Research FOR FARMERS

SUMMER - 1956

The new Animal Pathology Laboratory (eastern branch) of the Canada Department of Agriculture, located on the campus of Mount Allison University, Sackville, N.B., which was opened earlier this year to better serve the needs of the four Atlantic provinces in problems of disease affecting poultry, livestock, and fur-bearing animals.

CANADA DEPARTMENT OF AGRICULTURE

Research
FOR FARMERS

CANADA DEPARTMENT OF AGRICULTURE
Ottawa, Ontario

Rt. Hon. JAMES G. GARDINER, *Minister*
J. G. TAGGART, C.B.E. *Deputy Minister*

SUMMER - 1956

Vol. 1 No. 1

"*Research for Farmers*" is published quarterly by the Canada Department of Agriculture. Its purpose is to help keep extension workers informed of developments in research and experimentation as carried on by the various units of the Department.

Message from the Minister

With the publication of this first issue of "Research for Farmers" the Canada Department of Agriculture enters a new area in the publishing field. For many years the Department has been producing reports and bulletins aimed at informing farmers, homemakers and others of the work of the department and the application of its research findings. In addition, much of the scientific research within the Departmental organization is reported on the pages of various scientific and technical journals so that other research workers are kept informed. The present publication, to be issued on a quarterly basis, has been designed to meet the needs of extension workers associated mainly with provincial departments of agriculture. It is intended to keep these men in close touch with developments in the Department's research program so that they will be in a better position to interpret these developments to those they serve. The subject matter carried will be limited to coverage of the results of investigations within the Department.

It is my hope that "Research for Farmers" will serve a useful purpose in helping to bridge the gap between the research worker and the extension man in the field.

JAMES G. GARDINER,
Minister of Agriculture.

COVER STORY

In the Maritimes, it is unknown what part marshlands play in causing disease in animals. Certain disease-producing organisms, which in dry areas, for example, are of little interest, may be stealing revenue from the livestock men in marshland areas. More common conditions general throughout Canada, such as Brucellosis and vibriosis (two diseases causing infertility in breeding animals) require special study as they relate to management in these areas. The new Maritime area laboratory, working with its headquarters and other branch units, will give greater service to the Atlantic area than has been possible in the past.

Alfalfa and clovers must be cross-pollinated to ensure satisfactory seed crops. According to the author, honeybees help but certain wild species of bees are the best pollinators. Farmers should take advantage of the services of every pollinating bee in the area.

Pollination of Alfalfa and Clovers by Bees

G. A. Hobbs

ALFALFA AND CLOVERS are alike in their need for cross-pollination of the flowers to produce a satisfactory crop of seed. It is possible for the blossoms to be self-pollinated but seed yields are low. Our tests show that cross-pollination produces seven times as much plump seed and this is accomplished only by bees, chiefly the honeybees, the bumble bees, and the leaf-cutter bees. Bees forage for nectar and pollen. In most cases, nectar and pollen are secured from the same flower, but bees may forage for one or the other and may gather the nectar from one flower and the pollen from another.

Alfalfa a Problem

If we had to rely on honeybees and bumble bees, little alfalfa seed could be grown in or near intensively cultivated areas where clovers are grown in Canada. The problem lies in the mechanism of the alfalfa blossom. The structure of the alfalfa flower is such that the blossom must be "tripped" by bees in order to accomplish cross-pollination.

Author examining pod formation on alfalfa to evaluate effectiveness of wild bees in alfalfa seed production. Dr. Hobbs is an Entomologist specializing in Forage Crop Insects, Science Service Laboratory, Lethbridge, Alta.

When a bee visits an alfalfa flower, the restraining mechanisms on the keel are parted, releasing the sexual column, which springs forward and violently strikes the underside of the bee. Thus it picks up from the bee the pollen necessary for cross-fertilization. When honeybees trip alfalfa blossoms they sometimes have to struggle violently to release their tongues caught by the sexual column. They apparently do not like to be struck by this column and soon learn to gather nectar without tripping the flowers. They do this by inserting their tongues at the side of the blossom between the wing petal and the standard.

Even when honeybees were forced to gather pollen from alfalfa by being caged over it for 33 days, when released they flew to other less accessible but more easily worked pollen sources. Nectar-gathering honeybees accidentally trip an insignificant proportion of the alfalfa flowers they visit in

Alfalfa flower (left) and red clover flower (right) after being pollinated. Sexual column of alfalfa flower is pressed against the standard petal and will remain there; fertilization must take place at time of tripping. Sexual column of clover flower is free and will soon be covered by the keel returning to its normal position; fertilization may take place at once or by a bee visiting the blossom later.

southern Alberta. Except for the few inexperienced honeybees or for the large and clumsy, nectar-collecting bumble bees, only pollen collecting bees will trip and cross-pollinate alfalfa blossoms.

Honeybees can be used effectively for alfalfa only where all competing growth has been destroyed within their flight range, an impossible task in most areas. Bumble bees are of real importance only in areas where clovers are not being grown for hay or seed.

Leaf-Cutter Bees to the Rescue

Why then can one be a fairly successful alfalfa seed grower in areas where seed crops of alsike or red clover are being grown or where the countryside is contaminated with weeds like Canada thistle or mustard? The leaf-cutter bee provides the answer. Fortunately leaf-cutter bees prefer alfalfa as a source of pollen and, if the alfalfa field is near their nests, their pollen-gathering activities often result in the production of a seed crop of commercial importance. But unfortunately populations of leaf-cutter bees may be limited in the areas where they are needed, and moreover they live and work alone rather than in colonies. Female leaf-cutter bees tunnel in rotten wood, or in the earth beneath clumps of grass. During her adult life a female completes an average of 15 cells made from neatly cut leaf-pieces. The important species of leaf-cutter bees do not emerge to build and provision their nests until late in June or early in July, and they fly only when the temperature is above 64°F. This presents another problem. Full advantage of their services is gained only when long periods of good weather coincide with the blooming period of alfalfa and the flight period of the bees. Under these conditions a single female of one of the two important, prairie-nesting species of southern Alberta can trip and cross-pollinate 84,000 flowers in a season and in so doing will be directly responsible for producing about 2 pounds of seed.

So long as honeybees or bumble bees are available, clover does not present the problem that alfalfa does. When honeybees or bumble bees have a choice between clover and alfalfa they always collect pollen from clover. Counts made in adjacent fields of red clover and alfalfa showed 8 bumble bees on red clover for every 1 on alfalfa. Moreover, a bee cannot secure either nectar or pollen without cross-pollinating clover. With the clover flower the male parts and the female parts lie between the fused petals that form the keel of the flower. When a bee inserts its tongue in the throat of a clover flower, the keel is pushed back and the tongue accidentally touches the stamens and stigma as it probes for nectar. When the tongue is withdrawn, the keel slowly moves forward to again hide the sexual column.

Honeybees and bumble bees are also able to muster more concentrated work forces than the leaf-cutter bees that live and work alone. Honeybees overwinter in colonies and are able to build up brood quickly in the spring, while bumble bees overwinter as fertilized queens and establish homes and raise the initial broods that take over foraging duties.

Why Yields of Alfalfa Fluctuate

The presence of suitable insect pollinators is of course the most important assurance of success but many factors influence seed yield. Growers may recall that best yields of alfalfa seed were achieved when acreage was small, when fields lay close to waste land, when there was still little weed growth on the farm or along ditches or roadsides, or when the weather remained warm throughout the flowering period of the alfalfa. Declining yields were associated with increased acreage of alfalfa and a consequent reduction in waste land and bee population, with an abundance of fireweed, Canada thistle, or other flowering weeds, and with cold, wet weather during July.

Alfalfa often begins to bloom before the leaf-cutter bees have emerged from their tunnels or before the bumble bee queens have had time to establish nests and build up their colonies. As the individual flower lives only about 5 days, many will have died before the bees visit the field.

The leaf-cutter bee cutting oblong piece of chokecherry leaf to be used in cell construction; note circular piece for capping a cell cut from same leaf. *Inset:* Two cells of a ground-nesting leaf-cutter bee excavated from beneath a clump of prairie grass; cells were made of chokecherry leaves.

Our work in southern Alberta indicates that "clipping" the alfalfa when it is small, will postpone blooming so as to begin no earlier than July 1. In other regions this date will depend on when the species of bees responsible for alfalfa seed setting in the area emerge or build up to where they are of most use, or on when the first frost usually occurs. About 40 good days are required to mature seed after fertilization has taken place. It is possible to adjust blooming to coincide with the flight of the principal pollinators but even this will not ensure a good seed crop if a late flight is followed by an early frost.

Things Being Done to Increase Populations of Pollinators

Efforts to increase the various species of native bees for pollination of alfalfa are now being made by a number of research institutions. Some are trying to "domesticate" bumble bees. Queens are captured in the spring and placed in provisioned domiciles so that they will establish nests that can later be moved to the field to be pollinated. Such domiciles were put out on the prairie at Hays, Alta., in the fall of 1954. The following spring bumble bee queens established nests and built up strong colonies in more than 10 per cent of these domiciles. Because the important species of leaf-cutter bees prefer to dig their own tunnels and live alone, a different approach must be used. Work has been started to assess the factors preventing increases in their populations. All bees have insect enemies so attempts are being made to destroy the more important of these and thus allow the population of pollinators to increase. In the northern bush country, logs in the proper stage of decay for the log-nesting species of leaf-cutter bees are being provided. For pollination of alfalfa we may always have to bring the field to the bee habitat but we no longer need to tailor its size to a limited native population of leaf-cutter bees.

Leaf-cutter bee gathering nectar and pollen from alfalfa flower.

Control of Pests

When control measures against the pests that destroy bud and flower of clovers and alfalfa are necessary, extreme care must be taken to protect the insect pollinators. Because the species we must rely on for the production of alfalfa seed are females of solitary species, their potential offspring will also be destroyed if they are killed by an insecticide, and the following year's crop will suffer accordingly. Similarly the field force of a colony of honeybees that pollinate clovers may be destroyed and, if the poison is slow acting, bees and brood within the hive may also be destroyed. If the pests reach economic proportions, they can be destroyed with DDT during the pre-bloom stage or, if the crop is in bloom, with Toxaphene, which is less toxic to bees. Toxaphene should be applied during an evening when bee activity in the field has ceased.

What All This Means to Canadian Seed Growers

Farmers in areas where honeybees do not gather pollen from alfalfa and where their nectar-gathering activities result in little tripping and even less cross-pollination, must rely on leaf-cutter bees or bumble bees to cross-pollinate alfalfa. Until the work on increasing native bee pollinators can be put to practical use, acreages will have to be kept down to the level at which the existing population can do a proper job. We must take advantage of the services of every pollinating bee in the area. We can do this by planting alfalfa in long, narrow fields adjacent to areas where wild bees will nest; by ridding fields, ditches, and roadsides of competing flowers; by isolating the field as much as possible from competing crops, and by bringing it into bloom when the principal species of pollinators are active.

Rust Resistant

SELKIRK WHEAT

Result of 13 Years' Research

R. F. Peterson

CANADA has suffered heavy losses from stem rust and leaf rust of wheat at various times during the past half century. One of the most destructive epidemics occurred in 1954, when a new stem rust race known as 15B and virulent races of leaf rust became widespread. Fortunately, the existence of 15B had been known since 1939 at which time the plan for the development of Selkirk was initiated. Wheat varieties such as Thatcher, Redman, Regent and Apex that had resisted rust for many years were susceptible to the newer stem and leaf rust races. Consequently, wheat losses caused by rusts were great and one estimate placed these losses at 135 million bushels.

During the winter of 1953-54 the Canada Department of Agriculture released to Canadian farmers some 170,000 bushels of seed of a new rust-resistant bread wheat named Selkirk. In 1954 Selkirk resisted the rust satisfactorily and gave good yields. Well over three million bushels of seed of Selkirk were available for seeding in Canada in 1955 and ample seed is in sight for everyone needing this variety in 1956.

The breeding of rust-resistant wheats for the so-called *rust area* (Manitoba and eastern Saskatchewan) is centered at the Cereal Breeding Laboratory and the Plant Pathology Laboratory at Winnipeg and is carried out in co-operation with the Experimental Farms at Morden and Brandon in Manitoba, and at Indian Head and Melfort in Saskatchewan. Many different crosses have been made and many potential varieties have been developed and tested for field performance and quality. Varieties named and released are as follows: Renown (1936), Coronation (1938), Regent (1939), Redman (1947), and Selkirk (1953).

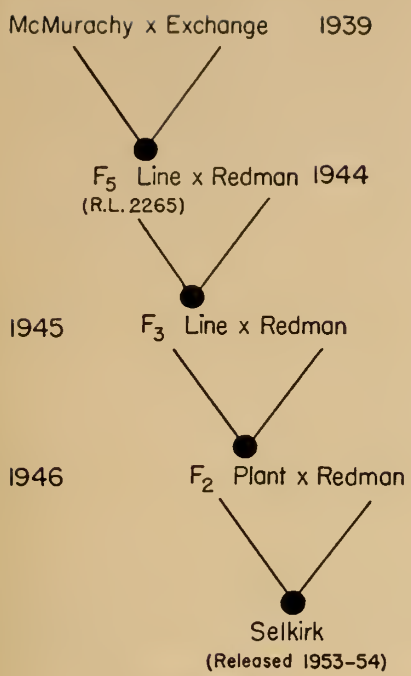
The variety known as McMurachy was originally discovered in 1930 by Mr. S. J. McMurachy as a single rust-resistant plant in a field of Garnet wheat on his farm at Strathclair, Manitoba. This variety was outstanding in resistance to all races of stem rust known in Canada during the 1930's and 1940's. It has considerable resistance to common root rot and has a good type of head and seed. Unfortunately it is very deficient in baking strength. The variety, Exchange, obtained from the Indiana Agricultural Experiment Station in 1938, was found to have outstanding resistance to leaf rust, but its baking quality also was poor.

First Cross Made in 1939

McMurachy and Exchange were crossed in 1939 in order to combine in one variety the stem-rust resistance of McMurachy and the leaf-rust resistance of Exchange. The resulting variety, R.L.2265, met this requirement, but, as was expected, it had very poor baking qualities.

Redman wheat was then used in the crossing program because of its many good characteristics. It was resistant to bunt and to stem-rust races other than race 15B, and moderately resistant to loose smut and root rot. It gave good yields and had satisfactory baking qualities.

Dr. R. F. Peterson studying hybrid seeds from a cross made in greenhouse. He is Officer-in-Charge, Cereal Breeding Laboratory, Winnipeg, Man.



Selkirk "blueprint".

R.L.2265 was crossed with Redman in the field in the summer of 1944, and this may be considered the beginning of the development of Selkirk wheat. The first and second hybrid generations were grown in the greenhouse the following winter. In 1945 a third generation line with a high degree of rust resistance was crossed with Redman. Then, in 1946, a resistant second generation plant from this cross was again crossed with Redman. This system of backcrossing was used to combine the overall good performance of Redman with the rust resistance of R.L.2265.

Many strains from this final cross were tested for several years under rust conditions throughout the rust area. The most promising lines were tested in co-operative yield tests throughout the Prairie Provinces from 1950 onward. Quality tests were made at the Cereal Crops Division at Ottawa, and at the Grain Research Laboratory of the Board of Grain Commissioners at Winnipeg.

By the fall of 1952 the most promising of these lines from the standpoint of disease resistance, yield and quality proved to be one known as C.T. 181 and a purified stock of the same variety known as C.T. 186. The C.T. 186 stock had more stem-rust resistance than either McMurachy or Redman and had considerable leaf-rust resistance.

C.T. 186 Became Selkirk in 1953

Since the danger of more destructive rust epidemics was imminent, the Canada Department of Agriculture decided in 1952 to increase seed of C.T. 186 in California and Arizona during the winter months of 1952-53. One hundred and fifty acres of this variety were grown under irrigation and over 5,000 bushels of seed were harvested. This seed was returned to Canada and increased on Experimental Farms and by contract growers in Canada in 1953. In December, 1953, C.T. 186 was licensed and accepted for registration under the name of 'Selkirk'. Then followed the distribution of some 170,000 bushels of seed to Canadian farmers in the winter of 1953-54. A second distribution was made in 1954-55. The seeding of well over three million bushels of Selkirk wheat in Canada in 1955 resulted in a heavy crop which ensures ample seed supplies of this variety for 1956.

Average yields of Redman, Thatcher, Lee, and Selkirk for the three years 1952-54 in co-operative yield tests in the Prairie Provinces are shown below. There were 66 tests, an average of 22 each year. The superiority of Selkirk in the rust area is obvious. Note also that Selkirk outyielded Redman in Alberta where rust was not a factor.

During the period 1952-54, surveys of rusts carried out by plant pathologists have disclosed three new stem rust races in Canada which are capable of attacking Selkirk wheat. These races: (15B3, and two biotypes of race 29) have so far appeared only in small amounts. There is a danger, however, that when Selkirk wheat is widely grown some of these rust races may multiply and become quite destructive. New wheat varieties having resistance to these rusts are being developed.

Average yield in bushels per acre of four wheat varieties in Co-operative yield tests in Western Canada in 1952-54

	Manitoba	Saskatchewan	Alberta	Mean for Western Canada
Redman.	36.5	28.8	43.4	35.3
Thatcher.	35.2	30.7	46.2	36.8
Lee.	40.0	30.1	41.8	36.2
Selkirk.	45.8	33.2	45.3	40.1



Left to right: Cross breeding involves much careful work with individual plants; Selkirk was derived by back-crossing the hybrid (McMurachy X Exchange). Selkirk is a high quality bread wheat; extensive tests have shown it to be equal to Marquis in milling and baking quality. Comparative yields of Thatcher and Selkirk grown on adjacent fields; susceptible-to-15B Thatcher yielded only 7 bushels to the acre while 15B-resistant Selkirk produced 42 bushels; respective bushel weights were 53 lb. (Thatcher) and 64 lb. (Selkirk). Display jars contain amounts in direct proportion to the yield per acre.

L/r: Colony of healthy European pine sawfly larvae. Author scrutinizing virus material used in making disease sprays; Dr. Bird is a specialist on Insect Viruses at the Insect Pathology Laboratory, Sault Ste. Marie, Ont. European pine sawfly larvae killed by virus disease.

Controlling Insects by Virus Diseases

F. T. Bird

THE USE OF virus disease organisms to control insects has proved successful in Canada against certain destructive pests and research is being continued in an effort to increase the usefulness of disease organisms in controlling such pests biologically.

The use of disease organisms to control insects has many advantages over insecticides. These organisms are frequently selective, destroying only the one species of insect and not harming the beneficial parasitic and predaceous insects, nor do they have any effect on man or other forms of animal life. Together with other natural factors, they may provide adequate control for many years. Once established, they can multiply rapidly from small introductions, and whereas it is impossible to control large outbreaks of certain insects by spraying poisons, small foci of infection from which diseases may spread can be rapidly established either from the air or from the ground. Disease organisms are often very inexpensive to produce. On the other hand, they do not kill so rapidly as insecticides and several days may elapse from the time of infection until the insects begin to die off.

Pioneer Canadian Work

In Canada, except for work by A. G. Dustan on fungus diseases of the green apple bug and the European apple sucker in Nova Scotia, diseases of insects were practically ignored until about 1940 when an outbreak of a destructive forest insect, the European spruce sawfly, was controlled by a virus disease. This was followed by an intensive program of research on the disease at Fredericton, N.B. In 1950, a modern laboratory was completed at Sault Ste. Marie, Ont., for basic studies on viruses, bacteria, fungi, and protozoa, pathogenic to insects.

Not until the development of the electron microscope were extracted and purified viruses actually seen, and only very recently have techniques been developed to the point where viruses can be seen in the host cells. Prior to the use of the electron microscope, the indication of the activity of a virus disease in an insect was the lumping together of a certain cell component (chromatin) and the formation of small crystal-like bodies called polyhedra. Electron microscopy has shown that rod-shaped virus organisms, about one ten-thousandth part of an inch long, are formed in the chromatin, and that the polyhedra, whose formation is still a mystery, contain a large number of these rods. An insect killed by virus contains several hundred millions of the polyhedra. When swallowed by a healthy insect, the polyhedra dissolve in the stomach juices and the virus particles are liberated. In the larvae of most moths and butterflies, the virus organisms pass through the stomach wall and attack blood, fat, and other cells. In the larvae of sawflies, the viruses attack the cells of the stomach wall and the insect dies when the stomach is destroyed. Within the polyhedra, the virus is very resistant to aging and may remain virulent for many years.

Virus Quick Acting

Some of the viruses are extremely virulent and under laboratory conditions larvae may die within five or six days after infection. Viruses usually affect the larvae of insects but those infected late in their development may survive and reach the adult stage. The viruses, however, are transmitted through the eggs of the adult, and many of the progeny of infected adults die. This is the principal method by which viruses are transmitted from one year to the next. During the growing season, foliage contaminated by viruses is the usual source of infection. In other words, transmission of a virus from the eggs of infected adults starts a disease epidemic but most of the subsequent mortality results from larvae coming in contact with the virus on the foliage and is dependent to some extent on population density.

As mentioned earlier, an outbreak of the European spruce sawfly in Eastern Canada was brought under control by a virus disease. This sawfly was accidentally introduced into Canada and, as often happens, it was not accompanied by any of its natural enemies and proceeded to multiply to outbreak proportions. In an effort to bring it under control, large numbers of parasites were obtained in Europe and released in Canada. Apparently some of this material had come from virus-infected hosts and carried the infection to the Canadian population. In a few years the outbreak had subsided, and the sawfly has not been of any economic significance since 1942.

The European pine sawfly is another introduced insect. It was first found in North America in New Jersey about 30 years ago. The first Canadian discovery was near Windsor, Ont., in 1939, and ten years later it had spread throughout most of southwestern Ontario. In Europe, where the insect is native, it is seldom serious, being held in check chiefly by a virus disease, but as in the case of the spruce sawfly, the disease was not introduced with the insect. The sawfly increased, unchecked except where there was insufficient food, and severe infestations occurred in plantations of Scots, jack, and red pine.

In 1949, several virus-killed European pine sawfly larvae were obtained from Sweden. Laboratory studies showed this virus to be similar to the one that killed the spruce sawfly, and virulent against the Canadian population of the pine sawfly. Here then was an excellent opportunity to demonstrate whether an insect could be controlled by the introduction and artificial dissemination of a virus. It also offered a rare opportunity to study the establishment and spread of a virus of a hitherto disease-free population.

Virus Spray Experiments

Field tests in 1950, using a hand-operated 3-gallon pressure sprayer, showed the virus to be extremely virulent under field conditions. Fifteen days after spraying, 47·7 per cent of the larvae were killed by the lowest concentration of virus tested (2,000 polyhedra per milliliter of water or the virus contents of one larva in 30 gallons of water), and 98·8 per cent died when

Left: A suspension of virus in water being blown into a sawfly-infested Scots pine plantation; mist blower method caused heavy mortality over an area of more than five acres. ***Right:*** Spraying of virus from an aircraft over marked courses; aerial spraying has been successful over large areas. **Lower *right:*** Collecting diseased and dead larvae from sawfly-infested Scots pine trees sprayed with virus. Virus contents of one larva in one gallon of water make a very lethal spray.

200,000 polyhedra per milliliter of water were used.

In 1951, large-scale experiments were carried out using a mist-blower. The machine was placed at the windward edge of a sawfly-infested plantation and the virus, in the form of a watery mist, was blown over the trees into the plantation. It was possible from one position to cause heavy mortality over an area of more than five acres.

In 1953, tests were made by disseminating the virus from aircraft. In one experiment 50 acres of Scots pine, infested with the sawfly, were sprayed with virus suspension containing 5,000,000 polyhedra per milliliter of water to which skim-milk powder was added as a sticker at the rate of 1 pound to 20 gallons of water. The spray was applied at the rate of $\frac{1}{2}$ gallon of the suspension per acre. Fourteen days after spraying, 89·1 per cent of the larvae were diseased or dead and six days later the percentage increased to 99·2.

In other experiments the aircraft flew over another sawfly-infested Scots pine plantation along parallel lines 300 feet apart, about 15-50 feet above tree-top level, using different concentrations of virus at the same rate of application (about $\frac{1}{2}$ gallon per acre). The swath width of heavy mortality from virus increased with the concentration of virus used, and at the heaviest concentration few insects survived.

Mortality Rate

Although total mortality can be caused in a plantation or other restricted area by complete coverage with the spray of virus suspension, this is not necessary for practical control. In fact, it is not desirable unless extreme defoliation is expected. An area treated in this manner will be re-infested by adults that fly in from unsprayed plantations and also by sawflies that remained in the cocoon stage in the ground for more than one year. Since sawflies from these sources of re-infestation will not be infected by virus, the population will soon build up again to dangerous levels. However, if incomplete spraying is done, a small proportion of the population will survive even though they may be infected. These individuals will pass on the disease through the egg to the next generation, which will thus serve as a source of continuing infection, and this process will be repeated each year without further treatment. This was well demonstrated in one experiment where an application of nine gallons of suspension was made in 1951 to a plantation of 100 acres. In each of the next two years severe defoliation occurred, although many insects died from the disease. In 1954, the epidemic had intensified to the point where the sawfly population was brought under control. The loss from defoliation was not significant, since the trees were not of merchantable size; by the time they are ready to cut they will again bear a full complement of needles and thus be satisfactory for the Christmas-tree trade.

Some Insects Resistant

It must be emphasized that, despite these two outstanding successes in the control of some insects by virus diseases, others appear to be resistant to disease organisms. The spruce budworm is susceptible to three different viruses, a protozoon, and a fungus disease but none of them is sufficiently virulent to cause extensive mortality. Only moderate mortality resulted when suspensions of a virus discovered in larvae of the jack-pine sawfly were sprayed on infested trees, indicating that this insect is also comparatively resistant to disease.

Electron-microscope (inset) picture of a virus-infested gut cell of a sawfly showing (*a*) chromatin material and (*b*) polyhedra containing many rod-shaped virus organisms. Their method of formation is still uncertain. (Magnification: x5,000.)

While this article has been concerned only with the control of destructive insects by virus diseases, other diseases caused by fungi, bacteria and protozoa are also being studied. There is at present no way of knowing the part that disease organisms can eventually be made to play in regulating the balance of insect populations, but continued research will undoubtedly increase the usefulness of these agents of biological control.

PARKLAND—A New Malting Barley Variety

"Parkland" was developed at the Experimental Farm, Brandon, Man., and licenced last March. It is a smooth-awned, rust resistant, high yielding and widely adapted variety. It is equal to Montcalm in malting quality and superior in yielding ability and strength of straw. While other varieties have been developed by selection, Parkland is the first malting barley resulting from the efforts of plant breeders in the Experimental Farms Service. Only one other variety of malting barley has ever been bred in Canada—Montcalm—developed at Macdonald College.

Nearly ten million acres of barley were planted in Canada in 1955 and the 1956 forecast indicates an increase of nearly six per cent. The attention given to barley by farmers, industry, and plant scientists during recent years has been a highlight of cereal development in Canada.

Diagnosing Mineral Deficiencies in Fruit Trees

H. R. McLarty

AND

J. A. Stewart

In the studies of boron nutrition of peach in sand culture, the effective rate of application under varying moisture levels is being investigated by the Plant Pathology Laboratory, Summerland, B.C. Dr. McLarty (right) in charge of the Laboratory, and J. A. Stewart (left) check the effects of mineral deficiency.

ANYONE unfamiliar with the symptoms of mineral deficiencies in fruit trees, who tries to identify some troublesome disorder from the mass of literature now available is likely to be confused. Based on considerable experience in the diagnosis of mineral deficiencies of fruit trees in the Okanagan Valley of British Columbia and a knowledge of some of the pitfalls, we offer the following suggestions, hoping that they may prove useful to workers in other areas.

Work was started when the conditions known locally as drought spot, corky core and dieback of fruit trees in the Okanagan Valley were found to be caused by a deficiency of boron. As early as 1922, this problem was investigated when growers reported losses of approximately 90,000 boxes of apples from corky core. In 1934, when boron deficiency was proved to be responsible for these three disorders, estimated losses were as high as 1,000,000 boxes.

We soon found that applications of boron did not correct all the troubles of this nature, and we showed in later years that a lack of zinc, magnesium, manganese or iron, either singly or in combinations, may also be involved. After considerable experience, we recognized that a deficiency of each of these elements led to characteristic, and in some cases specific, symptoms. Field tests were developed to verify the cause of these symptoms. In many cases the solutions used for the field tests can also be used as a control spray. Detailed control measures are not given here since we are concerned only with diagnosing the trouble.

There are three diagnostic symptoms for boron deficiency: dieback of twigs in the spring on any kind of fruit tree, drought spot of apple and pear, and corky core of apple.

While dieback may be due to many causes, there are certain characteristic features if a boron deficiency is involved. In the early spring the twigs are healthy in all respects, but during the time when normal twigs are under active growth, the buds either do not grow at all, or else the growth is weak, and they later wither and fall away. Soon afterwards the bark begins to shrink and dieback occurs.

Drought spot of apple and pear was so named before the cause was known to be a boron deficiency. The skin breaks down sometime between 10 days after petal fall and before the fruit

***Top:* Magnesium deficiency on apple showing defoliation.**
***Right:* Zinc deficiency on apple.**

reaches approximately an inch in diameter. The tissues affected are mostly on the calyx end of the fruit, and may be present as well-defined spots or spread over the surface in irregularly shaped blotches. As the fruits develop they become severely deformed.

The corky core symptom is usually seen most on apple, and some varieties are more susceptible than others. In our region, McIntosh and Jonathan are the best "indicators". On McIntosh, areas that are light brown in color and somewhat corky in texture, appear in the flesh of the fruit just outside the core at any time after the fruit reaches a diameter of approximately an inch. On Jonathan, the corky tissue is normally confined to the core area.

When these symptoms occur on fruit trees, a boron deficiency can be readily verified by means of a simple field test. A spray of two pounds of boric acid in 100 gallons of water applied in August or early September will prevent die-back, drought spot and corky core in the following year. Having confirmed that a boron deficiency is present, the appropriate control spray can be applied.

Zinc

A deficiency of zinc is harder to determine than one of boron. There are no characteristic markings on the fruit, and the foliage and twig symptoms may be confused with those from other causes. The most characteristic symptoms are "little leaf" and "rosette" of apple. These are best seen early in the growing season as soon as the foliage on normal trees is fully developed. Later in the year, growth on affected trees may be quite normal and the early symptoms largely obscured. We have found it difficult to distinguish between certain types of winter injury and zinc deficiency. The field test for confirming the cause of these symptoms is not so conclusive as that for boron. The test that we have used is a spray of 25 lb. of zinc sulphate in 100 gallons of water applied just before the end of the dormant season. In most cases this will stop the appearance of rosette and little leaf in the subsequent spring growth, but cases are known where three such sprays had to be given to prevent further deficiency symptoms. If a zinc deficiency is confirmed by this test, a similar solution may be used for a control spray, as recommended in the literature.

Magnesium

The most reliable symptom of magnesium deficiency is that found on apple leaves. McIntosh and Newtown are particularly valuable indicators in our area.

The deficiency shows up as a leaf blotch, in which irregular patches of dead tissue are found between the veins or at the edge of the leaf. Each year this symptom first appears about the time that general growth ceases. The old spur leaves and the basal leaves on the current season's spring growth are the first to be affected, and later the younger leaves. The tissue is at first light green in color but soon changes through varying shades of yellow or gray to a dark brown. Trees are more severely injured in the "heavy crop" than in the "off" year. Affected leaves fall prematurely and the fruit may be reduced in size when many leaves are damaged. In our area this leaf symptom is specific for a magnesium deficiency.

The field test for confirming a magnesium deficiency takes a full growing season to complete. Four applications of a spray of 20 lb. of magnesium sulphate in 100 gallons of water are required, starting as soon as the first leaves have reached full size and repeating at ten-day intervals. This test has been found fairly reliable in preventing leaf blotch caused by magnesium deficiency and control measures can then be applied.

Manganese

The characteristic symptom of manganese deficiency is confined to the leaves but it cannot be classified as specific since it may be confused with that caused by a lack of zinc. Under our conditions, shortly after the leaves have reached full size, small irregularly shaped spots light green in color, appear between the veins and at the leaf edges. These areas gradually merge into a pattern of light green bands between the veins, and at the leaf edges, with normal green bands following the veins. This pattern is essentially the same on apricot, peach, and apple. We have noted no characteristic fruit or twig symptom.

The field test is made by a spray application of 2 lb. of manganese sulphate in 100 gallons of water when the spots first appear. If the symptoms are caused by manganese deficiency the leaves will return to normal color within about ten days. The test is reliable only if the spray application is correctly timed. Control of manganese deficiency is obtained by a similar spray application.

Boron deficiency on peach.

Iron

Any tree showing bright yellow foliage either throughout the whole tree or on an entire limb is likely to be suffering from iron deficiency, although other factors may be involved.

A field test that will show whether the yellowing is caused by an iron deficiency consists of spraying the fully developed foliage with 2 lb. of ferrous sulphate in 100 gallons of water. This spray will probably cause damage to the foliage and dead spots may appear wherever the droplets of spray have dried on the leaves. Where the yellowing was caused by lack of available iron the tissue immediately surrounding the dead areas will turn a normal green color.

Boron deficiency, corky core on apple.

Since control measures for iron deficiencies are not yet fully worked out for fruit trees, the spray outlined above for testing purposes should not be used as a control as it often causes damage to the foliage. We are working on this problem at present, but although results are promising we are not yet ready to make general recommendations.

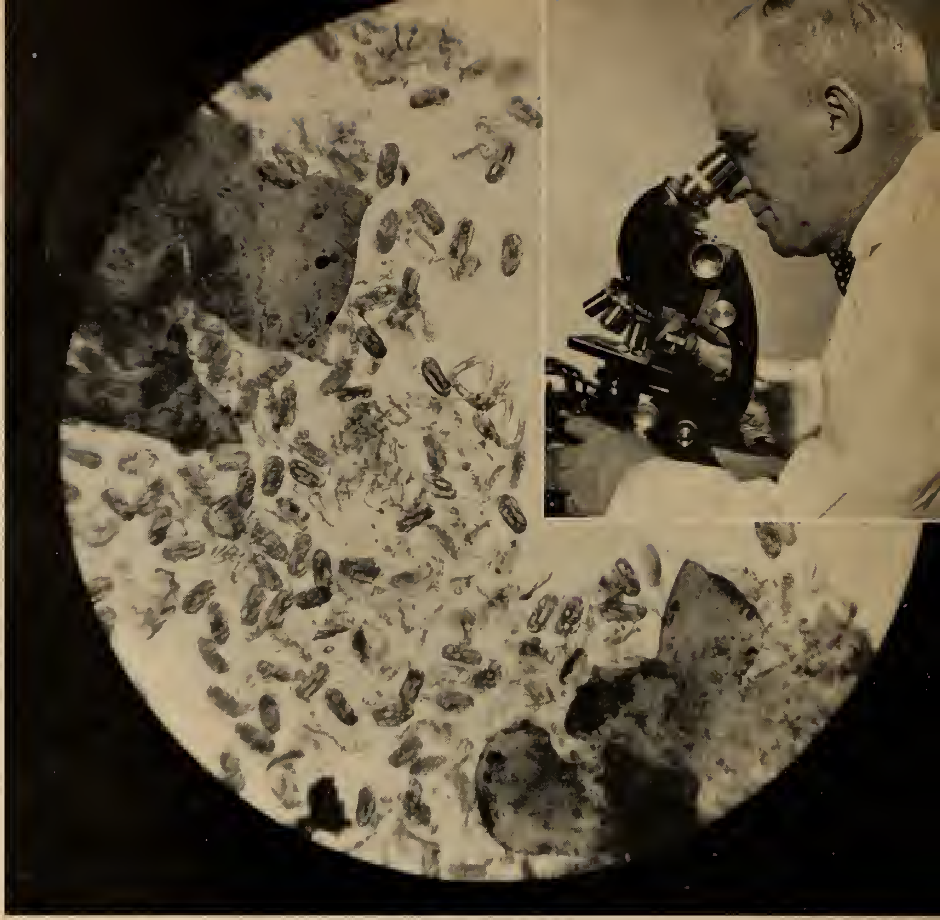
We often find cases where two or more deficiencies are present at the same time. The results of field tests must then be treated with caution. If a tree's condition is definitely improved as a result of a field test, but not completely cured, the remaining symptoms should be compared carefully with those given for other deficiencies and the appropriate field tests carried out.

The diagnosis of mineral deficiencies in an untested area by reference to the available literature may be difficult and inconclusive. This article describes characteristic symptoms caused by deficiencies of boron, zinc, magnesium, manganese and iron as they occur on fruit trees in the Okanagan Valley of British Columbia and outlines field tests found valuable for confirming the diagnosis of these disorders.

L/r: Manganese deficiency on apricot, peach, and apple leaves. Healthy leaves above.

Nematodes are not rare creatures and enormous populations are frequently found in farm soils. Some may be harmless but others can seriously injure farm crops.

Readers might well become better acquainted with the names of some of these important crop pests as they will be hearing more and more about them as time goes on. The author invites you to . . .



Photomicrograph of a ruptured cyst of the sugar-beet nematode showing eggs and larvae contained. *Inset:* The author is Head of the Nematology Section, Ottawa.

MEET THE NEMATODES

A. D. Baker

IN A STORY about insects it would hardly be necessary to explain the general appearance of an insect and where some of them could be found. But nematodes are not insects and the number of people who know what a nematode looks like is amazingly small. A large intermediate group of people would recognize that nematodes are "some kind of worm", but the largest group would belong in the category that might well exclaim "What in the world is a nematode?"

All Worms Not Nematodes

Nematodes are worms but not all worms are nematodes. The common earthworm that you put on your hook when you go fishing is not a nematode and neither is a tapeworm, a fluke, or a leech. The designation of "worm" is rather freely applied to a wide variety of invertebrates (and humans?), including some insect larvae that are referred to in this way.

These animals have been referred to as "nematodes", "nemas", "eelworms", and "roundworms". Don't let these different names confuse you, as they are just different ways of referring to the same thing. The term nematode is preferable and is now being used most widely. Roundworm is an older term and was used chiefly in referring to nematode parasites of vertebrates, while the term eelworm has been used to quite an extent for some plant-parasitic and free-living nematodes. Nema was a term introduced by the late Chief Nematologist, United States Department of Agriculture, Dr. N. A. Cobb, and, while it has the merit of brevity, its general use has not followed.

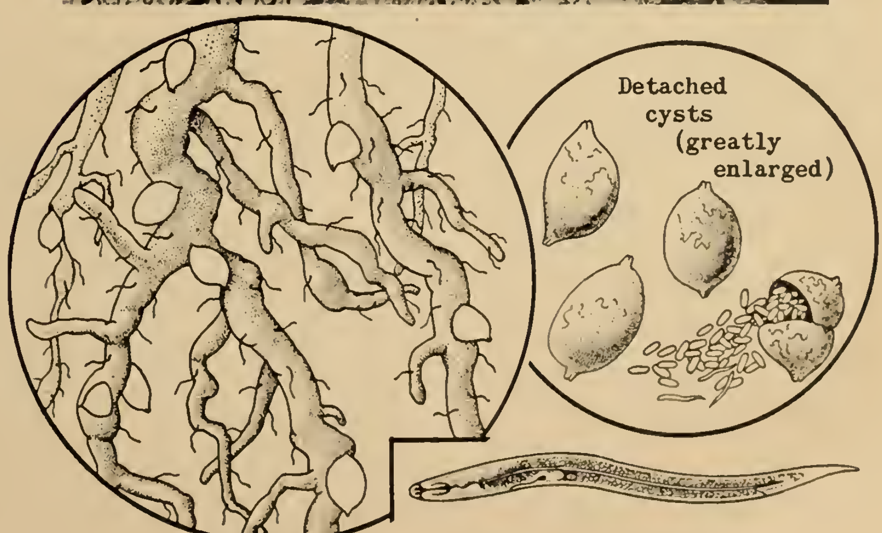
Billions to the Acre

Nematodes are not rare creatures but rather they are among the commonest and most widespread animals in the world. It was Dr. Cobb (1914) who wrote "If all the matter in the universe except the nematodes were swept away, our world would still be dimly recognizable". And of those on the farm he said: "The nematodes from a 10-acre field, if arranged single file, would form a procession long enough to reach around the earth". The populations of nematodes in the world are truly enormous, and they are to be found in almost every conceivable environment from the polar regions to the equator. They are in the oceans, in rivers, in lakes, in streams, in soil, in and on plants, and there are many that live as parasites and associates of many lower and higher animals. Arable farm soils sometimes support enormous populations and even insects are overshadowed by the great number of individual nematodes. Nematode population in soils is usually expressed in terms of number of billions to the acre. To find nematodes in soil is no occasion for surpise; but rather it is occasion for some surprise if they are not found.

Why do we not see nematodes more frequently if they are so numerous? This is a good question, but it has a good answer. Most nematodes are very small and many measure only a fraction of a millimeter in length. Nematodes do not fly, jump, or run, and they are usually found in environments where they are rather well concealed.

If an organism attacks man or his animals man will usually give first attention to that species. This is what has occurred in the study of nematodes, so that the early records dealt largely with the parasites of vertebrates. The study of nematodes attacking food plants would be expected to follow next in order, but this was greatly delayed as these plant pests were easily overlooked and generally invisible to the naked eye. Crop failure and plant injury might occur where the cause could not be disclosed and in such cases the trouble might be labelled "soil sickness" or even "soil exhaustion". Plant nematology is one of the younger sciences because the study of all the smaller nematodes, wherever found, had to await the development of adequate optical equipment. For differentiation, internal characters are used to a great extent and even the larger species often look very much alike externally.

The outer leaves of a nemotade-infested beet plant tend to wilt, change color and die. Sketches illustrate a nematode-infested sugar beet, an affected beet root (enlarged) showing female nematodes, the detached cysts (greatly enlarged), and the larva of a nematode (greatly enlarged).



Food Varies

The food of nematodes varies widely. Many species feed on decaying matter, others feed on bacteria, some on algae, many on fungi, on cultivated crops, on trees, on weeds, and many on animals. However, all nematodes are not injurious. Many are harmless and some beneficial. There are species that are predators and feed on other nematodes. On the other hand, nematodes may be attacked by other forms of life, such as fungi and protozoa. Soil-inhabiting nematodes probably play an important role in the economy of farm soils, but the picture is not yet clear and a great amount of research is still needed.

Life Cycle

The life cycle of a nematode is usually fairly simple, somewhat resembling that of an insect having an incomplete metamorphosis. Most nematode species are bisexual and they may lay eggs or give birth to living young. In some cases males may be rare or even unknown and in some forms the sperm as well as the ova may develop within what is termed the female. In any event the young nematode that hatches from the nematode egg usually has the same general appearance as the adult except for the absence of sexual characters. As this larva continues to grow, it periodically sheds its skin or molts. Typically there may be five stages separated by four molts, so that the terms first-stage larva, second-stage larva, etc., to adult, are generally employed. In some forms a larval skin may be temporarily retained and the larva is said to be ensheathed.

Anyone who has had the opportunity of viewing live nematodes under the microscope is likely to be impressed by their movements. The vigor of these movements varies with different groups. With some forms the wiggling or lashing may be very vigorous, while others appear sluggish, and these differences may be often correlated with different habits. Nematodes bend their bodies upwards and downwards and not from side to side, although some slight lateral movement occurs when they are coiling, etc. Unlike an earthworm, which lengthens and shortens its body while it moves, the length of a nematode and its proportionate width does not change perceptably.

SOME COMMON NAMES OF NEMATODES

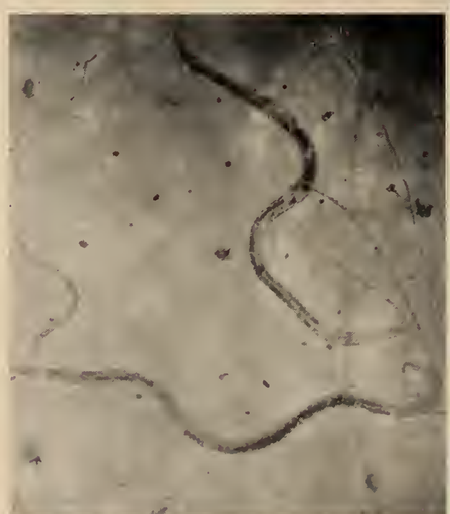
Nematodes constitute a separate phylum of the Animal Kingdom known as the Nematoda. This phylum is divided into two classes, the Phasmidia and the Aphasmidia. The increasing use of common names for some of the species and genera of plant-parasitic nematodes may prove a helpful factor in assisting the layman to become better acquainted with some of these important crop pests. Readers might well get to know these names as they will be hearing more and more about them as time goes on. Examples of common names that have been applied to some of these nematode groups are as follows: cyst nematodes (*Heterodera*); root-knot nematodes (*Meloidogyne*); root-lesion nematodes (*Pratylenchus*); stunt nematodes (*Tylenchorhynchus*); bulb and stem nematodes (*Ditylenchus*); ring nematodes (*Criconema* and *Criconemoides*); lance nematodes (*Hoplolaimus*); spiral nematodes (*Rotylenchus*); sting nematodes (*Belonolaimus*); stubby-root nematodes (*Trichodorus*); pin nematodes (*Paratylenchus*); loose-coated nematodes (*Hemicycliophora*); dagger nematodes (*Xiphinema*); etc. There are also quite a number of common names used for particular species.

Research Assistance Available

A nemalogoist is a specialist who studies a large and important group of animals and he requires, at least, the same high standing of training demanded of any other specialist. Nematology is not a side line of some other specialty and it will reach its fullest development only when this fact is ultimately recognized. In Canada nematology is being increasingly supported because of growing recognition of the probable enormous economic importance of this much neglected group of animals.

The Nematode Investigations Section in the Entomology Division of the Canada Department of Agriculture was established for the study of plant-parasitic nematodes, the nematodes of soil and fresh water, and the nematode parasites of insects. When some unexplained trouble arises in the growing of farm crops the normal practice is to seek expert advice. In the past, when the trouble was due to nematodes, this assistance was not available. Now however, with the right specialist the right answer may be obtained, and much confusion sometimes avoided. The scientist supplying the right answer will always feel amply rewarded by a few words of kindly encouragement, such as, "We never had any of these troubles until you fellows came around".

Left: Potato-rot nematode. *Right:* Sliced potato showing injury by potato-rot nematode.



Edmond Cloutier, C.M.G., O.A., D.S.P., Queen's Printer and Controller of Stationery, Ottawa, 1956.