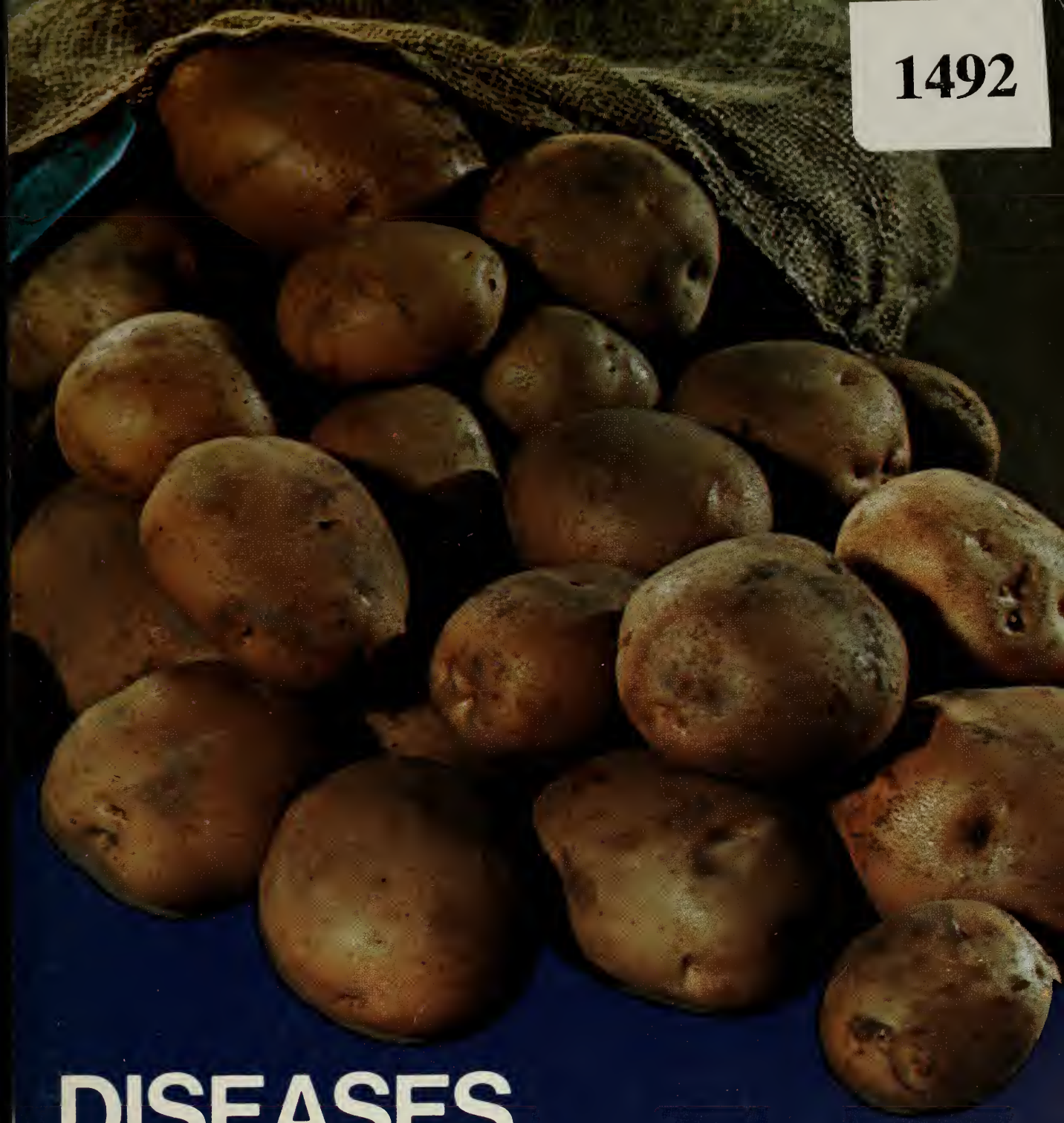

DISEASES AND PESTS OF POTATOES

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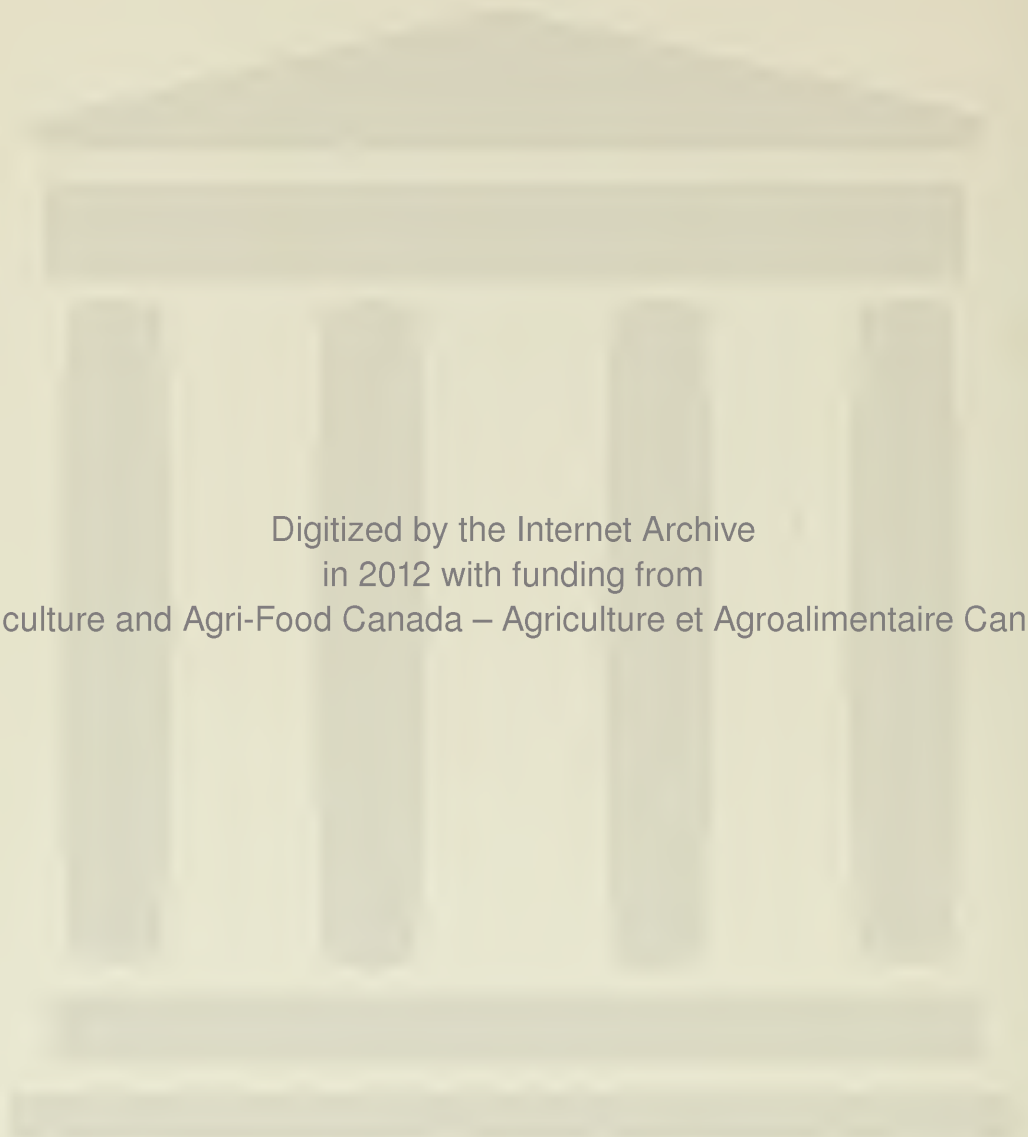

DISEASES AND PESTS OF POTATOES

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CONTENTS

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. For more information, consult your agricultural representative or provincial specialist.

Cautions. Because most of the pesticides used on potatoes are poisonous, use them only when required. Follow carefully the directions and warnings on the containers.

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, disinfect all equipment and use a bactericidal dip for the cutting knives.

RESISTANT VARIETIES

Although no variety is resistant to all disorders some varieties are more resistant than others to certain diseases. In areas where a disease is known to be a problem, losses can frequently be reduced by growing the more resistant variety.

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 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.

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.

It is best to consult your provincial specialist on the control of insects and diseases before selecting materials.

In order to obtain effective control with pesticides, they must be applied at the proper time and with the proper equipment.

Dusts should be applied during calm weather while there is moisture on the leaves. Sprays should be applied when there is little wind, humidity is high, and thermal air currents are moving downward, that is, at dawn or early morning.

In fields larger than 10 acres (4.05 ha), greater yields and a higher net return per acre have been obtained when pesticides were applied by means of aircraft.

Regardless of whether aircraft or high-, low-, or ultralow-volume ground sprayers are used, the amount of active ingredient of the pesticide to be applied per acre remains the same.

For information on field sprayers, their component parts, and how to use them efficiently, consult CDA Publication 1482, *Field Sprayers*.

SEED POTATO IMPROVEMENT

The quality of seed is a major consideration in potato production. The several factors that determine quality of seed set standards for classes of certification of seed potatoes wherever they are grown. The standards reflect the various levels of health and purity within the different classes of certified seed potato crops. These are maintained in growing crops through specified tolerances for diseased plants, abnormal plants, and rogues or "foreign" varieties, together with conditions in the field relating to hygiene, and isolation from other potato crops.

Seed certification. The highest levels of purity and health in potato crops are achieved through growers' participation in the

seed potato program operated by the Canada Department of Agriculture.

The production and maintenance of Elite classes of seed are main features in the development of Canada's certified seed potato program. At present there are five classes of seed; and potatoes certified in Elite I and Elite II classes are the basic stocks used to produce all seed in the commercial classes Elite III, Foundation and Certified. The only crops eligible for certification are those planted from the Elite I, Elite II, Elite III and Foundation classes. A growing crop is certified at least one class below that of the class of seed used to plant the inspected crop. So, beginning with Elite I, there is a continuous annual reduction in the classes of seed stocks as they move from basic stocks to commercial production.

Virus testing. In the earlier days of seed potato certification, concern first centered on obvious diseases in growing crops because of their serious effect on yield. However, a stage in seed potato improvement was eventually reached when obvious disease ceased to be a major problem, and the less obvious attracted more attention. The mild and often transient symptoms of the latter raised a control problem that could not be overcome by roguing, and so a new approach was adopted to further improve the health of good seed stocks. A system of testing was, therefore, set up in many countries to detect the presence of viruses in potato plants that seemed to be healthy, and from the results of these tests to obtain tubers that were free of virus infections. This is now routine procedure in all countries with progressive seed potato certification programs.

Virus freeing. Sometimes, however, as with most of the old varieties, all known stocks of a variety may be totally infected with a latent virus. Virus-free plants from such lots are obtained by growing portions of plant tissue from the required variety under aseptic conditions. The procedure, known as "meristem culture," is based on the knowledge that the growing tips of infected potato sprouts are often free from virus. So in many countries, including Canada, virus-free stocks are available in all potato varieties for commercial seed production.

Clone selecting. Elite seed potato material is produced and maintained as disease-free nuclear stocks by confirmed, tested freedom from bacterial and viral infections, and by the practice of clone selecting. A clone is a number of tubers or plants derived from the same mother plant by vegetative reproduction.

A clone may be of any size, from a few tubers to many thousands or a single plant to a growing crop of several acres. Seed production by clonal selection, therefore, means multiplying stocks from selected, single, healthy plants of the most desirable type within a variety in successive stages up to commercial crop acreages.

Seed quality. When potatoes are sold as seed from certified crops, they are required to be true to type and, as far as practically possible, free from severely damaged and misshapen tubers and obvious diseases. However, complete freedom from all mechanical

damage and diseases should not be expected. The most efficient methods of harvesting, storing and packing cannot prevent some small degree of damage, and most popular varieties are quite susceptible to one or more of the many common tuber diseases.

Some of these diseases such as late blight, common scab, fusarium dry rot, skin spot, black scurf, phoma rot and silver scurf are readily visible on the tuber. Net necrosis and some of the wilt diseases may be detected only when the apparently healthy tubers are cut to expose tuber flesh. But the most insidious of tuber-borne diseases are those caused by virus infections that have effect on total weight of crop, but little or no visible effects either on or within potato tubers. Seed potato certification programs are designed to keep these problems to a minimum.

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 the development of rots. When you put the potatoes into storage, keep them at 60 to 65°F (16 to 18°C) and 90 to 95% 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 (10°C). If you plan to store them for more than a month for seed, store them at 38 to 40°F (3 to 4°C). If you must store them at 50°F (10°C) 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 (Fig. 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 (Fig. 2, 3) is usually dry and hard. Under moist conditions, tufts of white spores grow out of the infected areas (Fig. 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 (16°C), the relative humidity is 100%, and there are water droplets on the leaves. Usually about 5 days of favorable weather are enough to produce a crop of these spores 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 moderately resistant, this variety still requires up to seven fungicidal sprays in a season.

The most important control measure is spraying or dusting with a 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 grayish 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 grayish green clusters of spores (Fig. 5). In severe infections all the leaves are blighted and a soft

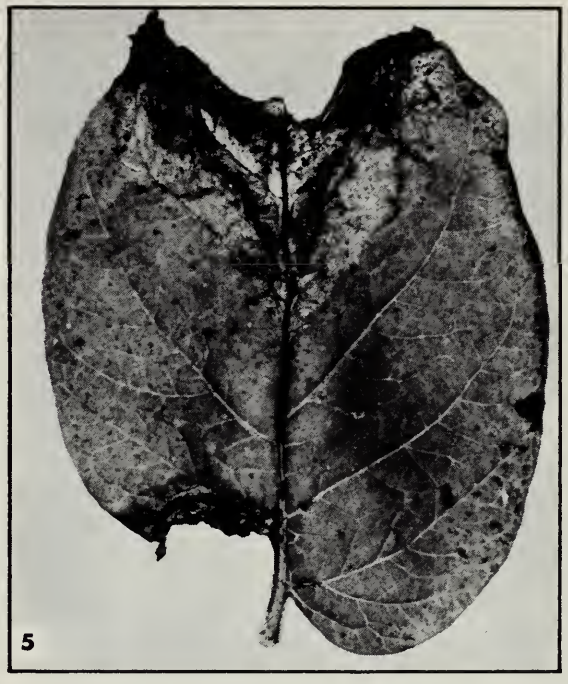


Fig. 1. Late blight, spores around a lesion on a leaflet.

Fig. 2. Late blight, tuber rot.

Fig. 3. Late blight, tuber rot.

Fig. 4. Late blight, tufts of spores on stored tuber.

Fig. 5. Gray mold, leaflet with spores around lesion (top).

gray rot attacks the stems. If the vines are disturbed as you walk through them, the spores billow up like a small cloud of dust. The tuber rot (Fig. 6) is flabby, slightly watery, and odorless, and the tuber surface may be covered by blackish 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 (16 to 18°C) 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 (4°C) or below, gray mold may develop.

EARLY BLIGHT

Early blight, or leaf spot, is a common foliage disease of potatoes. This blight attacks tomatoes, eggplants, 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 (Fig. 7). The disease is readily identified by the close, concentric rings within each spot. The spots may unite, killing large areas and causing a 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 1/8 inch (0.32 cm) 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.

VERTICILLIUM WILT

Verticillium wilt has been reported from every province in Canada except Newfoundland. Two species of the wilt fungus occur; one causes earlier and more severe symptoms than the other and frequently overwinters on tubers. These fungi have many other hosts, but wilt symptoms are not produced in all of them. Of the potato fields inspected for seed each year in the provinces of New Brunswick and Prince Edward Island, verticillium and fusarium wilts together account for about 2% of the rejections. In table stock, severe infections of verticillium wilt may reduce the yield by as much as 20%. Wilt severity and resultant yield losses depend on the level of inoculum and weather conditions.

Symptoms. About flowering time, the leaves wilt from the bottom of the plant upward (Fig. 8). The wilted foliage becomes yellow, and then brown. Sometimes only one stem of a plant is affected, or a single stem may escape infection while the rest of the

Fig. 6. Gray mold, tuber rot.

Fig. 7. Early blight on leaflet.

Fig. 8. Verticillium wilt, symptoms on plant.

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 (Fig. 9). 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 (Fig. 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. Seed treatment is effective in preventing infection from seed.

If the land is infested, practice a 3- or 4-year rotation including a cereal crop and hay, but not strawberries, raspberries, tomatoes, peppers, eggplants, or Brussels sprouts. Do not use tubers from a diseased crop for seed.

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 (Fig. 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.

BACTERIAL RING ROT

Bacterial ring rot is one of the most serious diseases of potatoes 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

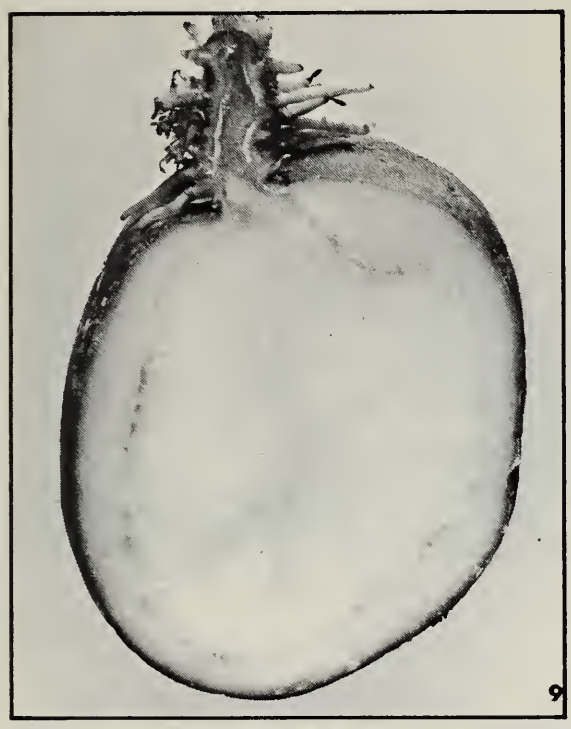


Fig. 9. Verticillium wilt, tuber discolored in the vascular ring.

Fig. 10. Verticillium wilt, fungus growing on potato stem.

Fig. 11. Fusarium wilt, discoloration in stem.

Fig. 12. Bacterial ring rot, leaflets of infected plant.

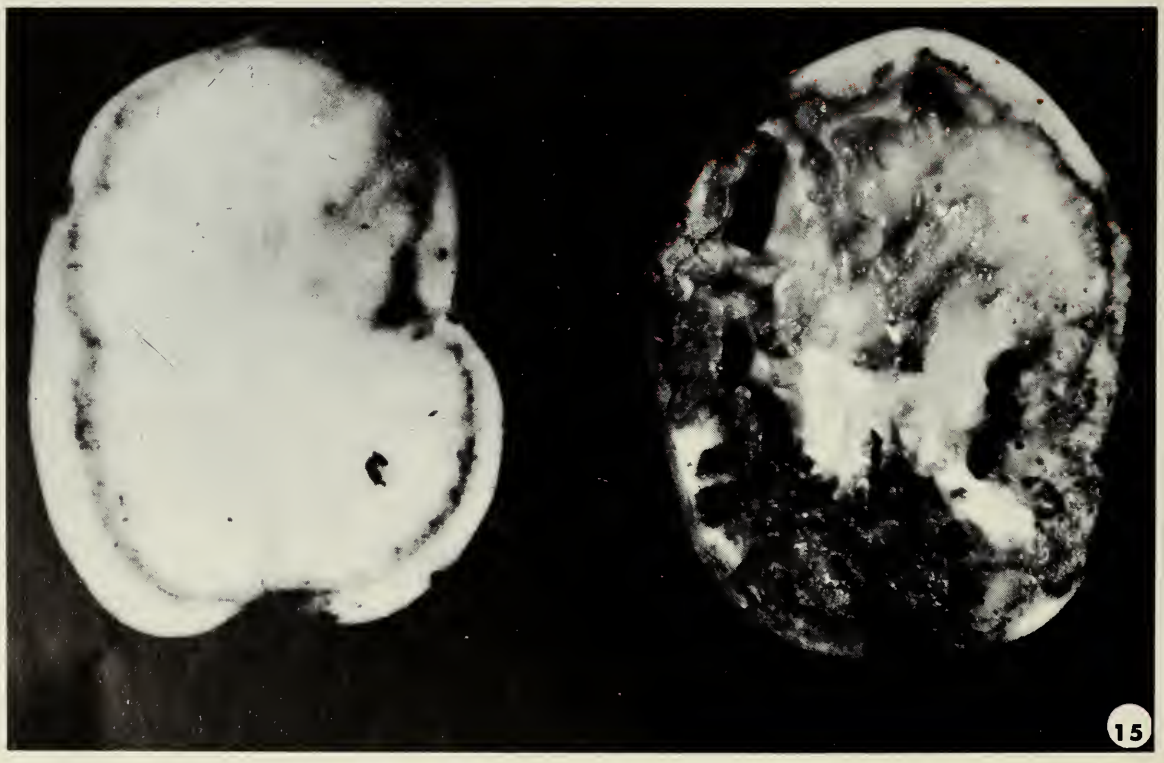
bloom. One or more stems of a plant may wilt while the remainder appear healthy. The affected leaflets turn pale green, and pale yellowish areas develop between veins (Fig. 12). The disease develops rapidly in hot, dry weather. It may be difficult to recognize the disease in cool weather, in resistant 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 (Fig. 13). Lightly infected tubers may appear healthy. When the tuber is cut across the stem end, a creamy yellow to light brown rot (Fig. 14) shows in the vascular ring ; the rot is crumbly to cheesy and odorless. If you squeeze a cut

Fig. 13. Bacterial ring rot, severely affected tuber.

Fig. 14. Bacterial ring rot, infected vascular ring. Note the yellowish color of the vascular ring and the bacterial ooze.

Fig. 15. Bacterial ring rot: *left*, early symptoms in tuber; *right*, late symptoms.



tuber between the thumb and fingers, a substance oozes from the affected part of the ring (Fig. 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 form, they are invaded through the stolons.

The disease is spread mainly by the 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 from the disease. In one season the disease may spread from a few infected tubers to 30% of the crop.

In growing certified seed, plant small whole tubers and so avoid using the cutting knife. If you cut the seed, disinfect the cutting knife.

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.

BLACK DOT

Black dot occurs in nearly all the provinces. It reduces the 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 (Fig. 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 (Fig. 18).

Life cycle. The overwintering bodies of the fungus can survive for at least 8 years even in the absence of suitable hosts. In infested soil, the fungus attacks all underground parts of potatoes 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 from the disease. Also, avoid rotations with tomatoes, cole crops, or cucurbits.

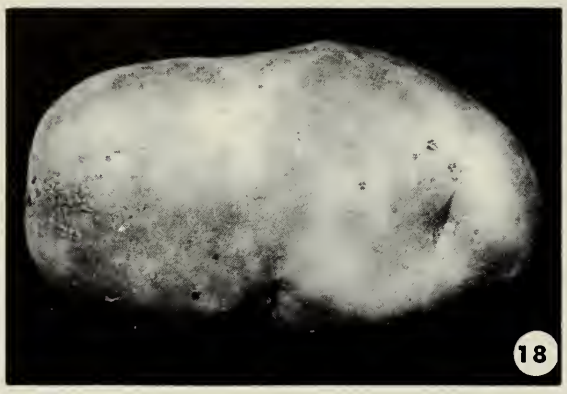
Destroy diseased tubers soon after harvest, or disinfect them. Destroy all debris from infected crops.

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

Fig. 16. Black dot, overwintering bodies of fungus on stem and roots.

Fig. 17. Black dot, overwintering bodies of fungus on split stems.

Fig. 18. Black dot, tuber with lesions (left).



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 upward and the foliage gradually fades from deep green to yellowish 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 (Fig. 19).

Tubers produced from infected plants have a central soft rot at the stem end (Fig. 20). If secondary infection develops (Fig. 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 upward 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.

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.

RHIZOCTONIA

Every year rhizoctonia, also called black scurf, causes serious losses somewhere in Canada. Losses have averaged as high as 15% and in some years whole fields have been destroyed. The disease is

Fig. 19. Blackleg, lesion at base of stem.

Fig. 20. Blackleg, lesion at base of stem and at stem end of tuber.

Fig. 21. Blackleg and soft rot in tuber.

caused by a soil-borne fungus of worldwide distribution. There are many strains attacking many different crops.

Symptoms. In the spring, the fungus 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. Damage at this stage usually results in misses. 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.

The underground tubers form in a tight cluster and are small, numerous, and misshapen from crowding (Fig. 22). Thin layers of irregular black lumps (sclerotia) up to 1/4 inch (0.64 cm) in diameter are often seen on mature tubers from plants that show few or no symptoms. The black lumps are commonly called "the dirt that won't wash off" (Fig. 23).

Life cycle. The fungus lives indefinitely in the soil on plant debris. The resting bodies may be carried long distances on diseased plants. Under favorable conditions they germinate and may invade plant parts at or below the soil line.

Fig. 22. Rhizoctonia, aerial, and deformed tubers.

Fig. 23. Rhizoctonia, symptoms on tuber.

Spores are produced as a grayish white powdery film on stems just above the soil line. Spores may be produced on stems of healthy as well as diseased plants.

Control. A green cover crop plowed down before planting to potatoes may reduce the amount of disease in a field that had a high level of plant symptoms or disease in the last potato crop. Crop rotation is generally not effective in reducing or eliminating losses.

Avoid planting in cold, wet soil and cover the seed pieces with not more than 2 inches (5 cm) of soil. This promotes rapid growth of the plants and helps them escape the disease. The numbers of sclerotia on tubers can be reduced by harvesting as soon as the tubers are mature.

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

Disinfect infected tubers before planting.

It also helps to plant when the soil is warm enough to permit rapid growth.

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 farmland and garden plots around Conception Bay, in eastern Newfoundland. Only a small area of the west coast of the island is infested. Every precaution is being taken to keep this disease from becoming established on the mainland.

Symptoms. Wart may develop on all parts of the potato plant

except the roots (Fig. 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. Because 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. 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. Several different races of wart are present in Newfoundland soils, and no commercial variety is resistant to all of them. When planted in most soils, Urgenta and Pink Pearl will remain free of wart infection. Kennebec and Sebago are highly resistant and will produce tubers substantially free from wart when planted in infested soil.

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.

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, 1/4 to 1/16 inch (0.64 to 0.16 cm) in diameter, that are filled with brownish powder (Fig. 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 provinces. 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.

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 (Fig. 26). They may be superficial russetted spots or greatly roughened blotches.

Fig. 24. Potato wart at base of stem and on tuber.

Fig. 25. Powdery scab.

Fig. 26. Common scab.

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 1/2 ton (0.5 tonne) or less of finely ground limestone per acre (0.405 ha).

When growing potatoes on mildly infested soils, use the acid fertilizer, ammonium sulfate, 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 from 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 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 (Fig. 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 in storage and in tuber debris left in the soil after harvest. 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, cull out noticeably infected ones at digging and grading, and rid the field of all tubers left after harvest.

FUSARIUM 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 toward the center of the tuber and serious decay may occur before it is observed (Fig. 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.

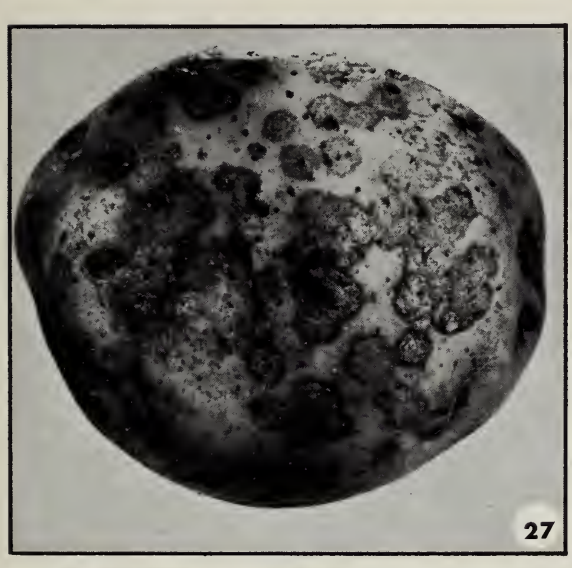
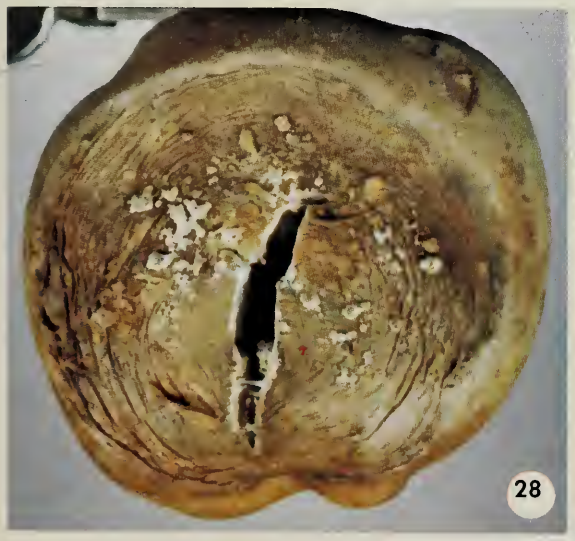
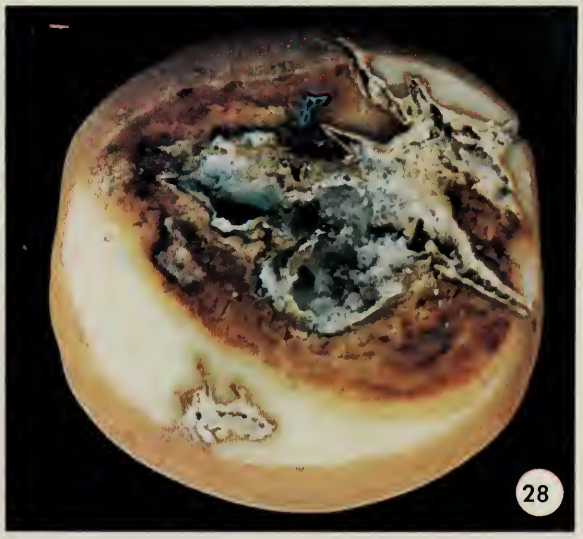


Fig. 27. Silver scurf.

Fig. 28. Fusarium dry rot, symptoms: *left*, on whole tuber; *right*, on cut 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, 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 sulphureum* Schlecht (F. *sambucinum* Fckl. f. 6 Wr.)], whereas Irish Cobbler, Hunter, and Netted Gem are moderately resistant. Hunter, Keswick, and Netted Gem are highly susceptible to another species [*Fusarium coeruleum* (Lib.) Sacc.], 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 (Fig. 29). Cracks may appear in the skin over the lesions. The tissue underneath is black, shrunken, and decayed (Fig. 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 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 (Fig. 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.

Fig. 29. Phoma rot.

Fig. 30. Phoma rot.

Fig. 31. Leak.

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 (Fig. 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.

BACTERIAL SOFT ROT

Bacterial soft rot is very widespread and usually occurs in association with 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 (0.3 to 0.6 cm) in diameter. These give the tuber a pockmarked appearance (Fig. 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 (Fig. 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

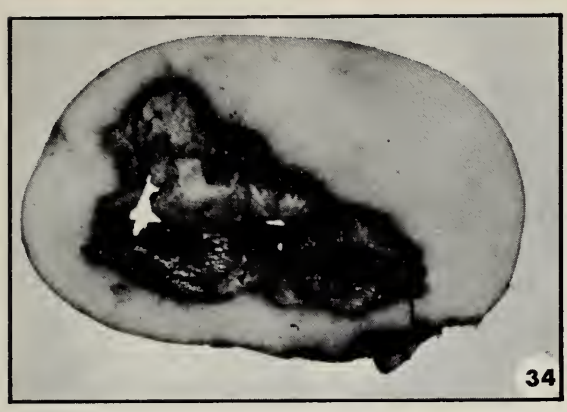


Fig. 32. Pink rot.

Fig. 33. Bacterial soft rot, beginning at lenticels on tuber.

Fig. 34. Bacterial soft rot, in advanced stage.

controlling soft rot. Avoid injuring the tubers, especially when they are immature. During the first week or 10 days of storage maintain a temperature of 60°F (16°C) 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, New Brunswick and Quebec. It is caused by a bacterium, which is a common inhabitant of most soils.

Symptoms. At harvest the tubers are pink to brown in patches around the eyes and at the eye end (Fig. 35). The discoloration is usually little more than skin deep, and often the skin dries out and cracks. However, if the disease is severe, internal reddish brown to black areas, internal cavities, and soft rot may develop. When this occurs it may be mistaken for an initial stage of late blight tuber rot.

Tubers exhibiting pink eye symptoms will often develop soft rot in storage particularly at high temperatures. This phase is known as high temperature breakdown.

Life cycle. The bacterium usually lives on dead organic matter in the soil and is not normally considered a pathogen. However, for reasons not fully understood, the bacterium may invade the potato tuber and typical symptoms may develop. The disease is often associated with a high incidence of verticillium wilt, but can also be found on tubers of plants free from wilt. The disease is more

evident near the end of the growing season and seems to be more abundant when soil moisture is high.

In storage, the bacteria spread from diseased to healthy tubers through wounds or natural openings such as lenticels. Bacteria will rot tubers more rapidly at storage temperatures above 45°F (7.2°C).

Control. Kennebec is perhaps the most susceptible variety grown in the Maritimes and Quebec. Some pink eye has also been seen on Katahdin, Sebago, and Netted Gem.

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.

SKIN SPOT

Skin spot occurs in a number of provinces and, although it is more prevalent than previously thought, losses are usually small.

Symptoms. The first symptoms are small, light brown lesions on roots, stolons and belowground parts of the stem. Lesions are light in color and often coalesce to produce a darkened, transversely cracked area. On the stored tuber, small craterlike depressions with raised centers are formed (Fig. 36). When dry, these pimplelike areas are slightly darker in color than the healthy skin, but when wet they become purplish black. The pimples can be picked out, leaving circular pits of healthy flesh. When tubers are severely diseased, plants may not be produced or they emerge slowly and unevenly.

Life cycle. The main source of infection is the seed tuber. Spores from infected sets attack underground parts of the plant and the

Fig. 35. Pink eye.

Fig. 36. Skin spot.

spores produced by these infections attack the new tubers through breathing pores, superficial wounds, and eyes. In cool, damp storages the fungus spreads from tuber to tuber.

Control. Plant healthy seed. Damage to eyes is decreased by early harvesting and by drying the tubers before storage. Avoid bruising tubers when harvesting and grading. Prevent excessive humidity in storage and ensure adequate ventilation.

VIRUS AND MYCOPLASMA DISEASES

Several viruses attack potatoes 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 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 have symptoms resembling those of other viruses in the group.

SIMPLE MOSAIC

This is the commonest of all virus diseases and 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 (Fig. 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 viruses X and M, which are 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 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 may differ 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. If, however, infection occurs late in the season, there may be little or no development of symptoms.

Tubers from infected plants produce plants with symptoms that

Fig. 37. Simple mosaic, faint mottle.

Fig. 38. Rugose mosaic.

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 (Fig. 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 caused by an aphid-borne virus called virus Y, alone or in combination with virus 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 including Katahdin, Kennebec and Sebago 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.

With 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.

With 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, and the tissue becomes dry, leathery,

Fig. 39. Leaf roll, typical symptoms.

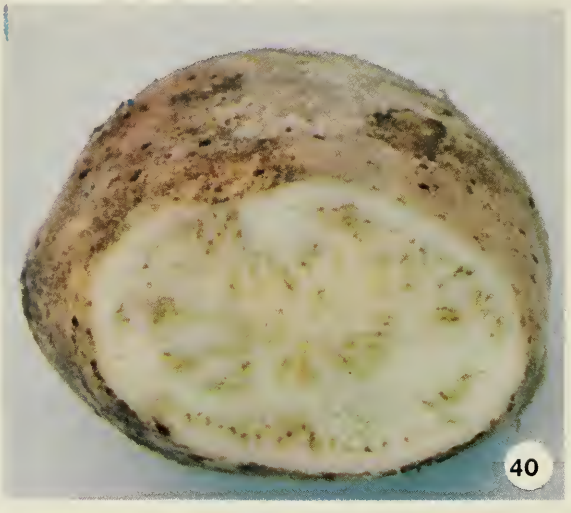


Fig. 40. Leaf roll, net necrosis in tuber.

Fig. 41. Spindle tuber, typical foliage.

Fig. 42. *Above*, healthy tubers; *below*, spindle tubers of the same varieties.

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 (Fig. 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 (Fig. 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 (Fig. 41). The disease is most obvious in hot weather.

In most varieties, the tubers are longer than normal, often have pointed stem ends, and sometimes crack. The eyes are more numerous and shallower than usual (Fig. 42).

Cause. The disease is caused by a virus that is spread to healthy plants by contact with infected plants, by cultivation equipment, and by any agent that causes damage to the plant.

Control. Since the foliage symptoms are often difficult to identify planting high-grade 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 (Fig. 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 the season the tubers produced may escape infection.

Cause. The disease is caused by a mycoplasma, 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.

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 (Fig. 44).

Fig. 43. Purple-top wilt: *left*, early symptoms; *right*, late symptoms.

Fig. 44. Calico, leaf symptoms.

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 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 (Fig. 45).

The stolons are abnormally white and long and bear numerous small tubers, often in chains. As the aboveground symptoms

Fig. 45. Witches'-broom, typical foliage, numerous stolons, and small tubers.

develop, the newly formed tubers sprout and produce slender plants.

Cause. The disease is caused by a mycoplasma, but the method of spread in the field is not yet known. At least three strains of the organism 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 toward 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 througout 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.

Cause. The disease is caused by a mycoplasma. It is suspected that the disease is spread by some insect.

Control. The only known method of control 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 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 (Fig. 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 (Fig. 47).

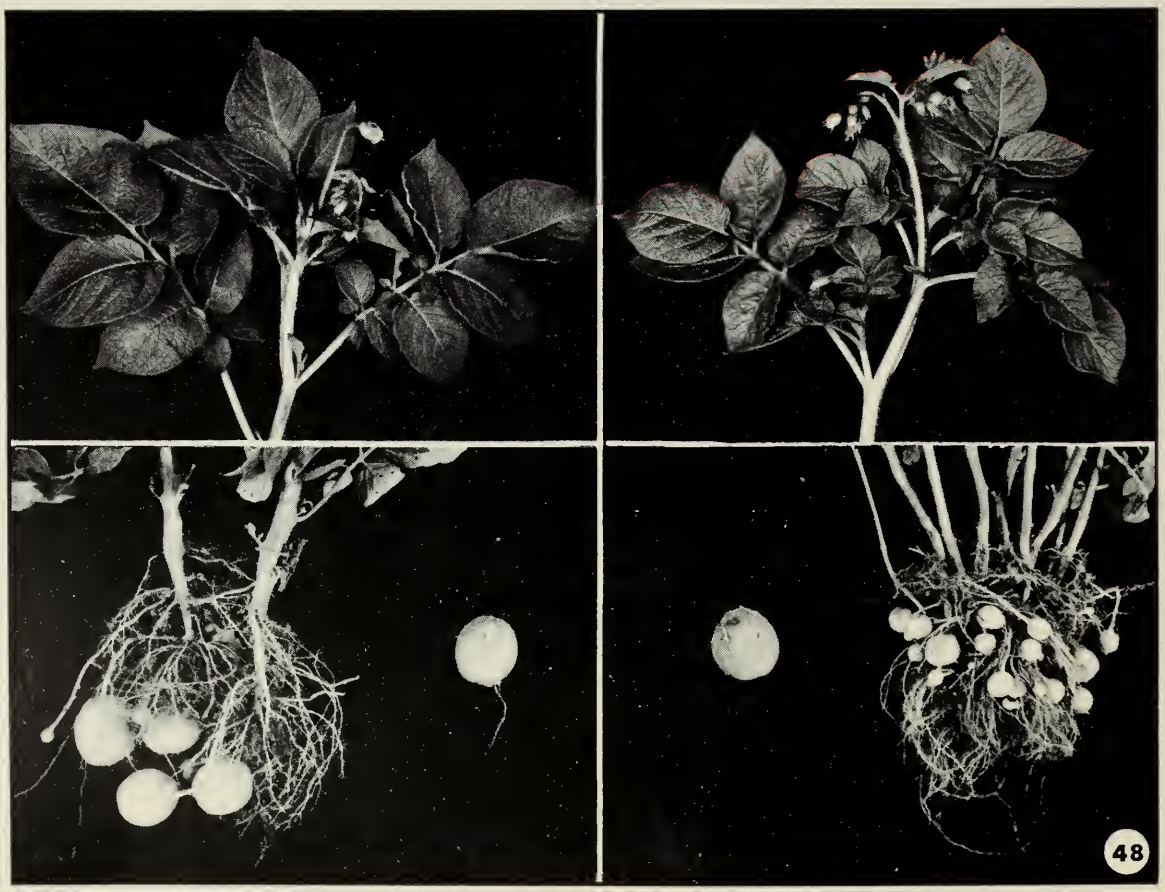
LITTLE LEAF

This abnormality (Fig. 48) has been observed in Eastern Canada,

Fig. 46. Wilding, large, heart-shaped terminal leaflets.

Fig. 47. Stitched end, abnormal tuber and sprouts.

Fig. 48. *Left*, healthy plant; *right*, plant affected with little leaf.



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, stolons, and tubers.

FOLIAGE INSECTS — 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 are thought to spread spindle tuber 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 (Fig. 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 1/2 inch (1.3 cm) 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 (20 to 25 cm). They are about 3/8 inch (0.95 cm) long and 1/4 inch (0.64 cm) wide and have black and yellow stripes that run lengthwise on the wing covers.

Control. To control either the adults or the larvae, apply a

Fig. 49. Colorado potato beetle: *left*, eggs; *center*, larvae; *right*, adult.

recommended insecticide. 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 (Fig. 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.

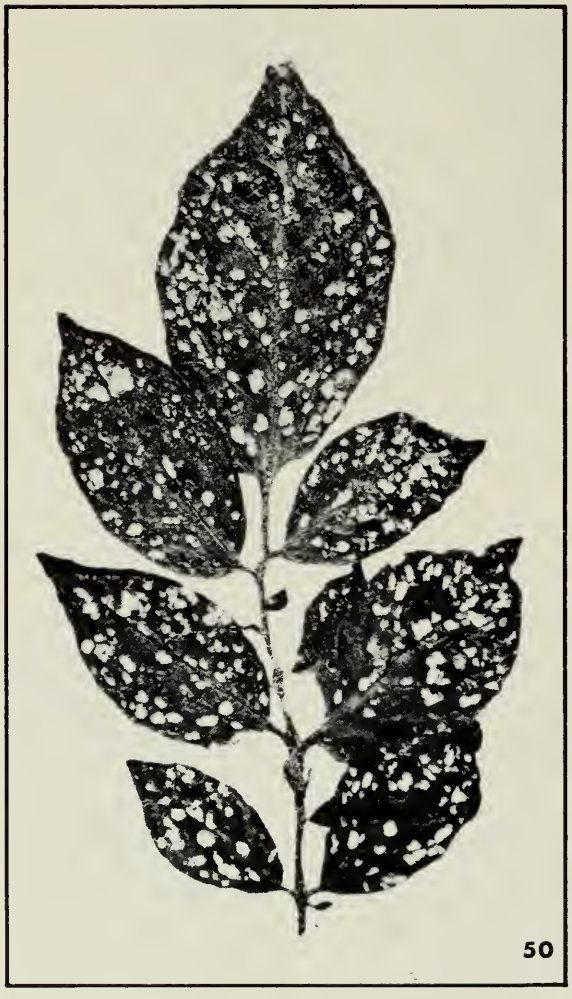


Fig. 50. Leaf damaged by flea beetles.

Fig. 51. Tuber damaged by grubs of the western flea beetle.

Fig. 52. Tuber damaged by grubs of the tuber flea beetle.

Fig. 53. Tuber flea beetle, adult. About 25 times natural size.

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

The larvae are whitish, slender, cylindrical grubs with brownish heads. They are only 1/8 to 1/2 inch (0.32 to 1.27 cm) long when full-grown. In the tubers they make a network of fine tunnels (Fig. 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 (Fig. 53) are small beetles about 1/16 inch (0.16 cm) 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.

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 1/5 inch (0.51 cm) long. They begin to emerge 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 1/3 to 1 inch (0.85 to 2.54 cm) long (Fig. 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 an insecticide promptly and thoroughly.

CUTWORMS

Many species of cutworms attack potatoes and they vary greatly

Fig. 54. Adult of a blister beetle, about 3 times natural size.

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 (2 to 5 cm) 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.

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 curly dwarf disease.

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, consult your provincial specialist.

FOLIAGE INSECTS — 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 to dark green

(Fig. 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, and mild mosaic. 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, and related shrubs. In the spring wingless females hatch from these eggs and they produce winged forms, which fly to weeds, potatoes, and other crops. These and all later generations on potatoes give birth to 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 from the summer host plants mate with the wingless females, which lay the overwintering eggs.

If the climate is mild enough, as in the Fraser Valley or on Vancouver Island, 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 these at planting time is usually effective for the season.

Some foliage sprays or dusts are also effective against these aphids. For recommendations consult your provincial specialist.

BUCKTHORN APHID

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

It is green or lemon yellow (Fig. 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 buckthorn. In the spring they hatch into females that give birth to females, some of which become winged.

The winged ones migrate to a wide range of summer host plants such as lady's-thumb, shepherd's-purse, 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 eggs on the buckthorn.

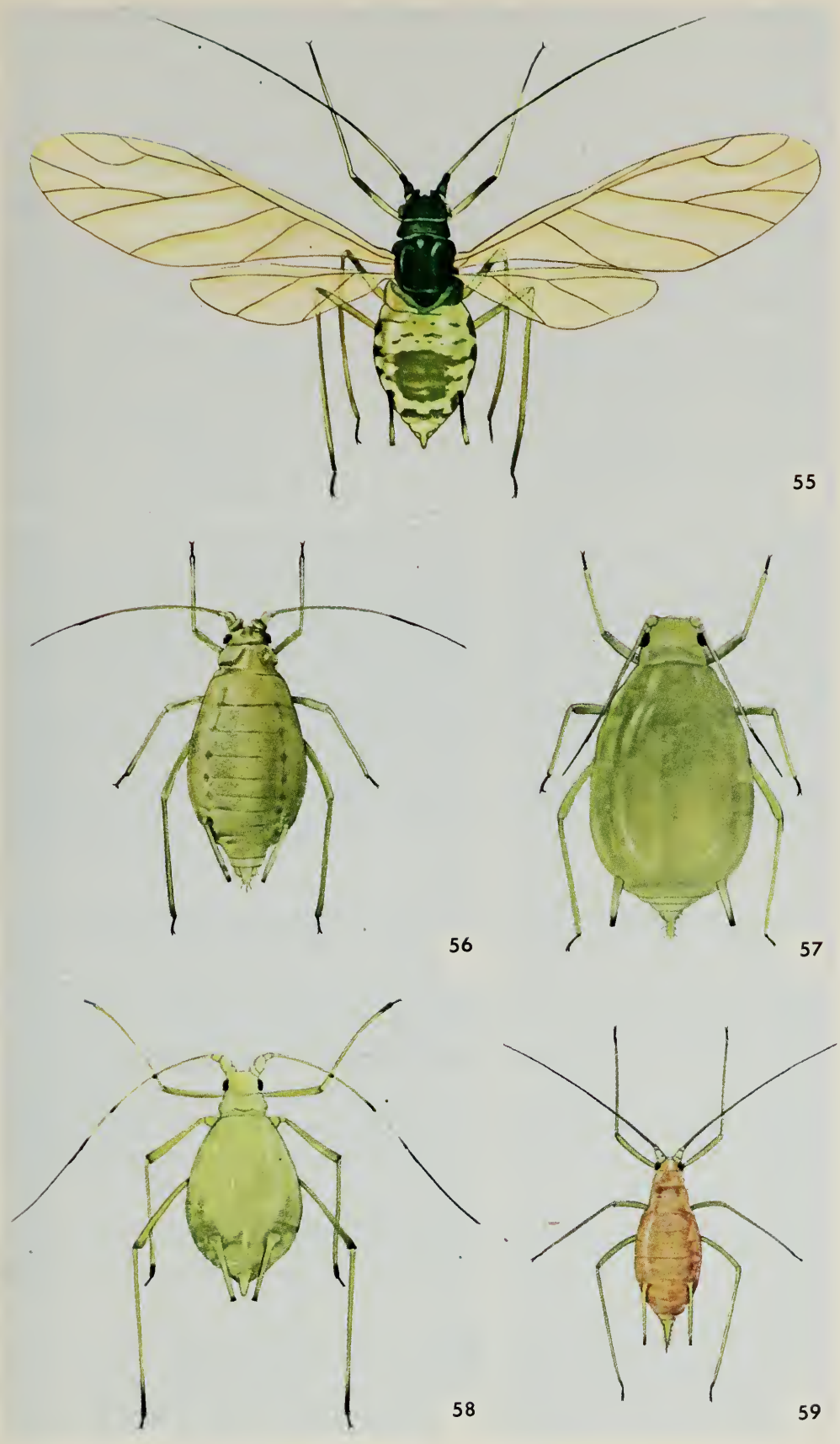


Fig. 55-59. Female aphids. 55. Green peach aphid, winged (X18). 56. Green peach aphid, wingless (X19). 57. Buckthorn aphid (X25). 58. Foxglove aphid (X11). 59. Potato aphid (X7). All of these females are the forms that give birth to young aphids. (Magnifications are approximate.)

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

FOXGLOVE APHID

This aphid (Fig. 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 like the green peach aphid, introduces toxins that affect the plants.

Life cycle. The eggs overwinter on foxglove, hawkweed, and plantain. Females hatch in the spring and give birth to young females, all wingless. Some second generation and the majority of the third generation are winged females; 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 few winged forms develop. Consequently, infestations simply die out when the secondary hosts are killed by frost or otherwise. Wingless males develop in the fall not only on the overwintering hosts but also on some secondary hosts. Egg-laying females develop here also and after mating will deposit eggs. But, usually only eggs laid on foxglove, hawkweed, or plantain overwinter successfully.

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 (Fig. 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, and rugose mosaic. 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 give birth to 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 30 plant families also act as summer hosts for this aphid, the most common being lamb's-quarters, hempnettle, and lady's-thumb. There are several generations of winged and wingless females during the summer.

Winged males and females appear in the 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 (Fig. 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, consult your provincial specialist.

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 curl upward, turn yellow, 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.

Fig. 60. Adult of the tarnished plant bug, about 6 times natural size.

The newly hatched nymphs are pale green and resemble the adults except that they have no wings.

The adults (Fig. 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 a recommended insecticide may be necessary for adequate control. Consult your provincial specialist.

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 potatoes 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 are usually light yellowish after the first molt. They become full-grown in about 3 weeks.

The adults are about 1/8 inch (0.32 cm) 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 to lay eggs 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 from weeds. Destroy all weeds in headlands and adjoining areas to reduce breeding sites. If purple-top wilt has been found in your area, apply a recommended insecticide. Consult your provincial specialist.

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 (Fig. 62). Aerial tubers may also form in the leaf axils.

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

Fig. 61. Adult of the potato leafhopper, about 24 times natural size.

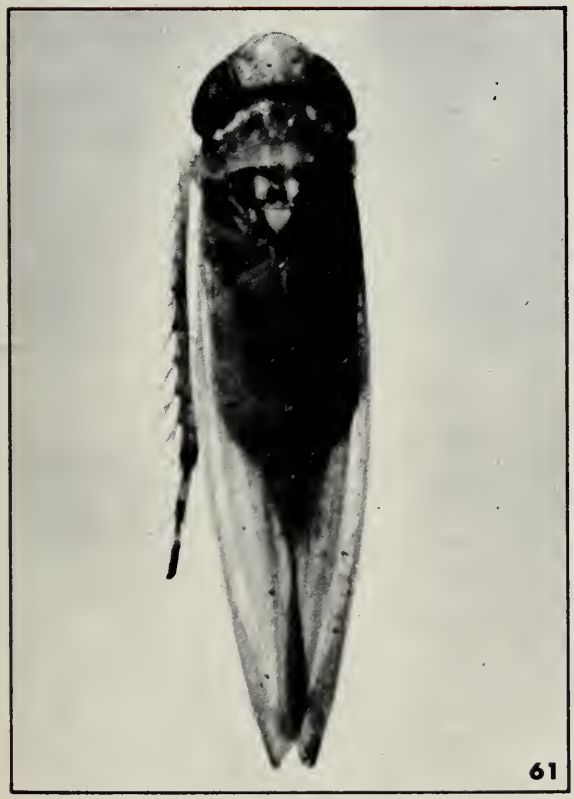
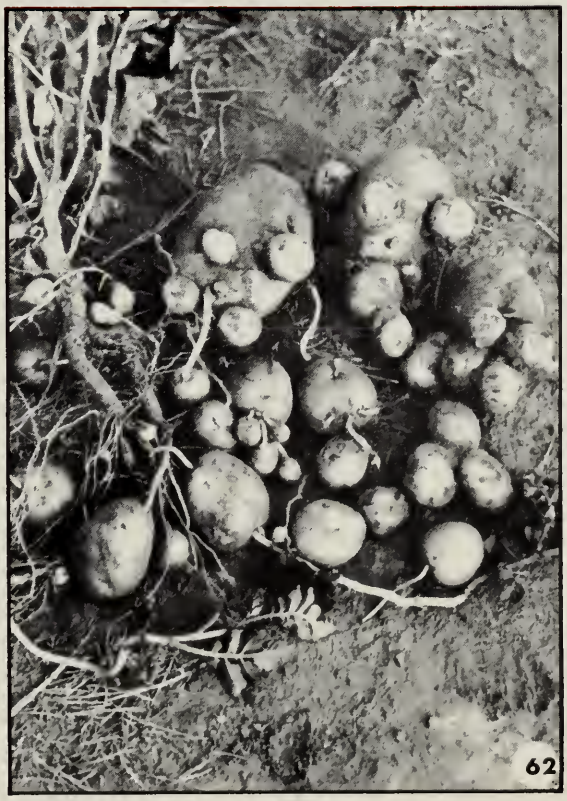


Fig. 62. Tubers unmarketable because of feeding by the potato psyllid on the foliage.



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 10 generations in a season.

Control. Apply a recommended insecticide.

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 (Fig. 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 (0.16 cm) long. The females are wingless, the males winged. They overwinter in potato fields, and on potatoes in storage if enough moisture is present.

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 (Fig. 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 (Fig. 65) remain in the

Fig. 63. Tuber damaged by maggots of the potato scab gnat.

Fig. 64. Tuber damaged by white grubs.

Fig. 65. A fully developed white grub.

Fig. 66. A June beetle, nearly twice natural size.

subsoil and develop into beetles 6 to 8 inches (15 to 20 cm) 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 (Fig. 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 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 a recommended insecticide.

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 (Fig. 67) and so lower the grade and often make them unmarketable. More important they provide entrance points for rhizoctonia and blackleg.

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 (Fig. 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 (Fig. 69) are slender, hard-shelled beetles about 1/2 inch (1.3 cm) 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 (10 per m^2) of land treat the soil, or else avoid planting potatoes before the third season after breaking the sod. If control is needed apply a recommended insecticide.

Because the species differ from area to area, use the insecticide and cultural practices recommended by your local agricultural

Fig. 67. A tuber damaged by wireworms.

Fig. 68. Full-grown wireworms.

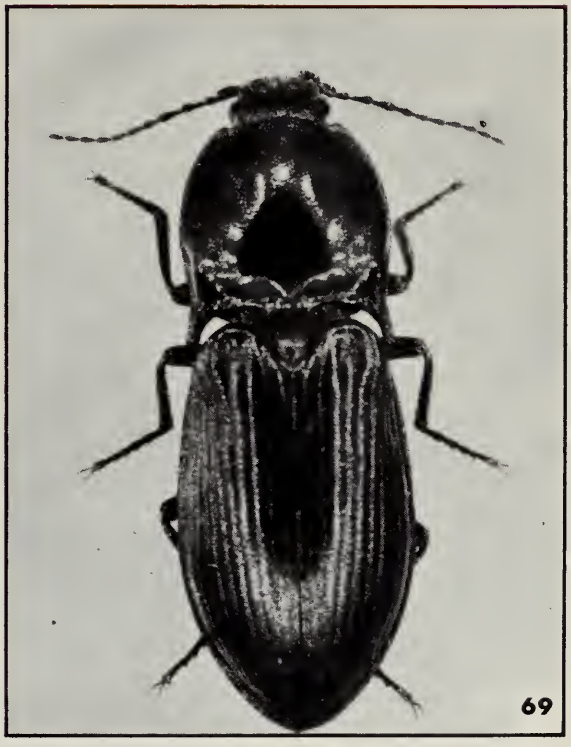


Fig. 69. An adult of a wireworm, about 7 times natural size.

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 weather is cold. They pupate in the soil, the pupae taking 2 to 3 weeks to develop into adults.

The adults are flies about 1/5 inch (0.5 cm) 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. If seed treatment is necessary consult your provincial specialist.

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 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 (Fig. 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, consult your provincial specialist.

SLUGS

Slugs may damage the tubers severely (Fig. 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

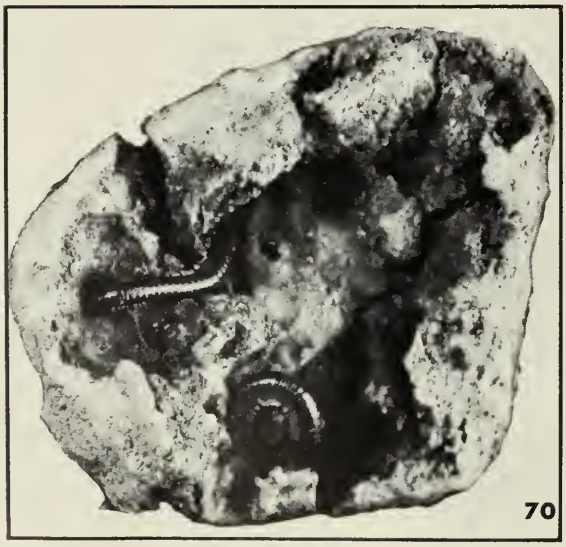


Fig. 70. Millipedes feeding on a seed piece.

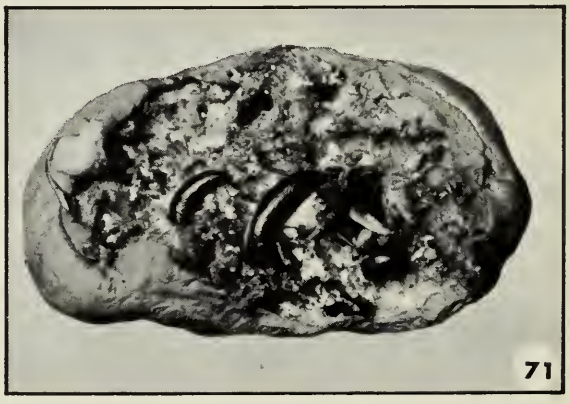


Fig. 71. A potato being damaged by slugs.

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. 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 (2 to 20 cm) 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. If treatment is necessary consult your provincial specialist.

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 eastern Newfoundland 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 wilt in dry spells. The affected plants may die. On the roots, cysts form (Fig. 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 potatoes or related plants. Only a certain percentage of the larvae hatch each year and therefore cysts may contain viable larvae for several years.

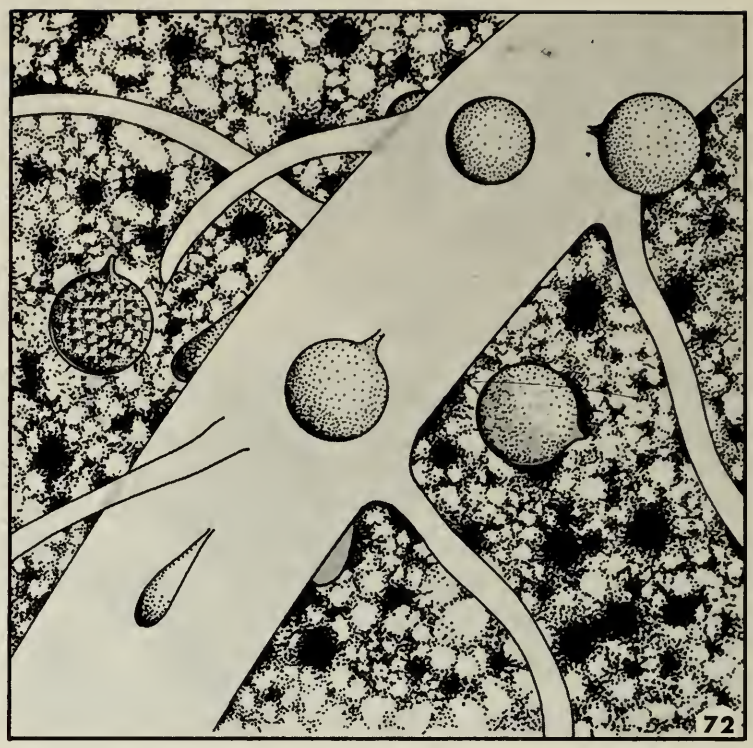


Fig. 72. Potato-cyst nematode, cysts on potato roots and in the soil, about 45 times natural size.

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 (13°C).

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. To prevent the development of heavy infestations of the nematode, it is best not to grow potatoes on lightly infested soils more often than once in every 3 or 4 years. Where land has become infested a significant reduction in cyst numbers can be obtained by growing a resistant variety such as Peconic or Wauseon.

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

It is possible to control the nematode by fumigating the land. 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.

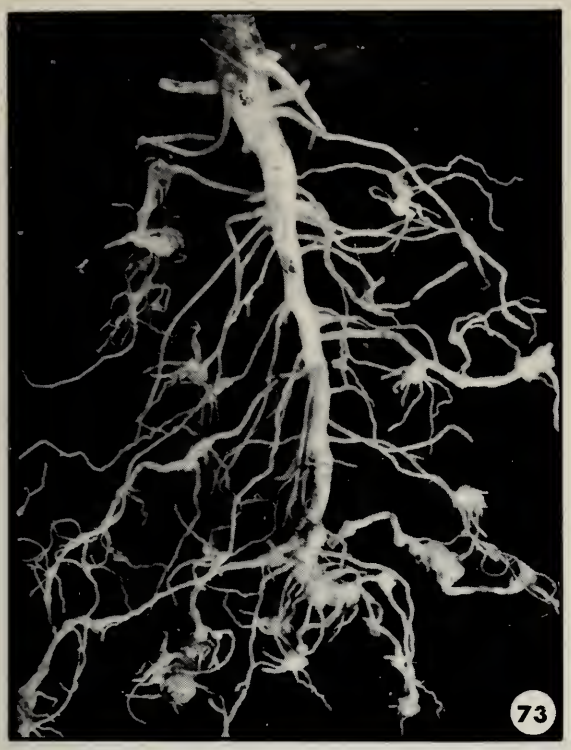


Fig. 73. Tomato roots infested by root-knot nematodes.

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 (Fig. 73) on the potato roots. Those formed by the northern root-knot nematode are less than 1/4 inch (0.6 cm) in diameter; those formed by the other species, from 1/4 to 2 inches (0.6 to 5 cm). 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.

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 nonsusceptible crops for at least 4 years in succession. Grasses and grains are not susceptible.

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 1/8 inch (0.3 cm) 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, 1/2 inch (1 cm) or more wide, develops in the skin. The tissue in the hollow area gradually dies and dries out, and irregular, three-cornered cracks (Fig. 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, because 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

Fig. 74. Potato-rot nematode, external symptoms.

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.

PHYSIOLOGICAL DISORDERS

MANGANESE TOXICITY

Manganese toxicity may occur when potatoes are grown in soils that are highly acid, with pH values below 5.2.

Symptoms. Excess manganese causes black flecks on the plant stems and leaf stalks; the condition is known as a stem streak necrosis. The flecks soon develop into long streaks or areas of black, dead tissue (Fig. 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, Cherokee, and Sebago are some of the more susceptible varieties, whereas Kennebec, Norgleam, and Netted Gem are less susceptible. 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.

Fig. 75. Manganese toxicity, dead spots and streaks on stem of potato.

Fig. 76. Manganese toxicity, spots on leaf.

MAGNESIUM DEFICIENCY

Magnesium deficiency is most common in the Atlantic region on strongly acid, coarse-textured soils and on soils that have received high rates of either calcitic limestone or potassium, or both.

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 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% 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 (16°C) for reconditioning when making chips.

Symptoms. Sprouts grow inward and cause bulges and cracks in the tubers (Fig. 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 when they are applied uniformly at recommended rates.

Control. If you must store potatoes at a temperature above 50°F (10°C), use a sprout inhibitor. Avoid deep piling of tubers in storage.

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

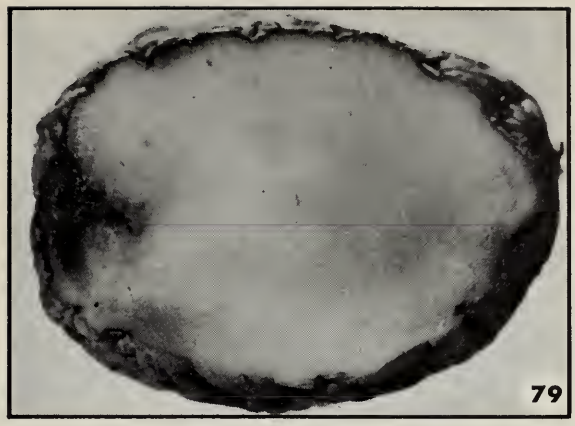


Fig. 77. Internal sprouting in stored potato.

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

Fig. 79. Internal black spot in stored potato.

Fig. 80. Pressure bruise in stored potato.

the stem end (Fig. 78) and show no external symptoms. The affected areas are bluish gray to brown or black. They vary considerably in size but are rarely found more than 1/4 inch (0.64 cm) below the surface (Fig. 79).

Cause. The cause is unknown. Susceptibility varies with the season and with the variety.

It has been shown conclusively, however, that tuber firmness and tuber temperature at handling are related to susceptibility; and that increased susceptibility follows loss of tissue turgor. Basically, black spot does not develop until the tubers have been subjected to a bruising force.

Control. Because bruising may occur during harvesting, grading, and packing operations, every effort should be made to reduce the means by which injuries occur. In storage all the evidence indicates that black spot can be controlled by proper storage management to prevent shrinkage and by warming the tubers to 50°F (10°C) prior to grading out of storage.

SECONDARY TUBERS

Symptoms. Several small tubers may form on plants like beads

on a string (Fig. 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 soil.

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 (Fig. 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 (Fig. 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. Provide adequate ventilation and avoid high temperatures 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 (Fig. 84) that may be

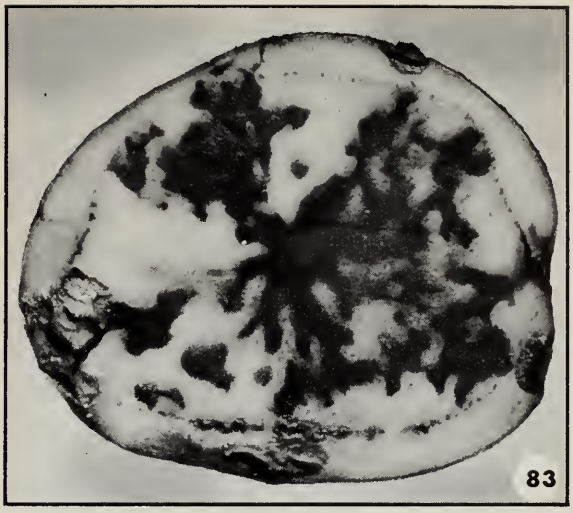


Fig. 81. Secondary tubers.
Fig. 82. Hollow heart.
Fig. 83. Black heart.

Fig. 84. Stem-end browning.

1/2 inch (1 cm) deep. The disorder is readily confused with the tuber symptoms of leaf 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.

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 lights 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 (Fig. 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 (Fig. 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 shrivels 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.

Fig. 85. Growth cracks.

Fig. 86. Thumb-nail cracks.

Fig. 87. A leaf injured by a herbicide.

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 used to control weeds along roadsides or in adjoining crops, and by hail, lightning, and frost. The tubers are often damaged by rough handling, overuse of fertilizer, frost and lightning, and 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 (Fig. 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 (6 m) 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 (Fig. 88). Severely frosted tubers have blackened eyes, cheesy flesh, and a sour odor.

Tubers that have been exposed to temperatures 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 (Fig. 89). Tubers that have been chilled but show no symptoms produce weak, slow-growing plants.

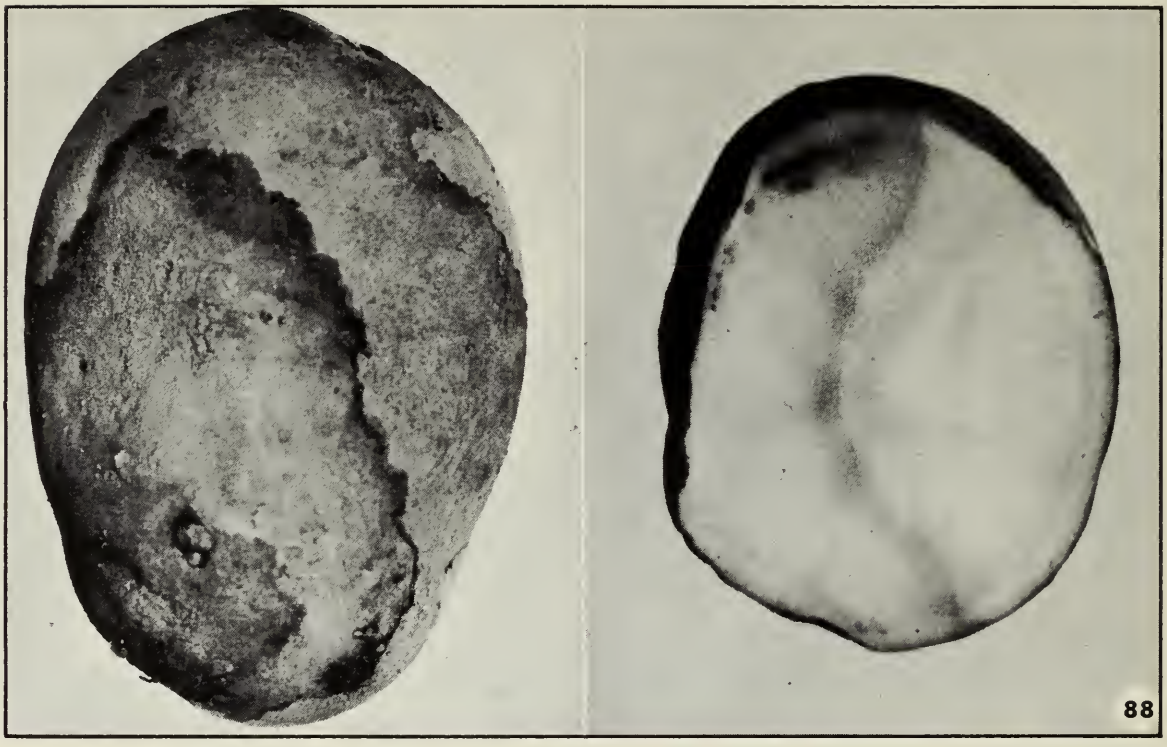
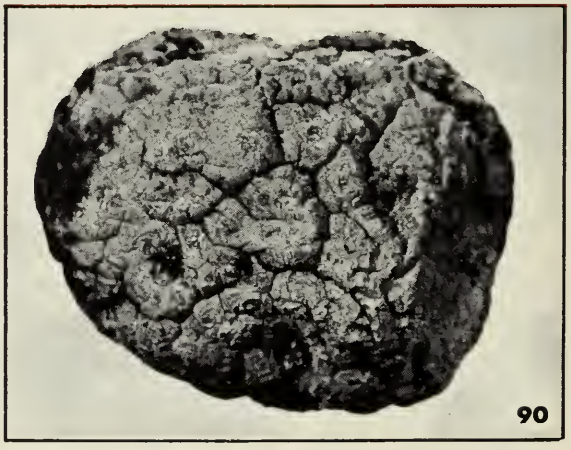


Fig. 88. *Left*, a frosted tuber beginning to leak; *right*, discoloration caused by frost.

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

Fig. 90. Alligator skin.



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

The needle-sharp tips of the underground stems of couchgrass may grow through the tubers.

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

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.

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

Avoid growing potatoes in fields heavily infested with couchgrass.

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* Retired.

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 sulphureum* Schlecht (*F. 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 ultimum* Trow
Phoma rot	*Phoma exidua* Desm. var. *exidua* (*P. solanicola* Prill & Delacr.)
Pink eye	*Pseudomonas fluorescens* (Flügge) Migula
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. [*Helmisporium atrovirens* (Harz) Mason & Hughes]
Skin spot	*Oospora pustulans* Owen & Wakef.
Soft rot	*Erwinia carotovora* (L.R. Jones) Holland
Verticillium wilt	*Verticillium albo-atrum* Reinke & Berth. *V. dahliae* Kleb.
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	*Acyrthosiphon solani* (Kaltenbach)
Grasshoppers	*Melanoplus* spp.
Green peach aphid	*Myzus persicae* (Sulzer)
Millipedes	Diplopoda
Northern root-knot nematode	*Meloidogyne hapla* Chitwood
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)
Seed-corn maggot	*Hylemya platura* Meigen [= *H. cilicrura* (Rondani)]
Six-spotted leafhopper	*Macrosteles fascifrons* (Stål)
Slugs	Limacidae
Southern root-knot nematode	*Meloidogyne arenaria* (Neal) Chitwood
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

CONVERSION FACTORS FOR METRIC SYSTEM

Imperial units	Approximate conversion factor	Results in:	
LINEAR			
inch	x 25	**millimetre**	**(mm)**
foot	x 30	**centimetre**	**(cm)**
yard	x 0.9	**metre**	**(m)**
mile	x 1.6	**kilometre**	**(km)**
AREA			
square inch	x 6.5	**square centimetre**	**(cm^2)**
square foot	x 0.09	**square metre**	**(m^2)**
acre	x 0.40	**hectare**	**(ha)**
VOLUME			
cubic inch	x 16	**cubic centimetre**	**(cm^3)**
cubic foot	x 28	**cubic decimetre**	**(dm^3)**
cubic yard	x 0.8	**cubic metre**	**(m^3)**
fluid ounce	x 28	**millilitre**	**(ml)**
pint	x 0.57	**litre**	**(ℓ)**
quart	x 1.1	**litre**	**(ℓ)**
gallon	x 4.5	**litre**	**(ℓ)**
WEIGHT			
ounce	x 28	**gram**	**(g)**
pound	x 0.45	**kilogram**	**(kg)**
short ton (2000 lb)	x 0.9	**tonne**	**(t)**
TEMPERATURE			
degrees Fahrenheit	(°F-32) x 0.56 or (°F-32) x 5/9	**degrees Celsius**	**(°C)**
PRESSURE			
pounds per square inch	x 6.9	**kilopascal**	**(kPa)**
POWER			
horsepower	x 746	**watt**	**(W)**
	x 0.75	**kilowatt**	**(kW)**
SPEED			
feet per second	x 0.30	**metres per second**	**(m/s)**
miles per hour	x 1.6	**kilometres per hour**	**(km/h)**
AGRICULTURE			
gallons per acre	x 11.23	**litres per hectare**	**(ℓ/ha)**
quarts per acre	x 2.8	**litres per hectare**	**(ℓ/ha)**
pints per acre	x 1.4	**litres per hectare**	**(ℓ/ha)**
fluid ounces per acre	x 70	**millilitres per hectare**	**(ml/ha)**
tons per acre	x 2.24	**tonnes per hectare**	**(t/ha)**
pounds per acre	x 1.12	**kilograms per hectare**	**(kg/ha)**
ounces per acre	x 70	**grams per hectare**	**(g/ha)**
plants per acre	x 2.47	**plants per hectare**	**(plants/ha)**