22 Greenhouse cucumber

Figures *22.1* to *22.36; 22.15T1; 22.31T1; 22.36T1*

BACTERIAL DISEASES

▶ 22.1 Angular leaf spot *Figs. 22.1; 9.1a,b*

Pseudomonas syringae pv. *lachrymans* (Smith & Bryan) Young *et al.*

Angular leaf spot (see Cucurbits, angular leaf spot, 9.1) is rare in greenhouse cucumber and has been seen only where affected field cucumber crops have been handled by green house workers. It is likely to be a problem only in poorly ventilated greenhouses with overhead irrigation or excessive condensation.

Management

Cultural practices — Pathogen-free seed should be used for planting. Overhead irrigation should be avoided and relative humidity kept low. Leaf injury should be minimized and crops should not be worked in if the foliage or fruit is wet.

Selected references

Kritzman, G., and D. Zutra. 1983. Systemic movement of *Pseudomonas syringae* pv. *lachrymans* in the stem, leaves, fruits and seeds of cucumber. *Can. J. Plant Pathol.* 5: 273-278.

(Original by W.R. Jarvis and J.G. Menzies)

▶ 22.2 Bacterial wilt *Figs. 9.2a,b*

Erwinia tracheiphila (Smith) Bergey *et al.*

Bacterial wilt (see Cucurbits, bacterial wilt, 9.2) is occasionally a problem on greenhouse cucumber.

Management

Cultural practices — The disease can be controlled in greenhouses by placing screens on ventilators and doors to prevent entry of cucumber beetles, which vector the pathogen, and by roguing diseased plants as soon as possible. Raising the temperature briefly above 30°C activates the defense mechanisms of the host and helps to control the disease.

(Original by J.G. Menzies and W.R. Jarvis)

FUNGAL DISEASES

▶ 22.3 Anthracnose *Figs. 9.3a-c*

Colletotrichum orbiculare (Berk. & Mont.) Arx
(syn. *Colletotrichum lagenarium* (Pass.) Ellis & Halst.)
(teleomorph *Glomerella lagenaria* F. Stevens)

Anthracnose is a minor disease of greenhouse cucumber (see Cucurbits, anthracnose, 9.3).

Management

Cultural practices — Anthracnose can be controlled by reducing high relative humidity through ventilation and heating, and by avoiding overhead irrigation. Crops should not be worked if the foliage is wet. Greenhouses should be thoroughly cleaned after a diseased crop has been removed.

(Original by J.G. Menzies)

▶ 22.4 Black root rot *Figs. 22.4a,b*

Phomopsis sclerotioides van Kesteren

Black root rot is generally a minor disease of greenhouse cucumber, but it has caused yield losses of up to 50% in a few greenhouses in British Columbia. This disease can affect plants grown in soil, rockwool and other soilless media. It is more prevalent in operations where crop hygiene is poor The host range of the pathogen is restricted to members of the Cucurbitaceae family.

Symptoms Roots develop pale brown areas which darken and eventually turn black as the disease progresses *(22.4a).* These areas may be sunken and bordered by darker areas. Coalescence eventually occurs, with diseased tissue demarcated from healthy tissue by a fine wavy black line. Close examination of diseased roots with a 10X hand lens will also reveal a second symptom, a definite mosaic, almost like a chess-board pattern, of small black sclerotia *(22.4b)* on dark mycelium. The roots may be girdled and killed.

The cortical tissue of the roots eventually sloughs off, exposing the vascular strands. The expression of symptoms in the aerial parts of the plant is determined by the degree of root infection and by environmental conditions. Stems may become infected at the base as the fungus grows from diseased roots. Stem lesions are elongate and brown or black, with amber gummy exudations. Infected plants are stunted with few lateral shoots and small, downward- cupped leaves. The leaves, initially darker green than usual, may also exhibit chlorosis and necrosis. Partially developed fruit will not mature. An irreversible wilt often occurs when fruiting begins. The disease is more severe in cool, overwet soils and substrates where root growth is suboptimal. It is often seen in soil where straw mulch has been put down prematurely, thereby insulating cold soil.

Causal agent *Phomopsis sclerotioides* is readily isolated from surface- sterilized incipient lesions on roots. Pycnidia, though very rare on roots, are subglobose to variable in shape, stromatic, and up to 300 pm wide. Conidiophores are hyaline and simple or rarely branched. The conidio- genous cells are enteroblastic, phialidic, simple, and cylindrical to subob- clavate. They produce A-conidia, which are hyaline, unicellular, fusiform to ellipsoid, usually guttulate with a guttule at each end, and measure 7 to 10 by 2.5 to 3.5 pm. On sterile bean pods, B-conidia are also produced, but rarely. In culture, the fungus produces abundant sclerotial plates.

Confirmation of the disease requires culturing and identification of conidia. *Phomopsis sclerotioides* produces pseudosclerotia, whereas *Phomopsis cucurbitae,* which causes black rot, produces A- and B-conidia but no sclerotia. Media suitable for sporulation include cherry agar and sterile green bean pods. The fungus is fast-growing on malt agar, at first sparse and off-white, then darkening with age.

Disease cycle The pathogen survives and is transmitted in soil, usually in infected plant residues. It grows quickly through soil and rapidly colonizes plant roots. Rockwool and other soilless substrates can become infested through soil contamination, such as by placing transplant blocks on the ground or by allowing soil-contaminated water to splash or flood onto them.

Management

Cultural practices — Annual steam pasteurization of infested soil and the use of non-infested or soilless rooting media can help in disease prevention. It is important not to allow infested soil to contaminate soilless media. Seedlings and transplants should be raised on clean benches, well out of reach of splashing soil and flooding. If the disease is detected early enough by wilt symptoms that go into remission at night and on cloudy days, the stem base may be mounded up with clean, peaty soil. This promotes the growth of adventitious roots that permit the plant to survive and yield perhaps 80% or more of its potential. Grafting onto gourd rootstocks *(Cucurbita ficifolia* Bouché) helps maintain crop yields, but in heavily infested soil gourd rootstocks can become infected.

Chemical control — Soil fumigation may provide some control if done to effective depths.

Selected references

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Wiggell, P., and C.J. Simpson. 1969. Observations on the control of *Phomopsis* root rot of cucumber. *Plant Pathol.* 18:71-77.

(Original by J.G. Menzies and W.R. Jarvis)

▶ 22.5 Black rot

Phomopsis cucurbitae McKeen

Black rot is an uncommon fungal disease of greenhouse cucumber and has not been observed in the field in Canada. It has been reported only from Ontario and British Columbia. This disease has been found only on cucurbits.

Symptoms Black rot occurs on the stems, leaves, petioles, peduncles and fruit of cucurbits. Infections first appear as water-soaked, oily green areas on senescent and moribund tendrils, fruit stems, petioles and suckers that arise at the stem nodes. Amber-colored gummy exudations accompany nodal infections. Nodal lesions can spread both up and down the stem. They are initially superficial but eventually penetrate the vascular tissue and girdle the stem, resulting in the death of plant tissues above the lesion. Fruit may be infected via the flowers, and the flesh quickly becomes soft, rotted and water- soaked. Finally, the fruit shrinks, becomes mummified and emits a lemon-like odor. On all affected tissues, tiny, black, spore-bearing pycnidia of the fungus break through the outer epidermis, often in long, parallel rows on blanched, tattered, dry outer tissues. If seed is sown in artificially infested soil, lesions develop on the cotyledons and hypocotyl. The lesions are initially pale beige but become blackened with pycnidia. Roots are pale brown and are soft and spongy.

Symptoms of black rot can resemble those of gummy stem blight and distinguishing between them may require microscopic observations or culturing of the pathogens.

Causal agent *Phomopsis cucurbitae* produces dark brown to black pycnidia that are variable in shape, stromatic, and as much as 1 mm wide. Conidiophores are hyaline, and simple or branched. Conidiogenous cells are enteroblastic, phialidic and simple cylindrical to subobclavate. Conidia are of two types: A-conidia are hyaline, unicellular, fusiform to ellipsoid, usually two-guttulate with a guttule at each end, sometimes three-gut- tulate, and measure 8 to 12 by 2.5 to 3 µm; B-conidia are hyaline, unicellular, filiform, curved, and measure 18 to 26 by 1 µm.

Phomopsis sclerotioides, which causes black root rot, superficially resembles *P. cucurbitae* but produces mostly A-conidia and sclerotia (see black root rot, 22.4).

Disease cycle Infections often occur first on dead and dying tendrils, peduncles, petioles and suckers arising from stem nodes. These infections move to the stem, girdle it and cause death of tissues above the lesion. Fruit can be infected via attached flowers. The method of survival between crops is unknown, but the fungus is unlikely to be seed- borne. The disease progresses quickly on succulent plants and is favored by high humidity. Because the fungus produces sticky, hydrophilic spores in long tendrils from the pycnidia, spread occurs mainly by splashing water and on tools and fingers.

Management

Cultural practices — Spread of this disease may be prevented by good ventilation, which promotes rapid drying of senescing plant parts and prevents establishment of the fungus. Removal of infested crop residues and a thorough cleaning of the greenhouse after crop removal helps prevent spread and survival of the pathogen.

Selected references
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McKeen, C.D. 1957. Phomopsis black rot of cucurbits. *Can. J. Bot.* 35:43- 50.
Punithalingam, E., and P. Holliday. 1975. *Phomopsis cucurbitae.* CMI Descriptions of Pathogenic Fungi and Bacteria, No. 469. Commonw. Mycol. Inst., Kew, Surrey, England. 2 pp.

(Original by J.G. Menzies and W.R. Jarvis)

▶ 22.6 Choanephora rot

Choanephora cucurbitarum (Berk. & Ravenel) Thaxt.

Choanephora rot (see Cucurbits, choanephora rot, 9.4) is a minor disease of greenhouse cucumber.

Management

Cultural practices — Choanephora rot can be controlled by avoiding the use of overhead irrigation and by not working in the crop when the foliage is wet. Greenhouses should be thoroughly cleansed after a diseased crop has been removed.

(Original by J.G. Menzies)

▶ 22.7 Crown and root rot, damping-off *Figs. 22.7a-d*

Pythium spp.
Rhizoctonia solani Kühn
(teleomorph *Thanatephorus cucumeris* (A.B. Frank) Donk)
Fusarium spp.
Bacteria

Pythium species appear to be the primary cause of damping-off and crown and root rot, but other fungi and soft-rotting bacteria are occasionally associated with plants affected by these diseases. The pathogens that cause these diseases have wide host ranges that include many types of vegetable crops.

Symptoms Plants affected by crown and root rot usually are noticed when they suddenly wilt (22*.7d),* particularly during warm, sunny weather. *Pythium* causes an orange-brown rot of the crown, which may extend 8 to 10 cm up the stem *(22.7a,c).* Stem lesions appear chlorotic and yellow-white initially. As the disease progresses, the lesions turn brown- orange. Affected tissues usually appear dry rather than water- soaked, and infected plants produce few lateral roots from the crown region. Severely affected plants are weakly anchored and can be easily lifted out of the growing medium. Plants may recover if not severely diseased, but prolonged wilting leads to plant death. Mature crops can also wilt suddenly because of destruction of tiny feeder roots by *Pythium* spp. There may be no other symptom. See also 22.29.

Symptoms of damping-off include a reduction in seedling emergence and toppling over of young seedlings

(22.7b) (see Cucurbits, pythium root rot, 9.12). Root and stem lesions on young seedlings are pale brown and appear water-soaked.

Causal agents Several species of *Pythium* (see Cucurbits, 9.11, 9.12) may be involved in damping-off and crown and root rot. Sporangia are various sizes and shapes and intercalary or terminal on the mycelium. They may germinate via a germ tube or via a short germ tube and terminal vesicle within which zoospores are produced. The oogonia have a single oospore at maturity and germinate directly or produce zoospores. These spores are released through a pore or evacuation tube into a vesicle where they mature before being liberated.

Fusarium solani and *F. oxysporum* (see Cucurbits, fusarium foot rot, 9.5, and fusarium wilt, 9.6) are frequently isolated from the rotting tissues at the base of the stem but their etiologic role is uncertain. Bacteria are also profusely evident and undoubtedly contribute to soft rotting (see Tomato, fusarium crown and root rot, 18.9).

Rhizoctonia solani (see Bean, 15B.7) tends to attack older seedlings, causing late damping-off.

Disease cycle The fungi that cause crown and root rot and damping-off are common in propagation mixes, soil and untreated water. Symptoms of crown and root rot typically appear about 8 to 12 weeks after seeding, at early fruit set, or during the late season on older plants. Plants rarely show symptoms before being transplanted. Severe infections are often associated with stresses such as high temperatures and excess moisture. Damping-off pathogens can spread quickly in cool, wet growing media, especially soil. Infection and pathogen spread are aided by excess nitrogen and overcrowding of the plants. Spread of the pathogens in the greenhouse can occur through irrigation water. *Pythium* spp. also can be vectored by fungus gnat larvae and shore flies. Both water and flies can explain the damaging appearance of pythium root rots in hydroponic greenhouses. In addition, soilless media are often contaminated by soil splash, flooding, or simply by putting planting blocks on the floor. Hanging baskets of ornamentals are also sources of inoculum.

Management (see fungus gnats, 22.31, for their control)

Cultural practices — For damping-off (see Cucurbits, pythium root rot, 9.12), seedlings should not be overcrowded. Adequate ventilation helps to keep the growing media and foliage dry. Seed flats should be raised and placed out of the range of splashing water. Pathogen-free growing media should be used to produce transplants and for the main crop. NFT troughs, tanks and supply lines should be disinfested. Good drainage and avoidance of overwatering help to control damping-off and crown and root rot. Plants severely infected early in the season can be rogued and the area replanted with disease-free transplants. Sawdust mounded around the base of infected plants encourages adventitious root growth and extends plant survival a few weeks. The amendment of hydroponic nutrient solution with 100 ppm of soluble silica has been reported to reduce crown and root rot.

Chemical control — Hot water seed treatment followed by the application of a fungicidal seed protectant is recommended for controlling seed- and soil-borne damping-off fungi. Seedling trays can be drenched with fungicidal solutions to provide additional protection. Fungicide seed treatments are ineffective against crown and root rot.

Selected references

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Favrin, R.J., J.E. Rahe and B. Mauza. 1988. *Pythium* spp. associated with crown rot of cucumbers in British Columbia greenhouses. *Plant Dis.* 72:683-687.

Gardiner, R.B., W.R. Jarvis and J.L. Shipp. 1990. Ingestion of *Pythium* spp. by larvae of the fungus gnat *Bradysia impatiens* (Diptera: Sciaridae). *Ann. Appl. Biol.* 116:205-212.

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(Original by J.G. Menzies and W.R. Jarvis)

▶ 22.8 Downy mildew *Figs. 22.8a,b*

Pseudoperonospora cubensis (Berk. & M.A. Curtis) Rostovzer

This disease is common and often very destructive in end- of-season crops in poorly ventilated plastic greenhouses. It occurs throughout Canada but has been a problem mostly in Ontario. The pathogen attacks only Cucurbitaceae, mostly species that are cultivated, but it can occur on a few wild hosts, including wild cucumber.

Symptoms Downy mildew infections occur only on the leaves. Initial symptoms include angular, pale green areas separated by dark green islands on the upper surfaces of the leaves which may resemble mosaic mottle *(22.8a).* The pale-green areas eventually turn into the characteristic yellow, angular spots of downy mildew, bordered by the leaf veins. The lesions are brown on the lower surface of the leaves *(22.8b).* Under humid conditions, the lesions become covered with purple-brown sporangia as sporangiophores emerge in groups of one to five from stomata on the underside of the leaf. The leaf may wither and die as the lesions increase in size.The fruit is seldom infected by the pathogen but may be small and of poor quality as the result of leaf destruction.

Causal agent *Pseudoperonospora cubensis* is an obligate parasite. Sporangiophores are 180 to 400 µm long by 5 to 7 µm wide. They are basally inflated and dichotomously branched in the upper third. The sporiferous tips are subacute and bear single sporangia that are pale gray to olive-purple, ovoid to ellipsoid, thin walled, and have a papilla at the distal end. The sporangia measure 20 to 40 by 14 to 25 µm. Flagellate zoospores, 10 to 13 µm in diameter, are produced by germination of the sporangia. Oospores are rare, but if produced are light yellow or hyaline, globose, and measure 22 to 42 µm in diameter.

Disease cycle The fungus does not live in soil, but may overwinter in some areas as thick-walled oospores that can withstand low temperatures and humidities in the field or greenhouse. Oospores are unlikely to overwinter in the field in northern areas. Rather, the fungus probably arrives as wind-blown sporangia from the south. Sporangia are produced four to five days after infection and may be spread by wind, insects, clothing and tools to neighboring plants. Surface water on the foliage is essential for infection to occur. Once wet, the sporangia must remain so until they germinate, otherwise they die. Germinating sporangia give rise to motile zoospores that produce infective germ tubes to achieve infection. Sporangia germinate from 8 to 30°C, with the optimum being 15 to 20°C. Infection occurs over a temperature range of 16 to 22°C.

Management

Cultural practices — Infected leaves should be removed as soon as symptoms are noticed, and growers should destroy trash piles by composting or burial. Measures to promote air movement and reduce relative humidity, such as wider plant spacing, help to control the spread of the pathogen. Control of cucurbit weeds and volunteer hosts that harbor the pathogen also will reduce its spread. Growers should adjust ventilation and heating so that dew does not form on the plants and avoid the use of overhead irrigation.

Resistant cultivars — Some resistant cultivars are known, but they may be of poor quality and should be evaluated on a trial basis by growers.

Chemical control — Protectant fungicides will control the disease if applied on a preventive basis.

Selected references

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(Original by J.G. Menzies and W.R. Jarvis)

▶ 22.9 Fusarium wilt *Figs. 22.9a,b*

Fusarium oxysporum f. sp. *cucurbitacearum* Gerlagh & Blok (syn. *Fusarium oxysporum* f. sp. *cucumerinum* Owen)

Fusarium wilt (see Cucurbits, fusarium wilt, 9.6) is uncommon on greenhouse cucumber. The pathogen is both soil- and seed-borne.

Management

Cultural practices — Greenhouse growers should destroy diseased plants, prunings and other plant residues. Diseased crop residues should be handled carefully to minimize spore dispersal. If the disease is severe, the greenhouse area, containers and growing media should be disinfested and care should be taken to prevent reinfestation of growing media. Ideally, the greenhouse structure and benches also should be disinfested. Seed can be disinfested by heating it to 75°C for three days or to 80°C for two days.

Resistant cultivars — Some commercial cultivars are more resistant than others. The rootstock *Cucurbita ficifolia* is resistant.

Selected references

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Owen, J.H. 1956. Cucumber wilt caused by *Fusarium oxysporum* f. *cucumerinum* n.f. *Phytopathology* 46:153-157.

(Original by J.G. Menzies and W.R. Jarvis)

▶ 22.10 Gray mold *Figs. 22.10a-d*

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

In greenhouses, gray mold (see Lettuce, gray mold, 11.10) is often considered to be a disease of poor management, although environmental conditions also play an important role. Outbreaks occasionally are serious and may reduce fruit yields.

Management

Cultural practices — Heat and ventilation should be adequate to keep the humidity low enough to prevent dew from forming. Pruning the lower leaves opens the canopy to air circulation and helps keep humidity low in the crop. Infested crop residues should be buried.

Chemical control — Fungicides can provide effective control, but they should be used in alternation with one another to avoid the buildup of resistant strains.

Selected references

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(Original by J.G. Menzies and W.R. Jarvis)

▶ 22.11 Gummy stem blight *Figs. 22.11a-e*

Didymella bryoniae (Auersw.) Rehm
(syn. *Mycosphaerella melonis* (Pass.) Chiu & J.C. Walker)
(syn. *Mycosphaerella citrullina* (C.O. Smith) Gross.)
(anamorph *Ascochyta cucumis* Fautr. & Roum.)

This disease is common on greenhouse cucumber and can be a major problem. In Europe, it is still called mycosphaerella rot after the former name of the fungus. Gummy stem blight also can occur on field cucumber and melon, but it is generally a minor disease in the field.

Symptoms The first symptom on greenhouse cucumber is lesions on stubs left after the removal of fruit, leaves, tendrils or lateral shoots. These lesions may elongate and crack *(22.11a).* Sometimes, but not always, they exude a gold- brown gum *(22.11b).* Occasionally, they may girdle the stem *(22.11c),* causing wilt and eventual death of the plant *(22.1 11d).* Leaf symptoms usually appear at the edge of the leaf, initially as water-soaked lesions surrounded by a yellow halo. Lesions may also appear as circular spots on the middle of the lamina. These spots enlarge and become light brown and papery, and the leaves turn yellow and die. Fruit lesions appear as soft, wet, gray-green rots that are circular or irregular in shape *(22.1 le).* Sometimes, a gummy exudate develops at the center of the lesion and dries to a firm, golden brown deposit. Fruit may not show external signs of infection except for a constriction of the distal end, but it will be firm with a black internal discoloration. Pale-colored pycnidia and dark, globular pseudothecia are eventually produced on all leaf, stem and fruit lesions. Seedlings also may become infected, resulting in circular, tan or black spots on the cotyledons and stems. Deep lesions kill the seedlings; less severe lesions may not. Infected seedlings act as a source of inoculum for other plants.

Causal agent The pseudothecia of *Didymella bryoniae* are black, globose and immersed, becoming erumpent. They are 140 to 200 µm in diameter. The asci are bitunicate, cylindrical to subclavate, short stipitate or sessile, and measure 60 to 90 by 10 to 15 µm. Each ascus produces eight hyaline, biseriate ascospores, which are ellipsoid with their ends mostly rounded, slightly constricted at the septum, guttulate, and 14 to 18 by 4 to 7 µm. Associated pseudoparaphyses are hyaline, septate and branched. The pycnidia are dark brown, solitary or gregarious, immersed, eventually becoming erumpent. The pycnidia measure 120 to 180 µm in diameter. The conidia are hyaline, short, cylindrical with rounded ends, guttulate, mostly one-septate, though some are unicellular, and 6 to 10 by 3 to 4 µm.

Disease cycle The fungus can survive for up to two years as chlamydospores or dormant mycelium on undecomposed plant residue in the greenhouse or field. Primary infection of the new crop results from ascospores or conidia originating from pseudothecia or pycnidia, respectively, on plant residue. Primary infection occurs on cotyledons, leaves, stems, blossoms and fruit. Symptoms appear 3 to 10 days after infection. As the lesions age, pycnidia are produced and, under humid conditions, conidia ooze out in long gelatinous cirrhi that are dispersed by splashing water. Soon afterwards, ascospores are produced in pseudothecia on lesions and are spread by air currents. Spores can also be dispersed on pruning knives, wet hands and clothing. A water film on the plant surface is necessary for release of conidia, infection and further spread of the disease. Disease severity increases in high humidity. Plants may also be predisposed to infection by cucumber beetles, aphids and powdery mildew. Wounding is essential for the infection of older leaves and for fruit rot. Leaf infections usually occur at points of guttation under high humidity and where repeated guttation and evaporation have left toxic salt deposits. Flowers can be infected in as little as two hours when wet.

Management

Cultural practices — Environmental control is the most important means of managing this disease. To prevent spread of conidia, growers should try to enhance the evaporation of water from plant surfaces. Dew should never be allowed to form on the plants and the humidity should be kept low at night to avoid guttation. Overhead irrigation should be avoided. The ability of the fungus to survive for long periods in plant residue means that strict sanitation must be followed. Plants should be removed far from the greenhouse after harvest and soil beds should be disinfested. Prunings should also be removed and buried or composted. As soon as symptoms are observed on the new crop, measures should be taken to check the spread of the disease. Fruit should be handled with care to prevent wounding and stored at 12°C to reduce rot without affecting shelf-life.

Chemical control — Adequate control is hard to achieve with fungicides because cucumber plants grow fast, have dense foliage, and are continuously being wounded by picking and trimming. Fungicide sprays, if needed, must be applied weekly, which increases the risk of resistant strains of the pathogen evolving.

Selected references
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(Original by J.G. Menzies, W.R. Jarvis and I.A. MacLatchy)

▶ 22.12 Leaf blights *Figs. 22.12a,b; 9.8a,b*

Alternaria leaf blight *Alternaria* spp.
Ulocladium leaf spot *Ulocladium* spp.

These two diseases occur infrequently in greenhouse cucumber and control measures normally are not necessary. Melon and other cucurbits are alternative hosts for the pathogens. Symptoms and causal agents are described in Cucurbits, leaf blights, 9.8.

Management

Cultural practices — Growers can avoid introducing the pathogens by not growing melon and other cucurbits in or adjacent to cucumber greenhouses. Proper sanitation and humidity control help to control these diseases.

Chemical control — Foliar fungicides can be applied if leaf blight becomes a problem.

(Original by J.G. Menzies and W.R. Jarvis)

▶ 22.13 Leaf rot (pink mold rot) *Fig. 22.13*

Trichothecium roseum (Pers.:Fr.) Link (teleomorph *Hypomyces trichothecioides* Tubaki)

Leaf rot is a minor disease of greenhouse cucumber that has been reported only on leaves. Elsewhere, it has been reported to cause stem and fruit rots (see Cucurbits, leaf rot, 9.9. It may occur anywhere in poorly managed greenhouses. *Trichothecium roseum* is a widely distributed fungus and grows on many types of organic substrates including several species of woody and herbaceous plants.

Symptoms On greenhouse cucumber, small lesions usually occur on the upper leaves and larger, more numerous lesions on lower leaves. Initially, the lesions appear water- soaked with a fairly broad yellowish margin. Later, their centers dry and turn brownish-tan *(22.13)*. The centers may eventually fall out. On thin leaves, the lesions spread fast and may grow together to cover one-third or more of the leaf.

Causal agent *Trichothecium roseum* is easy to isolate. The fungus is a prolific producer of conidia in culture and is a “weed” mold in the laboratory. Growth is rapid, white at first, then pale rosy pink as the conidia develop. Conidiophores are long, slender, simple and septate. Conidia are borne apically and singly. They are attached in groups or chains, but not end to end. The conidia are hyaline or brightly colored, two-celled, ovoid to ellipsoid, measure 12 to 18 by 8 to 10 µm, appear in basipetal succession from the tip of the conidiophore, and bear a detachment scar and a thickened zone of contact with the neighboring conidium.

Disease cycle The fungus is air-borne but it may also enter the greenhouse on mulch materials or manure. Infection is almost always initiated from insect frass, petals or dead plant parts that fall onto leaves in a humid environment. The fungus is frequently seen on fruit rotted by other organisms.

Management

Cultural practices — Strict attention to greenhouse ventilation and humidity control should prevent this disease.

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(Original by J.G. Menzies and W.R. Jarvis)

▶ 22.14 Penicillium stem rot *Figs. 22.14a,b*

Penicillium oxalicum Currie & Thom

This disease was first reported from Ontario and subsequently from England, the Netherlands and Scandinavia. It is a major disease in southwestern Ontario, particularly in rockwool-grown crops in the Niagara area. *Penicillium oxalicum* has a cosmopolitan distribution and is commonly found in soil and on decaying organic matter. It has been reported on *Cucumis, Sorghum* and *Zea* species.

Symptoms Symptoms are sometimes confused with those of gummy stem blight and gray mold. Symptoms appear as water-soaked, olive-green areas at one or more of the nodes, 1 to 1.5 m from the ground in plants about 2 m tall, and usually only at nodes that have been pruned. Within a day or so, a bluish-gray fungal growth appears *(22.14a)*, giving off a cloud of conidia when touched. The stem splits open easily to reveal more fungal growth and a mass of conidia inside the rotted tissue. Unsupported stems collapse at the infected nodes and the top dies. The lesion expands rapidly, extending for several centimetres above and below the node and has a dry, pale brown margin, not unlike that caused by gummy stem blight and gray mold, if the external fungal growth is restricted. Senescent flowers bear conidiophores and a soft brown rot extends back into the fruit, which appears rather pointed *(22.14b).* Wounds on the fruit, including fingernail marks, can become infected. Infection may escape notice at harvest and develop further in storage, often followed by bacterial soft-rot.

Causal agent *Penicillium oxalicum* produces lesions that are readily distinguished from those of gummy stem blight and gray mold by profuse bluish-green sporulation. Initially tentatively identified as *P. crustosum* Thom, the pathogen is now recognized as *P. oxalicum.*

The fungus is readily isolated from conidia on lesions. It grows rapidly on a wide variety of agar media. Colonies on Czapek-Dox agar are blue- green, becoming jade-green with age, with a white margin. The texture is flat and velvety with a deep layer of conidia that shifts when the culture dish is tapped. The conidiophore is asymmetrical, biverticillate and smooth-walled. Conidia are smooth, elliptical and delicately verruculose. They measure 3.8 to 5.5 by 2.8 to 4.4 pm. Oxalic acid, which is produced in culture by *P. oxalicum,* may be of etiologic significance.

Disease cycle The fungus sporulates profusely on the lesions and inside the stem. It infects pruning wounds on the stem and wounds on the fruit made by pulling instead of cutting fruit cleanly. Precise environmental conditions for epidemic development are not known, but the disease is more prevalent in “soft” crops and it tends to be more severe in outside rows. Conidia are mostly air-borne but they can also be carried on knives and fingers. Infection is likely to occur where sap is exuded from pruning and other wounds in conditions of high humidity. The disease seems to be associated with excessive nitrogen and the stress of too many stem fruits. It is significantly more severe in crops grown in rockwool versus soil. No differences between cultivars have been detected. The pathogen is a very common soil fungus but is known as a pathogen only of cucumber and of corn seedlings and ears. It is seed-borne in corn. It probably survives between crops in crop and weed debris and in the soil.

Management

Cultural practices — The environment should be adjusted so that dew does not form on the plants at night and the difference between day and night temperatures is minimized. Warm, humid daytime air should be purged at dusk, particularly if the night promises to be cold and clear, in which case heat should be supplied at night and the ventilators left slightly open. Air circulation should be good at all times. To prevent plants from growing too luxuriantly, the potassium:nitrogen ratio of the fertilizer solution should be adjusted by increasing potassium and reducing nitrogen.

All stem fruits should be removed to a height of about 1 m. Side shoots should be cut cleanly with a sharp knife and knives should be disinfested at frequent intervals while working an affected crop. Badly infested areas should be worked last. Collapsed plants should be cut below the lesions and carefully removed in plastic bags to avoid spreading spores.

Fruit should be harvested with a knife, leaving 5 mm of stem, and should be handled carefully to avoid wounds. The fruit should be cooled as soon as possible. The storage area should be well ventilated. Overhead irrigation should be avoided.

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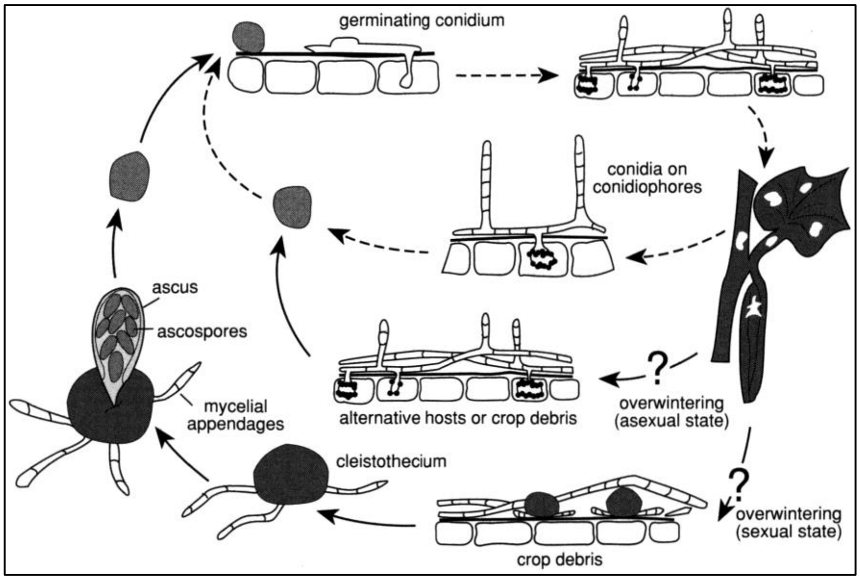
(Original by J.G. Menzies and W.R. Jarvis)

▶ 22.15 Powdery mildew *Figs. 22.15a-d; 22.15T1*

Erysiphe cichoracearum DC.
Sphaerotheca fuliginea (Schlechtend.:Fr.) Pollacci



22.15T1 Powdery mildew; disease cycle of *Sphaerotheca fuliginea.*

This is a major disease of greenhouse cucumber and can be caused by two species of fungi. In North America, *S. fuliginea* is more common than *E. cichoracearum.* In Canada, *E. cichoracearum* is known only in Alberta; elsewhere *S. fuliginea* is the only pathogen. In Europe, both fungi are common and may co-exist in the same crop. The two fungi, and especially *E. cichoracearum*, have wide host ranges that include many species of cultivated and native plants.

Symptoms Small, round, whitish, talcum-like spots on the stems and leaves are the first sign of disease *(22.15a).* These powdery colonies increase in number and grow together, eventually covering most of the upper and lower leaf surfaces (22*.15b).* Older colonies of *S. fuliginea* turn a dirty white with age; those of *E. cichoracearum* remain pure white. Severely affected leaves turn yellow, then brown and shrivelled. Fruit is usually, but not always *(22.15c),* free of visible infection, even in the presence of heavily infected foliage, but yield and fruit quality can be reduced by loss of leaves and water stress. Vines and fruit exposed when the foliage dies may wither and become whitish from sunburn. The teleomorph state of these fungi, imbedded in the colonies as small, brown or black, globose cleistothecia *(22.15d),* is rare in Canada. Cleistothecia of *S. fuliginea* have been reported only twice in Ontario.

Causal agent Most powdery mildew fungi are identified by characteristics of the sexual state. The brown to black, globose cleistothecia of *Sphaerotheca fuliginea* have branched appendages and contain one ascus, while the black globose cleistothecia of *Erysiphe cichoracearum* have unbranched appendages and contain 10 to 15 asci. Cleistothecia, however, are rarely present, so these two fungi are normally identified by the conidial state. Both *Erysiphe* and *Sphaerotheca* have *Oidium*-type conidiophores with long conidial chains and external mycelium. Conidia are ovoid-cylindrical, more cylindrical in *E. cichoracearum,* and measure 27.5 to 40 by 15 to 18 µm.

Conidia of *S. fuliginea* tend to produce forked germ tubes, whereas those of *E. cichoracearum* are unbranched. In addition, conidia of *S. fuliginea* contain refractive fibrosin bodies that are best seen in 3% potassium hydroxide solution.

Disease cycle These fungi survive from season to season in either the sexual or asexual state *(22.15T1).* The sexual cleistothecia are rare and probably are not of any significance to the disease cycle, except as a source of genetic variability. The fungi may survive as conidia or mycelium on a variety of host plants. Because of host specialization, weeds are not a usual source of powdery mildew for cucumber. The pathogens more likely survive from season to season in the asexual state on living cucurbits, spreading by wind-blown spores. Conidia may also survive in the greenhouse for short periods, infecting new cucumber crops, particularly when the new crop overlaps or follows too soon after removal of the old crop.

On a new crop, the disease cycle is initiated when conidia or ascospores contact susceptible host tissue. Conidia germinate at temperatures between 22 and 31°C, with the optimum 28°C. They survive for only a few hours at 27°C or higher, much longer at 5°C, but not at 1°C or lower. Conidia can germinate at relative humidities of 20% or lower, but the incidence of infection increases with the relative humidity. Conidial germination of *S. fuliginea* requires a deposit of dew but it does not occur in the presence of waterlogging. Paradoxically, mildew develops best in diurnally fluctuating conditions of temperature and humidity.

Cucurbit powdery mildew is more severe in shade than in full light, in close plant spacings, and where luxuriant growth occurs because of high nitrogen levels. Colonies from single conidia are rarely over 2 cm in diameter and slower growth occurs on senescent host tissue. Under ideal conditions, coni- dia are produced on the new colony five to seven days after infection but this may take longer if conditions are unfavorable. Conidial dissemination is almost exclusively by air currents but thrips and other insects have been reported to promote local spread. If sexuality and nutritional conditions are favorable, cleistothecia form, imbedded in the mycelia of the colonies, but this is rare. Mature ascospores are forcibly discharged as the cleistothecium imbibes water and ruptures. The ascospores are disseminated by air currents.

Management

Cultural practices — Spraying affected cucumber plants with water every two to three days will control powdery mildew. Plants should be sprayed in the morning, so they can dry in two to three hours. This prevents infection by other disease-causing organisms. Fogging considerably reduces disease severity.

Other cultural control techniques involve environmental management and sanitation procedures. Greenhouse temperatures should be maintained at about 21°C by heating and ventilation. Growers should avoid conditions that promote excessive succulent growth, such as excessive fertilization. Overcrowding, shading and overwatering also should be avoided. Allowing a period of two to three weeks when the greenhouse is thoroughly cleaned and empty between successive crops helps to prevent a carry-over of powdery mildew from an infected crop to a new one. Greenhouses and the surrounding area should be kept clear of susceptible crops, weeds and trash piles.

The amendment of hydroponic nutrient solutions with 100 ppm of soluble silica helps to control powdery mildew. The silica can be added in the form of potassium or sodium silicate. For effective control, silica must be constantly supplied to the plants. Silica sprays (1000 ppm) applied to the foliage may also reduce powdery mildew, but the solution must be adjusted to a pH of 5.5 using an acid such as phosphoric acid.

Resistant cultivars — Aramon, Bella, Cordoba, Fidelio, K8200, Marillo, Miland, Profito and TW242 are resistant to powdery mildew. Unfortunately most of these have not proven suitable for main crop (long-season) production in Canada.

Biological control — The fungi *Ampelomyces* and *Tilletiopsis* spp. are effective biocontrol agents of powdery mildew on greenhouse cucumber but are not commercially available.

Chemical control — Fungicides can be useful in controlling powdery mildew, especially systemics that offer protection to upper and lower leaf surfaces. However, some fungicides can damage cucumber plants, especially at high temperatures. Powdery mildew fungi may develop resistance to certain fungicides, for example, benzimidazoles, so an alternating spray program using two or more different fungicides is necessary to deter fungicide-resistant strains of the pathogen from evolving. Fungicides may also be harmful to certain biocontrol agents used in greenhouse pest management programs.

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(Original by J.G. Menzies and W.R. Jarvis)

▶ 22.16 Scab (gummosis) *Figs. 22.16; 9.13*

Cladosporium cucumerinum Ellis & Arth**.**

Scab or gummosis (for symptoms and causal agent, see Cucurbits, scab, 9.13) is not common in well-managed greenhouses, but it is seen occasionally throughout Canada.

Management ***Cultural practices*** — In the greenhouse, growers should minimize dew formation on the plants through ventilation and temperature control. Overhead irrigation should be avoided.

Resistant cultivars — Virtually all modern cultivars of long English cucumber are resistant. Growers should consult current seed catalogs.

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(Original by J.G. Menzies and W.R. Jarvis)

▶ 22.17 Verticillium wilt *Figs. 22.17a,b*

Verticillium albo-atrum Reinke & Berthier *Verticillium dahliae* Kleb.

This is an uncommon disease of greenhouse cucumber and is of minor economic importance. Both pathogens can attack several types of vegetable crops (see Potato, verticillium wilt, 16.20) and exist in specialized physiologic strains.

Symptoms The symptoms are very similar to those of fusarium wilt. Initial symptoms include wilting of the lower leaves, with recovery of the plant at night. As the disease progresses, some marginal and interveinal chlorosis develops on lower leaves (*22.17a*) and they may also show characteristic V-shaped lesions in which yellowing occurs in a fan pattern, narrowing proximally from the leaf margins *(22.17b).* The vascular tissues in the stem may become prominent. Cutting the stems of affected plants longitudinally reveals a brown discoloration of the vascular tissues. Wilt-infected plants usually die prematurely.

Causal agent (see Potato, verticillium wilt)

Disease cycle (see Potato, verticillium wilt, 16.20) *Verticillium albo-atrum* and *V. dahliae* survive primarily as dark, resting mycelium or microsclerotia, respectively, in plant debris in the soil. Because of this, verticillium wilt is more common in greenhouse cucumber grown in soil, but it also occurs in soilless media that become infested with the pathogens. *Verticillium* spp. infect the roots, where they invade the vessels and interfere with water transport.

Management

Cultural practices — If greenhouses become infested with *Verticillium* species, growers should fumigate the soil before transplanting, or spread plastic over the soil and use a soilless growing medium. Diseased plants should be removed from the greenhouse and destroyed. A thorough clean-up of the premises should be done after a diseased crop has been removed.

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(Original by J.G. Menzies)

▶ 22.18 White mold (sclerotinia stem rot) *Figs. 22.18a-d*

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

White mold (see Cucurbits, white mold, 9.14; see also Lettuce, drop, 11.9) is a fungal disease that is aggravated by poor management. It is not common in greenhouses and should not occur if plants are kept free from persistent water droplets and film, especially at flowering. In individual greenhouses it can occasionally destroy plants (*22.18a,b*) and rot fruit after picking (22.*18c,d).*

Management

Cultural practices — Plants should not be crowded unnecessarily and vigorous soft growth should be avoided. Good weed control around the greenhouse will remove or reduce alternative hosts of these pathogens. If the fungi become established in the greenhouse, steam pasteurization will kill the sclerotia in the soil. Chemical fumigation may not always be effective. Polyethylene sheets on the floor prevent ascospores dispersing from apothecia.

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(Original by J.G. Menzies and W.R. Jarvis)

VIRAL DISEASES

▶ 22.19 Beet pseudo-yellows *Fig. 22.19*

Beet pseudo-yellows virus

This disease is not usually a problem, but it can be destuctive in greenhouses where the greenhouse whitefly is also a problem. Hosts of beet pseudo-yellows virus include carrot, cucumber, flax, lettuce, muskmelon, spinach, squash and sugar beet. Some ornamentals and weeds also are attacked and may be a reservoir of the virus.

Symptoms This virus causes a chlorotic yellowing between the veins of older leaves *(22.19)* and a downward curling of the margins of affected leaves. The younger leaves may not be affected in the early stages of disease development. Symptoms have not been observed on fruit but affected plants age prematurely and are less productive.

Causal agent Attempts to observe beet pseudo-yellows virus using electron microscopy have not been successful. The nature of this virus is therefore uncertain.

Disease cycle The virus is transmitted by the greenhouse whitefly. Conditions that favor this pest also favor epidemic development of the virus. The whitefly becomes infective after only one hour of feeding on an infected host and it need feed for only one hour on a susceptible host to transmit the virus. The latent period of this virus in the vector is less than six hours, and the whitefly can retain the virus for four days. This virus has not been shown to be transmitted mechanically or by seed.

Management Control of the greenhouse whitefly is necessary to management of this disease (see greenhouse whitefly, 22.32).

Cultural practices — Ornamentals and other non-crop plants should not be introduced into the greenhouse as they may carry the virus.

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(Original by J.G. Menzies and W.R. Jarvis)

▶ 22.20 Cucumber mosaic *Figs. 22.20a,b; 9.15*

Cucumber mosaic virus

Cucumber mosaic is a worldwide problem on cucurbits. It is particularly important in temperate regions. Cucumber mosaic virus can infect plants in more than 40 angiosperm families. Crop hosts in Canada include clover, corn, cucumber, French bean, lettuce, melon, pepper, tomato, safflower, spinach, squash and sugar beet. Ornamental hosts include narcissus, gladiolus, impatiens, petunia, phlox and rudbeckia.

Symptoms This virus may infect plants at any stage of growth, but normally cucumber plants are infected at the six- to eight-leaf stage when they are growing rapidly. If seedlings are infected, the cotyledons wilt or turn yellow, and the plants are dwarfed. New leaves will be slightly mottled, wrinkled and distorted *(9.15)* with a slight downward curling of the edges. Infection of older, vigorously growing cucumber plants results in young leaves developing small, about 1 to 2 mm, greenish-yellow translucent lesions, which are normally confined by the leaf veins. The leaf edges curl downward and the leaf surface becomes finely wrinkled and distorted with slightly raised tissue between the small veins. Eventually, a yellow-green mottling develops *(22.20a)*. Occasionally, only the leaf tip turns yellowish without a sharply defined mottle. Older leaves may become severely affected and die, resulting in a slow decline of wilted plants. After infection, plant growth is stunted with shortened internodes. In lush-growing crops, infected vines may wither before showing signs of distortion and may die within seven days. Few fruits are set once infection occurs and fruit that does set has a yellow-green mottle on the stem, gradually extending over the entire fruit surface *(22.20b)*, interspersed with dark green areas that are usually raised and wart-like. Occasionally, fruit becomes smooth, green-white and blunt at the end. This symptom, known as white pickle, is characteristic.

Causal agent Cucumber mosaic virus particles are isometric, 30 nm in diameter and are composed of 180 subunits in pentamer-hexamer clusters. The particle center is hollow. Molecular weight is 5.8 to 6.7 by 10^6. Identification can be confirmed by inoculation to indicator plants. Cucumber develops a green or yellow-green systemic mosaic. Leaves of tobacco (*Nicotiana tabacum* L., N. *clevelandii* A. Gray, and *N. glutinosa* L.) leaves remain symptomless or develop chlorotic or necrotic lesions followed by a green or yellow-green systemic mosaic or ringspots, usually without necrosis. Tomato develops a systemic mosaic and fern leaf, with the leaf laminae much narrowed. French bean (*Phaseolus vulgaris* L.) develops local, pin-point, non-systemic, necrotic lesions in winter but not in summer. *Chenopodium amaranticolor* Coste & Reynier, and *C. quinoa* Willd. develop chlorotic or necrotic local lesions. Some cultivars of cow- pea (*Vigna unguiculata* (L.) Walp.) develop local lesions, and most isolates of cucumber mosaic virus are non-systemic in this plant.

Disease cycle This virus survives from season to season in alternative hosts. Transmission is facilitated by more than 60 species of aphids and at least two species of beetles (the striped and spotted cucumber beetles). All aphid stages can transmit the virus, which is acquired and inoculated in about one minute. There is no latent period and the virus is retained by the aphid for less than four hours. The virus is not transmitted transovarially to aphid offspring. The virus can also be transmitted by at least 10 species of dodder. The virus is systemic and can be spread in plant sap carried on pruning knives or pickers' hands. This virus is only rarely transmitted by seed. Symptoms usually appear within four to five days of infection in young plants and within 14 days in older plants. Symptoms develop faster at temperatures of 26 to 32°C than at 16 to 24°C. Symptoms are more severe on plants exposed to short days or reduced light.

Management

Cultural practices — Elimination of reservoir hosts in the area of cucumber greenhouses generally will reduce the amount of initial inoculum unless many different hosts are native to the area. If possible, growers should avoid double cropping and should not plant a new crop near infested crops or their residues. Elimination of alternative hosts in a 100-m-wide area around the perimeter of greenhouses will give satisfactory control of the virus in most years. Aphid control may also be useful in preventing spread of the virus, but it must be done promptly to prevent virus transfer. In greenhouses, ventilators can be fitted with screens to exclude aphids, aluminum mulch can be used to repel incoming aphids, and a barrier crop of wheat may delay or reduce viral spread to susceptible cucumber plants. Reduced handling of plants may also delay spread of this virus, though in general it is not readily transmitted by contact. Hands, clothing and tools should be washed frequently, and dipping hands and tools in skim milk minimizes spread.

Resistant cultivars — European seedless cultivars have little or no resistance to cucumber mosaic virus.

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(Original by J.G. Menzies and W.R. Jarvis)

▶ 22.21 Cucumber necrosis

Cucumber necrosis virus

Cucumber necrosis virus is soil-borne, affecting mainly greenhouse cucumber, but it can also infect field cucumber. It causes a minor disease of greenhouse cucumber.

Symptoms Young leaves turn upright and yellowish. The youngest leaves develop a purple tinge as their tissues desiccate and die. Yellow-green to tan-colored areas with pinpoint necrotic areas, 1 to 8 mm in diameter, may form on the leaf blades. These may fall out, leaving “shot-holes” of various sizes. The virus moves systemically through the plant, and leaves may show symptoms on only one side of the midrib. Severely affected leaves are malformed with dark green, flap-like enations on the lower surface. Enations often occur around a shot-hole or along a vein approximately two to three weeks after the first appearance of systemic symptoms; enations are often the only symptom during summer.

Causal agent Cucumber necrosis virus is an RNA-containing virus with isometric particles about 31 nm in diameter. The properties and host range of this virus and the cucumber strains of tobacco necrosis are similar, making serological tests the only reliable way to distinguish between them.

On cucumber, necrotic lesions develop in inoculated cotyledons in three to four days, enlarging to 3 to 5 mm. The cotyledons desiccate and die. Systemic symptoms may include: chlorotic or tan-colored areas with pinpoint necrotic centers that usually fall out leaving shot-holes of various sizes; severely deformed leaves, sometimes with dark green enations; and small fruits on stunted plants, occasionally with a green mottle.

Virus identity can be confirmed by inoculating indicator plants. *Gomphrena globosa* L. develops irregular, grayish necrotic lesions with reddish margins in three to five days. *Chenopodium amaranticolor* Coste & Reynier develops local necrotic lesions, 0.5 to 1 mm, in two to five days. The margins redden as the leaves age. Heavily infected leaves desiccate and fall.

Disease cycle This virus is transmitted by a soil-inhabiting fungus, *Olpidium radicale* Schwartz & Cook, which appears to infect only members of the family Cucurbitaceae. The virus can infect roots in soil contaminated with infested crop residues or sap. It also can be transmitted mechanically from plant to plant by rubbing abraded leaves with infective sap, a pathway that may apply in commercial greenhouses. Amaranthaceae, Chenopodiaceae, Compositae, Cucurbitaceae, Leguminosae and Solanaceae can be infected by mechanical inoculation with plant sap. In greenhouses, the virus is most severe in autumn and winter. As the days lengthen, symptoms become milder and indistinct, and plants that exhibited severe symptoms in the spring may display almost complete recovery by summer.

Management

Cultural practices — Steam sterilization of soil is necessary to control this soil-borne virus. Chemical fumigation is ineffective. Diseased plants should be rogued and removed without touching other plants, and they should be burned, not buried. Sap-contaminated tools should be heat sterilized, hands should be washed, and clothes changed after handling diseased plants and before entering a disease-free area.

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(Original by J.G. Menzies and W.R. Jarvis)

▶ 22.22 Cucumber pale fruit *Fig. 22.22*

Cucumber pale fruit viroid

This fruit disease of greenhouse cucumber was first observed in the Netherlands and has been reported since 1963 in other countries. If pale fruit becomes established in a cucumber crop, large reductions in fruit yield and quality can occur. In Canada, cucumber pale fruit has been a problem only in British Columbia. The pathogen is similar in its host range and reactions to potato spindle tuber viroid (see Potato, spindle tuber, 16.28) and chrysanthemum stunt viroid.

Symptoms The disease is more severe at higher temperatures. The most distinctive symptoms are pale-green, small and often slightly pear-shaped fruits (22.22). However, in plants grown at 30°C, leaf symptoms may appear before flower and fruit development. Developing leaves are small, blue-green and rugose. Leaf blades are undulating, with the edges turned downward and the tips bent downward or turned backwards. Upon aging, leaf symptoms fade, chlorosis appears and the plant may be somewhat stunted. Flowers may be stunted and crumpled with the edge of the petals slightly notched.

Causal agent This is a typical plant viroid: low molecular weight RNA, 1.1 to 1.3 x 10^5, having a unique structure. It is not found in healthy plants. It replicates autonomously despite its small size. Unlike viral nucleic acids, viroids are not encapsulated, so no virion-like particles can be isolated from infected tissues.

Several cucurbits are susceptible and exhibit discernible symptoms. *Benincasa hispida* (Thunb.) Cogn. (Chinese watermelon) may be most useful as an indicator plant because its incubation period is short and symptoms are pronounced. A local-lesion host has not been found. In cucumber, symptoms are identical to those of hop stunt viroid from which this viroid differs at 16 nucleotide positions with about 95% sequence homology. Cucumber plants can be individually tested by polyacrylamide gel electrophoresis. For direct detection in seed samples, DNA complementary to potato spindle tuber RNA can be used by the spot hybridization technique.

Disease cycle The pathogen is mechanically transmissible with crude sap expressed from infected cucumber plants. Slashing of the stems with a contaminated knife also infects plants. Seed transmission has been proven experimentally in tomato. The viroid normally occurs only in greenhouses. It does not overwinter in crop residue, and it does not appear to be transmitted by insects. Infected seed is the most likely initial source of inoculum.

Management

Cultural practices — Good sanitation during pruning and harvesting operations will minimize spread of the disease from infected to healthy plants.

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(Original by R. Stace-Smith, J.G. Menzies and W.R. Jarvis)

▶ 22.23 Watermelon mosaic *Figs. 22.23; 9.17a,b*

Watermelon mosaic virus

This virus was first reported on cucumber in 1975 in southern Ontario and has not been found elsewhere in Canada. Watermelon mosaic is generally of minor importance on greenhouse cucumber. Various hosts of watermelon mosaic virus occur in the families Cucurbitaceae and Leguminosae.

Symptoms Initially, leaves may show a yellow veinclearing and flecking, followed by a uniform green to dark green mosaic *(9.17a).* The leaf margins turn upward. There is subsequent leaf distortion with downward hooking of the edges, irregular venation, dark green vein-banding *(9.17b),* and dark green blisters between the veins *(22.23).* Leaf symptoms are usually uniform, resembling injury due to herbicides or other abiotic disorders. The fruits are severely shortened, curled and gnarled.

Causal agent Watermelon mosaic virus particles are flexuous filaments, about 750 nm long. The particles precipitate in plant sap at pH 4.9. The electrophoretic R_0 value is 0.25. Two distinct strains have been described in North America. Strain 1 is restricted to cucurbits; strain 2 is not. On cucurbits, these strains cannot be differentiated by their symptoms.

This virus can be distinguished from squash mosaic and cucumber mosaic because it infects watermelon systemically, and from cucumber green mottle mosaic and tobacco ringspot because it is transmitted by aphids. Watermelon develops systemic vein-banding, mosaic and leaf-dis-tortion. Pumpkin develops interveinal chlorosis, mosaic, raised green blisters and leaf distortion.

Disease cycle Limited evidence suggests that the virus is seed-borne. Sources of primary infection have not been fully identified. The virus is transmitted from plant to plant in a non-persistent manner by the green peach, melon and black bean aphids. The green peach aphid can acquire the virus from an infected plant after only 10 to 30 seconds of feeding. Secondary spread is also by aphid vectors. Disease symptoms appear one to two weeks after inoculation.

Management Effective control of this virus requires the elimination of reservoir hosts and aphid vectors.

Cultural practices — Greenhouses should be located in areas with limited populations of reservoir hosts, if possible, or upwind from them. Herbicide applications or other practices to control reservoir hosts around the greenhouse, in ditch banks or along hedge rows are helpful. The use of aphid-repellant aluminum foil mulches, oil sprays and protective crops around greenhouses can also reduce virus incidence in cucumber crops. Wheat grown as a protective crop around greenhouses provides feeding sites for aphids. As they feed, virus on their stylets is diluted by the wheat sap and loses its infectivity. Seed should be bought only from reputable sources.

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(Original by J.G. Menzies and W.R. Jarvis)

▶ 22.24 Zucchini yellow mosaic *Figs. 22.24a,b; 9.16a-c*

Zucchini yellow mosaic virus

In greenhouse cucumber, severe mosaic, yellowing and distortion of the leaves and fruit may occur *(22.24a,b).* Up to 80% of a cucumber crop was infected in one Ontario greenhouse. The disease has a limited distribution in Canada, having been reported only from Ontario, Alberta and British Columbia. (For more detail on this disease, see Cucurbits, zucchini yellow mosaic, 9.16.)

(Original by W.R. Jarvis and J.G. Menzies)

NON-INFECTIOUS DISEASES

▶ 22.25 Chilling injury, cold injury *Figs. 22.25a,b*

Cucumbers are sensitive to temperatures lower than the recommended minimum day or night temperatures for particular cultivars, and the effects are exaggerated under conditions of poor light. (See also field injury, *9.18a-c*.)

In the early part of the season, plants develop slowly with excessively large leaves. In a greenhouse with poorly insulated walls, there may be a marked gradient in heat distribution and plant height across the house. Similarly, turbulator fans cause patches of poor growth when they bring cold air down from the roof space. Flowering is delayed by low temperatures, and fruits may abort. Applying cold water may cause leaf puckering *(22.25a).*

Greenhouse cucumber fruit can be injured on the vine (cold injury) or in post-harvest storage (chilling injury) by low temperatures. Maturing fruit that is subject to cold drafts and sudden drops in temperature develops characteristic scars. These consist of white or light brown longitudinal marks, often on one side, but occasionally all around the fruit *(22.25b).* The scars are corky in appearance and, although superficial, they detract from market quality. Similar symptoms can result from thrips feeding on the developing fruit. In severe cases, the fruit may split. Slow- growing fruit may be bitter.

Chilling injury results in pitting of the fruit because of a collapse of epidermal tissues. These pits turn yellow and eventually may cause the entire fruit to become chlorotic. Chilling injury may increase the susceptibility of fruit to microbial decay.

Management

Cultural practices — The risk of cold injury can be lessened by reducing cold drafts in the greenhouse and by avoiding spraying plants with cold water. Air temperatures in the greenhouse should not be allowed to fall below 16°C. Chilling injury can be prevented by storing cucumber fruit between 10 and 13°C.

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(Original by W.R. Jarvis and J.G. Menzies)

▶ 22.26 Nutritional disorders *Figs. 22.26a-g*

Boron
Calcium
Copper
Iron
Magnesium
Manganese
Molybdenum
Nitrogen
Phosphorus
Potassium

Boron

(22.26a) Leaves of boron-deficient plants are leathery, acquire a dark green color and may exhibit death of the apical bud. Older leaves usually develop a brownish- yellow, interveinal chlorosis and scorched margins, while younger leaves may be malformed and cupped with prominent veins. Affected plants are brittle. Young fruits sometimes die. Developing fruits are malformed with longitudinal white stripes, as though exposed to cold.

Calcium

Calcium deficiency results in growing points turning dark and twisted, with young leaves stunted in size. Leaf edges curl downward and turn a pale brown color. Young fruit may shrivel, discolor and show signs of blossom-end rot. This problem can be quite common in rapidly growing crops. Affected plants are unable to regulate the internal distribution of calcium adequately owing to insufficient transpiration. High levels of potassium may restrict the uptake of calcium.

Copper

Copper deficiency results in short internodes, small leaves and yellow blotches between the veins on older leaves. This chlorosis usually moves steadily up the plant. The leaves will become dull green or bronze colored and wither.

Iron

Plants suffering from iron deficiency display interveinal yellowing of the youngest leaves (*22.26d*), with the veins gradually becoming yellow. Eventually, the whole leaf may turn yellow or yellowish-white. Older leaves generally remain green. Affected plants may cease to grow and fruit may become pale-colored.

Magnesium

Leaves on plants with magnesium deficiency exhibit interveinal yellowing, but the veins remain green *(22.26b).* In many cases, a green margin will remain around the leaf even under conditions of severe deficiency. Leaves may curl downward, become hard or brittle, and overall growth may be stunted. Affected fruits usually are pale green. These symptoms may be difficult to distinguish from those of manganese deficiency.

Manganese

Symptoms of manganese deficiency occur first on the oldest leaves in the form of pale green areas. Soon afterward, a net-like pattern appears with only green tissues occurring along the main veins. The leaves will become thin and die around the edges. This symptom may be difficult to distinguish from magnesium deficiency.

Molybdenum

Molybdenum-deficient plants are stunted and have scorched leaves (*22.26c*) with up-rolled margins. The symptoms generally start on the lower leaves and move upward on the plant.

Nitrogen

Nitrogen deficiency results in restricted plant growth and reduction in fruit numbers. Young leaves are small and pale yellow-green *(22.26e),* while older leaves turn yellow uniformly and may die prematurely. Affected fruits are short and pale green and the blossom end may be pointed (*22.26f*).

An excess of nitrogen results in stunted plants with small, dark green leaves. Affected leaves tend to curl downward and the petioles droop slightly. Chlorosis of leaf margins also may occur.

Phosphorus

Slight phosphorus deficiency may result in stunted plants without leaf symptoms. By contrast, a severe deficiency stunts growth, and younger leaves become small, stiff, turn dark grayish-green and expand slowly. Leaf veins and petioles turn reddish-purple and large brown areas may develop on the lower leaves and spread up the plant. Affected leaves eventually shrivel up.

Potassium

Cucumber plants suffering from potassium deficiency have small leaves showing chlorosis, bronzing and marginal scorching (*22.26g*). Deficient plants are usually severely stunted, while affected fruits have enlarged tips but remain undeveloped at the stem end. Such fruit may develop brown marks and have a bitter taste.

Management

Cultural practices — Low light and poor weather may result in a lack of ventilation, creating high humidity in the greenhouse, which restricts transpiration. Increasing the ventilation may improve the transpiration activity of the plants, and symptoms may disappear on new growth.

For the majority of these nutrient disorders, adjusting the mineral content of the nutrient solution will correct them. For calcium deficiency, altering the composition of the nutrient solutions may not always alleviate the problem. Foliar applications of calcium nitrate (0.5 kg/500 L water plus a wetting agent), or 150 g potassium nitrate plus 100 g calcium nitrate per litre of stock solution diluted 1:200, will alleviate calcium stress.

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Roorda van Eysinga, J.P.N.L., and K.W. Smilde. 1981. *Nutritional Disorders in Glasshouse Tomatoes, Cucumbers and Lettuce.* Centre Agric. Publ. Doc., Wageningen, The Netherlands. 130 pp.
Winsor, G., and P. Adams. 1987. *Diagnosis of Mineral Disorders in Plants.* Vol. 3. *Glasshouse Crops.* H.M.S.O., London, England. 168 pp.

(Original by J.G. Menzies)

▶ 22.27 Premature fruit yellowing

This is a common post-harvest fruit disorder of greenhouse cucumber. The cause is unknown, but it appears to be related to growing conditions during fruiting.

Management

Cultural practices — Increasing the concentration of fertilizer in the nutrient solution and decreasing the fruit number per plant may lessen the incidence of premature fruit yellowing. This disorder also can be reduced by increasing the amount of light reaching the fruit through practices such as leaf pruning.

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Lin, W., and D.L. Ehret. 1991. Nutrient concentrations and fruit thinning affect the shelf life of long English cucumber. *HortScience* 26:1299-1300.

(Original by J.G. Menzies)

▶ 22.28 Root death *Fig. 22.28*

In healthy plants, roots die and are replaced throughout the cropping season, but sometimes roots die suddenly and faster than they can be replaced. Collapse of the plant is then spectacular, particularly in systems using the nutrient film technique (NFT).

Symptoms Plants wilt and collapse within five to eight hours, and there is no recovery. In NFT systems, the roots turn brown *(22.28)* and slimy and, when disturbed, disintegrate completely into fragments. Usually, most of a crop is affected simultaneously.

Causal agent Several factors may cause root death but the condition is usually associated with stress. Conditions such as low or high temperature, high electrical conductivity, poor oxygenation of the nutrient solution, or too heavy a fruit load on small, weak or diseased plants may occur singly or together, exacerbating root death. Extensive root growth in NFT systems can lead to inefficient flow rates of nutrient solution around the roots, which can result in high electrical conductivity and poor aeration of the solution. In hydroponic systems, the sudden collapse of the crop is diagnostic, together with the complete disintegration of the root system.

Disease cycle Root death is more a physiological disorder than a disease caused by a specific microorganism. However, it is not unusual to isolate pathogenic fungi and bacteria from dead roots. *Clostridium* bacteria are often present. They are anaerobic and their presence suggests a local deficiency of oxygen at the root surface, which could cause the roots to autolyse or self-destruct. Usually, most of a crop is affected simultaneously, probably reflecting a nutritional or osmotic imbalance in the fertilizer system, or marked shifts in source- sink relationships in the plant. Generally, cucumber soil media temperatures must be above 15°C. Lower temperatures result in decreased root activity and reduced plant growth. If the air temperature is around 25°C and root temperature is 15°C, the root system is unable to sustain the top growth. This results in root dieback and eventual death of the plant. A high electrical conductivity around the root reduces or prevents water uptake into the root from the growing medium. Eventually, excess water accumulates around the roots, thus decreasing aeration and causing root death by anoxia. The electrical conductivity of the feed solution and growing medium is determined by, and adjusted for plant vigor, age of plants, time of season, environmental conditions in the greenhouse and outdoors, and type of growing medium. In a rockwool system, the electrical conductivity is usually high at the start of the season when the plant is small and light intensity is low. As the plant develops and light levels increase, the conductivity should be lowered. However, during these periods, the conductivity may be raised or lowered by a few points (0.2 mS/cm) when an extended period of cloudy or sunny warm weather is experienced. In an artificial growing medium, such as rockwool, the conductivity can be as high as 3.0 mS/cm compared to 1.5 to 1.8 mS/cm in soil.

Management

Cultural practices — Root death can be corrected by avoiding stress conditions; however, once wilting has begun, it is irreversible and rapid. NFT and rockwool systems lack the buffering capacity of soil to mask and retard symptoms, so constant attention is needed to avoid the sudden stress imposed by any of a number of production accidents.

Selected references

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Van der Vlugt, J.L.F. 1989. A literature review concerning root death in cucumber and other crops. *Norw. J. Agric. Sci.* 3:265-274.

(Original by W.R. Jarvis and J.G. Menzies)

▶ 22.29 Sudden wilting

Sudden wilting of cucumber plants can be caused by temperature and moisture extremes. If cucumber is exposed to rapid decreases in temperature, sudden wilting may occur. Affected plants usually recover but, if cool conditions persist, such as near the insulated wall in a greenhouse, permanent stunting may result. High temperatures also will cause temporary wilting of cucumber plants, and persistent high temperatures may cause the margins of lower leaves to die. This type of wilt often expresses itself in the early part of the season on warm, sunny days. If the young plants have not had time to develop adequate root systems, they wilt, but most plants recover.

Insufficient water can result in wilting or stunting of cucumber plants and, if uncorrected, they will eventually die. Overwatering can result in wilting, yellowing, root injury and reduced growth rates. See also 22.7.

Management

Cultural practices — Greenhouse temperatures should be maintained between 18 and 27°C. Irrigation schedules of cucumber crops should be carefully monitored, especially during hot weather.

(Original by J.G. Menzies)

NEMATODE PESTS

▶ 22.30 Root-knot nematodes *Figs. 22.30a-d*

Northern root-knot nematode

Meloidogyne hapla Chitwood

Southern root-knot nematodes

Meloidogyne arenaria (Neal) Chitwood
Meloidogyne incognita (Kofoid & White) Chitwood
Meloidogyne javanica (Treub) Chitwood

Greenhouse cucumber and solanaceous vegetables are very susceptible to damage from root-knot nematodes. Infected transplants may be a source of inoculum in greenhouses. Southern root-knot nematodes occasionally are imported with transplants from the United States.

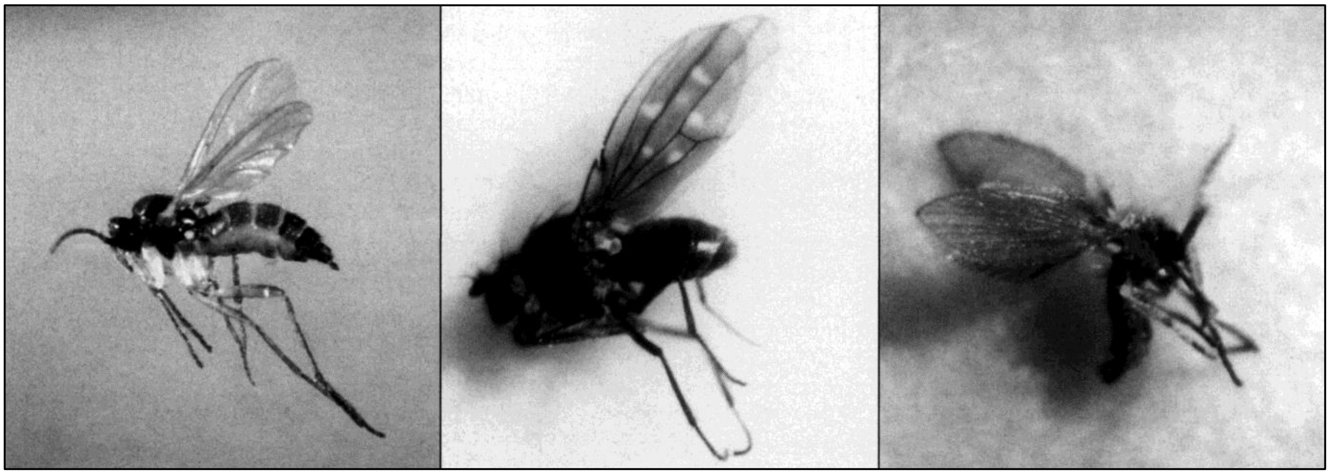
Symptoms include yellowing and stunting of stalks, early senescence, prolific branching of rootlets, and production of small, spherical galls on roots (*22.30a-d*). For a complete description, see Carrot, 6.20; see also Greenhouse tomato, 25.26, and Management of nematode pests, 3.12.

INSECT PESTS

▶ 22.31 Fungus gnats *Figs. 22.31a-c; 22.31T1*

Bradysia spp.
Corynoptera spp.

Fungus gnats are found wherever greenhouse crops are grown in Canada. They are rarely a problem on greenhouse tomato or pepper, but they may damage greenhouse cucumber crops and bedding plants. Fungus gnats are more of a problem when cucumber roots are first damaged by a nutrient imbalance or waterlogging, as in sawdust media. Adults can annoy workers through sheer numbers, but generally they are a minor and easily controlled nuisance.



22.31T1 Fungus gnat (left), shore fly (center), and moth fly (right); compare wings, body shape and leg length; adults 2-3 mm long.

Fungus gnats form a normal part of the decomposer chain in greenhouse soils, regardless of the type of crop being grown.

Damage The larva is the damaging stage, feeding on roots and root hairs. Only rarely are plants killed, but growth reduction may result and feeding opens wounds through which pathogens may invade. Plants grown free of soil, such as in hydroponic and sterile potting media, are more susceptible to damage than plants grown in soil.

There is evidence that fungus gnat adults may transmit or be involved in the movement of soil-borne diseases of greenhouse crops, notably root rots caused by *Pythium* species in cucumber and crown and root rot caused by *Fusarium oxysporum* f. sp. *radicis-lycopersici* in tomato.

Identification Fungus gnats are small dark flies (*22.31b*) (family Sciaridae), often referred to the genera *Bradysia* and *Corynoptera.* The adults are 2 to 3 mm in length. They may be mistaken for shore flies (Ephydridae) and moth flies (Psychodidae) (*22.31T1*), both of which are common but not damaging in greenhouses, or for adult *Aphidoletes,* which are biocontrol agents for aphids (see melon aphid, 22.33). Larvae of fungus gnats grow to 4 to 5 mm in length, are legless, characteristically white or almost transparent and have a prominent, black head *(22.31b).* The eggs are ovoid and cream-colored.

Life history Fungus gnat females lay eggs singly or in clusters of 2 to 10 in crevices in moist soils, in potting mix and in hydroponic media. Females can lay 100 to 200 eggs over a two- to four-day period. The eggs hatch in two to four days, and larvae require 14 to 16 days to complete development at 20°C. They feed on fungal mycelia, detritus, roots and root hairs. Pupation (*22.31a*) occurs at or just below the surface of the medium; after three to five days, the pupa wriggles to the surface before the adult emerges. The gnats are found outdoors and probably enter greenhouses continually through doorways and vents, becoming established where suitable oviposition sites are available.

Management

Monitoring — There is no action threshold for fungus gnats. Tolerable populations vary from grower to grower. If signs of damage are observed in the greenhouse, such as afternoon wilting, in conjunction with large numbers of fungus gnats around the base of the plants and larvae in the culture medium, then control measures should be initiated immediately. Also, if yellow sticky traps (see greenhouse whitefly, 22.32) become covered with fungus gnat adults within seven days, then treatment is warranted.

Cultural practices — Growers should avoid overwatering because wet conditions favor outbreaks. Waste plant material should be removed and good sanitation should be followed at all times.

Biological control — If an outbreak occurs in greenhouses where biological control is being used for other greenhouse pests, then every attempt should be made to use a biocontrol agent for fungus gnats. Various biocontrol agents are available for this purpose. A nematode *(Heterorhabditis* sp.) is effective in controlling fungus gnat larvae, but it does not reproduce in the body of the gnat larva and must be reapplied whenever gnat populations resurge. A predatory mite, *Hypoaspis* (syn. *Geolaelaps)* sp. *(22.31c),* also is available commercially in Canada. If applied early in the season, it can effectively limit the increase in fungus gnat populations. The mite should be applied at a rate of 50 individuals per plant at planting-out to achieve satisfactory control.

Chemical control — Fungus gnat larvae and adults may be controlled by spray or drench application of insecticides to the surface of the culture medium. There are no documented cases of resistance to insecticides but resistance has been suspected in several instances.

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(Original by D.R. Gillespie)

▶ 22.32 Greenhouse whitefly *Figs. 22.32a-d; 22.34d*

Trialeurodes vaporariorum (Westwood)

The greenhouse whitefly (see Greenhouse tomato, 25.27) can be found on greenhouse cucumber crops wherever they are grown in Canada. On greenhouse cucumber, its biology is similar to that described for greenhouse tomato, the major difference being that whitefly egg production and adult longevity are 10 to 15% greater on cucumber than on tomato.

Damage The greenhouse whitefly is a major pest of greenhouse cucumber. Whitefly outbreaks have the potential to decrease yield and fruit quality through feeding damage (*22.32a*) and honeydew deposits, which encourage the subsequent growth of mold fungi *(22.32b).*

On greenhouse cucumber, the greenhouse whitefly is important as a vector of beet pseudo-yellows and contributes to the rapid spread of the disease throughout the crop.

Identification Whiteflies should be seen by an expert to confirm their identity. In general, the greenhouse whitefly is snowy white, and the wings are held horizontally over the body at rest *{22.32c).* It can usually be found on the undersides of upper leaves, flying weakly when disturbed. (For more detail, see Greenhouse tomato, 25.27.)

Life history (see Greenhouse tomato, 25.27)

Management The greenhouse whitefly can be controlled effectively using cultural procedures and biological control. At present, whiteflies are being controlled biologically on the majority of greenhouse cucumber crops in British Columbia, Alberta and the Maritime provinces.

Monitoring — The standard monitoring method for the greenhouse whitefly is the yellow sticky trap (*22.34d*). Traps should be hung as soon as plants are set out, and spaced uniformly throughout the greenhouse at a density of one trap per 20 to 50 plants. The traps should be hung with the middle of the trap level with the top of the crop, and inspected weekly. Monitoring should begin when the crop is planted, and biocontrol implemented when the first whitefly is detected.

Cultural control — Yellow sticky traps also can be used at a rate of one trap per two to five plants in whitefly hotspots to remove excessive numbers of whitefly adults from the tops of plants.

Biological control — The parasitic wasp *Encarsia formosa* Gahan is an effective biocontrol agent for the greenhouse whitefly on cucumber crops, and it should be introduced into the greenhouse as soon as the first whitefly is detected on a trap. The wasp is not attracted to the yellow sticky traps used for monitoring. The number of parasites that are released on each introduction date is greater for cucumber than for tomato because cucumber has more hairs on the leaf underside, causing the parasite to move more slowly and search for hosts less efficiently on cucumber than on tomato. Releases at a rate of one parasite pupa per two cucumber plants is recommended each week for 8 to 10 weeks or until 60 to 80% parasitism is achieved, which is estimated by counting the proportion of whitefly pupae (scales) that have turned black (*22.32d*). Whitefly scales turn black 10 to 14 days after parasitization.

Chemical control — As with greenhouse tomato, whitefly resistance to registered insecticides limits the value of chemical control. Insecticidal treatments should only be necessary toward the end of the growing season. If whiteflies are present on the crop at the end of the season, the crop should be fumigated prior to removal.

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(Original by J.L. Shipp and D.R. Gillespie)

22.33 Melon (cotton) aphid *Figs. 22.33a,b*

Aphis gossypii Glover

The melon aphid can be a problem on greenhouse cucumber throughout Canada, especially in the fall. It has only recently become a problem in greenhouse cucumber in British Columbia.

The melon aphid feeds on a variety of plants, including such vegetable crops as bean, celery, cucumber, melon, pepper and potato.

Damage Concentrations of as many as 2000 aphids per leaf develop quickly on cucumber, causing infested leaves to wilt and collapse. Younger leaves become dark green and stunted, usually with rolled or distorted edges. Large amounts of honeydew are deposited onto the leaf surfaces below colonies of aphids, encouraging a dense growth of sooty mold. Even after damaging levels of melon aphids have been controlled by pesticides, yields may take five to seven weeks to return to normal levels.

This aphid can act as a carrier of plant viruses into the greenhouse, and is an efficient vector of cucumber mosaic and watermelon mosaic viruses.

Identification The melon aphid (family Aphididae) is 1 to 3 mm in length, and globular in shape with a pair of short, black projections (cornicles) and several dark marks on the abdomen. The tubercles between the antennae are not prominent. When populations are sparse, adults are nearly black or green, nymphs somewhat lighter. As crowding increases, nymphs range from olive-green to light yellow in the densest colonies *(22.33b).* Winged adults are dark green to black *(22.33a).*

Life history Melon aphids are adapted to high temperatures. At 27°C, the aphids mature in seven days. Adults can produce an average of 40 nymphs in as few as seven days. Populations increase as much as 10- to 12-fold per week on cucumber (but only 4-fold on greenhouse eggplant crops). On greenhouse cucumber, infestations usually occur first on the lowest leaves, then spread throughout the plant. When colonies become crowded, winged forms are produced and these migrate to neighboring plants. Winged aphids also move from outdoor crops, ornamentals or weeds into greenhouses during the growing season or in early fall.

Management Action to control melon aphids must be taken as soon as the first aphid is detected because they reproduce so quickly.

Monitoring — Growers should check their crop routinely for the first sign of aphids. A threshold of seven melon aphids per square centimetre or 1000 aphids per plant has been determined (in England) as an action threshold for the application of pesticides; this threshold is unrealistically high if cucumber mosaic or watermelon mosaic are present.

Cultural practices — Growers should screen greenhouse vents, maintain a weed- and garden-free area around the greenhouse, and keep ornamentals and vegetable crops out of the same greenhouse range.

Biological control — The most promising biocontrol agent is the predatory midge *Aphidoletes aphidimyza* (Rondani). Preliminary studies in Canada suggest that it should be applied at a rate of 15 to 20 midges per plant for several weeks to achieve control. The midge must be introduced when the aphid population is extremely low, with releases starting when the first aphid is detected.

Chemical control — Aphids frequently develop resistance to pesticides, so periodical product rotation is suggested. Insecticides, where effective, must be used frequently to achieve satisfactory control. Insecticidal soap and pyrethroid sprays are not effective against the melon aphid.

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(Original by L.A. Gilkeson)

22.34 Western flower thrips *Figs. 22.34a-i; 25.29*

Frankliniella occidentalis (Pergande)

The western flower thrips is a major pest of greenhouse cucumber in Canada. It is widely distributed throughout the greenhouse industry and can be found wherever greenhouse cucumber crops are grown from British Columbia to Nova Scotia.

The host plant range for the western flower thrips is very broad and includes many field and greenhouse vegetables, ornamentals, weeds, berries and tree fruits.

Damage Both immature and adult western flower thrips feed by piercing the leaf surface with their mouthparts and sucking the contents of the plant cells. This causes the formation of silvery white streaks or specks on the leaves and blossoms, accompanied by dark specks of fecal deposits (frass) *(22.34a).* Extensive thrips damage to the leaves reduces the photosynthetic ability of the plant, resulting in lower yield. Feeding damage also may be present on the fruit in the form of flecks and striations similar to those on the leaves *(22.34b).* This thrips also causes severe distortion or curling of cucumber fruit *(22.34c),* which lowers the grade of the fruit. Thrips damage can occur at any time in the growing season. In Alberta and British Columbia, the most severe problems occur in May and June. In Ontario, thrips impact is greatest in July and August, at which time feeding damage on the leaves and fruit, as well as damage from too frequent application of pesticides, can seriously decrease the yield and fruit quality.

The western flower thrips is a vector of tomato spotted wilt virus in pepper and tomato.

Identification In Canada, the thrips genus *Frankliniella* can be distinguished from other thrips genera by its eight-segmented antennae, well-developed setae on the anterior part of the thorax (prothorax) (a long pair anteriorly and shorter ones mid-laterally), and two longitudinal veins bearing two rows of setae on the forewings.

The western flower thrips (family Thripidae) adult (*22.34g; 25.29)* is winged, 1 to 2 mm in length, and females have a straw-brown head and thorax and a darker brown abdomen. Because of its small size, variation in color, and the existence of similar species, this thrips is impossible to identify with certainty at the species level without high-power magnification.

In greenhouses, the western flower thrips might be confused with the onion thrips, which is usually uniformly brown. However, the adult western flower thrips has two, very small divisions (annuli) at the tip of the antennae and a pair of dorso-anterior setae on the prothorax, whereas the adult onion thrips has only one terminal antennal annulus and lacks dorso- anterior prothoracic setae. Immatures of these and other thrips are impossible to identify to species.

Life history Female adults of the western flower thrips live up to 30 days and lay 2 to 10 eggs per day. Eggs are inserted individually into the plant's leaves, stems, and flowers and hatch in three to six days. There are two nymphal (or larval) instars that feed and mature on leaves and flowers. After six to nine days, the mature, second- instar nymph drops to the soil and enters the propupal and pupal stages *(22.34e,f).* The pupa is a non-feeding stage during which the wings and other adult structures form. Adults emerge after five to seven days and fly to host plants where they feed, mate and lay eggs. Development from egg to adult takes approximately 15 days at 25°C. Temperatures above 25°C and low humidities are optimal for development and longevity of the western flower thrips and the induction of its outbreaks. The adult is a weak flier and, under most conditions, it tends to hop and run rather than fly, but adult thrips can disperse throughout the greenhouse by flying. Adult thrips are transported on wind currents and enter greenhouses through vents and doorways. All thrips stages may spread between greenhouses by the movement of infested plants, soil, farm implements and picking tools, and on workers' clothing.

Management The western flower thrips can be effectively controlled using cultural procedures and biological control. Repeated introduction of the biocontrol agents usually is necessary, and both the pest and predators must be carefully monitored. Over-reliance on chemical control is unwise because thrips rapidly acquire resistance to insecticides.

Monitoring — Population monitoring for the western flower thrips is critical to the success of biological control and consists of several distinct steps. An early detection program should be implemented as soon as the crop is planted or earlier. For this, blue or yellow sticky traps *(22.34d)* are positioned evenly throughout the crop. The western flower thrips is more attracted to blue than to yellow, so blue sticky traps are preferred for monitoring the adult thrips population. Early detection provides adequate early warning of thrips.

Once biological control has started, predators and thrips both should be monitored by checking a minimum of 25 leaves per 2000 m^2 weekly. Commercial pest management monitoring services may be available for this. There should be no more than 10 immature thrips per leaf. The predators should be evenly distributed throughout the greenhouse. Once the predators are established, thrips populations can be expected to decline or remain stable. Lack of establishment of predators may indicate poor quality of predators or that pesticide residues are present on the crop or the greenhouse structures.

Blue or yellow sticky traps should be maintained to monitor population trends and detect immigration of adults, which may occur in June and August, particularly after hay harvesting in nearby fields.

Cultural practices — Commercially available blue or yellow sticky ribbons can be used for mass trapping as well as for monitoring, but other cultural practices also are effective in preventing outbreaks. For instance, at the beginning of the cropping season, the soil might be steam- sterilized to kill soil stages of the thrips. Greenhouse vents can be covered with very fine screening to prevent thrips infiltration from outdoors, weeds should be removed from around the perimeter of the greenhouse, and ornamentals should not be planted in close proximity to the greenhouse. Also, non-crop material, such as ornamental plants, should not be brought into the greenhouse.

If thrips are present at the end of the growing season, an infested crop should be treated with an appropriate insecticide, preferably a fumigant, prior to removing the plants. Then, all plant material should be removed and destroyed to prevent reinfestation. The greenhouse then should be heated for at least two days to control any remaining thrips. This is particularly important between spring and fall crops. During the winter, below-freezing temperatures in the greenhouse will not control the western flower thrips, but keeping the greenhouse heated for two or more days without any plants is an effective control practice.

Biological control — Several biocontrol agents are commercially available to control western flower thrips. They should be released immediately after the first thrips or thrips damage is seen in the greenhouse. Commercially available biocontrol agents include the predatory mites *Amblyseius* (syn. *Neoseiulus*) *cucumeris* Oudemans and *Amblyseius* (syn. *Neoseiulus) barkeri* Schuster & Pritchard.

Amblyseius cucumeris (22.34h) is the mite most commonly used to keep the western flower thrips below economically damaging levels on cucumber. The mites are sometimes introduced when the crop is planted. This mite normally is sensitive to daylength and does not lay eggs during short-day conditions, such as occur between late September and late February, unless the greenhouse temperature remains at or above 21 °C. A non-diapausing strain now is commercially available and it has replaced the short-day sensitive strain. Releases should be at a rate of 50 to 100 mites per plant every one to two weeks until approximately 75% of the leaves have mites or until every leaf with a thrips also has a predatory mite. If more than 10% of the leaves have adult thrips, or more than 25% have immature thrips, the initial thrips population is too high, in which case growers should apply a non-residual insecticide and wait at least two weeks, depending on the insecticide, before releasing predatory mites.

A soil-dwelling predatory mite, *Hypoaspis* (syn. *Geolaelaps)* species *(22.31c),* marketed as a biocontrol agent for fungus gnats and applied to the floor or growing media, also preys on propupae and pupae of the western flower thrips, reducing adult emergence by about 40 to 60%. This rate of predation is not sufficient to provide control, but this species of mite can contribute to the overall success of a biological control program for the western flower thrips.

The minute pirate bugs (*22.34i*) *Orius tristicolor* (White) and *O. insidiosus* (Say) also are effective biocontrol agents for western flower thrips and are available commercially. Greenhouse releases at the rate of one bug per one or two cucumber plants over a period of several weeks will provide control within four to six weeks after application. These bugs are effective from March throughout the growing season.

Chemical control — The western flower thrips is difficult to control with chemicals because adults and immatures feed in the crevices of blossoms and fruit and on leaf undersides, making chemical contact difficult. Moreover, the western flower thrips is becoming resistant to all insecticides registered for use on greenhouse cucumber crops in Canada, and it seems to acquire resistance very rapidly to new products. Nevertheless, chemical control may be necessary toward the end of the growing season.

Synthetic pyrethroid products are not compatible with predatory mites or any biocontrol agents. Also, elemental sulfur for control of powdery mildew may interfere with the success of the predatory mites. In Alberta, spray applications of sulphur at label rates have had minimal effect.

When using pesticides, several applications are needed. They should be spaced at approximately four-day intervals to provide adequate control of both adult and immature thrips.

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(Original by D.R. Gillespie and J.L.Shipp)

▶ 22.35 Other insect pests *Figs. 22.35a-d; 9.21*

- Caterpillars
- Cucumber beetles
  - Spotted cucumber beetle *Diabrotica undecimpunctata howardi* Barber
  - Striped cucumber beetle *Acalymma vittatum* (Fabricius)
- Leafminers
  - Chrysanthemum leafminer *Liriomyza trifolii* (Burgess)
  - Vegetable leafminer *Liriomyza sativae* Blanchard
- Onion thrips *Thrips tabaci* Lindeman
- Plant bugs *Lygus* spp.

The above-mentioned insect pests occur sporadically on greenhouse cucumber crops in various parts of Canada.

Caterpillars

of various species can cause some degree of defoliation on greenhouse cucumber crops. They or the adult moths invade the greenhouse from outside and are usually only casual pests. Occasionally they may be a severe problem in individual greenhouses (see Greenhouse tomato, 25.30). Besides screening vents, application of the microbial insecticide *Bacillus thuringiensis* Berliner is the recommended control procedure for these pests.

Cucumber beetles

The spotted cucumber beetle and striped cucumber beetle (9.27) occasionally can be important to greenhouse cucumber crops because the adult beetles are efficient vectors of bacterial wilt. The striped cucumber beetle is the more important vector of the two species (see Cucurbits, 9.21). The adult beetles overwinter in weeds and trash, and become active in early spring. The disease can be transmitted to the crop at any time, but the beetles usually do not move into greenhouses until early to mid-summer. The best management strategy for cucumber beetles in greenhouse cucumber is cultural control by screening vents and maintaining a weed- and trash-free barrier around the greenhouse. Pesticides can be used but require application at least once per week, and they may cause plant injury and yield loss. No biocontrol agents are available for cucumber beetles.

Leafminers

The chrysanthemum leafminer (22.*35a,b)* and vegetable leafminer occur sporadically on greenhouse cucumber crops (see Greenhouse tomato, 25.28). The chrysanthemum leafminer is usually a problem only where greenhouse cucumber is grown in proximity to greenhouse flowers, particularly chrysanthemum. The vegetable leafminer is not yet a problem in greenhouse cucumber crops in British Columbia or Alberta, but it is more important than the chrysanthemum leafminer in Ontario. Control measures should be implemented as soon as the first leafminer is detected in the crop because leafminer populations can increase rapidly. Infestations can be controlled by pruning the mined leaves from the infested plants. Parasitic wasps are commercially available for biological control of leafminers (see Greenhouse tomato). Adult leafminers also can be controlled using insecticides, but leafminer populations are usually resistant.

Onion thrips

(see Onion, 13.27; see also Greenhouse tomato, 25.29) Before about 1985, the onion thrips (*22.35c*) was the only thrips pest on greenhouse cucumber. Since then, although still relatively common on greenhouse cucumber in all parts of Canada, it has been eclipsed by the western flower thrips. The onion thrips tends to be restricted to the lower strata of cucumber crops. It is less common in cucumber flowers and does not appear to be involved in fruit curling or to cause direct feeding-damage to the fruit. It is relatively easy to control with a variety of insecticides. Biocontrol agents for western flower thrips and fungus gnats also feed on onion thrips.

Plant bugs,

particulary various *Lygus* species (family Miridae), have recently become a problem on greenhouse cucumber crops. Information on their biology and control is limited. Adults and nymphs are relatively large, brown to green bugs (*22.35d*). They are very active at greenhouse temperatures. Adults and nymphs are sucking insects and feed on plant sap from stems, particularly near the tender growing tip of the plant. Feeding damage eventually may kill the growing tip, but the plant can generate a new growing tip from lateral shoots. This slows growth and can cause substantial yield loss. Flowers and developing fruit also may abort or be deformed, causing loss of quality and yield. Plant bugs migrate into greenhouses in late summer, being more of a problem to the fall crop. There are reports of plant bugs overwintering in greenhouses and being found on transplants in early spring. Treatment with insecticides is the current control recommendation for plant bugs.

(Original by D.R. Gillespie and J.L. Shipp)

MITE PESTS

▶ 22.36 Two-spotted spider mite *Figs. 22.36a-g; 22.36T1*

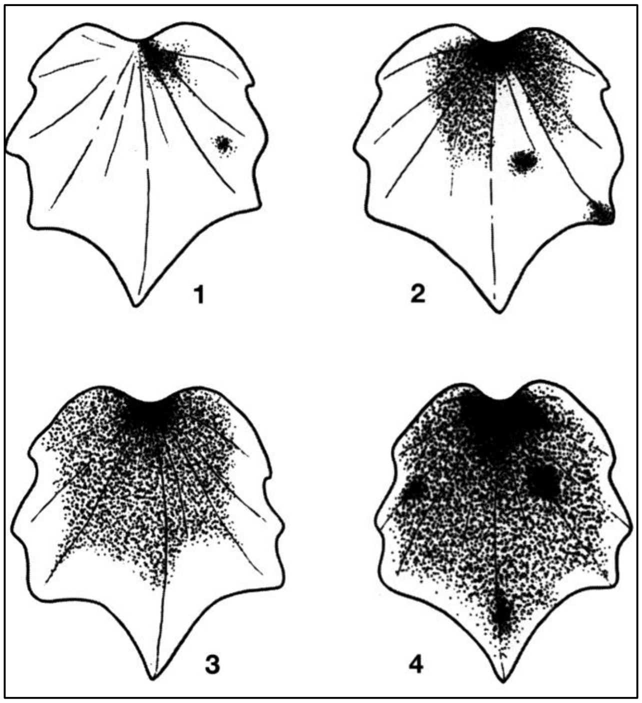
Tetranychus urticae Koch

The two-spotted spider mite can be found across southern Canada on a variety of crops, including fruit trees, vegetables, ornamentals and field, vine and berry crops. In greenhouses, hot, dry conditions favor its multiplication in the upper reaches of the crop in mid- to late summer.

The mite has a very broad host range, but greenhouse cucumber is a preferred host. Chickweed (*Stellaria* spp.) is an important weed host in the greenhouse.

Damage The two-spotted spider mite is a major pest of greenhouse cucumber. Outbreaks will cause moderate to severe losses and, in extreme cases, can destroy a crop. Spider mites feed by puncturing plant cells. This produces small, yellow or white, speckled feeding lesions that can coalesce and cause leaf death when extensive. Initial infestations may occur anywhere on the plant but are usual on leaf undersides. As populations increase, the greatest damage is generally on the canopy leaves because the adult females tend to move upward and the life cycle is faster at higher temperatures.

Spider mite damage (*22.36a-c*) is distinguished from thrips damage by the presence of fine webbing on leaf undersides (*22.36c*) and/or a silver sheen on damaged surfaces (22.*36b,c),* and by the absence of fecal deposits.



22.36T1 Two-spotted spider mite; indices (1-4) for leaf damage on greenhouse cucumber. Reprinted from *Biological Pest Control — The Glasshouse Experience*, N.W. Hussey & N.E.A. Scopes, eds. Copyright © 1985 by N.W. Hussey and N.E.A. Scopes. Used by permission of the publisher, Cornell Univ. Press.

Identification The two-spotted spider mite (family Tetranychidae) adult is 0.5 mm in length and is visible without magnification. During the growing season, it is pale yellowish-green with two distinct, bilaterally symmetrical black spots, one on either side of the body (*22.36e*). Overwintering adults are bright orange *(22.36f)* with a pair of dark spots. The eggs are small, 0.14 mm in diameter, spherical and white. The larval stage is small and white, and has three pairs of legs. Later stages have four pairs of legs (*22.36e,f*).

Life history Spider mites have five developmental stages: egg, larva, protonymph, deutonymph and adult. Adult females lay approximately 100 eggs on the lower leaf surface. The rate of oviposition is affected by relative humidity. At 20°C and a relative humidity of 36%, females lay an average of seven to eight eggs per day. At a relative humidity of 95%, this reduces to about five eggs per day. Development time from egg to adult is inversely dependent on temperature; 3.5 days at 32°C, 14.5 days at 21°C, and 21 days at 18°C. The two-spotted spider mite is very mobile when it is dispersing into a crop. Development usually takes place on the same leaf where the egg was deposited, and the mite confines itself to the infested plant as long as there is adequate food. Once the plant dies, or when the mite population is very high, the mites aggregate at the top of the plant or leaf tips and hang from the plant by dense "ropes" or silken strands. These silken strands and any mites on them are easily spread by attachment to people and equipment.

The adult females have a non-feeding stage (diapause) that is induced by short daylength and influenced by low temperature and reduction in host plant quality. Under short-day conditions, the normally pale yellowish-green females turn bright orange (*22.36d*), cease feeding and egg laying, and leave the plants to seek dark crevices in which to overwinter. Daylengths of less than 13 hours induce this behavior. Low temperatures, such as when greenhouse heating is shut down, and the presence of only senescing plant material for food facilitate diapause induction. High temperatures and succulent, growing plant material discourage diapause induction. A period of chilling is required to terminate diapause, and warm conditions induce the females to move from the wintering sites and seek new host plants. In general, hibernating females begin to emerge when the heat is turned on in the greenhouse, and these mites are the usual source of early spring infestations.

Management The two-spotted spider mite can be controlled effectively, using a combination of cultural practices and biological control.

Monitoring — Spider mite infestations in a crop are detected by routine examination of the leaves. As soon as the mites or their damage are found, predatory mites should be introduced at the appropriate rate. A damage-rating system has been devised in Britain. For successful control, only a few leaves in the greenhouse should be in damage indices 1 and 2 (*22.36T1*), and the average damage index should be much less than 1. Significant crop loss will occur at a mean damage index of 1.9, and a 40% loss can be expected five weeks after a damage index of 2.5. Growers who use predatory mites to control spider mites frequently tolerate localized areas of high damage, particularly if the predators are numerous, because the infestation usually collapses quickly.

Cultural practices — Sanitation is one of the most important cultural practices to prevent spider mite infestations in greenhouses. Weeds should be removed from the vicinity of the greenhouse and a 3-m-wide, weed-free zone should be maintained around the perimeter. Movement of equipment, people and plant material from infested to non- infested areas should be restricted. If spider mites are present on the crop at the end of the season, the crop should be treated with a fumigant miticide before removal. All crop residue should be removed and destroyed to prevent reinfestation of the greenhouse. Particular attention should be given to spider mite infestations late in the season. Control at that time will reduce the number of overwintered mites available to infest the greenhouse in the spring.

Biological control — The predatory mite *Phytoseiulus persimilis* Athias-Henriot (*22.36g*) is an effective biological control agent for the two-spotted spider mite, being widely used in all areas of Canada where greenhouse cucumber is grown. To ensure success, the predatory mite must be introduced when the prey population is low. Mites should be introduced on young plants at the rate of one predator per plant, plus weekly additions of one predator per infested leaf until predators are present on every infested leaf. On large plants, introductions should be on a weekly or biweekly basis at a rate of 10 predators per plant, plus 10 per infested leaf. Uniform distribution of the predator is important for control, which can be expected within five weeks after the initial introduction. The miticide fenbutatin-oxide does not harm the predatory mite.

Survival and reproduction of the predatory mite decline under hot, dry conditions. Otherwise, it has a short, one- week life cycle compared to the spider mite, which takes two weeks to mature. Thus, the number of predatory mites can increase to the point that they overtake and eliminate the spider mite from the greenhouse. Recurrence of spider mites should be monitored carefully, and predatory mites should be re-introduced if necessary.

Chemical control — Spider mite outbreaks can be controlled using miticides, but it is important to treat populations when their numbers are low. For effective chemical control, all leaf surfaces must be covered with the pesticide. If moderate to severe, localized outbreaks of spider mites occur after periods of hot, dry weather, then a miticide can be used prior to the re-introduction of predators.

The two-spotted spider mite has acquired extensive resistance to most miticides. Resistance varies from region to region and between greenhouses. The selection of miticides must be determined on a case-by-case basis.

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