available nitrogen with the trees.

Supplementary Sources of Organic Matter for Cultivated Orchards

The use of green manure or cover crops annually may not provide complete replacement for the soil organic matter used or burnt up during the cultivation period and it may be necessary to provide other sources:

Farmyard manure may be employed as a partial satisfactory source of organic matter and as a partial substitute for chemical fertilizers, if applied annually. However, excessive quantities of manure applied at any one time may delay the trees hardening off in the fall and produce apples of poor storage quality, since it makes its nitrogen available over a long period. Fifteen tons per acre should be considered as a moderately heavy application if applied over the entire orchard area.

Hay or Straw.—Farmyard manure may often be used to greater advantage for the production of other crops and since there is a general scarcity of manure in fruit districts organic substitutes may be employed. The Horticultural Experiment Station, Vineland Station, Ontario (Ontario Department of Agriculture Bulletin 437), has recommended the following: "the application of hay or straw in the orchard in the late fall at the rate of two tons per acre, lightly disked to partly break it up and incorporate it. If legume hays are used no nitrogen supplement to aid decomposition is needed, but the non-legume hay and straws need about 150 pounds per ton of some form of nitrogen to hasten decomposition and prevent competition with the tree. One-half of this amount is broadcast over the material when applied and both are lightly disked. Early the next spring the remaining half of the nitrogen should be applied. Treated in this way, two tons of straw or hay are the equivalent in organic matter of about seven tons of manure."

Comparison of Production Under Different Systems of Management

That the sod system of management, properly handled, is capable of producing trees of high vigour and as high production as clean cultivation is borne out by the following figures obtained from plots in an orchard located in Bloomfield, Prince Edward County, Ontario. The trees used for the trial are the McIntosh variety, twenty-seven years old at the beginning of the experiment. The orchard is located on Newcastle loam, a soil with medium good natural drainage and medium organic matter content. For a number of years previous to starting the experiment fertility and organic matter had been maintained by application of pea cannery refuse. Each year the orchard was cultivated and a cover crop sown during midsummer. In general, the orchard had been well handled, the trees were in good vigour and productive.

The methods of management employed in the experiment are as follows:

(1) Trees are grown in a sod of orchard grass, timothy and blue grass and a mulch of 75 pounds of straw is placed around each tree during the late fall. With thirty-five trees to the acre, application of straw is at the rate of approximately 1⅓ tons per acre. A 9-5-7 fertilizer is applied each spring at the rate of 500 pounds per acre. The grass is cut when necessary throughout the season and allowed to lie where cut.

(2) The plot is ploughed as early as possible in the spring and kept cultivated until the middle of June when a cover crop of Crown millet is sown. A short time before harvest the crop is cut and left on the ground. Fifteen tons of barnyard manure and 600 pounds of a 4-8-10 fertilizer are applied early in the spring.

(3) This method is similar to that employed by the grower before the experiment was begun. No manure or fertilizer are used, but the ground is heavily mulched each year with pea cannery refuse. The soil is cultivated each year until the middle of June when a cover crop of Crown millet is sown, which is cut before harvest and left on the ground.

Plot	Treatment	Girth Increase per tree in Inches	Yield of Crop Bus. per tree	Six Year Average Bus. per Acre
I	Sod, mulch	1·387	21·97	758·31
II	Cultivation, cover crop, manure	1·219	21·69	748·31
III	Cultivation, cover crop, cannery refuse	1·281	20·01	690·36

The six year average yield is satisfactory with all treatments. However it is worthy of note that the sod mulch block has been slightly more productive and less expensive to operate than method 2.

Another soil management trial has been conducted for the last seven years in an orchard located at Brighton, Ontario. The trees used for the trial are the Stark variety. about twenty-five years of age at the beginning of the experiment. The soil is Smithfield silt loam, a highly calcareous, well drained soil with shallow profile. Previous to starting the experiment the orchard had been clean cultivated, but no consistent cover crop program had been followed. Soil fertility was low, the trees lacked vigour and symptoms of nitrogen and mineral deficiencies were evident.

The systems of management employed in the experiment are as follows:

(1) Clean cultivation from early in the spring until the first of July, when a cover crop of Crown millet is sown. A short time before harvest the crop is cut and left on the ground. Early in the spring the equivalent of 9-5-7 fertilizer is applied at the rate of 11 pounds per tree.

(2) Sod Mulch—The area was seeded down to a mixture of timothy, orchard grass and Kentucky blue. The grass is cut when necessary throughout the season and allowed to lie where cut. A straw or old hay mulch is applied around the trees in November at the rate of 75 to 100 pounds per tree. A 9-5-7 fertilizer is applied early in the spring at the rate of 11 pounds per tree.

(3) Check—Clean cultivation from early in the spring until the first of July, then a volunteer crop of weeds or grass allowed to grow. No manure or chemical fertilizers are applied.

In the first year of seeding down, the sod plot was definitely starved for nitrogen, as indicated by light yellowish-green foliage and reduced growth. Subsequently, an additional 2 pounds of ammonium sulphate was applied per tree to aid decomposition of the straw mulch. By the second season where this procedure was adopted the sod plot was outstanding in vigour, size and colour of leaves, amount and quality of growth.

Plot	Treatment	Average Growth and Yield for Four Year Period		
		Tree Girth Increase	Bus. per tree	Bus. per acre
I	Clean cultivation, cover, 9–5–7	7·57	8·74	306
II	Sod mulch, 9–5–7	8·45	13·03	456
III	Check—clean cultivation, volunteer cover	7·29	8·38	293

These yields compare unfavourably with those secured in the experiment formerly described. It must be realized, however, that it is located on a poorer soil type and that the orchard was in a very poor state of fertility when the experiment was started. The sod mulch system has raised the vigour and yields appreciably, while clean cultivation, cover and commercial fertilizer has not succeeded in raising the yield appreciably during this period. In Plot I appreciably higher yields might be expected if additional organic matter was added in the form of manure or straw.

Management of Young Orchard

Trees set out in cultivated land generally become established more quickly and make more vigorous growth than those planted directly in sod. Even if it is intended to adopt the sod mulch system of management it is desirable to practise clean cultivation, at least in the area occupied by the tree roots, for the first three or four years until the trees become well established.

Modification of Clean Cultivation for Erosive Soils and Steep Slopes

It is not always necessary or even advisable on erosive soils and steep slopes to practise cultivation for this period over the entire orchard area.

If the site for the orchard already has an established dense sod, relatively free of weeds and composed of suitable grass species, no delay in setting out the orchard is necessary. If the ground cover is not suitable or if the site has formerly been employed for cultivated crops, it would be well to consider seeding a sod cover at least one year before planting. A suitable grass mixture will be found under the heading "Handling the Sod Mulch System" on page 12. In this way the trees are provided with vegetative protection against erosion from the time they are planted.

When it is time to plant the orchard, back furrow strips six to eight feet wide in the sod at proper intervals and cultivate this area until the trees are three to five years of age. Mow the middle areas, leaving the cuttings to lie where cut. If the site is not sodded at the time of planting proceed with the planting the same as in sod but immediately fertilize and seed the middles to a grass mixture as recommended under sod mulch management. When the trees are three to five years of age the roots will have extended into the middles and the tree rows can then be seeded and the orchard handled under the sod mulch system for bearing orchards. If clean cultivation is to be used on erosive sites the orchard should preferably be planted and cultivated on the contour or after the trees are three to five years old the middles can be cultivated and ground cover grown in the tree rows.

In the case of rough, stony land, any cultivation may not be practical and it may be necessary to set out the trees directly in sod. In this case the area directly over the root system should be kept spaded or worked or the trees may be heavily mulched directly after planting with straw or hay to discourage grass growth, and prevent competition for nutrients and soil moisture. If non-leguminous material is used for mulching it would be well to sprinkle the mulch with one pound per tree of ammonium sulphate or other nitrogenous fertilizer to encourage its decomposition.

Intercropping

On non-erosive sites intercrops may be grown to good advantage in the early years as they decrease the cost of bringing the trees into bearing. At no time, however, should the intercrops be permitted to interfere with the growth or management of the apple trees and they should be generously manured and fertilized. Whenever possible, a fall cover crop such as fall rye should be used to help maintain soil organic matter. The trees increase in diameter approximately one foot per year, therefore the area devoted to intercrops should be reduced each year until the strip becomes too narrow.

Crops should not be chosen which require the maximum amounts of water and soil nutrients at the same season that the trees are actively growing. Oats and other small grains make their entire growth in the early part of the growing season and thus are unsatisfactory. Potatoes are one of the best crops to use for this purpose, as are also beans, tomatoes and similar vegetables. When late planted crops are used, such as some of the vegetables, the land should be cultivated frequently prior to planting to keep it free from weeds. Raspberries are rather troublesome as their foliage is very subject to spray injury and thus interferes with spraying operations.

Soil Management in the Bearing Orchard

Handling the Sod Mulch System.—If an orchard has been cultivated during its early life, the first step is to seed it down to a suitable sod. Plants for this purpose should be capable of growing vigorously under conditions of partial shade and of withstanding orchard travel during spraying and harvest. They should also be comparatively shallow rooted so that they will offer a minimum amount of competition to the trees for soil moisture during critical dry periods. Since alfalfa is a legume the nitrogen content of the soil would be built up by the use of an alfalfa sod but since it is deep rooted it often competes too seriously with the trees for moisture. If alfalfa is employed it should be mowed frequently and growth, around the trees particularly, discouraged by the maintenance of a thick mulch layer.

A grass mixture which has been found suitable under general orchard conditions is at follows:

Timothy	5 pounds
Orchard Grass	10 pounds
Kentucky or Canada Blue	5 pounds
Red Top	3 pounds,

making a total of 23 pounds per acre.

Orchard grass is a vigorous grower which will provide bulk of material for mulching purposes and will also survive conditions existing in old, heavily shaded orchards. Canada Blue will become established more readily than Kentucky Blue on soils low in organic matter or moisture-holding capacity and either will make a dense ground cover.

Soil Fertility and Moisture

While there is less danger of organic matter depletion in sod orchards than in cultivated ones, the use of sod introduces the problem of possible competition with the tree for nutrients and soil moisture. Until a decomposing mulch layer has been built up around the trees and the grass growth in this area is smothered for the greater part of the season, competition for nutrients may exist. During this period trees in sod have higher fertilizer requirements, especially nitrogen, than those in cultivated orchards and extra nitrogen must be applied. After the system has been in force for a short time the soil fertility is raised by the decomposing organic matter and fertilizer requirements are reduced. Mowing the orchard frequently is one of the best assurances that the sod will not unduly compete with the trees for soil moisture. The first mowing should be done prior to the onset of dry weather since, if delayed, a great deal of soil moisture will already have been removed by transpiration from the growing grass. In addition, if the grass is left until it has reached a mature dry stage it might well constitute a fire hazard. Subsequent mowings should be made when the grass grows to a height of about one foot, the cut material being left where it falls or forked under the trees as a mulch, but none of the cuttings should be removed from the orchard.

Mulching—An Essential Feature of Sod Management

The use of a mulch should be considered as an essential part of sod culture management as it minimizes competition for soil moisture by smothering the growth of the sod or weeds during the growing period of the tree and also checks loss of moisture by evaporation from the soil surface. It promotes biological activity and after a partially composed mulch layer has become established it also improves soil fertility as previously indicated.

The first fall after the orchard is seeded down it will be necessary to bring in straw, old hay or similar material, spreading it from about 18 inches from the trunk to a distance 2 to 3 feet beyond the spread of the branches. To be most effective in controlling grass growth and conserving moisture the first application should be about six inches deep. It may be necessary to repeat this application for two to three years, after which the cuttings from between the rows may be sufficient to maintain a satisfactory mulch. Some growers have experienced difficulty in securing sufficient mulch material at a reasonable cost and in this regard close planting of sod orchards should be avoided to permit the growth of considerable amounts of grass between the rows for mulch purposes. To encourage the production of mulch material the grass strip between the rows should be fertilized separately from the trees. For this purpose the treatment recommended is the application of 200 to 300 pounds of a 2-12-6 per acre or a formula which has been found satisfactory for grassland on a similar soil type.

It is impossible to state in exact terms just how much mulch material it will be necessary to apply annually, since the amount will vary with the rate of decomposition. As a guide it may be said that the mulch layer should be sufficiently heavy to suppress grass growth under the trees for the greater part of the summer or during the growing period of the trees. Such a mulch layer should be maintained even if it is necessary to bring in outside material at irregular intervals. Any fire hazard which might arise from bringing in supplementary mulch material from an outside source may be largely overcome by applying such material late in the fall when it has a chance of becoming thoroughly wetted. The lower layers will then become an integral part of the surface soil by partial decomposition before hot, dry weather starts in. If applied during the summer it remains as a loose, dry mass on top of the soil that cannot fulfil its functions during that season and moreover constitutes a fire hazard.

Sources of Supplementary Mulch Materials

Straw, old or spoiled hay or ordinary crop refuse make suitable mulching material. If farmyard manure is used for mulching purposes the following factors should be considered. Excessive quantities of manure applied at any one time may delay hardening off in the fall, rendering the trees susceptible to winter injury. The application of farmyard manure at a greater rate than 6 to 7 tons per acre is not recommended, if applied only to the area occupied by the tree roots. This weight of manure would not furnish the depth of covering and therefore would not be so successful in smothering sod growth or in checking loss of moisture from the ground surface as a much lighter weight of hay or straw. Manure may be used at the rate suggested above, along with hay or straw or with the grass cut between the rows. If manure is employed in conjunction with hay or straw as a mulch it should be unnecessary to supply extra nitrogen for mulch decomposition. If manure is available, it could be employed to better advantage by spreading it over the entire ground area, thus promoting vigorous growth of grass, which could be employed for mulching purposes.

Sawdust or Shavings.—Several workers have reported excellent results when sawdust or shavings were employed as a mulch for various crops. Our experiments with such materials in apple orchards have not been conducted for a sufficient length of time to evaluate them. If sawdust or shavings are used directly from the mill then low nitrogen content and high acidity may cause adverse effects. Such effects should be overcome by adding 150 pounds of sulphate of ammonia or its equivalent to each ton of material or by allowing such material to soak up liquid manure when employed for stable bedding. It may also be necessary to add lime to counteract acidity.

Hazard from Mice

One of the hazards in the use of mulch that a fruit grower should keep in mind is the fact that mice find favourable conditions beneath a mulch. The mulch should be kept at a little distance from the tree trunks and particularly in the case of young trees the mulch should be pulled away from the trunks each fall. It has been found that a circular mound of gravel or crushed stone placed around the trunks of the trees is quite a good deterrent for mice.

Wire guards around the tree trunks, reaching below the surface of the ground, offer considerable protection but it is also necessary to carry on a carefully executed poisoning program during the fall for the control of mice.

Handling the Clean Cultivation and Cover Crop System

It has already been pointed out that under the clean cultivation system an efficient program of organic matter replacement is an essential, effected by the use of either green manure crops, farm manure, hay or straw or all three. Many growers continue clean cultivation without providing some method of replenishing the organic matter. This system should in all cases be followed by a cover crop.

If the soil type and the amount of material to be incorporated into the soil permit, disking should be employed rather than ploughing. It is not necessary to throughly incorporate the material into the soil; in fact, the maintenance of a trashy mulch on the surface exercises a considerable effect on erosion control.

Figs. 1, 2 and 3 portray different expressions of phosphorus-deficient conditions. Fig. 4—Leaf from tree deficient in phosphorus and potassium. Note reddish-brown margins resemble discoloration in phosphorus-deficient leaf Fig. 1, while tip of leaf has greyish scorching typical of potassium deficiency as seen in Fig. 5. Fig. 5—This stage of potassium deficiency is subsequent to Figs. 1 to 4, Illustration 3, and precedes the final broken and ragged appearance shown in Illustration 4. Fig. 6—Uniform pale yellowish-green leaf, typical of nitrogen deficiency. Fig. 7—Blistering and burning of the leaf apex due to excessive nitrogen. Fig. 8—Burnt and perforated area due to calcium deficiency.

Illustration 2

Lime-induced chlorosis—Iron deficiency within the plant due to excessive lime in the soil. Intervenal tissue has turned yellow while veins and tissue immediately joining have remained normal green.

FIG. 1—Early stage of potassium deficiency showing olive-brown discoloration on the margins. FIG. 2—Symptoms more advanced showing brownish-orange scorching. FIGS. 3 and 4—Discoloration has extended further into body of the leaf and scorched areas have become enlarged and reddish-brown.

ILLUSTRATION 4

A shoot from a tree in an advanced stage of potassium deficiency. The leaves are hard and brittle, the margins broken and ragged with a distinctive cigar-ash grey colour along the margins and extending into the body of the leaf.

ILLUSTRATION 5

Various expressions of magnesium deficiency, FIG. 1 depicting a commonly encountered early stage prior to burning, FIGS. 2 to 5 variously advanced stages.

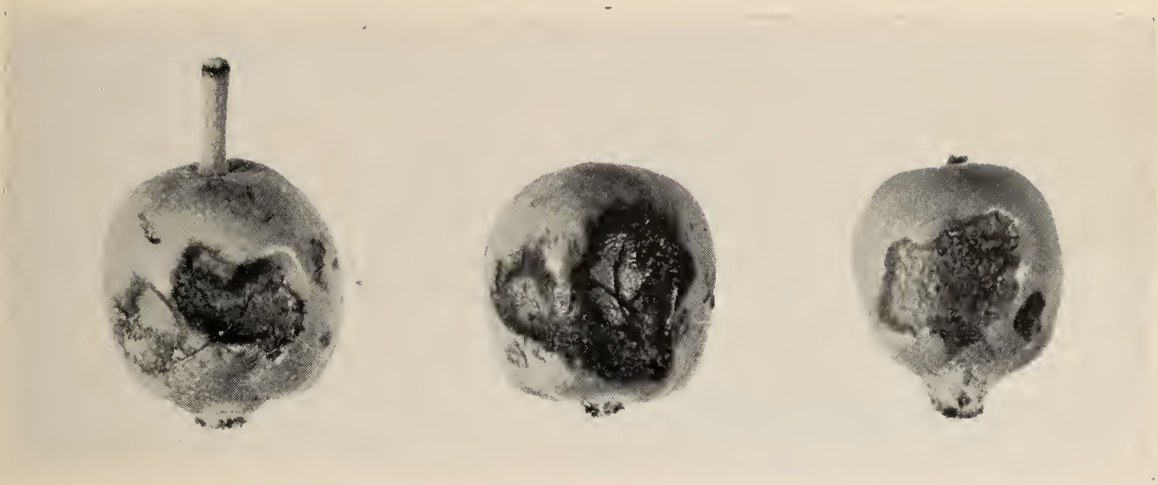
Illustration 6

Rolling of leaves, accompanied by burning, due to magnesium deficiency.

Illustration 7

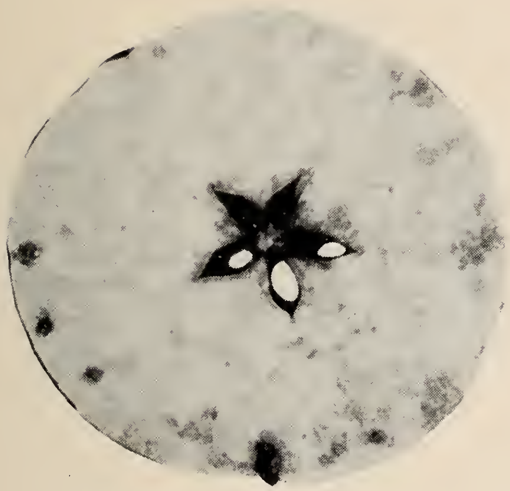
Defoliation following symptoms shown in Fig. 2, a characteristic result of severe magnesium deficiency.

Illustration 8



Drought-spot affecting young apples (natural size).

Illustration 9

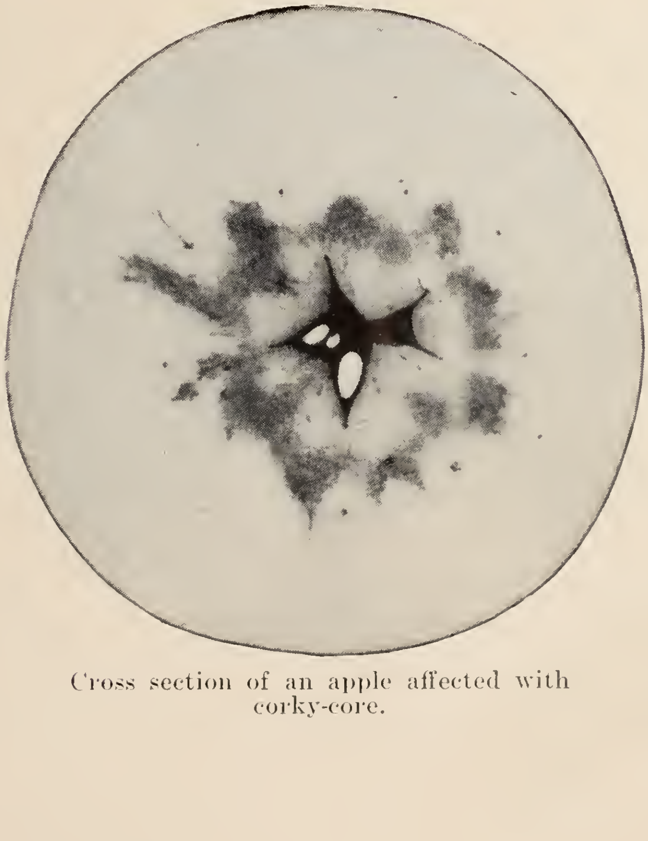


Cross section of an apple affected with internal cork.

Illustration 11

Cross section of an apple affected with Bitter-pit.

Illustration 10



Cross section of an apple affected with corky-core.

ILLUSTRATION 12

FIG. 1—Initial symptoms of drought-spot or superficial cork affecting McIntosh, occurring as irregular small to large light brown russeted patches on the skin.
FIG. 2—Later stages of drought-spot or superficial cork affecting McIntosh. The affected areas have become darker brown, roughened and cracked. Deep cracks or splits have also occurred.
FIGS. 3 and 4—Drought-spot or superficial cork affecting Ben Davis.
FIG. 5—Intermediate stage of drought-spot or superficial cork affecting Stark.
FIG. 6—Intermediate stage of drought-spot or superficial cork affecting Salome.

ILLUSTRATION 13

FIGS. 1 and 2—External symptoms of typical tree-pit affecting Spy seedling.
FIG. 3—External symptoms of internal cork affecting Fameuse. Note distorted and knobby appearance.
FIG. 4—Lenticel spotting on variety Salome.
FIG. 5—Tree-pit affecting Baxter seedling. The external symptoms are somewhat different from typical tree-pit, in that the normal coloured pits are encircled by a reddish-brown halo of lighter colour.
FIG. 6—Blotchy-pit affecting Stark.

Illustration 14

Branches of Delicious severely affected with measles.

Courtesy Dr. A. B. Groves, Virginia Agricultural Experiment Station, Winchester, Va.

Illustration 15

Discoloration of wood in branches of Delicious.

Courtesy Dr. A. B. Groves, Virginia Agricultural Experiment Station, Winchester, Va.

Since cultivation speeds up the decomposition of organic matter by increasing soil aeration it should be discontinued relatively early in the season. The time to discontinue cultivation will vary with the location but cultivation should not be continued for more than about six weeks, so that the cover crop should generally be seeded from the middle of June to the first week in July. A short time before harvest the cover crop may be cut and let lie. It has been found desirable to fertilize for the cover crop apart from the fertilizer specifically required by the trees and it is recommended that a low-nitrogen fertilizer such as a 2-12-6 be applied at the rate of 200 to 300 pounds per acre just previous to seeding.

For details regarding a suitable cover crop or other supplementary sources of organic matter refer to the previous section on organic matter maintenance.

APPLE NUTRITION

To obtain the most profitable returns from the use of any fertilizer it is necessary that the grower be in a position to employ sound judgment based on a knowledge of fundamental principles; a properly interpreted soil analysis; a symptomatic diagnosis or a combination of both. Although general recommendations are of necessity given they cannot hope to meet the needs of even the majority of cases. If the nutrition of the apple tree could be considered separately from the various soil and environmental conditions a definite formula could be given for its feeding, but trees are grown in soils of widely variable physical and chemical composition, each different soil condition having an influence on availabilty of nutrients to the tree.

The availability of nutrients in a given soil is itself affected by variations of climatic factors, especially rainfall.

Nutrient Requirements of Apple Trees

Primarily one should appreciate the requirements of an apple tree and have some understanding of the role of each element involved in its feeding.

Nitrogen

This element is absolutely essential for the growth of a tree, and is probably the most generally required element of all. It is doubtful if any but organic soils can maintain a high state of fertility without frequent applications of nitrogen in some form or other. Since too much nitrogen at one time is not a good thing, and, as it may frequently be lost from a soil by leaching and by bacterial action, it is not desirable to make heavy spasmodic applications. Smaller amounts applied annually are preferable.

Sources of Nitrogen.—Manure, any decayed organic matter, sulphate of ammonia, ammonium nitrate, nitrate of soda, and cyanamide are the more common carriers of this element.

Organic nitrogen, such as is found in manure or other vegetable material, is generally more slowly available than is the mineral form, but where a quick response is not essential it is quite satisfactory.

In regard to inorganic sources of nitrogen, it is preferable to employ sulphate of ammonia on soils that are alkaline; on acid soils the other forms are quite satisfactory. Generally, a combination of organic and inorganic sources is best and this is accomplished by the grass mulch system of orcharding discussed previously.

Potassium

This element is just as essential as nitrogen. It is necessary for the manufacture and translocation of the sugars and starches of the leaves and fruit, and trees growing on soils low in this element are likely to produce poorly coloured fruit with low sugar content. Potassium is particularly necessary for a proper root development and is a factor in controlling both the uptake and loss of water by the plant. The apple fruit itself contains a considerable quantity of potassium. Every barrel of apples contains about four ounces of potassium or the equivalent of half a pound of muriate of potash, so that a tree producing a crop of four barrels would utilize two pounds of muriate of potash in the fruit alone, without making any allowance for the potassium used to make roots, trunk, limbs and leaves. It is thus easy to see that it would require a wonderful soil to provide indefinitely the required amounts of this element.

Sources of Potassium.—Manure, muriate of potash, sulphate of potash and unleached wood ashes all supply potassium. On soils low in potassium it is generally better to employ the mineral carriers; this will be better understood after reading the section on balance.

Phosphorus

This is the next most important element in apple nutrition. While large amounts are not required, it is an extremely important element. An apple tree grown in pure sand will die more quickly from phosphorus starvation than from the lack of other elements, but a very small amount will maintain life and production. It is essential in the manufacture of the proteins produced by the leaves and fruit and like most plant foods is necessary in the production of roots.

Sources of Phosphorus.—Bonemeal (very slowly available); basic slag; superphosphate (sometimes called acid phosphate); ammophos. The latter contains both nitrogen and phosphorus, but is not generally employed in orchards.

Calcium

Lime or calcium is just as essential in plant growth as any of the other elements, but probably is less often required in the fertilizer mixture. This is due to the fact that in a great many soils there are large amounts of calcium as parent material. The ash of an apple contains a large percentage of calcium, but since most sprays contain a considerable amount of lime it is doubtful if further applications are needed except in extreme cases of soil acidity where liming may be recommended. Since vigorous growth of cover crops or permanent sod will not be obtained on soils of high acidity, liming may be necessary for this purpose and will have an indirect effect on tree performance. Excess of lime is a more common trouble, often being associated with the occurrence of "lime-induced chlorosis", due to a deficiency of iron or manganese within the plant (Illustration 16) and drought spot, internal cork or corky core, due to a deficiency of boron (Illustrations 8, 9, 10, 12). Intake of potassium may also be interfered with, as discussed under lime-potassium balance on page 19.

Sources of Calcium.—Gypsum (calcium sulphate), although supplying lime for plant use, is of no value for the correction of soil acidity; marl or shell marl; ground or crushed limestone. There are two kinds of limestone, calcitic and magnesian (dolomite). The former consists mainly of carbonate of lime, the latter of carbonates of both lime and magnesia. Quicklime and slaked lime are employed less frequently, being more expensive than ground limestone and more difficult to handle.

On acid soils where liming is required to correct the soil acidity, it is now considered desirable, where possible, to employ dolomitic limestone, since magnesium deficiency has been found more prevalent on acid soils and has also been found difficult to correct.

Magnesium

This element is necessary for the development of chlorophyll or green colouring material of the leaf. Since the publication of the original bulletin in 1941 deficiency of magnesium has been definitely on the increase in many of the older orchard sections and now constitutes one of the more important fertilizer troubles in many areas.

Sources of Magnesium.—Dolomitic limestone (slowly available source of both calcium and magnesium); magnesium sulphate; sulphate of potash magnesia (containing both potassium and magnesium); kieserite; seawater magnesium oxide; calcined dolomite.

Boron

Boron is one of the so-called minor or trace elements and is required only in very small amounts. It is absolutely essential for healthy development of many species of plants, as in its complete absence plants suffer from various disorders and die.

Sources of Boron.—Boric acid; borax (sodium tetraborate). Both these sources of boron have given satisfactory results but the latter is cheaper.

Iron

Iron is another minor element essential for the development of the green colouring matter in leaves, without which the leaf cannot function efficiently. It is generally present in all soils but may become unavailable to the tree, as will be explained under the section on balanced nutrition.

Sources of Iron.—Ferrous sulphate; ferric citrate; ferrous tartrate; ferric chloride.

Manganese

This is another minor or trace element related to chlorophyll formation and essential to the growth of plants. Very few definite examples of the lack of this element for apple trees have been encountered. Manganese deficiency is most commonly encountered in alkaline soils.

Sources of Manganese.—Manganese sulphate.

Zinc

Zinc is a minor element necessary for plant life, but so far no definite cases of its deficiency in Canadian soils have been noticed. In the western United States it has been found a remedy for certain cases of little-leaf and rosette of apple trees.

Sources of Zinc.—Zinc sulphate.

Balanced Nutrition Essential

The foregoing paragraphs have listed the known important major and minor elements necessary for the production of a satisfactory crop of apples. With all these available in sufficient but not excessive amounts, production of maximum crops is not a difficult procedure. With any one of them absent or available in insufficient quantity serious nutritional difficulties may arise. Even excess amounts of any of these elements may give rise to serious disorders. Just what a sufficient amount is, or what constitutes an excess, cannot definitely be stated with mathematical precision since relative amounts are often of more importance than the actual amount available. Thus the relationship or balance between certain elements is of paramount importance and this factor must be fully appreciated. Whether this correct relationship or balance between the different elements exists in a given soil depends on several factors such as the original soil content; the cultural treatment the soil has received over a period of years and the fertilizer program which has been followed. Even starting with a perfectly balanced soil, man can and often does destroy its fertility by faulty manipulation such as:

(*a*) Continuous clean cultivation, which brings about a depletion of the organic matter and a lowering of the nitrogen content and which may also, due to the lower organic matter, render unavailable certain of the mineral elements.

(*b*) The continuous use of a single-element fertilizer, which tends to build up this particular element to an excessive amount and which at the same time encourages the plant to draw more heavily on the soil for the other elements not applied. In this manner there is a tendency to deplete the soil and upset the original nutritional balance. Some of these balances are fairly well understood and will bear examination.

Nitrogen-Potassium Balance

The relationship between nitrogen and potassium is very important. The larger the amount of nitrogen available up to a certain point, the greater growth the plant is able to make. The more it grows the greater is the demand from the soil for all other elements, but of these elements potassium seems to be in particular demand. Frequently a soil may have sufficient available potassium to satisfy a tree when grown under a certain nitrogen level, but if the nitrogen is raised beyond that level a deficiency of potassium may result which can only be corrected by further additions of that element. The amount of potassium required, therefore, is dependent to a large extent on the amount of available nitrogen. Thus the continuous use of a nitrogen-only fertilizer or a fertilizer high in nitrogen and low in potassium could easily lead to a deficient potassium condition.

Phosphorus-Potassium Balance

Under commercial conditions the possibility of an excess of phosphorus is not so likely as an excess of nitrogen, but there are recorded instances of where excessively high phosphorus has brought about a deficient potassium condition. Since apple trees do not feed heavily on this element, the continuous use of large quantities of phosphoric fertilizers without the application of potassium is not to be recommended.

On many acid soils, which are frequently low in available phosphorus, this element becomes so deficient that the soil is unable to support a satisfactory cover crop or grow a grass sod. Under such conditions the phosphorus deficiency should be corrected, both by correcting the acidity through the use of lime and by liberal applications of a phosphatic fertilizer, but the continuous applications of excessive lime or phosphorus could lead to serious difficulties.

Lime-Potassium Balance

On soils excessively high in lime the intake of potassium may be interfered with, so that on soils naturally high in lime it may be necessary to pay special attention to the available potassium supply. The continued use of lime in the absence of potash fertilizers is not considered to be sound practice.

Lime-Iron-Manganese Balance

Another important balance is the relation between lime and the availability of both iron and manganese. On high-lime soils it is not uncommon to find apple trees suffering from a deficiency of either or both of these minor elements.

Potassium-Magnesium Balance

Generally the accumulation of large amounts of potassium in a soil does not do any harm, but it is possible on low-magnesium soils to aggravate a magnesium deficiency by the continued use of potash without an adequate amount of some form of magnesium.

In recent years several instances of this have been brought to attention, where growers have undertaken to correct a potassium-deficient condition by the liberal application of a potassic fertilizer and thus brought on a magnesium-deficient condition, which in turn has required correction.

As soils get older magnesium will become of greater and greater importance in soil economy.

Symptomatic Diagnosis

The following colour plates and black and white illustrations present material useful in the diagnosis of certain nutritional deficiencies.

Nitrogen Deficiency

A deficiency of nitrogen is very quickly reflected in:

(*a*) Smaller leaves.

(*b*) Shorter terminal growth of a spindly nature.

(*c*) Light brown or bright red bark.

(*d*) A paling of the foliage to pale green, greenish-yellow or even yellow in severe cases (Illustration 1, fig. 6). Note that the leaf is not scorched or burned in any way; neither is it mottled, nor does it possess any amount of green tissue adjacent to the veins. It is merely a uniform pale yellowish-green. Fortunately, a tree suffering from low nitrogen can easily and quickly be corrected by the application of some quickly available nitrogenous fertilizer.

Nitrogen Excess

(*a*) With an over-abundance of nitrogen, trees are over-vegetative, producing an excessive amount of growth of a succulent nature; too many water sprouts develop.

(*b*) The leaves are large, at first a very dark green colour. Later such leaves may show a puckering at the tip, followed by a browning or burning (Illustration 1, fig. 7). Unless there is a commensurate supply of available potassium, an induced deficiency of this element may occur, causing marginal scorching of the leaves (Illustration 1, fig. 5; Illustration 3, all figures).

(*c*) The fruit is poorly coloured.

Corrective measures.—Drastically reduce or omit the application of nitrogenous fertilizers until the foliage becomes medium green in colour and growth is adequate but not excessive.

Up to a certain point the effect of excess available nitrogen may be overcome by increasing the available supply of potassium. While reducing or omitting nitrogenous fertilizers increase the application of muriate of potash or sulphate of potash to 250 to 300 pounds per acre for mature trees until foliage symptoms of potassium deficiency are corrected.

Potassium Deficiency

A deficiency of potassium is probably one of the most common and most serious disorders in Canadian orchards and is fairly easily recognized by foliage symptoms.

Foliage Symptoms.—Symptoms first appear on the lower leaves of current growth, progressing upwards as the deficiency advances. Except in cases of rather severe potassium deficiency the terminal leaves may remain normal. Before any scorching appears the leaf may merely present a certain amount of olive-brown discoloration generally confined to the margins as in Illustration 3, fig. 1. A little later in the season some of these leaves will show an orange or reddish-brown margin as in Illustration 3, fig. 2, presenting a combination of a brown or scorched margin with a tone of olive-brown discoloration next to it.

Still later, the scorching becomes more pronounced as in Illustration 3, figs. 3 and 4, with the scorched areas presenting a reddish-brown appearance and the olive-brown discoloration still remaining next to it.

Finally, the scorched tissue changes from orange or reddish-brown to greyish-brown with a distinctive ashy grey along the margins, sometimes extending more or less into the body of the leaf (Illustration 1, fig. 5). The leaves become hard and brittle and the margins of affected leaves become broken and ragged (Illustration 4).

Since there is a possibility of confusing magnesium deficiency scorching with potassium deficiency scorching follow carefully the explanation under magnesium deficiency symptoms.

Corrective Measures.—Since an abundant supply of available nitrogen aggravates a deficiency of potassium, nitrogen applications should be omitted or materially reduced until the deficiency is corrected.

Soil applications of sulphate or muriate of potash should be applied at the rate of 200 to 500 pounds per acre to mature trees, according to the severity of the disorder.

Phosphorus Deficiency

A lack of phosphorus expresses itself in:

(*a*) Delayed bud break in the spring.

(*b*) Fewer leaf buds.

(*c*) Abnormally small leaves.

(*d*) Foliage dull dark green, lacking lustre; later in the season taking on a bronzed appearance except in the region of the midrib, or the midrib and secondary veins. Illustration 1, figs. 1, 2 and 3, portrays different expressions of phosphorus deficient conditions. Maturity and abscission of leaves occurs early.

(*e*) Growth is limited and slender.

Corrective Measures.—Annual applications of 175 to 200 pounds of 20 per cent superphosphate will maintain a satisfactory level of available phosphorus in the average orchard soil. If an actual deficiency exists it may be necessary to increase this amount until deficiency symptoms disappear.

Calcium Deficiency

No actual cases of calcium starvation of apple trees in the field have been encountered.

Pot trees grown in sandstone and not supplied with calcium had the following characteristics:

Foliage Symptoms.—For a time rather large and luxuriant foliage is produced. Later the leaves become normal to slightly small in size. The foliage becomes somewhat light green and a marked rolling of the leaves occurs, exposing the margins of the under surfaces. The margins of the under surfaces are often discoloured, reddish-purple with the veins in the same area similarly affected. The margins become burned, changing from medium to dark brown or blackish-brown. Similar patches sometimes occur in the centre of the leaf (Illustration 1, fig. 8).

Corrective Measures.—Calcium deficiency will probably occur only on very acid soils with a pH below 5·0 to 5·5. A soil reaction from pH 6·0 to 6·5 appears to be suitable for apple trees. A soil reaction below pH 5·5 will likely be unfavourable to the growth of many cover crops or permanent sods.

A liming material such as ground limestone will raise the pH or correct high acidity and at the same time serve as a source of calcium. Since magnesium deficiency is also likely to occur on such acid soils, a dolomitic or magnesium limestone is preferable to a calcitic limestone. The ground limestone should be spread uniformly and a more favourable response will be secured if it is ploughed into the soil. The rate of application will vary from one-half to two tons per acre, according to the degree of soil acidity.

Magnesium Deficiency

Leaves showing the effect of magnesium deficiency may at first glance be confused with those suffering from potassium deficiency, but a careful examination will reveal certain distinguishing differences (Illustration 5).

Foliage Symptoms.—Foliage symptoms of magnesium deficiency are not generally apparent until the latter part of July. Up until this time growth is not appreciably retarded, the leaves are normal in colour and somewhat large in size. The symptoms first appear at the base of the current year's growth and progress upwards. In some varieties such as the Melba the most prominent foliage sympton is a yellowing, beginning around the leaf margins and progressing inwards towards the midrib. The veins and tissue adjoining the veins remain green, producing an effect of green and yellow bands (Illustration 5, fig. 1). The yellowed bands of tissue ultimately die and become brown in colour (Ilustration 5, figs. 2, 4 and 5). On some varieties such as Fameuse and McIntosh similarly affected leaves may occur although as often as not marginal or central intervenal blotches of dead brown tissue appear without any previous or accompanying bands of yellow tissue (Illustration 5, figs. 3, 4 and 5). When patches of dead tissue occur without any previous or accompanying yellow bands the brown patch is surrounded by a narrow region of light green to yellow-green tissue (Illustration 5, fig. 3). This characteristic helps to distinguish between marginal or central breakdown of tissue due to magnesium deficiency and that due to a deficiency of potassium. In the latter case the tissue bordering the brown area is a distinctive olive-brown.

By the middle of September dead patches involve a large area of individual leaves (Illustration 5, fig. 5). The leaves become rolled (Illustration 6) and premature defoliation of the older basal leaves takes place (Illustration 7). The fruit is reduced in size and has an immature appearance.

Corrective Measures.—Magnesium deficiency has become fairly widespread in the eastern portion of North America. In many cases it is only of an incipient nature, not causing any serious defoliation; in other instances almost complete defoliation may occur by late August, especially in wet years. In such cases a dry season may almost completely remove the trouble for that year.

Generally it is much more acute on strongly acid, low-lime soils and under these conditions it is difficult to correct by soil applications.

When the deficiency occurs on acid soils the first step should be to apply dolomitic limestone at the rate of two tons to the acre. This material should be ground so as to pass a 100 mesh sieve. If possible, the land should be ploughed in spring so as to permit the material to be worked into the soil.

Experience has shown that this is *not* a quick remedy; from three to five years may elapse before any marked recovery can be noted. If the orchard is in sod and cannot be ploughed response may be slower unless a very heavy mulch is maintained and permitted to rot down, in which case the roots feeding in the mulch layer will begin to pick up the magnesium. In addition to the above, in order to obtain immediate relief the use of magnesium sulphate in the cover sprays has to date given satisfactory results.

For this purpose it is recommended that 20 pounds of magnesium sulphate be added to every 100 gallons of the regular spray solution, starting with the calyx spray and continuing for two or three more applications. Experience has shown that leaves showing less than 0·4 per cent MgO in dry weight are apt to suffer from magnesium deficiency. The following results from spraying are typical of many instances in correcting this trouble.

Treatment	MgO per cent dry weight in leaves
4 sprays 2 per cent Epsom Salts (magnesium sulphate)	0·43
Check (not treated)	0·26

On soils that are not decidedly acid (pH 6·5 or above) soil applications of magnesium sulphate, worked into the soil if possible, may give early response, if applied at the rate of 12 pounds per tree. The frequency of application required will vary with the severity of the condition. If this does not give response in the year of application the spray method may be employed for a few years.

If magnesium deficiency occurs on soils high in potash it is advisable to omit any potash in the fertilizer until the trouble has been corrected.

On new orchard sites where acid soil is to be used for orchard purposes it is highly desirable to apply at least two tons of dolomitic limestone to the acre *prior* to planting, working the material into the top six inches of soil.

Watch for magnesium deficient symptoms and as soon as they are observed apply the remedy. If in doubt forward leaves and soil samples to your nearest agricultural experiment station.

Scorching or Burning of Leaves Due to Other Causes Than Nutrient Deficiences or Excesses

The distinguishing characteristics between scorching of leaves due to potassium deficiency and scorching due to magnesium deficiency have been pointed out already. Burning or scorching of the leaves may also be caused by spray injury or sudden drought due to extreme temperatures. The following tabulated list of symptoms will serve to distinguish between burning due to these causes and that due to a deficiency of either magnesium or potassium.

Characteristics of Magnesium or Potassium Deficiency Scorching of the Foliage.

(1) Comparatively slow, gradual development of symptoms during the growing season as previously described.

(2) Symptoms first appear on the basal leaves of shoots and progress slowly to the upper leaves. Unless the deficiency is very severe the terminal leaves may remain unaffected.

(3) Leaves do not drop off prematurely in the case of potassium deficiency, while in magnesium deficiency defoliation commences at the base of affected shoots and progresses upwards slowly.

Characteristics of Foliage Scorching Due to Spray Injury or Extreme Drought

(1) Sudden occurrence of burning without any previous symptoms. Portion of leaf not burned is normal in colour; the burnt area being sharply delimited.

(2) Leaves on any part of the shoot may be burned in the case of spray injury. This burning takes place simultaneously on any affected leaves. There is not any progression of symptoms from leaves on one part of the shoot to another. In the case of spray injury young terminal leaves may be more severely injured than basal leaves. In the case of trees affected by drought the burning may be rather similar to potassium deficiency scorch and occur from the basal leaves upwards, leaving the terminal leaves unaffected. It can generally be distinguished from potassium deficiency by its sudden occurrence in acute form without any of the preleminary stages previously described.

(3) If burning is severe enough to cause marked defoliation, leaf fall occurs shortly after the burning is apparent and the defoliation which occurs takes place in the space of two or three days.

Boron Deficiency

It is only in extreme cases of boron deficiency that the growth and foliage of the tree are obviously affected. Long before the deficiency reaches this stage severe disorders of the fruit occurs.

In a consideration of physiological disorders of apples which occur on the tree, it is necessary to distinguish between (*a*) those which may be corrected by boron (*b*) those which do not respond to boron treatment.

The troubles which respond to boron are classed as drought-spot or superficial cork, internal cork and corky-core.

Drought-Spot or Superficial Cork.—This type of cork may appear very early in the life of the fruit (Illustration 8). If it occurs somewhat later it first appears as irregular, small to large, light brown, russeted patches on the skin (Illustration 12, fig. 1). These areas later become rugose, darker brown in colour, and as they grow become roughened and cracked (Illustration 12, figs. 5 and 6). The lesions may not extend deeply into the flesh, although in severe cases deep cracks or splits may be formed, (Illustration 12, fig. 2). The disorder has been found on the following varieties either alone or associated with internal cork or corky-core: Fameuse, McIntosh, Wealthy, Stark, Northern Spy, Salome. The disorder exhibits somewhat different symptoms on the variety Ben Davis (Illustration 12, figs. 3 and 4). The initial russeted areas are not present but the fruit is malformed due to irregular depressions dark brown in colour. Internally the lesions are found involving the skin or within 2mm. of the skin. They are dark brown, usually having a green border.

Internal Cork.—This disorder often appears when the apple is but half grown. Fruits affected at this stage increase but little in size and often drop badly. Affected fruits may be detected on the tree by the blushed or red portion of the apple being somewhat darker in colour than is normal. In some varieties fruit affected early in its growth becomes markedly deformed and knobby (Illustration 13, fig. 3). In other varieties of fruit affected later in their growth, there is no external evidence of the disorder. If the fruit is cut it will show light brown spots of dead cork-like tissue in the region of the core or scattered throughout the flesh (Illustration 9). The Fameuse variety is particularly susceptible to this form of cork.

Corky-Core.—In this type of cork the outside of the apple appears perfectly normal. On cutting the fruit transversely light brown patches or a continuous band of brown tissue are found in the core area (Illustration 10). The McIntosh variety is particularly susceptible to this trouble.

Corrective Measures.—All the above troubles have responded to boron treatment and recommendations for control are as follows: Boron should be applied either in the early spring or fall to orchards in any area where cork has been found and where no application of boron has yet been made.

Orchards on Acid Soils.—Apply 4 ounces of borax to trees up to 10 years of age, 8 ounces to trees from 10 to 20 years of age and 8 to 16 ounces to older trees. If boric acid is used the rates should be two-thirds those mentioned. To apply this small quantity the borax or boric acid may be mixed with several times its volume of dry sand or soil as an aid in spreading.

Orchards on Alkaline Soils.—If the soil is alkaline and high in lime, effective control may not be obtained by applications to the soil in a season when very low soil moisture conditions exist. Under these conditions more effective control may be obtained by incorporating boron with the regular spray. If this is done, two applications should be sufficient, one at the time of the calyx spray and one with the second spray after that, using borax at the rate of 2½ pounds to 100 gallons of the spray mixture. The foregoing recommendations are not to be considered as annual treatments, since there is the possibility of creating toxic concentrations of boron. A single treatment has been found effective for a period of three years. The safest procedure would be to forego further applications until the disorder again makes its appearance.

Foliage and Growth Symptoms of Boron Deficiency.—A dying-back of shoots and limbs may also be brought about by a deficiency of boron. In the spring, buds on last year's terminal growth fail to develop, although no browning of the cambium is seen at this stage as is the case where failure of bud break is due to frost injury. As the season advances the affected buds and bark tissue die, leaving dead shoots projecting beyond the foliage. Several new shoots may extend beyond the dead tip. The leaves on such shoots may occur in tufts of narrow leaves to which the term rosette has been applied.

Measles.—In certain varieties such as the Delicious, boron deficiency may also cause pimples or blisters on the bark. The affected areas enlarge the following season and small cracks appear in concentric arrangement at the margin of the lesions. Upon cutting through such lesions necrotic areas will be seen in the tissue just underneath the bark or deeper in the wood (Illustrations 14 and 15).

Bitter-Pit and Blotchy-Pit.—These are physiological troubles which have not responded to treatment with boron. These troubles may be confused with cork, but there are distinguishing differences. Pitting does not show up until the fruit is approaching maturity or may not show up until the apples have remained in storage for some time.

Typical Bitter-Pit.—The first symptom is the appearance of slightly discoloured spots, deeper green on green fruit and darker red on red fruit, somewhat sunken or depressed and generally regular in outline. They are likely to be more numerous towards the calyx end (Illustration 13, figs. 1 and 2). When an affected apple is cut, it shows groups of brown, broken down pulp cells in the flesh just under the skin and the affected tissue is generally confined to this area (Illustration 11).

Blotchy-Pit.—In this case the pits are less clearly defined, irregular in outline, larger in size, less sunken, deep green or mottled green and brown blotchy depressions (Illustration 13, fig. 6). Large brown necrotic areas are found in the flesh near the core or close to the surface.

No definite cure has been found for pit disorders, but there is some knowledge available concerning their control. They occur most frequently on late maturing varieties such as Northern Spy, Baldwin, Baxter, etc. Where pit troubles occur the only advice possible at present is to refrain from heavy nitrogen applications and avoid attempts to force tree growth. Adopt a complete fertilizer somewhat lower in nitrogen than ordinarily employed. Avoid excessive pruning in any one season and endeavour to maintain an adequate and continuous moisture supply. On sod orchards heavy mulching has aided in this connection.

Iron and Manganese Deficiency

Foliage symptoms brought about by a deficiency of either of these two elements is sometimes referred to as lime-induced chlorosis and is generally associated with alkaline soils, high in lime. Leaves affected with this type of chlorosis turn a mottled green, sometimes bleaching out to almost pale yellow or white with the veins remaining green for a considerable time (Illustration 2). In some cases manganese deficiency may be differentiated from iron deficiency by the occurrence of dead spots on the chlorotic leaves.

Corrective Measures.—In the majority of cases of iron deficiency soil applications have not been found satisfactory but are always worth trying especially when alkalinity is only slight. Spraying has not been found practical in many instances. The most universally adopted method is the employment of injections in the trunk. The size of hole recommended is $\frac{1}{2}$-inch bored with a good sharp bit. The number of holes depends upon the size of trunk. A good rough rule is to bore as many holes as the diameter of the tree in inches. Thus a tree with a diameter of 10 inches would require 10 holes spaced in a spiral manner that does not weaken the tree. In boring, point the bit slightly downward to prevent material from dropping out and drill to a depth of from 1 inch to 3 inches. Trunks from 2 to 5 inches in diameter require holes 1 inch deep, those with trunks 6 to 12 inches in diameter require holes 2 inches deep and those with diameters over 13 inches require holes 3 inches deep.

After the holes have been drilled fill with iron sulphate, using about 1 gram of material for a hole 1 inch deep, 2 grams for a 2-inch hole and 3 grams for a 3-inch hole. In order to prevent the iron sulphate from coming in contact with the bark and causing possible injury to the living tissue, the chemical may be placed in size 000 gelatin capsules, placing 1 gram in each. The required number of capsules are then placed in each hole, the hole being closed with a wound dressing material or closed with a cork coming flush with its wood. The gelatin capsules gradually dissolve and release the ferrous sulphate. Thus a tree 10 inches in diameter would have 10 holes 2 inches deep and the total amount of iron sulphate employed would be in the neighbourhood of 20 grams (slightly less than 1 ounce).

Manganese deficiency may be quite easily controlled by applications of 1 per cent solution of manganese sulphate. This may be added to the regular calyx and other cover sprays. Two applications are usually sufficient.

Zinc Deficiency

No instances of zinc deficiency in Canadian apple orchards have yet been recorded.

GENERAL FERTILIZER RECOMMENDATIONS

In the foregoing pages an attempt has been made to list and describe the function of the plant food elements which an apple tree must absorb from the soil. Attention has been drawn to the importance of balance or correct relationship between the available quantities of each element and a number of such fundamental relationships have been discussed. Symptoms useful in diagnosing deficiencies and excesses of individual elements have been described by means of colour plates and illustrations and corrective measures given.

Bearing these fundamentals in mind a grower should be in the position to fertilize individual orchards and even individual trees, according to their specific requirements, rather than rigidly adhere to general fertilizer recommendations which are recommended for orchards on normal soils and are intended to be flexible. Although all the elements mentioned heretofore are necessary for healthy tree growth, it is generally recognized that only nitrogen, phosphorus and potassium require constant replacement in normal orchard soils. Fertilizer consisting of these three elements is known as a "complete fertilizer."

Nitrogen—The Growth Regulating Factor

Since nitrogen, of all the elements, is the most effective growth regulating factor, it is a good practice to apply nitrogen separately from the minerals. The nitrogen status of a tree can be fairly accurately estimated by foliage colour and amount and quality of shoot growth. A lack of nitrogen is very quickly expressed by the tree in restricted growth and light green foliage (Plate 1, fig, 6) and fortunately this condition can be readily corrected by the application of a quickly available nitrogenous fertilizer. It is therefore recommended that mineral fertilizers be applied yearly in the amounts suggested and that nitrogen be employed as a balance wheel, using the colour of the foliage and amount and quality of shoot growth to indicate the rates of application. Ordinarily 400 pounds of ammonium sulphate per acre or its equivalent would be considered a moderately heavy application and should only be employed on soils not high in nitrogen. An application of 300 pounds would be a moderate application. If the available mineral content of the soil is high the heavier application would be satisfactory; if low it would doubtless do as much harm as good. Since many orchards are not solidly planted and contain trees of different ages, growers often prefer to apply the fertilizer only to the soil area occupied by the tree roots. An application of three-quarters of a pound of ammonium sulphate for each inch of trunk diameter would constitute a moderately heavy application. Orchards in sod generally require heavier applications of quickly available nitrogen than do orchards which are cultivated. This is especially true in areas where the mulch material does not decompose rapidly owing to the lack of sustained adequate moisture supplies. Where such conditions prevail it may be necessary to apply a supplementary dressing of ammonium sulphate to the mulch material at a rate of two pounds per tree. To accomplish its purpose nitrogen should be applied early in the spring, well in advance of three growth.

The annual applications of phosphoric acid and potassium to be employed will vary a great deal with the type of soil, so that the following recommendations can only be used as a general guide. Mineral fertilizers may be applied either in the spring or fall, but on cultivated orchards should be applied at a time when it is possible to work the soil immediately.

The Following General Fertilizer Program is Suggested

(1) Apply 200 pounds per acre of 20 per cent superphosphate; 125 pounds per acre of either sulphate or muriate of potash; nitrogen as needed in amounts suggested in the preceding paragraph and in the form preferred by the grower. On alkaline soils a nitrogen fertilizer with residual acid reaction such as sulphate of ammonia should be used.

(2) Where it is desired to apply the nitrogen along with the minerals in a complete fertilizer, a 9-5-7 is recommended at the rate of 700 pounds per acre or one and one-half pounds per inch of trunk diameter. It must be noted that this is to be considered as a maintenance fertilizer on soils in which the plant foods are in a well balanced condition.

(3) Where leaf scorch due to potassium deficiency is present, it would be well to eliminate the nitrogen for a season at least and rely solely upon minerals, applying superphosphate at 200 pounds per acre and sulphate or muriate of potash at 350 to 400 pounds per acre until the deficiency is corrected. On such soils a 4-8-10 should prove a good maintenance fertilizer. The above amounts apply to the tree area and are applied from a point 18 inches from the trunk to a couple of feet beyond the spread of the branches. In order to maintain a good growth of grass it has been found profitable to fertilize the grass strip separately and for this purpose apply 150 to 300 pounds of a 2-12-6 per acre of land treated. In the case of cover crops this may be applied at the time of seeding down; in the case of sod mulch orchards it may be applied in early spring.

(4) Where manure is available it may be employed successfully. On the average most barnyard manure is about correct in its proportion of nitrogen, phosphorus and potassium for orchard use. Annual applications of 6 to 7 tons per acre to the tree area should be sufficient to provide the equivalent of 700 to 800 pounds of a 9-5-7. Since the nitrogen in manure is rendered available rather slowly it may be necessary to supplement manure with a quickly available nitrogenous fertilizer early in the spring. Excessive quantities of manure may delay the trees hardening off in the fall, rendering them susceptible to winter injury.

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OTTAWA
EDMOND CLOUTIER, C.M.G., B.A., L.Ph.,
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