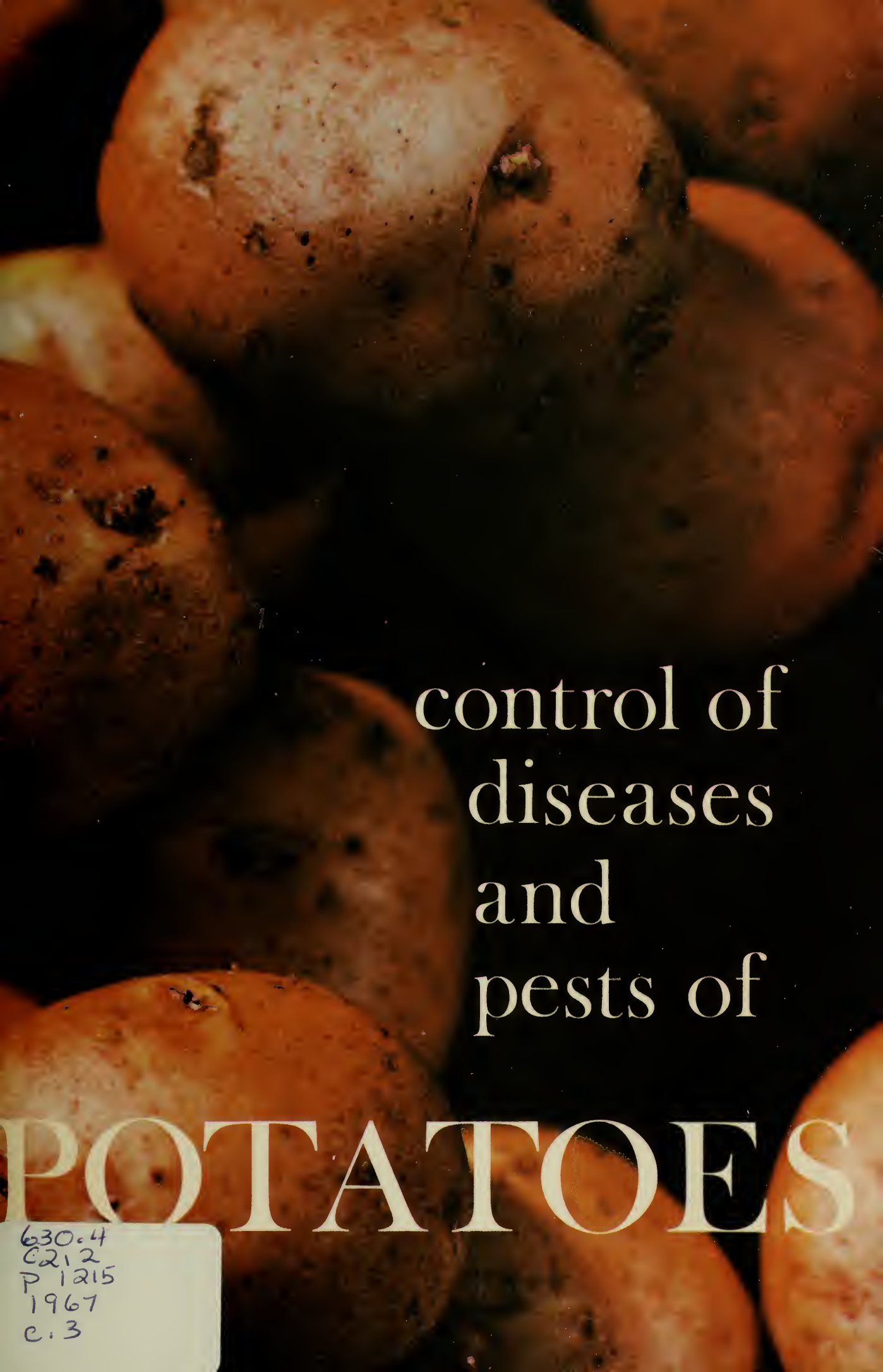

control of diseases and pests of POTATOES

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CANADA DEPARTMENT OF AGRICULTURE • PUBLICATION 1215 1967

Available by mail from the Queen's Printer, Ottawa,
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ROGER DUHAMEL, F.R.S.C.
Queen's Printer and Controller of Stationery
Ottawa, Canada
1967

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INTRODUCTION

There are means of controlling the diseases, physiological disorders, insects, nematodes, and other pests of potatoes. To know the cultural practices to follow or the appropriate pesticides to apply, you need to be able to recognize the diseases, disorders, and pests that are important in your area.

In this publication the most important diseases, disorders, and pests of the potato are described and illustrated and the control measures outlined. For more information, consult your agricultural representative or provincial specialist, or write to the nearest insect or plant disease laboratory of the Canada Department of Agriculture or to the Scientific Information Section, Canada Department of Agriculture, Central Experimental Farm, Ottawa.

Cautions — Most of the pesticides used on potatoes are poisonous. When using any, follow closely all the cautions listed on the label, especially those on rates of application. For some of the treatments an interval may be required between the last application and harvest. The interval varies with the material used, the number of applications, and the amount applied. To avoid residues that would render the potatoes unfit for sale, keep to the stated interval.

CONTROL MEASURES

Crop Rotation and Sanitation

If you grow potatoes continuously on the same land, disease-causing fungi and bacteria and also insect pests may multiply in the soil. To reduce or eliminate some of these problems, crop rotation is the most effective means.

After harvesting the potatoes, gather and burn the crop debris and culls. In the spring, bury cull piles before or soon after planting. If you plow the dead potato plants under after harvest, some disease organisms will be carried into the soil. Also, stalk- and tuber-infesting insects may overwinter in the dead plants. Potato plants growing from cull piles in the spring are the main source of blight spores for the new crop.

To control blackleg and bacterial ring rot, you must disinfect all equipment and use a bactericidal dip for the cutting knives.

Resistant Varieties

The most desirable way to control diseases and pests would be to grow resistant varieties. But, as new strains of most disease organisms are continually developing, a succession of new resistant varieties would be necessary.

Late blight, for example, may be controlled by growing field-resistant varieties and applying a fungicide less often than on other varieties.

Seed Treatment

Diseases like common scab, powdery scab, fusarium dry rot, and rhizoctonia are caused by organisms that may be carried on the surface of tubers. Treating the seed with Semesan Bel destroys these surface-borne organisms. But, if the soil is already infested, seed treatment will not prevent these organisms from infecting the new tubers.

Fungicides and Insecticides

To control many fungus diseases and insects, the only practical means is to apply a protective or eradicant spray or dust when the organism is in a vulnerable stage. All satisfactory chemicals kill the fungi or insects without harming the potato plant.

If you use dusts, apply them during calm weather while there is dew or rain on the leaves. Apply those containing copper, arsenic, or DDT early in the morning or late in the evening.

No one insecticide or fungicide controls all potato insects or diseases. The best material and the rate may vary from one part of the country to another.

Though the recommendations given in this publication were generally suitable when it was prepared, it is best to consult your provincial calendar on control of insects and diseases before selecting materials.

Spray coverage depends on the number, kind, and placement of nozzles. Adjust the nozzles so that the spray will cover all plant surfaces thoroughly. The hollow or solid cone type of nozzle is best.

For best coverage, use a sprayer with a trailing boom. This kind of boom has a series of boomlets each of which is mounted on a metal shoe. Each boomlet has several nozzles, some of which are directed downward and outward from the top and others upward and out from the bottom. You may get adequate coverage with four standard nozzles per row, two of them on drop pipes directing spray to the lower parts of the plant, and two directed downward and slightly forward to the upper parts.

If you spray with ground equipment, apply 75 to 150 gallons per acre at 200 to 400 pounds pressure per square inch,

or 20 to 40 gallons at 40 to 80 pounds. If you use aircraft apply 5 to 8 gallons per acre.

Dusts may be applied with either ground equipment or aircraft, but generally a heavier dosage is necessary with aircraft.

Tuber Units

To improve and maintain foundation seed stocks, plant by the tuber-unit method. As virus diseases are readily spread from field to field, have the plots as far away as possible from other potato fields.

From known good seed stock select healthy tubers of 8 to 10 ounces, and typical of the variety. Apply seed treatments before sprouts begin to grow. After sprouts appear, cut the tubers into four thick parts, each with at least two healthy sprouts. Plant the seed pieces from each tuber consecutively in the row, leaving a double space between units.

Rogue diseased and weak plants as soon as they appear. Even though only one plant in a unit appears to be affected, remove all plants in the unit. When a tuber is infected with a virus, all plants grown from it are usually infected; the symptoms may appear more quickly in some plants than others.

When the plants are well grown, but before blossom time, select and stake the units that are uniform and most vigorous. Harvest all the staked units by hand, and select tubers of the most desirable type for planting your seed plot the next year.

Storage Management

Suitable storage management permits orderly marketing of the crop and aids in quality control. The practices vary both with the degree of maturation of the tubers and their intended use.

To store potatoes well, have them mature at harvest and as free as possible from skinning, cuts, and bruises. Mechanical injuries favor development of rots. When you put the potatoes into storage, keep them at 60 to 65°F and 90 to 95 percent relative humidity for 2 to 3 weeks. This allows the skin to toughen, and cuts and bruises to heal.

Then, if you plan to market them soon for the fresh market, or at any time for processing, store them at 50°F. If you plan to store them for more than a month for seed, store them at 38 to 40°F. If you must store them at 50°F for more than a month, use a sprout inhibitor. Keep the humidity as high as possible without causing condensation of moisture on the tubers or the building.

FUNGUS AND BACTERIAL DISEASES

Late Blight

Late blight is the most serious disease of potatoes, particularly where the weather is consistently cool and rainy in late summer and fall. Except in Alberta, Saskatchewan and inland British Columbia, the crop is under a constant threat of severe attack unless sprays or dusts are applied.

Symptoms — Brown or black spots develop on the leaves and enlarge into lesions, or dead areas, surrounded by a pale-green zone. The outer zone appears water-soaked and in wet weather the under surface is covered by a whitish, velvet mold (Figure 1) consisting of spores of the fungus. Soon the whole leaf becomes blighted, the fungus spreads to the stems and the whole plant dies. In severe outbreaks, blighted

fields give off a foul, distinctive odor that can be smelled for miles.

Infected tubers develop purplish-brown areas and the ensuing rot (Figures 2, 3) is usually dry and hard. Under moist conditions, tufts of white spores grow out of the infected areas (Figure 4).

Life cycle — The fungus survives the winter in infected tubers, either in storage or in the soil. In the spring it grows vigorously in cull piles or on volunteer potato plants.

When conditions become favorable, usually about July, spores produced on these potatoes are blown to the foliage of the new crop. Here they germinate in drops of moisture to produce many small, swimming spores, which penetrate the plants. These spores form in greatest numbers when the daytime temperature is about 60°F, the relative humidity is 100 percent, and there are water droplets on the leaves. Usually about 5 days of favorable weather are enough to produce a crop of these spores

Figure 1 — Late blight: spores around a lesion on a leaflet.
Figure 2 — Late blight: tuber rot.
Figure 3 — Late blight: tuber rot.
Figure 4 — Late blight: tufts of spores on stored tuber.

on the leaves. They are spread to healthy plants by wind and splashing rain.

Tubers become infected by swimming spores that are washed off the leaves into the soil. The spores usually enter through the eyes. The tubers are more likely to become infected in open, gravelly soils than in compact ones. The fungus does not spread from tuber to tuber in storage.

Control — Destroy cull piles by burying them or by spraying with a herbicide. No varieties are immune to blight. Although the foliage of Sebago is somewhat resistant and the tubers highly resistant, this variety still requires up to 7 fungicidal sprays in a season.

The most important control measure is spraying or dusting with bordeaux mixture, fixed copper, nabam, maneb or another recommended fungicide. Apply the fungicide every 7 to 10 days, depending on the weather, from about July until the foliage begins to mature. Killing the foliage then with a herbicide reduces infection of the tubers.

See your provincial spray calendar for recommendations on the chemicals to use, the concentration, and the timing of applications. In some provinces, warnings are provided by meteorologists and pathologists through the newspapers, radio, and TV.

Gray Mold

Gray mold appears on the foliage late in the season and may be mistaken for late blight. This disease is rather common in the Maritime Provinces and has been reported from Ontario and Quebec. It is most common in areas that have high humidity and poor air drainage. It may also cause tuber rot.

Symptoms — A gray-green lesion with concentric rings appears on the leaves, often with an injury or a dried blossom at the center. The lesion is about the same size as a typical one of late blight, and may be covered by gray-green clusters of spores (Figure 5). In severe infections all the leaves are blighted and a soft gray rot attacks the stems. If the vines are disturbed as one walks through them, the spores billow up like a small cloud of dust. The tuber rot (Figure 6) is flabby, slightly watery, and odorless, and the tuber surfaces may be covered by black-brown resting bodies of the fungus.

Life cycle — The fungus overwinters as dark-colored resting bodies on crop debris of potatoes and many other hosts. In spring, the resting bodies produce spores in cuplike structures. When the temperature and humidity are favorable, the spores are released and blown to plant parts where they can grow. Often they infect dying parts of flowers, which act as centers of infection.

Control — On the foliage the disease is usually not serious. To reduce rot, allow the tubers to dry off well before gathering them, so that the skin may harden, and store them at about 60 to 65°F under high humidity for at least a week or 10 days. If you harvest on cold days and put tubers directly into storage at 40°F or below, gray mold may develop.

Early Blight

Early blight, or leaf spot, is a common foliage disease of potatoes. This blight attacks tomato, eggplant, and related plants. It appears slightly earlier in the season than late blight, but often causes its greatest damage to leaves late in the season if the weather is favorable.

Symptoms — Lesions appear first on older leaves as small, circular or oval, brown to black spots that gradually enlarge (Figure 7). The disease is readily identified by the close, concentric rings within each spot. The spots may unite, killing large areas and causing a

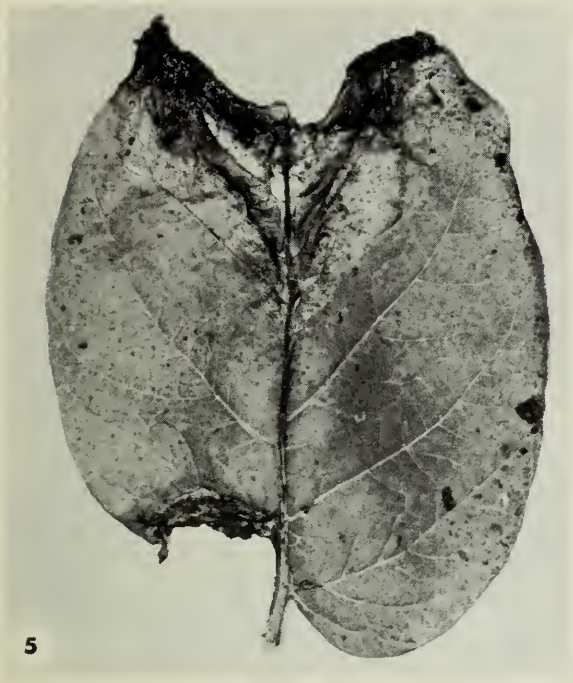

Figure 5 — Gray mold: leaflet with spores around lesion (top).

Figure 6 — Gray mold: tuber rot.

Figure 7 — Early blight on leaflet.

rolling that resembles tipburn. Warm humid weather intensifies the disease and the vines may die.

The fungus occasionally affects the tubers; the lesions are circular, about ⅛ inch deep, and have raised edges. Other rot-producing organisms may enter through the lesions.

Life cycle — Early blight is carried over from year to year on potato debris. In the spring, spores form on the debris and are spread to new growth by wind, rain, and insects. Under favorable moisture conditions the spores germinate and the fungus penetrates the leaf tissue to form lesions. At intervals through the summer more spores form on the lesions and spread the disease. In September and October, the fungus develops extensively on late varieties. After harvest, debris carries it into the soil.

Control — Where the disease is serious, burn the dead vines after harvest. Spray the foliage with a fungicide recommended for late blight. Begin when the disease appears and continue at 10-day intervals into September.

Because potatoes can become susceptible to early blight through lack of certain nutrients, keep the soil fertile by applying adequate fertilizers.

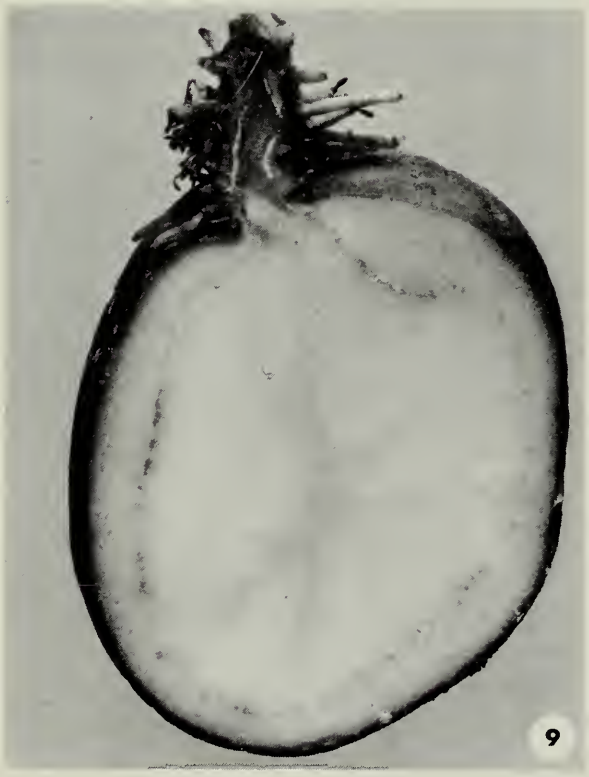

Figure 8 — Verticillium wilt in plant grown in infested soil.

Figure 9 — Verticillium wilt: tuber discolored in the vascular ring.

Figure 10 — Verticillium wilt: fungus growing on potato stem.

Verticillium Wilt

Verticillium wilt has been reported from every province in Canada except Newfoundland. The fungus has many other hosts, but wilt symptoms are not produced in some of them. The disease is more severe in southern Alberta, southwestern Ontario, and Nova Scotia than in other areas. Of the fields inspected for seed, verticillium and fusarium wilts together account for about 2 percent of the rejections. In table stock, they may reduce the yield by 20 to 25 percent.

Symptoms — About flowering time, the leaves wilt from the bottom of the plant upwards (Figure 8). The wilted foliage becomes yellow, then brown. Sometimes only one stem of a plant is affected, or a single stem may escape infection while the rest of the plant dies. If temperatures are low and the soil moisture high, a typical wilt does not usually develop but the plants turn yellow and wither from the base. Severely affected plants are stunted and die quickly.

In infected tubers the vascular ring is discolored (Figure 9): in Kennebec, shallow pink-brown lesions often develop around the eyes; this symptom is less common in other varieties. Also the vascular ring in the stolons and stalks is usually discolored.

Life cycle — The wilt usually develops from infected seed pieces or from contaminated soil. The organism (Figure 10) enters the plant through the roots and may penetrate most of the vascular tissue, including the tubers, as the season advances. The fungus may persist in the soil for 2 to 7 years, depending on the strain of the fungus and the crop rotation practiced.

Control — For treating the seed, mercury compounds are highly effective.

If the land is infested, practice a 3- or 4-year rotation including a cereal crop and hay but not tomatoes or strawberries. Tubers from a diseased crop should not be used for seed. Destroy all tops from infected crops.

Varieties differ widely in resistance to this wilt. Ontario, Houma, and Hunter are highly resistant; Sebago, Katahdin, and Green Mountain are slightly to moderately resistant; Irish Cobbler, Fundy, and Kennebec are highly susceptible.

Fusarium Wilt

Fusarium wilt has been reported from most of the provinces. It is often confused with verticillium wilt but is less important.

Symptoms — In general, this wilt can be distinguished from verticillium wilt by the extensive invasion of areas next to the vascular tissues (Figure 11). In wet, cold soil the underground part of the stem may rot early in the season, and the plant then wilts and dies. During hot, dry weather or late in the season the wilt may develop more slowly and there may be more extensive discoloration of the stem and new tubers. Sometimes the plant turns golden yellow, except for a few green leaves at the top.

If soil moisture is excessive, especially in irrigated areas, the base of the stem is girdled by a rot similar to that caused by rhizoctonia. The leaves roll upward, turn purple, and have a rosette appearance, and aerial tubers form.

Severely affected tubers are discolored in the vascular area and develop a dry, powdery rot at the stem end. New tubers may develop extensive watery rot.

Life cycle — Spores overwinter in potato debris in the soil or in infected potatoes in storage. During the growing season the fungus invades the roots and spreads through the plant into the tubers.

Control — Treat the seed and practice crop rotation and sanitation as recommended for verticillium wilt.

Figure 11 — Fusarium wilt: discoloration in stem.

Bacterial Ring Rot

Bacterial ring rot is one of the most serious diseases of potato in Canada. It is highly infectious, and is readily spread by potato cutters, planters, harvesters, and even containers. A field is rejected for certified seed if one diseased plant is found. Losses in table stock may be high because tubers may rot in the field or in storage.

Symptoms — The first symptom is a wilting and a slight rolling of leaflets of the lower leaves, usually soon after the potatoes bloom. One or more stems of a plant may wilt while the remainder appear healthy. The affected leaflets turn pale green, and pale-yellowish areas develop between veins (Figure 12). The disease develops rapidly in hot, dry weather. It may be difficult to recognize the disease in cool weather, in resistant varieties, or in fields affected by late blight.

Infected tubers may have reddish areas near the eyes or the skin may be cracked or swollen (Figure 13). Lightly infected tubers may appear healthy. When the tuber is cut across the stem end, a creamy-yellow to light-brown rot (Figure 14) shows in the vascular ring; the rot is crumbly to cheesy and odorless. If you squeeze a cut tuber between the thumb and fingers, a substance oozes from the affected part of the ring (Figure 15). Often, infected tubers are invaded by soft-rot organisms and may disintegrate, leaving only the outer shells. Such hollow tubers are often found in the field.

Life cycle — The bacteria overwinter in diseased tubers and on containers and implements. When infected seed is planted, the organism passes into the foliage, causing wilt. As the new tubers are formed, they are invaded through the stolons.

The disease is spread mainly by the


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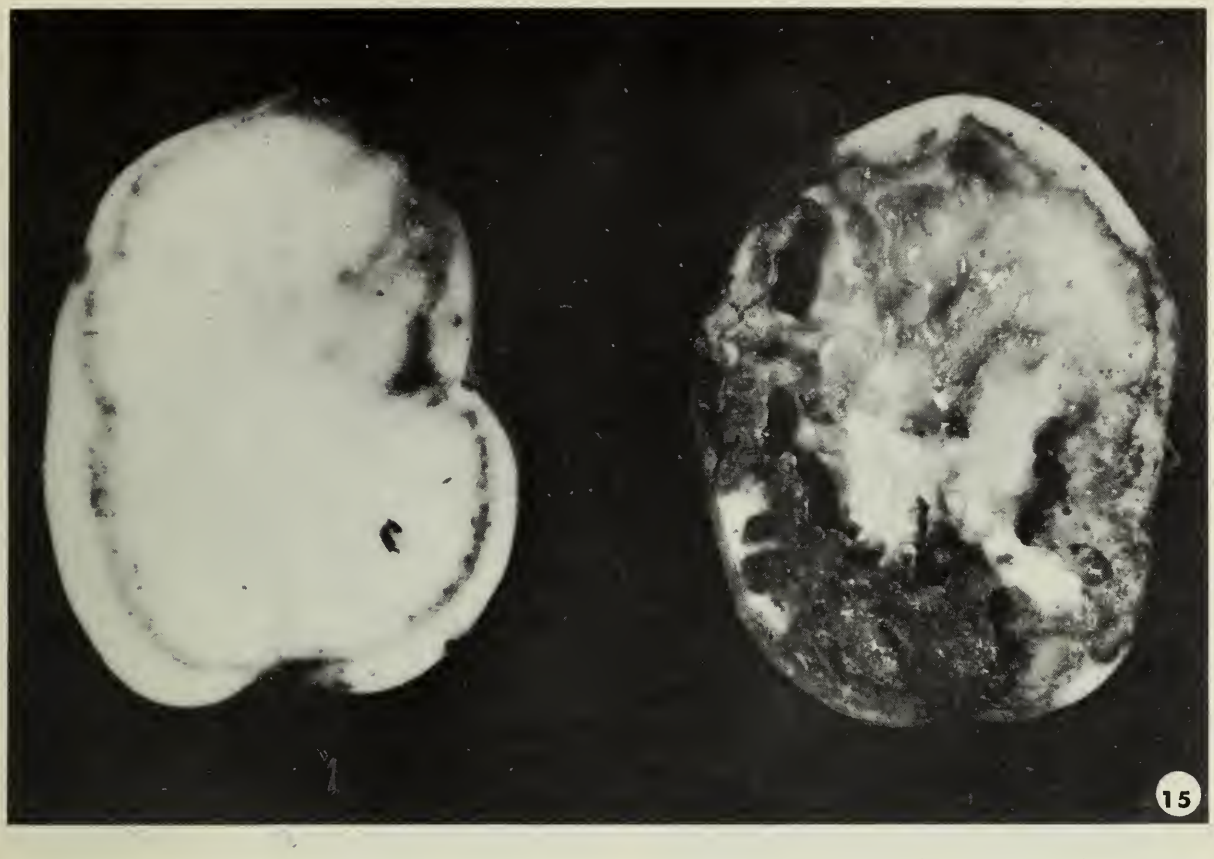

Figure 12 — Bacterial ring rot: leaflets of infected plant.

Figure 13 — Bacterial ring rot: severely affected tuber.

Figure 14 — Bacterial ring rot: infected vascular ring. Note the yellowish color of the vascular ring and the bacterial ooze.

Figure 15 — Bacterial ring rot: left, early symptoms in tuber; right, late symptoms.

knife used for cutting tubers into seed pieces and by potato planters, especially the picker type. It is spread from farm to farm by exchange of cutting, planting, and harvesting machinery and used jute bags and other containers.

Control — The only practical way to control ring rot is to plant seed that is free of the disease. In one season the disease may spread from a few infected tubers to 30 percent of the crop.

In growing certified seed, it is preferable to plant small whole tubers and so avoid using the cutting knife. If you cut the seed, disinfect the cutting knife continuously with mercuric chloride solution (1-1000).

If the disease is found on your farm, sell the whole crop without storing it. Clean and disinfect all your potato machinery, equipment, and storage space. Destroy all used bags.

If you borrow or lend potato equipment, be sure to disinfect it thoroughly before using it on your farm.

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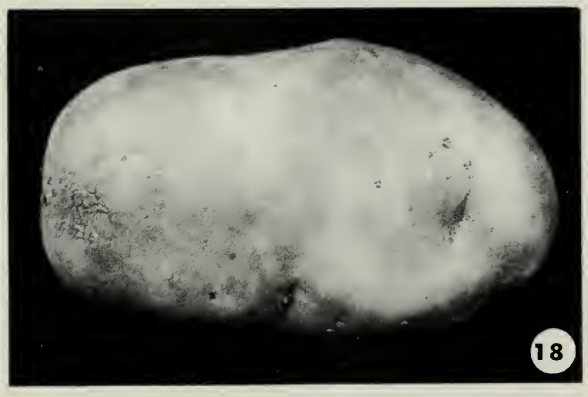

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Black Dot

Black dot occurs in nearly all the provinces. It reduces yield in some areas but in others it is of minor economic importance.

Symptoms — At flowering time the topmost leaf tips turn yellow, then entire leaflets, and later the lower leaves. The leaves may also curl and roll, usually during midsummer and fall.

Lesions, bearing overwintering bodies of the fungus, may form on the stem up to a few inches above the soil level, and also on the stolons and tubers (Figures 16, 17). When the lesions destroy the stolons, the yield is reduced, especially if the tubers are not mature. The lesions on the tubers are irregular gray or discolored patches (Figure 18).

Life cycle — The overwintering bodies of the fungus can survive for two years even in the absence of suitable hosts. In infested soil, the fungus attacks all underground parts of the potato early in the season. It also attacks tomatoes, cole crops, and cucurbits.

Control — Because the fungus carries over on the tubers, obtain seed from areas free of the disease. Also, avoid rotations with tomatoes, cole crops, or cucurbits.

Destroy diseased tubers soon after harvest, or disinfect them with an organic mercury or hot formaldehyde. Destroy all debris from infected crops.

As the fungus seldom attacks vigorous plants, follow good fertility and cultural practices.

Figure 16 — Black dot: overwintering bodies of fungus on stem and roots.

Figure 17 — Black dot: overwintering bodies of fungus on split stems.

Figure 18 — Black dot: tuber with lesions (left).

Figure 19 — Blackleg: lesion at base of stem.

Figure 20 — Blackleg: lesion at base of stem and at stem end of tuber.

Figure 21 — Blackleg and soft rot in tuber.

Blackleg

This disease is common in most of Canada and under favorable conditions can cause heavy losses in both seed and table stock.

Symptoms — About flowering time the upper leaves of one or more shoots roll upwards and the foliage gradually fades from deep green to yellow-green. The plant wilts and finally dies as the lower stem is girdled with rot. The name "blackleg" is derived from the inky-black color of the stem just above the soil line (Figure 19).

Tubers produced from infected plants have a central soft rot at the stem end (Figure 20). If secondary infection develops (Figure 21), the tubers have a putrid smell.

Life cycle — The bacteria causing blackleg overwinter in infected plant debris in the field, and in stored tubers. They may be spread at planting time by contaminated machinery and cutting knives. Infections usually begin in the seed piece and extend upwards into the

stem. Root maggots and nematodes may introduce the bacteria into wounds.

The disease is favored by cool, wet soil and by continuous cropping to potatoes.

Control — Control measures are similar to those recommended for bacterial ring rot.

To prevent the organism from spreading, disinfect the seed with mercuric chloride or Semesan Bel.

Varieties differ widely in resistance, the most resistant being Katahdin and Netted Gem. Irish Cobbler, Green Mountain, Cherokee, Pontiac, Hunter, and Kennebec are moderately resistant, but Sebago, Huron, and Fundy are very susceptible.

Figure 22 — Rhizoctonia: symptoms on tuber.

Figure 23 — Rhizoctonia: aerial and deformed tubers.

Rhizoctonia, or Black Scurf

Every year this disease causes serious losses somewhere in Canada. Losses have averaged as high as 15 percent, and in some years whole fields have been destroyed. The disease is caused by a soil-borne fungus of worldwide distribution. There are many strains attacking many different crops.

Symptoms — Symptoms on mature tubers are thin layers of brown scurf and irregular black lumps up to ¼ inch in diameter (Figure 22), often called the "dirt that won't wash off."

In the spring, the disease causes dark-brown lesions on roots, stolons, and sprouts, and may kill the part attacked. It may kill the tips of sprouts before they emerge, or cause cankers that girdle the sprouts so that they die later.

When plants are attacked after they emerge, the leaves become thick and sparse, roll upward, and turn slightly reddish. The stalks also thicken and may bear aerial tubers (Figure 23).

The underground tubers form in a cluster and are misshapen from crowding. On young tubers, injury ranges from shallow netting to growth cracks or shallow pits of dry rot.

Life cycle — The fungus lives indefinitely in the soil on plant debris. The resting bodies may be carried long distances on diseased plants or potato tubers. Under favorable conditions they germinate and invade potato stems, especially through wounds and breathing pores.

On organic soils, spores are produced as a grayish-white powdery film on the stem above the soil line. They are dislodged by wind or splashing rain and aid greatly in spread of the fungus.

Control — You may reduce losses by using a 3- or 4-year rotation, including a green cover crop plowed down before you plant the potatoes.

Before planting infected tubers, disinfect them with Semesan Bel.

It also helps to plant when the soil is warm enough to permit rapid growth. This allows some of the plants to escape the disease. Harvest the crop as soon as it is mature, as mature tubers are readily infected.

Violet Root Rot

This disease occurs on organic soils in a few places in Canada, including the Thedford Marsh in Ontario and several localities in Alberta.

Symptoms — The foliage may turn yellow, wilt, or die in patches. The underground parts of the plant are covered with a layer of fungus threads that range from pale buff or violet when young to violet-brown or chocolate when mature. The threads can be removed easily, but small dark spots remain on the skin of the tuber.

Life cycle — The fungus overwinters in the soil as small violet black lumps. Early in the spring these produce fungus threads, which develop into a violet mat around the bases of plants. Spores forming on the mat can spread the disease.

Control — Practice crop rotation and sanitation as recommended for rhizoctonia.

Potato Wart

Potato wart, a serious and destructive disease, is found only in Newfoundland and Labrador, where the cool weather and abundant rainfall favor its development. Surveys made between 1949 and 1964 showed that wart is most severe in farm land and garden plots around Conception Bay in eastern Newfoundland. Only a small area of the west coast of the island is infested.

Symptoms — Wart may develop on all parts of the potato plant except the roots (Figure 24). It consists of a rough, warty growth that varies considerably in size. On tubers, it ranges from a pustule the size of a pea to a mass covering the entire potato. When wart forms underground, it is white at first and then pinkish to brown and finally black. Above ground, it is green and then black. The wart masses usually break down and decay soon after turning black. Since the roots are not attacked, growth of the tops is not affected. Symptoms of wart do not appear before harvest unless the stalks are attacked.

Life cycle — The fungus can persist in soil for long periods without a host.

Figure 24 — Potato wart at base of stem and on tuber.

It may die out after 12 to 15 years of row-crop culture, but it can survive up to 25 years in grassland that is not cultivated. It persists as resting spores that germinate to release swimming spores in the presence of young plants of potatoes or tomatoes. These spores infect the host tissues and stimulate them into abnormal growth. When the warty growths decay, the resting spores that have been formed are released into the soil.

Control — The best way to control wart on infested land is to plant resistant varieties. At present, no varieties are immune to the race of wart in Newfoundland. But Kennebec, Sebago, and the Dutch variety Urgenta are highly resistant and will produce crops of wart-free tubers in infested land.

To avoid introducing wart, use seed grown in wart-free areas and do not use contaminated machinery or tools.

Keep wart from building up by practicing rotations of 4 or 5 years.

Eradication of wart from the soil by fungicides is possible but costly. Heavy applications of copper sulphate or formalin, followed by lime to neutralize the residual acidity are effective.

Powdery Scab

Powdery scab has been sporadic in Canada since 1913. It is most common in coastal areas where cool weather and wet soil favor its development. It is much less important than common scab but if severe it can spoil the appearance of tubers.

Symptoms — On young tubers, small gray pustules occur in patches or singly. At harvest the pustules dry and break down, leaving circular to oval pits, ¼ to 1/16 inch in diameter, that are filled with brownish powder (Figure 25). In storage a dry, sunken rot may develop about the pits. On roots, nodules may be formed.

Life cycle — The brown powder in the broken-down pustules consists of many spore balls. These spores are spread in the soil and on scabby tubers they are introduced to uninfested areas. They may remain viable for at least 5 years. They germinate during wet, cool weather and infect young tubers.

Control — Use scab-free land and a long rotation. Plant disease-free tubers.

Common Scab

Common scab, a soil-borne disease, occurs in every Canadian province. It is generally more severe in the west and in Ontario than in the Atlantic prov-

inces. Although the disease does not affect eating quality, scabby potatoes are unattractive to consumers and are wasteful because of the deep paring required. Severe infestations reduce yields. Traces of scab disqualify potatoes for seed.

This scab attacks tubers, stems, stolons, and roots. The organism infects tubers when they are young and expanding rapidly, and stimulates growth of corky tissue. It doesn't develop on tubers in storage.

The scab also occurs on turnips, sugar beets, garden beets, and radishes.

Symptoms — The first symptoms are minute reddish-brown lesions around the breathing pores of young tubers. They increase in size, turn dark, and form circular scabbed areas that are either isolated or in large corky masses (Figure 26). They may be superficial russetted spots or greatly roughened blotches.

Life cycle — The organism does not depend solely on potatoes and potato debris to carry it over from one year to the next. It is normally present in most soils but its abundance and behavior are affected by soil conditions.

Barnyard manure applied to the soil usually favors scab. The organism persists for many years in fields that receive heavy applications of manure or on sites of old barnyards.

The disease does not usually occur in soils with a pH below 5 but may be severe in soils with a pH of 6 or above. Warm, dry soils favor development of the disease.

Control — Be careful with applications of lime. Where it is necessary to grow legumes, or to correct excessive acidity, apply lime immediately after the potato harvest, and do not lime again until after potatoes reappear in the rotation. To most medium acid soils, apply ½ ton or less of finely ground limestone.

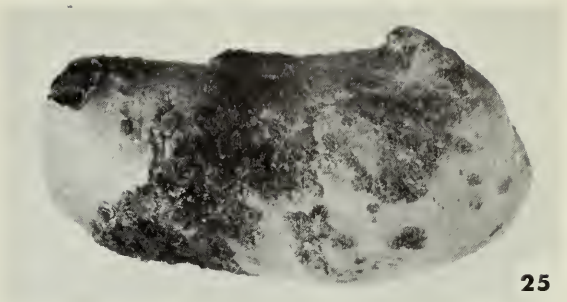
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Figure 25 — Powdery scab.
Figure 26 — Common scab.

When growing potatoes on mildly infested soils, use the acid fertilizer, ammonium sulphate, for normal nitrogen requirements.

Use a 3- to 5-year crop rotation, preferably with legumes.

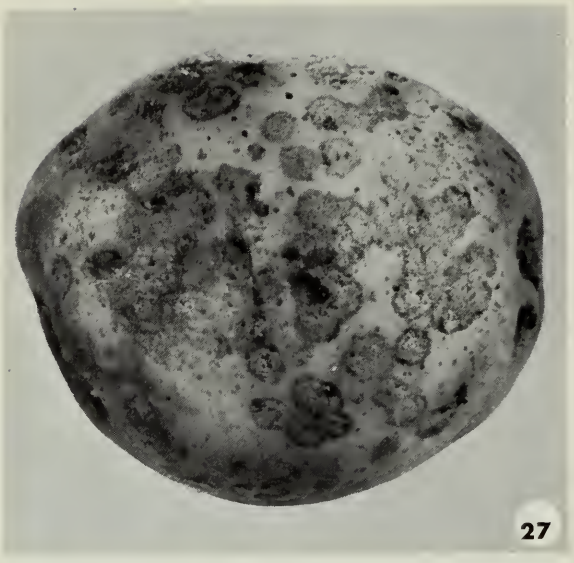
Do not add large amounts of fresh manure or debris to potato soils, and do not pile and burn dead potato tops or other refuse in fields.

Use scab-free seed on land free of scab or land that has not been planted previously to potatoes.

The most effective way of controlling scab is to plant resistant varieties. No variety is immune, but Avon, Huron, Netted Gem (Russet Burbank), Cherokee, and Sebago are moderately resistant.

Silver Scurf

Silver Scurf is a very widespread disease of potato tubers that has previously



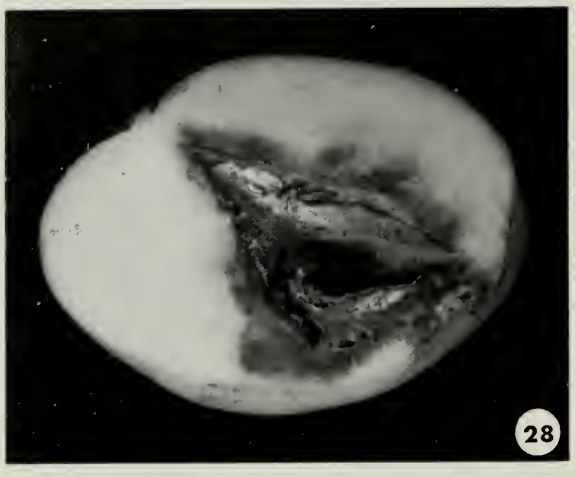


Figure 27 — Silver scurf.
Figure 28 — Fusarium dry rot.

been considered of little economic importance. However, the increasing demand for clean potatoes has recently made it a major problem. This is particularly true where potatoes are washed before being offered for sale in plastic bags.

Symptoms — Extensive round, dark spots form on the surfaces of the tubers. On wet tubers the spots are silvery and easily seen (Figure 27). After prolonged storage under warm, moist conditions, spores may form in the diseased spots and make the tubers look sooty or smudgy. In storage, the spores may infect healthy potatoes. The affected areas become black and may develop small black lumps.

Life cycle — The fungus lives in infected tubers and in the soil. The severity of the disease depends on the time at which the tubers are harvested: the later the harvest, the more severe the disease. Tubers may be infected to varying degrees, many of them showing no external signs of the disease.

Control — Harvest tubers as soon as they are mature, and cull out noticeably infected ones.

Dry Rot

Growers and shippers often suffer serious losses because of dry rot in potatoes held in storage. Also, under certain conditions, potatoes certified as healthy at the point of origin may develop serious rot in transit.

Symptoms — Dry rot may show first as a clearly visible shrinking and darkening of part of the tuber, or it may progress towards the center of the tuber and serious decay may occur before it is observed (Figure 28). Depending on the variety, the diseased tissue may be light brown to black and dry to slightly moist or cheesy. Cavities containing white threads of the fungus form in the rotted tissue. The cavity walls are often tinted salmon-pink or blue, and in the later stages of decay the white threads of the fungus may appear on the surface of the tuber.

Life cycle — The fungus that causes dry rot is present in most soils. It infects tubers only through wounds or bruises. The amount of decay in storage depends on the following: concentration of the fungus in the soil; amount of damage to the tubers during digging and harvesting; and susceptibility of the variety. The fungus does not attack growing plants. A hot, dry growing

season favors development of the fungus in the soil.

Control — Treat the seed with a mercury compound and avoid bruising tubers when harvesting and grading.

Varieties differ markedly in susceptibility to dry rot. Sebago, Keswick, and Kennebec are highly susceptible to one strain of the fungus (*Fusarium sambucinum* f.6), whereas Irish Cobbler, Hunter, and Netted Gem are moderately resistant. Hunter, Keswick, and Netted Gem are highly susceptible to another species (*Fusarium coeruleum*), whereas Kennebec, Sebago, and Green Mountain are moderately resistant.

Phoma Rot

Phoma rot is rare in Canada outside Prince Edward Island and New Brunswick, where it has been found as a storage rot. Sometimes infected potatoes are rejected for seed or table stock. The disease is often called "pocket rot" or "buttonhole rot."

Symptoms — The early symptoms are similar to those of dry rot. Phoma rot, however, usually affects only part of the tuber, whereas dry rot eventually destroys it.

Externally, tubers have circular brown to gray lesions resembling depressions caused by the thumb (Figure 29). Cracks may appear in the skin over the lesions. The tissue underneath is black, shrunken, and decayed (Figure 30), and on its removal a cavity bordered by firm, healthy tissue is left.

Life cycle — The fungus becomes abundant in infested soils planted to potatoes in successive years but declines

Figure 29 — Phoma rot.

Figure 30 — Phoma rot.

Figure 31 — Leak.

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rapidly under grain, hay, or pasture. The fungus cannot infect uninjured tubers but enters through wounds caused by rough handling or by diseases such as powdery scab. Phoma rot is spread by rain and soil water.

Control — To keep the disease from building up in infested land, practice crop rotations. Also, follow practices that reduce powdery scab.

Avoid wounding tubers during harvesting and grading.

Fundy, Katahdin, Kennebec, and Irish Cobbler are moderately resistant to the rot, but Sebago and Green Mountain are susceptible.

Leak

Leak occurs in all potato-growing areas of Canada. It is particularly serious in the moist soils of the lower Gaspé peninsula, and in years of heavy rainfall it can cause losses in the field and in storage in the Maritime Provinces. It is particularly troublesome on immature tubers dug on warm fall days.

Symptoms — Infected tubers of white-skinned varieties often have light- to dark-brown lesions on the surface. When tubers are harvested in hot weather, the lesions occur mostly at the stem end. The flesh of infected tubers is granular and very watery, and may range from cream through shades of brown to black. A dark-brown to black line on the skin (Figure 31) usually marks off the decayed area. Water may drip freely from tubers in the early stages of decay, especially if they are stored or shipped at high temperatures.

Life cycle — The fungus is present in many soils and attacks the roots of many plants. It invades potato tubers through cuts or wounds and is usually followed by bacteria and other fungi. The fungus can overwinter in plant debris, especially in wet soils.

Control — Do not grow potatoes on poorly drained soils. In wet years, dig the crop when it is fully mature and avoid bruising the tubers. Keep the potatoes as dry as possible and store them promptly at the recommended temperature and humidity.

Pink Rot

Pink rot has been found in coastal British Columbia, the St. Lawrence River valley, and occasionally in New Brunswick and Prince Edward Island. It has never been common in any of these areas, and has not caused serious losses. The disease is favored by high soil moisture and is found in low areas in fields, or in fields irrigated heavily late in the season.

Symptoms — The stem may have soft, watery rot near the ground level. The plant wilts and soon dies.

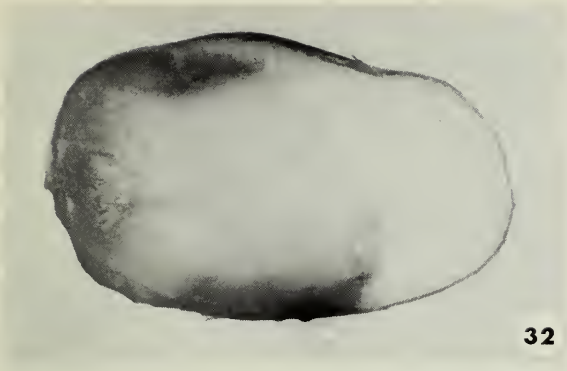
Infected tubers are dull brown, with darker-brown eyes and breathing pores. Internal rot usually begins at the stem end and is cream to light brown. The affected tissue is rubbery and, when it is squeezed, water runs out of it. When the tissue is exposed to the air it becomes pink, and on continued exposure turns dark brown to black (Figure 32).

Life cycle — The spores of the organism are found in roots, stolons, tubers, and stems. Tubers are infected through the stolons or wounds or by contact with diseased tubers in storage. Under very favorable conditions they may be infected in the soil, through the eyes, breathing pores, or wounds.

Control — Use healthy seed and avoid growing potatoes on the same land in consecutive years. Rogue all diseased plants and destroy their tubers. Avoid irrigating heavily late in the season. If only part of a field is infested, harvest and store the potatoes separately.

Soft Rot

Bacterial soft rot is very widespread and usually occurs in association with



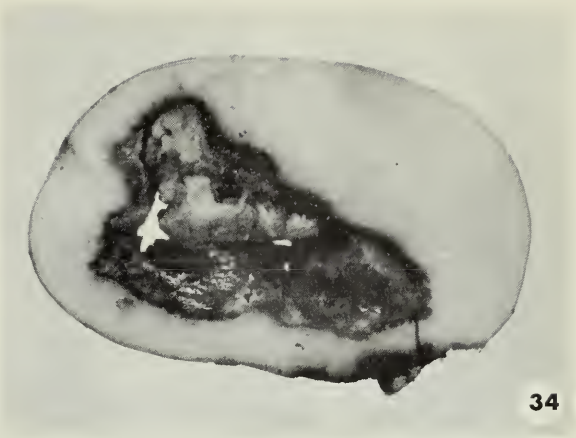


Figure 32 — Pink rot.

Figure 33 — Soft rot beginning at lenticels on tuber.

Figure 34 — Soft rot in advanced stage.

other diseases such as late blight, leak, pink rot, and blackleg. It may follow freezing injury and may be serious in transit or storage if the temperature and humidity are not maintained properly. In wet years it may cause considerable damage.

Symptoms — When the tubers are infected through the breathing pores, blisters formed in the affected tissues collapse to produce sunken areas 1/8 to 1/4 inch in diameter. These give the tuber a pockmarked appearance (Figure 33). If the tubers are infected through large bruises, the external lesions are blisterlike; when they are pressed, rotten tissue squirts out. Infected areas are at first cream-colored but later become gray-brown and ooze a foul-smelling, slimy, stringlike mass of bacteria and decomposed cells (Figure 34). A dark border usually separates diseased and healthy tissue.

Life cycle — The organism lives in the soil, and dirt adhering to tubers at harvest is a source of infection. The organism invades tubers through injuries or lesions caused by other organisms. Infected tubers can spread the disease to healthy ones in storage.

Control — Control of other tuber diseases helps greatly in controlling soft rot. Avoid injuring the tubers, especially when they are immature. During the first week or ten days of storage maintain a temperature of 60°F and adequate ventilation to promote rapid healing of wounds. If the potatoes are to be shipped an appreciable distance by rail or by boat, this healing is very important.

Pink Eye

Pink eye, or "brown eye," is common in Nova Scotia and is found occasionally in Prince Edward Island and New Brunswick.

Figure 35 — Pink eye.

Figure 36 — Pink eye invading tuber.

Symptoms — At harvest the tubers are pink to brown in patches around the eyes and at the eye end (Figure 35). The lesions are little more than skin-deep, but the whole tuber may become a rotten mass after infection by other rot organisms (Figure 36).

When cut, the rotted tissue is rather dark, tinged with green, and has a sweetish odor, whereas ordinary soft rot is colorless and foul-smelling.

Life cycle — Pink eye is associated with verticillium wilt. The organisms causing pink eye are probably present at all times on the tuber surfaces and gain entry to tissues weakened by the wilt.

Control — Control of verticillium wilt also controls pink eye.

Seed-piece Rot

Seed-piece rot can be caused by late blight, early blight, fusarium rots, phoma rot, blackleg, and bacterial soft rot. Control of these diseases helps to reduce the amount of seed-piece rot.

The rot may also be caused by maggots, freezing, low soil temperature, excess soil water, and improper use of disinfectants or fertilizer.

VIRUS DISEASES

Several viruses attack the potato and any one may be spread to healthy plants, tuber sprouts, and seed pieces from diseased plants or tubers. Most of these diseases do not affect the eating or selling qualities of potatoes for table stock, but all reduce the size or number of tubers produced. They are the main cause of rejection of fields for seed, and the reduction in marketable yield is comparable to the reduction in size and vigor of infected plants.

Ever since potatoes have been grown commercially, growers have noticed that continuous planting from the same stock has caused plants to deteriorate in vigor, and tubers to become smaller. This deterioration, or "running out," is now known to be due to virus diseases and is the chief reason most table-stock growers must change their seed often.

The viruses are spread to healthy plants by contact with diseased ones or by sap-feeding insects. Those that cause

the most common severe diseases are spread by aphids. The typical symptoms of infection are dwarfing of the plants; mottling, distortion, or rolling of the leaves; or black streaking on the veins. If the veins have black streaks, the leaves soon shrivel, die, and hang from the stems. The commonest virus diseases found in potato fields are mosaics.

The mosaic diseases are a group of three forms called simple, mild, and rugose mosaics. These blend into one another and each form is caused by a different virus or combination of viruses. The mosaic or mottle is most prominent in cool, dull weather, such as may occur during the early part of the growing season.

Though most of the mosaic viruses have distinctive symptoms, some strains of them have symptoms resembling those of other viruses in the group.

Simple Mosaic

This is the commonest of all virus diseases and it is found in almost every crop of susceptible varieties grown for table stock.

Symptoms — The plants are mottled in shades of light and dark green (Figure 37), varying from very conspicuous to barely noticeable. The mottle is most obvious in cool, dull weather. The leaves are not wrinkled, and they and the plants are not reduced in size.

The tubers have no obvious defect.

Cause — The disease is caused by potato virus X, which is spread to healthy plants mainly by brushing or rubbing of foliage: usually by the hands or damp clothing of roguers, by implements, or by animals that have been in an infected crop. It may spread when plants touch in the wind, and also by contact between roots or between seed pieces or their sprouts, and by the cutting knife.

Control — Use a high grade of certified seed. Rogue out plants with obvious mosaic, including the seed pieces, as soon as they are detected.

Mild Mosaic

This disease is found in most potato-growing areas, but because it is more obvious than simple mosaic it can be kept under control more easily by roguing.

Symptoms — Leaves of plants with mild mosaic have a light-green to yellowish mottle. The leaves are slightly wrinkled or smaller than normal, and the plants are slightly dwarfed.

Usually the tubers have no obvious defects.

Cause — This disease is usually caused by two viruses in combination. When a plant infected with virus A or X becomes infected by the other of these viruses, mild mosaic develops.

Control — Some varieties are so resistant to virus A that for practical purposes they are called immune to this virus. However, if the disease does appear in crops of these varieties it can be due to a severe strain of virus X alone. Roguing, the use of certified seed, and

Figure 37 — Simple mosaic: faint mottle.

Figure 38 — Rugose mosaic.

control of aphids that spread virus A are the most effective ways of controlling the disease.

Rugose Mosaic

Rugose mosaic is the most serious of the mosaic diseases and the symptoms are easily distinguished from those of simple and mild mosaics.

Symptoms — In the first year that a plant is infected, the symptoms are different from those in the following years. Black streaks develop in the veins, leaf stalks, and stems, causing the leaves to shrivel and remain hanging from the plant by a thread of dead tissue. Later the plant is reduced to bare stems with a few leaves at the top, giving a "palm tree" effect.

Tubers from infected plants produce plants with symptoms that caused the disease to be named rugose mosaic. Usually the fully developed leaves are mottled, wrinkled, distorted, and reduced in size and the leaf stalks are brittle (Figure 38). The whole plant is usually dwarfed and is called rugose because of its rough appearance.

Tubers from infected and from healthy plants are clearly different when observed in bulk. Affected tubers are much smaller, but they have no other symptoms of the disease.

Cause — Rugose mosaic is usually caused by an aphid-borne virus called virus Y, alone or in combination with either or both viruses A and X. However, there are many strains of virus Y and symptoms vary in severity according to the strain.

Control — Roguing throughout the growing season, use of certified seed, and control of aphids are the most effective ways of controlling the disease. If possible, grow potatoes intended for seed on a part of the farm where the prevailing wind will not bring in aphids from other potato fields. At present, there are no varieties on the market that are immune to virus Y, but many popular varieties are fairly resistant.

Leaf Roll

This disease is found wherever potatoes are grown and aphids are abundant. Causes other than viruses may produce symptoms similar to those of leaf roll, for example, the rolling of the bottom leaves or of all the leaves of plants during dry weather.

Symptoms — The foliage symptoms are of two kinds. *Primary* leaf roll occurs when a healthy plant is infected during the growing season. *Secondary* leaf roll occurs when the plant is infected because the virus was present in the seed piece.

Primary leaf roll: If a plant is infected early in the growing season, the upper leaves begin to roll and become pale green and stiffer than normal as the plant approaches maturity. Plants affected late in the season may not show any symptoms.

Secondary leaf roll: The symptoms appear when the plant is quite young, and on new growth as it develops. The margins of affected leaves roll upward,

Figure 39 — Leaf roll: typical symptoms.

Figure 40 — Leaf roll: net necrosis in tuber.

and the tissue becomes dry, leathery, and thicker than normal. The leaves are brittle, and rattle when shaken. The plants are stunted, light green, and erect. In some varieties the leaves become slightly red or purple at their bases (Figure 39).

Diseased tubers may be smaller or fewer than normal, or both, so that the marketable crop is reduced. The surface of the tuber appears normal, but tubers of some varieties with primary leaf roll may show net necrosis when cut. This is a network of brown strands, or dead tissue, extending through the tuber near the stem end (Figure 40). The tubers from plants with primary leaf roll, whether showing symptoms of net necrosis or not, produce plants with secondary leaf roll.

Cause — Leaf roll is caused by a virus that is spread by the four species of aphids common on potatoes. Several strains are known and it is thought that the different strains account for the various degrees of severity of the disease, often found in the same variety.

Control — Follow the practices recommended for rugose mosaic. No commercial varieties are immune or notably resistant to leaf roll.

Spindle Tuber

Spindle tuber is not so widespread as mosaic or leaf roll, but it is serious in some areas because it affects a high percentage of the plants. It got its name from the shape of tubers produced by diseased plants.

Symptoms — Affected plants are erect, slightly stunted, and usually darker green than normal. The leaves are set at a sharp angle to the stem, making the plant look stiff. Only when stiffness and dwarfing are well developed is the plant conspicuous (Figure 41). The disease is most obvious in hot weather.

In most varieties, the tubers are longer than normal, are thinnest near the center, and sometimes crack. The eyes are more numerous and shallower than usual (Figure 42).

Cause — The disease is caused by a virus that is spread to healthy plants by contact with infected plants, by cultiva-

tion equipment, and by aphids, flea beetles, and biting insects.

Control — Since the foliage symptoms are often difficult to identify, roguing tuber-unit seed is the most effective method of control. Disinfect the cutting knife if the disease is known to be in the seed stock.

Purple-top Wilt

This disease is widespread in Canada. Because all potato varieties are susceptible, it sometimes causes severe losses.

Symptoms — Vigorous short branches grow out from the junctions of the main stems and the normal branches. The short branches swell at their bases and often have aerial tubers. Leaflets on the upper branches do not enlarge normally but roll at their bases and, depending on the variety, may be tinged pink, purple, or yellow (Figure 43). Except for the color, symptoms are much the same for all varieties. Dead tissues within stems just above ground level cause the vines to wilt a few weeks after the plant symptoms have developed fully.

Some tubers become flabby and produce hairlike sprouts the following spring. If plants become infected late in

Figure 41 — Spindle tuber: typical foliage.

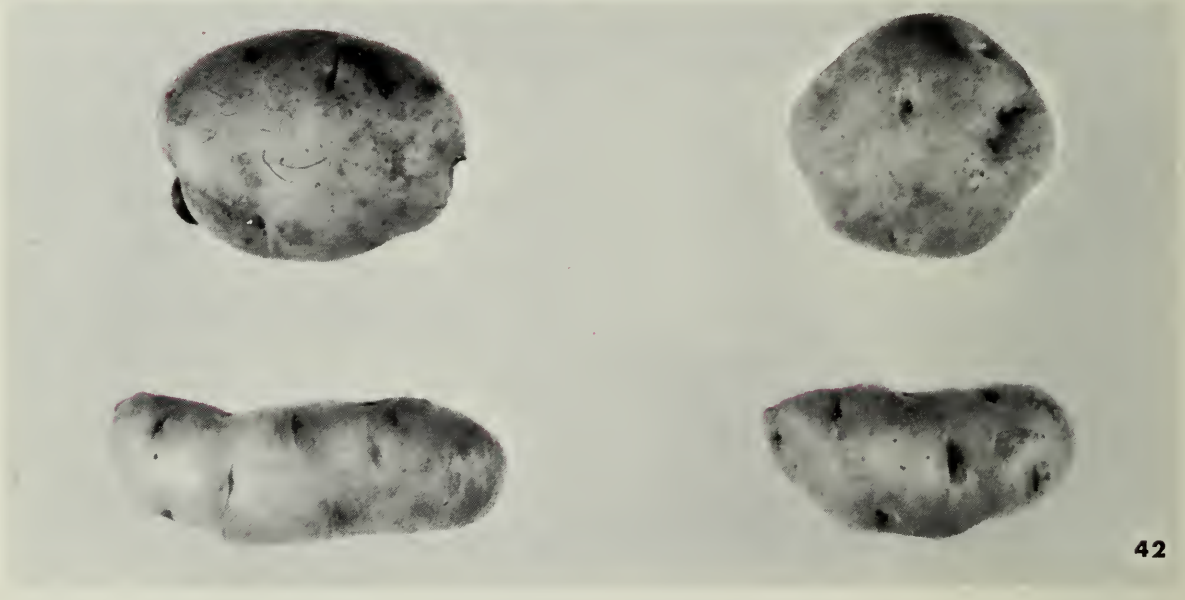


Figure 42 — Above, healthy tubers; below, spindle tubers of the same varieties.

Figure 43 — Purple-top wilt: left, early symptoms; right, late symptoms.

the season the tubers produced may escape infection.

Cause — The disease is caused by the aster yellows virus, which is spread from overwintered weeds, clover, and other plants by the six-spotted leafhopper.

Control — Plant certified seed. Eradicate weeds around the headlands. Control leafhoppers with insecticides, and grow potatoes in fields as far away as possible from clover fields.

Figure 44 — Calico: leaf symptoms.

Calico

This disease is found only rarely and so is of little economic importance.

Symptoms — The foliage symptoms are distinctive but they do not appear until well into the growing season. Though the leaves are not dwarfed, they are strongly mottled with pale to bright-yellow blotches (Figure 44).

The tubers may be misshapen and cracked, and few to the plant.

Cause — Calico is caused by a virus closely related to the alfalfa mosaic virus. The source of infection is usually nearby fields of clover or alfalfa, or volunteer potato plants still growing in the field from a previous crop. The virus is carried to potato plants by aphids.

Control — If you plant potatoes in an alfalfa or clover field that was severely infected with alfalfa mosaic, destroy volunteer alfalfa and clover plants.

Witches'-broom

Witches'-broom is found in Canada but is important only in British Columbia.

Symptoms — When healthy plants

Figure 45 — Witches'-broom: typical foliage, numerous stolons, and small tubers.

become infected, they are dwarfed, the leaves are lighter green than normal, and often the margins are reddish yellow. The buds at the junctions of the main stem and the branches grow and make the plant bushy.

Plants from infected seed have many shoots. These produce side shoots, making the plant look very bushy and erect. The stems and petioles are round and smooth (Figure 45).

The stolons are abnormally white and long, and bear numerous small tubers, often in chains. As the aboveground symptoms develop, the newly formed tubers sprout and produce slender plants.

Cause — The disease is caused by a virus but the method of spread in the field is not yet known. At least three strains of the virus have been found.

Control — Eliminate from planting stocks all tubers that have premature sprouts, especially hairlike ones. Rogue out plants that have symptoms of the disease.

Yellow Dwarf

Although this disease has a serious effect on both plants and tubers, it is not widespread in commercial potato crops.

Symptoms — The foliage is dwarfed, wrinkled, and yellowish green, and the upper surfaces of the leaves are rough. The growing tips of the plants die early and the stems develop a yellow tinge. This is hastened by warm, dry weather. When diseased stalks are cut, rusty-brown specks are found inside.

The tubers are small, irregular, and cracked. The cracks evidently start at the bud end and look like growth cracks. When tubers are cut they usually have brown spots scattered in the central area and towards the bud end.

Cause — The disease is caused by the yellow dwarf virus, which is spread by the clover leafhopper (*Aceratagallia sanguinolenta* [Prov.]). This insect can retain the virus during the winter and infect healthy plants in the spring.

Control — Plant certified seed as far as possible from clover fields and rogue diseased plants throughout the growing season.

Haywire

Haywire is most common in British Columbia but is not of economic importance.

Symptoms — Affected plants are dwarfed, have a bunchy or rosette appearance due to an increased number of sideshoots, and have shortened top growth. The leaflets are rough, stiff, erect, rolled, pointed, and slightly yellow.

Seed pieces may produce little tubers instead of plants. Diseased plants produce no tubers or set only a few close to the stem.

Figure 46 — Wilding: large, heart-shaped terminal leaflets.

Cause — The disease is considered to be due to a virus because it has been spread by grafting from infected to healthy plants. It is suspected that the disease is spread by some insect.

Control — The only known method is by roguing.

VARIATIONS

From time to time, potato plants have types of foliage or habits of growth that are not normal for the variety. When plants grown from the tubers are abnormal in the same way, they are called *variations*. Some of the variations may affect yield or time to maturity and therefore are of commercial importance. But whether or not the variations affect the yield, they are still important because foliage and habits of growth are characters used in identifying varieties. A change in appearance will cause doubt as to identity.

The commonest and most important of the variations are wildings and giant hill. Minor variations, such as stitched end and little leaf, have been found in various parts of Canada.

Wildings

Though wildings are common only in western Europe, they probably occur in Canada more often than has been reported.

Symptoms — Wildings have darker-green and smoother foliage than normal plants of the same variety and they

Figure 47 — Stitched end: abnormal tuber and sprouts.

Figure 48 — Left, healthy plant; right, plant affected with little leaf.

mature earlier. They rarely flower, and the short, numerous stems make the plant look bushy. Leaflets at the fringe of the plant are very large and heart-shaped (Figure 46).

Wildings produce several times as many tubers as normal plants, but most are too small for sale.

Cause — The cause is unknown. In countries where wildings are common, they reduce the yields so much that they are grouped with severe virus diseases for certifying seed.

Control — Planting sets from large tubers and roguing are the only known methods of control.

Giant Hill

Giant hill is common in all varieties and is important because of its effect on yield and time to maturity. The plants mature much later than normal ones of the same variety, so that the disorder is most serious when it occurs in varieties grown for the early market.

Symptoms — The stems are tall and vigorous, but fewer than normal. Each has many flowers, so that the plants are conspicuous in a crop that has reached full growth. The profusion of flowers is especially noticeable in varieties that normally have little or no bloom. The plants stand out most when the normal foliage is maturing because they remain green much longer. They appear to be more resistant to late blight than normal plants because they become susceptible later. They are readily infected by late blight about 2 or 3 weeks after normal plants, but then they are damaged just about as much.

Giant hill may not reduce the yield if the plants are allowed to mature, but the tubers are usually few, large and rough.

Cause — The cause is unknown. Giant hill is most common in northern areas, where there are long periods of daylight each day during most of the growing season. Some varieties are more prone to produce these abnormal plants than others.

Control — Rogue out affected plants when normal ones are past the flowering stage and giant hill plants are still blooming profusely.

Stitched End

This abnormality, considered to be genetic, affects both the foliage and the tubers. It has been reported only from western Canada. The plants have broad, flat stems. The tubers are usually flat, especially the bud end, which looks like a wound that has been stitched. Infected tubers sprout early (Figure 47).

Little Leaf

This abnormality (Figure 48) has been observed in Eastern Canada, chiefly in Sebago. Small leaflets are the most noticeable feature. During early growth the plants appear normal, but later many stems and stolons develop and the whole plant becomes dwarfed. All parts of an affected plant are small, especially the leaflets, the stolons, and the tubers.

FOLIAGE PESTS — CHEWING

Colorado Potato Beetle

This insect is found across Canada. Both the larvae and the adults feed on the leaves of the potato. Unless controlled, they soon strip and kill the plants so that tubers do not develop or the yield is greatly reduced. This insect is one of the agents that spread spindle tuber, bacterial wilt, and bacterial ring rot.

Description and life cycle — The females lay orange-yellow eggs on the undersides of the leaves in bunches of a dozen or more (Figure 49). They hatch in 4 to 9 days.

The larvae are humpbacked and reddish with prominent black spots. They pass through four similar stages, each larger than the one before. They become full-grown in 2 to 3 weeks, when they are little more than ½ inch long. Then they go into the soil, form cells, and change to yellowish, motionless pupae. In 5 to 10 days the adults emerge.

Only the adults survive the winter, in the soil at a depth of 8 to 10 inches.

Figure 49 — Colorado potato beetle: upper row, eggs and larvae; lower, full-grown larva in soil, pupa, and adult.

They are about ⅜ inch long and ¼ inch wide, and have black and yellow stripes that run lengthwise on the wing covers.

Control — To control either the adults or the larvae, apply one of the following:

	Rate per acre
Azinphosmethyl	
spray concentrate	
2 pounds per gallon	1½ quarts
Carbaryl	
50% wettable powder	2 pounds
DDT	
emulsible concentrate	
2½ pounds of DDT per gallon	1½ quarts
50% wettable powder	2 pounds
Endosulfan	
emulsible concentrate	
2 pounds per gallon	1 quart
50% wettable powder	1 pound

Preferably apply the insecticide early to kill the adults before they lay eggs. Repeat as often as necessary.

Flea Beetles

The potato flea beetle is found in every province except British Columbia, the western flea beetle only in Alberta and British Columbia, and the tuber flea beetle only in British Columbia. Adults of all three species eat small, round, irregular holes in the leaves (Figure 50). Larvae of the tuber flea beetle usually feed on the new tubers, but those of the other two species feed mainly on the fine rootlets and only occasionally on the tubers.

All three species may spread bacterial diseases and spindle tuber. Damaged tubers may be unmarketable, and are readily infected by scab and rhizoctonia.

Description and life cycle — The females lay tiny eggs just below the soil

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Figure 50 — Leaf damaged by flea beetles.

Figure 51 — Tuber damaged by grubs of the western flea beetle.

Figure 52 — Tuber damaged by grubs of the tuber flea beetle.

Figure 53 — Tuber flea beetle: adult. About 25 times natural size.

surface, near the plants. The eggs hatch in about 10 days.

The larvae are whitish, slender, cylindrical grubs with brownish heads. They are only ⅛ to ½ inch long when full-grown. In the tubers they make a network of fine tunnels (Figures 51, 52). Rough pimples form on the surface where they enter, and cracks where their tunnels come together. Wide cracks sometimes look like common scab.

The grubs become full-grown in 4 to 5 weeks and then change into pupae. The adults emerge 7 to 10 days later.

The adults (Figure 53) are small beetles about 1/16 inch long that jump when disturbed. They spend the winter under leaves, grass, or trash along the margins of fields and in protected places. They emerge in the spring and feed on various weeds and cultivated plants until the potato plants appear. The adults do most damage to the potato foliage soon after the plants come up and again in August, when a new generation appears.

The life cycle is usually completed in 4 to 6 weeks.

Control — Insecticides applied to the leaves will kill the adults before they can lay their eggs. Three to six applications are usually required, depending on the season and the locality.

To control adults of any of the species, apply one of the insecticides listed under the Colorado potato beetle.

To control the tuber flea beetle, apply one of the following before planting and work it thoroughly and quickly into the soil:

	Rate per acre
Dieldrin	
2.5% dust	160 pounds
Chlordane	
5% dust	140 pounds
65.5% emulsible concentrate	1¼ gallons

Do not repeat the application to the same soil more than once in 3 years.

Potato Stem Borer

This moth is found in Eastern Canada. The caterpillars feed first in the stems of grasses and later move to larger plants, especially ragweed, as they grow. They seldom attack potatoes except on newly plowed grassland that has been overrun with weeds. They cause the stalks to wilt and die.

Description and life cycle — The eggs are laid on grasses in late summer and hatch in May. The larvae become full-grown by late June and pupate in the soil. The moths are found from mid-June to September.

Control — Practice clean cultivation, especially along the margins of fields. When intending to plant potatoes on sod land, plow it as soon as possible after haying and keep the weeds down. When potatoes are infested, burn the stalks or plow them under as soon after harvest as possible.

Stalk Borer

The stalk borer is seldom a pest of potatoes. It has been found in all provinces from Manitoba eastward except Newfoundland. The caterpillars tunnel in the stalks and cause the plants to wilt and die. In large fields they usually attack only the plants along the borders.

Description and life cycle — The eggs are laid in the fall on dead grasses, especially couchgrass and other weeds.

The caterpillars appear in late spring and feed first on young grasses. As they grow, they move into larger plants, especially weeds. They are very restless and often move from the stem of one plant to that of another. They become full-grown in about 80 days, and then enter the soil and pupate.

The adults are dark olive-brown moths about ⅕ inch long. The begin emerging in September and live about 15 days.

Control — Practice clean cultivation as recommended for the potato stem borer.

Blister Beetles

Several species of blister beetles are found in Canada. They vary from one area to another in both species and importance.

The adults feed on a wide variety of broad-leaved plants, including potatoes

and legumes. They are ⅓ to 1 inch long (Figure 54). They may be black, gray, brown, blue, spotted, or striped. They usually feed in swarms, and move about a great deal.

Life cycle — The eggs are laid in the soil in late June or July. The larvae feed mainly on grasshopper or cricket eggs. The adults usually emerge in June.

Control — When the beetles attack, apply DDT promptly and thoroughly. Use DDT as a spray at 1½ pounds of 50 percent wettable powder per acre.

Cutworms

Many species of cutworms attack potatoes and they vary greatly in abundance from year to year. The adults are commonly known as miller moths.

Some species cut the stems at soil level, causing the plants to fall over and wilt. Others feed on the roots and underground stems. Some may occur in great numbers and strip many plants as they crawl by the thousands from field to field.

Some of the species overwinter as caterpillars, and others as pupae.

Description and life cycle — The eggs are laid in the soil or on grasses and weeds.

The larvae are gray or brownish, hairless caterpillars. When full-grown, they are 1 to 2 inches long. Most of the species live in the top layer of soil or debris during the day and feed at night.

The adults are medium-sized, heavy-bodied moths, usually dull brown or gray. They fly mostly at night and are sometimes seen around lights.

Control — Where cutworms regularly cause damage by cutting the stems at soil level, it is best to apply a dust before the plants emerge. Use DDT at 2 to 3 pounds of the active ingredient per acre, or toxaphene at 2 pounds. For control later in the season, make a second application.

Figure 54 — Adult of a blister beetle. About 3 times natural size.

Grasshoppers

Grasshoppers are a problem mainly in Western Canada, several species usually being found in each locality. They damage mainly the foliage of potatoes, and some species spread spindle tuber and unmottled early dwarf diseases.

Description and life cycle — The eggs are laid in late summer or early fall in packetlike masses, or pods, just below the soil surface. They hatch in April, May, and June.

The newly hatched young look like the adults except that they are smaller and have no wings. They shed their skins usually five times and become adults with wings in late summer or early fall.

The adults feed until the first heavy frost. Those of some species often fly many miles to new feeding grounds.

Control — Summerfallow stubble fields if the grasshopper forecast indicates that eggs are plentiful. Begin surface tillage in the fall and repeat in the spring.

If an insecticide is needed, use toxa-

phene at 2½ pounds of the active ingredient per acre as a dust or at 1½ pounds in a spray; 80 percent carbaryl wettable powder at 10 ounces; or 43.5 percent dimethoate emulsible concentrate at ½ pint.

FOLIAGE PESTS — SUCKING

Green Peach Aphid

This small, soft-bodied insect feeds on many kinds of plants and is common across Canada. It is pale yellowish green (Figures 55, 56) and is found mostly on the undersides of leaves on the lower half of the potato plant.

This aphid spreads the viruses of leaf roll, rugose mosaic, mild mosaic, and spindle tuber. Also, toxins it introduces may cause curling, mottling, wrinkling, streaking, and premature death of leaflets and also of the plants in dry seasons. It may reduce yields.

Life cycle — The eggs overwinter on peach and plum trees. In the spring, the eggs produce only females, both winged and wingless. These and all later generations on potatoes give birth to young females, some of which become winged and fly from field to field.

In the fall, winged females usually appear on the potato plants and fly to peach and plum trees. They give birth to wingless, egg-laying females. Males then appear from the summer host plants and mate with the wingless females, which lay the overwintering eggs.

If the climate is mild enough, as on the Pacific coast, eggs are not laid and females continue to give birth to young females throughout the winter. Even in colder areas this is possible in storehouses and on house and greenhouse plants.

Control — Certain insecticides that are taken into the plant sap kill most of these aphids and also reduce the spread of leaf roll. A single application of one of the following at planting time is usually effective for the season: 20 pounds of 10 percent disulfoton or of 10 percent phorate per acre.

Some foliage sprays or dusts are also effective against these aphids. Begin spraying or dusting 2 weeks after the plants emerge. Make a second application in 2 weeks, a third and fourth at 7-day intervals, and a fifth after 10-14 days. Use any one of the following:

	Rate per acre
Malathion	
50% emulsible concentrate	1½ pints
Endosulfan	
emulsible concentrate 2 pounds of endosulfan per gallon	1 quart
3% dust	40 pounds
Diazinon	
50% emulsible concentrate	¾ pints
50% wettable powder	¾ pounds
Dimethoate	
emulsible concentrate 4 pounds per gallon	10 fluid ounces

Buckthorn Aphid

This is the smallest of the four species of aphids found on potato. It is green

Figures 55-59 — Female aphids. 55, Green peach aphid, winged (×18). 56, Green peach aphid, wingless (×19). 57, Buckthorn aphid (×25). 58, Foxglove aphid (×11). 59, Potato aphid (×7). All of these females are the forms that give birth to young aphids. (Magnifications are approximate.)

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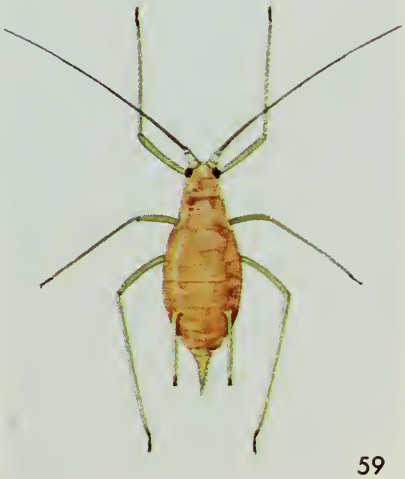

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or lemon yellow (Figure 57), and is found mostly on the middle and bottom leaves. It occurs in spots in a field except in very dry years, when it may spread evenly throughout the field in enormous numbers and kill the vines prematurely.

This aphid spreads leaf roll, mild mosaic, and rugose mosaic.

Life Cycle — The eggs overwinter on the branches of buckthorn. In the spring they hatch into females that give birth to young females, some of which become winged.

The winged ones migrate to a wide range of summer host plants such as ladysthumb, shepherdspurse, yellow cress, zinnia, and especially potato. Several generations, mostly of wingless females, develop on these plants at a rate of about one generation a week in ideal weather.

Later in the summer or in the fall, winged males and females appear and return to the buckthorn. The winged females give birth to wingless females, which mate with the winged males and lay overwintering eggs on the buckthorn.

Control — Follow the same practices as for the green peach aphid.

Foxglove Aphid

This aphid (Figure 58) is seldom abundant. It may be light green, yellow green, or a shiny dark green. It is larger than the green peach aphid but smaller than the potato aphid.

This aphid spreads leaf roll, and also introduces toxins that affect the plants like those of the green peach aphid.

Life cycle — The eggs overwinter on foxglove and hawkweeds. Females hatch in the spring and give birth to young females, all wingless. By the third generation, winged females are usually produced and some of these fly to potato and other plants.

During the summer there are several generations but few if any of the aphids are winged. In the fall, aphids that remained on foxglove or hawkweeds throughout the summer produce wingless males and females. After mating, these females lay overwintering eggs on these plants.

Control — Follow the same practices as for the green peach aphid.

Potato Aphid

This is the largest of the aphids found on potato. It is usually some shade of green (Figure 59), but may be red, brown, yellow, orange, or even purple. It is usually found at the growing tips of the potato plants and, if numerous, may cover the flower stalks.

This aphid spreads leaf roll, mild mosaic, rugose mosaic, and spindle tuber. It covers the upper leaves with sticky honeydew. The toxins it introduces may cause curling, mottling, wrinkling, streaking, and premature death of the leaflets and, if abundant, may kill the plants. It reduces yields.

Life cycle — The eggs, which are black and glistening, overwinter on rose bushes. They are also laid on strawberries, raspberries, and apples but spring colonies seldom develop on these plants. In the spring, wingless females hatch and for about 2 weeks give birth to young females, some of which become winged.

In summer the winged females fly to various plants, usually some member of the nightshade family such as potato, tomato, or tobacco. Some thirty plant families also act as summer hosts for this aphid, the most common being lambsquarters, hempnettle, and ladysthumb. There are several generations of winged and wingless females during the summer.

Winged males and females appear in late summer or early fall and fly to roses. On these plants the winged females give birth to wingless females that

mate with the winged males and produce eggs.

Control — Follow the same practices as for the green peach aphid.

Tarnished Plant Bug

This insect attacks a wide variety of economic plants and weeds throughout Canada. It feeds by piercing the plant tissues and sucking the sap. This destroys flowers and may make the leaves curl and the new growth wilt. The insect also spreads spindle tuber.

Life cycle — The insect passes the winter as an adult (Figure 60). It becomes active early in the spring and attacks many early flowering plants.

The eggs are laid singly in the plant tissues or in the florets. They hatch in about 10 days.

The nymphs are yellowish green. They shed their skins five times and gradually come to look like the adults.

The adults are strong fliers. They overwinter under many kinds of shelter, especially plants that remain semierect in the fall.

The life cycle is completed in 3 or 4 weeks and there may be two to five generations a season.

Control — To help keep the insect down, clean up weeds and so destroy its wintering places. If an insecticide is needed, apply DDT or endosulfan at the rates given for flea beetles.

Potato Leafhopper

The potato leafhopper is common in Eastern Canada, is abundant in southern Ontario, and also occurs in Manitoba and southern Saskatchewan. Both adults and nymphs feed by sucking the sap from the leaves and stems. While feeding, they introduce into the potato a toxin that causes hopperburn. In affected plants the tips and margins of the leaflets cur upward, turn yellow,

Figure 60 — Adult of the tarnished plant bug. About 6 times natural size.

and finally become brown and brittle. The plants die early and yield is reduced.

Description and life cycle — The eggs are laid in slits in the leaf veins and stems. They hatch in 7 to 10 days.

The newly hatched nymphs are pale

Figure 61 — Adult of the potato leafhopper. About 24 times natural size.

green and resemble the adults except that they have no wings.

The adults (Figure 61) are small, wedge-shaped, pale green, and very active. They begin to lay eggs about 5 days after the final nymphal stage and there are two or three generations a year. They do not overwinter in Canada but migrate from the United States in late April or May.

Control — Several applications of an insecticide may be necessary for adequate control. Begin about mid-June and continue at 10-day intervals throughout July. Use one of the following:

Sprays	*Amount per acre*
DDT	
50% wettable powder	2 pounds
Methoxychlor	
50% wettable powder	4 pounds
Malathion	
25% wettable powder	4 pounds
Carbaryl	
50% wettable powder	2 pounds
Dusts	
DDT, 5%	20 pounds
Malathion, 4%	25 pounds

Four-lined Plant Bug

This insect, a minor pest of potatoes, has been reported as far west as Saskatchewan. It punctures the leaves and causes conspicuous dark spots to form. These may later dry and fall out, leaving holes in the leaves.

Description and life cycle — The eggs overwinter in the tissues of various herbaceous weeds. They hatch in May and early June.

The newly hatched nymphs resemble the adults except that they are smaller and are wingless. They feed on young weeds, becoming full-grown by the end of June.

The adults scatter to feed on many kinds of plants, including the potato. They are apple green and have four black stripes down the back.

There is only one generation a year.

Control — Practicing clean cultivation and burning weeds and crop refuse in the fall or early spring help to destroy many unhatched eggs.

Six-spotted Leafhopper

This insect is important on potato because it spreads aster yellows or purple-top wilt disease. The adults usually take up the virus while feeding on infected weeds and other plants, and spread it when they feed on healthy potatoes. The leafhoppers are common in all the provinces and the Northwest Territories.

Description and life cycle — Eggs overwinter on fall-sown rye, wheat, barley, and wild grasses. They begin to hatch in May. The nymphs are black and wingless when newly hatched, but usually light yellowish after the first molt. They become full-grown in about 3 weeks.

The adults are about ⅛ inch long, wedge-shaped, and usually olive green to dark greenish brown. As the cereals and grasses mature, the adults that have developed on them disperse to vegetables, including potatoes, or weeds.

There are two or more generations a year.

In the prairies and southwestern Ontario, adults migrate in great numbers from the southern United States. They begin egg-laying in mid-May on winter cereals, spring-seeded oats, or early vegetables. As some of these adults are infected with the virus when they arrive, they are usually the main source of purple-top wilt in these two areas.

Control — Keep potatoes and nearby crops free of weeds. Destroy all weeds in headlands and adjoining areas to reduce breeding sites. If purple-top wilt has

Figure 62 — Tubers unmarketable because of feeding by the potato psyllid on the foliage.

been found in your area, apply an insecticide beginning about mid-May even though the leafhoppers may be scarce. Use one of the following, at 7- to 10-day intervals:

Sprays	*Amount per acre*
DDT	
50% wettable powder	3 pounds
25% emulsible concentrate	2 quarts
Malathion	
25% wettable powder	4 pounds
50% emulsible concentrate	1½ pints
Dimethoate emulsible concentrate 4 pounds per gallon	10 fluid ounces
Dusts	
DDT, 5%	30-40 pounds
Malathion, 4%	25-30 pounds

Potato Psyllid

This insect has been reported from Quebec, Saskatchewan, Alberta, and British Columbia. Feeding by the nymphs causes a disease known as psyllid or potato yellows, which closely resembles leaf roll and aster yellows. It causes the outer leaves to curl and turn light green or yellow. The tubers grow slowly and many are too small to be marketable (Figure 62). Aerial tubers may also form in the leaf axils.

Description and life cycle — The eggs are lightly yellow to orange, spindle-shaped, and suspended from the leaves on short stalks. They hatch in 3 to 8 days.

The nymphs, pale green and tiny, sit flat on the leaves. They become full-grown in 13 to 17 days. They secrete a white wax that may often be seen on the leaves and on the ground.

The adults are very active and are sometimes called jumping plant lice. They overwinter in the United States and migrate north in late May and June.

There may be as many as ten generations in a season.

Control — Apply an insecticide four or five times at 10-day intervals beginning when the plants are 4 or 5 inches high. Use DDT at 2 pounds of 50 percent wettable powder per acre, or 2 quarts of 25 percent emulsible concentrate, or 35 to 40 pounds of 3 percent dust.

TUBER PESTS

Potato Scab Gnat

The maggots of this gnat usually live on soil fungi and decaying vegetable matter. Sometimes they feed on potato seed pieces, and on the tubers in the field or in storage. When abundant they may attack the stems of the plants as well as the seed pieces. They may weaken or kill the plants and lower the grade of the tubers. Injury to the developing tubers (Figure 63) resembles that caused by common scab. The insect thrives in alkaline soils and those that are only slightly acid.

Description and life cycle — Eggs are laid in soft spots on tubers, on cut seed, and in loose soil. They hatch in 4 to 8 days.

The larvae, very small white maggots with black heads, take 11 to 14 days to mature. They then leave the tubers, conceal themselves in debris, and pupate.

The adults emerge 2 to 7 days after the maggots pupate, and breed almost at once. They are dusky-brown flies about 1/16 inch long. The females are wingless, the males winged. They overwinter in potato fields, and on potatoes in storage if enough moisture is present.

Figure 63 — Tuber damaged by maggots of the potato scab gnat.

There are several generations a year in the field.

Control — The scab gnat seldom attacks potatoes in strongly acid soils (pH about 5). If it is a pest, use clean seed and follow a crop rotation.

White Grubs

White grubs damage potatoes by eating large, circular holes (Figure 64). The injury is seldom seen until harvest time unless skunks dig up the tubers to eat the grubs.

Description and life cycle — The insects need up to 3 years to grow from egg to adult. In most areas, damage may be severe only every third year, usually the one after the adults are numerous.

The pearly white eggs are laid from mid-May to the end of June in grassland or patches of weeds in cultivated fields. They hatch in 2 to 3 weeks.

The grubs of most of the species develop as follows. During the first year they feed on the fine roots of plants from July to September and then move down into the subsoil for the winter. In the second year they move upward as the soil warms in the spring, and begin feeding a few inches below the surface. They feed vigorously, mainly on roots and tubers, and return to the subsoil to hibernate. During the third year, most of the grubs (Figure 65) remain in the subsoil and develop into beetles 6 to 8 inches below the surface in the late summer.

The adults stay in the soil until early May of the next year. They are large, hard-shelled beetles known as May or June beetles (Figure 66). They feed at night on the foliage of many trees, and lay their eggs during the day. They are often seen around lights.

Control — It is usually enough to

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Figure 64 — Tuber damaged by white grubs.

Figure 65 — A fully developed white grub. About natural size.

Figure 66 — A June beetle. Nearly twice natural size.

avoid planting potatoes on land that has been in sod for 2 years or more, or to till the soil at the right time of the insect's life cycle. Summer tillage alone, especially in the first or the second year of the cycle, may give satisfactory control. The best time to till the soil to kill the first-year grubs is from late July to September; for second-year grubs, from early May to late June.

If you plant potatoes on sod land the year after June beetles are abundant, apply an insecticide. Apply one of the following before planting and work it into the soil:

	Amount per acre
DDT	
emulsible concentrate 2.5 pounds per gallon	10 gallons
50% wettable powder	50 pounds
Chlordane	
emulsible concentrate 8 pounds active per gallon	5-10 pints
40% wettable powder	13-25 pounds

Do not treat oftener than once every four years.

Wireworms

Various species of wireworms are major pests of potatoes in Canada. They feed on the seed pieces and may kill the plants or retard their growth. They chew deep pits or holes in the new tubers (Figure 67) and so lower the grade and often make them unmarketable. More important, they provide entrance points for rhizoctonia and blackleg.

Figure 67 — A tuber damaged by wireworms.

Figure 68 — Full-grown wireworms.

Figure 69 — An adult of a wireworm. About 7 times natural size.

Description and life cycle — The eggs are laid in late spring. They hatch in 3 to 7 weeks.

The young larvae feed on the seed pieces, roots, and tubers of the growing plants. They take 2 to 5 years to become full-grown (Figure 68), depending on the species. They feed in the upper layers of the soil in spring and summer, and move down in hot dry weather and to pass the winter. They often gather in groups, and sometimes 50 or more are found in one tuber.

The adults (Figure 69) are slender, hard-shelled beetles about ½ inch long. They are called click beetles because of their habit of snapping themselves into the air with a click when placed on their backs. The adults develop about midsummer but remain inactive in the soil until the following spring.

Control — Cultural practices and crop rotations help to keep wireworms from damaging potatoes. Because there are different species in different areas and their habits differ as well as the crops,

soil, and climate, the practices must suit local conditions.

Generally, wireworms increase in numbers in sod. If there is one wireworm or more per square foot of land you should treat the soil, or else avoid planting potatoes before the third season after breaking the sod.

If an insecticide is needed, broadcast applications are usually the most effective. When broadcast and worked into the soil, chlordane and dieldrin are usually effective for 3 to 5 years. Apply one of them at the following rate:

	Amount per acre
Chlordane	
emulsible concentrate	
8 pounds of chlordane	
per gallon	5-10 pints
Dieldrin	
5% granular	40 pounds

Do not treat the same soil again for at least 4 years.

Because the species differ from area to area, use the insecticide and cultural practices recommended by your local agricultural authority. Some species die out rapidly under tillage, but others increase. A few species increase under irrigation.

Seed-corn Maggot

This maggot is a pest of potatoes chiefly in the Maritime Provinces, Quebec, and Ontario. The damage is greatest in cool, wet seasons. The maggot usually attacks the seed piece, through unhealed injuries or diseased surfaces. It may spread the bacterium that causes blackleg.

The maggot is a common pest of beans, corn, and peas.

Description and life cycle — The eggs of the first generation are laid in May or June in soil where decaying vegetable matter is plentiful. They hatch in 2 or 3 days.

The maggots usually mature in 7 to 12 days, but take longer if the weather is cold. They pupate in the soil, the pupae taking 2 to 3 weeks to develop into adults.

The adults are flies about $\frac{1}{5}$ inch long. They are greenish or grayish to nearly black and look like small house flies.

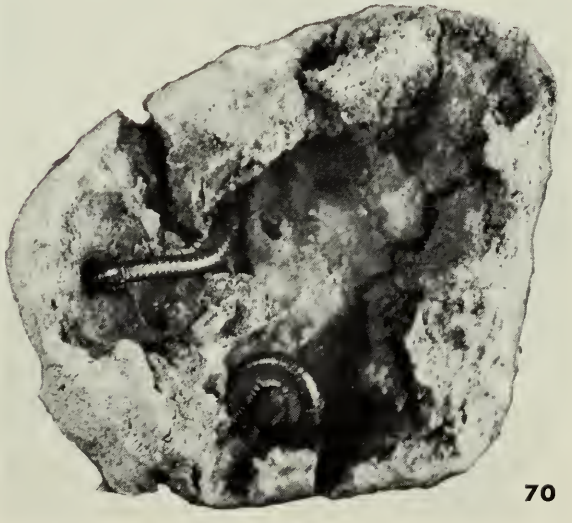
There may be two or more generations a year, depending on the season.

Control — Dip the seed pieces in a mixture containing 50 percent diazinon wettable powder at 1 ounce in $7\frac{1}{2}$ gallons of water. You may combine the insecticide with Semesan Bel or captan for control of seed-borne diseases. Dry the seed thoroughly. Plant on well-drained, warm land.

Millipedes

Millipedes are sometimes mistaken for wireworms and do much the same damage to potatoes. The adults are hard, slender, gray to purple-brown, and wormlike. Their bodies are divided into many segments, each with two pairs of legs; they have more than 50 pairs in all. Both the adults and the

Figure 70 — Millipedes feeding on a seed piece.



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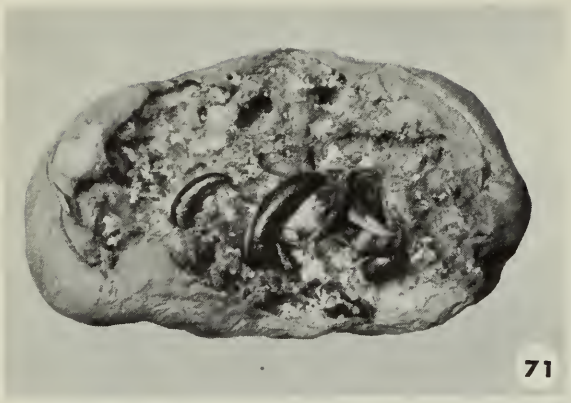


Figure 71 — A potato being damaged by slugs.

earlier stages usually feed on decaying vegetable matter.

They enter potatoes through injuries caused by insects or disease and are especially destructive in cold, wet seasons. They tunnel into the tubers and may also feed on the planted seed (Figure 70).

Life cycle — The eggs are laid in the soil in clusters of 20 to 100. They hatch in about 3 weeks. The young ones are small "worms" with fewer legs and segments than the adults. They grow very slowly. There is probably only one generation a year.

Control — Millipedes thrive in land that is heavily manured. Avoid planting potatoes soon after manuring. If a pesticide is needed, use one of the treatments recommended for wireworms.

Slugs

Slugs may damage the tubers severely (Figure 71). They also injure the plants by eating the stalks and foliage, especially young shoots. They need hiding places, feed at night or on dull days, and are most destructive in wet climates and seasons. Several species attack the potato.

Description and life cycle — The eggs are laid in the fall and spring, in groups in damp places under debris or in the soil. They look like little balls of jelly, and can stand heat, cold, and drying.

Figure 72 — Potato-cyst nematode: cysts on potato roots and in the soil. About 45 times natural size.

They turn yellow before they hatch, in about a month.

The larvae are very small and look like the adults except in size.

The adults are from 1 to 8 inches long, depending on the species. They are grayish or brown, slimy, legless, and soft-bodied. They leave shiny trails made by a slimy substance given off from their bodies.

Control — Long grass, plant rubbish, and sacks and boxes left on the ground make hiding places for slugs during the day. Avoiding these may be enough to prevent damage.

Metaldehyde baits are highly attractive and toxic to slugs. Use a commercial bait or prepare one by mixing 1 ounce of powdered metaldehyde with 4 quarts of bran (3 pounds with 100 pounds). Apply it in the evening between the rows in small piles the size of a 50-cent piece.

Copper in any form is also toxic to slugs. Mix one part by volume of dehydrated copper sulphate with ten parts of hydrated lime, and apply the dust at 40 to 60 pounds per acre. Apply it in the evening after dark, when most of the slugs are out feeding.

NEMATODES

In most stages of their life cycle the nematodes, or eelworms, that attack potatoes are invisible to the naked eye. Of the four species found in Canada, cysts or galls of three can be seen on the roots.

Potatoes may not be sold for seed from areas infested by the potato-cyst nematode or the potato-rot nematode.

Potato-cyst Nematode

The potato-cyst, or golden, nematode is found in Canada only in Newfoundland, where it is widely distributed in the northern and eastern areas and in the Saanich Peninsula of Vancouver Island. Every precaution is being taken to keep this nematode from becoming established on the mainland.

The nematode feeds only on potato, tomato, and related plants, but it may persist in the soil for as long as 15 years without feeding.

Symptoms — In the field the first sign of the presence of the nematode is that the plants in one or more areas are stunted and, in dry spells, wilt. The affected plants may die. On the roots, cysts form (Figure 72) which are visible to the naked eye. These are spherical, about the size of a common pinhead, and white or yellow. When they mature they become brown and drop off the roots. In a heavy infestation the roots are short, swollen, and brownish.

Life cycle — The cyst, or resting stage, contains the eggs. The young nematodes, or larvae, hatch and emerge from the cysts in the presence of excretions from the roots of growing potato or related plants. Only a certain percentage of the larvae hatch each year and therefore cysts may contain viable larvae for several years.

The larvae enter the roots to feed. They become adults in 4 to 7 weeks, depending on the temperature. They develop little at temperatures below 55°F.

After being fertilized, the female becomes rounded and most of her body comes outside the root. Then she is white, most of her internal organs have degenerated, and her body is becoming a cyst full of eggs. She gradually turns yellow, then brown, and finally dark brown. At this stage the cyst is mature and has a tough, protective skin. The

cysts usually mature in September or October, though at harvest some white or yellow females may be found on the roots.

Control — The best means of control on heavily infested land is to grow potatoes not more than once every 5 years. This reduces the infestation enough for the yield to be normal. On lightly infested land, grow potatoes once in only 3, or preferably 4, years.

Early varieties are usually not infested as heavily as late varieties.

It is possible to control the nematode by fumigating the land with a commercial mixture of dichloropropene and dichloropropane, with specially adapted cultivators. The treatment, however, is expensive and is profitable only on irrigated land.

Root-knot Nematodes

Two species of root-knot nematodes attack potatoes in Canada. The northern root-knot nematode is the more widespread. The southern root-knot nematode has been found on potatoes in British Columbia only.

Severe damage by these nematodes is rare. Each of them infests many species of plants, tomatoes being readily infested by both.

Symptoms — These nematodes form distinctive galls (Figure 73) on the potato roots. Those formed by the northern root-knot nematode are less than ¼ inch in diameter; those formed by the other species, from ¼ to 2 inches. The nematodes sometimes attack the tubers, forming small nodules on the surface.

Light infestations usually escape notice. In a heavy infestation, either species may damage the roots severely. Then the plant is stunted, wilts in dry spells, and yields less than a normal plant.

Figure 73 — Tomato roots infested by root-knot nematodes. (Damage to potatoes is similar.)

Figure 74 — Potato-rot nematode: external symptoms.

Life cycle — The two species have similar life cycles.

The eggs overwinter in the galls on the roots. On hatching, the larvae enter the roots of suitable plants. As they feed, the roots form oversized cells, and hence the galls.

When the females mature they lay their eggs within the galls, or in a gelatinous envelope attached to the female.

Some of the eggs hatch even though suitable plants are not available, so that in 5 or more years the nematodes die out in the absence of suitable plants.

Control — The most effective way to control these nematodes is to grow non-susceptible crops for at least 4 years in succession. Grasses and grains are not susceptible.

Fumigating the land with a commercial mixture of dichloropropene and dichloropropane controls the nematodes but is usually not profitable.

Potato-rot Nematode

The potato-rot nematode occurs in three small areas in Prince Edward Island, where it was found in 1945, and near Vancouver in British Columbia. It infests both potatoes and bulbous iris.

The nematode causes most damage during storage. All the crop from a badly infested field may rot.

Symptoms — The nematode begins to feed on the tuber just under the skin, and the early injury cannot be seen unless the tuber is peeled. The injured area is a small pit, about ⅛ inch in diameter, surrounded by a snow-white ring. To detect the nematode it is necessary to examine the affected tissue under a microscope.

Later the damage is readily visible without peeling the tuber. A slight hollow, ½ inch or more wide, develops in the skin. The tissue in the hollow area gradually dies and dries out, and irregular, three-cornered cracks (Figure 74) develop along the margin. As the damaged area enlarges, the area of dry, cracked skin also enlarges, so that a sack of damaged potatoes rustles as if it were filled with wrapping paper.

Bacteria and fungi enter the tuber through the affected area and cause rot, either wet or dry. The rot causes most of the damage.

Life cycle — This nematode feeds mainly on fungi and can survive in fallow soil for several years. In Prince Edward Island it increases in numbers in fields with clover, as clovers there are subject to a fungal root rot in the second and later years.

The nematode overwinters as adults or as larvae.

In potato fields the larvae feed on the roots, and later the tubers. In tubers they grow best when they bring fungi with them. Few nematodes survive in rotted tubers.

Control — Growing potatoes on the same land for 2 or 3 years in succession controls this nematode. The potatoes act as a trap crop. Most of the nematodes are removed from the field at harvest. If the whole tuber rots, in storage or in the field, the nematodes die.

A short rotation is helpful, such as one of potatoes, grain, and grass with alfalfa, or a root crop such as rutabagas. Alfalfa is suitable as it is not susceptible to the nematode.

To control a heavy infestation, fumigating the land with ethylene dibromide is effective but is usually not profitable.

Manganese Toxicity

Manganese toxicity may occur when potatoes are grown in soils that are highly acid.

Symptoms — Excess manganese causes black flecks on the plant stems and leaf stalks, the condition being known as a stem streak necrosis. The flecks soon develop into long streaks or areas of black, dead tissue (Figures 75, 76). The older leaf stalks become brittle and fall off at a light touch. In severe cases, areas between the veins of the leaflets die and are readily visible on the undersides.

Varieties differ in susceptibility to manganese toxicity. Keswick and Cherokee are the most susceptible and Kennebec and Norgleam the least. The dead areas do not usually show until the plants are well developed. Streaks caused by viruses, late blight, or other diseases can be confused with those caused by excess manganese.

Control — The best safeguard against manganese toxicity is adequate use of lime. Have your soil analyzed to determine the proper amount of lime that may be applied without favoring scab.

Magnesium Deficiency

Magnesium deficiency is common on the highly acid soils of eastern Quebec and New Brunswick. It may also occur in other provinces.

Symptoms — Potato plants growing in soil deficient in magnesium are lighter green than normal ones. The loss of color begins at the margins of the lower leaves and gradually spreads between the veins toward the centers of the leaflets. In advanced stages of the disorder, small areas between the veins become brown and die and eventually the entire leaf turns brown and may drop off. The lower leaves of affected plants are usually brittle, unlike those that yellow when maturing.

When the deficiency is mild, only the lower leaves show symptoms. When it is

Figure 75 — Manganese toxicity: dead spots and streaks on stem of potato.

Figure 76 — Manganese toxicity: spots on leaf.


75


76

severe, the entire plant is yellow and stunted.

The symptoms are usually most evident after a warm, dry period.

Control — If the soil is low in magnesium or is highly acid, apply a fertilizer containing 1 percent magnesium oxide (MgO). If you use dolomitic limestone as a source of magnesium, have your soil analyzed to determine the amount that may be applied without favoring scab.

Internal Sprouting

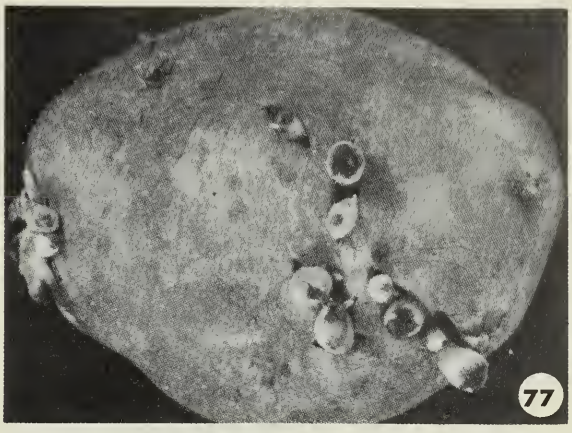
Internal sprouting is a problem when potatoes are stored for long periods at temperatures near 60°F for reconditioning when making chips.

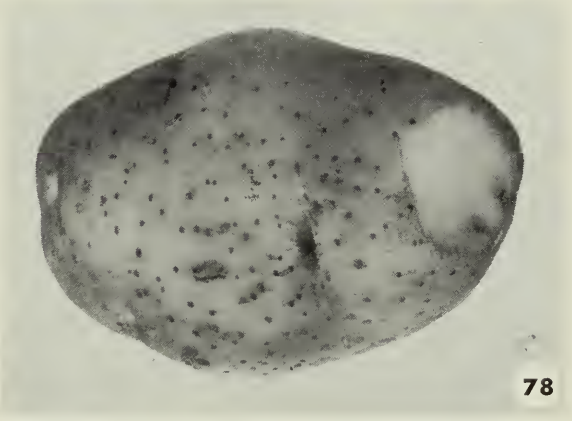
Symptoms — Sprouts grow inward and cause bulges and cracks in the tubers (Figure 77). Sometimes small new tubers develop inside the mother tuber.

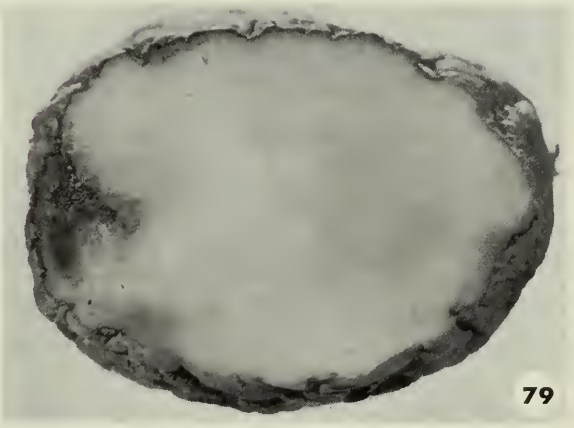
Cause — Any condition that hastens the aging of tubers favors internal sprouting. Potatoes may age rapidly in hot, dry weather before harvest, at high storage temperatures, and from repeated desprouting.

There is no evidence that sprout inhibitors cause this disorder.

Control — If you must store potatoes at a temperature above 50°F, use a sprout inhibitor. Avoid deep piling of tubers in storage.







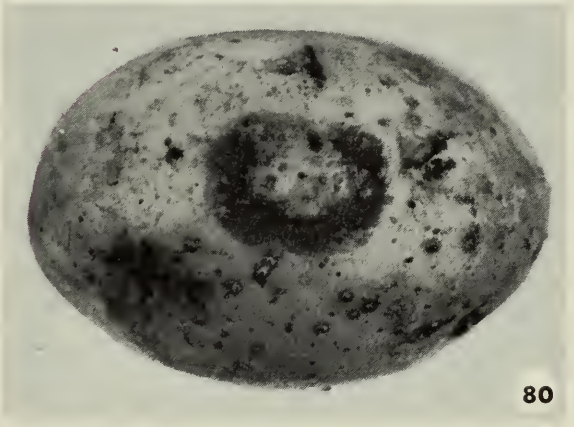


Figure 77 — Internal sprouting in stored potato.

Figure 78 — Internal black spot at stem end of freshly dug potato.

Figure 79 — Internal black spot in stored potato.

Figure 80 — Pressure bruise in stored potato.

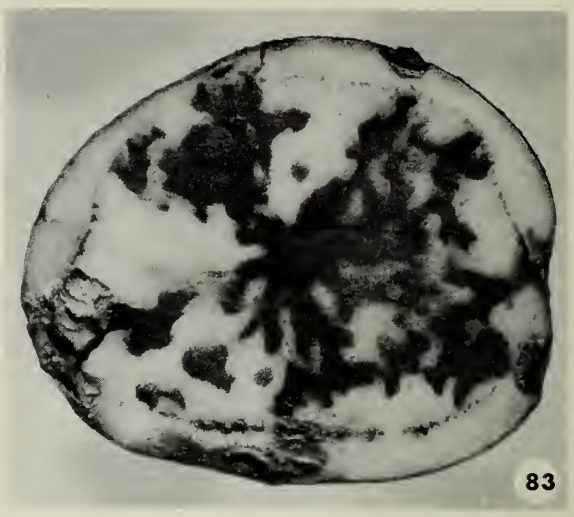


Figure 81 — Secondary tubers.
Figure 82 — Hollow heart.
Figure 83 — Black heart.

Internal Black Spot

This disorder is usually important only in tubers stored for several months, but freshly harvested tubers may also be severely affected. It may be common in dry years. The disorder is sometimes called internal blue or brown spot.

Symptoms — Usually the tubers are discolored internally near the stem end (Figure 78) and show no external symptoms. The affected areas are blue-gray to brown or black. They vary considerably in size but are rarely found more than ¼ inch below the surface (Figure 79).

Cause — The cause is unknown. Loss of moisture in the growing tubers in dry weather may then make them more susceptible to internal bruising from rough handling at harvest. The discolored areas are found mainly under pressure bruises (Figure 80) in potatoes stored in deep bins. It may occur in tubers that are jarred considerably during grading and packaging after several months in cool storage. Some scientists have found that it may be caused by low availability of potassium in the soil.

Control — It is not known how to prevent the disorder. To reduce it, avoid bruising and deep piling of potatoes in storage. Also, have the soil tested for availability of potassium.

Secondary Tubers

Symptoms — Several small tubers may form on plants like beads on a string (Figure 81), or they may form in clusters at the end of short sprouts. Growth stops and no leafy shoots develop.

Cause — The disorder is evidently due to an abnormally high concentration of cell sap in the seed pieces. This condition may be induced by high storage temperatures, removal of sprouts, or planting in cold, dry soils.

Control — Avoid high storage temperatures and planting in cold, dry soil.

Hollow Heart

Hollow heart is found mainly in large tubers. Certain varieties, such as Canso and Sequoia, are susceptible.

Symptoms — There is no outward symptom of the disorder. Cut tubers have irregular hollow areas in the center (Figure 82). The cavity usually has a brown lining. If the cracks extend to the surface the tubers may rot in storage.

Cause — Any condition, such as overfertilization, that induces the plant to produce oversize tubers may cause the disorder.

Control — Proper spacing, timely top killing, and avoidance of susceptible varieties help to reduce the number of affected tubers.

Black Heart

Black heart occurs not only in stored but also in newly harvested tubers.

Symptoms — The flesh at the center of the tuber is dark gray to black, soft, and watery. The discoloration may occur only in small, irregular pockets or may spread to most of the tuber (Figure 83). Often the affected tissue shrinks, forming cavities.

Cause — Tubers may develop black heart if they don't have enough oxygen during growth or in storage. It often develops in tubers when being shipped by rail or by boat, and sometimes in those in poorly ventilated storages. Also, if water lies on land for a long time before harvest the tubers may be "drowned" and black heart will develop.

Control — Have adequate ventilation and avoid high temperature in storages. Avoid planting potatoes on poorly drained land; if this is not possible, in wet seasons harvest and store the potatoes separately.

Stem-end Browning

This disorder may occur in all commercial varieties.

Symptoms — If you cut a thin slice from the stem end of a tuber, you can see reddish-brown to black streaks (Figure 84) that may be ½ inch deep. The disorder is readily confused with the tuber symptoms of roll and verticillium and fusarium wilts.

Cause — This disorder usually develops when potato tops are killed rapidly, either by chemicals or by frost. It is sometimes caused by overuse of fertilizers, or improper fertilizer mixtures.

Control — Use chemicals that kill the tops gradually. Do not dig the crop until 2 weeks after top killing.

Tuber Greening

Greened tubers are found in many potato fields. The disorder is serious in table stock because the tubers may cause solanine poisoning.

Figure 84 — Stem-end browning.

Figure 85 — Growth cracks.

Symptoms — The skin of the tubers turns as green as aboveground parts of the plant. The flesh may also be green or yellowish green.

Cause — Greening is caused by exposure to sunlight, or to artificial light in storage.

In the field, most greening results from shallow planting or improper hilling. Certain varieties, notably Kennebec, are susceptible.

Control — To reduce greening, practice deep planting and proper hilling. Avoid excessive exposure to artificial light in storage.

Growth Cracks

This disorder is common in potato crops in some years.

Symptoms — There may be one or more cracks in a tuber (Figure 85). The disorder is usually common when many of the tubers are knobby or otherwise malformed. The cracks due to spindle tuber are indistinguishable from growth cracks.

Cause — Cracking may be caused by very rapid growth, as when a rainy period follows a long dry spell. It can also be caused by severe rhizoctonia.

Control — If possible, irrigate in dry years to keep the soil moist. Eliminate spindle tuber from the seed and control rhizoctonia.

Thumb-nail Cracks

This minor disorder is common in stored potatoes. The cracks can occur, however, on potatoes before they are put in storage and their abundance varies with the season and the variety.

Symptoms — The cracks (Figure 86) are identical with the injury caused when a thumb nail is pressed into the skin of a tuber. If there are many cracks the tubers may shrivel.

Cause — Cracking is attributed to rough handling and too low humidity during harvest or storage.

Control — Handle the tubers carefully and store them at as high a humidity as possible without causing condensation of moisture on the tubers or the building.

Jelly-end Rot

This disorder is often found on Netted Gem and is more common in Western Canada than in the east.

Symptoms — The symptoms appear at the stem end of the potato or occasionally on knobs. At first the flesh is glassy, jellylike, and slightly watery. As the tuber ages, the affected tissue shriv-

Figure 86 — Thumb-nail cracks.

els and dries, leaving a fluffy mass. The rot does not usually spread in storage. It occurs most often on long, narrow, or pointed tubers.

Cause — This rot is caused by conditions that interfere with the deposition of starch in the growing tissues, especially at the stem end of the tuber. There is some evidence that fluctuations in moisture supply during the growing season may be responsible. The disorder is most common when a hot, dry summer is followed by a cool, rainy fall.

Control — Early irrigation appears to reduce the amount of rot. If you can't irrigate, follow cultural practices that help retain soil moisture, such as adequate spacing of rows and proper hilling and cultivation.

Do not store your potatoes if many are affected.

INJURIES

The foliage can be injured by tractors and spray rigs, by chemicals such as 2,4-D used to control weeds along roadsides or in adjoining crops, and by hail, lightning, and frost. The tubers are often damaged by rough handling, by overuse of fertilizer, by frost and lightning, and by couchgrass growing through them.

Symptoms — The vines may be mangled and cut off by the wheels of tractors, particularly when the foliage fills the rows.

Herbicides may deform the foliage (Figure 87) and so reduce the yield.

Hail shatters the foliage and bruises the stems. The injured areas heal to form white elliptical scars. The plants usually recover by producing lateral shoots. Lightning may kill plants in patches as large as 20 feet in diameter. It may cook the tubers at the stem ends so that they later develop soft rot.

Lightly frosted tubers have soft, watery areas bordered by dark lines (Figure 88). Severely frosted tubers have blackened eyes, cheesy flesh, and a sour odor.

Tubers that have been exposed to temperature two or three degrees above their freezing point may be chilled. The severity of the chill depends on the temperature and the length of time exposed. When chilling effects become visible it is usually as gray patches (Figure 89). Tubers that have been chilled but show no symptoms produce weak, slow-growing plants.

Overuse of fertilizer may cause "alligator skin" (Figure 90). The skin is severely russetted and corrugated because the growing tubers come in contact with the fertilizer.

The needle-sharp tips of the under-

Figure 87 — A leaf injured by a herbicide.

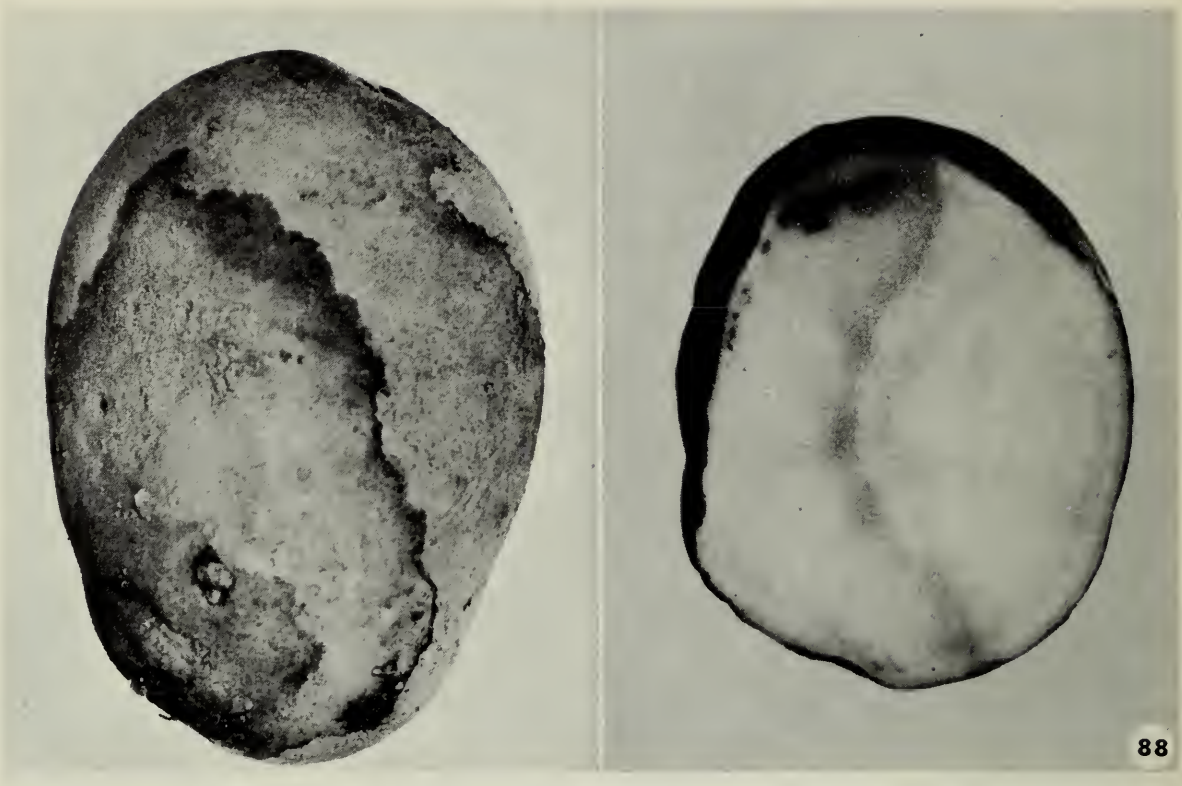


Figure 88 — Left: a frosted tuber beginning to leak. Right: discoloration caused by frost.

Figure 89 -- A tuber damaged by long exposure to a temperature just above freezing.

Figure 90 — Alligator skin.

ground stems of couchgrass may grow through the tubers.

Control — To prevent excessive damage to foliage when spraying or dusting, use vine lifters on your tractors.

Avoid applying herbicides to roadside weeds on windy days. When spraying them, have the nozzles as close as possible to the ground to prevent drift. To control weeds in potato fields, use dinoseb.

Harvest the crop before there is hazard of damage by frost. In winter, insulate and ventilate your storage house properly.

Avoid growing potatoes in fields heavily infested with couchgrass.

ACKNOWLEDGMENTS

Various officers of the Department, including the Plant Protection Division, helped in preparing this publication by contributing information or photographs. The authors are especially indebted to Dr. D.S. MacLachlan, Ottawa, Mr. V.E. Henderson, Ottawa, and Mr. E.C. Reid, Edmonton, Alta., all of the Plant Protection Division, and to the following in the Research Branch: Dr. O.A. Olsen, St. John's, Nfld.; Mr. G.W. Ayers and Mr. J.E. Campbell, Charlottetown, P.E.I.; Mr. K.A. Harrison, Kentville, N.S.; Dr. R.H. Bagnall and Mr. C.H. Lawrence, Fredericton, N.B.; Dr. G.I. Ouellette, Mr. H. Généreux, and Mr. J. Santerre, La Pocatière, Que.; Mr. J. Lafrance, St. Jean, Que.; Mr. C.G. MacNay, Ottawa; Dr. G.E. Swailes, Lethbridge, Alta.; Dr. N.S. Wright and Dr. H.R. McCarthy, Vancouver, B.C.

The following contributed photographs: Dr. D. Hille Ris Lambers, Bladluisonderzoek, P. N. O. Bennekom, Netherlands (Figures 55-59); University of Maine, Orono (Figures 6, 36); Professor A.E. Muskett, Queen's University, Belfast, Northern Ireland (Figures 31, 32); Professor W.J. Hooker, University of Michigan, Ann Arbor (Figure 11).

Some brand names are used in this publication because the chemical names are difficult for general use and there are no official common names for the active ingredients.

SCIENTIFIC NAMES OF THE ORGANISMS

Diseases

Bacterial ring rot	*Corynebacterium sepedonicum* (Spieck. & Kotth.) Skapt. & Burkh.
Black dot	*Colletotrichum coccodes* (Wallr.) Hughes
Blackleg	*Erwinia atroseptica* (van Hall) Jennison
Common scab	*Streptomyces scabies* (Thaxt.) Waks. & Henrici
Dry rot	*Fusarium sambucinum* Fckl. f.6 Wr. *F. coeruleum* (Lib.) Sacc. *F. avenaceum* (Fr.) Sacc.
Early blight	*Alternaria solani* (Ell. & G. Martin) Sor.
Fusarium wilt	*Fusarium solani* (Mart.) Appel & Wr. emend. Snyd. & Hans. *F. solani* var, *eumartii* (Carpenter) Wr. *F. avenaceum* (Fr.) Sacc. *F. oxysporum* Schlecht. emend. Snyd. & Hans.
Gray mold	*Botrytis cinerea* Pers.
Late blight	*Phytophthora infestans* (Mont.) de Bary
Leak	*Pythium debaryanum* Hesse
Phoma rot	*Phoma tuberosa* Melhus, Rosenbaum & Schultz
Pink eye	Associated with *Verticillium* spp.
Pink rot	*Phytophthora erythroseptica* Pethybr.
Potato wart	*Synchytrium endobioticum* (Schilb.) Perc.
Powdery scab	*Spongospora subterranea* (Wallr.) Lagherh.
Rhizoctonia, or black scurf	*Rhizoctonia solani* Kühn
Silver scurf	*Helminthosporium solani* Dur. & Mont.
Soft rot	*Erwinia carotovora* (L. R. Jones) Holland
Verticillium wilt	*Verticillium albo-atrum* Reinke & Berth.
Violet root rot	*Rhizoctonia crocorum* (Pers.) DC. ex Fr.

Insects and Related Pests

Blister beetles	*Epicauta* spp.
Buckthorn aphid	*Aphis nasturtii* Kaltenbach
Colorado potato beetle	*Leptinotarsa decemlineata* (Say)
Cutworms	Noctuidae
Four-lined plant bug	*Poecilocapsus lineatus* (Fabricius)
Foxglove aphid	*Aulacorthum solani* (Kaltenbach)
Grasshoppers	*Melanophus* spp.
Green peach aphid	*Myzus persicae* (Sulzer)
Millipedes	Diplopoda
Potato aphid	*Macrosiphum euphorbiae* (Thomas)
Potato cyst, or golden nematode	*Heterodera rostochiensis* Wr.
Potato flea beetle	*Epitrix cucumeris* (Harris)
Potato leafhopper	*Empoasca fabae* (Harris)
Potato psyllid	*Paratrioza cockerelli* (Sulc)
Potato-rot nematode	*Ditylenchus destructor* Thorne
Potato scab gnat	*Pnyxia scabiei* (Hopkins)
Potato stem borer	*Hydroecia micacea* (Esper)
Northern root-knot nematode	*Meloidogyne hapla* Chitwood
Southern root-knot nematode	*Meloidogyne arenaria* (Neal) Chitwood
Seed-corn maggot	*Hylemya platora* Meigen [= *H. cilicrura* (Rondani)]
Six-spotted leafhopper	*Macrosteles fascifrons* (Stål)
Slugs	Limacidae
Stalk borer	*Papaipema nebris* (Guenée)
Tarnished plant bug	*Lygus lineolaris* (Palisot de Beauvois)
Tuber flea beetle	*Epitrix tuberis* Gentner
Western potato flea beetle	*Epitrix subcrinita* (LeConte)
White grubs	*Phyllophaga* spp.
Wireworms	Elateridae