11 Lettuce, chicory, endive

BACTERIAL DISEASES

▶ 11.1 Bacterial soft rots *Figs. 11.1 a, b*

Bacterial wilt (dry leaf spot)

Xanthomonas campestris pv. *vitians* (Brown) Dye

Head rot (slime rot)

Erwinia carotovora subsp. *carotovora* (Jones) Bergey *et al.*

These bacteria also cause soft rot. *Erwinia* is by far the more widely distributed and about 80% of slime rots are caused by *E. carotovora,* mostly in hydroponic greenhouse production, and in marketed heads as a storage disease. Both bacteria are common pathogens on lettuce, endive and chicory. They affect most vegetable crops and some weeds.

Symptoms Bacterial wilt or dry leaf spot caused by *Xanthomonas campestris* pv. *vitians* begins as water- soaked spots in wilted, wedge-shaped areas along the margins of the leaves. As the spots enlarge, they become olive- green around the edge and dry in the center. Infection can extend to the stem, resulting in an olive-green decay and hollowing. The causal bacterium is seed-borne.

Erwinia carotovora subsp. *carotovora* causes wilting of the lower leaves and vascular discoloration in the stem and leaf veins of the growing crop. Stems are generally soft, water- soaked and discolored dark green, brown or black. Dark spots on leaves spread (*11.1a),* leading to a slimy breakdown of one or more leaves and eventually involving the entire head (*11.1b).* The slime phase, in which some leaves or the entire head are infected, is the most common cause of loss in the market place. *Erwinia* infection is easily recognized by soft rot and slime symptoms that are not common to other lettuce pathogens. Species of *Sclerotinia* and *Botrytis* also cause soft rots, but they are accompanied by characteristic mycelium. (See also pseudomonas diseases, 11.3.)

Causal agents To differentiate these bacteria, isolation and comparison of colony color and flagellar characters is a minimum for presumptive diagnosis.

Xanthomonas campestris pv. *vitians* is an aerobic, Gram-negative rod, measuring 0.7 to 3.0 by 0.4 to 0.5 µm. It occurs singly or in pairs and has a single polar flagellum. Colonies on agar are yellow, convex and shiny, and produce a yellow pigment, xanthomonadin.

(For a description of *Erwinia carotovora* subsp. *carotovora,* see Potato, bacterial soft rot, 16.2.)

Disease cycle Both bacteria are relatively weak pathogens and require a wound such as frost injury or mechanical damage to infect a healthy plant. *Erwinia* is most likely to infect injured or harvested lettuce. It commonly follows other pathogens and non-parasitic disorders such as tipburn. Slime development in transit follows infection in the field or during harvest and packing procedures. Breakdown can be rapid and complete if temperatures are allowed to rise in transit and during warehousing.

Management

Cultural practices — Lettuce crops should remain relatively free of bacterial soft rots if grown without excessive nitrogen or overhead irrigation. Because the bacteria are often secondary to other pathogens, a comprehensive disease control program may be required. For dry leaf spot, crop rotation and control of wild lettuce may significantly reduce inoculum. To reduce populations of *Erwinia carotovora* subsp. *carotovora,* most vegetable crops should be avoided in rotations and non-susceptible crops such as cereals, grasses or corn should be grown. To deter both diseases, good air and soil drainage and avoidance of sprinkler irrigation when crops are nearing maturity are suggested. Proper packing and storage procedures also should be observed. Care during harvest and handling to minimize injury and rapid cooling of the harvested heads will reduce bacterial soft rot losses. Heads that are trimmed and wrapped prior to packing suffer less injury from soft rot than untrimmed naked heads that are frequently forced into bulge-packed cartons. Transit and storage temperatures should be as close to 0°C as possible without freezing.

Selected references

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(Original by D.J. Ormrod and W.R. Jarvis)

▶ 11.2 Infectious corky root

Rhizomonas suberifaciens van Brüggen & Jochimsen

Infectious corky root occurs in fields repeatedly cropped to lettuce. As yet, it has not been reported in Canada. The symptoms of this disease can be confused with those of non-infectious corky root (see non-infectious corky root, 11.20). *Rhizomonas suberifaciens* has been reported only on lettuce.

Symptoms Above-ground symptoms range from no apparent effect to yellowing of lower leaves, wilting, stunted growth and poor head formation. The first symptoms on the roots are yellow lesions that enlarge and coalesce until the entire tap root is dark brown, rough and cracked. Lower feeder roots slough off and more roots may be produced near the soil surface. Similar symptoms can be induced by ammonia or nitrite liberated from nitrogenous fertilizers and from chicken manure.

Causal agent *Rhizomonas suberifaciens* is a fastidious, soil-borne, Gram- negative bacterium that has only recently been isolated and characterized (see non-infectious corky root, 11.20). It is rod-shaped (0.3 to 0.6 by 0.6 to 1.4 pm), aerobic and microaerophilic, oxidase positive and catalase negative. It has a single, lateral flagellum. Optimum growth occurs at 29 to 33°C. Colonies are circular, umbonate and translucent, becoming raised at the edge and wrinkled in the centre with age. It produces a low-molecular weight toxin (MW less than 340), which is heat stable and soluble.

On soils repeatedly cropped to lettuce, unthrifty growth and a brown corky root system are suggestive of the disease. Confirmation requires isolation of the causal bacterium. Nutritional imbalances can cause similar symptoms.

Disease cycle The causal organism can persist in the soil for at least three years in the absence of lettuce, and can survive and damage crops equally in sandy and clay soils. The disease tends to build up in incidence and severity with continued lettuce cropping. The number of marketable heads and head weight both decrease with increasing bacterial populations in the soil. Under experimental conditions, disease severity and reduction in plant growth were lowest at 10°C and greatest at 31°C. This finding supports field observations that the disease is generally more severe in warm climates and in summer and fall crops compared to spring crops.

Management

Cultural practices — Poor drainage, excessive irrigation, and soil compaction are thought to aggravate the disease. Regular crop rotation is recommended to prevent corky root. When it occurs, a longer rotation is recommended, including green manure crops. Raised beds and reduced irrigation are recommended to encourage deep rooting.

Resistant cultivars — Tolerant cultivars, including Green Lake, Marquette and Montello, are available, and there is considerable resistance in other species of *Lactuca.*

Selected references

Brown, P.R., and R.W. Michelmore. 1988. The genetics of corky root resistance in lettuce. *Phytopathology* 78:1145-1150.

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(Original by D.J. Ormrod)

▶ 11.3 Pseudomonas diseases *Figs. 11.3a-d*

Slime
Brown rot
Varnish spot
Butt rot
Head rot

Pseudomonas cichorii (Swingle) Stapp
Pseudomonas fluorescens (Trevisan) Migula (syn. *Pseudomonas marginalis* (Brown) Stevens)
Pseudomonas viridiflava (Burkholder) Dowson (syn. *Pseudomonas viridilivida* (Brown) Stevens)

The *Pseudomonas* species listed here all cause soft-rot; they are widely distributed and occur commonly in soil as opportunistic pathogens that can cause significant crop losses from time to time. Pseudomonas diseases often have a very complex etiology, with causal organisms often occurring together. Isolation of the pathogen(s) is necessary to be sure of the cause. This complex etiology has also led to confusion in disease names, so that they have come to be descriptive of symptoms without attribution to a specific pathogen.

Pseudomonas species can infect numerous dicotyledonous hosts. Lettuce, endive and chicory are subject to attack, especially in mechanically damaged and soft-grown plants.

Symptoms More than one bacterium is usually associated with slime rot and brown rot. Slime rots are characterized as water-soaked, translucent wet rots. Brown rots appear as localized oval-shaped, brown to red lesions *(11.3a-c).*

Pseudomonas cichorii causes small, irregular, yellow to brown, circular spots that enlarge and grow together, often along the leaf veins. These spots may be black under wet conditions or pale and papery under dry conditions. This bacterium is also responsible for varnish spot, in which shiny, dark-brown, firm, necrotic spots measuring a few mm in diameter occur on the blades and petioles of the inner leaves. The wrapper leaves show no symptoms, making the disease impossible to detect at harvest without removing the outer leaves.

Pseudomonas fluorescens causes marginal leaf spots. Decayed tissue appears first at the leaf margins and then progresses down the leaves *(11.3b).* The veins become brown and the affected area of the blade turns brown to black under wet conditions or pale and papery under dry conditions. The same bacterium is implicated in butt rot, in which the pith of the stem develops a firm dark-green decay that is apparent when the stems are cut at harvest.

Pseudomonas viridiflava has been reported on lettuce, producing a decay that tends to follow the midrib of older leaves *(11.3d).* Under favorable conditions, the disease will move to younger leaves, but it does not affect the stem or root.

Causal agents *Pseudomonas* species are aerobic, pectolytic, Gram-negative rods with several polar flagella. They form white colonies on nutrient agar and produce a fluorescent pigment on King's B medium. The gross symptoms of infected plants, combined with isolation of characteristic bacterial colonies that fluoresce on King's B medium, are sufficient to identify these pathogens, at least to genus. Nutritional, physiological, protein fingerprinting, and serological techniques differentiate the species.

One survey of chicory roots revealed 61 pathogenic isolates of bacteria in seven taxonomic groups. The rots fell into the slime rot and brown rot groups. *Pseudomonas marginalis* was responsible for about half the rots, together with *P. viridiflava* and three groups of unidentified fluorescent pseudomonad bacteria.

Pseudomonas cichorii is an obligately aerobic, Gram-negative rod, which is about 0.8 by 1.3 µm, motile with several polar flagella, and nonspore-forming. Colonies on nutrient agar are round, white, slightly raised, translucent, and have somewhat irregular margins. On King's B medium, a fluorescent, greenish pigment is formed and may diffuse into the agar.

Pseudomonas fluorescens is an aerobic Gram-negative rod, measuring 0.7 to 0.8 by 2.3 to 2.8 µm. It is normally motile with polar multitrichous flagella. Occasionally it is non-motile. Cultures produce diffusible fluorescent pigments, especially on iron-deficient media, such as King's B medium.

Colonies of *P. fluorescens* are slimy on media containing 2 to 4% sucrose because of levan formation. The bacterium is non-lipolytic. It is able to denitrify and hydrolyse gelatin but is unable to hydrolyse starch. This bacterium produces a highly effective biosurfactant known as vis- cosin (see Crucifers, head rot, 8.3).

Pseudomonas viridiflava is an aerobic. Gram-negative, non-sporing rod with one to two polar flagella. Colonies on nutrient agar vary from cream- colored to yellowish, mucoid and convex to grayish, flatter and matt. A greenish, fluorescent pigment is formed on King's B medium.

In general, pathogenic, fluorescent pseudomonads can be distinguished from non-pathogenic pseudomonads on the basis of LOPAT tests for levan production, oxidase, potato soft rot, arginine dihydrolase, and tobacco hypersensivity. *Pseudomonas fluorescens, P. cichorii* and *P. viridiflava* are distinguished by their ability to utilize nitrate, sorbitol, tartrates and other substrates (see Table 11.3 and Selected references, Schaad 1988).

Table 11.3 Key to differentiate fluorescent Pseudomonas species on lettuce

Test	*P.fluorescens*	*P.cichorii*	*P.viridiflava*	*P.syringae*
Oxidase	+	+	–	–
Arginine dihydrolase	+	–	–	–
Nitrite to nitrogen	+	–	–	–
Growth at 41 °C	–	–	–	–
Utilization of:				
Mannitol	+	+	+	V
Geraniol	–	–	–	–
Benzoate	–	–	–	–
Cellobiose	–	–	–	–
Sorbitol	+	+	+	V
Trehalose	+	–	–	–
Sucrose	+	–	–	V
m-tartrate	V	+	+	V
D-tartrate	V	–	+	V
D-arabinose	–	–	–	–
L-rhamnose	V	–	–	–

Tobacco hypersensitivity	–	+	+	+
Potato rot	+	–	+	–
Symbols: + positive; – negative; V variable.				

Disease cycle Pseudomonas diseases usually follow some type of injury or abnormally wet conditions. Varnish spot can occur in the absence of injury but only on lettuce plants approaching maturity. The latter disease is believed to result from splashing soil and water during sprinkler irrigation.

Management

Cultural practices — In the field, good soil drainage and air movement through the crop canopy deter pseudomonas diseases. Overhead irrigation should be avoided when heads are approaching maturity, particularly in fields with a history of varnish spot.

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(Original by D.J. Ormrod and W.R. Jarvis)

FUNGAL DISEASES

▶ 11.4 Anthracnose (ring spot), fire of endive *Fig. 11.4*

Microdochium pancittonicinum Sutton, Galea & Price in Galea, Price & Sutton
(syn. *Marssonina panattoniana* (Berl.) Magnus.)

This disease is prevalent in overwintered crops and during cool, wet weather in the fall. It commonly infects early crop transplants if inoculum has been allowed to build up in fields previously cropped to lettuce. It is also common in unheated greenhouses with a history of monocrops of lettuce or endive (see Greenhouse lettuce, anthracnose).

Anthracnose affects lettuce, endive and chicory, and also has been reported on related composite weeds, which may serve as a reservoir of inoculum. Isolates from endive can infect chicory and the related *Cichorium pumilum* Jacq., garden lettuce and prickly lettuce *(Lactuca serriola* L.).

Symptoms The fungus causes anthracnose or ring spot on lettuce as well as various leaf spots on weeds in the Compositae. It also causes fire disease in endive. The first symptoms of infection, tiny water-soaked lesions, appear on the undersides of leaves and on veins and petioles. The lesions enlarge to form straw-colored spots, 2 to 4 mm in diameter (*71.4).* Eventually, the centers of the spots turn white and dry and frequently drop out, giving a characteristic and diagnostic shot-hole appearance. Lesions on the midrib are sunken, more elongate, measure 1 by 4 to 5 mm, and tend to grow together, producing an overall rusty appearance. Outer leaves wilt and, in severe cases, heart leaves may rot entirely. Infected plants tend to be stunted and yellow-brown. Under humid conditions, white to pink spore masses may appear at the edge of the lesions. In endive, the disease is named fire because the lesions on the midribs are red.

Causal agent *Microdochium panattonianum* may or may not produce conidiophores. If present, they are produced in acervuli embedded in infected leaf tissue. The conidiophores are one- to two-septate, hyaline, smooth, discrete, sparsely branched near the point of origin or integrated, with one to four conidiogenous cells. They are 7.5 to 16 µm long, cylindrical to irregular or lageniform, with the conidiogenous region narrower, 1.5 to 2.0 µm in width with a broader base, 2.5 to 4.0 µm. The conidiogenous region proliferates enteroblastically to produce additional conidia at successively higher levels, sometimes combined with sympodial holoblastic proliferation.

Conidia are about 5 to 15 pm, slightly curved and two-celled, with the apical cell larger and slightly beaked. They are holoblastic, hyaline, dry, fusiform, curved, one- to two-septate, obtuse at the apex, with the upper cell wider and the lower cell strongly tapered to a truncate base, measuring 12.5 to 15.5 by 2.5 to 3.5 pm and forming effuse, white to pink, smooth masses that are eguttulate or with several small guttules.

The fungus is readily isolated from conidia on the host. Growth in culture is slow. On malt-extract agar and potato-dextrose agar, colonies have a pale, fleshy pink color with a raised convoluted appearance. On water agar, the fungus forms numerous bulbous cells in a sparse, white, spreading mycelium.

Disease cycle The fungus may be seed-borne but overwinters primarily as conidia, mycelium and microsclerotia in residue from diseased plants and in wild hosts. The primary source of inoculum is infested leaf residue left at or near the soil surface. Germination and infection occur between 15 and 34°C when wind-blown or splashed inoculum contacts lettuce seedlings. The disease can be serious in marketed produce.

Management

Cultural practices — Before plants are started, growers should thoroughly clean and disinfest greenhouse and seedbed areas, and eliminate wild lettuce from the vicinity of propagating areas and fields. Seed should be disease-free, desert-grown, and treated with an approved fungicide. In fields with a history of disease, lettuce and endive should be rotated with non-susceptible crops for at least one year. A long rotation is necessary to decompose inoculum in accumulated trash. Fields should be deep plowed because the fungus can survive for very long periods in dry residue on the soil surface. Weeds should be controlled because they provide a humid microclimate conducive to infection.

Growers should avoid working in infected crops when they are wet, take precautions to avoid moving spores on clothing and equipment, and avoid sprinkler irrigation in fields suspected of having a high population of microsclerotia.

Selected references

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(Original by D.J. Ormrod and W.R. Jarvis)

▶ 11.5 Black root rot *Fig. 11.5*

Chalara elegans Nag Raj & Kendrick
(synanamorph *Trichocladium basicola* (Berk. & Broome) J.W. Carmichael)
(syn. *Thielaviopsis basicola* (Berk. & Broome) Ferraris)

Black root rot has been seen occasionally on chicory in southwestern Ontario and has the potential to be a problem where the pathogen has built up significant populations, for example on old tobacco soils. It is a major disease of chicory in South Africa. The pathogen has a very wide host range, attacking plants in over 40 genera and 15 families (see Bean, black root rot, 15B.4).

Symptoms Lesions on the taproot vary from superficial, light brown spots to sunken, gray to black areas extending to 3 cm in diameter and 3 to 4 mm deep (77.5). Sometimes the entire internal root tissue has a brown marbled appearance. Secondary roots blacken and die.

Causal agent (see Carrot, black root rot, 6.6)

Disease cycle Little is known of the epidemiology of black root rot on chicory. Chlamydospores enable it to survive for long periods in soil. Research in South Africa has shown that the optimum temperature for infection is about 25°C, with marbling symptoms mostly appearing at 30°C.

Management

Cultural practices — Growers should follow a long rotation, particularly after crops such as tobacco, which is readily infected by the pathogen. The soil in forcing beds should be disinfested if the black root rot pathogen is present.

Selected references

Nag Raj, T.R., and B. Kendrick. 1975. *A Monograph of Chalara and Allied Genera.* Univ. Waterloo Press, Waterloo, Ontario. 200 pp. Prinsloo, G.C. 1986. Black root rot of chicory in South Africa. *Phytophylactica* 18:225-226.

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(Original by W.R. Jarvis)

▶ 11.6 Bottom rot *Figs. 11.6a,b*

Rhizoctonia solani Kühn

(teleomorph *Thanatephorus cucumeris* (A.B. Frank) Donk)

The causal fungus is responsible for bottom rot, a major head rot of lettuce, and it is a principal cause of wirestem or late damping-off. It is a common soil inhabitant in virtually all soils and occurs in several anastomosis groups, some of which are widely distributed. Lettuce, related vegetable crops and some weeds are potential hosts of *Rhizoctonia solani.*

Symptoms Symptoms first appear when head lettuce is approaching maturity and the basal leaves have reflexed and are in direct contact with the soil. Rust-colored sunken lesions appear on the midrib of lower leaves (*11.6a).* Under dry conditions, the lesions enlarge slowly and it may be possible to salvage diseased crops by trimming infected leaves at harvest. Under damp conditions, the lesions expand over the entire midrib and cause the leaf blade to collapse. If conditions are favorable, the fungus will rot the leaves one by one as it progresses upward and inward *(11.6b).*

Bottom rot differs from drop disease in having no conspicuous mycelium, and from gray mold in having no obvious sporulation. Gray mold has gray to brown spore masses. Drop has a fluffy white mycelium associated with the affected tissues; however, mixed infections are not unusual.

Causal agent (see Bean, rhizoctonia root rot, 15B.7)

Disease cycle (see Bean, rhizoctonia root rot, 15B.7) The fungus is active during warm weather, provided moisture is adequate. Under damp conditions, seedlings or more mature plant parts become infected through direct contact with mycelium in the soil. If plant damage is extensive, numerous sclerotia may form, thus increasing the overwintering inoculum.

Management

Cultural practices — It is advisable to seed early during the cooler part of the growing season and to rotate lettuce with grasses, cereals, legumes or other nonhosts in order to increase organic matter and decrease the population of the pathogen. Growers should avoid growing head lettuce in fields with a history of bottom rot and plant in areas with good soil and air drainage. Growing lettuce on raised beds provides improved air circulation near the plant base, where infection is most likely to occur.

Resistant cultivars — Early maturing and more upright types of lettuce such as Romaine are more likely to escape infection.

Chemical control — Soil fumigation helps control bottom rot.

Selected references

Mordue, J.E.M. 1974. *Thanatephorus cucumeris.* CMI Descriptions of Pathogenic Fungi and Bacteria, No. 406. Commonw. Mycol. Inst., Kew, Surrey, England. 2 pp.

Pieczarka, D.J., and J.W. Lorbeer. 1974. Control of bottom rot of lettuce by ridging and fungicide application. *Plant Dis. Rep.* 58:837-840.

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(Original by D.J. Ormrod)

▶ 11.7 Damping-off, stunt *Figs. 11.7a-c*

Bacteria
Pythium spp.
Other fungi

Damping-off is a frequent problem in early lettuce when cold, wet weather follows seeding. Several soil- and seed- borne fungi and bacteria may cause damping-off, but *Pythium* species are most important and are well known for their role in damping-off, seed decay and root rot. Most seedling vegetable crops are subject to damping-off, but lettuce is particularly vulnerable.

Symptoms Poor emergence, sudden collapse and death of seedlings and unthrifty growth are characteristic. Onset usually coincides with cool, damp conditions following seeding. Under these conditions, soil-borne fungal pathogens may attack and kill seedlings that would otherwise survive under warmer, drier conditions.

In early or pre-emergence damping-off, seedlings fail to emerge either because the seed decays before germination or the seedlings die before reaching the soil surface. In late or post-emergence damping-off, seedlings emerge but they are infected, usually at the soil line, and collapse (*11.7a).* Older seedlings also may be infected in the outer stem or root tissues. They continue to live but with reduced vigor, showing symptoms known as wirestem or root rot. Such plants rarely reach marketable size or quality. Pythium infection may move into the crown tissues, causing "stunt" or collapse of older plants (*1 1.7b,c).*

Causal agent (see Beet, pythium root rot, 5.7; and Carrot, cavity spot, 6.8, and pythium root dieback, 6.13)

Late damping-off is frequently caused by the bottom rot fungus *Rhizoctonia solani.*

Disease cycle Most field soils contain pathogens that can cause damping-off. Some organisms, such as *Pythium* spp., have long-lived resting spores. Others grow saprophytically on decomposing organic matter. (For detailed information, see bottom rot, 11.6; see also Beet, pythium root rot, 5.7; and Carrot, cavity spot, 6.8, and pythium root dieback, 6.13.)

Management

Cultural practices — Raised beds or well- drained soils should be used for early plantings. Growers should avoid seeding or transplanting into cold, wet soils.

Chemical control — It is advisable to use seed that has been freshly treated with an appropriate fungicide.

Selected references

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(Original by D.J. Ormrod)

▶ 11.8 Downy mildew *Figs. 11.8a, b*

Bremia lactucae Regel

Downy mildew is a common fungal disease wherever lettuce is grown. It is a disease of cool, wet weather. It is most damaging in the field on early spring or late fall crops. It can also be a major disease of greenhouse lettuce. Isolates of *Bremia lactuca* from cultivated lettuce are restricted in host range to species of the same taxonomic sub-section of *Lactuca.*

Symptoms Early infection of seedlings causes a cessation of cotyledon growth that leads to stunting or death of the plant. Sporulation occurs on both sides of the cotyledons, which become chlorotic. Cotyledons become less susceptible as they age and true leaves are less susceptible than cotyledons. Leaves of infected seedlings display slight chlorosis and a rolling of the leaf margins. Severe early infection may delay maturity and result in crops of inferior quality.

On older plants, the first sign may be the appearance of sporangiophores from leaf stomata *(11.8a).* These appear as discrete white projections that are visible to the naked eye. The sporangiophores are usually confined to the undersurfaces of mature leaves but, occasionally, they may occur on the upper leaf surface. On older leaves, lesions appear as light green or yellow areas delimited by large leaf veins on the upper surfaces. These chlorotic lesions turn necrotic or translucent and become brittle, especially near the leaf margin *(11.8b).* The fungus may become systemic in the plant and cause a black-brown discoloration of stem tissues and leaf bases near the shoot tips of mature heads. Diseased leaves often become infected by soft rot bacteria and fungi.

Downy mildew is frequently complicated by the presence of secondary soft-rotting bacteria and trimming waste may be considerable in marketed produce.

Causal agent Sporangiophores of *Bremia lactucae* emerge from stomata in groups of one to three and measure 200 to 1500 by 6 to 19 µm. They are septate with three to seven dichotomous branches, giving the sporangio- phore a tapering, disk-like appearance. The branch tips are swollen into an inverted, cone-like, tapering vesicle, measuring 8 to 15 pm and bearing three to five sterigmata each with a single sporangium. The sporangium is spherical to ovoid, hyaline, and measures 12 to 31 by 11 to 28 µm with a slightly thickened papilla. It has a pedicel up to 2 µm in length. Sporangia resemble those of *Phytophthora infestans,* a closely related fungus that causes late blight of potato and tomato. Oogonia vary in size up to 30 pm. Antheridia are probably diclinous. Oospores are spherical, aplerotic, 20 to 31 µm (mean 25 µm), with smooth walls about 3 pm thick. Remnants of the oogonium may adhere to the oospore wall, giving it a yellow-brown wrinkled appearance.

The disease can be identified by leaf symptoms and microscopic examination of the sporangia and sporangiophores, but race identification requires inoculation of differentially resistant cultivars of lettuce. The white mold on the underside of infected leaves glistens and can be seen with the naked eye. White sporulation from stomata with a very characteristic disk-like mass of sporangiophore branches is diagnostic.

Disease cycle *Bremia lactucae* survives between crops as mycelium and oospores in residue from infected crops and in cultivated and wild lettuce plants that overwinter. Oospores form in infected tissue and are produced in diseased leaves. They are stimulated to germinate near the host. Sporulation occurs at high humidity at night and coni- dia are dispersed by wind or splashing water. Sporangia germinate between 0 and 21°C (optimum around 10°C) to produce hyphae or zoospores, both of which are infective and can penetrate the epidermis within three hours. Infection occurs directly through the stomata. A coenocytic mycelium ramifies through the leaf tissue and produces dendroid sporangiophores that emerge through the stomata of the lower leaf epidermis. Infected tissue eventually turns brown, giving rise to the term “brown margin,” and a downy weft of white mold develops on the underside of infected leaves. Sporangia are produced in abundance when night temperatures range from 5 to 10°C and day temperatures are 12 to 20°C, with an overcast sky and relative humidity near 100%. They are readily windblown. Germination and infection can occur if sporangia land on a susceptible host that is covered by a film of moisture for at least five to seven hours. In adjacent successive plantings, the first diseased crop will serve as a source of inoculum for subsequent plantings.

Management

Cultural practices — Crop rotation is a standard method of control for the downy mildews, coupled with deep plowing to bury all crop residues. Fields with a history of downy mildew and impeded soil or air drainage should not be used for early and late plantings.

Resistant cultivars — The use of resistant cultivars has had only limited success because the resistance has been quickly overcome by the pathogen. Analysis of the genetics of host resistance and pathogen virulence has demonstrated that the introduction of resistant cultivars promotes the rapid appearance of the corresponding virulent races of *B. lactucae.* If resistant cultivars are to be introduced into lettuce-growing areas, the racial composition of the *B. lactucae* population should be assessed beforehand.

Chemical control — Protective fungicides are registered in Canada but should be used only in an early preventive program when no other strategy appears to be effective.

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(Original by D.J. Ormrod and W.R. Jarvis)

▶ 11.9 Drop (white mold) *Figs. 11.9a-f*

Sclerotinia minor Jagger
Sclerotinia sclerotiorum (Lib.) de Bary
(syn. *Whetzelinia sclerotiorum* (Lib.) Korf & Dumont)

Sclerotinia disease of lettuce is usually referred to as drop. On other crops, it is often called white mold or watery soft rot. It also is a major disease of chicory and endive where it is known as white mold or sclerotiniose. *Sclerotinia* spp. often are widespread in the soil. *Sclerotinia sclerotiorum* is much more prevalent than *S. minor. Sclerotinia* spp. have a very wide host range, including many weeds and vegetable crops, such as cabbage, carrot, celery, lettuce, tomato and bean.

Symptoms On lettuce, the name “drop” reflects the first obvious symptom. Plants at various stages of maturity appear wilted and the outer leaves drop to the ground, while remaining attached to the plant (7*1.9a).* The fungus infects the petioles and spreads to the center of the head. Once these symptoms appear, the plant is unharvestable. Pulling up a plant with drop usually reveals a fluffy white mycelium and large, dark, oval or round sclerotia *(S. sclerotiorum) (11.9b)* or aggregates of small irregular sclerotia in various stages of development *(S. minor)* (7*1.9d).*

Any tissues may be affected, and initial infections, like those of gray mold, are often associated with pieces of dead, dying or wounded tissue. Stem infections (77.9c), particularly with *S. minor,* usually occur at the soil level on senescent cotyledons or in leaf axils. Large black sclerotia, often lying in a mass of white mycelium, are characteristic of *S. sclerotiorum* (7*1.9b,f).* Smaller, coalescing masses of always external sclerotia are typical of *S. minor.* Apothecia (77.9c) are inconspicuous but may be found at the soil surface by careful searching in spring and throughout cool moist summers.

White mold is often confused with gray mold, particularly when there is copious development of the cottony mycelium. The mycelium of *S. sclerotiorum* is pure white, not the off-white of gray mold. Large sclerotia lying loosely on the white mycelium are easily visible under leaves and differentiate drop from bottom rot and gray mold.

Causal agent (For a description of *Sclerotinia sclerotiorum,* see Bean, white mold, 15B.9.) Sclerotia of *Sclerotinia minor* are 2 to 3 mm across, always external and embedded in mycelium. They form all over the colony and are often aggregated into crusts or flat masses. One to several flat to slightly concave, disk-like, stalked apothecia may arise from a single sclerotium. The stipe is 3 to 30 mm in length and bears the apothecium, or fruiting body, that becomes convex or funnel shaped with age. It is a fleshy, pale, beige or yellow-brown structure, measuring 3 to 5 mm in diameter. The upper surface, the hyménium, is an area of densely packed cylindrical asci, each containing eight ascospores. The ascospores are unicellular, elliptical-obovoid, hyaline and biguttulate, measuring 8 to 17 by 5 to 7 pm (length:width ratio about 2).

Both fungi grow readily on a variety of agar media and produce typical sclerotia in culture. These usually produce abundant apothecia when placed on damp sand or floated on water in diffuse light at about 25°C.

Disease cycle (see Bean, white mold, 15B.9) Sclerotia form on infected plants and fall to the soil when the host tissue disintegrates. Under prolonged moist conditions, such as beneath a leaf on the soil surface, germination of sclerotia is myceliogenic, particularly in *S. minor.* This mycelium can infect lettuce plants directly.

Management

Monitoring — White mold may occur in chicory stored for forcing (*77.9f*). Before storage, roots should be carefully inspected for any sign of infection; any roots with symptoms should be rejected.

Cultural practices — A four- to five-year rotation with com, cereals or forage grasses is recommended if the disease has been severe. Where it has not been severe, shorter rotations with onion and potato can be used. Because many vegetable crops, weeds and trash piles are sources of inoculum, growers should rogue and remove infected plants to reduce inoculum for succeeding crops. This is not as effective for *S. sclerotiorum* because its ascospores commonly are blown from nearby fields and waste areas. Weeds among the crop may create a canopy conducive to infection. Crop rows should be oriented parallel to the prevailing wind with generous spacing in and between the rows, allowing plants to dry quickly after rain. Weeds and volunteer host plants should be controlled at all times and trash piles should be removed and buried deeply or burned. Control is best achieved by crop rotation. At least three or four years of cereals are needed to reduce appreciably the number of sclerotia by biological attrition. Flooding the soil between crops also helps to control the disease. If the disease appears in chicory forcing beds, the presence of sclerotia makes it necessary to sterilize the soil by steam or fumigation. Overhead irrigation should be avoided where drop is a potential problem.

Resistant cultivars — No resistant cultivars of lettuce, chicory or endive are currently available, but those with a more open growth are less susceptible than those with a dense canopy where water is slow to evaporate.

Biological control — Sclerotia are damaged by fly larvae and parasitized by a number of other fungi. There has been limited success in biological control, but not on a commercial scale.

Chemical control — Soil fumigation reduces the inoculum, but it is probably economic only in light soils where other pathogens or weeds will also be controlled.

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(Original by D.J. Ormrod and W.R. Jarvis)

▶ 11.10 Gray mold *Figs. 11.10a-f*

Botrytis cinerea Pers.:Fr.
(teleomorph *Botryotinia fuckeliana* (de Bary) Whetzel)
(syn. *Sclerotinia fuckeliana* (de Bary) Fuckel)

The fungus that causes gray mold is a widespread saprophyte on dead and dying plant material. Under cool, humid conditions, it readily invades wounds and soft tissues and can do considerable damage. It usually infects tissues that are damaged by other agents, such as frost, insects, rough handling, guttation (salt damage on leaf points exuding water drops) and improper fertilization. On field-grown lettuce, gray mold is most serious in early spring and late fall. In the greenhouse, gray mold is often said to be a disease of bad management. In retail stores, the fungus can spread from plant to plant, a condition called nesting. Gray mold is one of the most prevalent and damaging market diseases of lettuce, chicory and endive.

This fungus has hundreds of hosts, ranging from forest seedlings to virtually all vegetables and ornamentals as well as weeds. It is a common pathogen of lettuce, chicory and endive (see also Asparagus, botrytis blight, 4.1).

Symptoms Gray mold often infects greenhouse-grown seedlings following attack by other damping-off organisms. Affected seedlings usually fail to produce a marketable head. The fungus also may cause a root rot *(11.10e),* or more commonly a head rot that often destroys the inner leaves (*11.10a,b)* before any external symptoms appear, most frequently in fields planted in early spring under cool, wet conditions. In storage, chicory roots can develop infection anywhere but especially in damaged tissues. Roots can rot quickly. Externally, the rot is barely distinguishable in color from the root tissue, but internally the affected tissue is watery and pale brown, though not appreciably softened.

In the greenhouse, gray mold is the most important head rot disease of lettuce and endive. It thrives under humid conditions and cannot be prevented by using soil fumigation or the nutrient film method. On stems and leaves, especially on leaves in contact with the soil, the first sign of infection is a water-soaked area, usually associated with a piece of dead tissue. The lesion dries out and becomes pale gray to beige-colored *(11.10c).* Under humid conditions, a gray-brown mass of thread-like conidiophores forms and a dry mass of conidia *(11.10f)* disperses in a cloud when disturbed. In fleshy tissues, resistant resting sclerotial bodies are formed *(11.10d).* The sclerotia are black, hard and flat or somewhat rounded, and measure 2 to 5 mm in diameter. Under very humid conditions, sporulation is sparse. Instead, there is copious growth of a dirty white cottony mycelium that is sometimes confused with white mold.

Gray mold is more severe in packing sheds and retail outlets where sources of ethylene, such as from ripening tomatoes or apples, are present. It can cause severe damage in chicory roots stored for forcing, particularly in roots that are wet, dirty and already latently infected from the field. In contrast to phoma rot, there is no sharp line demarcating gray mold rot from the rest of the root.

Causal agent The taxonomy of *Botrytis* and *Botryotinia* is complicated. Not all *Botrytis* fungi of the *cinerea* type necessarily have *Botryotinia fuckeliana* as the teleomorph, or indeed any teleomorph. The type species of *Botrytis* is *B. convoluta* Whetzel & Deighton from iris. It has conidia of the *cinerea* type but the sclerotia are distinctive by being convoluted. Its teleomorph is *Botryotinia convoluta* (Drayton) Whetzel.

Botryotinia fuckeliana is rarely seen in nature. It consists of an apotheci- um, a tiny, fleshy, funnel-shaped, brown structure that is about 1 to 5 mm in diameter and is borne on a slender stalk 2 to 20 mm long arising from a Sclerotium. The top surface of the apothecium bears large numbers of asci, each containing eight hyaline, unicellular ascospores that are ejected violently into the air. The ascospores measure 8.5 to 10 by 3.5 to 4 µm. Apothecia can be obtained in culture by mating isolates of *Botrytis cinerea.*

There are a number of anamorphs of *Botryotinia fuckeliana* by which, collectively, isolates can be identified. The conidial state is referable to the form-genus *Botrytis* Pers., the microconidial apparatus is referable to *Myrioconium* Syd., sclerotia are referred to *Sclerotium* Tode, and the organs of attachment, which are relatively large and complex structures, also are characteristic of *Botrytis.* The generally recognized form-species is *Botrytis cinerea.* Since the teleomorph of *B. cinerea sensu stricto* is rare, most isolates identified as *B. cinerea* are more accurately designated as *Botrytis* of the *cinerea* type.

The conidiophores are tall, stout, dark below and paler near the apex, irregularly branched and 1 to 2 mm or more in length. Near the apex, a number of short, septate, sporogenous branches are produced, each with a terminal ampulla on which the conidia develop synchronously on short, fine denticles. At intervals along the conidiophore, botryose clusters of conidia are formed from short side branches that bear sporogenous cells, giving the appearance of nodal areas of sporulation.

The conidia are hyaline or slightly pigmented, gray to brown in mass, ellipsoid-obovoid with an inconspicuous denticle of attachment. They measure 10 to 13 by 6 to 10 µm. They are produced in abundance on infected tissues under humid conditions.

The sclerotium is a flat, convex or loaf-shaped, hard black body, 2 to 5 mm, usually formed just below the host cuticle, eventually erumpent, and falling onto the soil upon disintegration of the host tissue. It may persist in dry soil for several months or years. Germination is usually conidiogenic, but may also be myceliogenic and cause direct tissue infection. Sclerotia rarely give rise to apothecia.

Microconidia are often formed in sporodochia in culture. They are hyaline, spherical, 2 to 3 µm, and are formed in chains from phialides that are single and inside old hyphae or in penicillate clusters. They are not infective and serve only for spermatization.

Botrytis cinerea grows readily on a wide variety of artificial media. It sporulates best on low-nutrient agar in near-uv light. On rich media It forms abundant sclerotia, randomly scattered over the culture.

Disease cycle The gray mold fungus is common on dead and dying plant parts, especially under moist conditions. Initiation of an epidemic usually occurs from air-borne conidia that can infect soft tissues, wounds and blossoms whenever moisture is available. Sclerotia may also be a significant source of inoculum, especially in lettuce that grows close to the soil and traps moisture under and around the leaves. Sclerotia may persist in dry soil for several months or years. The fungus can sporulate on infected tissue within a few days of infection, so secondary spread can be rapid. The conidia land on a wet surface and germinate, the germ tube penetrating the cuticle in five to eight hours at the optimum temperature of 15 to 20°C. Infection is considerably enhanced if the spores alight on dead or dying tissue. The fungus rapidly invades such tissue, utilizing the nutrients released. Under these conditions, the fungus has considerable infective potential, quickly breaking down any resistance. Thus, infections are very common on senescent cotyledons and freshly damaged leaves.

Once inside the tissue, the fungus advances rapidly, producing a soft rot by dissolving the pectic materials. At this stage, it is also highly infective to healthy tissue in contact with its cottony mycelium. Pockets of infection (nesting) are often seen in packed produce and on chicory roots stored for forcing. When infected tissue has been fully colonized by the fungus, sclerotia are formed which, either immediately or after a period of dormancy, produce copious conidia. Sclerotia are the main source of conidia to maintain the epidemic. Conidia are also formed directly at the surface of affected tissue.

Management

Cultural practices — Crops are seldom affected if grown in well-drained soil and in well-ventilated sites. In field sites with cold, wet soils and protected from drying winds, rows are best oriented parallel to the prevailing wind with the rows and plants spaced adequately to give as much ventilation as possible. Susceptibility may be reduced by decreasing nitrogen and increasing calcium levels in the crop. Trash piles of any plant material should be eliminated because they are potential sources of inoculum and sclerotia. In chicory forcing beds, correct fertilizer balance and adequate air movement should be achieved. On cool clear nights after warm humid days, the moist air should be ventilated from the forcing house and sufficient heat applied at night to prevent dew formation. Watering should be done when the plants will dry quickly. Chicory roots are especially prone to mechanical damage, but all roots for forcing should be lifted very carefully. Any damaged tissue is vulnerable to phoma rot as well as to gray mold.

Chemical control — Fungicides should be used with caution because the gray mold pathogen is often quick to develop fungicide-tolerant races; fungicides then only serve to suppress natural competitors, often making the disease more severe.

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(Original by D.J. Ormrod and W.R. Jarvis)

▶ 11.11 Phoma rot

Phoma exigua var. *exigua* Desmaz.

This fungal disease is occasionally seen on chicory in storage. The pathogen attacks only damaged roots.

Symptoms The rot may appear anywhere on the root. It is brown and wrinkled in external appearance with a sharp line of demarcation from healthy tissue. The root becomes rubbery.

Causal agent *Phoma exigua* var. *exigua* must be isolated for confirmation. The fungus grows on oatmeal and malt extract agars; on 2% malt agar it is characteristically zonate. This distinguishes it from the closely related *P. exigua* var. *foveata,* which additionally forms anthraquinone pigments that turn red on exposure to ammonia vapor. It forms globose, thin-walled, dark brown to black, immersed pycnidia containing ampulli- form, hyaline phialides with hyaline, cylindrical, aseptate conidia. The pycnidia measure 90 to 200 pm, and the conidia 4 to 5 by 2 to 3 pm. In the rotted tissue, the pathogen forms only septate mycelium with no pycnidia.

In contrast to gray mold, phoma rot does not spread from root to root.

Disease cycle Chicory roots are easily damaged by mechanical handling. The pathogen can attack them at temperatures between 0 and 10°C, and at relative humidities of 95 to 97%.

Management (see gray mold, 11.10)

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(Original by W.R. Jarvis)

▶ 11.12 Powdery mildew *Fig. 23.10*

Erysiphe cichoracearum DC.

Powdery mildew first became a problem on cultivated field lettuce in California in 1951, presumably as a result of mutation from the previously known wild lettuce strain of *Erysiphe cichoracaerum.* The disease rarely occurs in the field in Canada, but it has been observed in hydroponic greenhouses (see Greenhouse lettuce, powdery mildew, 23.10). The cultivated lettuce strain can infect a wide range of hosts in the laboratory, but in the field only cultivated lettuce is a significant source of inoculum.

Symptoms White, powdery accumulations of mycelium and conidia appear in spots on both the upper and lower surfaces of older leaves *(23.10).* As the spots enlarge, leaves lose their bright color and fade to yellow and finally brown. Tiny, black, spherical cleistothecia may appear on mature lesions. Severely infected heads may be stunted and unmarketable. Late-infected heads may be salvaged by removing the outer leaves.

Causal agent *Erysiphe cichoracearum* has a well-developed mycelium. Conidia occur in long chains, are ellipsoid to barrel shaped, and measure 25 to 45 by 14 to 26 pm. Cleistothecia are globose or irregular, 90 to 135 µm in diameter with numerous, rarely branched appendages, one to four times as long as the diameter of the cleistothecium. Asci number 10 to 25 and measure 60 to 90 by 25 to 50 µm. Ascospores number two, rarely three, and measure 20 to 30 by 12 to 18 µm.

Powdery mildew can be distinguished from downy mildew because the pathogen sporulates on both leaf surfaces with conidia in chains, whereas downy mildew sporulates primarily on the leaf undersurface with sporangia attached singly to tree-like sporangiophores. Powdery mildew caused by *Erysiphe* has conidia that germinate by a simple germ tube terminating in an appressorium.

Disease cycle Initial infection is by ascospores released from cleistothecia in residues from previous crops. Subsequent spread during the growing season, both within and between fields, in by conidia. Conidia are released in clumps of two or three under dry, windy conditions and may be carried up to 200 km by wind. Conidia germinate and infect most rapidly between 18 and 25°C at a relative himidity of 95 to 98%. Some germination occurs at very low humidity, but none occurs at 100% relative humidity. The minor importance of the disease on field lettuce in Canada can probably be attributed to below-optimum temperatures at night even when the relative humidity is optimal for disease development. In the greenhouse, optimal temperature and humidity conditions are more likely to coincide.

Management

Cultural practices — Sanitation and elimination of trash piles in and around the greenhouse, and prompt incorporation of crop residues in the field reduce the likelihood of spread to subsequent crops.

Resistant cultivars — The use of resistant cultivars should be investigated where cultural practices are not sufficient.

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(Original by D.J. Ormrod)

▶ 11.13 Rust *Figs. 11.13a,b*

Puccinia dioicae Magnus (syn. *Puccinia extensicola* Plowr.)
Puccinia hieracii f. sp. *cichoriae* (Bellynck & J. Kickx fil.) Boerema & Verhoeven (syn. *Puccinia patruelis* Arthur)

Puccinia is one of the most economically damaging genera of rust fungi worldwide. It has been recorded frequently in commercial lettuce but is rarely damaging. Rust of chicory and endive has rarely been recorded. *Puccinia dioicae* occurs on lettuce. *Puccinia hieracii* occurs on chicory, endive and on *Hieracium* and other Compositae, but only as host-specific races.

Symptoms On lettuce, groups of 50 to 200 whitish-yellow aecia appear as powdery yellow masses about 1.5 cm across on the lower surface of outer leaves (*11.13a,b*). The corresponding area of the upper leaf surface appears as a large yellow spot.

Causal agent *Puccinia diociae* is macrocyclic and heteroecious, producing spermagonia and aecia on lettuce and uredinia and telia on sedges *(Carex* spp.). Aeciospores are globoid, 12 to 21 µm in diameter, with colorless, finely verrucose walls. Uredinia are light cinnamon-brown. Urediniospores are globoid to obovoid, 12 to 20 by 16 to 26 µm, with cinnamon-brown, echinulate walls containing two pores in the upper part. Tellia are dark chocolate-brown to black. Teliospores are clavate-oblong,

12 to 22 by 32 to 50 µm, rounded, truncate above, narrowed below, slightly constricted, with chesnut-brown walls. Other species of *Puccinia* occur occasionally on lettuce and commonly on sedges.

Puccinia hieracii f. sp. *cichoriae* is autoecious. Spermagonia are yellow. Urediosori are cinnamon, tiny, and form on small pale spots. Urediniospores are globose to ellipsoid, echinulate, yellow-brown, and measure 24 to 29 by 16 to 25 µm, with two germ pores. Telia are similar to the uredinia but somewhat darker brown. Teliospores are ellipsoid-ovate, rounded, scarcely constricted, delicately verrucose, brown and measure 25 to 40 by 16 to 24 µm.

Disease cycle Rust diseases of lettuce generally occur on sedges in the uredinial and telial stages. Basidiospores carry the disease to lettuce wherre spermagonial and aecial stages occur. Aeciospores carry the disease back to sedges. The chicory/endive rust pathogen has no alternate host. Small clusters of spermagonia appear on the leaves, together with uredinia and telia.

Management

Cultural practices — When rust occurs in field lettuce, eradication of sedges within 100 metres is usually sufficient to protect the crop. In trials in Alberta, lettuce seeded in the fall exhibited 100% infection the following spring, compared to less than 1% infection in the same cultivars seeded in the spring.

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(Original by D.J. Ormrod and W.R. Jarvis)

▶ 11.14 Septoria leaf spot

Septoria lactucae Pass.

Leaf spot was first reported on lettuce in Quebec in 1941. It has remained a minor fungal disease and has not been reported west of Manitoba. Lettuce, other vegetable crops and several weeds are affected.

Symptoms Small, irregular, chlorotic spots first appear on the outer leaves. They enlarge and change from yellow to olive-brown. Older lesions may have a chlorotic margin.

This disease is readily distinguished from anthracnose by the larger, more irregular spots that usually have numerous, pin-point, black pycnidia in the center. Microscopic examination should be used to confirm differences in conidial morphology.

Causal agent *Septoria lactucae* pycnidia are chiefly epiphyllous, immersed, becoming erumpent, and measure 100 to 200 µm in diameter. Conidiophores line the inside of the pycnidium. Conidia are hyaline, straight or curved, have one to three septa, and measure 25 to 40 by 1.5 to 2 µm. The fungus can readily be isolated from cirrhi of conidia that extrude from the pycnidia in humid conditions.

Disease cycle Pycnidia are carried on seed, on residues from infected crops, and on weed hosts. Conidia germinate and are infective above 12°C in the presence of free water or at humidity over 90% for 24 hours. Pycnidia and conidia are produced within five days, making rapid disease build-up possible.

Management

Cultural practices — In addition to rotations with non-susceptible crops for at least one year in fields where the disease has occurred, and elimination of wild lettuce from the vicinity of propagation areas and fields, growers should use disease-free, desert-grown seed if possible. Seed can be disinfested by hot-water treatment at 48°C for 30 minutes, but germination may be reduced. Infected crop residues should be disked under promptly to facilitate breakdown and to prevent spores from being transported on clothing and equipment.

Growers should avoid seeding adjacent to infected plantings or in areas with poor air and soil drainage, and avoid working in infected crops when they are wet.

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(Original by D.J. Ormrod)

VIRAL AND VIRAL-LIKE DISEASES

▶ 11.15 Asteryellows *Figs. 11.15a, b*

Aster yellows mycoplasma-like organism

Aster yellows was first reported in Canada in 1930. It now occurs regularly wherever the aster leafhopper is common. Crop losses of up to 100% in lettuce have been reported in Ontario. Though the disease is not seed-borne, it interferes with flower and seed formation. Aster yellows affects more than 300 different plants in 48 families.

Symptoms In lettuce, the center leaves show symptoms first *(11.15a).* They appear chlorotic and fail to develop normally, remaining as short stubs, or they may be twisted and curled, exuding pink to brown latex when straightened. Light brown latex deposits on the underside of the midribs are diagnostic. Plants infected early will develop an overall yellowing of the outer leaves *(11.15b).* If the plant was infected at a very early stage, it will be stunted and have twisted yellow leaves. Plants infected at later stages of growth will be very pale internally and there will be evidence of tipburn. Symptoms usually are most severe in July and August.

The percentage of plants infected with aster yellows in a field can vary from 0 to 100%, depending upon the prevalence of leafhoppers carrying the pathogen. Lettuce is most vulnerable when the plants are in the seedling stage and until they are about three-quarters grown. Excessive heat and drought adversely affect leafhopper development and survival, and may reduce the incidence of aster yellows. Conversely, heavy rainfall may make plants more succulent and attractive to leafhoppers.

Causal agent The pathogen is a prokaryote that is enclosed by a membrane but lacks a true cell wall. Cells contain DNA and ribosomes but no membrane-enclosed inclusions. They measure 0.3 to 0.8 µm, and are irregular in shape, from globose to cylindrical. The pathogen inhabits the phloem tissues of infected plants and is transmitted from plant to plant by phloem-feeding leafhoppers in which it multiplies. Aster yellows symptoms on lettuce differ from mosaics caused by viruses; younger leaves are affected first and the growing point is often malformed. Transmission studies and electron microscopy can be used to confirm visual diagnosis. Advanced techniques such as complementary DNA hybridization are also available, should greater precision be necessary.

Disease cycle The pathogen can overwinter in susceptible grains, perennial weeds and ornamentals. Several leafhopper species can acquire the pathogen and transmit it to lettuce and other susceptible crops.

Management

Cultural practices — Forage legumes grown close to susceptible vegetable crops should be sprayed with a registered insecticide before being cut for hay or seed (see aster leafhopper, 11.23). In areas where leafhoppers are abundant and aster yellows occurs regularly, it is important to control perennial host plants within the crop and around the field margins.

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(Original by D.J. Ormrod and M. Valk)

▶ 11.16 Big vein *Fig. 11.16*

Lettuce big-vein virus

Lettuce big vein is caused by a virus that is vectored by a soil-borne fungus. In Canada, the disease was first reported in Ontario in 1940. It is common in lettuce grown during cool weather in infested soil, but it is not highly destructive to the crop. The fungal vector has a very wide host range, infecting the roots of many plants.

Symptoms The most distinctive symptom is vein clearing of the tissue adjacent to the leaf veins, making them appear wider than normal *(11.16).* During the cooler part of the growing season, infected leaves have enlarged veins that are translucent when held up to the light. Leaves also may appear puffy and ruffled at the margins. Plants infected in the early seedling stage may die or remain stunted.

Causal agent The pathogen has been isolated and characterized as having labile rod-shaped particles, measuring 324 by 18 nm and 152 by 18 nm. Serology suggests a close relationship of the big-vein virus with tobacco stunt virus.

Disease cycle The pathogen can be carried in the soil for at least eight years in resting sporangia of the oomycete fungus *Olpidium brassicae* (Woronin) P.A. Dang. Cool, wet soil conditions favor the fungus vector. In the presence of a susceptible host, the fungal sporangia germinate to produce zoospores that carry the big vein pathogen into the roots. The uninfected fungus acquires the pathogen upon entry into the roots of infected lettuce, and it releases infected zoospores into the soil water or forms resting sporangia in old roots remaining in the soil after harvest.

Management

Cultural practices — Seedbeds and greenhouse soils can be steamed or fumigated to lower the vector and pathogen populations. Growers should avoid early planting in poorly drained fields with a history of big vein.

Resistant cultivars — Lettuce cultivars differ in tolerance to big vein.

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(Original by D.J. Ormrod)

▶ 11.17 Lettuce mosaic *Figs. 11.17a, b; 23.14*

Lettuce mosaic virus

Lettuce mosaic is a widely distributed, seed-borne virus disease. Until recently, up to 5% seed infection was not unusual. Besides lettuce and endive, cultivated hosts such as sweet pea, green pea and a number of flowers are sources of inoculum. In addition, perennial and biennial weeds, such as groundsel (*Senecio* spp.) and sow thistle *(Sonchus* spp.), also can serve as sources of inoculum for subsequent crops.

Symptoms On lettuce, curled-leaf endive and broadleaved endive, lettuce mosaic causes chlorotic or yellow spotting and a reduction in size *(11.17a).* These symptoms may resemble those of turnip mosaic. Some pathotypes are more severe, causing marked yellowing, distortion and stunting. Plants grown from infected seed or those infected in the early stages of growth are stunted and have pale green to yellow mottled leaves *(11.17b, 23.14).* Leaf margins are ruffled and outer leaves may die. In older plants, mottling may be indistinct, but a uniform, dull gray-green color is characteristic.

Causal agent Lettuce mosaic virus is a flexuous rod in the potyvirus group, measuring 746 by 22 nm. Besides being aphid-borne, it is seed- borne and sap-transmitted. In aphids, it is stylet-mediated and non-persistent. Diagnosis is based on symptoms on indicator plants such as quinoa *(Chenopodium quinoa* Willd.) and globe amaranth (*Gomphrena globosa* L.). On quinoa, lettuce mosaic causes local lesions and mosaic symptoms. Systemic reaction of young leaves may be equivocal. ELISA tests are useful for confirmation. Commercial diagnostic reagents are available. Several other viruses cause similar symptoms on lettuce but they are not as widespread or common.

Disease cycle Seed-borne inoculum is the most important source of lettuce mosaic, but the virus is also transmitted by aphids, particularly the green peach and potato aphids. These aphids acquire the virus by feeding on infected plants. They then infect other plants in the field or in other fields, as well as susceptible weeds in the vicinity. The speed and extent of spread after seedling emergence is proportional to aphid population levels and their movement.

Management

Cultural practices — With the use of virus indexing, which can detect one infected seed in as many as 30 000 seeds, disease incidence has declined markedly. Growers are still advised to plow down crop refuse immediately after harvest, to eliminate host weeds adjacent to lettuce fields, to destroy overwintered broadleaved weeds, and to control aphids (see aphids, 11.24). In climates that permit year-round lettuce production, a lettuce-free period has been used as a control measure. This is only useful if there are no other infected host plants in the vicinity. In Canada, winter serves as the lettuce-free period. Seeding new plantings adjacent to old ones should be avoided.

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(Original by D.J. Ormrod and W.R. Jarvis)

▶ 11.18 Other viral diseases *Fig. 23.15*

Artichoke Italian latent virus
Beet mild yellowing virus
Beet western yellows virus
Chicory yellow mottle virus
Cucumber mosaic virus
Lettuce infectious yellows virus
Tomato spotted wilt virus

Numerous other viruses can infect lettuce. The most damaging are those causing beet western yellows, lettuce infectious yellows, cucumber mosaic, and tomato spotted wilt. Endive is host to beet western yellows, beet mild yellowing, which is probably a closely related strain of beet western yellows, chicory yellow mottle, and artichoke Italian latent viruses. Beet western yellows affects vegetable crops such as sugar beet, rutabaga, turnip, spinach and lettuce, and weeds. Chicory yellow mottle also affects parsley. Cucumber mosaic virus has a very wide host range. Lettuce infectious yellows virus also infects other vegetables, ornamentals and weeds. Tomato spotted wilt virus has a wide host range, including greenhouse tomato, pepper and ornamentals.

Symptoms Beet western yellows, cucumber mosaic, and lettuce infectious yellows cause yellowing, particularly of older leaves, and stunting if plants are infected early. On lettuce, the symptoms resemble those of lettuce mosaic and physiological disorders such as magnesium deficiency. Lettuce infectious yellows virus is semi-persistent in the whitefly vector. In plants affected by beet western yellows, the older leaves tend to yellow, but the veins remain green. Tomato spotted wilt virus causes more severe symptoms *(23.15),* which include numerous tiny necrotic spots, petiole curvature and brown streaks on the underside of the leaf midribs. It can be acquired by thrips larvae and then transmitted when they reach the adult stage.

In endive, artichoke Italian latent virus produces a generalized yellowing and stunting; symptoms of beet western yellows and beet mild yellowing are often very mild, sometimes resembling deficiency symptoms, or they are absent; and, chicory yellow mottle virus causes a bright yellow mottle with a ringspot and line pattern.

Causal agents Many viruses cause yellowing symptoms. Laboratory tests may be needed to identify the virus or combination of viruses present in a particular diseased plant.

Artichoke Italian latent virus is a RNA-containing nepovirus with isometric particles about 30 nm in diameter. In soil, it is transmitted by the nematode *Longidorus apulus* Lamberti & Bleve-Zacheo and is native to southern Italy and Bulgaria. Indexing is by mechanical inoculation to tobacco or globe amaranth, *Gomphrena globosa* L., both of which develop necrotic, whitish, ring-like local lesions.

Beet mild yellowing virus is a luteovirus serologically related to beet western yellows virus but differs in particle morphology and by its persistence in its aphid vector, usually the green peach aphid or the black bean aphid. Its particles are isometric, about 26 nm in diameter. The virus produces characteristic reddening on Miner's lettuce (*Montia perfoliata* (Donn.:Willd.) Howell) 15 to 25 days after transmission by the green peach aphid. Weed hosts include shepherd's-purse (*Capsella bursa-pas- loris* (L.) Medic.) and groundsel (*Senecio vulgaris* L.).

Beet western yellows virus is an isometric particle in the luteovirus group, measuring about 26 nm in diameter. It is persistent and aphid- borne. Indexing can be done as described for beet mild yellowing virus.

Chicory yellow mottle virus has angular, isometric RNA-containing particles about 30 nm in diameter. It is readily sap-transmitted to the diagnostic species *Phaseolus vulgaris* L., *Cucurbita pepo* L. and other species, but it is found naturally only in chicory and parsley.

Cucumber mosaic virus is an isometric virus in the cucumovirus group, measuring about 30 nm in diameter. It is transmitted mechanically and by numerous aphids in a non-persistent manner.

Lettuce infectious yellows virus, similar to the closteroviruses, has long flexuous rods measuring 13 to 14 by 1800 to 2000 nm.

Tomato spotted wilt virus is an isometric particle measuring 70 to 90 nm in diameter.

Disease cycle Beet western yellows virus is readily transmitted by aphids. The green peach aphid is its most important vector. Lettuce infectious yellows virus is transmitted by the sweetpotato whitefly (see Foreign diseases and pests, 3.10). Infection of greenhouse-grown lettuce crops or transplants may occur if infectious sweetpotato whiteflies are present on ornamentals in the same greenhouse. Tomato spotted wilt virus is transmitted by thrips, particularly the western flower thrips in greenhouses, and the onion thrips outdoors. Cucumber mosaic virus is transmitted by the green peach aphid and other aphids. Artichoke Italian latent virus has two serological variants, both of which are transmitted by nematodes *(Longidorus* spp.). A vector for chicory yellow mottle virus is unknown.

Management

Cultural practices — Growers are advised to keep ditches and roadways free of weed hosts and, in field production, to plow crop residues promptly after harvest. Lettuce or lettuce transplants should not be grown in the same greenhouse as vegetables or ornamentals that harbor viruses, whiteflies, thrips or aphids (see Insect pests, 11.23-11.26, for their control).

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(Original by D.J. Ormrod and W.R. Jarvis)

NON-INFECTIOUS DISEASES

▶ 11.19 Nutrient disorders *Figs. 11.19a-c; 23.16*

Manganese deficiency
Manganese toxicity
Tipburn

Manganese deficiency commonly occurs in lettuce crops grown in muck soils above pH 6.5. Muck soils underlain with calcareous subsoils are also susceptible, as are areas within fields where mineral ridges surface through degrading muck soils. Plants are stunted and have a yellow-gray appearance. Necrotic spots occur on leaf margins (*11.19a).* Midribs may be hollow. Manganese deficiency can be corrected by lowering the soil pH or by applying manganese sulphate to the soil or foliage. Maneb fungicide is a source of manganese when applied to the foliage for downy mildew control.

Manganese toxicity symptoms on lettuce are irregular yellow margins on the older leaves, sharply contrasting with the rest of the leaf that stays green (*11.19b).* Care must be taken when applying manganese sulphate because manganese can be present at toxic levels in soils with a pH below 6.0 and it can damage the leaves when applied in excess.

Tipburn occurs on the inner leaves of head-forming vegetables such as lettuce, cabbage and Brussels sprouts. It is a result of calcium deficiency in the growing tissues of the inner leaves. The first symptoms are necrotic spots near the leaf tips that expand until the entire edge of the leaf is brown *(11.19c, 23.16).* Injured tissues may become affected by bacterial soft rot (see head rot, 11.1). Tipburn is second only to bruise injury as the most commonly reported non-infectious disorder of head lettuce. Many inter-related factors contribute to calcium uptake and tipburn. The condition can be reduced to some extent by soil calcium levels that are high relative to competing elements such as potassium and magnesium, by reducing nitrogen applications to limit growth, especially during warm weather, by harvesting slightly before maturity and, in the case of greenhouse crops, by keeping the nighttime humidity high. Cultivars differ in tolerance to tipburn.

▶ 11.20 Other disorders *Fig. 11.20*

Non-infectious corky root
Pink rib
Russet spot

Non-infectious corky root

is a disease of lettuce characterized by dark brown lesions and corky ridges on the taproot, rotting-off of side roots, and red or yellow-brown discoloration of the stele. These symptoms are induced by ammonia and possibly nitrite released from nitrogenous fertilizers. This condition contrasts with infectious corky root, which is not induced by high nitrogen but by a fastidious bacterium, *Rhizomonas suberifaciens,* and which has different symptoms (see infectious corky root, 11.2).

In experimental studies of non-infectious corky root, external reddish discoloration and corkiness were induced by 160 kg of nitrogen per hectare when both urea and ammonium nitrate were applied, and by 350 kg or more of nitrogen per hectare when only ammonium nitrate was used. Nitrogen toxicity seems to be related more to ammonium nitrogen in the tissue rather than nitrate nitrogen.

The use of ammonium- and nitrite-releasing fertilizers should be avoided. Nitrate fertilizers are relatively safe in the absence of *R. suberifaciens* but infectious corky root increases in severity with increasing nitrogen applied as ammonium sulfate, ammonium nitrate, urea, or calcium nitrate.

Pink rib

first appears as a pink discoloration at the base of the midveins of lettuce leaves *(11.20).* The discoloration extends throughout the veins of the outer leaves, then progresses into the younger leaves. The cause of pink rib is unknown. It is aggravated by bruising, tight packing and high storage temperature.

Russet spot

is a common disorder of head lettuce. It first appears as small tan-colored pits on the outer leaves *(11.20).* The pits may be clustered along the midrib or scattered on the blades. Russet spot occurs on mature and overmature heads in the field and on harvested lettuce in storage and transit. The condition is caused primarily by ethylene injury and can be prevented by reducing ethylene concentrations in the storage atmosphere. It is best to avoid storing or transporting lettuce with ripening fruit, to use battery- powered rather than propane-fueled fork lifts in cold storage areas, and to store lettuce separately from fruit in retail holding rooms and home refrigerators.

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(Original by D.J. Ormrod and W.R. Jarvis)

NEMATODE PESTS

▶ 11.21 Northern root-knot nematode *Fig. 7.15b*

Meloidogyne hapla Chitwood

Symptoms include yellowing, prolific branching of rootlets, and production of small, spherical galls on roots. In head lettuce, there is a delay in maturation or lack of head formation. For a complete description and management strategies, see Carrot, northern root-knot nematode, 6.20; see also Management of nematode pests, 3.12.

▶ 11.22 Root-lesion nematode *Fig. 16.38T1*

Pratylenchus penetrans (Cobb) Filip. & Stek.

Symptoms include wilting and stunting in patches in heavy infestations; leaves become yellow. Secondary roots become necrotic, with dried areas. For a complete description, see Potato, 16.38; see also Management of nematode pests, 3.12.

INSECT PESTS

▶ 11.23 Aster leafhopper *Figs. 11.23a, b*

Macrosteles quadrilineatus (Forbes)
(syn. *Macrosteles fascifrons* of authors, not Stål)

The aster leafhopper is found throughout Canada wherever cereal grains are grown. It is common in the south-central United States and migrates northward on air currents in the spring to invade the northern states and Canada. Thus, southern Canada is subject to an annual spring migration of adults from the south. They usually arrive before eggs of local populations hatch but nymphs have been found in Alberta before immigrant adults appear.

This insect has been recorded on more than 100 plant species in at least 40 families. Although cereals and grasses appear to be preferred hosts, large populations can develop on such vegetable crops as the head, leaf and Boston types of lettuce. The aster leafhopper is a major pest of certain vegetables because it transmits the causal agent of aster yellows, the severity of which varies widely, depending upon location and seasonal conditions. Losses of up to 100% have been reported in lettuce, celery, and carrot. Potato and onion can be affected to a lesser degree.

Damage Symptoms of aster yellows are described in the viral and viral-like diseases of lettuce section. Direct feeding injury by aster leafhopper normally is of little or no economic importance.

Once leafhoppers have acquired the aster yellows mycoplasma-like organism, they remain infective for life. A feeding period of eight hours on infected plants is required for acquisition. After three weeks, they are able to infect other plants. A feeding period of about eight hours is required to transmit the mycoplasma-like organism, which explains why chemical control of aster yellows is usually more effective than that for aphid-transmitted viruses. The level of infectivity in migrant populations from the southern United States is a major factor determining the severity of aster yellows in the midwestern states and Manitoba. Importance of migrants in relation to disease severity in Ontario is less well documented.

Identification The aster leafhopper (family Cicadellidae) adult is about 3 mm long, slender, pale gray-green with six black spots on the front of its head (*11.23a,b*). If disturbed, it immediately moves by short flights to nearby plants. The nymph resembles the adult in shape but it is smaller, tan colored and lacks wings. A dark-winged strain occurs in western Alberta.

The leafhopper known as *Macrosteles fascifrons* (Stål) has been confused with the aster leafhopper in the past but now is considered to be a separate species, which also is migrant into Canada, feeding strictly on certain types of rushes *(Juncus* sp.) (see Additional references, Hamilton 1983).

Life history Populations infesting crops in Canada arise from two sources. The insect overwinters in the egg stage in winter cereals, wild grasses and weeds, but survival of eggs is contingent upon the severity of winter temperatures and the amount of snow cover. Nymphs emerge from early May in southern Ontario to late May or early June in the Holland Marsh area, depending on geographical location, and they complete their development to adults in two to three weeks. However, southern Ontario and the Prairie provinces also are affected by large numbers of adult leafhoppers that migrate northward and westward on warm air currents from the southern United States. These leafhoppers arrive about mid- to late May or June, before local populations have matured, and lay their eggs on winter and spring cereals, grasses, weeds and such early seeded vegetables as lettuce. Hatching occurs in about eight days and new adults appear in about two to three weeks. As the various crops mature, the new adults, which originate from either overwintered eggs or migrants, disperse to more succulent crops, such as lettuce and other vegetables. There are three to five generations per year, depending on geographic location in Canada. In the fall, as annual crops mature, the leafhoppers move to winter cereals where they lay eggs that may survive the winter and give rise to the next spring generation.

Management The primary purpose in controlling the aster leafhopper is to reduce the potential for the spread of disease. Unfortunately, a method to determine the amount of infection in the leafhopper population has not been developed and there are few alternatives to insecticides, which must be applied without any knowledge of disease potential and may not always be economical.

Monitoring — Aster leafhopper can be monitored by means of yellow sticky traps. Growers should start monitoring for adults in early spring. Spraying is suggested as soon as adults are caught on the traps because action and economic thresholds have not been established in Canada. Although monitoring is useful for establishing the presence of the leafhopper and provides some indication of its abundance, a more important factor in the spread of the disease is the proportion of the population that is infective.

Cultural practices — Lettuce fields should be plowed immediately after harvest to remove sources of disease inoculum and to eliminate leafhopper breeding areas. Weeds in headlands and ditches also should be controlled to prevent susceptible species from serving as a reservoir of disease inoculum. The use of a reflective surface, such as aluminum foil, to repel adult leafhoppers has shown some promise.

Chemical control — In Canada, the aster leafhopper has not shown resistance to insecticide products that are registered for use on lettuce. Granular materials can be placed near the seed at seeding time. Foliar sprays can be applied as soon as leafhoppers appear and repeated at five- to seven-day intervals as long as monitoring indicates a need. With four to five sprays, leafhopper numbers can be sufficiently reduced to avoid significant infection. Attempts should be made to reduce leafhopper populations in adjacent susceptible vegetable crops and in headlands and ditch areas. In Quebec, direct damage from leafhoppers and the incidence of aster yellows infection are low in lettuce and treatment usually is not required. In general, treatments on lettuce for other insects also control aster leafhopper.

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(Original by M. Valk and A.B. Stevenson)

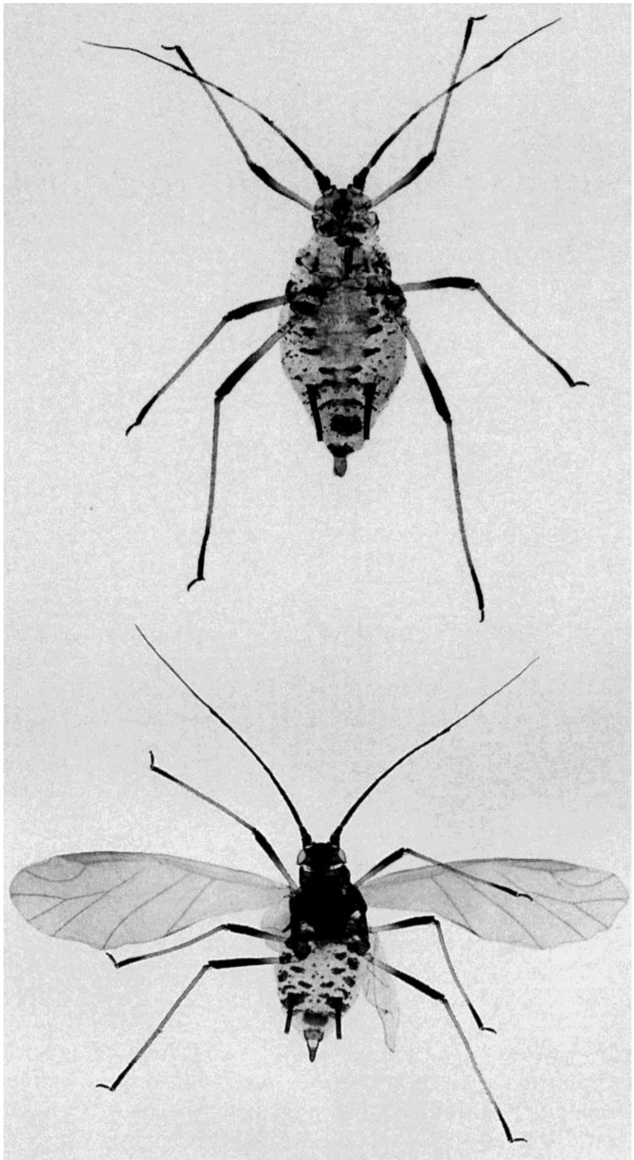
▶ 11.24 Lettuce aphid *Figs. 11.24T1, T2*

Nasonovia ribisnigri (Mosley)

The lettuce aphid is native to Europe. In Canada, it has been reported in British Columbia, Quebec and New Brunswick. It was not a pest in North America until 1981, when it caused significant damage to commercial plantings of head lettuce in southwestern British Columbia. In British Columbia, the head-lettuce market almost collapsed in 1982 because of cosmetic damage caused by this aphid, which remains the major pest of lettuce in that region.

This aphid’s primary hosts are *Ribes* spp. Secondary hosts are lettuce and plants in several families.

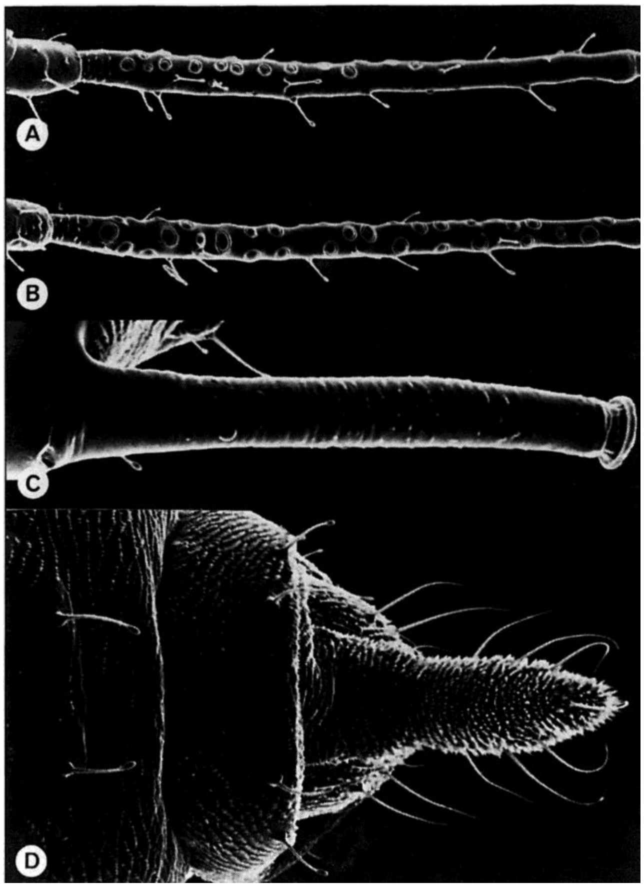
Damage Unlike other lettuce-infesting aphids, this aphid tends to colonize leaves inside the developing heads, causing cosmetic damage and making the head unmarketable. The aphid cannot be killed with foliar contact sprays after it is inside the lettuce head.



11.24T1 Lettuce aphid; photomicrographs of wingless (above) and winged adults, which are usually pale green; length 2-3 mm.

This aphid can transmit cucumber mosaic and possibly beet western yellows. It has not been implicated as a vector of lettuce mosaic.

Identification The adult aphid is 2 to 3 mm in length and olive-green, with a distinctive dorsal pattern, especially in the winged form (*11.24T1*). Antennae are long with sensory organs (secondary sensoria) on the basal part of segment III in wingless forms and along the entire third segment in winged forms. The paired abdominal projections (cornicles) are cylindrical with a distinct, ring-like incision. The tip of the abdomen (cauda) is finger shaped, usually with seven, hair-like setae (*11.24T2).* Various color forms exist, including a pink form.



11.24T2 Lettuce aphid; A,B) scanning electron micrographs of third segment of antenna of wingless (A) and winged (B) adults; C) cornicle; D) tip of abdomen.

Life history The lettuce aphid overwinters as eggs on currant and gooseberry (*Ribes* spp.) and possibly other plants. In British Columbia, eggs hatch in late March and April. Winged aphids migrate into lettuce fields in May and June. There they complete many winged and wingless generations throughout the summer, flying to other lettuce fields and starting new colonies. In October, winged aphids return to primary hosts, mate, and lay eggs.

Management

Monitoring — Commencing about three weeks after seeding, lettuce fields should be checked for aphids twice weekly before heading begins, by walking along the outside beds and examining four heads at 20-pace intervals in each bed. The process of examination entails stripping the plants and inspecting each leaf for aphids. If a single aphid is found, a spray program should begin immediately. After heading, sampling is too time consuming and can be abandoned where growers are on a strict routine of chemical control. Because of a zero tolerance level for this aphid on lettuce in British Columbia, monitoring usually is used to ensure that chemical control programs are efficient.

Cultural practices — To prevent aphids from spreading to other lettuce fields, growers should destroy and bury all crop residue after harvest. The removal of *Ribes* plants over a wide area has reduced the problem.

Resistant cultivars — See Helden *et al.* (1993) in Selected references.

Chemical control — In southwestern British Columbia, this aphid can be controlled on head lettuce only by routine application of insecticides. No other procedure ensures that the field will be free of aphids at harvest. After thinning, sprays should be applied every 7 to 10 days until just before heading. At early heading, a systemic insecticide is required to eliminate any build-up of aphids inside the head. To guard against reinfestation, additional sprays are required on a weekly basis from heading until the prescribed pre-harvest interval.

Selected references

Helden, M. van, W.F. Tjallingii and F.L. Dieleman. 1993. The resistance of lettuce (*Lactuca sativa* L.) to *Nasonovia ribisnigri:* bionomics of *N. ribisnigri* on near isogenic lettuce lines. *Entomol. Exp. Appl.* 66:53-58.

Mackenzie, J.R., and R.S. Vernon. 1988. Sampling for distribution of the lettuce aphid, *Nasonovia ribisnigri* (Homoptera: Aphididae), in fields and within heads. *J. Entomol. Soc. British Columbia* 85:10-14.

(Original by R.S. Vernon and J.R. Mackenzie)

▶ 11.25 Other aphids

Aphids other than the lettuce aphid occasionally infest lettuce. Their presence and their molted skins (exuviae) between the leaves of the head may reduce the attractiveness and marketability of the crop. They are also potential vectors of plant pathogenic viruses. Such infestations may be difficult to control because the aphids are protected from insecticidal applications by the outer leaves. Undetermined species of root aphids have been reported attacking head lettuce and stunting plant growth in the Holland Marsh area of Ontario. They are common in New Brunswick and Nova Scotia, and also are found in Quebec.

Selected references

Reinink, K., and F.L. Dieleman. 1989. Resistance in lettuce to the leaf aphids *Macrosiphum euphorbiae* and *Uroleucon sonchi. Ann. Appl. Biol.* 115:489-498.

Reinink, K., F.L. Dieleman and R. Groenwold. 1988. Selection of lines of lettuce with a high level of partial resistance to *Myzus persicae. Euphytica* 37:241-245.

(Original by A.B. Stevenson)

▶ 11.26 Other insect pests *Figs. 11.26; 8.40; 7.21*

Cabbage looper *Trichoplusia ni* (Hübner)
Cutworms
Tarnished plant bug *Lygus lineolaris* (Palisot de Beauvois)

Cabbage looper

(see Crucifers) (*8.40b-f)* Cabbage looper larvae occasionally attack lettuce, chewing holes in the leaves similar to those they chew on cabbage.

Cutworms

(see Carrot, 6.25; and Tomato, 18.35) (*11.26*)

Tarnished plant bug

(see Celery) *(7.21b,d,e)* The tarnished plant bug occasionally attacks the heads of lettuce, causing small holes with brown margins in the leaves. Damage can be sufficiently severe to make the heads unmarketable.

(Original by A.B. Stevenson)

OTHER PESTS

▶ 11.27 Slugs and snails *Figs. 11.27a-c; 3.11e*

Black slug *Arion ater* (L.)
Brown garden snail *Helix aspersa* Müller
Gray garden slug *Deroceras reticulatum* (Müller)
Spotted garden slug *Limax maximus* L.

The pest species of slugs and snails in Canada are of European origin. The gray garden slug *(11.27c)* (see Crucifers, 8.49) occurs locally in most urban areas of Canada. The brown garden snail *(3.11e)* (see Introduced diseases and pests, 3.11) occurs in the lower Fraser Valley and southern Vancouver Island of British Columbia. The black slug (*11.27a)* occurs in the same areas of British Columbia, as well as eastern Quebec, Prince Edward Island, the Avalon Peninsula of Newfoundland and in Sussex, New Brunswick, where it was found recently. The spotted garden slug (*11.27b*) occurs in the eastern Avalon Peninsula of Newfoundland and in the vicinity of Vancouver, British Columbia. Recently it was found at Sillery, Quebec, and there are dated records of its presence in Ontario.

Practically all vegetable crops are suitable hosts for land slugs and snails. Other favored hosts include daisy, gladiolus, iris, narcissus, salvia and strawberry. None of these slugs and snails has been implicated in the transmission of plant pathogens in Canada.

Damage In general, all above-ground plant parts are attacked, including foliage and fruit some distance above the ground, and plants become covered with slime trails and excreta. Below-ground parts of plants, such as bulbs and tubers, also may be attacked (see Potato, 16.53).

Life history Native species tend to be solitary and arouse little concern. The introduced land slugs and snails tend to be colonial. The introduced species also tend to be restricted to urban environments. They are most active at night when it is cool and humid, climbing up vegetation to feed on leaves and fruits. They burrow into the soil or under litter during the day and, in dry conditions, they protect their bodies with mucous secretions. Land slugs and snails tend to become more active as the temperature drops, feeding at night or on cloudy days and showing a preference for damp situations. All individuals are hermaphroditic, having both male and female reproductive organs. The male organs usually develop first and degenerate later, so these animals mate and then become female.

The brown garden snail can live for several years. It mates and lays its eggs in the spring. Slugs mate in late summer and lay their eggs in the fall. In greenhouses or other protected areas, a slug may lay up to 400 eggs, though clutches of 30 to 150 are usual. Slug eggs hatch early in the spring. The young slugs may mature, breed, and die all in one season, or they may mature the following year, depending upon the species. In greenhouses, slugs may remain active year-round.

Identification Terrestrial slugs and snails in Canada have a shell and a ventral foot for crawling, and they obtain oxygen from either air or water by means of a vascular lung. Their stomach loops through the interior of the foot, and the excretory pore (anus) is positioned near the head on the right side of the body. Land snails do not close the aperture of their shell, thus differing from fresh-water snails, which posses a cover (operculum). The shell in most terrestrial slugs is concealed within a fleshy hood (mantle). Slugs and snails possess eyes at the tip of a second pair of tentacles (*11.27b).* Their eggs are colorless to white.

Management

Monitoring — Slugs and snails can be seen while they are still active in the early morning or late in the evening. Slime trails and excreta are signs of their presence.

Cultural practices — Destruction of hiding places is best done by burying plant residue and by clearing boards or stones away from the sides of buildings. In the past, some heavily infested areas were burned. A less drastic, more permanent, and environmentally more acceptable solution is to eliminate shady, damp areas. Hand-picking can be successful, and trap plants can be used to concentrate slugs and snails prior to hand-picking. Metal barriers are effective but practical only around raised beds.

Biological control — Mammals, birds, reptiles and amphibians are occasional predators on slugs and snails. Some native snails are carnivorous on other snails. Among insects, there are predatory beetles and flies, but none is marketed commercially.

Chemical control — Baits, employing wheat bran or corn meal combined with a pesticide, can be used but they should not be applied directly onto vegetable crops. Feeding stations should be located where pets and birds cannot gain access. Chemical sprays can be effective but timing of applications is critical.

(Original by D.C. Read, R.A. Costello and J.A. Garland)

ADDITIONAL REFERENCES

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