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FUNGAL DISEASES

▶ 10.1 Canker of hop

Fusarium sambucinum Fuckel
(teleomorph *Gibberella pulicaris* (Fr.:Fr.) Sacc.)

Infection just above the crown can result in girdling and sudden wilting of hop vines. The presence of an obvious canker and the sudden death of the plant differentiates this disease from verticillium wilt, in which the symptoms appear gradually, starting with the lower leaves. Canker has been a minor problem on commercial hop. Prompt removal of infected vines is reported to reduce *Fusarium* inoculum and subsequent infections.

Selected references
Booth, C. 1969. *Gibberella pulicaris.* CMI Descriptions of Pathogenic Fungi and Bacteria, No. 385. Commonw. Mycol. Inst., Kew, Surrey, England. 2 pp.

(Original by D.J. Ormrod)

▶ 10.2 Downy mildew of hop *Fig. 10.2*

Pseudoperonospora humuli (Miyabe & Takah.) G.W. Wils.

Downy mildew is the most important disease of hop worldwide. It was first reported in Japan in 1905, in North America in 1910, and in Britain in 1920. It is well established in the hop fields of coastal British Columbia. Hop is the only host of *P. humuli.*

Symptoms The first sign of infection occurs early in the spring when the new shoots are just emerging from the crowns. Systemically infected shoots, known as primary basal spikes, are stunted, pale and have tightly clustered, curled leaves *(10.2).* Secondary infections of otherwise healthy shoots appear later as discrete spots or brown patches on the growing tips, leaves, flowers and cones. Infected cones may be unsaleable.

Causal agent The mycelium of *Pseudoperonospora humuli* is nonseptate and intercellular. Sporangiophores are 200 to 460 by 7 µm, with wide- spreading, stiff, dichotomous branches. Sporangia are 22 to 30 by 16 µm, ellipsoid with an apical papilla, and germinate by producing zoospores. Oospores are 25 to 40 µm, spherical and have a smooth, light brown wall.

Disease cycle The pathogen overwinters in infected hop crowns and can be carried to new locations as mycelium in diseased rootstocks. Infected dormant buds give rise to primary basal spikes in the spring. When the ambient temperature exceeds 6°C, sporangiophores emerge through the stomates of infected tissue and release sporangia. If free water is available, the sporangia that land on hop leaves or other organs germinate to form motile zoospores. The zoospores encyst and form germ tubes that can penetrate the host tissue, usually through the stomates.

Once inside the host, the mycelium continues to grow, symptoms appear and sporangia are produced when temperatures range from 10 to 25°C. Secondary infection can occur anytime during the growing season when the foliage is wet from rain. Periods of wetness from dew are inadequate for infection.

Management

Cultural practices — Only disease-free crowns should be used for planting and replanting. Volunteer hop plants should be removed from the vicinity of hop yards. Primary basal spikes should be pruned off early in the spring before the pathogen has a chance to sporulate. Regular pruning should be delayed as long as possible to shorten the exposure period of vines selected for training.

Resistant cultivars — The cultivar Fuggles is resistant to downy mildew, while Brewer's Gold, Bullion and Cascade are tolerant.

Chemical control — In Canada, one drench application of a systemic fungicide in early spring reduces the level of primary inoculum. Later, when weather conditions favor mildew, conventional, protectant fungicide sprays can be used to prevent secondary infection. In Europe, disease forecasting systems have been used for several years and, in some cases, have been successful in reducing the number of spray applications by up to 50%.

Selected references

Coley-Smith, J.R. 1962. Overwintering of hop downy mildew, *Pseudoperonospora humuli* (Miy. and Tak.) Wilson. *Ann. Appl. Biol.* 50:235-248.

Frances, S.M. 1983. *Pseudoperonospora humuli.* CMI Descriptions of Pathogenic Fungi and Bacteria, No. 769. Commonw. Mycol. Inst., Kew, Surrey, England. 2 pp.

Skotland, C.B., and R.R. Romanko. 1964. Life history of the hop downy mildew fungus. *Wash. State Univ.* **(***Pullman***)** *Agric. Exp. Stn. Circ.* 433. 6 pp.

Royle, D.J. 1979. Prediction of hop downy mildew to rationalize fungicide use. Pages 49-56 *in Annu. Rep. 1978,* Dep. Hop Res., Wye College, Ashford, Kent, U.K.

(Original by D.J. Ormrod)

▶ 10.3 Leaf scorch of parsley *Figs. 10.3a,b*

Alternaria radicina Meier, Drechs. & E.D. Eddy
(syn. *Stemphylium radicinum* (Meier, Drechs. & E.D. Eddy) Neergaard)

Leaf scorch of parsley has damping-off and petiole spot phases. It has not yet been reported on parsley but does occur on other umbelliferous crops (see Carrot, black rot, 6.7).

Symptoms Seedlings fail to emerge or topple over after emergence *(10.3a).* Later, dark brown to black lesions may develop on petioles and leaves *(10.3b).* These symptoms can be confused with those caused by other *Alternaria* spp.

Causal agent (see Carrot, black rot, 6.7) Damping-off, petiole lesions and dark leaf spots with evidence of black mycelium and/or conidia usually indicate the presence of *Alternaria* spp. Conidia of *A. radicina* are unbeaked, whereas those of other *Alternaria* spp. have long, flexuous or branched beaks, or the beak is shorter than the conidium body.

Disease cycle (see Carrot, black rot, 6.7) *Alternaria radicina* is spread by infested seed and diseased crop residue. It can survive in the soil for up to six years. Conidium viability is lost more quickly if diseased residue is buried rather than being left on the soil surface. Conidium germination and infection requires one to two weeks and is most rapid at relative humidities over 90% and temperatures above 27°C. A fresh crop of conidia can be produced within two to three weeks and, under favorable conditions, secondary spread and infection occur.

Management

Cultural practices — Parsley growers should follow a rotation, avoiding not only parsley but also carrot, parsnip, celery and celeriac. Where the disease has occurred, a four- to five-year rotation is suggested. Pathogen-free seed, if available, should be used, otherwise seed should be hot-water treated at 50°C for 20 minutes. Diseased crop residues should be turned under to reduce the spread of fungal spores.

Selected references

Ellis, M.B., and P. Holliday. 1972. *Alternaria radicina.* CMI Descriptions of Pathogenic Fungi and Bacteria, No. 346. Commonw. Mycol. Inst., Kew, Surrey, England. 2 pp.

Gindrat, D. 1979. *Alternaria radicina,* an important disease of umbelliferous market garden crops. *Rev. Suisse Vitic. Arboric. Horde.* 11:257-267.

(Original by D.J. Ormrod)

▶ 10.4 Leaf spots of parsley *Fig. 10.4*

Alternaria leaf spot *Alternaria dauci* (Kühn) Groves & Skolko
Phoma leaf spot *Phoma anethi* (Pers.:Fr.) Sacc.
(synanamorph *Cercosporidium punctum* (Lacr.) Deighton)
Septoria leaf spot *Septoria petroselini* (Lib.) Desmaz.

Parsley is susceptible to several fungal leaf spot diseases that are closely related to those occurring on carrot and celery.

Symptoms Alternaria leaf spots are irregularly shaped and dark brown to black with a yellow border. When numerous, they may coalesce, giving the leaflets a blighted appearance.

Phoma anethi causes small, sub-circular to irregular, olive to brown spots and can cause blighting of the foliage when numerous. Dill and fennel also are susceptible *(10.10a).*

Septoria leaf spots *(10.4)* are small, somewhat angular, grayish brown, with a definite dark cinnamon-brown margin. They often contain dark pycnidia on the upper side of the foliage. Small, oval, cinnamon-brown lesions may be present on the petioles also. Early lesions may not be readily evident on curled parsley cultivars because of extreme leaf curling and small leaf size.

Causal agent Differentiation of the three genera of fungi that most commonly cause leaf spots on parsley requires microscopic examination of mature lesions with conidia.

Alternaria dauci (see Carrot, alternaria leaf blight, 6.5) conidia have long flexuous or branched beaks.

Phoma anethi is the pycnidial state of *Cercosporidium punctum,* which produces a stroma from which simple, mostly continuous conidiophores with geniculations arise. The conidia are smooth, clavate, cylindrical to obclavate, mostly pale brown, few- to several-celled, and measure 18 to 51 by 4 to 9 µm.

Septoria petroselini forms dark pycnidia that are immersed in the leaf tissue and contain hyaline conidia with three to four erosswalls. Conidial dimensions are 30 to 40 by 1 to 2 pm.

Disease cycle All three pathogens can be carried in or on seed, thereby introducing leaf spot diseases to new areas. These fungi can also survive in undecomposed crop residues. Conidia are produced at temperatures between 10 and 30°C, and they are disseminated by splashing water, by direct contact through handling, and on infested tools. Infection, symptom expression and sporulation can occur in 10 to 15 days at 20°C.

Management

Cultural practices — Parsley growers should obtain seed from dry regions where the diseases do not occur, or use a hot-water treatment at 50°C for 20 minutes to disinfest seed. Sanitation and crop rotation are important steps in reducing the survival of the pathogens in the soil. All umbelliferous crops should be avoided in rotation with parsley. Where no disease has been observed, a two- to three-year rotation should suffice. Where disease problems have occurred, a four- to five-year rotation is suggested. Irrigation should be timed to minimize periods of leaf wetness.

Resistant cultivars — The parsnip-rooted cultivars Early Sugar and Hamburg Thick-Rooted are highly resistant to *Septoria petroselini,* while Plain Dark Green Italian and Improved Market Gardener are resistant, and the curled- leaf cultivars Sherwood Decorator and Banquet are highly susceptible.

Selected references

Cerkauskas, R.F. 1991. Susceptibility of parsley cultivars to septoria blight. *Can. J. Plant Pathol.* 13:273. (Abstr.)

Cerkauskas, R.F., and J. Uyenaka. 1990. First report of *Septoria* blight of parsley in Ontario. *Plant Dis.* 74:1037.

(Original by D.J. Ormrod and R.F. Cerkauskas)

▶ 10.5 Powdery mildew of hop, mint, sage and parsley *Fig. 10.5*

Erysiphe cichoracearum DC.:Mérat

Sphaerotheca macularis (Wallr.:Fr.) Lind
(syn. *Sphaerotheca humuli* (DC.) Burrill)

Powdery mildew, caused by *Erysiphe cichoracearum,* can be a serious disease of scotch spearmint. It is usually a minor problem on peppermint, wild mint (*Mentha arvensis* L.) and sage. *Erysiphe cichoracearum* has a wide host range, mostly on Compositae, and occurs in physiologic strains. Other species of *Erysiphe* and *Sphaerotheca* have been reported on mint in North America. *Erysiphe heraclei* DC. has been recorded in Europe. In the fall of 1990, a 500 m^2 outdoor planting of parsley in coastal British Columbia was 100% infected by an *Erysiphe* species, probably *E. heraclei,* although no cleistothecia were observed.

Powdery mildew caused by *S. macularis* occurs worldwide on hop and on strawberry and several other members of the rose family (Rosaceae). This is the oldest known hop disease, having first been observed early in the 19th Century, but it is no longer a significant problem. Mechanical harvesting, in which the vines are completely removed from the field, has probably been effective in eliminating most of the overwintering inoculum. Powdery mildew resistance has been bred into some of the newer hop cultivars.

Symptoms A powdery, gray-white growth of conidia and conidiophores occurs on the upper surface of leaves and on stems. Infected leaves eventually turn yellow *(10.5)* and drop. Small brown or black fruiting bodies (cleistothecia) may appear on diseased tissues late in the season.

Causal agent (For a description of *Erysiphe cichoracearum,* see Lettuce, powdery mildew, 11.12.)

Sphaerotheca macularis has hyaline, highly branched mycelium that grows on both leaf surfaces but is more persistent on the upper surface. Conidia are in chains, ellipsoidal to barrel shaped, 25 to 38 by 15 to 23 µm. Cleistothecia are globose, dark brown to black, 60 to 125 µm in diameter, with numerous brown, unbranched appendages three to five times the diameter of the cleistothecia. A single ascus, measuring 50 to 90 by 45 to 75 µm and containing eight ascospores that are 18 to 25 by 12 to 18 µm, differentiates it from *E. cichoracearum,* which has multiple asci.

Disease cycle Mildew fungi overwinter as mycelium or cleistothecia on infested stubble. In the spring, conidia or ascospores infect new foliage. Conidial production occurs throughout the summer, but cleistothecia are produced only in the late summer or fall. Little is known about the effect of growing conditions on the incidence of powdery mildew, which is often most severe during cool cloudy weather.

Management

Cultural practices — Fields should be clean cultivated in the fall to bury infested crop residues. Where practical, flaming can also be used to destroy diseased stubble.

Resistant cultivars — Where powdery mildew has been a recurring problem, the use of alternative cultivars should be investigated.

Selected references

Kapoor, J.N. 1967. *Erysiphe cichoracearum.* CMI Descriptions of Pathogenic Fungi and Bacteria, No. 152. Commonw. Mycol. Inst., Kew, Surrey, England. 2 pp.

Mukerji, K.G. 1968. *Sphaerotheca macularis.* CMI Descriptions of Pathogenic Fungi and Bacteria, No. 188. Commonw. Mycol. Inst., Kew, Surrey, England. 2 pp.

(Original by D.J. Ormrod)

▶ 10.6 Pythium root rot of parsley *Figs. 10.6a,b*

Pythium spp.

In Canada, root rot of parsley has been attributed to unidentified *Pythium* spp. In Ireland, *Pythium paroecandrum* Drechs. is reported as the cause of root rot on this plant. *Pythium* spp. can attack a wide variety of herbs and spices.

Symptoms Affected plants appear yellow and stunted *(10.6a).* Immature roots are brown and, in severe cases, the entire root system may be rotted *(10.6b).*

Causal agent (see Carrot, pythium root dieback, 6.13) Confirmation of *Pythium* spp. requires isolation on selective culture media.

Disease cycle *Pythium* fungi are soil-borne. High populations can build up if diseased roots are left to rot in the soil. Severe root rot can occur if parsley is seeded into infested beds. High soil moisture favors infection.

Management

Cultural control — For parsley, improved drainage, such as the use of raised beds, and rotation with unrelated crops, such as cereals, corn and allium crops, are recommended. Where feasible, removal of infected plants will reduce the carry-over of inoculum.

Selected references

McCracken, A.R. 1984. *Pythium paroecandrum* associated with a root rot of parsley. *Plant Pathol.* 33:603-604.

(Original by D.J. Ormrod)

▶ 10.7 Rust of mint *Figs. 10.7a,b*

Puccinia menthae Pers.:Pers.

Rust of mint occurs worldwide. It is the most troublesome disease reported by fresh mint growers in British Columbia. There are two races of *P. menthae* on mint; one infects peppermint and the other spearmint. Both races can attack scotch spearmint. The only other rust on mint is *P. angustata* Peck, for which sedges (Cyperaceae) are the primary hosts and mint is the alternate host on which pycnia and aecia occur.

The numerous races of mint rust have varying abilities to infect different hosts. Wild mint (*Mentha arvensis* L.), savory, dittany (*Cunila* spp.) and the herb *Hedeoma* spp. may be attacked by races of *P. menthae* that infect cultivated mints.

Symptoms Rust is usually first noticed in early spring. New shoots are swollen, exhibit yellow, blister-like spots, break off easily, and have malformed, chlorotic leaves *(10.7a).* Aeciospores are produced in reddish-brown blisters on young shoots and infect developing leaves. Later, cinnamon-brown pustules containing urediniospores appear on the stems and undersides of leaves *(10.7b).* Leaf infection results in destruction of the oil glands, yellowing and defoliation. Dark brown teliospores form on the stems and occasionally on the rhizomes in the fall. The gross symptoms and presence of spore forms appropriate for the time of year are sufficient to identify the disease.

Causal agent *Puccinia menthae* has globose pycnia. 90 to 160 µm in diameter, which occur in small groups with the aecia, which are 0.3 to 0.4 µm in diameter. Aeciospores are spheroidal or ellipsoidal, 18 to 24 µm in diameter, and hyaline or pale. Uredinia are scattered or in small concentric groups, buff colored and up to 0.5 µm in diameter. Urediniospores are ellipsoidal or obovoidal, 22 to 26 by 18 to 22 µm, with a finely echinulate wall. Telia are similar to uredinia but dark brown. Teliospores are ellipsoidal, obtuse above, usually with slightly projecting caps, slightly constricted at the septum, and measure 22 to 30 by 17 to 24 µm. The spore wall is yellow-brown and may be verrucose or smooth.

Disease cycle *Puccinia menthae* is an autoecious, macro- cyclic rust fungus. It overwinters as teliospores on mint stubble and on wild or volunteer plants. These spores germinate to form basidia and basidiospores in the late fall to early spring. The basidiospores infect the earliest shoots from late winter to early spring, depending on the geographical area. In spearmint but not in peppermint, the basidiospore infection appears to result in systemic invasion of the shoots. These infections give rise to the pycnial and aecial stages. Aeciospores are produced from early spring to early summer, with the heaviest production in the spring. They disperse over short distances, generally less than one metre, and infect newly emerging leaves, resulting in the uredinial stage. Urediniospores are produced from spring until late summer and infect new leaves under favorable conditions, finally leading to the telial stage in the fall. Urediniospores are responsible for long-distance spread and can result in areawide epidemics. Rust is most severe during cool, damp growing seasons. Urediniospore viability is greatly reduced by bright sunlight and air temperatures greater than 32°C.

Management

Cultural practices **—** Rhizomes can be hot- water treated to rid them of adhering teliospores if it is necessary to start a new planting of a cultivar that cannot be grown from seed. Hot-water treatment should be done under carefully controlled conditions and only where isolation from infected mint makes it worthwhile. Infection can be greatly reduced by turning under crop residues in the fall or early spring, although this is not recommended where there is a danger of spreading verticillium wilt. Flaming the entire crop in the spring to break the cycle between the aecial and uredinial stages has been the most successful control method over the past 25 years. Timing is critical in that all stubble and new growth must be destroyed on an area-wide basis so that the late flush of new growth can emerge without danger of being infected by air-borne urediniospores from adjacent fields or border areas. Flame treatment is highly effective for peppermint and common spearmint; it is not recommended for scotch spearmint because the rust can overwinter on rhizomes.

Resistant cultivars — The peppermint cultivars Murray Mitcham and Todd's Mitcham are resistant to rust under moderate disease pressure.

Selected references

Beresford, R.M., and R.I. Mulholland. 1987. Mint rust on cultivated peppermint in Canterbury: disease cycle and control by flaming. *N.Z. J. Exp. Agric.* 15:229-233.

Horner, C.E. 1963. Field disease cycle of peppermint rust. *Phytopathology* 53:1063-1067.

Horner, C.E. 1965. Control of mint rust by propane gas flaming and contact herbicide. *Plant Dis. Rep.* 49:393-395.

Laundon, G.F., and J.M. Waterston. 1964. *Puccinia menthae.* CMI Descriptions of Pathogenic Fungi and Bacteria, No. 7. Commonw. Mycol. Inst., Kew, Surrey, England. 2 pp.

Roberts, D.D., and C.E Horner. 1981. Sources of resistance to *Puccinia menthae* in mint. *Plant Dis.* 65:322-324.

(Original by D.J. Ormrod)

▶ 10.8 Sooty mold of hop

Fumago vagans Pers.

Sooty mold grows on honeydew produced by the hop aphid and probably by other aphid species during feeding. If unchecked, the entire plant may be covered with the fungus, resulting in contamination and downgrading of the cones. An effective aphid control program will prevent this problem and may also reduce the spread of hop mosaic virus, which is transmitted by the same aphid.

Management When aphid populations are high enough to require the use of control measures, damage from sooty mold may be prevented by the use of registered insecticides.

(Original by D.J. Ormrod)

▶ 10.9 Verticillium wilt of mint and hop *Figs. 10.9a-d*

Verticillium albo-atrum Reinke & Berth.
Verticillium dahliae Kleb.

Verticillium wilt caused by *V. dahliae* is the most serious disease of mint in the major production areas of North America. It has led to the decline of the mint industry in the midwest United States and an accompanying shift in production to Oregon and Washington, where it is now the major disease as well. The distribution of verticillium wilt on mint in Canada is not known. It has been identified in field-grown peppermint in southern Alberta. In Nova Scotia, *V. dahliae* has been reported on savory.

Verticillium wilt caused by *V. albo-atrum* can be a very destructive disease on hop if it is caused by a virulent or "progressive" strain. Both progressive and less virulent, "fluctuating" strains have been identified in England, where considerable research has been done over the past 60 years. Strains of *V. dahliae* can also infect hop, but rarely cause serious symptoms; in Canada, verticillium wilt caused by *V. dahliae* has been found occasionally on hop, but there are no records of it causing significant losses.

Symptoms Infected peppermint and spearmint plants show any or all of the following symptoms: asymmetric leaf growth *(10.9c),* dwarfing, chlorosis (*10.9d*), browning or purpling of the leaves, wilting, stem cankers, death of lower leaves, and finally death of the plant *(10.9a).* The disease first appears in small, well-defined areas that can expand rapidly to cover entire fields within three to five years. The presence of symptomatic plants from which *V. dahliae* can be isolated is indicative of the disease. Other *Verticillium* species may be isolated, but they tend to be non-pathogenic to mint.

On hop *(10.9b),* infected plants exhibit a progressive yellowing and dying of the leaves from the bottom up during the latter part of the growing season. Cutting into the bark shows light brown discoloration of the woody tissue extending well up from the base of the vine. Severely infected vines die completely before harvest, but the crowns survive and in subsequent years send up new vines, which may or may not show symptoms.

Causal agents (see Greenhouse cucumber, verticillium wilt, 22.17)

Disease cycle *Verticillium dahliae* can be introduced on infected plant rhizomes of mint or as microsclerotia in crop residues that are wind-blown or otherwise moved from infested fields. It can persist as microsclerotia in crop residues or in soil for five years or more. When mint is planted in the field, the roots can be infected directly from soil- borne microsclerotia. The fungus then spreads through the roots and into the stems where vascular browning occurs and microsclerotia are produced. Infection is encouraged by high soil moisture and temperature; symptom expression is most pronounced under warm, dry conditions.

In hop, the pathogen overwinters in infected crowns and can be introduced to a new field through infected root cuttings. Propagules can also survive in crop residues in the soil for several years after the removal of an infected crop. Wilt caused by *V. dahliae* has been seen where hop was planted in fields previously cropped to hosts such as potato (see Potato, verticillium wilt, 16.20). Most infection occurs through root contact with mycelial fragments in crop debris, or with microsclerotia in the case of *V. dahliae.*

Management

Cultural practices — Mint growers should plant certified, disease-free rhizomes, especially in fields where mint has not previously been grown. Infested fields should be removed from production before wilt becomes severe. Fields of peppermint with low levels of disease, but which are to be kept in production, should be flamed within one week of harvest to slow the build-up of inoculum. Fields with low to moderate levels of disease can be replanted after rotation for four to five years to non-susceptible crops.

In areas where *V. albo-atrum* is a serious problem on hop, an integrated control program is required. This involves the use of disease-free planting stock, rotation with grasses or cereals for a minimum of two years after removal of a diseased crop, the use of resistant cultivars, and restricting nitrogen fertilization. In areas where *V. dahliae* is of greater concern, the use of disease-free planting stock and the avoidance of fields previously cropped to a susceptible host are generally sufficient.

Resistant cultivars — Todd's Mitcham or Murray Mitcham peppermint cultivars can be used in infested fields, provided inoculum levels are not excessive.

Biological control — Cross-protection by inoculation with the non-pathogenic species *Verticillium nigrescens* Pethybr. has shown promise.

Selected references

Devaux, A.L., and W.E. Sackston. 1966. Taxonomy of *Verticillium* species causing wilt of horticultural crops in Quebec. *Can. J. Bot.* 44:803-811. Gourley, C.D. 1979. *Verticillium dahliae* from stunted plants of summer savory. *Can. Plant Dis. Surv.* 59:18.

Hawksworth, D.L., and P.W. Talboys. 1970. *Verticillium albo-atrum.* CM1 Descriptions of Pathogenic Fungi and Bacteria, No. 255. Commonw. Mycol. Inst., Kew, Surrey, England. 2 pp.

Hawksworth, D.L., and P.W. Talboys. 1970. *Verticillium dahliae.* CMI Descriptions of Pathogenic Fungi and Bacteria, No. 256. Commonw. Mycol. Inst., Kew, Surrey, England. 2 pp.

Horner, C.E., and H.L. Dooley. 1965. Propane flaming kills *Verticillium dahliae* in peppermint stubble. *Plant Dis. Rep.* 49:581-582.

Keyworth, W.G. 1942. Verticillium wilt of the hop. *Ann. Appl. Biol.* 24:346- 357.

Melouk, H.A., and C.E. Horner. 1975. Cross protection in mints by *Verticillium nigrescens* against *V. dahliae. Phytopathology* 65:767-796. Talboys, P.W. 1987. Verticillium wilt in English hops: retrospect and prospect. *Can. J. Plant Pathol.* 9:68-77.

(Original by D.J. Ormrod)

▶ 10.10 Other fungal diseases of herbs *Figs. 10. 10a-c*

Published records of other fungal diseases of herbs and spices in Canada are scant and incomplete; they refer to anthracnose, blights, downy and powdery mildews, gray mold, leaf scorch and leaf spots, stem and root rots, rusts, and rusty root. In some cases, microorganisms have been identified in association with diseased plants, but no pathogenicity tests have been conducted. In other cases, only tentative identifications of pathogens have been made.

When diagnosing diseases on herbs and spices, lists of pathogens and abiotic disorders on other closely related plants should be consulted. The following list of diseases and causal agents is provided for general information:

Anise
- leaf spot (*Cercospora mcilkoffii* Bubâk)
- rust *{Puccinia pimpinellae* (F. Strauss) Mart.)
- stem rot (*Sclerotinia sclerotiorum* (Lib.) de Bary; see Bean, white mold, 15B.9)

Basil
- powdery mildew (*Sphaerotheca macularis* (Wallr.:Fr.) Lind; see powdery mildew, 10.5)

Borage
- leaf spot (*Ramularia* spp.)

Burnet
- powdery mildew (*Sphaerotheca macularis*; see powdery mildew, 10.5)

Caraway
- stem rot (*Sclerotinia sclerotiorum*; see Bean, white mold, 15B.9)

Chives
- downy mildew (*Peronospora destructor* (Berk.) Casp. in Berk.; see Onion, downy mildew, 13.6)
- rust (*Puccinia allii* F. Rudolphi)

Coriander
- anthracnose (*Gloeosporium* spp.)

Corn-salad
- leaf spot (*Septoria* spp.)

Dill
- phoma blight (*10.10a*) (*Phoma anethi* (Pers.:Fr) Sacc.; see leaf spots of parsley, 10.4)
- rusty root (*Alternaria* spp., *Cylindrocarpon* spp.)
- stem rot (*Sclerotinia sclerotiorum*; see Bean, white mold, 15B.9)

Fenugreek
- leaf spots (*Cercospora traversiana* Sacc.)
- powdery mildew (*Erysiphe polygoni* DC.; see Crucifers, powdery mildew, 8.12)
- thielaviopsis root rot (*10.10b*) (*Chalara elegans* Nag Raj & Kendrick; see Bean, black root rot, 15B.4)

Horseradish
- leaf spot (*Cercospora armoraciae* Sacc., *Entylomella armoraci- ae* (Fuckel) Sif.)
- white rust *{Albugo candida* (Pers.) Kuntze; see Crucifers, white rust, 8.15)

Lavender
- leaf spot *{Septoria lavendulae* Desmaz.)

Lemon balm
- gray mold *{Botrytis cinerea* Pers.:Fr.; see Lettuce, gray mold, 11.10)
- leaf spot *{Phoma exigua* Desmaz.; see Lettuce, phoma rot, 11.11)

Sage

powdery mildew *{Erysiphe cichoracearum* DC.:Mérat; see Lettuce, powdery mildew, 11.12)
stem rot (*Sclerotinia sclerotiorum,* see Bean, white mold, 15B.9)

Savory
root rot (*Pythium oligandrum* Drechs.; see pythium root rot, 10.6)
wilt (*Verticillium dahliae* Kleb.; see verticillium wilt of mint and hop, 10.9)

Tarragon
root rot (*10.10c) {Fusarium* sp.)
rust (*Puccinia tanaceri* var. *dracunculina* (Fahrendorff) Cummins)

Thyme
gray mold (*Botrytis cinerea;* see Lettuce, gray mold, 11.10)

Management In general, fungal diseases of herbs and spices must be controlled by cultural means.

Cultural practices — Good soil drainage, crop rotation, proper fertilization, the use of disease-free seed and the destruction of infested plant residues are important methods.

Chemical control — Fungicides have been registered for use only on dill and horseradish.

Selected references

Chipman, E.W. 1980. ***Growing Savory Herbs.*** Can. Dep. Agric. Publ. 1158. 16 pp.
Zimmer, R.C. 1984. Cercospora leaf spot and powdery mildew of fenugreek, a potential new crop in Canada. ***Can. Plant Dis. Surv.*** 64:33-34.

(Original by D.J. Ormrod and R.J. Howard)

VIRAL AND VIRAL-LIKE DISEASES

▶ 10.11 Aster yellows *Figs. 10.11 a, b*

Aster yellows mycoplasma-like organism

Parsley, dill *(10.11a,b)* and sage are susceptible to aster yellows (see Lettuce, aster yellows, 11.15).

Symptoms Symptoms on parsley may resemble those of carrot motley dwarf and celery mosaic. Significant damage can occur in areas where the leafhopper vectors are numerous (see Lettuce, aster leafhopper, 11.23).

(Original by D.J. Ormrod and R.J. Howard)

▶ 10.12 Miscellaneous viral diseases *Fig. 10.12*

Broad bean wilt virus
Carrot motley dwarf (carrot mottle virus plus carrot red leaf virus)
Celery mosaic virus
Cucumber mosaic virus
Hop mosaic virus (hop latent virus)
Hop nettle head (arabis mosaic virus plus prunus necrotic ringspot virus)
Tomato spotted wilt virus

Several viruses are capable of infecting hop, parsley, and possibly other herbs and spices. In hop, these viruses can cause a range of symptoms from non-expression (latent) to severe.

Parsley is susceptible to a number of viral diseases, such as carrot motley dwarf (70.72), which is caused by a combination of carrot mottle virus and carrot red leaf virus. Other viral diseases, such as celery mosaic, cucumber mosaic and broad bean wilt, also affect parsley but cause mild or no symptoms. None of these viruses causes significant loss in Canada.

Tomato spotted wilt (see Greenhouse tomato, tomato spotted wilt, 25.22) may affect sage, lemon balm and peppermint.

Symptoms Hop mosaic virus causes severe damage to the cultivar Goldings. Leaves are mottled and curled, and the vines are stiff and cannot climb. Infected plants die within one or two years. Other cultivars, including Fuggles, are symptomless carriers. Hop plants infected with nettle head disease exhibit rigid vines with shortened internodes and do not twist normally. Carrot motley dwarf causes dwarfing, and leaf reddening and yellowing in parsley, much as in carrot; celery mosaic causes a golden-yellow chlorosis with necrotic spotting in parsley; cucumber mosaic and broad bean wilt cause little or no symptoms in parsley.

Causal agent Arabis mosaic virus is a nepovirus with isometric particles about 30 nm in diameter. Broad bean wilt virus is an RNA-containing fabavirus with isometric particles about 25 nm in diameter. Carrot mottle virus has enveloped, isometric, RNA-containing particles that are approximately 52 nm in diameter. Carrot red leaf virus is a luteovirus that has RNA-containing, isometric particles about 25 nm in diameter. Celery mosaic virus, classed as a potyvirus, has flexuous, filamentous particles about 780 nm in length. Cucumber mosaic virus (see Greenhouse cucumber, cucumber mosaic, 22.20) has isometric particles that are 30 nm in diameter. Hop mosaic virus has rod-shaped particles about 656 nm in length. Prunus necrotic ringspot is an ilarvirus with quasi-spherical particles, 25 to 35 nm in diameter.

Carrot motley dwarf can be identified by symptoms and by mechanical and aphid transmission of the viral pathogen to indicator plants. Celery mosaic is identified by serology, electron microscopy and transmission to celery, which becomes malformed as a result of systemic infection. Broad bean wilt and cucumber mosaic can be confirmed serologically or by inoculation onto diagnostic indicator plants.

Disease cycle Arabis mosaic virus is transmitted by the nematode *Xiphinema diversicaudatum* (Micoletzky) Thome, which has a limited distribution in Canada, and by seed and sap. Carrot mottle virus is transmitted in a persistent manner by the carrot-willow aphid. It is usually associated with carrot red leaf virus in umbelliferous plants. Celery mosaic is transmitted in a non-persistent manner by several aphid species, including the green peach aphid, from infected celery, poison hemlock (*Conium maculatum* L.), and other umbelliferous plants. Cucumber mosaic and broad bean wilt both have a wide host range, numbering many plant families, and are transmitted by numerous aphid species, including the green peach aphid. Hop mosaic virus is transmitted by several species of aphids, including the hop aphid and the potato aphid. Prunus necrotic ringspot virus is transmitted by sap and seed but there is no known vector.

Management Aphid control is important. In hop plantings affected by nettle head disease, control of the nematode vector is important.

Cultural practices — Prompt incorporation of the residues from diseased crops and destruction of wild and volunteer plants will reduce the carry-over of viruses and their vectors.

Selected references

Francki, R.I.B., D.W. Mossop and T. Hatta. 1979. Cucumber mosaic virus. CMI/AAB Descriptions of Plant Viruses, No. 213. Commonw. Mycol. Inst./Assoc. Appl. Biol., Kew, Surrey, England. 6 pp.

Barbara, D.J., and A.N. Adams. 1981. Hop mosaic virus. CMI/AAB Descriptions of Plant Viruses, No. 241. Commonw. Mycol. Inst./Assoc. Appl. Biol., Kew, Surrey, England. 4 pp.

Barbara, D.J., and A.N. Adams. 1983. American hop latent virus. CMI/AAB Descriptions of Plant Viruses, No. 262. Commonw. Mycol. Inst./Assoc. Appl. Biol., Kew, Surrey, England. 3 pp.

Frowd, J.A., and J.A. Tomlinson. 1972. The isolation and identification of parsley viruses occurring in Britain. *Ann. Appl. Biol.* 72:177-188.

Fulton, R.W. 1970. Prunus necrotic ringspot virus. CMI/AAB Descriptions of Plant Viruses, No. 5. Commonw. Mycol. Inst./Assoc. Appl. Biol., Kew, Surrey, England. 4 pp.

Murrant, A.F. 1970. Arabis mosaic virus. CMI/AAB Descriptions of Plant Viruses, No. 16. Commonw. Mycol. Inst./Assoc. Appl. Biol., Kew, Surrey, England. 4 pp.

Murrant, A.F. 1974. Carrot mottle virus. CMI/AAB Descriptions of Plant Viruses, No. 137. Commonw. Mycol. Inst./Assoc. Appl. Biol., Kew, Surrey, England. 4 pp.

Murrant, A.F. 1975. Occurrence of mottle and redleaf components of carrot motley dwarf disease in British Columbia. *Can. Plant Dis. Surv.* 55:103-105.

Shepard, J.F., and R.G. Grogan. 1971. Celery mosaic virus. CMI/AAB Descriptions of Plant Viruses, No. 50. Commonw. Mycol. Inst./Assoc. Appl. Biol., Kew, Surrey, England. 3 pp.

Taylor, R.H., and L.L. Stubbs. 1972. Broad bean wilt virus. CMI/AAB Descriptions of Plant Viruses, No. 81. Commonw. Mycol. Inst./Assoc. Appl. Biol., Kew, Surrey, England. 4 pp.

Waterhouse, P.M., and A.F. Murrant. 1982. Carrot red leaf virus. CMI/AAB Descriptions of Plant Viruses, No. 249. Commonw. Mycol. Inst./Assoc. Appl. Biol., Kew, Surrey, England. 4 pp.

(Original by D.J. Ormrod and R.J. Howard)

INSECT PESTS

▶ 10.13 Aphids *Figs. 16.41a,b; 16.42a-c*

Carrot-willow aphid *Cavariella aegopodii* (Scopoli)
Green peach aphid *Myzus persicae* (Sulzer)
Hop aphid *Phorodon humuli* (Schrank)
Potato aphid *Macrosiphum euphorbiae* (Thomas)
Other aphids

The carrot-willow aphid occurs in southwestern British Columbia and the Maritime provinces in Canada. It transmits carrot mottle and carrot red leaf viruses in parsley and other umbelliferous plants. Other aphids, including the green peach aphid (see Potato, 16.41), are important in the transmission of celery mosaic, cucumber mosaic and broad bean wilt viruses in parsley.

The hop aphid is the only aphid that has been identified from hop in British Columbia; however, the potato aphid is widespread and common on numerous crops and weeds in that area. Both aphids are vectors of the virus causing hop mosaic, the most important virus disease of hop. Honeydew produced by aphids supports the growth of sooty molds, which can disfigure hop (see sooty mold of hop, 10.8).

Management Aphid control on parsley and hop may be achieved by the use of registered pesticides when necessary. At present, other strategies are not available for managing aphids on these crops.

(Original by D.J. Ormrod)

▶ 10.14 Flea beetles *Figs. 10.14a, b*

Hop flea beetle *Psylliodes punctulata* Melsheimer
Horseradish flea beetle *Phyllotreta armoraciae* (Koch)
Other crucifer-feeding flea beetles *Phyllotreta* spp.

The flea beetles occurring on mustard are the same as those on canola and cole crops (see Crucifers, 8.44). These and other species can attack hop and horseradish. The hop flea beetle is native to North America. It is present in low numbers across most of Canada. It feeds on hop as well as crucifers, garden beet, and rhubarb. The horseradish flea beetle is an incidental and sporadic pest on horseradish in Canada.

Damage After overwintering, adult flea beetles (*10.14a)* feed on the cotyledons and first true leaves of young plants early in the spring, causing small round holes that give the leaf a "shot-hole" appearance *(10.14b).* Extensive flea beetle feeding on mustard causes seedling mortality, delayed plant development and maturity, unevenness in plant height, reduced seed yield and increased chlorophyll content of the seed. Horseradish flea beetle larvae mine the petioles and leaf midribs. Because horseradish roots increase in size in the latter part of the growing season, defoliation by flea beetles moving onto the crop after other cruciferous crops are harvested may result in decreased root size. Overwintered hop flea beetles attack and kill seedlings as these appear just above the soil level, although damage to well-established plants may be light. Flea beetle damage tends to be less in wet years.

Identification (see Crucifers, flea beetles, 8.44)

Life history Flea beetles usually have one generation per year in Canada. Adults overwinter in leaf litter and emerge from late April to early May. They fly to fields, mate, lay eggs and feed on cruciferous weeds and crops when these emerge. Eggs are laid in the soil on or near the roots of host plants, and the larvae feed on the roots; or, in the case of the horseradish flea beetle, on the petioles and midribs of host plants. The prepupal and pupal stages develop in the soil, and adults appear from mid-July onward and seek hibernation sites in late September and early October.

Management *Monitoring* — Growers should look for the shot-hole type of injury that is typical of adult feeding on transplants or cotyledons as seedlings emerge.

Cultural practices — There is higher resistance to flea beetle injury in yellow (white) mustard, *Sinapis alba* L., than in Oriental brown mustard. *Brassica juncea* (L.) Czem. & Coss. Late or delayed seedings and higher seeding rates of direct- seeded crops minimize flea beetle damage. Cruciferous weeds and volunteer crucifers should be controlled.

Selected references

Burgess, L. 1980. The horseradish flea beetle in Saskatchewan. *Blue Jay* 38:11-13.
Lamb, R.J. 1980. Hairs protect mustard (*Brassica hirta* 'Gisilba') from flea beetle feeding damage. *Can. J. Plant Sei.* 60:1439-1440.
Lamb, R.J. 1984. Effects of flea beetles, *Phyllotreta* spp. (Chrysomelidae: Coleoptera), on the survival, growth, seed yield and quality of canola, rape, and yellow mustard. *Can. Entomol.* 116:269-280.
Putnam, L.G. 1977. Responses of four *Brassica* seed crop species to attack by the crucifer flea beetle, *Phyllotreta cruciferae. Can. J. Plant Sei.* 57:987-989.

(Original by J.J. Soroka)

▶ 10.15 Other insect pests *Figs. 10.15a-c; 8.43b,cK*

Black swallowtails *Papilio* spp.
Carrot rust fly *Psila rosae* (Fabricius)
European earwig *Forficula auricularia* L.

Black swallowtail larvae (see Parsnip, 14.7) (*10.15a)* and carrot rust fly larvae (see Carrot, 6.23) (*10.15b)* are found on parsley and sometimes on dill in home gardens. The European earwig (see Crucifers, 8.43) will eat and defecate on leaves of many plants, including basil and parsley *(10.15c).* The following records on "horsemint" in Manitoba were supplied by A.J. Kolach: leafrollers, *Pyrausta* sp.; sap beetle larvae, *Carpophilus* sp.; and a clear-wing moth borer, possibly *Ramosia rileyana* (H. Edwards).

OTHER PESTS

▶ 10.16 Mites and slugs *Fig. 11.27c*

Mites The mite pests on herbs and spices in Canada are unknown, apart from *Dictyna* and *Tetragnatha* species recorded on "horsemint" in Manitoba by A.J. Kolach, and the two-spotted spider mite *Tetranychus urticae* Koch on hop. (For more information about the two-spotted spider mite, see Greenhouse cucumber, 22.36.)

Selected references

Sites, R.W., and W.W. Cone. 1985. Vertical dispersion of two-spotted spider mites on hops throughout the growing season. *J. Entomol. Soc. Br. Columbia* 82: 22-25.

Slugs Most vegetable crops in home gardens suffer some degree of slug damage (see Lettuce, 11.27), but dill is particularly prone to attack. The slugs climb the stems of young dill plants and totally devour the leaves. At sites where slugs are numerous, dill tops will be reduced *(11.27c).*

(Original by J.A. Garland)

ADDITIONAL REFERENCES

Burgess, A.H. 1964. *Hops: Botany, Cultivation, and Utilization.* Interscience Publishers Inc., New York. 300 pp.
Conners, I.L. 1967. *An Annotated Index of Plant Diseases in Canada.* Can. Dep. Agric. Publ. 1251. 381 pp.
Darby, P., and C.B. Skotland. 1992. Proposed list of common names for diseases (*Humulus lupulus* L.). *Phytopathol. News* 26:86-87.
Ginns, J.H. 1986. *Compendium of Plant Disease and Decay Fungi in Canada, 1960-1980.* Can. Dep. Agric. Publ. 1813. 416 pp.
Green, R.J., Jr., and C.B. Skotland. 1992. Proposed list of common names for diseases of mint (*Mentha piperita* L., *M. cardiaca* Baker, *M. spicata* L., and *M. arvensis* L.). *Phytopathol. News* 26:39.
Lima, P. 1986. *The Harrowsmith Illustrated Book of Herbs.* Camden House Publ. Ltd., Camden East, Ontario. 175 pp.
Magie, R.O. 1944. Disease and insect control on hops. *New York State Agric. Exp. Stn.* **(***Geneva) Bull.* 708. 20 pp.
Maloy, O.C., and C.B. Skotland. 1969. Diseases of mint. Wash. State Univ. (Pullman) Ext. Circ. 357. 4 pp.