DISEASES OF CARROTS IN CANADA

PUBLICATION ~~1615~~
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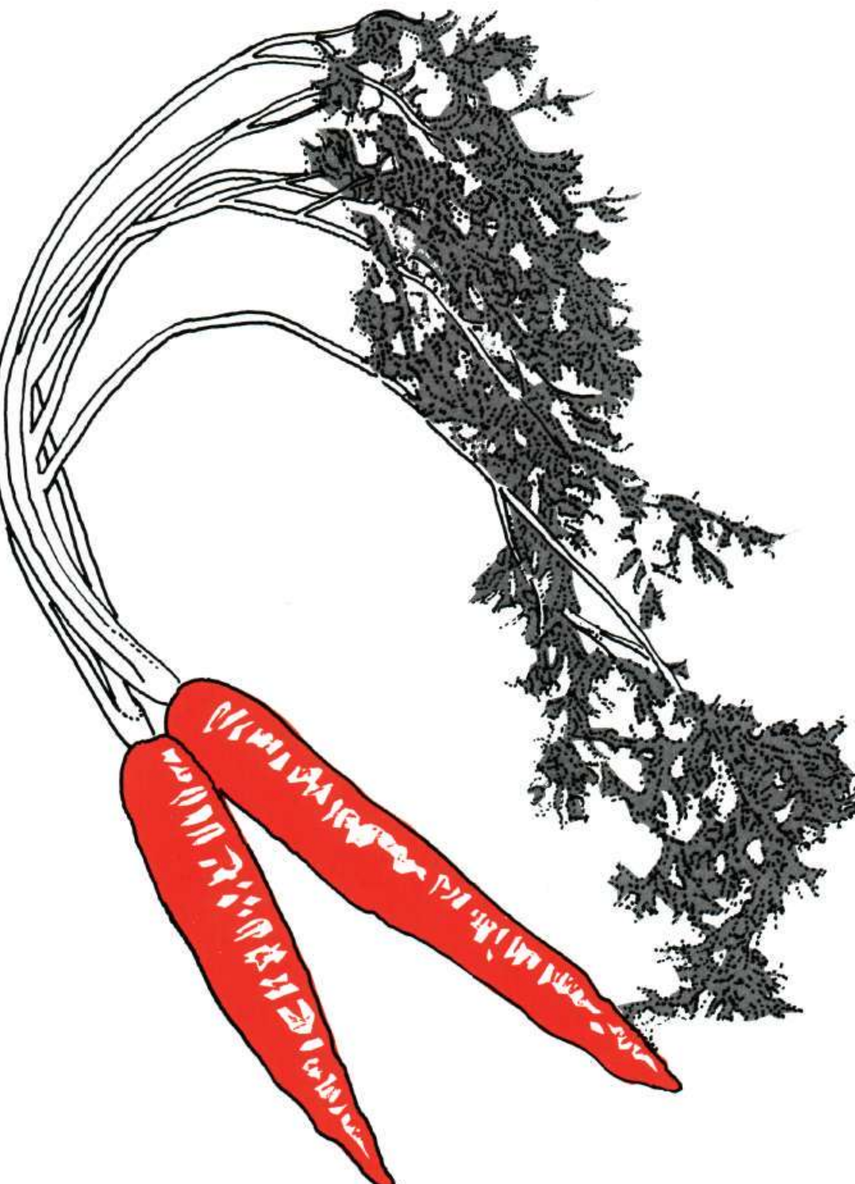

Agriculture Canada

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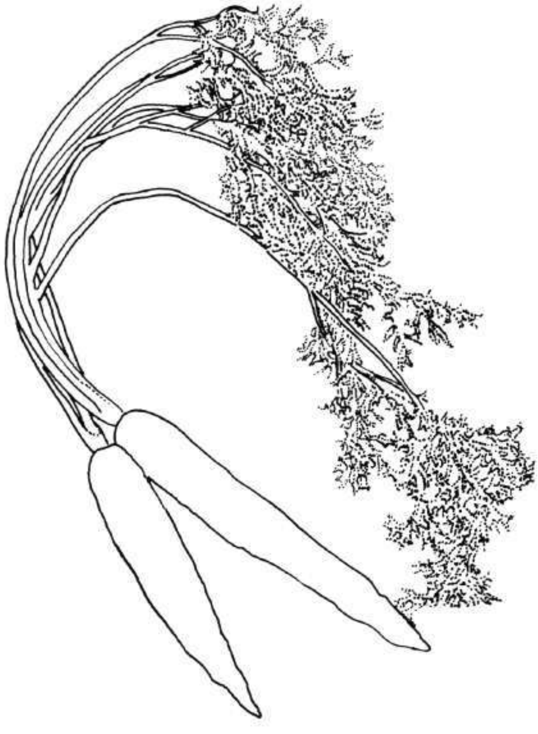

PUBLICATION 1615, *available from*
Information Services, Agriculture Canada, Ottawa K1A 0C7

Cat. No. A43–1615/1980E ISBN: 0-662-111/2-5
Revised 1980; Reprinted 1981 5M–5:81

Aussi disponible en français

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INTRODUCTION

The carrot crop is one of the most important crops in Canadian vegetable production. The 6000 ha planted annually yield an average of 25 t/ha. The bulk of this production is intended for the fresh market, and the remainder is used for processing. Canada is practically self-sufficient in carrot production; imports from the United States represent approximately 20% of the total production, with exports slightly exceeding this percentage.

The carrot is a cool-season vegetable that is best adapted to areas with long, cool growing seasons. Deep, loose, fertile soils with good water-holding capacity are necessary for the development of long, straight roots. Well-drained, sandy loam, peat, or muck are ideal for carrot production. Approximately 75–80% of the Canadian carrot crop is grown on organic soils; Quebec and Ontario are the main production centers.

Disease control is an important consideration in growing a healthy, high-yielding carrot crop. Therefore, to prevent or control diseases, early recognition is imperative. This publication describes and illustrates the main carrot diseases in Canada. Storage diseases and disorders have been omitted because they have been described in other publications.

CAUSES OF PLANT DISEASES

Diseases are caused by parasitic fungi, bacteria, nematodes, and mycoplasmas and viruses, or they may be physiogenic disorders caused by unfavorable environmental conditions.

Fungi

Fungi are mostly microscopic plants that depend on other living plants or dead organic matter for their existence. Fungi produce countless numbers of spores, which are carried by wind or other means to their hosts. There, under favorable conditions of temperature and moisture, they germinate and infect healthy plants. Between growing seasons, many fungi survive as dormant spores, mycelia, or sclerotia in plant debris or in the soil.

Bacteria

Bacteria are microscopic, single-celled, rod-shaped organisms that multiply quickly in the plant. Often they occur as a secretion on the surface of diseased plants. In other cases, the bacteria are released when the diseased tissue breaks open. Then they are spread to other plants by splashing water, rain, insects, and man.

Nematodes

Nematodes are small, usually microscopic, wormlike organisms that live in the soil. The endoparasites penetrate the roots of plants, whereas the ectoparasites feed on the roots from the outside. When either type is present in large numbers, affected plants become unhealthy and crop yields are reduced. The root-knot nematode produces swellings or galls on the roots of carrots, lettuce, tomatoes, and many other plants.

Mycoplasmas and viruses

Mycoplasmas and viruses are the smallest forms of life that cause disease in plants. They are so small that they cannot be seen through an ordinary light microscope, but their shape and size can be determined with an electron microscope. They are made up of complex protein substances that multiply rapidly in the plant. They are transmitted by various means such as insects, seeds, or mechanical contact.

Physiogenic disorders

These disorders are caused by environmental conditions that seriously affect normal growth. Such conditions may be adverse temperature or moisture above or below ground, unbalanced nutrition, deficiency or excess of minerals, acidity or alkalinity of soil, poor drainage, or industrial fumes.

GENERAL CONTROL MEASURES

The objective of plant-disease control is to combat harmful organisms. This prevents economic losses and increases the value of the crop. Control practices are desirable only when the cost, in terms of money and effort, is less than the financial losses caused by diseases. Control measures must also be planned to fit into an integrated program of crop production. It is usually much easier and preferable to prevent plant diseases than to cure them. Therefore, the use of one or several practices is desirable. These include sanitation, crop rotation, treatment of seed and foliage with fungicides, soil fumigation, and the use of resistant or tolerant varieties.

Sanitation

Many foliage disease organisms such as *Alternaria* and *Cercospora* may persist in decayed plant material, where they continue to live and sometimes complete their life cycle. Therefore, it is important to dispose of infected crop debris or residues by burning, plowing, or any other means to prevent the buildup of the source of infection.

The destruction of weeds in and around fields should help to reduce the spread of certain diseases, because several weeds are reservoirs of mycoplasmas, viruses, and the insects that disseminate them, such as the aster leafhopper, vector of the mycoplasma that causes aster yellows.

Crop rotation

Crop rotation helps to control certain diseases when other crops not affected by the disease are included in the cropping sequence or rotation. The practice of crop rotation prevents the excessive multiplication or buildup of soil-borne organisms against which chemical control is not effective or is too costly for practical use.

The length of a rotation depends on how long an organism can survive in the absence of its host crop. Certain organisms, such as those causing foliar blights, can survive in crop debris for a limited time. Thus a 2- to 3-year rotation may be sufficient to prevent the carry-over of inoculum from the crop refuse once it has been completely decomposed.

Nematodes and other soil-borne organisms, such as those that cause clubroot and onion smut, may persist almost indefinitely in the soil, thus requiring a rotation of 5 years or more to reduce the amount of inoculum. Such a rotation may be impractical or of limited value, especially for those organisms that can survive and multiply on weeds.

Fungicide treatments for seed and foliage

Seed should be treated with a protectant fungicide to help prevent seed decay and damping-off caused by fungi on the seed surface or in the soil. Seed treated by hot water to kill bacteria and fungi in or on the seed should also be dusted with a fungicide. Mix the fungicide thoroughly with the seed before seeding, following the manufacturer's directions. This treatment is effective against fungi on the seed surface. Planting carrot seed that has been treated with fungicide should improve the stand.

Foliar diseases are difficult to control once they have become established in a field. Fungicide treatments only prevent the disease from developing and spreading to other plants or fields. It is recommended to begin the applications of a good protectant fungicide early in the life of the crop, when it is 10–15 cm high. This helps to prevent the buildup of inoculum. It is also easier to obtain a better coverage and a good protection for all the plants when the foliage is not too dense. Make two consecutive applications at intervals of 7–10 days, and then repeat the treatment according to a weather-timed fungicide spray scheme.

Fumigation for nematode control

In undertaking soil fumigation, it is important to consider the objective of the treatment as well as the cost in relation to the value of the crop and to the expected benefits. Chemical fumigation has become a common practice with many carrot growers. This practice should be integrated with a good program of crop rotation. Consult a nematologist to determine how large the nematode population must be before fumigation becomes economically justified. Chemical fumigation may be beneficial, because it not only kills nematodes but also destroys pathogenic fungi, bacteria, soil insects, and weeds.

Soil can be fumigated either in the fall or in the spring. To avoid delays in planting in the spring, fall fumigation is recommended. The soil temperature should be at least 5°C at a depth of 15–20 cm, with adequate moisture. The soil should also be reasonably free from undecomposed crop residue. Carefully follow provincial recommendations and manufacturer's directions concerning dosage and methods of use. The soil surface must be sealed immediately after injection by watering (irrigation), leveling with boards, packing, or other methods. After spring fumigation, the soil must be left undisturbed for at least a week before planting, especially if the weather is wet and cool. With fall applications, do not disturb the soil after sealing until the normal spring cultivation is started.

Resistant or tolerant cultivars

The use of resistant cultivars is the best and the cheapest method of plant-disease control. Certain diseases caused by persistent soil-inhabiting organisms cannot be controlled in any other way. Several diseases cannot be controlled by any currently known means and probably will not be controllable until resistant cultivars have been developed. At present, there are very few disease-resistant cultivars; however, some cultivars, such as Spartan Delight and Spartan Fancy, show some tolerance for rusty root. Breeding for resistance is constantly in progress.

DISEASES CAUSED BY FUNGI

Alternaria blight (Brûlure alternarienne)

Alternaria dauci (Kühn) Groves & Skolko

Alternaria blight (Fig. 1) is a common foliage disease of carrots in Canada. The disease is produced by a fungus, *Alternaria dauci* (Kühn) Groves & Skolko. An early attack of the seedlings causes a damping-off. On the foliage of mature plants the lesions are dark brown to black, edged with yellow, and they first appear at the margin of the leaflets. The leaflets may shrivel and die, which makes the plants appear blighted. Because older leaves are attacked more often than younger ones, the disease appears somewhat later than cercospora blight. The fungus may also attack the roots after mechanical injury. The lesions are irregular, are dark brown to black, and produce a shallow, firm decay.

The pathogen subsists on or in the seed and on diseased crop debris in the soil. The spores and mycelium produced are spread by wind, running water, splashing rain, and moving objects. Free moisture is essential for infection to occur. Cool weather is most favorable for the development of alternaria blight; it is therefore more likely to occur later in the season. This contrasts with cercospora blight, which usually appears earlier.

Control measures

To prevent the disease, the following procedures are recommended:

- Practice a 3-year rotation to prevent inoculum from surviving in crop refuse.
- Treat the seed with a protectant fungicide before seeding.
- Spray the foliage with an effective fungicide. Begin the treatments when the carrots are 10–15 cm high and make two consecutive applications, 7–10 days apart. Then repeat the treatment according to weather conditions or to disease forecasts. It is preferable to begin the applications of fungicide early, to prevent the buildup of inoculum. It is also easier to obtain better coverage and good protection when the foliage is not too dense.
- Whenever possible, use cultivars with known resistance or tolerance.

Cercospora blight (Brûlure cercosporéenne)

Cercospora carotae (Pass.) Solh.

Cercospora blight (Figs. 2, 3), another widespread disease, is produced by a fungus, *Cercospora carotae* (Pass.) Solh. It attacks the leaves, leafstalks, stems, and floral parts but not the root. Lesions first appear along the margins of the leaves and cause the edges to curl. Spots inside the leaf edges are small, roughly circular, tan or gray to brown or almost black, with a dead center surrounded by a yellowy area with no clear border. As the spots increase in number and size, the entire leaflet withers and dies. At this stage, the symptoms may be mistaken for those of alternaria blight. On the leafstalks and stems, the lesions are elliptical, tan to brown, with a paler center. In humid weather the spots are darker. Sometimes the lesions may merge and girdle the stem. This often causes the stems to break and the leaves die. Because infected carrot tops tend to break easily, mechanical harvesting becomes a difficult operation. When the floral parts are attacked early, they shrivel before the seed is borne, but later attacks may permit the fungus to penetrate the seed without showing symptoms.

Between crops, the organism lives on or in the seed and on infected crop refuse. The spores produced are air-borne and are spread by wind, splashing rain, and moving objects. Because the disease develops rapidly in hot or humid conditions, it is likely to occur in July or early August. The fungus attacks younger leaves in preference to older ones, in contrast with alternaria blight.

Control measures

The control measures are the same as those for alternaria blight.

Rusty root or pythium root dieback (Rousselure ou dépérissement pythien des radicelles)

Pythium spp.

Rusty root (Fig. 4) is caused by several species of *Pythium*. These are widespread near Bradford, Ont., and in British Columbia. The fungus *Pythium* persists indefinitely in organic soil.

The first symptoms appear when the carrots are about 10–15 cm high. The tops wilt during the day and recover at night. After several days of this intermittent wilting, the older leaves begin to show signs of disease at the margins. Growth slows down and the leaves become discolored. Infected areas on the root become flaky in texture and the roots become distinctly rusty red. The carrots formed are short, stubby, forked, and knobby. Many of these misshapen carrots produce fibrous branch roots that hold the soil during harvesting. The rusty-root symptom is evident on these fibrous roots throughout the growing season.

This disease is more severe in wet soils than in moist or dry soils.

Control measures

There is no practical and efficient control method known at present; therefore, control involves several practices:

- Use precision seeding, 3 cm apart.
- Rotate crops, with carrots following onions.
- Seed cultivars with known tolerance for rusty root, for example, Spartan Delight or Spartan Fancy.
- If possible, avoid wet soils.

Violet root rot (Rhizoctone violet)

Rhizoctonia crocorum (Pers.) DC. ex Fr.

Violet root rot (Fig. 5) is limited to a few isolated localities in Canada and is not confined to one particular soil type. The causal organism, *Rhizoctonia crocorum* (Pers.) DC. ex Fr., is native to Canada and the disease seems to be more serious on newly broken land.

The disease first appears in midsummer and occurs in patches in the field. By fall, the advanced stage of infection causes deep lesions in the root of the carrot. A thick mycelial weft and spores cover the root and present a characteristic purplish coloration. Small lesions develop on the carrot, but they soon enlarge and coalesce so that the infected part of the carrot appears grossly decayed. The decay is dark purplish brown, firm, and leathery. It is usually shallow at harvest time, but during storage the disease agent slowly penetrates deeper into the root tissues. When they are freshly pulled, diseased carrots usually have a considerable mass of soil adhering to them.

Control measure

The only known control at present is to avoid infected areas.

Rhizoctonia crown rot and cavity spot (Rhizoctone commun)

Rhizoctonia solani Kühn

Rhizoctonia crown rot and cavity spot (Fig. 6) occur sporadically, though they are caused by a soil-borne fungus, *Rhizoctonia solani* Kühn, which is destructive to many kinds of plants throughout the world. The disease is most prevalent in organic soils that have a history of successive carrot cropping.

The infection results in a damping-off of young seedlings and a crown rot later in the season and during storage. Diseased carrots have a few enlarged inner leaves surrounded by whorls of wilted or dead foliage. The crown rot appears as a dark brown to black decay in a band around the crown. The cavity spot shows dry, sunken, dark brown lesions at the point of lateral root emergence. The lesions are usually more numerous on the upper portion of the carrot root. When infected roots are freshly pulled, intertwining mycelium causes a mass of soil to adhere to them.

Control measure

No practical control measure is available at present.

Sclerotinia rot (Pourriture sclérotique)

Sclerotinia sclerotiorum (Lib.) de By.

Sclerotinia rot (Figs. 7, 8) is caused by *Sclerotinia sclerotiorum* (Lib.) de By., a destructive disease organism that is found in nearly every part of the world except the warmer areas of the tropics. It is recognized as one of the most important disease organisms that cause severe losses to stored carrots.

Although sclerotinia rot is mainly a storage disease of carrots, plants can be infected in the field, where a damping-off sometimes occurs. On the foliage (Fig. 7), the attack starts at the base of the leafstalk and then spreads rapidly to other parts of the plants. The leafstalks turn dark brown, the tissues collapse, and the foliage dies. Under moist conditions, a white cottony mycelium appears on the infected plants, and later small black sclerotia appear on the leafstalks. Crown infection usually follows and continues to develop in storage. On the surface of the infected roots (Fig. 8), the fungus produces a characteristic growth of white cottony mycelium with black, oval to irregularly shaped sclerotia. The invaded tissues are darker in color, and as the decay progresses, they become soft and watery but without sliminess. The lack of slime distinguishes this disease from bacterial soft rot. During storage, the disease spreads rapidly from infected roots to healthy ones, especially at temperatures above 0°C.

Sclerotinia is a fairly low-temperature organism that requires abundant moisture. It thrives best under continuously cool, rainy or foggy conditions. The optimum temperature for infection is between 15 and 20°C.

The fungus survives for several years in the soil, normally in the form of black sclerotia, but it can also live from season to season as active mycelia in living or dead plants. When the sclerotia are dry, they may remain alive for several years, but when they have been wet for some time, they may decompose in less than a year.

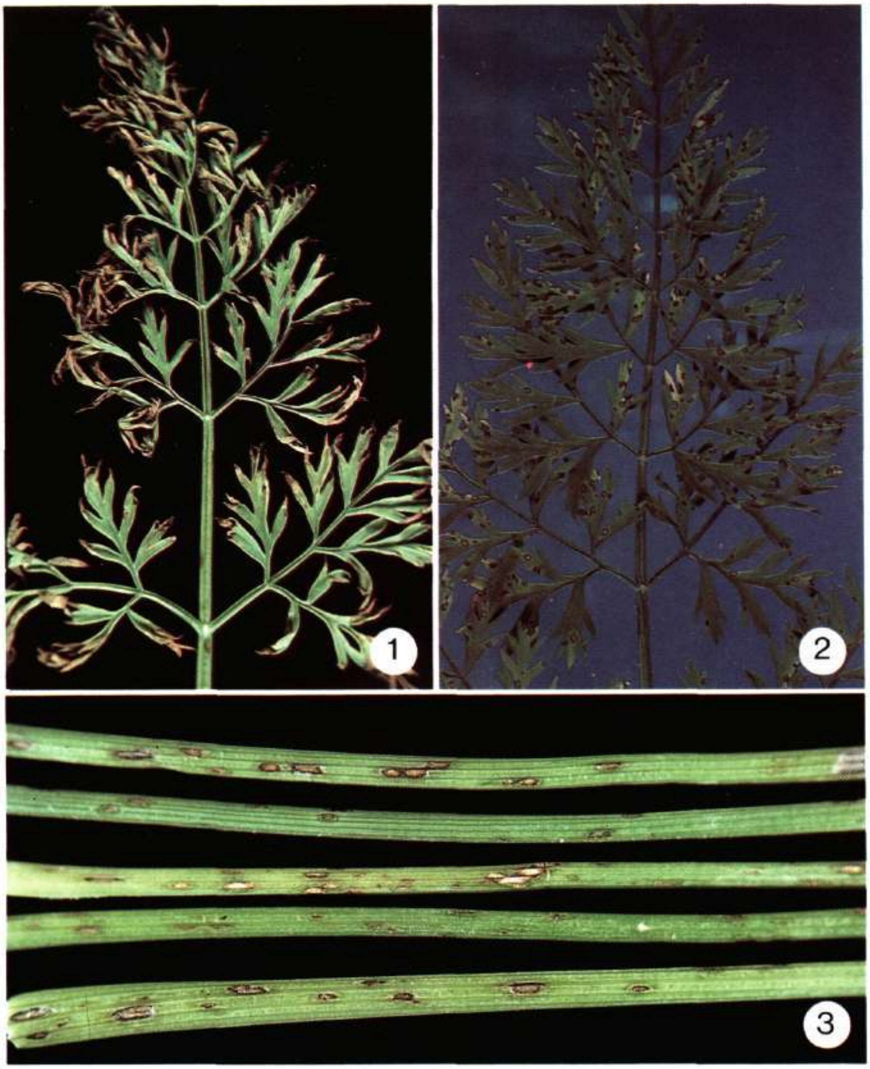

Fig. 1. Alternaria blight. Lesions appear at the margin of the leaflets.

Fig. 2. Cercospora blight. Tan brown, circular, decayed spots on leaflets.

Fig. 3. Cercospora blight on leafstalks. Lesions are tan, elliptical, and depressed.

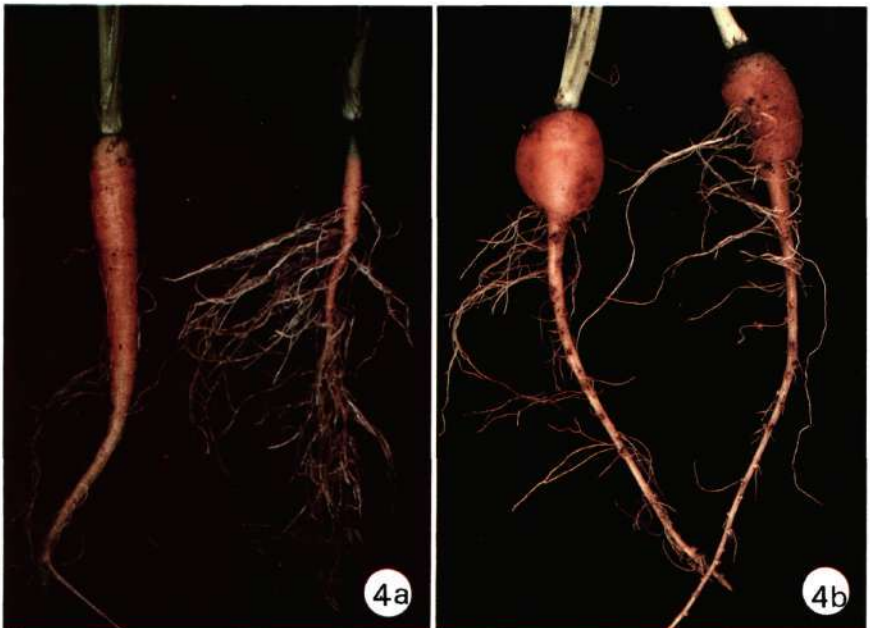

Fig. 4. Rusty root disease: (*a*) note distinct rusty red roots (*b*) stubby and fibrous roots with rattail appearance.

Fig. 5. Violet root rot with dark purplish brown lesions and decay.

Fig. 6. Crown rot and cavity spot caused by *Rhizoctonia*, with dark brown to black decay at the crown.

Fig. 7. Sclerotinia rot, field symptoms: blighted and decaying foliage.

Fig. 8. Sclerotinia rot, storage symptoms: decaying root with white cottony mycelium and black sclerotia.

Fig. 9. Black rot, field symptoms.

Fig. 10. Crown gall (note galls on roots).

Fig. 11. Aster yellows on foliage showing whitish foliage and proliferation of new, yellowy shoots at the crown.

Fig. 12. Aster yellows on roots showing excessive fibrous rootlets in four rows along the axis of the main root.

Fig. 13. Bacterial blight, leafstalk and stem infection (note gummy bacterial secretion).

Fig. 14. Heat canker showing enlargement just above the constriction, which is formed by the death and shrinkage of the cortex cells.

Control measures

The control of sclerotinia rot remains difficult and many recommendations have been made but none are entirely satisfactory. The following are the most practical and economical methods:

- Practice a 3-year rotation with resistant crops such as beets, onions, spinach, corn, or cereals.
- Do not plant carrots immediately after planting a susceptible crop such as lettuce or celery.
- At harvest, avoid all bruising, and store only healthy carrots.
- Precool the carrots and store them at appropriate temperature and relative humidity. Initial infection is much lower if the relative humidity is below 92%.

Black rot (Pourriture noire)

Stemphylium radicinum (Meier, Drechs. & Eddy) Neerg.

Black rot (Fig. 9) is caused by a seed-borne fungus, *Stemphylium radicinum* (Meier, Drechs. & Eddy) Neerg., that is widely distributed throughout the world. It attacks any part of the plant and survives on carrot debris in the soil, but infested seed is probably the most important source of infection.

In the field, the disease agent causes a damping-off. On the foliage the infection usually starts at the base of the older leafstalks, which turn dark brown to black, and finally the entire leaf is killed. Occasionally, black, irregular lesions develop on the edges of the leaflets; they are difficult to distinguish from lesions caused by *Alternaria dauci*. Infection appears on the sides of the roots as tiny, black, scab-like spots. The growing point of the taproot may be killed by the disease. This often causes the root to develop two or more growing points and produces a forked root. On stored carrots, the spots are round, shallow, and slightly depressed. If the root tip has been infected, most of the lower part may become rotten and black. During storage, the rot occurs on the crown and often penetrates into the core. At high humidity, the decay is soft and watery with a brownish advancing margin. The disease agent requires a relative humidity above 92% for rapid development.

Control measures

- Practice crop rotation and use only seed treated with hot water and fungicide.
- Use fungicide treatments to control leaf diseases because they reduce black rot in storage.
- Clean and disinfect the storage house before storing carrots.
- Maintain storage temperature near 0°C and relative humidity at 92% to keep storage decay to a minimum.

Common scab (Gale commune)

Streptomyces scabies (Thaxt.) Waks. & Henrici

This disease occurs throughout the world and attacks many crops. In Canada, it has been reported only on rare occasions.

The causal organism is *Streptomyces scabies* (Thaxt.) Waks. & Henrici. It is classified by some scientists as one of the higher bacteria and by others as one of the lowest forms of true fungi. Streptomyces organisms are found abundantly in nearly every soil, but most of them are not harmful to living plants. Some forms of this organism cause a damping-off or seedling death. The surviving plants show typical scab symptoms on the roots. The scab lesions are formed by the abnormal growth of the host cells, giving rise to corky tissue that is usually darker than the healthy tissue. The scab spots are sometimes sunken below or raised above the surface of the healthy skin. Many single spots may join up, to form continuous scabby areas.

Alkaline soils favor the development of common scab. Infection also tends to be greater in fairly dry soil.

Control measures

The disease is rarely severe enough in carrots to warrant control; however, if it becomes troublesome the following procedures are recommended:

- Avoid planting in alkaline soil or apply acid-producing fertilizers like ammonium sulfate or limited quantities of sulfur during the previous fall.
- Practice a long rotation with small grain, grasses, or corn.

DISEASES CAUSED BY BACTERIA

Crown gall (Tumeur du collet)

Agrobacterium tumefaciens (E.F. Sm. & Town.) Conn.

Crown gall (Fig. 10) on carrots has been reported only on a few occasions. The causal agent is a bacterium, *Agrobacterium tumefaciens* (E.F. Sm. & Town.) Conn., which causes tubular to irregular, yellowish to tan galls on the stem near the crown or on the roots. One or more galls, of various sizes, may appear on a single plant about midsummer and continue to increase in number and size until harvest. The bacteria produce a growth hormone, which sometimes causes swellings that resemble the irregular enlargements induced by plant-growth hormones.

The bacteria are carried in and on the galls and live for at least a year in the soil in the absence of a suitable host. Crown gall is more often observed in alkaline than in acid soils.

Control measures

If the disease appears in truck crops, practice a long rotation with corn, oats, grasses, onions, or other immune crops.

Bacterial blight (Brûlure bactérienne)

Xanthomonas carotae (Kendr.) Dows.

Bacterial blight (Fig. 13) occurs occasionally throughout Canada but causes little damage. It is most serious on the seed crop, as it not only reduces yields but also infects seeds that form an important source of inoculum in spreading the disease.

This disease is caused by a bacterium, *Xanthomonas carotae* (Kendr.) Dows., that produces irregular brown spots on the leaves, dark brown streaks on the leafstalks and stems, and a blighting of the floral parts. On the foliage, the lesions begin as small, irregular yellow areas that turn to dark brown, water-soaked spots within a few days. The center of these lesions becomes dry and brittle, with an irregular yellow halo. Curling of the leaf segments follows and the entire leaflet often dies. When leaf infection is severe, linear lesions extend to the leafstalks and stems and a gummy bacterial secretion appears. Unfolded umbels may be infected and killed, thus reducing the seed yield. When the bacteria are washed down to the roots, brown to maroon lesions are formed. They develop into either slightly raised pustules or slightly sunken craters with flakes of black diseased tissue in the center bearing gray masses of bacterial ooze. Large, rough, sunken cankers are formed when several scab spots coalesce into one.

The bacteria persist on and in the seed and may live for at least a year in the soil or on crop debris. They are spread by insects, splashing rain, or irrigation water from infected plants. Infection requires the presence of dew or rain and spreads faster when carrots are grown close together.

Control measures

- Practice a 2-year rotation if infested soil is not likely to be washed or blown into the growing area from neighboring fields. Destroy all crop residue at harvest.

- Use seed treated with hot water or treat the seed with hot water at 52°C for 10 minutes. After the seed has dried, dust with a protectant fungicide.

DISEASE CAUSED BY NEMATODES

Root knot (Nodosité des racines)

Meloidogyne hapla Chitwood

Root knot (Fig. 15) is caused by the nematode *Meloidogyne hapla* Chitwood and is often found in vegetable-producing areas, particularly in muck soils. Many crops, particularly carrots, are severely damaged by this disease.

In the field, poor plant growth occurs in patchy areas. The plants attacked are stunted, and the foliage is pale in color and inclined to wilt. Numerous galls appear on the root at the site of penetration by the nematode. Above the galls, the roots often branch to form clumps of hairy roots. The tissue of the invaded portion of the root produces nodules or swellings on lateral roots or rootlets. The unmarketable roots are forked, knobby, hairy, and misshapen. Masses of soil cling to the roots when they are pulled or harvested.

In the soil, nematode larvae are eel-like in shape and microscopic in size. The larvae enter near the root tip or rootlets of the plant, where they feed. At maturity, the pear-shaped females lay several hundred eggs in a gelatinous mass on the surface of the roots.

Root-knot nematodes are most active during the hot summer months and several generations may occur, depending largely on air temperatures. Soil moisture is important, because continuous flooding may kill many larvae and egg masses. Soil temperature is also extremely important; the optimum temperature for penetration is about 22–24°C. Alternate freezing and thawing may be detrimental to the larvae.

The larvae do not move far within a field during the growing season. The principal means of transportation is in surface or drainage water, in moving soil, in infested seedlings, and in roots used for seed production or tubers. The root-knot nematode can reproduce indefinitely in the presence of susceptible crops or weeds.

Control measures

Preventive measures should be used to avoid nematode infestation in soils that are not already infested. It is easier and less costly to prevent soil infestation by nematodes than it is to control them.

Fig. 15. Root knot caused by *Meloidogyne hapla*: abnormal growth of carrot, with nodules or swellings on lateral roots or rootlets.

- In the field, a good program of crop rotation with periodic soil fumigation is recommended. Do not grow carrots for more than 2 consecutive years on the same field. Rotate with resistant or nonhost plants, such as corn or cereals, for at least 2 years. In the absence of host plants, populations of nematodes tend to decline rapidly.
- Chemical control complements crop rotation. Nematocides are commonly applied to control nematodes that feed on root crops. Follow provincial recommendations for application of nematocides. Plant carrots after soil fumigation. The soil can be fumigated either in the fall or spring; however, fall fumigation is preferable to avoid delays in spring planting. The soil temperature should be at least 5°C at a depth of 15–20 cm. For most efficient action of nematocides, the moisture content should be at a level that encourages good seed germination. The soil surface must be sealed immediately after fumigation in the spring and left undisturbed for at least a week, depending on weather conditions. With fall fumigation, the soil should not be disturbed after sealing until the normal spring cultivation is started.
- Alternate flooding and drying, as well as clean summer fallow, appear to reduce root-knot nematode populations. However, these methods are not practical enough to be recommended in Canada.

DISEASE CAUSED BY MYCOPLASMA-LIKE ORGANISMS

Yellows or aster yellows (Jaunisse)

Aster yellows mycoplasma (AYM)

The yellows disease (Figs. 11, 12) is important, because it occurs on many ornamental, vegetable, and weed plants. The severity of the disease and the injury to the carrot crop depend on the age of the plant when it is infected and the length of time the disease has to develop before the crop is harvested. The disease is most severe on late-harvested crops grown for processing.

The disease is caused by the aster yellows mycoplasma (AYM), which is transmitted to the carrots by the aster leafhopper, *Macrosteles fascifrons* (Stål).

The first symptom noticed in the field is a yellowing, with some veinclearing of the younger leaves at the center of the crown. Later, a mass of new sickly shoots grow from the crown, giving a witches'-broom appearance to the top. The older leaves are whitish at first, and then become bronze or reddened, or both. The leafstalks are twisted and eventually break off, leaving a short bunchy top unsuited to mechanical harvesting and to bunching for the fresh market. On the roots, many malformed, fibrous rootlets usually appear, growing in four rows along the axis of the main root. The color, texture, and flavor of diseased roots are altered. The crowns of diseased plants are likely to develop bacterial soft rot in moist weather. The disease can continue to progress in storage. On the seed plants, various degrees of stunting occur as well as malformation, chlorosis, and sterility of the flowering umbels.

The aster leafhopper is the most important vector of the yellows disease. The insect migrates along the St. Lawrence River in Quebec or overwinters in the egg stage on winter grains or grasses. In the spring, the eggs hatch and the nymphs feed on the overwintering host. As the insects reach the adult stage, they begin to migrate to other plants and invade carrot fields. In some parts of the country, such as Manitoba, leafhoppers sometimes migrate in large numbers from the south. The leafhoppers pick up the infection by feeding on infected perennial hosts and spread the disease to healthy plants.

Control measures

- The most important method of control is to eradicate all perennial or biennial weeds on which the microorganism (AYM) can survive. The weeds grow along roadways, ditch banks, fence rows, and in open fields.
- Avoid planting immediately next to a diseased or susceptible crop planted earlier, such as lettuce.
- Spray with an insecticide at intervals often enough to reduce leafhopper populations; follow provincial recommendations. Also spray the surroundings of the field to destroy the insects on the weeds. Begin applications when the first leafhoppers appear and repeat the insecticide treatment, especially during the peak of the population. Consult an entomologist.
- Immediately after harvesting, destroy or plow under all crop residues, especially lettuce, on which the disease and the leafhopper can continue to thrive.
- Plant cultivars of reputed tolerance for the yellows disease.

PHYSIOGENIC DISORDERS

Hollow heart (Cœur creux)

Boron deficiency

Boron deficiency occurs in many crops. In carrots, boron deficiency is rarely troublesome, but when it does occur, one or several of the following symptoms can be observed. The young leaves are yellowed and malformed and the foliage tends to lie flat rather than stand erect. A characteristic symptom is the appearance of one or several cavities in the central portion of the root, and splitting. The roots may not reach marketable size.

Symptoms of boron deficiency increase in dry seasons and in alkaline soils. Plants grown in soils with levels too high in nitrogen and potash show more severe damage.

Control measures

The only method of control is to add boron to the soil or to the growing plant. Although carrots are fairly tolerant, boron is usually needed only in very small quantities and an overdose can be toxic. Boron can be mixed with an ordinary fertilizer applied before seeding. It can also be applied as a foliar spray when the carrots are less than half grown. A second application may be required a few weeks later. Foliar sprays usually give faster and more effective results than soil applications, especially in a dry season. Follow provincial recommendations.

Heat canker (Chancre de chaleur)

High temperature

On a bright sunny day, the temperature at the soil surface, where light is absorbed, may reach 65°C. This causes heat injury.

The heat canker (Fig. 14) is usually first noticeable when young plants break at or near ground level. The tissues collapse at the point of injury and the plants wither and die. If the injury occurs later in the season, only the cortex dies. A constriction is formed by the death and shrinkage of the cortex cells. The vascular system may remain uninjured and the plant tops may stay alive for some time. Above the canker or constriction, there is an enlargement, because food that the tops have manufactured can no longer move downward to the roots. In most cankered plants, the stem breaks sooner or later and the plant dies; otherwise, the plant dies when the starving roots can no longer support the increasing needs of the portion above the ground.

Heat canker is the direct result of the high temperatures of the dry soil surface in immediate contact with the tender young stems. The amount of injury is influenced by the soil surface, the age of the plant tissues, and the temperature.

Control measures

- Seed early so that the seedlings pass the susceptible stage before the hot weather.
- Increase plant density to provide more shade for the seedlings.

ACKNOWLEDGMENTS

The author is greatly indebted to the following persons for contributing photographs: Professor J. C. Sutton, Department of Environmental Biology, University of Guelph, Guelph, Ont. (Fig. 4a); Professor P. H. Williams, Department of Plant Pathology, University of Wisconsin, Madison, WI (Fig. 13); and to Dr. C. D. McKeen, Research Coordinator, Ottawa, Ont., for his helpful suggestions and for reviewing the paper.

CONVERSION FACTORS

Metric units	Approximate conversion factors	Results in:
LINEAR		
millimetre (mm)	x 0.04	inch
centimetre (cm)	x 0.39	inch
metre (m)	x 3.28	feet
kilometre (km)	x 0.62	mile
AREA		
square centimetre (cm^2)	x 0.15	square inch
square metre (m^2)	x 1.2	square yard
square kilometre (km^2)	x 0.39	square mile
hectare (ha)	x 2.5	acres
VOLUME		
cubic centimetre (cm^3)	x 0.06	cubic inch
cubic metre (m^3)	x 35.31	cubic feet
	x 1.31	cubic yard
CAPACITY		
litre (L)	x 0.035	cubic feet
hectolitre (hL)	x 22	gallons
	x 2,5	bushels
WEIGHT		
gram (g)	x 0.04	oz avdp
kilogram (kg)	x 2.2	lb avdp
tonne (t)	x 1.1	short ton
AGRICULTURAL		
litres per hectare (L/ha)	x 0.089	gallons per acre
	x 0.357	quarts per acre
	x 0.71	pints per acre
millilitres per hectare (mL/ha)	x 0.014	fl. oz per acre
tonnes per hectare (t/ha)	x 0.45	tons per acre
kilograms per hectare (kg/ha)	x 0.89	lb per acre
grams per hectare (g/ha)	x 0.014	oz avdp per acre
plants per hectare (plants/ha)	x 0.405	plants per acre