24 Greenhouse pepper

FUNGAL DISEASES

▶ 24.1 Damping-off *Fig. 24.1*

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

Damping-off is common and can be severe where greenhouse hygiene is poor. It is more prevalent in soil-based media than in soilless mixes or rockwool. *Pythium* spp. and *R. solani* can attack many species of vegetable crops.

Symptoms Symptoms of damping-off of pepper are the same as those of greenhouse tomato. Pre-emergence damping-off has no above-ground symptoms,, as plants are killed before emerging. This problem usually is seen as well- defined areas in seedbeds and flats that are devoid of plants. Post-emergence damping-off is characterized by falling over of young seedlings *(24.1).* Occasionally, large groups of seedlings in beds or flats are killed. Older plants can also be attacked and may die if the disease is severe.

When attacked by *Pythium* spp., stems develop a wet, brown decay at the base; stems attacked by *R. solani* remain drier and are constricted and brown (wirestem symptom). Infected plants subsequently die.

Causal agents (see Bean, root rots, damping-off, seed decay, 15B.4; Beet, pythium and rhizoctonia root rots, 5.7, 5.8; and Carrot, cavity spot, 6.8, and pythium root dieback, 6.13)

Disease cycle (see Greenhouse tomato, damping-off, 25.7) *Pythium* species, the chief causal agents, are favored by prolonged cool, damp growing conditions, excess nitrogen in growing media, and overcrowding of seedlings.

Rhizoctonia solani can cause severe damping-off, wirestem and root rot of mature plants, especially in warm, moist, acidic growing media.

Management

Cultural practices — Growers should follow practices that favor rapid emergence and vigorous growth. Seedlings should be watered as lightly as possible in the morning so they can dry before the end of the day. They should be raised on benches with adequate ventilation and drainage. Seedlings in rockwool plugs or other soilless substrates should be kept on clean, disinfested benches, well away from the ground and water-splashed soil. They should never be below hanging baskets of ornamentals.

Chemical control — Growers should use pathogen-free or fungicide-treated seed and sow into growing media that have been disinfested by steam, chemical fumigation or incorporation of fungicides. Alternatively, inert growing media such as rockwool can be used. Further fungicide treatment of seedlings in the form of drenches may be useful.

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

▶ 24.2 Fusarium stem and fruit rot *Figs. 24.2a-c*

Fusarium solani (Mart.) Sacc.
(teleomorph *Nectria haematococca* Berk. & Broome)

In Canada, this disease was reported from pepper in commercial greenhouses in Ontario and British Columbia in 1991. Losses in fruit yield and plants were approximately 5%. *Fusarium solani* can attack a wide variety of plants including most greenhouse vegetables. Many physiologic races adapted to specific hosts have been recognized.

Symptoms Soft, dark brown or black lesions are formed on the stem, usually at nodes or wound sites *(24.2a).* These lesions may eventually develop orange to red spots, which are the fruiting bodies of the fungus *(24.2b).* Stem lesions can kill the plant. Pepper fruits *(24.2c)* may also develop black, water-soaked lesions beginning around the calyx. The lesions grow, coalesce and spread down the sides of the fruit. Copious mycelial growth of the pathogen occurs under humid conditions.

Causal agent *Fusarium solani* generally has single-celled, oval to kidney-shaped microconidia which vary from sparse to abundant. Macroconidia are abundant, stout, thick-walled and generally cylindrical. The dorsal and ventral surfaces are parallel for most of their length. The apical cell is blunt and rounded, or it is distinctly foot-shaped or notched. Conidiophores are unbranched but possess branched monophialides. Chlamydospores are formed singly or in pairs and are numerous.

On potato-dextrose agar, *F. solani* grows rapidly with abundant aerial mycelium. The agar surface quickly becomes covered with confluent sporodochia that give the appearance of pionnotes and color the surface cream, blue-green or blue but never orange. The undersurface is generally colorless but may be dark violet.

The pathogen is distinguished from *Fusarium oxysporum* by the morphology of the macroconidia, the elongate monophialides bearing microconidia, and the distinctive cream, blue-green or blue color of colonies on potato-dextrose agar. Some isolates form abundant perithecia in culture on potato-carrot agar, mostly on the sides of the petri dish.

Disease cycle *Fusarium solani* is an extremely common inhabitant of soils in Canada and is frequently saprophytic. It can invade pepper stems at the nodes or at the soil line, taking advantage of wounds created by pruning or salt damage. Rapidly growing, succulent crops are the most susceptible, as are ripening fruit compared to green fruit. Fruit that is damaged, especially around the calyx, is very susceptible to infection. The rot can continue in storage. Healthy, undamaged fruit is not usually attacked. Fallen or aborted fruit and senescent flowers may be colonized by the fungus.

Management

Cultural practices — Good crop hygiene and pruning by clean-cutting will help to control this disease. Diseased plants and fruit should be removed from the greenhouse and buried. If the disease is severe, the fruit should be picked at the green stage. Rockwool blocks should not be allowed to dry out at the top because damaging levels of evaporated fertilizer salts may accumulate around the stem base and thus favor infection. At the end of the growing season, greenhouses should be thoroughly cleaned and disinfested. If the crop was grown in soil, the beds should be disinfested. Soilless growing media should be discarded far away from the greenhouse or buried.

Selected references

Booth, C., and J.M. Waterston. 1964. *Fusarium solani*. CMI Descriptions of Pathogenic Fungi and Bacteria, No. 29. Commonw. Mycol. Inst., Kew, Surrey, England. 2 pp.

Nelson, P.E., T.A. Toussoun and W.F.O. Marasas. 1983. *Fusarium Species: An Illustrated Manual for Identification.* The Pennsylvania State University Press, University Park, Pennsylvania. 193 pp.

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

▶ 24.3 Gray mold *Figs. 25.12a-c*

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

Gray mold can infect leaves, stems and fruits of greenhouse pepper. It is widespread and can be severe in poorly managed greenhouses. It is not a problem where thorough hygiene and good cultural practices are observed. *Botrytis cinerea* can attack many plant species (see Lettuce, gray mold, 11.10).

Symptoms On greenhouse pepper, the first symptoms are often noticed when a lesion girdles the stem, which then collapses. The lesions are olive-green, sunken and soft with distinct margins. Leaf and stem lesions resemble those of gray mold on tomato

(25.12a-c). Infection can cause the entire fruit to rot, usually from the calyx end. The characteristic gray mold of the pathogen can develop on affected fruit, especially if the skin within a lesion is broken.

Causal agent (see Lettuce, gray mold, 11.10)

Disease cycle (see Lettuce, gray mold, 11.10). The fungus is favored by high humidity, invading the host through wounds in healthy tissue and through senescent tissue such as old flower parts.

Management (see Greenhouse tomato, gray mold, 25.12)

Cultural practices — Balancing heating and ventilation to maintain a relative humidity of 70 to 80% helps to prevent epidemics. It is essential to prevent dew forming on the plants, which should never be watered overhead. Gray mold is a disease of cool conditions (12 to 16°C), and thus adequate heat should be maintained without large fluctuations that cause dew to form. Crop residue should be removed and destroyed unless required for the survival of biocontrol agents, such as *Encarsia formosa* Gahan, a parasite of the greenhouse whitefly, in which case it should be kept dry to prevent colonization and sporulation of the fungus.

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

VIRAL DISEASES

▶ 24.4 Cucumber mosaic *Fig. 18.17*

Cucumber mosaic virus

Cucumber mosaic is a minor disease of greenhouse pepper, but has the potential to become a serious problem. The virus has a wide host range (see Greenhouse cucumber, cucumber mosaic, 22.20).

Symptoms Cucumber mosaic causes a severe mottling on pepper foliage, and older leaves may exhibit large, necrotic rings *(18.17)*. Fruit may be malformed, and conspicuous yellow, concentric rings or spots may occur on green fruit.

Causal agent (see Greenhouse cucumber, cucumber mosaic, 22.20)

Disease cycle (see Greenhouse tomato, cucumber mosaic, 25.18)

Management (see Greenhouse tomato, cucumber mosaic)

Selected references

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

(Original By J.G. Menzies)

▶ 24.5 Pepper mild mottle *Figs. 24.5a,b*

Pepper mild mottle virus

This disease occurs in virtually every country in the world where peppers are grown as a greenhouse crop. It was first observed in Canada on field-grown pepper in Richmond, British Columbia, in 1985. At the time, it was a minor problem. However, in 1990 it was detected in greenhouse pepper in British Columbia’s Fraser Valley and, in the course of the growing season, became a serious problem in three greenhouses. The estimated loss in the 1990 growing season was $1.2 million. The virus reappeared in a number of greenhouses in 1991, but the extent of losses is not known. British Columbia is the only province in which pepper mild mottle has been reported to date.

The virus systemically infects all *Capsicum* spp., including sweet peppers and hot peppers. Other species in the Solanaceae are susceptible, but not tomato or *Nicotiana glauca.*

Symptoms It is difficult to detect the disease in pepper foliage, because it causes a mild mottle that can be mistaken for other disorders. New growth shows more distinctive symptoms than older leaves *(24.5a)*. Interveinal yellowing, especially at the basal half of the leaf, mottling and growth reduction may be evident. The most conspicuous symptoms are on the fruits *(24.5b)*, which may have distinct bumps, pointed tips and chlorotic or necrotic depressed areas. Necrotic, depressed areas frequently occur in the crease at the calyx end.

Causal agent Pepper mild mottle virus is a member of the tobamovirus group. The virus particles appear identical to those of tobacco mosaic virus, the type member of the group. Pepper mild mottle virus is serologically related to several members of the tobamovirus group. It can be distinguished from other tobamoviruses that infect pepper on the basis of its serological reactions and its response when mechanically inoculated to a range of diagnostic indicator hosts. The virus multiplies in inoculated leaves of *Nicotiana tabacum* cv. Samsun and most tomato cultivars, but it does not become systemic. This distinguishes it from both tobacco mosaic virus and tomato mosaic virus.

Disease cycle The epidemiology depends to a large extent on the initial source of infection. Preliminary evidence in British Columbia indicates that the initial infection source may be contaminated or infected seed. This virus, like tomato mosaic virus, is seed-borne, either on the seed coat (contaminated) or in the endosperm (infected). Pepper mild mottle virus can be eradicated from the seed coat by treatment with acid, and virtually all sources of commercial pepper seed are treated with acid before distribution. However, a very small percentage of the seed harvested from an infected mother plant may carry the virus in a dormant state in the endosperm. This infection is not eradicated by seed treatment. The virus becomes systemic in seedlings arising from infected seed and such seedlings constitute a primary source of inoculum. Unless extreme care is used, one infected seedling in a flat could infect several seedlings at the time of transplanting. These, in turn, could be sources of secondary infection during the course of tending the crop from seedling to fruit production.

Once a disease outbreak has occurred in a greenhouse complex, the virus may survive for several months on plant debris and on the surface of equipment. In such instances, the primary infection source for a new crop may be surviving virus from the previous crop. It is speculated that pepper mild mottle virus could spread in water, which would be a concern where recirculating systems are used.

Management

Monitoring — Growers should inspect their plants at frequent intervals during the growing season and immediately rogue out any that are suspected of carrying the virus.

Cultural practices — Seed should be obtained from a reliable source. Seed producers are becoming aware of the problem and it is expected that virus-free seed will become available. Growers should not save their own seed unless the growing crop has been certified as free of the disease by an experienced advisor.

The fact that the virus may be seed-borne means that particular care should be taken at the transplanting stage. Seedlings should be sprayed with a skim milk solution a day before transplanting and workers should dip their hands in skim milk at frequent intervals during transplanting (see Greenhouse tomato, tobacco mosaic, 25.20). Care should be taken to minimize spread of the virus during growth of the crop. Any suspicious plants should be carefully removed from the greenhouse and employees should dip their hands in skim milk when working in those areas. All crop debris, growth bags and rooting media should be removed from the greenhouse at the end of the growing season. The entire greenhouse interior, including ceilings, walls, supports, wires and walkways should be pressure washed and scrubbed with a disinfestant such as quaternary ammonium.

Resistant cultivars — Sources of resistance have been identified, and it is anticipated that commercial cultivars that are resistant or immune to pepper mild mottle virus will be available within a few years. Cultivars with TM2 resistace, e.g. Samathan, Cubico and others, can become infected, but do not express symptoms unless infected when young or with high levels of the pathogen.

Selected references

Wetter, C., and C. Conti. 1988. Pepper mild mottle virus. AAB Descriptions of Plant Viruses, No. 330. Assoc. Appl. Biol., Wellesbourne, Warwick, U.K. 4 pp.

Stace-Smith, R., and G. Grant. 1990. Pepper mild mottle virus on green- house-grown peppers. *Phytopathology* 80:892. (Abstr.)

(Original by R. Stace-Smith and L.S. MacDonald)

24.6 Tobacco mosaic

Tobacco mosaic virus

This disease occurs on greenhouse pepper worldwide but is not common in Canada. Tobacco mosaic virus affects more than 150 plant genera, primarily herbaceous dicotyledons, including greenhouse tomato (see Greenhouse tomato, tobacco mosaic, 25.20; and Tomato, eggplant, pepper, tomato mosaic, 18.18).

Symptoms Symptoms vary with plant cultivar, virus strain and environmental conditions. The first symptoms on green-house pepper are necrosis along the main veins, with wilting and defoliation. Subsequent growth from lateral buds shows a mosaic and leaf distortion, but plants are rarely killed. Affected fruit is mottled and rough in appearance and, in severe cases, necrotic areas may occur on the surface.

Causal agent (see Greenhouse tomato, tobacco mosaic, 25.20)

Disease cycle (see Greenhouse tomato, tobacco mosaic)

Management

Cultural practices — Most of the control recommendations for greenhouse tomato (see Greenhouse tomato, tobacco mosaic) also can be applied to greenhouse pepper.

Resistant cultivars — Most cultivars of greenhouse pepper are susceptible to tobacco mosaic. However, a few resistant cultivars, including Cubico and Samantha, are available.

Selected references
Fletcher, J.T. 1963. Tobacco mosaic virus infection of sweet pepper. *Plant Pathol.* 12:113-114.
Zaitlin, M., and H.W. Israel. 1975. Tobacco Mosaic Virus (type strain). CMI/AAB Descriptions of Plant Viruses, No. 151. Commonw. Mycol. Inst./Assoc. Appl. Biol., Kew, Surrey, England. 6 pp.

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

24.7 Tomato mosaic

Tomato mosaic virus

Tomato mosaic is generally of minor importance in greenhouse pepper. This virus causes symptoms that resemble those caused by tobacco mosaic. Tomato mosaic virus also attacks greenhouse tomato (see Greenhouse tomato, tomato mosaic, 25.21). Laboratory tests are necessary to distinguish clearly between strains of tobacco mosaic and tomato mosaic viruses. Inoculations to indicator plants also help in the diagnosis.

Symptoms Symptoms vary with temperature, daylength, light intensity, plant age and cultivar. In general, pepper plants with tomato mosaic may show severe leaf necrosis and abscission, chronic mosaic and stunting.

Causal agent (see Greenhouse tomato, tomato mosaic, 25.21)

Disease cycle (see Greenhouse tomato, tomato mosaic)

Management Control of tomato mosaic in greenhouse pepper is similar to that in greenhouse tomato.

Cultural practices — Growers should use pathogen-free seed and apply seed treatments to kill the virus. Infected plants and crop residues should be removed, and strict sanitation practices observed.

Selected references
Hollings, M., and H. Huttinga. 1976. Tomato mosaic virus. CMI/AAB Descriptions of Plant Viruses, No. 56. Commonw. Mycol. Inst./Assoc. Appl. Biol., Kew, Surrey, England. 6 pp.
Pategas, K.G., A.C. Schuerer and C. Wetter. 1989. Management of tomato mosaic virus in hydroponically grown pepper *(Capsicum annuum). Plant Dis.* 73:570-573.

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

24.8 Tomato spotted wilt *Figs. 24.8a-c*

Tomato spotted wilt virus

This virus infects greenhouse pepper but it is not a widespread problem. It could be a serious threat to pepper crops if thrips were present, particularly the western flower thrips, which is the principal vector. Alternative hosts, including dahlias, impatiens and other ornamentals, are important sources of infection. Infected crops should be isolated and destroyed. This virus has a wide host range that includes many vegetables, ornamentals and weeds (see Greenhouse tomato, 25.22; and Tomato, eggplant, pepper, 18.19).

Symptoms Lesions surrounded by a black margin may form on stems of infected plants *(24.8a).* This may lead to branch dieback and a loss of leaders. Leaves *(24.8b)* may have blackish-brown, circular lesions or, more commonly, tan lesions surrounded by a black margin that resemble scorching damage from heating pipes. If plants are infected before fruit set, fruits develop unevenly and become misshapen. Orange, yellow or red spots surrounded by a dark green margin may develop on the fruit and may occur in ring patterns *(24.8c).* If fruits are infected after setting, ripening is uneven.

Causal agent (see Greenhouse tomato, 25.22)

Disease cycle (see Greenhouse tomato, 25.22)

Management The disease can be managed by monitoring for thrips and infected plants as early as possible. Vector control is the only way to limit disease spread, short of destroying the crop, and it is the only way to ensure that the disease is confined to the infested greenhouse.

Cultural practices — An infested greenhouse should not be used for pepper, tomato or any other susceptible crop until it has been thoroughly disinfested. Growers should remove and bury infected plants, including ornamentals, in and around the greenhouse. To eliminate reservoir hosts of both virus and thrips, a 3- to 6-metre-wide band around the perimeter of the greenhouse should be kept free of weeds. Weeds within greenhouses also should be controlled. Ornamental plants, particularly perennials, such as grapevines or oleander, and hanging baskets of annuals must not be grown near pepper crops. Sticky straps should be used to monitor thrips and control measures should be started at the first signs of this pest (see western flower thrips, 24.14).

Selected references
Ie, T.S. 1970. Tomato spotted wilt virus. CMI/AAB Descriptions of Plant Viruses, No. 39. Commonw. Mycol. Inst./Assoc. Appl. Biol., Kew, Surrey, England. 4 pp.

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

NON-INFECTIOUS DISEASES

▶ 24.9 Blossom-end rot *Figs. 24.9; 18.21c,d*

Blossom-end rot is a very common physiological disorder in greenhouse pepper and tomato (see Greenhouse tomato, blossom-end rot, 25.23). It is associated with environmental stress, especially drought, widely fluctuating moisture conditions, and calcium deficiency. Water-soaked spots, which later turn brown or black and become dry, firm or sunken, appear at or near the blossom-end of the fruit (*24.9; 18.21c,d*). Occasionally, discoloration may extend well into, or occur totally within, the fruit. Growers should avoid unnecessary stress on the plants by regular watering, ensuring that calcium uptake is adequate during fruiting. A soil test should be done before planting to determine whether adequate calcium will be available to the crop.

Selected references

Bradfield, E.G., and C.G. Guttridge. 1984. Effects of night-time humidity and nutrient solution concentration on the calcium content of tomato fruit. *Sei. Hortic.* 22:207-217.

(Original by R.J. Howard)

▶ 24.10 Sunscald *Fig. 18.29b*

Sunscald affects pepper fruits, especially those near maturity. Soft, bleached areas, which later become slightly sunken, develop on the exposed sides of the fruit *(18.29b)*. Growers should maintain adequate foliage to shade the fruit and provide supplementary shading or mist the plants with water during hot, sunny weather.

(Original by R.J. Howard)

NEMATODE PESTS

▶ 24.11 Northern root-knot nematode *Figs. 18.30; 25.26*

Meloidogyne hapla Chitwood

Symptoms Pepper, eggplant and tomato are very susceptible to damage from root-knot nematodes; damage includes stunting, chlorosis, early senescence, prolific branching of rootlets, and production of small, spherical galls on roots. Infected transplants may be a source of inoculum in greenhouses *(25.26)*. For a complete description, see Carrot, 6.20; see also Greenhouse tomato, 25.26; and Management of nematode pests, 3.12.

INSECT PESTS

▶ 24.12 Green peach aphid *Figs. 24.12a-e*

Myzus persicae (Sulzer)

This aphid (see Potato, 16.41) is an important pest of greenhouse pepper. It and other aphid species are difficult and expensive to control on greenhouse pepper, and relatively low numbers can cause economically important damage from the deposition of honeydew on fruit.

Outdoor hosts provide a source of wind-borne, winged forms (alates) of the green peach aphid, which may enter greenhouses through vents or other openings. Growers who overlap transplant production with the end of the previous crop often find that this aphid is well established on the new plants by the time they are set out. Clones of the aphid often continue to reproduce year-round.

Damage In greenhouse pepper, damage is worst under high intensity lights, and in the spring and fall when temperatures are moderate. High summer temperatures suppress aphid reproduction. High levels of soluble nitrogen in leaves may predispose the plants to aphid infestation, as does drought stress. Symptoms of aphid attack include honeydew accumulation, loss of blossoms and, in extreme infestations, defoliation of the plants. All aphid stages *(24.12a)* suck phloem sap, which weakens the plant. Severe infestations of more than 300 aphids per leaf *(24.12b)* result in leaf drop, high populations in flowers cause flowers to drop, and infestations on plant tips distort the growing leaves.

Honeydew becomes a nutrient source for sooty-mold fungi *(24.12e)*, which block light penetration, interrupt photosynthesis and lower fruit quality. On pepper fruit, economically important damage occurs from honeydew long before aphids directly damage the plants. Removing honeydew from the fruit involves extra handling by growers or packing houses, and fruit with sooty mold in the calyx may be rejected. If growers have to bear the cost of washing, virtually no honeydew is tolerated. If washing is part of the handling at packing houses, then honeydew is acceptable provided it can be washed off easily.

The green peach aphid is known to vector over 50 plant viruses but these have not been a problem in greenhouse pepper.

Identification Greenhouse populations of the green peach aphid (*24.12b*) sometimes appear pink or yellowish in the fall, although usually they are light green (see Potato, 16.41). Winged forms have a black or dark brown head and thorax, dark tips on the pair of abdominal projections (cornicles), and a dark central patch on the back of the abdomen. *Myzus nicotianae* Blackman, long regarded as a pink form of the green peach aphid in greenhouses, also attacks pepper.

Life history Green peach aphids mature 7 to 10 days after birth. They usually reach maximum reproductive rates five days later in the greenhouse, depending on the temperature, humidity and host plant. Average reproduction rate is three to four nymphs per day for approximately 20 days, yielding 50 to 100 offspring per female. Under springtime conditions of long days with warm but not excessively high temperatures, green peach aphid populations may increase 10- to 12- fold per week on greenhouse pepper crops. The populations usually occur as colonies of nymphs around a founding female on the underside of the oldest leaves, and on growing tips where movement of nutrients within the plant is greatest.

Management

Monitoring — Growers should start monitoring when the plants are small. Development of treatment thresholds in greenhouse pepper has been hampered by the generally patchy distribution of aphids in greenhouses. However, when aphid numbers exceed five per leaf *(24.12a),* honeydew accumulations begin to be economically important. A random weekly sample of one upper, one middle and one lower leaf from each of 60 plants per hectare, spaced evenly throughout the greenhouse, is suggested. The sample leaves should be individually bagged and aphids, predator eggs and larvae *(24.12d),* and unemerged parasite mummies (*24.12c*) counted later under magnification.

Biological control — Biological control of this aphid has been practiced in Canada since 1986 and is popular on greenhouse pepper crops. For best results, growers should combine low level, early releases of the parasitic wasp *Aphidius matricariae* Haliday *(3.7s; 24.12c*) with larger introductions of the predatory midge *Aphidoletes aphidimyza* (Rondani) *(24.12d)* when aphid populations start to increase quickly in March. The wasp should be released at a rate of one wasp per 20 plants as soon as the first aphid is seen, then weekly for two to three weeks. The midge should be released at a rate of one midge per small pepper plant, continued weekly for two to three weeks, when aphid populations exceed a mean of one aphid per lower leaf. On larger plants, or when aphids exceed three per leaf, releases should be increased to two midges per plant.

Chemical control — Effective control can be obtained with fumigants and sprays. Usually, treatments must be applied at three- to four-week intervals throughout the season.

Selected references

Gilkeson, L.A. 1990. Biological control of aphids in greenhouse sweet peppers and tomatoes. *IOBC WPRS Bull./Bull. OILB SROP* 13(5):64-70.

Meadow, R.W., W.C. Kelly and A.M. Shelton. 1985. Evaluation of *Aphidoletes aphidimyza* (Dip.:Cecidomyiidae) for control of *Myzus persicae* (Hom.:Aphididae) in greenhouse and field experiments in the United States. *Entomophaga* 30:385-392.

(Original by L.A. Gilkeson)

▶ 24.13 Pepper weevil *Figs. 24.13a-e*

Anthonomus eugenii Cano

The pepper weevil occurs in the southern United States, Mexico, Central America, and the West Indies. In Canada, it has been found on pepper fruit imported from Florida as recently as 1989-90. In 1992, and again in 1993, it was detected on a greenhouse pepper crop at Langley, British Columbia; however, its status as an established introduction in Canada is still open to question (see Foreign diseases and pests, 3.10).

Pepper cultivars with a thick mesocarp seem to be preferred, although all pepper species and cultivars are susceptible. Besides pepper, host plants include eggplant and other *Solanum* spp. In its native range, the nightshades and burs *Solanum americanum* Mill., *S. pseudogracile* Heiser, *S. carolinense* L., *S. nigrum* L., and *S. rostratum* Dunal are particularly important as overwintering hosts. The last two species also occur in western Canada and could be important as alternative hosts. Potato and tomato are fed upon by adults, but eggs apparently are not laid in the flowers or fruit of these plants.

Damage Adult pepper weevils feed on leaves *(24.13a)* and blossoms, and adults and larvae both bore into young fruit pods and feed among the seeds *(24.13c).* Fruit pods *(24.13b)* become discolored and usually abort after withering at the stem and/or calyx. Seeds in young pods fail to mature, are brown in color, and become withered. Although the adult weevil prefers to lay its eggs in young fruit pods, near-mature fruits also may be attacked. These will reach full ripeness but will contain weevil droppings (frass) and areas of decaying tissue.

Life history Eggs are laid in punctures made by the adults in flower buds or young fruit pods. After hatching, which occurs in three to five days, larvae bore into and feed on tissue within the developing fruit pod. They mature in 13 to 17 days, and pupate in the fruit pod in chambers lined with silk *(24.13d).* Adults *(24.13e)* emerge after a further three to six days. Larvae, pupae and adults may overwinter inside the infested fruit pod. The time to complete one generation ranges from 2 weeks under hot conditions to 6 weeks under cold conditions. There may be many generations a year. Adults are attracted to yellow, and adult males emit a pheromone that is attractive to the adult females.

Identification The pepper weevil (family Curculionidae) adult is 2.5 to 3.1 mm long and pale reddish brown to black, with shiny, gray or yellowish, scale-like hairs (setae) that impart a brassy pubescence. The snout (rostrum) is longer than the head and thorax combined, or about half as long as the body. Larvae are legless, white with a pale brown head, and about 4 mm long at maturity. The adult is winged and can fly.

Management ***Monitoring*** — Yellow traps alone are useful for monitoring populations in greenhouses.

Cultural practices — Sanitation is an effective control method for this pest because larvae and pupae are mostly inside the aborted flower buds and fruit. Growers should remove all aborted buds and fallen or infected fruit from the greenhouse every day and destroy them. The male pheromone may be available commercially; otherwise, yellow traps can be baited with adult male weevils to catch females, which then can be destroyed. Another practical strategy for use in some greenhouses and in some parts of Canada is to remove all plant residue from the greenhouse at the end of the cropping cycle and allow the temperature to drop below 0°C for several days during the winter. Where temperatures do not drop below freezing, or where mechanical or cultural factors preclude allowing the interior of the greenhouse to freeze, the greenhouse should be maintained at 25°C and as dry as possible for 5 to 7 days. Yellow sticky traps should be used to monitor adult weevils to ensure they are no longer present in the affected greenhouse, and cucumber or other non-host greenhouse crop should be grown in the next cropping cycle instead of pepper. All solanaceous weeds inside and on the outside perimeter of greenhouses must be removed.

Chemical control — No pesticides are registered against the pepper weevil in Canada.

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Riley, D.G. 1992. The pepper weevil and its management. Texas A&M University, Agricultural Extension Service. *Pest Leaflet. 4* pp.

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

▶ 24.14 Western flower thrips *Figs. 24.14a-d; 18.42i*

Frankliniella occidentalis (Pergande)

The western flower thrips (see Greenhouse cucumber, 22.34) is a major pest of greenhouse pepper wherever it is grown. This thrips can directly damage the fruit or indirectly decrease yield by reducing the photosynthetic capacity of the plant. A predatory mite has been used successfully to control this thrips on the majority of the greenhouse pepper acreage in British Columbia.

Damage The western flower thrips may occur on pepper crops any time after transplanting. In general, symptoms are similar to those on greenhouse cucumber. However, because the adult and immature thrips feed on pollen, which is a food source that is available on pepper but not on cucumber, they are found in large numbers on pepper flowers and fruit. Feeding scars often are apparent at the calyx end of pepper fruit and on the fruit itself (*18.421*). On developing fruit *(24.14b),* adult and immature thrips feed under the calyx, causing the ends of the calyx to turn up and exposing the pepper fruit to bacterial infection. Egg-laying scars occur on leaves (*24.14d)* and on fruit, on which "ghost" spotting *(24.14c)* also may occur where thrips eggs have hatched. Feeding by the thrips upon the growing tip of plants also deforms the leaves *(24.14a).*

The western flower thrips is an important vector of tomato spotted wilt virus in greenhouse pepper.

Identification (see Greenhouse cucumber)

Life history (see Greenhouse cucumber, 22.34)

Management

Cultural practices — (see Greenhouse cucumber, 22.34) The application of effective cultural practices is very important in preventing outbreaks of the western flower thrips on greenhouse pepper.

Monitoring — Growers should start monitoring for thrips when pepper is transplanted into the greenhouse. The western flower thrips can be monitored on greenhouse pepper with the same blue or yellow sticky traps *(3.7t)* discussed under greenhouse cucumber. Blue sticky traps are preferred in pepper crops because yellow traps catch high numbers of the parasitic wasp *Aphidius matricariae* Haliday, thereby interfering with the biological control of aphids (see green peach aphid, 24.12). The first detection of thrips is an appropriate time to implement biological control.

Biological control — A predatory mite *Amblyseius* (syn. *Neoseiulus) cucumeris* Oudemans is available commercially for control of western flower thrips. On greenhouse pepper, the mite should be introduced at the first detection of the thrips. Usually, only two or three releases are necessary.

To achieve thrips control on greenhouse pepper, about 10 mites per plant are necessary (fewer than for greenhouse cucumber). The mite is able to survive and increase in the absence of thrips because it also feeds on pepper pollen. Pollen feeding by the mite does not interfere with pepper pollination. If thrips control is desired during September to March, more frequent introductions of A. *cucumeris* may be necessary because subsequent generations of mites will enter into a state of arrested development (diapause).

The minute pirate bugs *(22.34i) Orius tristicolor* (White) and *O. insidiosus* (Say) also control western flower thrips on greenhouse pepper. Both species are available commercially and will provide adequate control when introduced at the rate of one bug per plant.

Chemical control — The value of chemical control is questionable because of extensive insecticide resistance in the western flower thrips. Most populations of the western flower thrips seem to have varying degrees of resistance to all chemicals used for thrips control on greenhouse vegetables. However, effective control may be obtained by spacing insecticidal treatments at approximately four-day intervals, repeated two or three times if and when thrips become too abundant. Fogging and other fumigant methods work best for adult and immature thrips in blossoms and on growing tips. Ground applications are the only way to control the pre- pupal and pupal stages.

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

▶ 24.15 Other insect pests

Caterpillars (loopers and other caterpillars)
Leafminers
  Chrysanthemum leafminer *Liriomyza trifolii* (Burgess)
  Vegetable leafminer *Liriomyza sativae* Blanchard
Melon (cotton) aphid *Aphis gossypii* Glover
Onion thrips *Thrips tabaci* Lindeman
Plant bugs *Lygus* spp.

For information on these pests, which occur sporadically on greenhouse pepper in Canada, see Greenhouse cucumber, 22.33; 22.35, and Greenhouse tomato, 25.28, 25.29.

MITE PESTS

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

Tetranychus urticae Koch

The two-spotted spider mite (see Greenhouse cucumber, 22.36) occurs in Canada wherever greenhouse pepper is grown.

Damage The two-spotted spider mite is a common pest of greenhouse pepper and, if uncontrolled, can cause serious damage to the crop. Symptoms are much the same as on greenhouse cucumber (*22.36a-f)* but early infestations and leaf damage on pepper are hard to detect. Unlike in cucumber, severe outbreaks do not kill pepper plants but may result in a significant decline in yield.

Management Control in greenhouses involves a combination of cultural practices and biological control because no pesticides are registered for use on greenhouse pepper in Canada.

Monitoring — The system described for greenhouse cucumber can be used, but comprehensive action thresholds have not been developed for greenhouse pepper.

Biological control — The two-spotted spider mite can be controlled effectively by the predatory mite *Phytoseiulus persimilis* Athias-Henriot (*22.36g*). (For the rate of introduction and timing of releases, of the predatory mite, see Greenhouse cucumber, two-spotted spider mite, 22.36).

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

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