Diseases of Field Crops

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Plant diseases take a large toll of our crops every year. Some of their damage is preventable, but only if the diseases are recognized early and appropriate control measures taken.

The purpose of this book is to describe the most common diseases of the field crops grown in the Prairie Provinces, to indicate their relative economic importance, and to give recommendations for their control.

Consult your local agricultural representatives for the latest recommendations on:

- Resistant varieties
- Seed disinfectants
- Fertilizers
- Fungicides
- Insecticides

which in the absence of seed treatment would cause considerable losses, is now relatively unimportant, partly because some wheat varieties are resistant to it, but mainly because farmers commonly treat their wheat seed with disinfectants before sowing. However, many farmers do not treat their barley and oat seed with disinfectants and consequently the seedling-infecting smuts of these crops still take their toll.

Plant disease control measures enrich our lives more than most people realize. The high-quality apples that we take for granted appear on our tables only because the fruit grower sprays his orchard with a fungicide to control apple scab. The clusters of luscious grapes that we buy in the stores are there only because the grape grower protects them from various diseases by spraying his vines with bordeaux mixture and other plant protectants. The same applies to most of the fruits and vegetables that are shipped to our markets from distant places. Western Canada's grain growers lag behind the more highly specialized fruit and vegetable growers in the application of plant disease control measures; but just as the latter have found it profitable to understand and control their plant diseases so, also, it pays our farmers to understand their plant diseases and take intelligent measures for their control.

CAUSES OF PLANT DISEASES

Fungi

Most diseases of our field crops are caused by microorganisms that have established a parasitic relationship with the plants. Of these microorganisms, the fungi cause most damage. Fungi, or molds as they are sometimes called, are actually minute plants that cannot produce chlorophyll, the green coloring matter that enables the higher plants to use the energy of light to manufacture food from air, water and the minerals of the soil. Fungi are thus dependent on food produced by green plants. Some have become able to grow on dead plant matter in the soil. Mushrooms are examples of this type of fungus. Other fungi have adapted themselves to a parasitic existence and extract nutrition from the plants on which they grow, thereby often doing severe damage to them.

The student of plant diseases, and anyone who attempts to devise measures for their control, needs to understand how these microorganisms invade plants, how they grow in them, and how they survive from year to year.

Stem rust of wheat is an example of a plant disease caused by a fungus. The characteristic red appearance of rusted plants is caused by masses of spores, the reproductive units of the fungus. Individually, these spores are too small to be seen with the naked eye, for each spore is only one thousandth of an inch in diameter. Collectively, they make up conspicuous, red, powdery masses containing millions of spores. These spores are readily carried great distances by winds and, though many of them are wasted, some fall on leaves or stems of wheat plants. In the presence of moisture, such as dew or raindrops, the spores germinate by sending out germ tubes

Figure 1. — Germinating spores of the red, or summer, stage of stem rust.

(Figure 1), which grow along the surface of leaves or stems and penetrate the plants through the numerous pores (stomata) on the plant surfaces. Once inside a plant, the germ tube grows and branches into a network of tubular structures that absorb food materials from the plant. In eight or ten days the fungus network sporulates, that is, produces a mass of new spores. In this manner, a single spore can infect a plant and produce, in a little more than a week, one hundred thousand or more spores. This process is repeated over and over again during the summer so long as wheat plants remain green. If spores are plentiful and moisture is abundant, a rust epidemic can build up in a few weeks. Damage to a plant is done partly by absorption of food by the fungus but chiefly by the drying up of the plant caused by evaporation of water through the numerous ruptures of the plant surface by the spore masses of the fungus.

Numerous other fungi attack field crops and it is characteristic of these parasitic organisms that each produces its own distinctive type of spore, each has a life cycle that differs somewhat from that of any other fungus, and each has preferences for particular kinds of crop plants. The fungi that cause bunt attack wheat, rye and related grasses, but not other plants. They infect the young seedlings shortly after germination, and do their damage after heading out by filling young seeds with fungus growth, which becomes converted into masses of bunt spores. These contaminate healthy seeds and start the same process over again when that seed is sown. The fungus that causes loose smut of barley infects barley heads when they are in flower and grows in developing barley seed without showing any evidence of damage to it. But when an infected seed is planted the fungus keeps pace with the growing plant, though there is no sign that it is infected until the whole head of the barley plant is converted into a mass of black fungus spores. The fungus that produces ergot of rye, wheat, barley and grasses survives the winter by means of ergot bodies (sclerotia), which are often very conspicuous in rye. These germinate on or just under the surface of the soil (Figure 2) at the time the cereals and grasses are in bloom. They discharge into the air masses of small spores, which infect the heads in which new ergot bodies are formed. The root-rotting fungus *Cochliobolus sativus* attacks chiefly the roots, the base of stems, and the leaves of wheat and barley on which are produced its characteristic spores (Figure 3). These spores survive the winter in the soil and on stubble and cause new infections the following spring. These are only a few examples of the great variety of devices by means of which the fungi adapt their parasitic existence to our growing crop plants.

Bacteria

Bacteria, though less important than fungi, cause diseases of many crops. The bacteria that cause plant diseases are rod-shaped and about one ten-thousandth of an inch long. Bacterial infection causes distinctive, water-soaked spots on the leaves of many kinds of plants. Bacteria also invade the young rootlets or wounded roots of certain plants and plug the vessels carrying water to their leaves. The infection makes the plants wilt and eventually die. Bacteria are spread from infected to healthy tissue by splashing rain. They are also spread on or inside infected seed or by wind-blown infected plant debris. Like many other disease organisms, bacteria can survive the winter on plant remains and reproduce disease the following spring.

Viruses

Diseases caused by viruses have been investigated less than those caused by fungi and bacteria but they are nevertheless of considerable economic importance. The question of whether or not viruses are microorganisms is debatable. Some prefer to look upon them as nonliving chemical structures. However that may be, they are extremely small particles, so small that they can be seen only by means of the electron microscope, which magnifies

Figure 2. — Fruiting structures produced by germinating ergot bodies. Spores are discharged into the air from the swollen tips.

many thousands of times. They can thrive only in living tissues, where they multiply and cause disease. Some virus diseases can be transmitted from plant to plant merely by the rubbing of one leaf against another. Most of them, however, are transmitted by insects such as aphids, leafhoppers or mites, which, in the course of feeding, transfer the viruses from one plant to another. Virus particles usually do not survive in dead plant tissues. They overwinter in perennial or biennial weeds and in some cases inside seed from infected plants.

Nutritional Deficiencies

Besides diseases caused by parasitic organisms there are a number of unhealthy conditions of growing plants, regarded as diseases, that are caused by improper nutrition. These conditions can sometimes be corrected if their cause is understood. Fortunately, the appearance of affected plants usually provides the clue to their cause.

To grow properly, all plants require minerals from the soil in definite quantities. Most nutritional diseases result from an underdose or an overdose of particular soil chemicals. For example, too little nitrogen in the soil, in the spring, before nitrifying soil bacteria have built the nitrogen up to its usual level, gives plants a yellow "chlorotic" appearance. In cereals, this condition can be prevented by applying a nitrogenous fertilizer when seeding the grain. Deficiency of manganese causes the gray speck disease of oats, which can be prevented by drilling manganese sulphate into the soil with the seed.

In certain districts patches of alkaline ground are common. These result from the accumulation of certain chemicals to a level at which they interfere with plant growth. This soil condition is not easy to cure but it is well to remember that certain plants can tolerate alkalinity better than others. For instance, barley can grow satisfactorily in alkaline patches in which wheat will not thrive.

Some types of chlorosis, or leaf yellowing, are caused by an overabundance of one chemical, which tends to render another chemical unavailable. Overabundance of lime tends to "bind" iron, that is, to hold it chemically in a form that plants cannot use. This can sometimes be remedied by spraying affected plants with a solution of iron sulphate.

Climate

Sudden changes in the environment in which a plant is growing will produce symptoms that may be confused with those of an infectious disease. Late spring frosts produce abnormal growth of some crops. When the growing point of sunflowers or peas is killed by frost, new growth will

Figure 3. — Spores of the fungus *Cochliobolus sativus*.

begin from a dormant bud or buds below the damaged area. This results in a plant with a distorted appearance or with an excessive number of branches. The growing point of cereals and grasses is protected from freezing by outer leaves and is seldom damaged, but these outer leaves often show horizontal bands of dead or damaged tissues. The growing point of fall-sown cereals such as rye is more exposed, however, and late spring frosts often cause partially filled heads.

Excessive heat early in the spring is also damaging. Radiant heat from the sun is greatest at the soil line and often "cooks" the outer layers of the tissue of leaves or young stems. Cereal leaves show bands of dead tissue (Color Figure 17), and such crops as flax develop a swelling at the base of their stems (heat canker) caused by the blocking of conducting vessels in the damaged stems.

GENERAL MEANS OF CONTROL

Use of Resistant Varieties

The ideal way to control a crop disease is to replace a susceptible variety with one that is resistant to the disease and at the same time good in all other respects. If such a variety is available, a grower does not have to resort to such expensive practices as dusting or spraying with fungicides.

The long and arduous task of producing satisfactory disease-resistant varieties is performed largely by institutions supported by public funds. One of the main undertakings of agricultural research organizations is to produce such varieties. The scientists in these institutions search the world for resistant breeding stocks. With their knowledge of the laws of heredity they are able to combine resistance with the good qualities of the varieties grown in their own area. An example of control by the use of resistant varieties occurred after the severe cereal rust epidemic of 1935. Within five years most of the acreage of wheat and oats in Manitoba and eastern Saskatchewan was sown to resistant varieties.

As explained later in this book under "Stem Rust," resistance is often of only temporary value because new races of disease-producing organisms keep appearing. Nevertheless very valuable and outstanding results have been achieved in the development of varieties resistant to many diseases of cereals and other field crops. In a publication such as this it would not be worth while to list resistant varieties because frequent revisions would be necessary. To find out which varieties are currently most useful, get in touch with your local agricultural representative.

Careful Selection of Seed

When you have chosen a variety, consider next the condition of the seed to be sown. Two things are important: not only should the seed be free from actual seed-borne disease organisms, it should also be as sound as possible, that is, free from cracks and breaks. This is an ideal that can seldom be achieved in commercial seed. Therefore, it is usually advisable to treat seed with a fungicide.

Freedom from Disease — Seed-borne disease organisms may occur on the surface of seed or inside seed. Organisms on the surface of seed can usually be killed by ordinary chemical treatments but those inside seed require a different treatment. For example, it is possible, by steeping infected seed in hot water, to destroy internally borne organisms without injuring the seed. Treatments for internally borne seed infections are harder to apply than those for surface-borne organisms. For this reason, it is sometimes preferable to buy registered or certified seed rather than to rely on seed treatment. Strict limitation of the percentage of certain disease organisms allowed in certified seed ensures that the seed is as disease-free as possible.

Diseased seed is often reduced in size and weight and carries spores, mycelium or other structures from which disease-producing organisms grow. Infected seedlings serve as a focal point from which an epidemic of the disease can start. Other sources of disease infection such as ergot, sclerotia or those of the fungus causing wilt of sunflowers and rape, or bits of rusted flax straw may also be mixed with seed. It is good practice, therefore, to remove shrunken seed and other debris by careful cleaning.

Soundness — Soundness of seed is very important in flax, but it is also important in other crops. Cracks and other fractures are most severe in seed that has been threshed under very dry conditions. These fractures serve as points of entry for soil-borne microorganisms after seed is sown. The blistering of seed by frost may have the same effect.

The harmful effects of fractures can be largely offset by appropriate seed treatment before sowing, but if there is a choice between sound and unsound seed, the choice should, of course, be made in favor of the sound seed. Fracturing of the seed can be reduced by care in adjusting threshing equipment.

Chemical Seed Treatment

Seed treatment with chemicals is desirable for much of the seed sown in the Prairie Provinces. All types of crop plants are subject to diseases that may be controlled by seed treatments. This method of control is two-fold in action. It acts first against the disease organisms on the surface of seed and, second, against harmful soil microorganisms before they enter damaged or germinating seed.

Treat all wheat seed with an appropriate fungicide before sowing, unless it is sound, healthy and free from surface-borne smut. Some seed-testing laboratories maintained by grain elevator companies will test seed samples, free of charge, for the presence of surface-borne spores of smut and seedling blights. A few laboratories will make similar tests for a fee. If an examining service reports that a sample possesses high germination (90 percent) and freedom from smut spores, the seed may be sown without treatment. However, freedom from smut alone does not imply that seed treatment may not be of value.

Treat all seed of oats, barley, flax, rye and peas with a suitable fungicide. Ensure that the seed is properly cleaned before treatment, that the fungicide is carefully applied and completely covers the seed, and that the directions supplied by the manufacturer are followed exactly.

Most seed treatment chemicals are poisonous and you must take special precautions when using them. Wear a respirator to avoid inhaling dust, and wear plastic gloves to prevent the chemicals from contacting your skin. Treat seed outdoors, if possible, or in well-ventilated quarters. It is against the law to sell treated grain other than for seed. Surplus treated seed should be sown for green-feed or may be stored and sown the following year. Do not feed treated grain to livestock.

A large number of chemicals are now available for seed treatment. Some of these are fungicides, some are insecticides, and some are a combination of both. Your choice will depend on the disease or insect you wish to control, or on whether you prefer to apply the chemical in the form of liquid, slurry, dust or a formulation designed for drillbox application. New products for seed treatment are constantly being developed. Enforcement of the Pest Control Products Act, administered by the Plant Products Division, Canada Department of Agriculture, ensures that any products on sale in Canada are suitable for the purposes for which they are sold. *For current recommendations on the use of seed treatment chemicals, consult your local agricultural representative.*

Crop Rotation and Sanitation

Plant sanitation or plant hygiene is a well-recognized means of controlling diseases of orchard crops, but it is not commonly practiced with field crops because most of these crops are renewed each year and the spread of diseases from old dead plants to new growth is less easily noticed. The practice of burning alfalfa stubble in seed fields before growth starts in the spring is a good illustration of control through sanitation. Most of the fungi causing leaf and stem diseases of this crop overwinter on dead foliage, and removing such material reduces early spring infection of the new growth. Even in cereal crops special conditions may result in such a rank growth that other methods of disposal become very difficult and burning may be necessary. Destruction of plant debris by burning or by covering it by plowing under tends to limit the build-up of disease, but these measures are not always advisable from the point of view of soil conservation. The straw cutter will permit disposal of the straw of most cereal crops, but recommendations for the maintenance of a trash cover, which are highly commendable for controlling soil drifting, pose a problem in the control of plant diseases. Perhaps the most effective answer to the danger from a trash cover is found in crop rotation. It provides for the destruction by natural means of the sources of infection in the remains of an old crop. When there is more than a year between plantings of the same kind of crop, there is time for the diseased stubble to decompose and the disease organisms to be destroyed by other micro-organisms or by antibiotics produced by them.

If crop rotation is not practiced with a crop such as barley, the bad effects are quickly evident. Leaf-spotting and root-rotting diseases over-winter readily on old stubble, especially if it is not plowed under. If barley is sown a second year the leaf-spotting diseases may cause serious losses in yield.

Fortunately most farmers are fully aware of the advantages of crop rotation. Ask your local agricultural representative about the best rotation for your particular district.

DISEASES OF WHEAT

Stem Rust

Puccinia graminis f. sp. *tritici*

Stem rust is the most destructive disease of cereals in the Prairie Provinces. It attacks wheat, barley, oats, rye and certain grasses. There are several kinds of stem rust which differ in that they attack different crops, although they all look very much alike. Stem rust of wheat attacks wheat, barley and wild barley but not oats or rye. Stem rust of rye attacks rye, barley, wild barley and couch grass but not wheat or oats. The rust of oats attacks not only oats but also wild oats and meadow fescue, though not wheat, barley or rye.

The tendency of stem rust to break up into units that differ parasitically is carried to extraordinary lengths. Not only is wheat stem rust different from oat stem rust; wheat stem rust itself is made up of a great many parasitically distinct strains or races. These strains can be distinguished from one another by their ability or inability to attack different wheat varieties.

The characteristic specificity of rust is economically important because there is a strong tendency for the races that attack a given wheat variety to increase from year to year where that variety is widely grown. Thus race 15B, which attacked Thatcher, Redman and Regent in 1950, increased so rapidly that, by 1956, the acreage sown to these varieties in Manitoba and eastern Saskatchewan dropped from 90 percent to 6 percent. The durum wheats suffered in the same way. They were rust resistant before the advent of race 15B in 1950. But this race attacked them heavily, and from 1950 onwards increased to such an extent that the durum wheats became even more rust susceptible than the bread wheats. The change did not take place in the wheats but rather in the rusts that attacked them.

Appearance — During summer, stem rust is easy to recognize on wheat plants because of brick-red eruptions, or pustules, on leaves and particularly on stems (Figure 4). This is the red or summer stage of the rust. Each pustule contains hundreds of thousands of spores, each of which may infect another plant and produce a new rust pustule in a week or 10 days. As wheat plants ripen, the rust pustules darken until they are

Figure 4. — Stem rust of wheat.

almost black. This change in appearance is caused by the formation of thick-walled, dark-brown spores that can resist the severest winter. This is the black, or winter, stage of the rust, which is responsible for the name "black stem rust." The two stages are, however, not two distinct kinds of rust but merely two phases of the same rust.

Disease Cycle — The black spores survive the winter and germinate in the spring, each spore producing four smaller spores known as sporidia. These sporidia cannot infect wheat or any other plant except for various species of barberry, the most important of which is the common barberry. The rust thus produced on the barberry cannot reinfect barberry; instead it infects wheat, giving rise to the red, summer stage of the rust.

The barberry's role in the rust life cycle is important for two reasons. First, it spreads the rust to grain and grasses in early summer. Second, while the rust is on the barberry different races can interbreed to produce new races. However, barberry is not essential for the appearance of rust each year in Canada. In North America, the red, or summer, stage of the rust is able to survive the winter in southern Texas and Mexico and then spread by wind-borne spores to other parts of the continent. Our stem-rust epidemics come mostly from this source.

Control — The best way to control rust is to grow stem-rust-resistant varieties. Experience has shown that varieties cannot be depended on to remain resistant indefinitely because new rust strains that can attack them develop. In this and other countries where stem rust is a menace, plant geneticists are constantly working to produce new rust-resistant varieties. As old varieties become susceptible new ones are introduced. Information on the best varieties to grow in any particular district at a given time can be obtained from experimental stations and district agricultural representatives.

You can also control rust by destroying barberry bushes. Barberry is not a native plant. It was introduced from Europe and is now common in the eastern United States and in some parts of Eastern Canada. It has never been grown extensively in the Prairie Provinces. A great barberry eradication campaign, begun in 1918, has resulted in the destruction of most barberry bushes in the Mississippi Valley states and Western Canada.

Wheat sown early stands a better chance of escaping rust infection than late-sown grain.

Leaf Rust

Puccinia recondita

Leaf rust, also caused by a fungus, is probably the second most destructive disease of wheat in Western Canada. Like stem rust, it is made up of many parasitically distinct strains known as physiologic races. Some wheat varieties, such as Thatcher, are susceptible to nearly all the North American races of this rust. Other varieties, such as Selkirk and Lee, are resistant to some races but susceptible to others. A new variety may be classed as resistant at first, but as it becomes more widely grown the leaf rust races that can attack it tend to become more prevalent year by year until the variety has to be regarded as susceptible.

Appearance — Leaf rust is largely confined to the leaves of wheat plants but occurs also, to a lesser extent, on the stems just below each leaf. Leaf rust pustules (Figure 5) are nearly round and are much

Figure 5. — Leaf rust of wheat.

smaller than those of stem rust. They are yellowish red, and may be so closely spaced on heavily rusted plants that they give the leaves an orange-red appearance. As the plants ripen the rust pustules darken until they become black. As in stem rust, the dark color is caused by the formation of thick-walled, dark-brown winter spores. These spores can survive our winter whereas the red, or summer, stage survives the winter only in the southern United States and, occasionally, in areas in which winter wheat is grown.

Disease Cycle — The black spores which live through the winter germinate in the spring, each spore producing four smaller spores called sporidia. These sporidia cannot infect wheat. They can, however, infect certain other plants, particularly certain kinds of meadow rue (*Thalictrum* spp.) that grow in Europe and Asia. The rust on meadow rue can, in turn, infect wheat to produce the red, summer stage. However, the kinds of meadow rue that are native to North America are so highly resistant that they do not contribute to the spread of the rust.

In North America the persistence of leaf rust from year to year is due to the overwintering of the red, summer stage in the southern United States and Mexico.

Control — The best control measure is the growing of resistant varieties. It is not easy to breed varieties resistant to all stem-rust races *and* all leaf-rust races. The well-known variety Thatcher, which was resistant to stem-rust races for many years, was never resistant to leaf rust. The value of leaf-rust resistance was clearly shown in 1954 when the variety Lee, which was resistant to leaf rust but susceptible to stem rust, greatly outyielded Thatcher, which was susceptible to both rusts.

Bunt

Tilletia caries and *Tilletia foetida*

Bunt of wheat, or smutty wheat, is caused by two closely related smut fungi. Because both forms of the disease look alike, develop in the same way and need the same type of control, no distinction between them will be made here. A third kind of bunt, called dwarf bunt, is now known to occur in British Columbia and Ontario on winter wheat.

Bunt occurs wherever wheat is grown, and before effective control methods were discovered it was a very serious disease in some wheat-producing countries. With the use of modern seed disinfectants, bunt of wheat has been practically eliminated from the Prairie Provinces. It remains only on farms where control measures are neglected, and in the winter-wheat area of southern Alberta where soil-borne smut spores sometimes reproduce the disease. Although losses caused by bunt of wheat have been very small in recent years, they still amount to many thousands of dollars annually. A high proportion of these losses arise because smutty wheat has to be sold at a discount.

The fungi causing bunt of wheat are each composed of several races which are indistinguishable in their appearance but differing in their ability to attack different varieties of wheat. Some also have a characteristic bunt odor whereas others do not.

Appearance — Smutted heads of wheat are usually bluish green in appearance and they remain green longer than healthy heads. Awns may fail to develop, or may fall off as smutted heads ripen. Sometimes all the heads of a plant are affected and at other times only one or two. The

Figure 6. — Loose smut of wheat.

heads themselves may be partially smutted, both normal grains and bunt balls occurring in the same head. Bunt balls resemble wheat kernels but they are bluish green at first, then change to various shades of brown as they reach maturity.

Disease Cycle — Bunt balls, each of which may contain up to nine million spores, are broken by threshing and the spores thus set free adhere to the surface of sound grain. Smut spores may also be carried by air currents to nearby fields that would otherwise be free of smut.

When a smutted seed is planted, the spores germinate simultaneously with the seed and their tiny germ tubes penetrate the young seedling. Once inside, the smut fungus develops with the growing point of the host plant until the head begins to form. Within the young head, the fungus threads branch profusely and replace the tissues of the young wheat kernels, except for the outer skin. These threads inside infected kernels change into spores and thus produce bunt balls.

Control — Modern seed disinfectants, if properly applied to wheat seed, give good control of bunt.

Loose Smut

Ustilago tritici

Loose smut of wheat (Figure 6) is almost identical in appearance with loose smut of barley. The fungi that cause the two diseases are very closely related. Since loose smut is more prevalent in barley than in wheat in the Prairie Provinces, it is dealt with in detail under "Diseases of Barley." The mycelium of the loose-smut fungus is borne inside the seed; thus, seed treatment chemicals will not control the disease.

Control — Sow certified smut-free seed or a resistant variety.

Common Root Rot

Cochliobolus sativus and *Fusarium* spp.

Common root rot is a very prevalent fungus disease of wheat and barley and it also affects other cereals and some grasses. It is particularly injurious to wheat in hot, dry seasons but is somewhat less damaging when there is adequate moisture.

Appearance — Early infections may be seen on wheat plants in the seedling stage as small brown spots or blotches at the base of leaf sheaths or below ground level. These spots enlarge as the season advances, spread to the base of the stems, and often penetrate the crowns and the crown roots (Color Figure 9). If an infected crown is cut open with a knife, its internal tissues are usually found to be brown, instead of white as in healthy plants.

The disease may attack only a few scattered plants, or nearly all the plants in a crop. Only rarely are diseased plants found in definite patches. Bleached, blighted plants with rotted crowns can sometimes be seen after the heading stage and before a crop is mature. Such plants are very conspicuous, their white color contrasting sharply with the green of healthly plants.

Disease Cycle — Wheat plants may be infected at any time by spores of the fungi, which are present in the soil, but they are usually attacked from early June to late July. Infection may occur in any part of the plants, including stems, leaves, heads and grains. Under dry prairie conditions, the portion of the stems in the top 3 inches of soil is most severely affected. As plants reach maturity the fungi produce abundant spores in invaded tissues. Spore production continues into the fall on the stubble of diseased plants. Generally, spores remain dormant in the soil for two or three years unless they are stimulated to germinate by green plants, including susceptible hosts, or by other organic materials close to them. Spores or plant fragments bearing the fungi may be spread by wind, rain, surface water and cultivated soil to produce new infection in current and succeeding crops.

Smudge or black-point in seed indicate that root-rot fungi may be present. Diseased seed can give rise to blighted seedlings. Soil-borne spores, however, are the main source of infection on the prairies.

Control — Shallow seeding, as practiced in moist soil, reduces the risk of infection. Rotation of cereal crops with noncereal crops, such as flax, rape or legumes, lowers the concentration of cereal root-rot fungi in the soil. Spring plowing to bury stubble of wheat and barley to a depth of 4 inches or more helps prevent infection of the next crop. Recommended chemical seed treatments are effective in reducing seedling infection when seed contains smudge or black-point kernels, but they do not protect seedlings from the soil-borne spores of the root-rot fungi.

Take-all Root Rot

Ophiobolus graminis

Take-all occurs chiefly in parkland areas of the Black soil zones of the prairies where it is often severe. This fungus disease may be troublesome if wheat follows wheat for several years in succession and it commonly appears in wheat crops after the breaking of native or cultivated sod land. Losses of 20 or 30 percent in some fields have been observed. In a few cases, damage has been much greater.

Appearance — Take-all is a conspicuous disease; affected plants are easily recognized both alone and in patches. Diseased plants are bleached, stunted and easily pulled from the soil because of their rotted roots (Figure 7). The rotted tissues at the base of the plants are shiny black. Sometimes the heads do not fill, or bear only shrunken kernels.

Take-all may be confused with prematurity blight, mentioned under "Common Root Rot," but it can usually be distinguished by the shiny black appearance of invaded tissues.

Disease Cycle — The stubble left after diseased plants are harvested is the main source of infection. The fungus completes its development on the

Figure 7. — Upper row: Take-all root rot of wheat. Lower row: roots of healthy wheat plants.

stubble during the fall and spring, and spores are released in time to infect the new crop. The disease develops in all the tissues at the base of the plants, usually causing death well before maturity.

Control — As a rule you can control take-all by alternating wheat with a resistant crop such as oats, or by keeping land fallow for a year. Maintenance of good soil fertility is also helpful.

Browning Root Rot

Pythium spp.

Browning root rot is primarily a disease of wheat and most commonly follows summerfallow. It can cause yield reductions up to 10 bushels per acre. Diseased crops ripen one to two weeks late.

Appearance — The characteristic browning is conspicuous only when plants are in the seedling stage, usually in June, when their lower leaves turn brown and die. Large, affected areas in a field are very noticeable and sometimes an entire crop appears to be dying. Plants are greatly retarded and fail to compete successfully with weeds. There are no distinct discolorations at the base of stems. The infection is entirely in the root system and is difficult to see unless the roots are washed.

Disease Cycle — The fungi that cause browning root rot remain in the soil indefinitely. They develop well only when moisture is adequate in the spring and early summer. Roots of plants growing in infertile soil are readily invaded and seriously damaged.

Control — Apply phosphate fertilizer as recommended by the agricultural representative in your district, as browning root rot occurs when soil nutrients are unbalanced. Increase the amount of organic matter in the soil by working in straw and manure, and sow seed in a firm seedbed.

Ergot

Claviceps purpurea

Ergot, caused by a fungus, occurs on a wide range of crop plants. Although it is most prevalent on rye and a number of grasses, it also attacks wheat, barley and, occasionally, oats. As a result of its ability to develop on cereal crops and grasses, both cultivated and wild, and because ergot bodies are poisonous to man and animals, this is a serious disease.

Since wheat is a staple food of man, even a trace of ergot bodies in grain constitutes a hazard. Unfortunately, ergot bodies, or fragments of them, are difficult to remove from grain. Although ergot seldom causes any appreciable loss in wheat yield, in some years it is sufficiently common in the Prairie Provinces to cause considerable loss through degrading the wheat. It is important, therefore, that all farmers be well acquainted with this disease and make every possible effort to control it. For a description of the disease and methods of control, see "Diseases of Rye."

Bacterial Blights

Xanthomonas translucens
Pseudomonas atrofaciens

The two bacterial diseases caused by *Xanthomonas translucens* and *Pseudomonas atrofaciens* can destroy a considerable proportion of the leaves and leaf sheaths of wheat plants. Their cause is not always recognized because the browned tissues are often thought to be dying of old age or to be suffering from a vague something called "poor growing conditions."

As a rule, neither of these diseases is severe over large areas, though local outbreaks may be intense. The severity of attack is closely related to the amount of wet weather.

Appearance — Both these diseases kill portions of wheat leaves causing light-brown patches. Often the dead areas appear near the leaf tips and have long streaks extending from them. The disease may be confined to only small spots or attack whole leaves or leaf-sheaths. At first, the spots are dark green and water-soaked, later a golden brown. When they are viewed against a bright sky, light areas can be seen in them. These light areas are caused by masses of bacteria in the leaf tissues. The spots may fade to light brown after a rainy spell.

The two blights look very similar on the leaves and sheaths, but as a rule quite different on the heads of wheat. One of them, bacterial black chaff, appears as dark stripes on the glumes (Color Figure 5). These stripes often fuse, turning the glumes completely black. The other disease produces two distinct symptoms: a light-brown spot at the base of the spikelet, which accounts for one of its names, basal glume rot; and a black spot at the base of the kernel, which accounts for its second name, bacterial black tip.

Disease Cycle — The bacteria enter wheat plants through breathing pores and water pores or through wounds. Once infection is established, the bacteria multiply rapidly. When there is rain or dew, they pass out into droplets on the surface of the plants. Insects may spread the bacteria and make wounds for their entry. Also, the splashing of rain drops is responsible for much local spread of infection.

Although the bacteria can overwinter in and on seed, few infections develop from this source. Experimental evidence suggests that bacteria overwintering on crop remains are a more usual source of infection and that in the spring the bacteria also spread from perennial grasses.

Control — The best way to control bacterial blights is to grow resistant varieties. Resistance to bacterial diseases is one basis of selection in the production of new rust-resistant varieties of wheat. Selected varieties can be expected to possess sufficient resistance to bacterial diseases for satisfactory farm use. Crop rotation and general sanitation measures help to check the diseases.

Head Discolorations

Xanthomonas translucens, Pseudomonas atrofaciens, Cochliobolus sativus, Alternaria tenuis, Septoria nodorum, Puccinia graminis,

Stripe Mosaic Virus, Weather Conditions

The heads, necks and stems of wheat may turn brown to black from a variety of causes when plants are approaching maturity. Browning is caused by the development of an insoluble, dark-brown pigment known as melanin. This pigment is formed when certain chemicals found in the plant tissues combine with oxygen. Invasion by several different kinds of disease organisms can bring about this change in color. Weather conditions play an important part in determining the severity and symptoms of the disease. Greenhouse experiments have shown that strong light alone, or high temperature in conjunction with high humidity, can cause dark discolorations on the heads, necks and stems of certain varieties. When discoloration occurs in the late stages of maturation of tissues, little harm, if any, is done to the kernels. If, on the other hand, it is the consequence of a general attack on a plant, by bacterial black chaff for example, discoloration indicates the presence of a disease that can cause appreciable loss.

Appearance — Brown or black head discolorations vary so much in appearance that a detailed description of all of them would be too long for this publication. Because they are caused by diseases either alone or in combination, it is sometimes difficult, even for a person with long experience, to decide which disease or combination of diseases is present.

Dark purplish discolorations have a well-known cause. They develop when there is a lack of phosphate in the soil.

Control — The most satisfactory means of control for head discoloration diseases is the use of resistant varieties. Wheat varieties bred for rust resistance are all subjected to tests for resistance to head discoloration diseases and this characteristic is used as one basis of selection.

Streak Mosaic

Wheat Streak Mosaic Virus

Wheat streak mosaic can cause severe reductions in yield and even complete failure of a wheat crop. This disease is a perennial menace in those areas of southern Alberta and southwestern Saskatchewan where winter wheat is grown regularly.

The wheat streak mosaic virus can be detected only by the symptoms it causes on infected plants. It cannot survive in ripe seed, in mature or dead plants, or in soil. It is perpetuated in certain susceptible living plants, principally wheat. It is carried from plant to plant by a white, four-legged wormlike mite, *Aceria tulipae*, that is only 1/100 inch long and therefore scarcely visible except with a strong magnifying glass or microscope.

Wheat streak mosaic is primarily a problem in winter wheat, but any variety of spring wheat may become diseased if grown near diseased winter wheat. Barley may also suffer slight damage from mosaic if grown beside diseased wheat. Although a number of cultivated and wild grasses can be infected with the virus under special conditions, none is seriously affected by it, and none appears important in perpetuating the disease in southern Alberta.

Appearance — The earliest symptoms of wheat streak mosaic are light-green to yellow dashes and streaks in young leaves (Color Figure 12). The yellowing may increase until there are only islands of green, or no green, left in the leaves, which then die. Diseased plants are stunted to varying extents, depending on the time of infection, growing conditions and other factors. Some plants die before heading. Others head and produce low-grade grain. Stunted plants are the most obvious indication of wheat streak mosaic when a crop is nearing maturity. If the proportion of diseased plants is small, these stunted plants will be intermingled with plants of normal or near normal height. In severely diseased crops, all plants will be stunted, but to varying extents, giving the stands a ragged appearance.

Disease Cycle — The virus that causes wheat streak mosaic, and the mites that transmit the virus, depend for survival on living plants at all times of the year. Winter wheat that is infested in the fall carries the virus and the mites over winter. The mites multiply rapidly on diseased wheat during the spring, summer and fall seasons when the weather is warm. The mites are wingless and so cannot fly, but they can be blown by the wind and can thus carry the virus to other plants. In this way spring wheat can become diseased when grown near winter wheat. Volunteer wheat can also become diseased and help carry the virus and mites during the summer and fall. Winter wheat that is sown early in the fall may become infected from any immature wheat growing in the same or nearby fields.

Control — Since both the virus and the mites that transmit it need susceptible living plants to survive and multiply, you can control the disease by keeping land free from all disease-carrying plants for a week or more before sowing wheat there or in adjacent fields. Do not sow winter wheat beside spring wheat until the latter is completely ripe. There is much greater danger of mosaic infection in early-sown than in late-sown winter wheat. The best time to seed winter wheat in southern Alberta is between September 1 and 15.

Do not plant spring wheat next to winter wheat that is diseased. Volunteer winter wheat should be destroyed before you plant spring wheat on the same land. If a winter wheat crop is so severely diseased with mosaic that it must be destroyed in the spring, it is not safe to reseed spring wheat on the same land until all the diseased winter wheat has been destroyed. It is safer to reseed the field to oats, flax or barley.

Powdery Mildew

Erysiphe graminis

In Western Canada, powdery mildew is a recurrent fungus disease of wheat, barley and a number of grasses. It occurs mainly during dry, cool seasons and may cause considerable damage. Although local infections occur almost every year, only occasionally do widespread epidemics develop in the Prairie Provinces.

Powdery mildew looks the same on wheat, barley and grasses but, like rust and smut, it is parasitically specific to individual or closely related groups of plants. Powdery mildew of wheat does not attack barley or oats, and that of barley does not attack wheat or oats. Moreover, in each of these specialized parasitic kinds of powdery mildew, there are several races. These races can be distinguished from one another only by their ability or inability to attack different varieties of the host crop.

Appearance — At first powdery mildew may be observed as small grayish-white spots on wheat leaves. These spots resemble very small heaps of white powder (Color Figure 16). The spots increase in number and size until the whole leaf and sheath area is covered with a whitish, powdery mass. Infected plants are stunted and their leaves eventually wither and shrivel up. When infection is heavy, wheat plants may fail to head out. The whitish, powdery spots or areas eventually become spotted with minute black dots, which are the sexual fruiting bodies of the fungus.

Disease Cycle — Powdery mildew survives the winter either as black fruiting bodies or as grayish mats of mycelium on the remains of infected plants. In the spring the spores, produced either in the fruiting bodies or on the mats of mycelium, are carried by air currents. When they are deposited on growing wheat plants they cause infections that develop a new crop of whitish, powdery spores. Unlike spores of many other fungi, the spores of powdery mildew can germinate in dry air. Plant infection and spread of the disease are not, therefore, dependent on dews and rains. In fact, frequent rains hinder the development of powdery mildew.

Control — Epidemics of this disease are infrequent in the Prairie Provinces and no specific control measures are recommended.

Speckled Leaf Blotch

Septoria avenae f. sp. *triticea*

Speckled leaf blotch is a common fungus disease of wheat in Manitoba and eastern Saskatchewan. The first signs of the disease are oval or elongated, buff-colored blotches on the leaves of wheat plants (Color Figure 8). These symptoms appear when plant growth is well advanced. Very small, black dots, the fruiting structures of the fungus, soon appear in the centers of these blotches (Color Figure 14). In wet weather, the dots discharge large numbers of spores, which spread over the leaves and cause new infections at such a rapid rate that the leaves soon become uniformly covered with the black, dotlike fruiting structures. These structures are so small that they are not readily seen with the naked eye. As the final phase of the disease does not occur until plants begin to ripen, the effect of the disease is chiefly to hasten the death of the leaves. Therefore, speckled leaf blotch, though very widespread, is not highly destructive. The fungus survives the winter on the dead leaves and stems of wheat plants.

Control — Crop rotation and deep plowing to bury crop remains retard development of the disease. No wheat varieties that show any appreciable resistance are available.

Ascochyta Leaf Spot

Ascochyta sorghi

This type of leaf spot often occurs on the saw-fly-resistant wheat varieties grown in the brown-soil zones of the prairies. Since the fungus lives on stubble over winter, it is particularly evident in the second wheat crop in the rotation: fallow, wheat, wheat. Severe infections develop during wet spring weather. Leaf spots are small, dark brown, and round to oval.

Large spots may have tan-colored center areas surrounded by dark margins. Leaf tissues around the spots turn yellow in a few days. As the spots enlarge they run together to form irregular blotches that cause the leaves to dry out and turn yellowish brown prematurely. Wheat varieties differ in their susceptibility to the disease.

Control — In areas where ascochyta leaf spot is severe, grow only those varieties recommended for their resistance.

Figure 8. — Covered smut of awned and hooded barley; healthy heads at right and left.

Splotch

A Nutritional Disorder

Splotch is a leaf condition that is frequently found in durum wheats, and less often in bread wheats. The disease is not caused by a fungus or bacterium and appears not to be caused by a virus. Experiments indicate that the disorder occurs when the nitrogen concentration in the soil is low. The earliest symptoms appear on the leaves on the upper half of stems. Numerous small, yellowish spots appear which gradually enlarge and merge to form large, irregular blotches that leave only small islands of green tissue in the leaf blades. Later the spots dry out and turn a light brown. Fertilization at the recommended rate will reduce the severity of the disease.

DISEASES OF BARLEY

Stem Rust

Puccinia graminis f. sp. *tritici*
Puccinia graminis f. sp. *secalis*

Barley is attacked by two distinct kinds of stem rust: wheat stem rust and rye stem rust. In the Prairie Provinces, wheat stem rust is by far the more common of the two. The best control measure is to grow one of several rust-resistant varieties that have been developed. These varieties appear to be somewhat less resistant to rye stem rust than to wheat stem rust, but this is not important so long as rye stem rust remains relatively uncommon. A more detailed account of stem rust is given under "Diseases of Wheat."

Leaf Rust

Puccinia hordei

Leaf rust of barley is one of the least destructive diseases of this crop in the Prairie Provinces but it sometimes causes considerable damage in the southern United States where winter barley is grown. It occurs almost every year in Manitoba and sometimes spreads into eastern or central Saskatchewan, but infection is generally light.

Appearance — The rust pustules of the summer stage of the fungus occur on leaves and sheaths as small, round, deep-orange eruptions. When infection is heavy, the pustules are spaced so close together that they give the leaves a golden-brown appearance. As plants ripen, the summer stage is partly replaced by the dark-gray pustules of the winter stage which are produced just below the surface of the leaves and sheaths.

Life Cycle — The thick-walled, dark-colored spores of the winter stage of the fungus survive the winter and germinate in the spring when each spore discharges several small, colorless spores (sporidia) into the air. These sporidia cannot infect barley; in fact, the only plant they are known to infect is the star-of-Bethlehem (*Ornithogalum umbellatum*). As this plant does not grow in Western Canada, the rust cannot reproduce itself there in this way. The summer stage of the rust survives the winter on winter barley in the southern United States, and from this source the rust gradually works its way north until it reaches Western Canada, usually early in July.

Control — No specific control measures are recommended for this disease as it rarely causes damage in Western Canada.

Covered and False Loose Smut

Ustilago hordei and *Ustilago nigra*

Covered and false loose smuts of barley are quite distinct in appearance but they are listed together here as their methods of development and their control are the same. These two fungus diseases attack barley and a number of related grasses but they do not attack any other cereal crop. Each of them is subdivided into a number of parasitic races which differ only in that they attack different varieties of barley.

These two barley smuts still cause extensive economic losses amounting to millions of dollars annually in Western Canada. If farmers would only become aware of the facts about these diseases such losses could be avoided. Both of them can be readily controlled by regular seed treatments with an effective seed disinfectant.

Appearance — Covered smut stunts an affected host plant, particularly the top internode of the stem; and the smutted head usually emerges through the sheath below the boot leaf. Smutted heads are compact and hard, and they usually contain vestiges of chaff and deformed awns (Figure 8). The compacted spores are not readily blown or washed away by wind and rain until harvested and threshed, then smutted heads are broken and large numbers of spores are set free to contaminate sound grain.

False loose smut, on the other hand, looks very much like true loose smut (Figure 9). Smutted heads emerge in the same manner and at the same time, and grow as tall as heads of healthy plants. At first each smutted head is covered by a delicate grayish membrane, which soon breaks down setting free a loose, dark-brown, powdery mass of spores. Eventually the spores are blown or washed away leaving an inconspicuous, bare rachis.

Disease Cycle — Both covered and false loose smuts of barley are carried over from season to season as seed-borne spores. Under favorable conditions, during maturation of a crop and storage of seed, some seed-borne spores may germinate and produce a certain amount of mycelium under the hulls of the seeds. Both mycelium and spores remain dormant until affected seeds are planted and begin to germinate. Then the thread-like germ tubes and the mycelium of the smut penetrate the very young seedlings and the smut grows with the infected plants until the heads begin to develop. In young, developing barley heads the smut mycelium displaces all or most of the plant tissues and by the time the affected heads emerge they contain smut spores instead of seed and chaff.

Control — Careful application of a recommended seed disinfectant gives good control of both covered and false loose smuts of barley.

Figure 9. — False loose smut of barley; healthy head at left.

Figure 10. — Loose smut of awned and hooded barley; healthy heads at right and left.

Loose Smut

Ustilago nuda

Loose smut is a serious fungus disease of barley. It can destroy a large proportion of a crop. In recent years the average loss from loose smut in Western Canada has amounted to 1 to 2 percent, but occasionally losses as high as 40 percent have been reported. This disease has been prevalent in the Prairie Provinces ever since barley became widely grown, but its severity has fluctuated somewhat with cycles of wet and dry years and with changes in varieties. Since the spores of loose smut are dispersed when a crop is in the flowering stage, the spores do not accumulate on the seed and the quality of the grain for feed is not affected. Consequently, the grain is not degraded as in the case of wheat contaminated with bunt. However, the smut does affect the value of grain grown for seed.

Appearance — Loose smut manifests itself at heading time. All parts of the head of a barley plant are attacked and destroyed except the rachis (Figure 10). About the time that the head emerges the thin membrane that surrounds the masses of smut spores breaks down and the dusty, brown spores are blown away so that in a few days only the bare rachis is left. The spore masses look like those of false loose smut, but ordinarily they are not quite so dark in color.

Disease Cycle — When spores of loose smut are blown into a healthy flower they germinate by means of long germ tubes, if the air is sufficiently humid and the temperature right. The mycelium developed from the spores penetrates the ovary and establishes itself in the embryo. As the seed matures the mycelium becomes dormant and remains in that condition until the seed germinates. Then the mycelium renews its activity and penetrates the plant tissues near the growing point of the barley plant. As the head begins to form it is attacked by the fungus and a mass of spores develops instead of the normal spikelets. The spores are mature by the time the infected plant heads out and, upon dispersal, those that come to rest in the flowers of healthy plants infect them and thus complete the life cycle of the fungus.

Control — You can control loose smut of barley by using certified smut-free seed or by growing a resistant variety. Seed treatment fungicides are not effective as the fungus mycelium is borne inside the seed.

Common Root Rot

Cochliobolus sativus and *Fusarium* spp.

Common root rot of barley is in almost every respect similar to common root rot of wheat. It is one of the most serious and widespread diseases of barley in Western Canada.

Appearance, Disease Cycle and Control — See "Common Root Rot" under "Diseases of Wheat."

Spot Blotch

Cochliobolus sativus

Spot blotch, a leaf disease of barley and wheat, is caused by one of the common root-rot fungi. Leaf infections develop under warm, moist conditions, and can cause severe damage. The disease is most serious in the eastern Prairie Provinces.

Appearance — Individual leaf spots are round to oblong, brownish in color, and have definite margins (Color Figure 10). Spots frequently fuse to form blotches. Eventually, blotches may cover a large area of a leaf blade and part of the leaf sheath. Heavily infected leaves dry out and die.

Disease Cycle and Control — See "Common Root Rot" under "Diseases of Wheat."

Net Blotch

Pyrenophora teres

Net blotch is one of the most common leaf-spot diseases of barley in the Prairie Provinces. Crop losses resulting from this disease are proportional to the amount of leaf area destroyed by the fungus. When conditions favor disease development heavy infection can reduce yields considerably.

Appearance — The disease attacks leaves and also leaf sheaths and glumes. Typical leaf blotches are light green or brownish at first. As the blotches develop, irregular lines appear. The lines are a darker brown than the surrounding area and give the blotches their characteristic, netted appearance. As the blotches grow older their centers become uniformly dark brown and the lines forming the net are visible only at the margin of each blotch (Color Figure 6). Sometimes, especially on young plants, the net does not develop and the blotches are uniformly deep brown. At first the blotches are small but they develop lengthwise along the leaves, and two or more of them may join to form long streaks.

Disease Cycle — The fungus overwinters on or in seed, or on the plant remains of a previous crop. In the spring, the overwintered fungus on seed or plant remains grows and infects the young plants of the new crop. Further spread of the disease is brought about by spores produced in the new infections on the young plants.

Control — The disease is seed-borne and hence seed treatment with a recommended seed disinfectant is a valuable method of control. Crop rotation is also an important control measure because it limits the spread of the disease from the remains of previous crops.

Speckled Leaf Blotch

Septoria passerinii

Speckled leaf blotch is one of a number of fungus diseases that attack the leaf blades and sheaths of barley. In years when environmental conditions favor its development, it is responsible for a large part of the damage caused by barley leaf diseases.

Appearance — Speckled leaf blotch appears first on barley leaf blades as grayish-green or straw-colored blotches, which may join to form irregular, dead areas on the leaves. In these areas are many very small, black dots, the fungus fruiting structures, which can be seen with a magnifying glass and sometimes with the unaided eye (Color Figure 14). Infections appear later on leaf sheaths and are most conspicuous on plants approaching maturity. Symptoms on the sheaths consist of darkened areas in which there are rows of black dots. The disease hastens maturity of a crop and symptoms may be confused with the natural dying of leaves on ripening plants (Color Figure 7).

Disease Cycle — The fungus overwinters in crop remains in the soil. In the spring and early summer, spores are produced on plant remains and are carried to growing plants by wind and water. The spores infect the plants, blotches develop, and spores spread to infect still other plants.

Control — Crop rotation is the most practical method of control. Deep plowing to bury crop remains is also of value.

Scald

Rhynchosporium secalis

Scald is one of the major leaf-spotting diseases in the northwestern barley areas of the Prairie Provinces. Losses in yield may be very heavy, depending on the extent of the leaf area killed by the fungus.

Appearance — Scald is primarily a foliage disease, attacking the leaves of barley plants conspicuously and their sheaths to a lesser extent. Scald may be recognized by the appearance of oval spots, which at first are water-soaked and gray-green. These areas dry rapidly and their centers become light gray. The central areas are ringed by dark-brown margins, which are the chief distinguishing feature of the leaf spot (Color Figure 11). Later these pale central areas may collapse and fall out. The spots often fuse so that entire leaves may be destroyed by the fungus.

Disease Cycle — The fungus overwinters on infected, dead leaves and probably on other crop remains. Spores are produced abundantly during the growing season and are carried readily by wind or rain from plant to plant. A cool, humid growing season favors scald. Although barley may be attacked at any stage of its growth, the disease is usually most severe just before and during the heading stage.

Control — Elimination of crop remains helps to control scald. However, since present cultural practices on the prairies tend to make this impractical, rotation of crops gives the best control.

Bacterial Blight

Xanthomonas translucens

Bacterial blight of barley is caused by a bacterium similar to the one that causes bacterial black chaff of wheat. The main difference between them is in the kind of crop they can attack. At times there are severe local outbreaks, and occasionally considerable damage is done over a wide area.

Appearance — The first sign of an attack of bacterial blight is the development on the leaves of barley plants of pale-green areas, some of which have small, brown spots in their centers. Later, these areas appear water-soaked. They may form stripes several inches long or may assume rounded or irregular shapes. At this stage, the bacteria ooze out into droplets of rain or dew, and when dry may be seen as thin scales of exudate or as tiny amber-colored beads (Figure 11). Later the infected spots become golden yellow and, finally, they turn pale brown.

To detect the disease at its later stages of development in a field, hold up

Figure 11. — Bacterial blight of barley. Note droplets of bacterial ooze.

an affected leaf and look at it against a bright part of the sky. If the disease is bacterial blight, you will see translucent areas in it.

In severe infections whole plants may become infected and their leaves entirely destroyed.

Disease Cycle — This is a seed-borne disease, the bacteria being carried mainly in infected hulls. The blight may also be carried over winter on crop remains and on infected grasses. In wet weather plant-to-plant spread in a field is rapid, but in dry weather crop recovery may occur as new uninfected growth develops.

Control — Whenever possible, sow seed from uninfected fields. Crop rotation helps to control the disease and barley should never be sown directly after barley.

Stripe Mosaic

Barley Stripe Mosaic Virus

This disease, which used to be known as false stripe, was first described in 1926 after a severe outbreak in 1924 at Brandon, Manitoba. Although stripe mosaic has often been reported in both the United States and Canada, it was not until 1950 that its cause was discovered to be a virus. Under exceptional conditions, as, for example, following artificial inoculation, it can reduce yield by as much as 75 percent, but ordinarily the disease does not cause much damage in Western Canada.

Appearance — Seedlings grown from infected seed are chlorotic at first and later become dotted with brown spots. The chlorosis may occur in stripes occupying various proportions of leaf surfaces (Color Figure 19). Diseased plants are often stunted, but if they are only lightly affected, the stunting is not very noticeable.

Stripe mosaic is most easily recognized at heading time. Some of the infected leaves have brown stripes that resemble a V, an inverted V, or a W. Such stripes always continue across a leaf from one edge to the other and separate the healthy tip from the diseased base.

As plants approach maturity, the disease becomes increasingly difficult to recognize, but affected plants are smaller than healthy ones.

Disease Cycle — This is one of the few seed-borne virus diseases. When diseased seed is sown, most of the resulting seedlings are infected and they develop into poor plants, if they survive at all. These plants are mottled and pale green, and seldom develop V-shaped stripes. On the other hand, the spread of infection from such plants to nearby healthy plants results in the formation of V-shaped stripes in the newly infected plants.

The spread of stripe mosaic in a field appears to depend on the direct contact of a diseased and a healthy plant or else on mechanical transfer of infective juice from a diseased to a healthy plant. Such transfers may be made by various farm implements. Transmission of stripe mosaic by insects has not been established, although it seems likely that several species may transmit it.

Control — Avoid sowing seed from an infected field. Ordinary seed treatments are useless against stripe mosaic.

Yellow Dwarf

Barley Yellow Dwarf Virus

Yellow dwarf disease is caused by a virus that is carried by several species of grass- and grain-infesting aphids. It was identified for the first time on barley in California where it caused a 10 percent loss of yield in 1951. Since then it has been recognized as a disease of oats and wheat as well as of barley. It occurs not only in California but also on the Great Plains, including the Canadian prairies. No serious damage has been definitely attributed to yellow dwarf in Canada, but it is a potentially serious disease.

Appearance — The first visible evidence of yellow dwarf on barley is a golden yellow discoloration at the tips of leaves, or sometimes in blotches. The discoloration progresses downward, principally along leaf margins until the leaves are entirely yellow, or striped with green and yellow. The symptoms on oats are similar to those on barley except that the leaves discolor in various shades of red rather than yellow. Wheat infected in the seedling stage becomes chlorotic and severely dwarfed. Barley, wheat and oats can all be stunted by this disease, but the degree of stunting depends on the relative susceptibility of the variety and on the stage of growth at which infection occurs. Early infection usually causes leaf discolorations as described above and severe stunting (Color Figure 13). Infection at later stages of growth causes yellowing of the upper leaves of barley and wheat and a corresponding reddening of oats, but little stunting.

Disease Cycle — Perennial wild grasses are a reservoir of the yellow dwarf virus throughout the year. Several common species of grass-infesting aphids are capable of carrying the virus to grain crops. A severe infection is therefore dependent on factors that favor the migration of large numbers of aphids from wild grasses to grain fields in the spring when the crops are young.

Control — Early sowing often reduces damage from infection since aphids usually become numerous in midsummer or later, when early-sown cereals are past the stage of greatest susceptibility to the disease.

Aster Yellows

Aster Yellows Virus

Aster yellows is caused by a virus that is carried by a leafhopper. It was first described as a disease of asters in 1922 and has been well known for many years as a disease of flax, many vegetables, ornamentals and weeds. It was not until 1960 that it was recognized on barley and later on wheat. Barley is more susceptible than wheat, and durum wheat is more susceptible than common wheat. The disease has not been shown to infect oats or rye. No serious losses of cereals have been definitely attributed to aster yellows although about 5 percent of the barley in some fields in Manitoba has been infected.

Appearance — Early symptoms on barley are chlorosis of the youngest leaves followed by deep-yellow blotching or yellowing from the tips of older leaves. Shortly after chlorosis appears the leaves roll backward at the edges and later the yellowed leaves die back from the tips. When plants are infected early or severely, internodes are shortened and leaves form close together, giving the plants a stunted, bushy appearance. These plants may produce sterile and deformed heads (Color Figure 20), or may fail to head and die prematurely. In late or mild infections, leaf symptoms may be minimal or absent; normal heads may be produced on the early culms, with sterile and deformed heads only on late culms. Early symptoms on wheat are yellow blotches on the tips of leaves. The blotches spread down the leaves and coalesce until the leaves become pale yellow to white with scattered green areas. Plants infected at the seedling stage die quickly without heading, whereas plants infected at a later stage are stunted and produce sterile heads.

Disease Cycle — The virus overwinters in some weeds, such as stinkweed, but it seems to come mainly from leafhoppers that migrate each spring into the Canadian prairies from the United States. Infection is therefore largely dependent on the size of the migrant population and the proportion of individuals carrying the disease.

Control — There is no practical method of control. Early-sown crops tend to be less affected than late-sown crops.

DISEASES OF OATS

Stem Rust

Puccinia graminis f. sp. *avenae*

Stem rust of oats attacks cultivated oats (Color Figure 18), wild oats and meadow fescue but does not attack wheat, barley or rye. It is made up of a number of parasitically distinct strains (physiologic races) of the fungus, which vary in their distribution from year to year. Control is achieved chiefly by growing rust-resistant varieties. A general discussion of stem rust is given under "Diseases of Wheat."

Crown Rust

Puccinia coronata f. sp. *avenae*

Crown rust, sometimes called leaf rust, occurs on wild and cultivated oats and on several grasses that grow throughout most of the agricultural area of Canada. This fungus disease often causes extensive damage in Eastern Canada and in Manitoba and eastern Saskatchewan. In western Saskatchewan, Alberta and British Columbia it is rarely of any economic importance. The rust does not infect wheat, barley or rye. Timothy is the only widely cultivated grass attacked by crown rust and it is only slightly susceptible. The amount of infection by crown rust varies greatly from year to year.

Crown rust, like other cereal rusts, consists of many parasitic races differing from one another in their ability to attack various oat varieties. At least 65 races of crown rust occur in North America. A large number of oat varieties are resistant to many of these races but no known variety is resistant to all of them. Oat varieties currently used in breeding for resistance to crown rust are susceptible to only a very few of the races and these races are, as yet, scarce.

Appearance — The summer stage of this rust produces orange pustules on the leaves, sheaths and glumes of oat plants. As the plants begin to ripen the orange spore masses are replaced by spores of the winter stage which form on the underside of the leaves and look shiny and black. Each black spore has pronglike projections which form a kind of crown around its apex — hence the name crown rust.

Disease Cycle — The winter spores survive until spring or early summer when they germinate and produce very small spores which are discharged into the air. They cannot infect oats or grasses but they do infect several kinds of buckthorn (*Rhamnus* spp.) of which the common buckthorn, a large shrub originally imported from Europe, is the most widespread. The rust produced on the buckthorn cannot reinfect buckthorn but infects oats, on which it produces the summer stage of the rust.

Susceptible buckthorns are common in many areas in the Maritime Provinces, Ontario and Quebec and are frequently responsible for local outbreaks of crown rust in these provinces. In Manitoba, most buckthorn plantings are in the larger towns and do not play a significant role in the spread of crown rust. Common buckthorn is found more rarely in Saskatchewan and Alberta than in Manitoba.

The summer stage of crown rust can survive the winter in the southern United States. The first crown rust infections that appear each summer in the Prairie Provinces are caused by wind-borne spores carried north from rusted fields in the United States.

Control — As with other cereal rusts, control is best accomplished by using an oat variety recommended for its resistance.

Other measures helpful in reducing crown rust infection are early sowing, which gives oat plants a chance to ripen before infection becomes heavy, and destruction of any buckthorn bushes in the vicinity of grain fields.

Smuts

Ustilago avenae and *Ustilago kolleri*

There are two kinds of smut of oats, a loose smut and a covered smut. Since the development and control of these two fungus diseases are the same and they resemble one another even in appearance, they can be described under the same heading. Both smuts occur in all countries where oats are grown. The loose type is more prevalent in humid regions whereas the covered is more common in drier regions.

Each of the oat smuts is made up of a number of distinct races. These races can interbreed and thus produce new races.

Appearance — Infected heads emerge at the same time as heads of healthy plants. When the loose-smut fungus destroys the seed and the chaff it replaces them with a powdery mass of spores. The spores of the covered smut fungus are enclosed in vestiges of the outer chaff.

Disease Cycle — Both the covered and the loose smut of oats are carried over from season to season as seed-borne spores. The development of mycelium beneath the hulls, during the ripening and harvesting of a crop and the storage of seed, is common when sufficient moisture is available. When infested seed is planted, germ tubes originating from seed-borne spores or mycelium penetrate the very young oat seedlings. The smut fungus and host plants develop together until flower clusters (panicles) begin to form. The smut destroys the flowers in the infected clusters and replaces the seed and most of the chaff with dark-brown spores.

Control — Grow one of the several smut-resistant varieties available. If you have to sow a susceptible variety you can control oats smuts by treating the seed with a recommended disinfectant.

Bacterial Blights

Pseudomonas coronafaciens
Pseudomonas striafaciens

Two bacterial diseases of oats, halo blight and stripe blight, are fairly common, although not very destructive, in the Prairie Provinces. Both diseases attack leaves more than other parts of oats plants. However, severe infections may kill some seedlings outright, and older plants may be attacked on their sheaths and panicles as well as on their leaves. Both diseases develop most rapidly during cool, wet weather.

Appearance — Halo blight produces light-green, oval spots, the centers of which become water-soaked and darker than the margins (Figure 12). The spots thus appear to be surrounded by pale-green halos. Later the whole spot, including the halo, turns brown. A number of spots may join together to form an irregular blotch.

Stripe blight produces spots that are not surrounded by a pale-green margin and they are often elongated into stripes. In late stages, the spots are brown throughout in both diseases and it is difficult to distinguish between them except by laboratory methods.

Disease Cycle — The bacteria of both diseases are seed-borne and may live over winter on infected crop remains. The first seedling infections develop from bacteria on the surface of the seeds. From these infections the disease can spread readily from leaf to leaf and from plant to plant in cool, moist, spring weather. In the late spring the disease in some fields may look severe, but often a spell of warm, dry weather will check it and permit new growth to be comparatively free from infection. During the growing season infection takes place through water pores at the tips of the leaves, through breathing pores (stomata) distributed over the surface of the leaves, and through wounds.

Control — The most effective method of control is the use of a resistant variety. Ordinary seed treatments which merely disinfect the surface of the seeds are ineffective against these diseases.

Gray Speck

Manganese Deficiency

Gray speck is caused by a lack of soluble manganese in the soil. Manganese is a mineral element essential to the growth of oats. Even if plenty of manganese is present in the soil, it is of no use unless the crop can take it up. Some soils hold it in an insoluble form. Living plants need it to

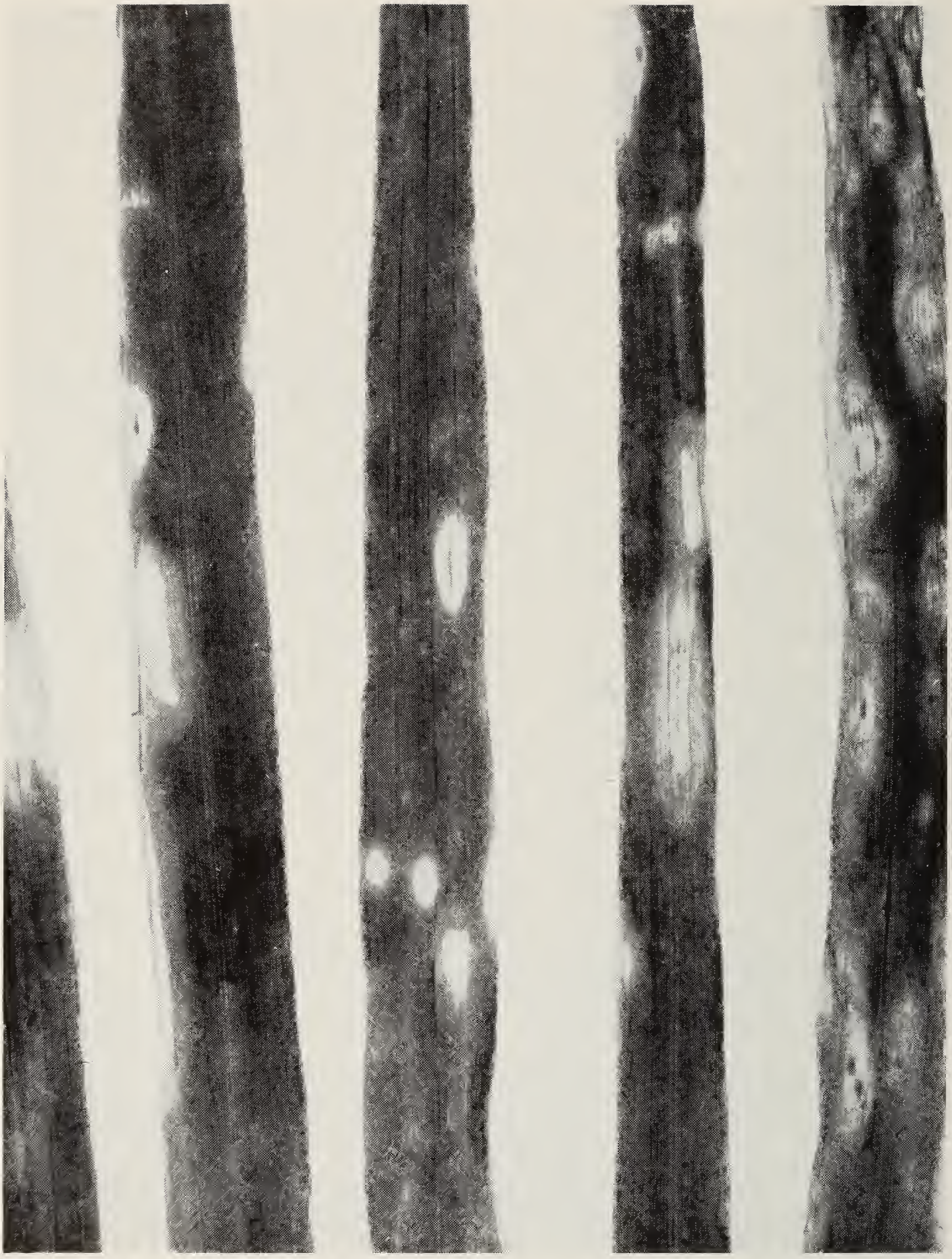


Figure 12. — Halo blight of oats.

convert nitrogen from the soil into proteins which have food value for man and animals. Gray speck affects oats chiefly, but is sometimes seen also on wheat and barley.

Because gray speck is the direct result of the scarcity of available manganese, its severity depends on the degree of the scarcity. Thus, when manganese is very scarce the disease can become so severe that a crop will

Figure 13. — Gray speck of oats.

not come into head. Furthermore, the growth that does take place will not even make good pasturage. Fortunately such conditions are rare on the prairies. Gray speck has been found in twelve districts of Manitoba and in at least one in Saskatchewan, but the acreages affected have been comparatively small. Although the damage has not been widespread, a farmer who happens to have a manganese-deficient field or farm may suffer seriously unless he learns to cope with this disease.

Appearance — An affected field may have an unthrifty, patchy or brownish appearance, which is noticeable even at a distance of several rods. The brownish appearance is attributable partly to old, affected leaves which die prematurely, and partly to numerous small dead spots distributed along leaves that are still green. At first such spots vary from light-green to gray and later from whitish to brown (Figure 13).

The first signs of disease do not usually appear until the fourth or fifth leaf has developed. A characteristic sign is a breaking-over of leaves about two-thirds of the distance from their tips. This breaking-over occurs at a point where a leaf has been killed by the disease. As the disease progresses, series of small, oval, whitish spots appear between the veins of the younger leaves. When leaf spots are few they may have little effect on the grain. Moderately heavy leaf and sheath damage may reduce the set of seed. Very severe damage may prevent heading. Under conditions of very great manganese deficiency, plants die early.

Control — Crops more tolerant to manganese deficiency should be substituted for oats on land known to be deficient in this mineral. Some benefit may be gained by applying manganese at seeding time by drilling a 65 percent solution of feed grade manganese sulphate into the soil at the rate of 100 pounds per acre. Manganese sulphate may also be applied as a 1 percent spray. Such applications are usually good for one season only, with little or no carry-over to the next crop.

Blast

A Nutritional Disorder

Appearance — Oat blast is a condition familiar to most farmers because every field of oats displays, shortly after heading, a considerable number of panicles with blasted spikelets. Instead of all the spikelets containing two kernels, there are a number of empty spikelets, usually in the lower part of the panicle, that have withered before the kernels were formed. Only partially formed, white, empty glumes are left and it is these that are responsible for the characteristic appearance of the disease (Figure 14).

Cause — To understand the cause of oat blast, it is necessary to know how the panicle of the oat plant is formed within the plant. Normally, several weeks before the panicle emerges, the plant begins to form young spikelets. Under favorable conditions these spikelets will mature. However, if growing conditions change greatly for the worse (as in a severe drought) shortly before the plants head out, they respond by sacrificing the spikelets on which they have expended the least energy. That is why blasted spikelets are usually on inner branches, near the base of the panicles where the youngest spikelets are located.

Control — There is no known way to control blast. Late-sown oats often have more blast than those sown early. Early sowing usually results in larger panicles and, even if there is considerable blast, better yields. Some varieties tend to be less susceptible to blast than others but they are not necessarily the best yielders.

Common Root Rot

Various Soil Fungi

Common root rot of oats is fairly prevalent but is not conspicuous except when it occurs as blight before a crop matures. In most respects it is similar to common root rot of wheat.

Speckled Leaf Blotch

Septoria avenae f. sp. *avenae*

Speckled leaf blotch, or black stem, is most prevalent in southern Manitoba. The disease affects leaves, stems, joints, spikelets and kernels

Figure 14. — Blast of oats. Left: blasted spikelets chiefly in lower part of panicle. Right: severe blasting in most of panicle.

and is sometimes very destructive. The brown spots on leaves are round to elliptical and may grow to ½ inch or more in length. Similar spots appear on leaf sheaths. Small, black fruiting bodies of the fungus are scattered over the spots. Grayish-brown to black lesions occur on stems, usually beneath an infected sheath. The fungus overwinters on seed and in plant debris. Varieties differ in susceptibility.

Control — In areas where the disease occurs a variety recommended for its resistance should be grown.

Yellow Dwarf

Barley Yellow Dwarf Virus

Yellow dwarf, or red leaf, is a virus disease transmitted by aphids. It causes stunting, reddening of leaves and partial blasting of florets. It also reduces straw and seed yields. See also "Diseases of Barley."

DISEASES OF RYE

Ergot

Claviceps purpurea

Ergot attacks cereals and grasses and is usually more severe on rye than on any other cereal. It reduces both grade and yield. If ergot bodies are eaten by animals they may cause abortion, loss of hooves, tails and ears and, in some instances, death.

Ergotism, caused in man by the eating of bread baked from flour contaminated with ergot, was at one time known as St. Anthony's fire. Severe epidemics of ergotism have occurred in Europe following ergoty harvests.

The medicinal uses of ergot have been recognized for at least three centuries and there is a regular, though limited, demand from drug houses for ergot of high quality.

Appearance — The first sign of ergot is the appearance of a sticky, honeydew ooze on affected heads. This usually forms about two weeks after the heads emerge. Soon characteristically dark-colored ergot bodies develop and replace some seeds (Figure 15). The shape and size of the ergot bodies are modified by the kind of plant on which they develop.

Disease Cycle — Ergot bodies fall from ripened heads to the ground, where they mature during the winter. In the spring, short stalks grow from these bodies (Figure 2) and produce spores at about the time susceptible grains and grasses are in the heading stage. These wind-borne spores germinate in the flowers of diseased plants and initiate the honeydew stage with its numerous smaller-sized spores which, in turn, may be spread to other plants.

Control — The most effective control measure is to cut the grasses along the borders of grain fields as soon as the grasses head out.

Rye should not be followed in a rotation by rye, wheat or barley. Oats, which seldom develop the disease, may be used to advantage in a rotation.

Figure 15. — Ergot in rye; healthy head in center.

Use clean seed. Do not allow combine screenings containing ergot bodies to fall on the ground.

In fields contaminated with ergot bodies the soil should be worked so as to bury them to a depth of at least 2 inches.

Bacterial Blight

Xanthomonas translucens

Bacterial blight is one of the more common diseases of fall rye in the Prairie Provinces. Infections that were so severe that they destroyed 60 percent of the leaf area of a crop have been observed.

Appearance — This disease looks like bacterial blight of wheat but its exudate is not visible so often.

Disease Cycle — Overwintering is similar to that of bacterial blight of wheat.

Control — Whenever possible, sow seed from uninfected fields. Crop rotation is helpful, but rye should not follow wheat. Prevent the spread of the disease from infected grass next to a field, for example, by burning the grass at the time of fall sowing.

Leaf Rust

Puccinia recondita

Leaf rust of rye, sometimes called brown rust of rye, is not very destructive in Western Canada, chiefly because winter rye, which is widely grown, matures before the rust has had time to produce much infection. However, since the rust fungus attacks both the leaves and the sheaths of rye plants, it can, under conditions favorable to infection, cause considerable damage, especially to spring rye.

Appearance — The summer stage of the fungus consists of elongated reddish-brown pustules on leaves and sheaths. These pustules contain powdery masses of summer spores which continue to produce new infections as long as rye plants remain green. As the plants ripen, spores of the black, or winter, stage are produced in the pustules which gradually change to a dark-gray color.

Life Cycle — The black spores may germinate in the fall, or they may survive the winter and germinate in the spring to produce very small, colorless spores that cannot infect rye but can infect an annual herb known as bugloss (*Lycopsis arvensis*). However, this plant is rare in North America and is not often found infected. It is, therefore, scarcely a factor in perpetuating the rust, which appears to survive from year to year by the overwintering of the summer stage. It is not certain that overwintering occurs in the Prairie Provinces but it doubtless does occur in more southerly areas from which wind-borne spores are carried north in early summer.

Control — Because of the small economic importance of rust, no attempt has been made to produce rust-resistant varieties of rye. In any case, such an undertaking would be more difficult than it has been with other cereals because rye cross-pollinates so readily. Winter rye usually escapes damage because it matures early. Early sowing generally enables spring rye to ripen before much infection takes place.

Stem Rust

Puccinia graminis f. sp. *secalis*

Stem rust of rye attacks not only rye but also barley, wild barley and couch grass. This rust fungus is not very destructive in the Prairie Provinces, chiefly, perhaps, because much of the rye grown there is winter rye which usually ripens early enough to escape infection. Spring rye, which ripens later, is more frequently infected, but not usually severely enough to suffer much damage. For a general discussion of stem rust, see "Diseases of Wheat."

DISEASES OF CORN

Rust

Puccinia sorghi

Corn rust does little damage in the Prairie Provinces. It occurs every year, however, and it could cause greater damage, especially if the corn acreage were increased. The rust attacks corn leaves and is usually most noticeable in August.

Appearance — The summer stage of the fungus appears as oblong, reddish-brown pustules bordered by the broken edges of leaf surfaces. These pustules contain the red, summer spores which are spread by wind and cause new infections as long as the corn leaves remain green. As plants ripen, dark-brown, thick-walled winter spores are produced in these same pustules, which then look black.

Disease Cycle — The winter spores survive the winter and, in the spring, produce a crop of small, colorless spores which are discharged into the air. These do not infect corn but can infect several different kinds of wood sorrel (*Oxalis* spp.) on which they produce rust. Later the rust can spread to corn and there reestablish the summer stage. However, wood sorrel is seldom infected in Western Canada. Corn rust reappears each year mainly because summer spores are carried north by air currents from the southern United States where they overwinter.

Control — Little attention has been given to control measures because corn rust has not been destructive. Infection can be reduced by planting early to achieve maximum development of a crop before the arrival of wind-borne spores.

Smut

Ustilago maydis

Smut is probably the most widely distributed disease of field and garden corn. In districts where warm and moderately dry weather prevails, it is very destructive to susceptible varieties. The loss in yield resulting from smut varies with the time plants become infected and with the size, number and location of their galls.

Corn smut differs from other cereal smuts in causing local rather than

Figure 16. — Corn smut.

systemic infections. It may attack any aboveground part of a plant that is actively growing, including stems, leaves, tassels, ears and even brace roots. The spores of this smut are very resistant to freezing and drying and have a variable period of dormancy. They can therefore remain viable in soil or crop remains for several years. The ability of the spores to produce large numbers of sporidia, which are adapted to distribution by wind, further increases the chance of infection.

Corn smut is not only very hardy but extremely variable. As a result, new races or strains develop frequently and it is difficult to produce varieties of corn that are completely resistant to smut. Nevertheless, many of the more recent hybrid corn varieties are at least highly tolerant to the disease.

Appearance — The mycelium of corn smut stimulates excessive development of infected plant tissues, causing the formation of an overgrowth, or gall (Figure 16). Young galls consist of plant tissues permeated by smut mycelium. Later, most of the plant cells in the infected parts die and the mycelium is transformed into spores. The galls are covered by grayish membranes that eventually rupture and release a powdery mass of olive-brown spores.

Disease Cycle — Smut spores on the surface of the soil or on crop remains germinate early in the summer, each producing four smaller spores known as sporidia. Under favorable conditions many sets of four sporidia may be produced by each overwintered spore. Both spores and sporidia are carried about by air currents and when they fall on any part of growing corn plants they can start infections. This process can continue throughout the summer whenever the weather is favorable. Later in the season, when smut galls mature, the spores from the galls are also blown about by wind, thus increasing the number of spores in the air and giving rise to new infections.

Control — In areas where only small plots of corn are grown, destruction of smut galls before the spores mature helps to control the disease. Where corn is grown on large acreages, resistant or tolerant varieties offer the only satisfactory means of control.

DISEASES OF FLAX

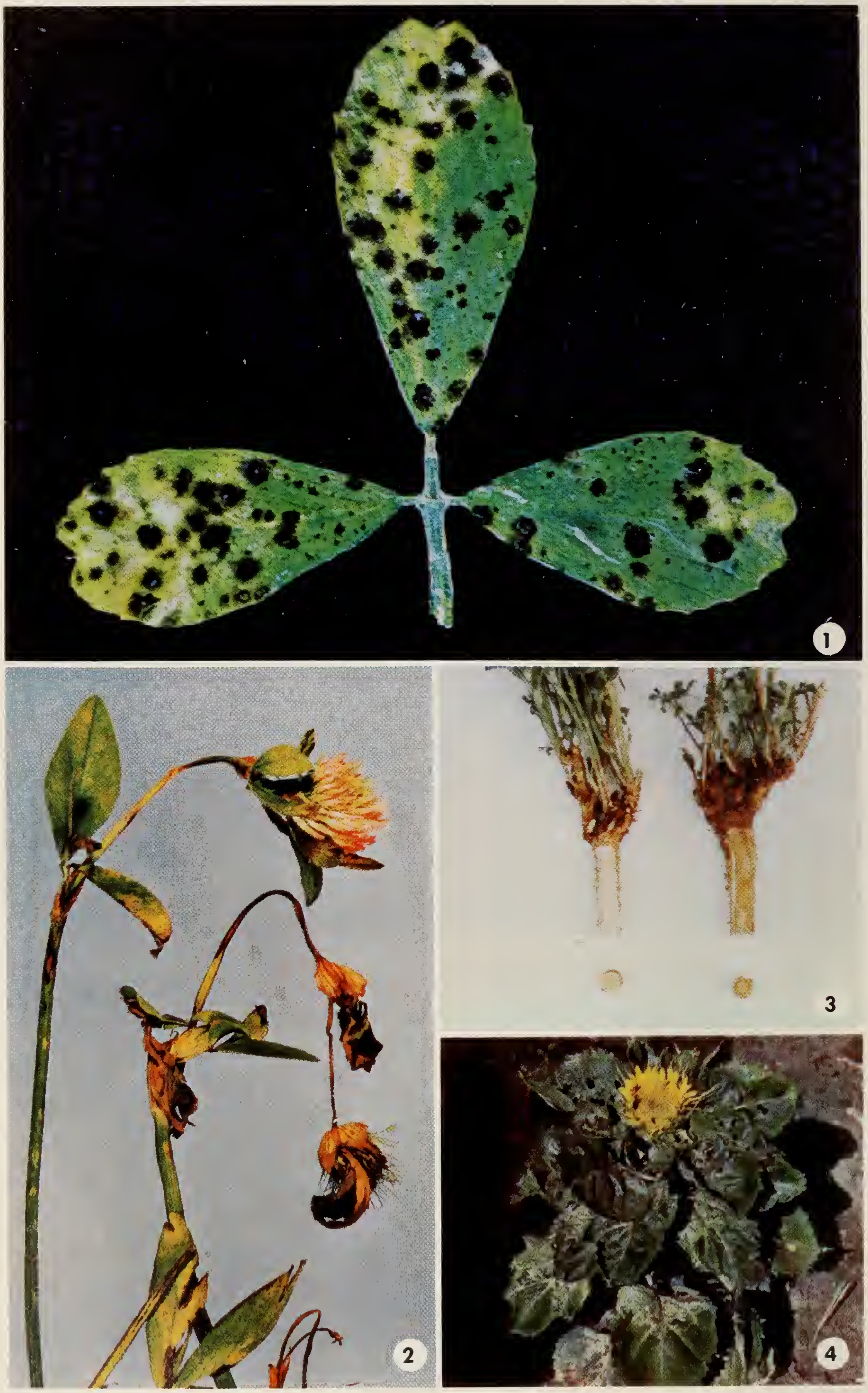
Rust

Melampsora lini

Rust is a fungus disease that attacks all the aboveground parts of flax plants. It is found throughout the world and occurs in Canada wherever flax is cultivated. When moisture conditions and temperature are favorable, rust may completely defoliate flax plants and cause extensive stem infections. As a result, the yield and quality of the seed and fiber are greatly reduced.

Appearance — The first infections, which usually appear in June, are inconspicuous pustules containing round, yellow masses of spores on the under side of seedling leaves. Later, similar but larger orange spore masses appear on leaves and stems. As plants approach maturity the pustules darken because black or winter spores develop inside them. The black stage rarely occurs on leaves, but may develop profusely on stems and pedicels, and even on bolls. Pustules of the black stage often girdle the stems, and may reach a length of several inches.

Disease Cycle — The black spores survive the winter and germinate in the spring to produce very small, colorless spores which are discharged into the air. These small spores infect the seedling leaves of flax and produce pustules of the yellow stage. Spores produced in these pustules cause further infections, in which the orange, or summer, spores are produced. The summer spores are the ones which spread the rust from plant to plant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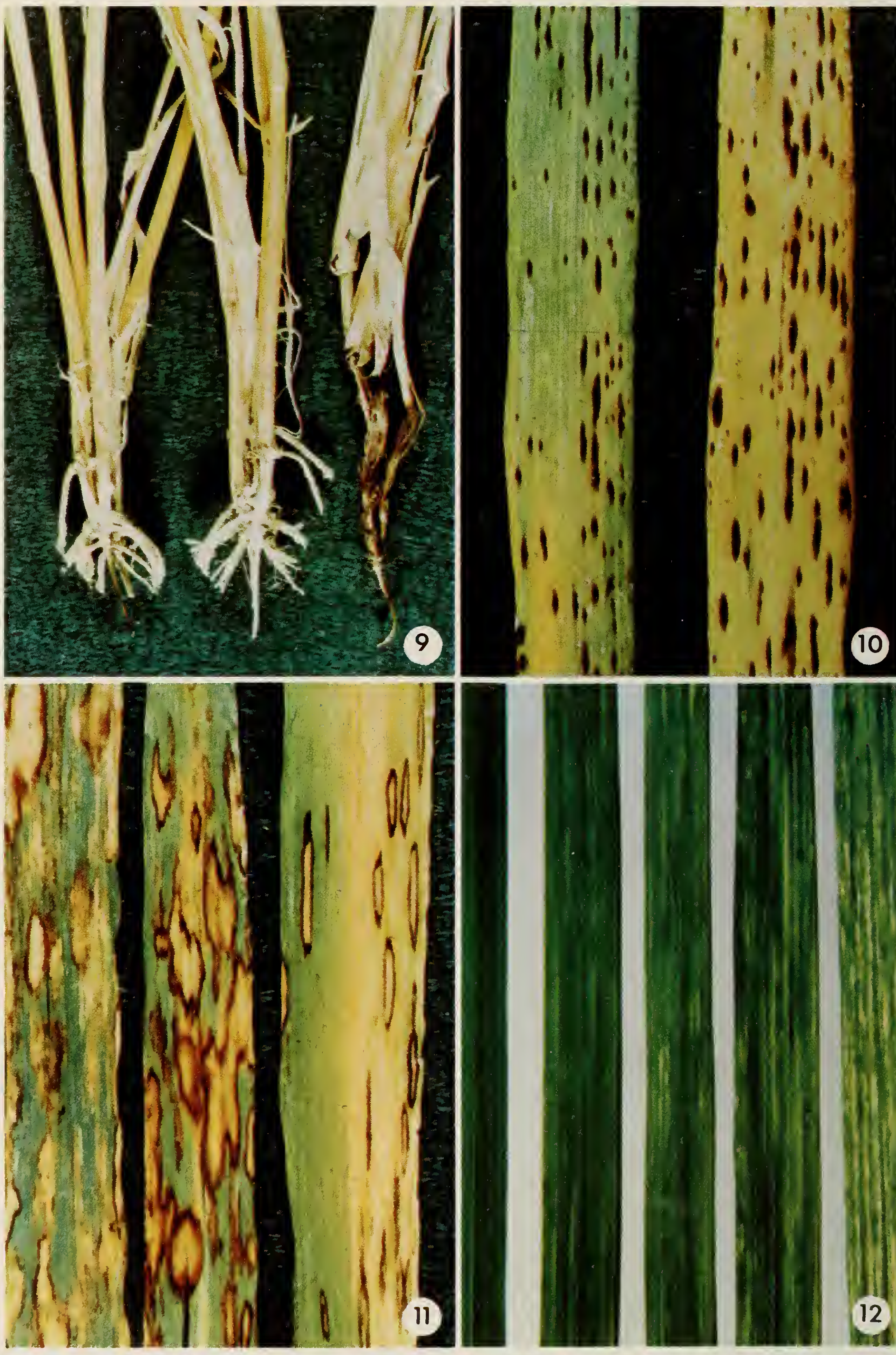
Left

(1) Common leaf spot of alfalfa. (2) Northern anthracnose of red clover. (3) Bacterial wilt of alfalfa; healthy plant on left. (4) Downy mildew of sunflower.

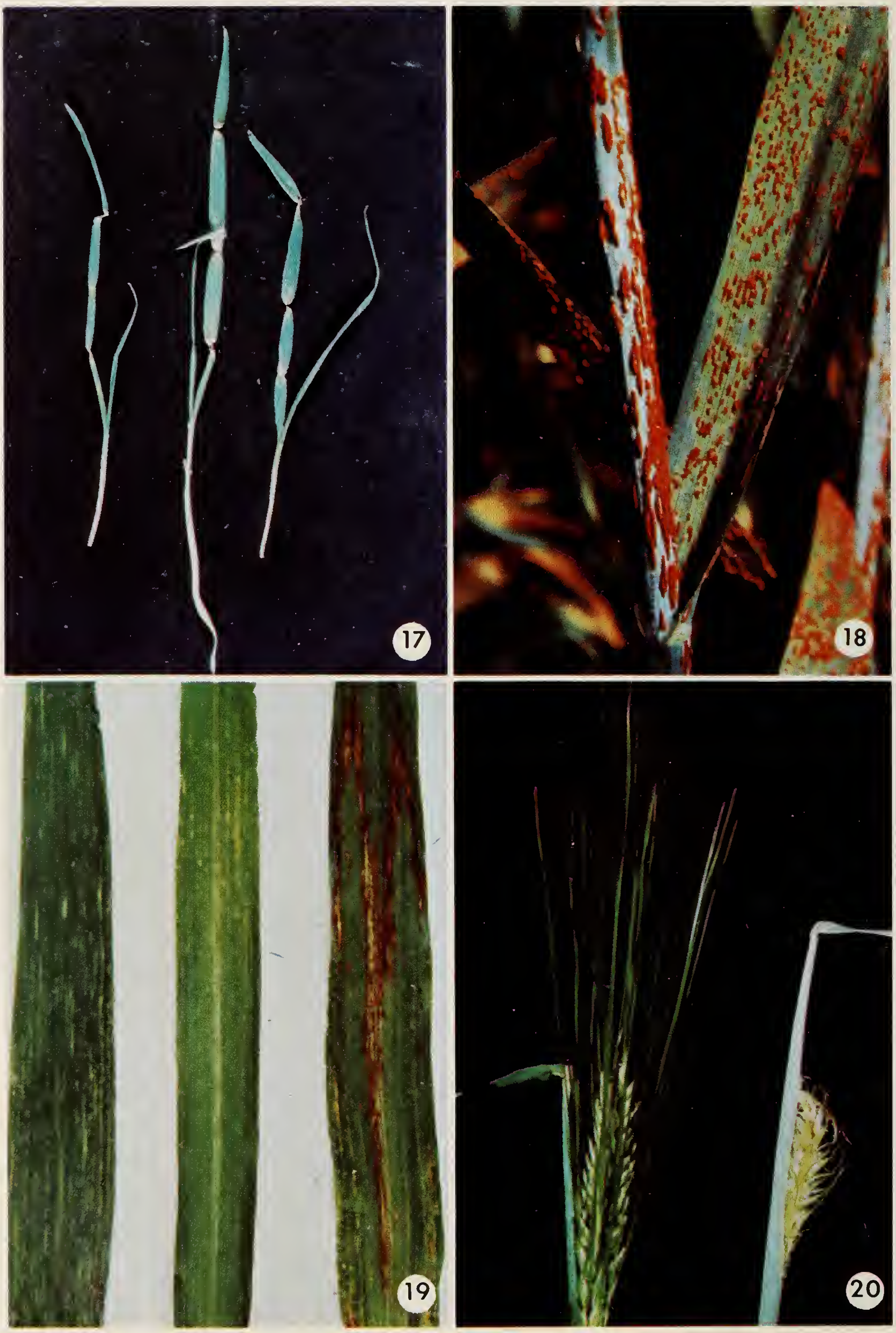
Above

(5) Bacterial black chaff of wheat. (6) Net blotch of barley. (7) Speckled leaf blotch of barley. (8) Early stage of speckled leaf blotch of wheat.



(9) Common root rot of wheat; healthy plant (center), moderate external and internal discolorations (left), severe disease with crown roots suppressed (right). Similar symptoms appear on barley and oats. (10) Spot blotch of wheat. Identical symptoms appear on barley. (11) Scald of barley. (12) Wheat streak mosaic.

(13) Barley yellow dwarf. (14) Selenophoma leaf spot of bromegrass. The black fruiting bodies of this fungus are similar to those of the fungi causing septoria diseases of cereals. (15) Verticillium wilt, or leaf mottle, of sunflowers. (16) Powdery mildew of red clover. The white powdery masses of fungus growth are characteristic of powdery mildew on cereals and other hosts.



(17) Heat banding of wheat. The symptoms of frost banding are similar. (18) Stem rust of oats. (19) Stripe mosaic of barley. (20) Aster yellows of barley; infected head (right) has twisted awns and is sterile.

and field to field throughout the growing season. The life cycle of the rust is completed by the formation of the black, winter spores on maturing plants. Flax rust goes through all its stages on the flax plant. It differs from cereal rusts, whose overwintered black spores can attack some other kind of plant but cannot infect the kind of plant on which they were produced. Flax rust goes through a sexual stage in the first infections produced on young flax plants early in the season. Since flax rust, like other rusts, consists of many different races, this sexual stage makes it possible for different races to cross and to produce new and perhaps more dangerous races.

Control — The most satisfactory means of control is the culture of rust-resistant varieties. Because rust overwinters on flax refuse, the disease can build up locally if flax is sown in the same field or in nearby fields year after year. Destroying the plant remains from a rusted crop, sowing flax in widely separated fields, and rotating flax with other crops, all help to reduce or prevent flax rust. The black spores may be spread on bits of rusted straw mixed with seed. Most of this rust is buried in seeding, but occasionally these spores can infect young seedlings. This source of infection may be serious because it can spread dangerous races from one place to another. It is therefore important to clean carefully any flax to be used for seeding and to treat all flax seed with a recommended seed disinfectant.

Pasmo

Septoria linicola

Pasmo is a fungus disease that attacks all the aboveground parts of flax plants. It has long been known in Manitoba and Saskatchewan but has been found only recently in Alberta. Early infection by pasmo can reduce the yield and quality of flax very markedly. Most of the loss is caused because infected plants ripen too fast and seeds do not fill normally. Later infections cause less damage, and if pasmo does not attack the plants until the seeds are almost ripe, it may do very little harm. However, if such infected flax is left to be straight-combined after other crops are harvested, heavy losses may result because of breaking-off of diseased bolls by wind and rain.

Appearance — Early in the growing season, pasmo shows up as brown spots on the leaves of infected flax plants. As the infection develops, the diseased leaves die and usually drop to the ground, although they may stick tightly to the stems. Later in the season, as the flax begins to ripen, small brown spots appear on infected stems. These spots enlarge and join together to form brown bands that encircle the stems (Figure 17). The brown bands formed in this way alternate with uninfected green bands to produce the mottled appearance which is typical of pasmo and makes it easy to recognize before harvest time. Severely infected plants turn completely brown and die. Flax flowers and young bolls are blighted if attacked by pasmo; older bolls may be discolored and the seeds inside them may be shriveled or killed by the disease. The slender stems that support the bolls are

Figure 17. — Pasmo of flax.

weakened by pasmo infection, so that ripe bolls may be broken from the plants by strong winds or heavy rains.

Disease Cycle — The pasmo fungus survives the winter as small, black, fruiting bodies (barely visible to the naked eye) on the stubble from diseased crops. The fruiting bodies may also occur on seed, particularly on light and shrunken seed from diseased crops, on chaff, and on small bits of stem mixed with seed. When this seed is sown, some of the first leaves may be infected. More commonly, however, infections start from diseased stubble from a preceding crop. Large numbers of spores ooze out of the fruiting bodies and are spread by wind and rain. The infections spread in a field to form small patches which turn brown. When temperatures are fairly high and there is sufficient moisture, the disease may spread very rapidly. The patches enlarge until a whole field may be affected, causing it to turn brown or ripen prematurely.

Control — As the fungus may be carried on or with seed, it is important to use the best seed available, to clean flax seed very thoroughly, and to treat it with a recommended seed disinfectant. To escape early infection sow flax as early as possible after danger of severe frost is past. Flax crops should be spaced several years apart in a rotation to help control pasmo and other diseases that live over on the stubble. When flax follows flax on the same land, losses from disease may be severe.

Canker

Nonparasitic

Cankers at the base of flax stems often occur after several days of excessively high temperatures or frost in late June or July. Heat cankers are caused by the soil around the stems of young flax plants becoming hot enough to injure or kill outer tissues which are important in the movement of food in the plant. In Western Canada damage is usually confined to small patches or to a small percentage of the plants scattered throughout a field, but losses up to 50 percent have occurred. Damage is usually most severe in thin stands on light soils.

Frost cankers are identical to heat cankers in appearance but are caused by freezing temperatures at the soil line. Cold air tends to settle in low areas in a field and temperatures there may be several degrees lower than the recorded air temperatures. In these depressions some plants may be killed by frost while only the outer stem tissues of others will be affected.

Appearance — Plants affected by heat or frost canker are constricted or girdled at or near the soil line. The belowground portion of the stem is usually thin and dry, while the area above the girdling is enlarged as a result of the accumulation of food from the leaves. The enlarged portion is often rough and cracked, or cankered. Affected plants usually fall over. Young plants killed by the stem injury may dry up and not be noticed. Plants that survive the injury, only to topple over later in the season, gradually turn yellow and die.

Control — There is no control for frost canker but some practices tend to reduce the incidence of heat canker. Early seeding helps flax plants to pass through the most susceptible stage before the weather gets hot. The only other control measure is to protect the base of young plants from direct

Figure 18. — Wilt of flax.

exposure to the sun and consequent overheating and injury. This may be done by seed treatment to ensure a good uniform stand, by heavy seeding, and by sowing north and south so that the plants shade each other from the sun during the hottest part of the day.

Seedling Blight and Root Rot

Rhizoctonia solani, Pythium spp. and *Fusarium* spp.

Seedling blight of flax is common in flax fields throughout Western Canada in June. It may be caused by several different soil-borne fungi, the most important of which, *Rhizoctonia*, is particularly destructive in moist, warm soil following summerfallow. In most years damage is relatively light, usually not exceeding 1 percent. In some years, however, losses may be heavy. Occasionally fields are almost completely destroyed.

Root rot of older plants is rarely as conspicuous as seedling blight.

Diseased plants may produce less seed than healthy plants, or may die before the seed is ripe. Root rot is caused by some of the same fungi which cause seedling blight.

Appearance — Plants affected by seedling blight may occur singly or in patches. The patches may involve only a few plants in a row, or may be many yards in diameter. Affected seedlings turn yellow, wilt and die. If they are killed early in the season, they may be beaten into the ground by rain and disappear. The roots of recently attacked plants show reddish to brown areas, but shrivel and turn uniformly dark within a few days. Diseased seedlings are difficult to distinguish from those killed by the flax-wilt fungus.

Root-rot symptoms usually appear on plants after the flowering stage. The plants turn brown prematurely and usually set few or no seeds. The underground portion of the stem, and the roots, are discolored and may be stunted.

Control — No control methods can be depended upon to prevent seedling blight completely, but certain measures can be used to reduce losses. Good seed, as free as possible from cracks, should be used. Early seeding helps young plants get past the most susceptible stage before conditions are favorable for rapid attack by blight organisms. *Rhizoctonia*, the most common cause of seedling blight, is most destructive on loose, well-worked soil. Sowing flax on second-crop land rather than summerfallow, and packing behind the seeder, help to provide a firm seedbed and to reduce seedling blight. Seed treatment with a recommended chemical helps to produce vigorous, fast-growing seedlings that escape infection.

The conditions favoring flax root rot are not well known. As some of the fungi that cause the disease tend to increase when flax is grown repeatedly on the same land, crop rotation should be practiced, even though it cannot be depended upon to give complete control of the disease.

Wilt

Fusarium oxysporum f. sp. *lini*

Flax wilt is caused by a soil-borne fungus which invades plants through their roots. The fungus builds up and the disease becomes progressively more severe in land cropped repeatedly to flax, causing what was formerly known as "flax-sick soil." Before the cause of the disease was discovered in 1900, flax was considered safe to grow only on newly broken land, because yields were often greatly reduced, or crops entirely lost, when flax was grown repeatedly on the same land. Knowledge of the cause of the disease and development of wilt-resistant varieties have since made it possible to include flax in regular cropping programs even in long-established agricultural areas.

Appearance — The wilt fungus may cause a blighting of seedlings before they emerge from the soil, or the death of young plants, as well as the characteristic wilting of plants right up to maturity. Blighting of seedlings may cause gaps in a stand. Later attacks cause yellowing and wilting of leaves, followed by wilting, browning and death of stems (Figure 18).

The tops of wilted plants often curve downward in the shape of a shepherd's crook. Wilted and dead plants may be scattered through the field, but more commonly they occur in patches. Frequently plants are only partly wilted, with a brown stripe extending from the soil line up along one side of the stem, while the leaves on the rest of the stem are quite healthy.

Disease Cycle — Once established in the soil, the wilt fungus may remain for many years. When susceptible flax is grown in infested soil, the roots are invaded and wilting results. Infection may occur in cool soil, but the disease usually develops best in warm weather. If susceptible flax is grown in the same soil for a number of years, there may be only traces of wilt in the first year, but in two to three years almost all the plants may be attacked. The mycelium and spores of the fungus survive most readily in the remains of diseased flax plants, but the fungus also seems able to maintain itself in the soil for a number of years even in the absence of flax. The fungus may be spread from field to field by wind-blown soil, or by run-off or irrigation water. It may also be spread as spores on the seed from a diseased crop. This is not a usual source of infection, but it may serve to introduce the fungus into soil previously free of wilt, or it may bring in new and possibly dangerous races of the fungus.

Control — The most effective way to control flax wilt is to sow only resistant varieties. Most popular varieties now grown are resistant to wilt. No variety is immune to wilt under all conditions, however, and as there are many races of the wilt fungus, which differ in their ability to attack various kinds of flax, there is no assurance that a variety that is wilt-resistant when it is first released will remain resistant, or that it will be resistant when grown in areas where it has not previously been tested. Crop rotation is important because it prevents an increase of the wilt fungus in the soil. Seed treatment with recommended chemicals reduces the chances of introducing seed-borne spores of the wilt fungus.

Stem Break and Browning

Polyspora lini

Stem break and browning are two forms of a disease, caused by a seed-borne fungus, that occurs in the park belt of Saskatchewan and Alberta and is responsible for appreciable damage in some years. The disease has been found in Manitoba but is neither common nor destructive there.

Appearance — The earliest symptoms are water-soaked spots, which develop very slowly on the first leaves. Plants are rarely killed in the seedling stage. The fungus spreads from the leaves to the first node of the stem and develops there. When plants are in bud or flower, they may break over at the weakened first node (Figure 19). They may live after falling over, but even if seed is set it is usually lost in harvesting. Infections on the upper part of the stem appear as oval or elongate brown spots, about ¼ inch long. The spots, which usually remain separate, are often surrounded by a narrow, purplish margin. Sometimes the spots are numerous

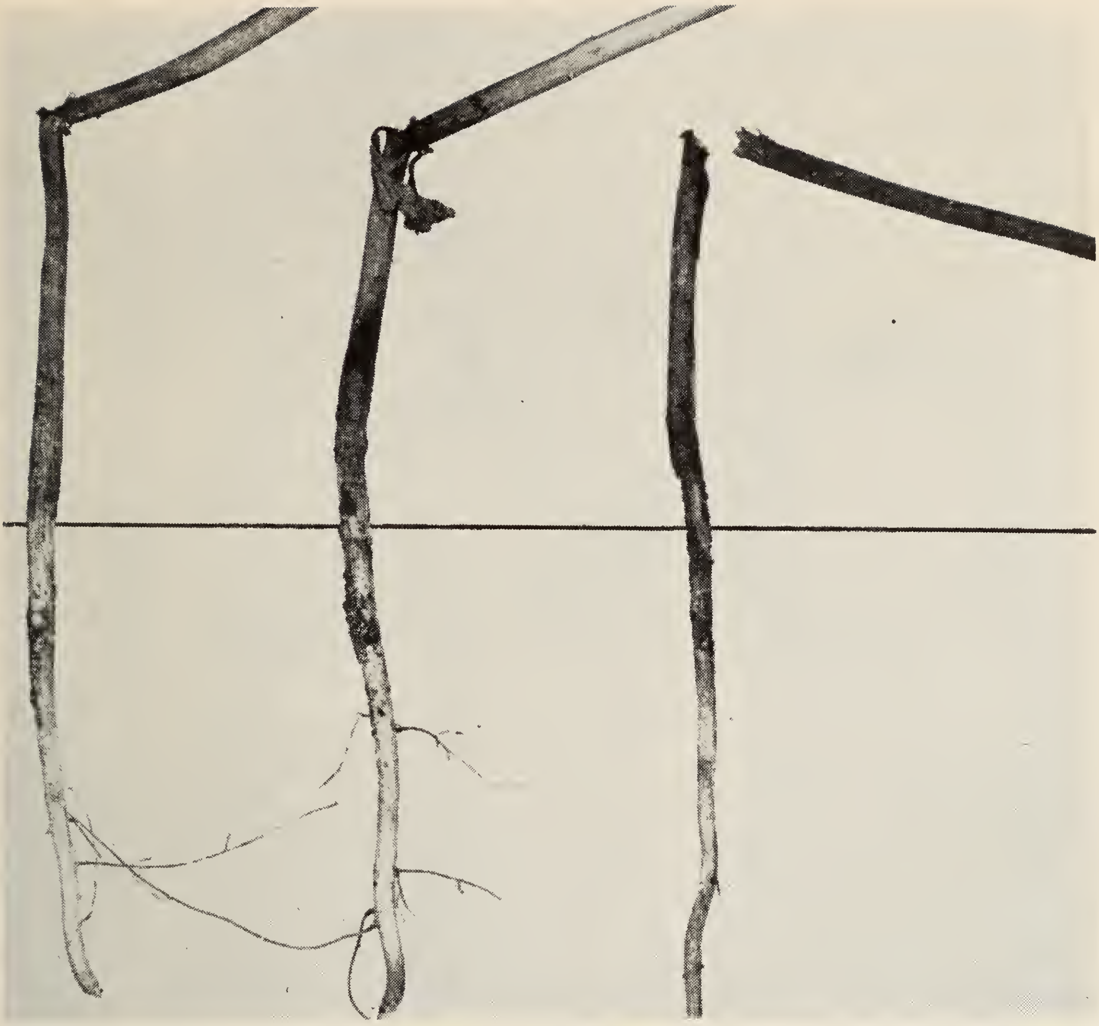


Figure 19 — Stem break of flax. The horizontal line represents the soil surface. (Photo by courtesy of Prof. T. C. Vanterpool)

enough to grow together and cover much of the stem. Patches of heavily infected plants appear brown, giving the disease the name "browning." The fungus may attack the bolls and penetrate the seeds. If the seeds are infected while they are young, they may be killed. If they are attacked when they are relatively mature, the fungus grows into the seed coat and survives there.

Disease Cycle — When diseased seed is sown and germinates, the seed coats are carried above the soil by the seed leaves, and spores from the seed coats start infections in the new crop. The fungus can also survive the winter on diseased stubble and produce spores, which may be spread by wind and rain.

Control — Chemical seed treatment may kill the spores on the surface of the seeds, but it is not usually effective against the mycelium within the seed coat. As the disease is largely seed-borne, it is important not to use seed from a crop showing stem break or browning. Crop rotation reduces infection derived from diseased stubble. Early seeding reduces injury by

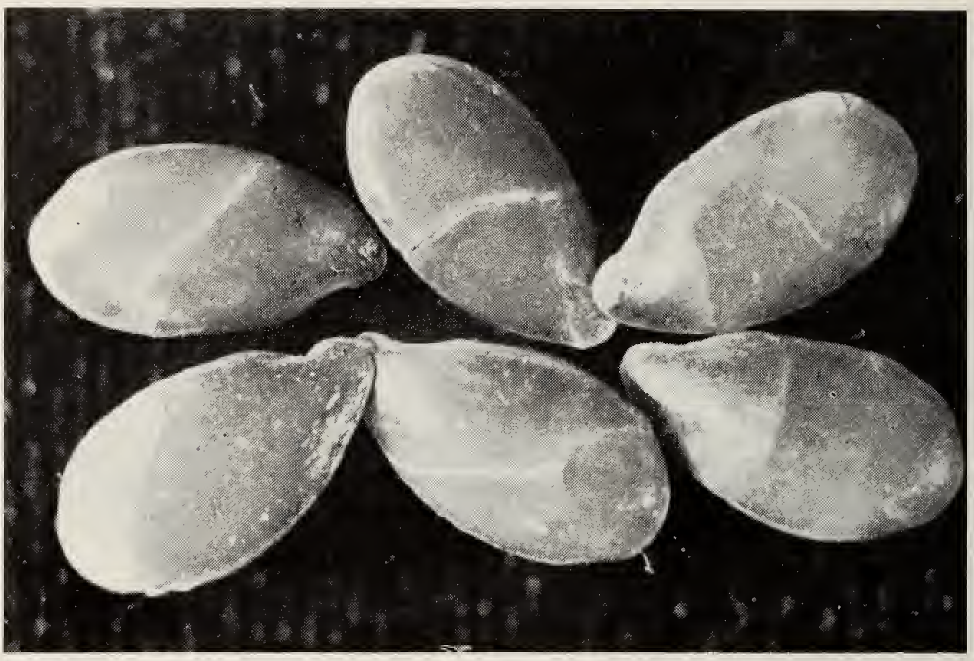


Figure 20. — Cracks in the seed coat of flax.

helping a flax crop to develop rapidly and to ripen before the disease becomes severe. There are differences in the reaction of flax varieties to stem break and browning, but the disease is not sufficiently important in Western Canada to require the growing of resistant varieties.

Seed Rot

Seed Cracking

The principal cause of seed rot in flax is the fracturing of seed by faulty threshing. A survey carried on for several years has shown that, on an average, over 50 percent of the flax seed produced in Western Canada is fractured. Large seeded varieties of flax seem to be more susceptible than small-seeded ones. Seed rot due to seed-fracture is now the chief reason for the recommendation that all the flax in Canada be treated with a protective fungicide before it is sown.

Appearance — Large breaks in the seed coat of flax can be seen without difficulty, but the much more common hairline cracks are almost invisible unless seeds are examined through a fairly powerful magnifying glass. Since the cracks are most abundant when flax is threshed during very dry weather, bright samples of seed are more likely to show injury than dull ones. The fractures are of different lengths, running inward from the edges of the seeds, sometimes completely across them. Figure 20 shows seeds soaked in a caustic soda solution to make the cracks more visible. Although very narrow, the cracks are generally deep, and they penetrate the dormant seed leaves within the seeds as well as the seed coat.

When fractured seed is sown it is attacked by a wide variety of soil microorganisms that enter the cracks and grow into the seed embryos. If

Figure 21. — Distorted floral parts of flax infected with aster yellows virus.

the fractures are many and conditions for germination are unfavorable, then the seed does not even begin to germinate but rots quickly. When conditions are favorable, fractured seeds may germinate but produce only weak seedlings with small, brown spots on the seed leaves. These spots are areas invaded by soil organisms. There is less seed-rotting in sandy soil than in clay soil. Soil temperature has relatively little effect on this disease.

Control — The best way to prevent seed rot is to treat flax seed with a protective seed disinfectant. The rate of application must be double or treble that used for seed of cereal crops.

Aster Yellows

Aster Yellows Virus

Aster yellows of flax causes severe losses in years when the disease is epidemic. Its prevalence depends on the number and time of arrival of leafhoppers and the percentage of these insects carrying the virus.

Appearance — The symptoms of aster yellows infection on flax are very conspicuous during and after flowering. Diseased plants are generally stunted and yellow, and flower parts are distorted. Petals remain greenish and leaflike and no seed is set (Figure 21). Symptoms appear only on the lateral branches of plants infected late in the season.

Disease Cycle and Control — See "Aster Yellows" under "Diseases of Barley."

Figure 22. — Boll blight of flax.

Chlorosis

Nonparasitic

A yellowing, or chlorosis, of young flax plants is common in many areas of Manitoba and Saskatchewan. Sometimes this condition is due to lack of aeration in water-logged soil. The lack of aeration results in a temporary nitrogen deficiency in the soil. When chlorosis occurs in the higher parts of fields, as well as in low, wet spots, it may be a sign of iron deficiency. This deficiency is induced by an excess of lime in the soil, which makes the iron unavailable to the plants. There are no practical control measures.

Boll Blight

Nonparasitic

The buds, flowers and young bolls of flax plants often fail to develop, particularly when warm, dry weather follows a cool, moist spell (Figure 22). Blighting of 30 percent or more of the bolls commonly occurs. The cause of the trouble is not definitely known, but blighting seems to be a response of plants whereby they sacrifice some bolls, formed early during favorable conditions, which cannot be brought to maturity because of drought, disease or other factors.

Top Dieback

Nonparasitic

The upper portions of flax plants may turn brown after a hot spell during the ripening period. Usually the discoloration involves the upper third of the stem, but sometimes whole plants may turn brown. The seeds of affected plants are usually thin and light. Discolored plants often occur in patches, but sometimes most of the plants in a field are affected.

DISEASES OF SUNFLOWERS

Rust

Puccinia helianthi

Sunflower rust is a fungus disease that affects the leaves and sometimes the stems and lower surface of the heads. The rust occurs wherever sunflowers are grown. It has been known in Manitoba, the main sunflower-growing region in North America, for more than 40 years, but did not cause serious losses until sunflower production became intensive over a fairly large area. Damage caused by the rust depends on the stage at which a crop is attacked. Early infection of susceptible varieties may reduce yields of seed by 25 to 50 percent. Late infections usually cause appreciably less damage.

Appearance — The first rust infections usually occur in mid-June on volunteer seedlings as small clusters of pale-yellow or orange spots on the upper surface of the first leaves. These are followed by yellow or orange

Figure 23. — Sunflower rust.

spots on the lower surface of the leaves. The most conspicuous stage of the rust usually begins to develop in July and August as dark-brown, small, dusty spots on both surfaces of the leaves (Figure 23). In bad rust years, almost the whole surface of the leaves may be rusted. The lower leaves usually show more rust than the upper leaves, as the infection commonly starts there. Heavily rusted leaves dry up and die prematurely, sometimes before the seeds have filled. As the plants ripen, the rust spots on the leaves turn darker brown. Spots on the stems turn black.

Disease Cycle — The sunflower rust fungus attacks only cultivated and wild sunflowers; it does not have an alternate host like the cereal rusts. The dark-brown or black spores, which are produced late in the season, overwinter on dead leaves and stems. In the spring, these overwintered spores germinate and produce spores, which infect volunteer sunflower seedlings, or young plants of the new crop in nearby fields. The first and second spore stages produced on young leaves are inconspicuous. As the brown summer-spore stage develops and spreads, it causes infections on other plants in the same field and in nearby fields. In warm, moist weather, new spores may be produced seven to ten days after infection takes place. The spores are carried by the wind, but as sunflowers are grown on a small area compared with the acreage sown to wheat, the number of spores in the air is relatively small, and long-distance spread by wind does not seem to be important. As a crop ripens, the summer spores are replaced by the overwintering spores, which are produced in the same rust spots.

Control — Because rust infection of sunflowers is usually of local origin, the disease may be controlled to a large extent by crop rotation, by destroying volunteer seedlings and the overwintered remains of the previous crop before the new crop has emerged, and by locating sunflower fields as far as possible from the fields where the crop was grown the preceding year. Rust-resistant varieties are available.

Leaf Mottle

Verticillium albo-atrum

Leaf mottle, or verticillium wilt, is the most destructive disease of sunflowers in Manitoba. Annual losses in the sunflower growing area are appreciable and in some fields where the disease is prevalent yield reductions of 50 percent have occurred. Leaf mottle is caused by a soil-borne fungus that increases in soil in which sunflowers or other susceptible crops are grown frequently.

Appearance — The symptoms of leaf mottle may appear about six weeks after planting but they become most obvious near flowering time. Affected plants occur singly, in groups, or in large areas. The disease appears first on the lower leaves and develops gradually on leaves higher along the stems. The tissue between the veins of affected leaves becomes pale green, then yellow, and finally dies and turns brown, giving the leaves a blotchy or mottled appearance (Color Figure 15). Black patches occur on the stems, particularly near the base. When cross sections of the lower stems are cut, a brown to black discoloration of the water-conducting vessels near the outer edge is evident. Severely diseased plants are stunted and may ripen prematurely or die before flowering is completed.

Disease Cycle — The fungus lives in the soil and overwinters by means of black resting bodies, or microsclerotia. It invades the young roots of a plant in the spring and produces spores, which move up the water-conducting vessels and into the leaves as the plant grows. Eventually the pathogen is present in all parts of the plant. It may invade developing seeds and thus become seed-borne. When the plant dies, the fungus produces the

Figure 24. — Sclerotinia wilt of sunflower.

black microsclerotia which are returned to the soil along with the plant refuse. The fungus will remain viable in soil for 10 or more years.

Control — Sunflowers should not be grown more than once every five years on the same land even though leaf mottle has never been a problem. This will retard the buildup of the fungus in the soil. Fields where a sunflower crop has been severely damaged by leaf mottle should not be sown to this crop again for at least 10 years. Although the fungus persists for many years in infested soil, it will gradually decrease in prevalence over this period if susceptible hosts are not available. Cereals, corn and flax are not susceptible and may be used in rotation. Sunflower varieties recommended for their resistance to leaf mottle should be grown.

Sclerotinia Wilt

Sclerotinia sclerotiorum

Wilt, stem rot, root rot and head rot of sunflowers are caused by a soil-borne fungus which also attacks a large number of different kinds of broad-leaved crop plants and common weeds. It is world-wide in distribution. The sunflower wilt disease has been known in Manitoba for many years. Almost every year traces of sclerotinia wilt occur in most sunflower fields; in a few fields 5 to 10 percent of the plants may be killed; occasionally about 50 percent of the plants are destroyed. Although the loss to individual growers is sometimes heavy, the percentage of the total crop lost in any year is usually not very great.

Appearance — Sclerotinia wilt usually appears in sunflower fields at about flowering time. Diseased plants occur singly, in small groups or in large patches. Some young plants show wilt symp'oms early in the season, but results in experimental plots indicate that wilt develops most rapidly following the warm weather of July and early August. The upper leaves of infected plants droop as if they were suffering from a shortage of water (Figure 24). Within two or three days, all the leaves wilt and dry out. In a very short time the plants die. Young, wilted plants often turn almost black; mature plants usually remain straw colored. The stems of wilted plants often appear shredded. They are weakened, and may break over at the soil line or at any point along the lower half of the stem. At the base of diseased plants, and as much as an inch or two above the soil line, there is often a mass of cottony-white mycelium of the fungus, containing dense white structures called sclerotia, which develop a hard rind and turn black as they mature. Sclerotia are also produced inside infected stems (Figure 25) and in sunflower heads rotted by the fungus. The size and shape of the sclerotia vary according to the tissues in which they are produced. They may be long and narrow if formed inside the stem, wide and flat if formed in the head, or almost round, from ⅛ to ¼ inch in diameter.

Disease Cycle — The sclerotia are the overwintering stage of the fungus. They can survive in the soil for one or more years. When conditions are suitable, they germinate by producing mycelium, which can infect the roots of susceptible plants. In moist, cool seasons, the sclerotia may produce small fruiting bodies that liberate spores into the air. The spores produced in this way are important in starting infections in some areas, but seem to be quite unimportant in Manitoba, where the spread of the fungus seems usually to be limited to the distance that the mycelium can extend through the soil.

Control — There are no varieties of sunflowers resistant to sclerotinia wilt. Many broad-leaved crops such as rape, mustard, sweet clover and field peas, as well as some vegetables, and common weeds such as pigweed and Canada thistle, are quite susceptible. The fungus can survive or increase on these plants. Cereal grains and grasses are not susceptible. Losses can usually be kept down to minor proportions by controlling susceptible weeds, and by sowing cereals or seeding down to grass between susceptible crops in a rotation.

Downy Mildew

Plasmopara halstedii

Downy mildew is caused by a soil-borne fungus that attacks sunflowers and closely related plants. Infected plants seldom produce any seed. Although the disease is present every year, losses greater than 20 percent are seldom encountered. It is most serious in years of cool, wet weather in the spring and early summer.

Appearance — Plants affected by downy mildew show the disease at almost any stage. Diseased plants may occur singly, in groups, or in large patches. Infected seedlings have a pale-green or yellowish area spreading out from the midribs of their leaves. In moist weather, the under surface of the pale portion may be covered with a downy growth of the white mycelium and spores of the fungus. As plants grow older, there may be some wrinkling and distortion associated with the pale color of the leaves, and the plants are usually stunted. At flowering time, when unaffected plants are 4 to 5 feet tall, mildewed plants may be from 6 inches to 2 or 3 feet tall. Stunted plants usually produce heads that may be normal in size, but as they contain only empty seeds and are light, they remain upright, instead of bending over as normal sunflower heads do (Color Figure 4).

Disease Cycle — The downy-mildew fungus has a resting-spore stage that can survive in the soil over winter, and possibly for many years. These spores germinate in moist soil and can attack the roots of young sunflowers. The mycelium of the fungus spreads, producing infection throughout the plants. In moist weather, the mycelium grows out from the under surface of diseased leaves and produces spores that can infect other plants, but this type of secondary infection is slight in Manitoba. The overwintering spores may be produced in the roots, stems or leaves of diseased plants, and are released into the soil when the diseased tissues rot. It has been suggested that the overwintering spores also form on sunflower seeds and transmit the disease when the seeds are sown, but the results of experiments to test this possibility have been inconclusive. Seed capable of germinating is rarely produced on plants completely invaded by infection. When such seed is sown, it does not give rise to mildewed seedlings.

Control — Sunflowers should not be included in a rotation oftener than once in five years. Although the downy-mildew fungus and some other disease-producing organisms can survive in the soil for several years, the chances of heavy infection are greatly reduced when susceptible crops are sown only at fairly long intervals. Susceptible weeds, such as ragweed, wild sunflowers and thistles, should be controlled. Because the fungus develops and spreads in moist soil, sunflowers should not be sown in low, wet fields.

Powdery Mildew

Erysiphe cichoracearum

Powdery mildew usually appears on sunflowers shortly before harvest, too late to affect seed yield. It is caused by the growth on their leaves of a fungus whose pale-colored mycelium and whitish spores give the leaves a dusty or powdery appearance.

Black Stem

Phoma oleracea var. *helianthi-tuberosi*

Black stem lesions usually start at the base of the leaf petioles and spread along the stems of sunflower plants. Several spots may join together to form large, black patches. Dark, irregularly-shaped spots on leaves and flower bracts are also caused by this fungus. Early infection destroys the leaves and weakens the plants. Crop rotation is an aid to control.

Leaf Spots

Septoria helianthi
Alternaria zinniae

The characteristic leaf spotting caused by the fungus *Septoria helianthi* is conspicuous but rarely cause for concern. In the spots, dead, brown tissue, ¼ to ½ inch in diameter, is surrounded by a narrow yellow ring that fuses gradually with the surrounding green tissues. Spots sometimes join together and entire leaves may turn brown and appear withered. The disease is most severe on the lower leaves. Dense plantings and humid weather promote this leaf spot.

The leaf spots caused by *Alternaria zinniae* are roughly circular and dark, with the central portion ringed like a target. Dark-brown streaks also occur on the stems of sunflowers. The disease is seldom severe enough to warrant control measures.

Aster Yellows

Aster Yellows Virus

Typically, aster yellows affects a sector of the head of an infected plant. The flowers in a wedge-shaped portion, or sector, of the head remain

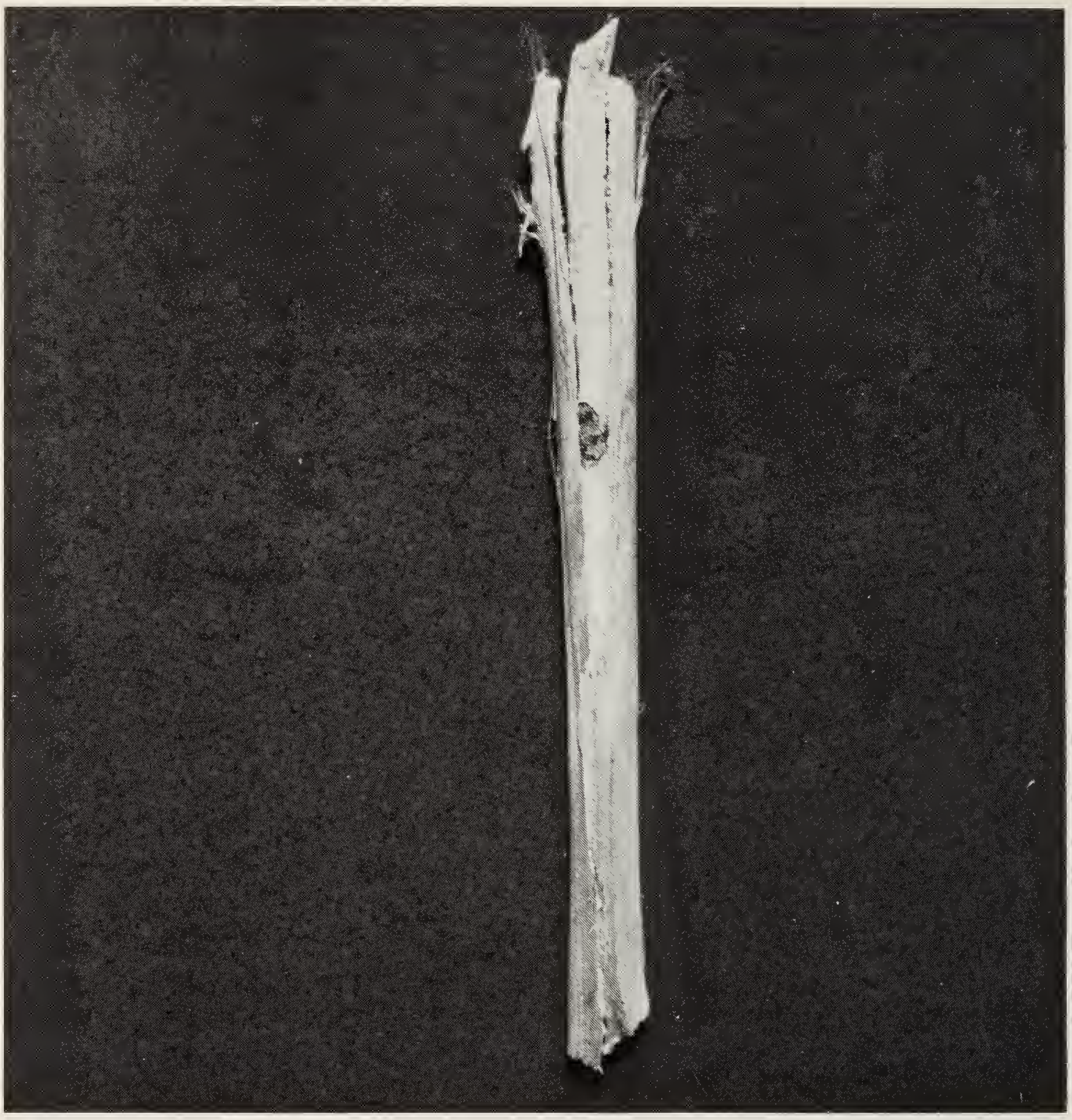


Figure 25. — Stem blight of rape; fungus sclerotium inside stem.

green, grow larger than the rest and do not set seed. As the disease develops, the sector turns brown and dies. The brown discoloration extends downward as a narrow stripe along the stem, at first only on the surface, but later in the deeper tissues as well. Some affected plants are stunted, some break over as a result of the weakening of their stems, but others survive and set seeds on the apparently normal portion of their heads. In years when the disease is severe, 10 to 25 percent of sunflower plants may be affected by yellows. There are no known control measures.

Head Rot

Various Fungi

Head rot occurs on maturing plants when wet weather prevails in the fall. Moisture collects in the receptacle of sunflower heads and provides ideal conditions for the growth of air-borne fungus spores. Infected heads become punky and disintegrate. There is no way to control this disease.

DISEASES OF RAPE

Stem Blight

Sclerotinia sclerotiorum

Stem blight occurs regularly in most areas of the prairies and is particularly destructive in years of above-average rainfall. In some fields up to 20 percent of the rape plants may be infected. The disease is most prevalent in heavy, lodged stands grown in moist soil.

Appearance — The stems of infected plants are white and tend to shred and break at their base. The plants have a wilted appearance and may die prematurely. Positive identification of the disease can be made by slitting the base of the stems. Inside infected stems a cottony, white mold is visible, and often black, hard, oval bodies (sclerotia) are present (Figure 25).

Disease Cycle and Control — See "Sclerotinia Wilt" under "Diseases of Sunflowers."

White Rust

Albugo cruciferarum

White rust, or staghead, occurs predominantly in the relatively moist rape-growing areas of the park belt. Its severity in a field depends largely on the crop sanitation and rotation practices of an individual grower. Up to 10 percent of the plants in some fields may be affected when conditions are favorable for the disease. The white rust fungus attacks many wild and cultivated plants in the cabbage family.

Appearance — The conspicuous stage of this disease, and the only one observed by most growers, is the deformation and swelling of the tips of flower stalks as plants mature. The swollen parts are often spiny and resemble a stag's horns (Figure 26, A). In moist weather, white, powdery masses of fungus spores develop on the surface of these spiny structures when green or on the leaves of the plants (Figure 26, B). Later, the white masses turn brown and resting spores are formed inside the staghead.

Disease Cycle — The fungus overwinters as thick-walled resting spores inside the swollen tips of plants. The infected tips may break off and fall to the ground or they may be broken at harvest to release spores, which become mixed with the seed. The following spring the spores germinate and infect the young seed leaves. Spores formed on these leaves are carried by air currents and spattering rain to other leaves and later to the flowers. Flower infection results in the formation of the spiny, swollen stagheads characteristic of the disease.

The fungus is an obligate parasite, which cannot live on dead plant material. In the absence of the host it survives in the spore stage.

Control — To reduce infection, use clean seed, and do not grow rape or

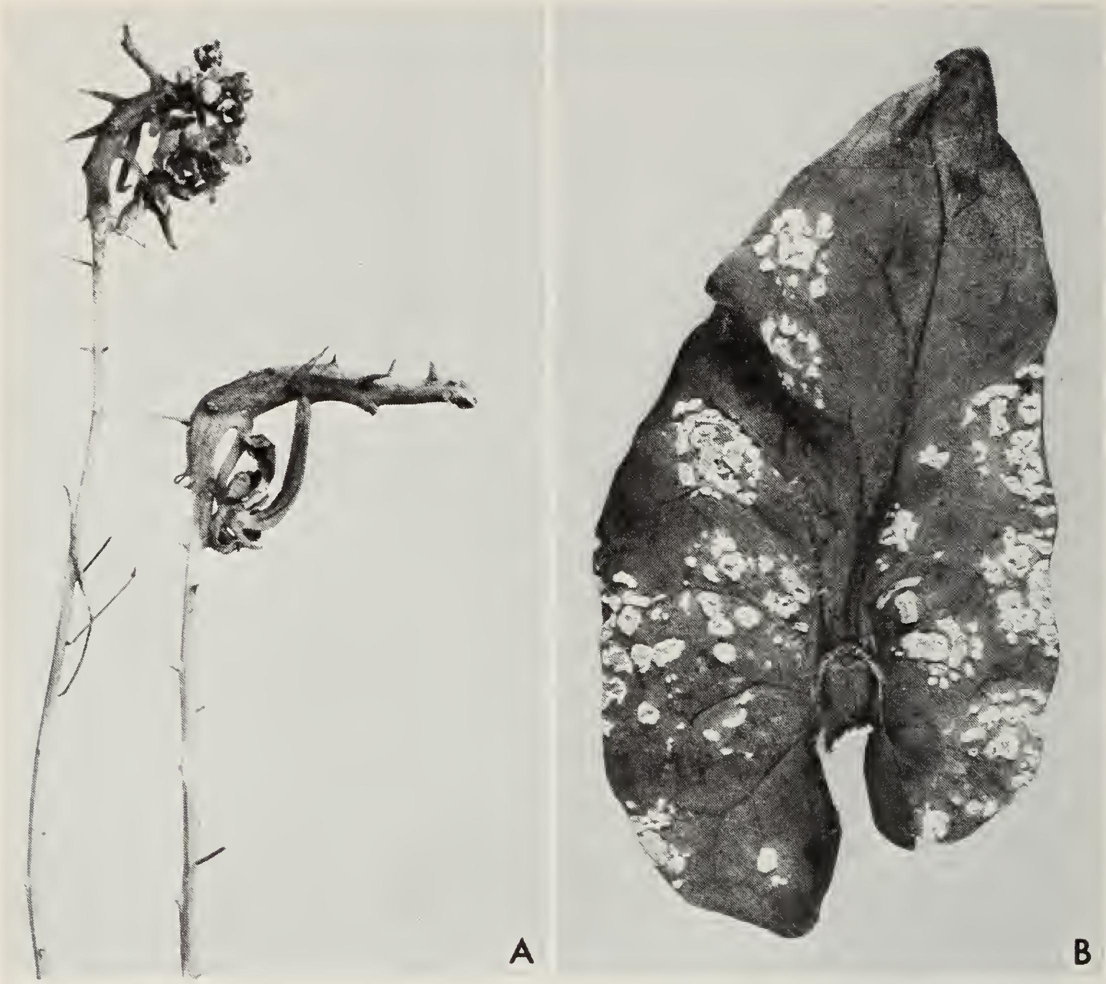


Figure 26. — White rust of rape; (A) deformed flower parts, (B) leaf pustules. (Photo by courtesy of Prof. T. C. Vanterpool)

mustard after these crops or next to a field sown to these crops the previous year. Do not grow rape on land infested with wild mustard or other weeds of the mustard family.

Downy Mildew

Peronospora parasitica

Downy mildew occurs with white rust, and infection by this complex is usually more damaging to a plant than infection by either one alone. Cool, moist weather favors development of the disease, so it is usually most severe in the northern parts of the park belt. The disease is of minor importance in dry years.

Appearance — Under optimum conditions for disease development, which rarely occur in Western Canada, mildew spots appear on leaves, stems and seed pods as small, purplish, irregular areas. The leaf spots enlarge to form yellow areas on the upper surface with a white, moldy growth beneath. Downy mildew is sometimes found on the floral parts of plants infected with white rust where it contributes to swelling and distortion.

Control — See "White Rust."

Black Spot

Alternaria brassicae and *A. raphani*

The diseases caused by these fungi are present every year in some parts of the prairies and in epidemic years they can cause severe damage. Losses of 20 percent in yield may result from premature splitting of pods and from shrinkage of seed on infected plants.

Appearance — The symptoms caused by each of these fungi are very similar. The most conspicuous symptoms are the black spots that occur on stems and pods (Figure 27). These begin as small brown to black points which change color as they enlarge, becoming either entirely black or dark bordered with a grayish-white center. The leaf spots vary in size and color depending on environmental conditions. They may be entirely gray under moist conditions (Figure 27), and gray with a purplish or black border or entirely black under less favorable conditions. Severely infected leaves wither and drop, and spotted pods become dry and shrunken and split prematurely. Spotted pods that are harvested contain shrunken seed

Figure 27. — Black spot on stem, pods and leaf of rape.

infested with the fungus. Infested seed gives rise to diseased seedlings which may be killed either before or after emergence.

Disease Cycle — Spores are produced on infected seedlings grown from infested seed and are spread by wind to healthy plants. The fungus also survives over winter on infected plant debris from which spores are spread to the next crop. Several weeds of the mustard family are hosts on which the fungus can live from year to year.

Control — Plump, disease-free seed of high germination, possibly from drier areas of the prairies, should be used in areas where the disease is prevalent. If such seed is not available, treatment of thoroughly cleaned seed with a recommended fungicide should be beneficial. As the fungus overwinters on plant debris, a rotation with any crop other than mustard will reduce infection from this source. Early swathing of badly infected crops may prevent serious losses from shattering and seed shrinkage.

Ring Spot

Mycosphaerella brassicicola

Ring spot, or black blight, is widespread in the northern part of Saskatchewan and Alberta. It is a very conspicuous disease but develops late in the life of rape plants and is only occasionally damaging.

Appearance — The fungus causes gray-speckled rings or blotches on leaves and blackening of stems and pods, the discoloration of the stems being most conspicuous.

Disease Cycle and Control — See "Black Spot."

Blackleg

Phoma lingam

Blackleg is a serious disease of such crucifers as cabbage, cauliflower and turnip in many parts of North America. In recent years it has become increasingly prevalent on rape in Western Canada.

Appearance — This fungus attacks the leaves, stems and roots of plants. Leaf spots, which are inconspicuous, pallid areas at first, gradually become well-defined spots with gray centers. On the stems the spots often have purplish borders. Very small, black dots (pycnidia), the fruiting bodies of the fungus, are scattered over the center of leaf and stem spots. The pycnidia are most conspicuous late in the season on lower stem portions and on the stubble of harvested fields. Lesions near the base of stems extend to the root system where black cankers are formed. The roots gradually disintegrate and the plants weaken.

Disease Cycle and Control — As for "Black Spot" but, as the fungus is borne inside the seed, seed treatment with chemicals is of no benefit.

Aster Yellows

Aster Yellows Virus

The prevalence of this disease depends largely upon the abundance and time of arrival of the leafhopper vector. It also depends on whether there are a few or a great number of leafhoppers infested with the virus. Traces of the disease can usually be found each year but seldom are more than 5 percent of rape plants infected.

Appearance — Symptoms are most pronounced on the heads of plants. The virus causes the pods to become distorted and sterile. Blue-green, puffy structures form instead of normal pods.

Disease Cycle and Control — See "Aster Yellows" under "Diseases of Barley."

Black Rot

Xanthomonas campestris

This bacterial disease occurs on many cultivated and wild plants of the mustard family, including cabbage, turnip, radish and mustard. Although the disease on rape is not prevalent in Western Canada, it is potentially a serious disease because it is seed-borne and difficult to control once established in an area.

Appearance — The disease-causing bacteria infect rape plants through water pores at the margin of their leaves and symptoms are evident first at this point. Infected leaf tissue turns yellow and the veins become dark colored. The yellow area is often v-shaped, with the widest part at the margin.

Disease Cycle — The bacteria survive the winter in infected plant debris and in or on seed. Seedlings become infected from seed-borne bacteria or from bacteria splashed from refuse by rain. Subsequent spread from infected plants occurs by wind-blown rain.

Control — Ordinary seed treatment chemicals are of no benefit as the bacteria occur inside the seed. Rape or mustard should not be grown more than once every three years on the same land.

DISEASES OF PEAS

Bacterial Blight

Pseudomonas pisi

The total field pea production of the Prairie Provinces does not rank in importance with that of a major cereal crop, but to a farmer whose pea crop occupies a substantial proportion of his acreage, bacterial blight of peas may seem more important than stem rust of wheat. Whether the pea plants are in a commercial field or a small garden, damage caused by bacterial blight is objectionable and to be avoided wherever possible.

Appearance — The disease causes dark-green, water-soaked spots on any or all the aboveground parts of pea plants: leaves, stems, leaf stalks and pods. Later these spots may dry and turn light brown. In a severe infection, the flowers may be attacked so that young pods either fail to form or shrivel up at an early stage. Older pods become more or less heavily spotted.

Disease Cycle — Infected seed (Figure 28) may initiate the disease in the spring, and secondary spread from infected seedlings can be rapid in moist weather. Injuries such as those caused by hail help to spread the disease. Sometimes, in severe attacks, a whole vine is killed without producing any seed. Under drier conditions, the disease may damage plants and result in a reduced yield of seed, a proportion of which will be either infected or surface-contaminated. The bacteria live readily and for long periods on dry seed.

Control — The best control measure is to sow seed from disease-free fields. Disease-free seed is most satisfactorily produced in irrigated areas where rainfall is less than half an inch during the growing season. Such conditions do not occur anywhere in Canada. Much of the seed for the canning pea crop is imported from irrigated areas in Idaho where the summer rainfall is low. Such seed is not always completely free of bacterial blight, but it carries so little infection that the disease does not become excessive in the single crop grown for canning.

Disease-free seed of field peas is not available. The seed is usually produced locally under somewhat moist conditions and the disease builds up and causes considerable losses in wet years. It seems likely that if sufficient demand existed for field-pea seed grown under dry air conditions, it would be possible to produce comparatively disease-free seed, as is the common practice with canning peas.

Ascochyta Blight

Ascochyta pisi, A. pinodella, and *Mycosphaerella pinodes*

Ascochyta blight, a fungus disease, is widespread. Occasionally it has been a serious threat to the seed and green-pea industries in moist areas.

Appearance — Somewhat similar though distinguishable symptoms are caused by the three parasites. The leaf spots caused by *M. pinodes* are purplish with indefinite margins. Fusion of the spots results in irregular brownish-purple blotches. Stem blotches are elongated at first; later, fusion of the blotches gives the entire lower stem a bluish cast. When small, pinpoint infections appear on the flower parts, blossom drop commonly follows. The symptoms of *A. pinodella* are like those of *M. pinodes* but less severe, yet it causes a more severe foot rot, that is, the base of plants is more severely attacked. On leaves, the sunken spots caused by *A. pisi* have clear-cut margins. The spots are tan or brown in the center and a darker shade of the same color at the margin. *A. pisi* may also cause a foot rot.

All three fungi infect seed through the pods. Infected seed may have either no visible symptoms or it may show various degrees of shrinkage and discoloration.

Disease Cycle — The three fungi can survive in the seed and thus be spread over long distances. They can also live over winter in infected pea straw but not in soil free of plant remains. On the straw, spores are produced which are spread about chiefly by the splashing of raindrops. One

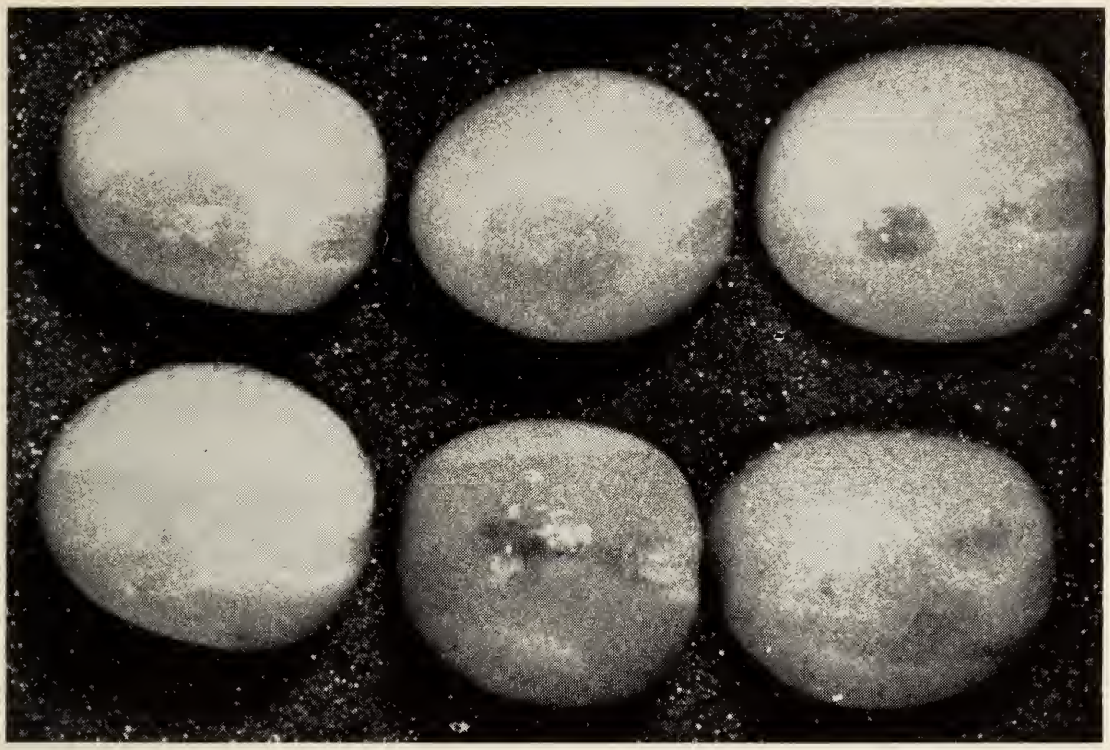


Figure 28. — Bacterial blight of peas; note watersoaked areas on seed.

of the fungi, *M. pinodes*, also develops a kind of spore that is shot out forcibly and carried in wind currents. These spores serve to spread the disease over wide areas.

The disease may appear on very young seedlings at the point of attachment of the seeds; such an infection is usually fatal to the seedlings. Later, infections may occur anywhere on the seedlings, and from the infected seedlings disease may spread in wet weather to nearby plants. Thus the disease may build up from a scattered infection in the early summer to a severe infection later in the season.

Control — The disease is best controlled by the use of disease-free seed, crop rotation and sanitation. Seed grown in semiarid, irrigated areas is likely to be free of infection. A four- or five-year rotation will largely eliminate the organisms from the soil. Every effort should be made to locate new plantings away from those of the previous season; and as much as possible of the pea straw and trash should be destroyed.

Root Rot

Aphanomyces euteiches, Fusarium solani, Pythium ultimum, Rhizoctonia solani

Root rot of peas is caused by a number of fungi which singly or together attack the outer layers of roots. The damage varies with the season. The disease may act as a seedling blight or it may attack late in the season. One year a crop may fail; the next year, on the same piece of land, a crop may be healthy.

Appearance — *Aphanomyces* causes a watery, soft rot of the outer layers of stems and roots near the soil line. In time, this tissue collapses and dies and all that remains is woody tissue. Young plants usually die; older plants are stunted and their leaves turn yellow and die from the ground up.

Fusarium root rot usually starts on seedlings at the junction of root and stem, where the seed is attached. The rot extends upwards on the stem and downwards on the root as a reddish-brown area. In time the stem becomes girdled. The disease is most damaging at high temperatures (80°F) and on later crops.

Rhizoctonia root rot is primarily a seedling disease in which a yellowish-brown rotting occurs near the point of seed attachment. The fungus often attacks the growing point of the seedling, killing it before it emerges. A soil temperature of 60° to 65°F is most favorable to the fungus.

Most of the damage from *Pythium* results from seedling injury and seed decay. Affected plants have a water-soaked, somewhat translucent and softened tissue extending above and below the region of seed attachment. The disease develops best in wet soil.

Disease Cycle — *Aphanomyces* and *Pythium* survive in the soil by means of thick-walled resting spores. These germinate and infect young tissue. *Rhizoctonia* and *Fusarium* survive as mycelium in the soil.

Control — Seed treatment largely controls seed decay and damping-off caused by *Fusarium, Pythium* and *Rhizoctonia* but it does not control infection beyond those stages. Aphanomyces root rot is not controllable by seed treatment. Crop rotation keeps the fungi from building up in the soil. No resistant varieties are available.

DISEASES OF ALFALFA AND SWEET CLOVER

Black Stem

Ascochyta imperfecta on Alfalfa
Ascochyta meliloti on Sweet Clover

Black stem is essentially a leaf and stem disease, but may also cause blighting of seedlings and diseased areas on the crowns of mature plants. Losses are caused by reduction in stands through seedling blight, crown rot and stem killing, by reduction in seed yield through blossom and pod drop and seed infection, and by reduction in hay yield through destruction of leaves. The disease is present in almost all areas where alfalfa and sweet clover are grown, and is especially severe in northern seed-growing areas where heavy dews, frequent rains and low evaporation are common.

Appearance — The disease appears in early summer as small, irregular, dark-brown or black spots on the lower leaves. There may be similar spots on crown buds and at the bottom of young stems, some of which are killed in their early growth. Spots may run together to form large, blackened areas which often girdle and kill older stems. Severe spotting on the leaves causes defoliation. During cool, moist weather, infection may spread to flower stalks, causing the blossoms or pods to drop off. Pod and seed infections also occur. Severely infected seed is shriveled, and usually is lost during threshing.

Disease Cycle — The fungus persists on seed, fallen leaves, pods and straw, and in crown tissues. The fruiting bodies of the fungus mature on dead plant tissues during the fall and spring and produce spores, which spread by water to new growth. The fungus will survive on dried plant material and seed for several years, but in the absence of the plants it usually does not persist more than two years in the soil.

Control — Hay crops should be cut before many of the leaves are destroyed by leaf spot. Burning the stubble of seed crops in the early spring destroys the fungus growing on dead plant material and usually reduces spring infection to some extent. This method of control should be used with caution as a crop may be badly damaged by burning after spring growth has begun.

Bacterial Wilt of Alfalfa

Corynebacterium insidiosum

Bacterial wilt has been the most widespread disease of alfalfa in the United States for many years. It has also proved very destructive in the irrigated areas of southern Alberta since it became established there about 1939. This disease greatly reduces the yield and shortens the life of stands of Grimm and other susceptible varieties. It is favored by abundant moisture and is usually most severe in low, poorly drained spots. Although it has spread into central and northern Alberta, Saskatchewan and Manitoba, severe general damage is still confined to irrigated areas. Local outbreaks, however, occur in other areas well supplied with moisture, especially after one or more seasons of heavy rainfall.

Appearance — A gradual stunting and yellowing of alfalfa plants in the second or third year of growth is usually the first sign of bacterial wilt. Their stems are shortened and bunched, and their leaves are smaller than normal, pale, and curled upward at the edges. Wilting of the tips of all the shoots on a plant sometimes occurs during warm weather. As the disease progresses, plants with all degrees of stunting, ranging from extremely dwarfed to nearly normal, appear in a field. The severely affected ones soon die and the others are progressively weakened.

Bacterial wilt can be identified, even before top symptoms appear, by examining the roots of suspected plants. If the bark of the main taproot of an infected plant is peeled, a yellowish-brown discoloration or streaking can be seen on the woody cylinder beneath, in contrast with the creamy white on the cylinder of a healthy plant. This discoloration becomes darker and extends into branch roots as infection develops. It appears as a brown ring in a cross section cut from the root of a severely infected plant (Color Figure 3).

Disease Cycle — The bacteria overwinter mainly in diseased alfalfa roots and in plant remains in the soil. They are carried by soil water and enter healthy plants in the spring through wounds produced by winter injury, insects or mechanical damage. As the bacteria develop inside the roots, the water-conducting tissues become clogged and this results in stunting, yellowing and eventual death of the plants. In the advanced stages of the disease, the bacteria accumulate in the crowns and basal stems and are released when these tissues start to decay.

Control — The use of resistant varieties of alfalfa is the only satisfactory means of controlling bacterial wilt. Several are available but specific varietal recommendations are dependent on their adaptability to local conditions.

Certain cultural practices may aid in delaying the spread and development of the disease. In irrigated areas only enough water should be used to secure good growth of the alfalfa. Water should not be allowed to run from a diseased stand to a young, healthy one, and all young stands should be cut before the mower is taken into older, diseased stands. Cultivation of diseased stands is seldom advisable since it wounds the alfalfa roots and spreads the bacteria. Fields that have been severely damaged by bacterial wilt should not be reseeded to alfalfa for at least two years. Cereals or other crops can be grown in the meantime since only alfalfa suffers damage under natural conditions.

Common Leaf Spot

Pseudopeziza medicaginis

Common leaf spot is caused by a parasitic fungus and is one of the major foliage diseases of alfalfa. Crop losses occur through killing of leaves and reduction in the quality of hay from infected fields. The disease is less severe on sweet clover, although local outbreaks may cause some damage. It is found in all parts of Western Canada.

Appearance — Common leaf spot may be recognized by small, dark-brown, circular spots that develop on the leaves of alfalfa plants (Color Figure 1). When the spots mature, a small, raised disk appears in the center of each. This is the fruiting body of the fungus, and its presence distinguishes the spots from those caused by the black-stem fungus. Alfalfa plants are not killed by the disease but, when severely infected, most of their lower leaves may drop off.

Disease Cycle — The fungus overwinters in infected leaves. In the spring, spores are discharged from the fruiting bodies in the centers of the spots and are carried by wind to new growth. These spores infect the leaves, and new spots, fruiting bodies and spores are produced. This cycle is repeated throughout the summer except during periods of prolonged dry weather. Infection and disease development are favored by cool, wet weather.

Control — Hay crops in which the leaves of the plants become badly spotted should be harvested before defoliation becomes severe. Resistant alfalfa varieties have been produced but they are not adapted to conditions in Western Canada.

Figure 29 — Winter crown rot of alfalfa.

Winter Crown Rot or Snow Mold

Unidentified Basidiomycete

Winter crown rot, or snow mold, of alfalfa is caused by an unidentified fungus. This fungus is responsible for extensive winter crown rot damage to alfalfa and other forage crops in Western Canada. The severity of winter crown rot varies greatly from year to year. Serious damage occurs in west-central Alberta, and relatively slight damage in southern Alberta. The disease has also been found in British Columbia, Saskatchewan and Manitoba, but it has not yet been reported outside Western Canada.

Appearance — The disease may be recognized in the spring by irregular patches of dead plants in alfalfa and clover fields. Sometimes the crowns may partially rot (Figure 29) and the alfalfa plants may become weak rather than die in patches. The aboveground parts of the plants are often killed or greatly weakened when only the crown buds and a small portion of the crown are affected, while the main root remains sound. White remnants of the fungus are sometimes found on the crowns of dead or damaged plants when the snow melts.

Disease Cycle — The crown rot fungus appears to spread by means of mycelium, since no spores or fruiting bodies have yet been found. It may spread both above and below the surface of the ground. It requires a period of growth before freeze-up in the late fall in order to inflict severe damage during the winter. As the soil temperature rises in the spring the fungus becomes relatively inactive until conditions are again favorable for growth in the fall.

Control — Following severe damage, crop rotation is the most valuable method of controlling winter crown rot. The fungus does not persist to any extent for longer than two or three years in land which has been summerfallowed or planted to annual crops or resistant grasses. Spring-sown cereals, brome or crested wheat grass can safely be planted in heavily infested land.

Most of the commonly grown varieties of alfalfa are highly susceptible, but progress is being made in a breeding program in which *Medicago falcata* and varieties derived from it are being used as a source of resistance.

Crown and Root Diseases

Various Soil-borne Fungi

Root- and crown-rotting fungi often attack alfalfa and sweet clover during the growing season and may cause serious losses. The damage is distinct from that caused by the previously described snow mold or winter injury in dormant plants. Several soil-inhabiting fungi, acting singly or in combination, cause varying degrees of damage in different areas and from season to season.

Crown bud rot is the most important disease of this type. It is caused by several soil-inhabiting fungi which rot crown buds and young shoots, particularly in moist soils. The disease develops and spreads most rapidly during the early part of the growing season, and it occurs commonly in all irrigated fields after the first season. There is a progressive decline in stand and yield as plants become partially devoid of crown buds and stems.

Root rots are sometimes destructive in sweet clover, especially in southern areas. The damage occurs most commonly in the second season of growth. Extensive rotting of the roots by fungi results in sudden wilting and death of the plants. This damage may occur early in the spring or during the summer.

Appearance — Crown bud rot can be recognized by the brown spotting and eventual death of young buds and shoots near the soil surface. This rotting may later extend into underlying crown tissues.

Root rots cause rotted areas of varying size, depth and color on taproots and secondary roots. Other symptoms include surface injuries or root canker, collar rot, heart rot and tip rot.

Disease Cycle — The fungi overwinter in diseased roots and crowns or in the soil. Young succulent tissues such as crown buds may be attacked directly as soon as the soil temperature rises sufficiently in the spring to allow growth of the fungi. Other tissues such as roots, which have a layer of protective cells, usually must be wounded in some manner before the fungi can penetrate. Such wounds may be caused by insects, winter injury or mechanical damage.

Control — The fungi involved in this type of disease are difficult to control under field conditions. Crop rotation will usually aid in reducing the damage because the more common of these fungi do not attack cereal crops. Alfalfa or sweet clover should not be reseeded for two or three years on land in which severe damage has occurred. Good cultural practices that promote vigorous growth such as proper fertilization and cutting procedures are of great value in decreasing losses. Alfalfa should be allowed sufficient time after the last cutting of the year to make about 10 inches of new growth before freeze-up. Late-fall cutting does not leave plants sufficient time to manufacture and store in their roots the reserves necessary for their winter survival and spring growth. Such plants are susceptible to winter injury and subsequent invasion by soil-borne fungi. Cultivation of alfalfa stands is generally of little value, and in fact may be harmful because injuries to roots and crowns caused by machinery may facilitate infection by fungi.

Stem Canker or Goose Neck of Sweet Clover

Ascochyta caulicola

This disease occurs in all three prairie provinces but usually causes little loss.

Appearance — Silvery-white cankers form on the stems, leaf stalks and, occasionally, on the midribs of leaves. The fruiting bodies of the fungus are readily seen as small black dots on the centers of the cankers. The lower part of the stems may be girdled with large cankers. Heavily infected stems often appear swollen, are retarded in development, and have fewer and smaller leaves. They also tend to twist and bend at the top.

Disease Cycle — Similar to black stem of alfalfa and sweet clover.

Control — Control measures are not usually necessary.

Seedling Blight

Pythium spp., *Fusarium* spp., *Rhizoctonia solani*

Seedling blight of sweet clover and alfalfa is responsible for much of the reduction occurring in new stands and its severity depends largely on the weather. With favorable moisture and temperature these fungi build up and cause heavy losses.

Appearance — Seeds, young seedlings and roots are attacked by species of *Pythium*. Many diseased seedlings fail to emerge. Later, as young plants emerge, they may be damped-off by other fungi attacking at the soil line. Young plants wither and soon disappear, leaving gaps in the rows. Little damage is done after plants reach the four- or five-leaf stage.

Disease Cycle — *Pythium* persists as resting spores in the soil and under very moist conditions it may cause serious seed rotting and preemergence blight. As temperatures rise to 60° or 65°F, *Rhizoctonia* attacks at the soil line; at higher temperatures, 75° to 85°F, *Fusarium* causes a similar type of damage. These fungi persist as mycelium in the soil.

Control — Seed treatment with nonmercurial fungicides prevents a certain amount of preemergence blighting but it is ineffective against fungi that attack at the soil line. The use of sound seed, shallow seeding and good preparation of the seedbed are recommended. No varietal resistance is known at present. Experiments have shown that seedling blight is most severe on sweet clover when it is sown after sweet clover, alfalfa or red clover, and less severe when it is sown after soybeans, corn or wheat.

Gray Leaf Spot

Stagonospora meliloti

Although widely distributed, this fungus seldom causes serious damage to leaves. The spots on alfalfa and sweet clover are gray, roughly circular in outline and about ⅛ to ¼ inch in diameter. In the centers of the gray spots the fruiting bodies of the fungus appear as numerous, small, black dots. Similar spots appear occasionally on stems. This fungus also attacks roots causing a crown and root rot. The fungus overwinters in diseased crop remains. Control measures are the same as those recommended for black stem.

Downy Mildew

Peronospora aestivalis

This disease occurs on alfalfa during wet or humid weather, particularly in the spring. Sweet clover is seldom attacked by downy mildew. Infected leaves at the top of plants are light-green and on the underside of these leaves a grayish-white fuzz can be seen. This moldy growth is made up of fungus threads and spores. When the disease is severe, stem growth is retarded and the leaves become twisted and rolled. The fungus grows through the whole plant and overwinters in the crown buds. It may also overwinter in dead leaves. The control measures outlined for black stem are effective in reducing spring infection.

Yellow Leaf Blotch

Pseudopeziza jonesii

This fungus attacks only alfalfa. The disease occurs in all parts of Western Canada and often causes severe defoliation, particularly in the northern seed-growing areas. It appears as yellow or orange blotches that run parallel to the leaf veins and on which are scattered very small orange or brown dots, which are fungus structures. In the fall, the fruiting bodies of the fungus are formed on the lower sides of the leaves where they remain in the dead tissues until spring. Control measures are the same as those recommended for black stem.

White Spot

Nonparasitic

The appearance of white spots on the leaves of alfalfa usually indicates a physiological disorder and not the result of infection by fungi or bacteria. The spots are seldom so numerous as to damage the leaves seriously, but they often indicate a disorder from which crop losses could occur. Three types of white spotting have been found. The first occurs in scattered plants in a field and is a genetic or hereditary character of the plants. The second occurs in most of the plants in a field and may be caused by irrigation or heavy rainfall after a period of dry weather. The third and most important type is that induced by a deficiency of potasium in the soil. When this occurs plants become less productive and a row of white spots appears just inside the margin of the leaves. This deficiency can be corrected by the application of fertilizer containing potash.

Bulb and Stem Nematode

Ditylenchus dipsaci

The disease caused by this tiny nematode is widespread in the irrigated alfalfa area of southern Alberta, where it causes slight to severe damage in older alfalfa stands. It can be recognized by thickened, brittle, deformed crown buds, which do not elongate normally to form stems. Severely infested plants are dwarfed and unthrifty and are noticeably less cold-hardy than healthy plants. Crop rotation is the most satisfactory method of control. A minimum of two years should elapse between alfalfa crops on nematode-infested land. During this period avoid growing common clover, oats or onions as the nematode can survive on them.

Sweet Clover Mosaic

A Virus Disease

This disease has been reported from all three prairie provinces. Usually only a few infected plants are found in a field but large patches may occur. The leaves of infected plants appear mottled, are usually smaller than normal and may be crinkled. Severely infected plants, most noticeable in the spring, are dwarfed. The virus overwinters in sweet clover plants and may be spread from them by aphids to other susceptible crops such as peas and beans. As the disease on peas and beans is even more important than on sweet clover, these crops should not be sown near sweet clover fields. No control measures are available for sweet clover.

Summer Black Stem of Sweet Clover

Cercospora davisii

Severe outbreaks of summer black stem in sweet clover seed crops have been reported in Manitoba. The fungus that causes the disease infects leaves, stems, pod stalks, seed pods and seeds in late summer during warm, humid weather. The leaf spots are large, roughly circular, and ashy gray to tawny in color. Infected leaves soon shrivel and drop. The spots on stems and pod stalks are reddish brown and under favorable conditions they enlarge rapidly and fuse together. Much of the stem appears dark brown to black when infection is severe. Infection of the pod stalks causes the seed pods to drop off prematurely. During wet weather new infections develop rapidly from wind-borne spores. No control methods are available.

DISEASES OF CLOVER

Northern Anthracnose

Kabatiella caulivora

Northern anthracnose occurs on red clover in the cooler sections of North America, Europe and Asia. It has been very destructive to red clover stands in central and northern Alberta in cool summer seasons. Red and crimson clovers appear to be the only ones infected to any appreciable extent but alsike and white clover are not entirely resistant.

Appearance — The fungus causes brown, sunken areas on stems and leaf stalks. Leaves and flower heads usually lop over, presenting a shepherd's crook appearance, after which they wilt and die and are broken off by the wind. Cracking of stem tissue is often pronounced (Color Figure 2).

Disease Cycle — The fungus overwinters on diseased stalks and leaves. In the spring, spores are produced. They infect neighboring plants and young seedlings. The disease does not appear to be transmissible by soil, or to a serious extent by seed.

Control — No effective control measures are known; however, recommended varieties should be used as they do show some resistance.

Root and Crown Rot

Various Soil-borne Fungi

Root and crown diseases of clovers are of major importance in Western Canada. Most clovers are highly susceptible to snow mold (see "Diseases of Alfalfa"), and severe damage often occurs in the central and northern areas of the prairies, particularly in alsike clover. During the growing season a root-and-crown-rot complex may result from successive attacks by several soil-inhabiting fungi. Second-year plants are usually most severely affected. In red clover, this damage is often associated with winter injury. Wounding by cultivation or by insects feeding on roots favors entrance of the fungi and development of crown and root rots.

Appearance — As with alfalfa, symptoms vary greatly, depending on the fungi involved. The crowns or roots of clover plants are usually severely rotted before the tops start to wilt or die. In other cases the plants are weakened through partial rotting of the crowns or taproots.

Disease Cycle and Control — See "Diseases of Alfalfa."

Powdery Mildew

Erysiphe polygoni

Powdery mildew is probably the most serious disease of red clover in North America and is prevalent in Western Canada. Severe epidemics lower the quality of hay and reduce yield.

Appearance — The disease is easily recognized by the light-gray powdery layer of mycelium and spores of the fungus found on the upper surface of leaves (Color Figure 16). The leaves become yellow and turn brown when infection is severe. Clover plants attacked during early growth are dwarfed.

Disease Cycle — The fungus persists on foliage and overwinters as mycelium, or possibly as spores. Dispersal of spores during the growing season may spread the disease rapidly. The disease is favored by moderately dry weather, although it has sometimes been severe in central Alberta during wet summer seasons.

Control — Powdery mildew is difficult to control in a field. Sulphur dusting has proved effective in some countries, but control by the use of resistant varieties is more practical. However, no resistant variety is adapted to Western Canada.

Other Diseases

Various Fungi, etc.

Several diseases occurring on clovers in Western Canada are usually of minor economic importance. Seedling blight is caused by several fungi, including species of *Pythium, Rhizoctonia* and *Fusarium* (see "Diseases of Alfalfa"). At least five distinct leaf diseases cause leaf spotting and may result in some defoliation. Black stem occurs on red clover but it is seldom as severe as on alfalfa. Sooty blotch, which appears as small black pustules on the underside of the leaves, is most common on alsike and white clovers, and rarely appears on red clover. Rust occurs commonly on clovers but usually appears too late in the season to cause serious damage. These diseases are generally favored by cool, wet weather.

Mosaic is the most common virus disease of clovers. Leaves are mottled and plants may become stunted if infection is severe. Witches'-broom, another virus disease, produces dwarfing and a bunchy growth. Most virus diseases of clovers can also infect peas, beans and several other plants.

No practical control measures have been developed for most of these diseases.

DISEASES OF GRASSES

Grass diseases are prevalent throughout Western Canada but the losses they cause are difficult to assess. Much of the hay crop is harvested from mixed stands or from naturally seeded wild meadows, and in such cases diseases usually do not become epidemic as they do in cereal crops where large areas are planted to one variety. Most of the many diseases of grasses are similar to those of the cereal crops already described and no detailed description of each individual disease is attempted here.

Root Rots

Snow mold may cause severe damage in cultivated and native grasses in central and northern areas (Figure 30). The appearance of the disease is similar to winter crown rot of alfalfa and clovers, which is caused by the same fungus. Crop rotation with a spring-sown cereal crop is the best method of control. Brome and crested wheat grass are highly resistant and can be safely planted in infested land. Common root rot, browning root rot and take-all occur on grasses as well as on cereals.

Smut

Head smut (*Ustilago bullata*) is widely distributed in Western Canada on a large number of grasses and it sometimes causes serious losses to wheat grasses. Diseased heads appear dark brown to purple-black. All or part of the floral structures may be destroyed by the smut fungus, and usually the heads on all the stems produced by an infected plant are diseased. Seedling infection occurs from seed contaminated with spores during harvesting. In perennial grass species, the mycelium of the smut fungus overwinters in the dormant plant tissues and invades new growth

Figure 30. — Snow mold of lawn grass.

the following spring. Infection occurs only in the seedling stage. Therefore, seed treatment with recommended seed disinfectants will control the disease.

Ergot

There are several reasons for controlling ergot disease on grasses. Severe losses in seed production of some grasses have occurred through attacks of this fungus. Ergot poisoning may result when livestock are allowed to graze heavily infected heads of grass or are fed contaminated seed screenings. Ergot infection of cereal crops can often be traced to diseased grass plants growing wild along the headlands of cereal fields. The disease affects a wide variety of grasses in Western Canada. For further details see "Diseases of Rye."

Rust

Several rusts occur on grasses, including stem rust (*Puccinia graminis*), leaf rust (*Puccinia recondita*) and crown rust (*Puccinia coronata*). The appearance and disease cycle of these rusts are similar to those described for cereals. Stem rust does not occur on brome grass.

Bacterial Blights

Halo blight (*Pseudomonas coronafaciens* var. *atropurpurea*) causes characteristic purplish-brown spots with lighter-colored borders on the leaves of brome and other species of grass. It is similar to halo blight of oats. Bacterial blight (*Xanthomonas translucens*) is another minor leaf disease of brome and some of the wheat grasses. Its appearance is described under "Bacterial Blight of Barley."

Powdery Mildew

Powdery mildew (*Erysiphe graminis*) occurs on many wild and cultivated grasses, including fescues, orchard grass and brome grass. It is generally more severe on seed crops than on those cut for hay. This is the same fungus that causes mildew on cereals.

Helminthosporium Leaf Spots

Many wild and cultivated grasses are attacked by species of *Helminthosporium.* In general the leaf spots are brown. The most widely distributed spot of this type is brown leaf spot of brome grass caused by *Helminthosporium bromi.* The disease appears early in the spring as elongated, brownish spots scattered over young leaves. The spots increase in size and develop a yellow halo surrounding the diseased area. As the spots enlarge and join together, the tips of the leaves become yellow and begin to wither. The leaves are gradually killed from the tips downward. The disease does not warrant extensive control measures.

Septoria Leaf Spots

The fungus *Septoria* attacks many wild and cultivated grasses causing symptoms similar to those caused by species of the same fungus on cereals. *Selenophoma bromigena*, a closely related fungus, is restricted to brome grass and may be destructive in a particular area when weather is favorable for its development. Mature spots caused by this fungus usually have a dark-brown border with lighter-colored centers in which tiny black dots can be seen (Color Figure 14). These, the fruiting bodies of the fungus, contain a large number of spores. The fruiting bodies may drop out of the spots, leaving small holes in the central area. When infection is severe, spots also appear on sheaths, stems and floral parts. The spores overwinter in the fruiting bodies in which they are produced and are spread to new growth in the spring by wind and rain. Where the disease is of economic importance crop rotation is recommended for its control.

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