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BACTERIAL DISEASES

▶ 18.1 Bacterial canker *Figs. 18.1 a-c*

Clavibacter michiganensis subsp. *michiganensis* (E.F. Smith) Davis *et al.*
(syn. *Corynebacterium michiganense* (E.F. Smith) Jensen)

Bacterial canker is encountered in the field and greenhouse (see Greenhouse tomato, bacterial canker, 25.1), occasionally causing considerable damage. Tomato is the major crop affected by this disease.

Symptoms Bacterial canker symptoms in field tomato vary dramatically from those observed in the greenhouse (see Greenhouse tomato, bacterial canker, 25.1). Primary or systemic infections from seed or clipped tomato seedlings cause the greatest level of plant loss, whereas secondary infection causes fruit lesions and a foliar "firing" or blight phase observed later in the season. Transplants may not express symptoms until six to eight weeks after infection. Initial symptom expression is accelerated by environmental stress. Diseased plants are stunted, vascular tissues discolor, open stem cankers become visible, and considerable plant mortality can occur. Transplants brought into Canada from the southern United States may show dark brown necrotic tissue at the site of clipping wounds. These wounds often extend deep into the stem tissue and may act as infection sites. A characteristic symptom of canker in field tomato is brown to black leaf margins with a thin, yellow, chlorotic band *(18.1a).* A necrotic peppering can be observed under the calyx scar by detaching the young tomato fruit. Stem nodes often appear puffy white at spots where the bacteria and its toxin accumulate. When stems are split lengthwise, a thin, light reddish-brown area usually can be seen within the vascular tissue *(18.1b).* This discoloration is most noticeable just above the soil line. Movement of bacteria into the fruit produces internal breakdown, with yellow to brown cavities extending into the seed cavity and eventually to the seeds. Positive identification of canker can be made in the field when "bird's-eye" spots are observed on the fruit *(18.1c).* These are relatively small, 2 mm diameter spots with minute light brown centers generally surrounded by a characteristic snow-white halo.

Early symptoms of bacterial spot on the fruit include a whitish, mottled lesion *(18.1c),* which then turns a characteristic corky black. However, bacterial canker does not produce the black spot phase on the leaves that is characteristic of the bacterial spot disease.

Bacterial canker can be misdiagnosed as bacterial wilt, which can have similar foliar wilt symptoms. The vascular browning, however, is more intense in bacterial wilt, moving into the pith and progressing further down into the stem below ground.

Causal agent (see Greenhouse tomato, bacterial canker, 25.1)

Disease cycle (see Greenhouse tomato, bacterial canker) The pathogen may survive in non-decomposed tomato crop residues in the field and on seed for up to five years. Infested seed is the main means of long-distance dispersal. The bacterium is easily spread within fields by splashing water, handling of infected plants and other cultural operations. It infects the host through wounds on leaves, broken trichomes or directly through leaf edge hydathodes and stomata. When tomato transplants are grown under field conditions in the southern United States, the mechanical clipping operation used to produce a shorter, sturdier plant often spreads the bacteria throughout the production beds. This results in many symptomless infected plants being shipped north. Within four to five weeks in Canadian fields, these plants begin to show canker symptoms. Increasing levels of nitrate nitrogen and decreasing levels of calcium have been shown to increase disease severity. Warm (24 to 32°C), wet weather favors pathogen spread and disease development.

Management

Cultural practices — The use of disease- free seed is the most effective management strategy. Proper fermentation during seed extraction is important because this process will control seed-borne bacterial pathogens. Acids, bleach or hot water can be used to disinfest seed of questionable status (see Greenhouse tomato, bacterial canker). The increasing use of locally grown greenhouse transplants has led to a reduction in canker incidence compared to the use of imported material.

Resistant cultivars — Sources of genetic resistance are being used in several breeding programs.

Chemical control — Copper-based bactericides have not been useful in controlling canker in field tomato.

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(Original by R.E. Pitblado and L.M. Tarder)

▶ 18.2 Bacterial soft rot *Fig. 18.2*

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

Bacterial soft rot can cause the complete collapse of fruit, but more commonly it reduces fruit marketability by causing a slimy rot. This disease occurs more frequently on pepper and eggplant than on tomato. The pathogen has a wide host range that includes many vegetable crops (see Potato, bacterial soft rot, 16.2).

Symptoms Stem and fruit wounds are initial sites of infection. Rot progresses into the stem and, in time, invades the fruit. The entire fruit fills with a watery, soft, slimy mass that is kept intact by the thin outer skin *(18.2).* When the skin breaks, the fruit collapses and dries into a shrivelled wrinkled mass. In pepper, the fruit stem (peduncle) initially discolors and several small dark lesions develop that later turn slimy See also Greenhouse tomato, bacterial stem rot, 25.3.

Causal agent (see Potato, bacterial soft rot, 16.2)

Disease cycle Soft rot bacteria are native inhabitants of field soils. Splashing rain carries them from the soil to the foliage where, under moist conditions, a rapid build-up of bacterial populations can occur. The bacteria can enter fruit through cuts, breaks, insect damage and abrasion. Frequently, a high incidence of soft rot is associated with harvesting during rainy periods and with washing the fruit after harvest. Moisture increases the susceptibility of fruit to the bacteria, which can enter the newly broken fruit stems at harvest as well as through other wounds.

Management

Cultural practices — Bacterial populations in soil often are high after crops of potato or cabbage; therefore, growers should avoid planting eggplant and pepper after those crops, rotating instead with crops such as bean, corn and soybean. It is best to harvest during dry weather and to minimize fruit injury at harvest. Fruit should be kept cool and dry during packing and storage. Prevention of insect wounds, such as those caused by the European corn borer, also is important.

Chemical control — Chlorination may help to eliminate soft rot bacteria from wash water and it reduces the risk of infection during washing. However, it does not arrest soft rot development in fruit infected before washing. Growers and packers should consult the Health Protection Branch, Health Canada, for guidelines on chlorinating vegetable wash water.

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(Original by R.E. Pitblado)

▶ 18.3 Bacterial speck *Figs. 18.3a,b*

Pseudomonas syringae pv. *tomato* (Okabe) Young *et al.*

This disease affects both greenhouse tomato and field tomato and can be particularly serious in wholepack and fresh-market crops. Tomato is the only known horticultural crop affected by bacterial speck.

Symptoms Symptoms may occur on the leaves, stems and fruit. On the leaves, tiny black specks, generally no more than 2 mm in diameter, appear first and are soon surrounded by a yellowish halo *(18.3a).* When numerous, the chlorotic areas can merge, giving the appearance of early blight. Affected leaflets become distorted, shrivel and fall off, thereby exposing the fruit to sunscald. Small black specks can also be seen on the fruit *(18.3b).* On green fruit, they are sometimes slightly raised, rough to the touch and surrounded by a narrow, green to yellow halo. Only green fruit is infected; the pH of skin tissue on green fruit is about 6.3, whereas on ripe fruit it is 5.2, which is too low to support bacterial growth. Once green fruit is infected, black lesions remain and are observed on red fruit late in the season. The tissue around the specks is slow to ripen and remains green longer. The same symptoms can also develop on the stems, but this is less characteristic. Fruit affected by bacterial speck is not acceptable for fresh market because of its appearance, nor for wholepack processing because it peels poorly, resulting in visible remains of specks and skin pieces (“tags”) on canned tomatoes as well as in the juice. This extraneous material lowers product quality.

Causal agent *Pseudomonas syringae* pv. *tomato* is an aerobic. Gram-negative, rod-shaped bacterium, measuring approximately 0.83 by 2.2 pm, with one to three flagella. Colonies produce a fluorescent green pigment on King's B medium in culture. This bacterium can be distinguished from other fluorescent pseudomonads by biochemical and physiological tests. It is negative for oxidase reaction and arginine dihydrolase. It is positive for levan production and ß-glucosidase activity. It utilizes D(-)tartrate but not erythritol or DL-lactate as sole carbon sources. It produces a hypersensitive reaction when infiltrated into tobacco at high concentrations (10^8 cfu/mL).

Disease cycle The pathogen is disseminated on seed, transplants and through infested crop residues. In cool (18 to 24°C), rainy weather, the bacteria multiply rapidly in infected plants. Through splashing water and cultural operations, such as picking, weeding, spraying and pruning, the bacteria are spread from infected to healthy plants. They can persist in the soil on infected plant material until it completely decomposes. The pathogen can also survive on seed. The main source of contamination in Canada, however, is from transplants imported from the United States. Transplants often appear healthy upon arrival, but harbor *Pseudomonas* bacteria that can develop later under cool, wet conditions.

Management

Cultural practices — The most important management strategy is to use disease-free seed. Proper fermentation and hot water, bleach or acid treatments all serve to disinfest contaminated seed (see Greenhouse tomato, bacterial canker, 25.1). In the case of transplants, it is important to purchase disease-free seedlings of known origin and to avoid clipping the seedlings to minimize secondary spread of the bacteria. Strict water management practices in local greenhouse-grown transplants significantly reduce the spread of the disease, delaying its appearance in the field. Growers should avoid working in fields when foliage is wet. If overhead irrigation is necessary, it should begin early in the day so that foliage can dry before evening. A two-year crop rotation is suggested to allow infested residues to decompose before tomato is planted again.

Resistant cultivars — Along with the discovery of the single, dominant Pto-gene, found in the breeding line ONT 7710, other sources of genetic resistance have been incorporated into many Canadian processing tomato cultivars.

Chemical control — Protective sprays of bactericides, such as copper compounds, are recommended only at the transplant seedling stage. Once tomato plants are transplanted in the field, effective control of bacterial speck is difficult to achieve using chemicals.

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(Original by R.E. Pitblado and L.M. Tartier)

▶ 18.4 Bacterial spot *Figs. 18.4a-f*

Xanthomonas campestris pv. *vesicatoria* (Doidge) Dye

Bacterial spot is a special problem for processors of wholepack tomatoes because infected fruit is difficult to peel. In field pepper, it is usually the most common and damaging disease. Tomato and pepper are the main crops affected by this disease.

Symptoms Symptoms can appear on the leaves, stems and fruit. On the leaves and stems of tomato, the first symptoms are black, circular spots, about 1 mm in diameter, surrounded by a yellow halo. These spots may be indistinguishable from those caused by bacterial speck. When the spots are numerous, they cause the foliage to dry up and are often misidentified as early blight. On the fruit, the first symptoms are small, dark brown to black raised spots *(18.4a),* which are sometimes surrounded by a greasy-looking white halo that is often mistaken for bacterial canker bird's-eye spotting. The spots increase to 4 to 5 mm in diameter, which is two to three times larger than those of bacterial speck, and become scabby. Spots eventually develop a corky appearance and their centers turn gray or brown (*18.4b,c*).

In pepper, foliar symptoms of bacterial spot are slightly different from those in tomato. Lesions turn dark brown to black with a pale tan central area (*18.4d,e*), giving the foliage a shot-hole appearance. Advanced symptoms show an irregular blighting throughout the leaf canopy. When spots are numerous, entire leaves may drop off. Fruit spots (*18.4f)* have a brown to black, raised, wart-like appearance similar to that observed on tomato. Secondary fruit rots may develop around the spots during damp weather.

Causal agent *Xanthomonas campestris* pv. *vesicatoria* is an aerobic, Gram-negative, rod-shaped bacterium measuring approximately 0.85 by 2.2 µm with one polar flagellum. It exhibits slow, viscous growth on nutrient or yeast extract-dextrose-calcium carbonate agar and has wet, shining yellow colonies. The bacterium produces acid but no gas from arabinose, glucose, sucrose, galactate, trehalose, cellobiose and fructose. Starch hydrolysis is variable. Pepper and tomato pathotypes of the pathogen have been described.

Disease cycle The bacterial spot pathogen has a higher optimum temperature (24 to 30°C) than does the bacterium that causes speck. Both organisms are spread rapidly from plant to plant by splashing water and by mechanical means. *Xanthomonas* bacteria survive in the soil on non-decom- posed plant residues and on seed from infected plants. The main source of infestation in Canada, however, is transplants imported from the United States.

Management

Cultural practices — Prevention of bacterial spot requires the use of the same methods of seed disinfestation as those recommended for bacterial canker (see Greenhouse tomato, bacterial canker, 25.1). Lowering the relative humidity, coupled with strict water management in locally grown plug-transplant greenhouses, retards disease development. Growers should avoid following pepper with tomato crops and *vice versa.* In addition to reducing contamination from one crop to another, tomato and pepper should not be grown in the same greenhouse.

Resistant cultivars — A low degree of field resistance has been identified, but high levels of resistance have not been incorporated into commercial cultivars.

Chemical control — Copper-based bactericides are available, but their effectiveness is limited because they kill only those bacteria on leaf surfaces. These products have given some control in fresh-market tomato crops, but spraying is not recommended for processing crops production. Spray intervals beyond four days are ineffective. Copper-resistant strains of *Xanthomonas campestris* have been detected in some areas.

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(Original by L.M. Tartier and R.E. Pitblado)

▶ 18.5 Bacterial wilt (brown rot, southern bacterial wilt)

Pseudomonas solanacearum (E.F. Smith) E.F. Smith

Bacterial wilt affects chiefly tomato crops in the southern United States, but some Canadian growers have experienced losses after using infected imported transplants. This disease can also affect pepper and eggplant. The pathogen is capable of attacking more than 200 species of plants in 33 families.

Symptoms Canadian growers usually notice leaf wilting within five weeks after transplanting plants from the southern United States, with the eventual collapse and death of infected plants. Field symptoms can be confused with those of bacterial canker, but a distinguishing symptom is the extensive vascular and internal discoloration in the lower stem associated with bacterial wilt. Infected plants exhibit dark vascular browning that extends into the cortical or pith regions and sometimes deep into the below-ground part of the stem. Most infected transplants die within two weeks, beyond which no further loss occurs. When infected stems or roots are cut crosswise and squeezed firmly, a gray to yellowish ooze appears. This disease can be distinguished from other wilts by placing an infected stem section in a glass of water. If bacterial wilt is present, a milky stream flows from the cut surface within five minutes.

Causal agent *Pseudomonas solanacearum* is an aerobic, Gram-negative, rod-shaped bacterium measuring approximately 0.6 by 1.7 pm with one to four polar flagella. All strains except those from banana and other musaceous hosts produce a dark brown diffusable pigment on a variety of agar media containing tyrosine. The pathogen is catalase- and oxidasepositive and forms nitrites from nitrates. It is a nonfluorescent pseudomonad. The pathogen is negative for levan production, starch hydrolysis, indole production, hydrogen sulfide and aesculin hydrolysis.

Disease cycle *Pseudomonas solanacearum* occurs throughout the world in areas with warm climates. Infection and disease development are favored by high temperatures (optimum 30 to 35°C) and high moisture. It survives in infested soil and crop residues, is seed-borne and can be found in numerous weed hosts. The bacteria do not survive in the field in Canada, but may persist in greenhouses. The disease quickly spreads within the cortex and pith of an infected plant, eventually causing death. In Canada, bacterial wilt has not been observed to spread in the field beyond initially infected plants.

Management

Cultural practices — Since the disease does not appear to spread in the field, it is self-eliminating and no control measures are warranted. Growers should use disease-free transplants and preferably those grown in local greenhouses.

Selected references

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(Original by R.E. Pitblado)

FUNGAL DISEASES

▶ 18.6 Anthracnose *Figs. 18.6a-c*

Colletotrichum coccodes (Wahr.) Hughes
(syn. *Colletotrichum atramentarium* (Berk. & Broome) Traub.)

Anthracnose is a major disease of ripe tomato fruit and can be especially serious for processors because it affects the taste of wholepack tomatoes, tomato juice and concentrate. Machine-harvested tomatoes are at the greatest risk because ripe fruit is held in the field longer for once-over mechanical harvesting. This disease also affects eggplant, pepper and potato (see Potato, black dot, 16.6).

Symptoms The most noticeable symptoms occur on ripe fruit. Small, circular, sunken spots appear at first, gradually expanding to about 20 mm in diameter (*18.6a,b*). Lesions formed by *Colletotrichum coccodes* are usually characterized by numerous, submerged, black microsclerotia which often form in concentric rings. When spots are numerous, they can merge and affect large areas of the fruit. Under humid conditions, the centers of these spots darken due to the development of hairs (setae) on the fruiting bodies of the pathogen *(18.6c)*. Pink gelatinous masses of conidia ooze from these sunken lesions, which often crack, allowing secondary organisms to invade and cause soft rot. Green fruit also can be infected but the symptoms may not appear until just before or more usually after harvest. Thus, this latent infection can be more serious than its appearance at harvest would indicate. Since infection results from spores present on plant residues, the side of the fruit touching the soil is more commonly infected and develops the greatest number of lesions. Tiny spots also may appear on the stems and leaves. Such spots are usually overlooked, but they often act as the initial source of inoculum that will infect the fruit once it has ripened.

Causal agent *Colletotrichum coccodes* has cylindrical-allantoid, one- celled, biguttulate hyaline conidia with rounded ends that measure 4 by 16 to 24 µm. In mass the conidia within the fruiting bodies (acervuli) appear pinkish. Black, straight or curved, septate setae, 65 to 112 µm long, are usually, but not invariably, present on the acervuli. Numerous, small, black microsclerotia about 0.5 mm in diameter form both on fruit and in culture. The fungus is readily isolated from diseased fruit on potato-dextrose agar.

Disease cycle Many common weeds and crop plants serve as symptomless hosts for *C. coccodes.* Weed tissue containing sclerotia could act as a source of primary inoculum for subsequent seasons or as a source of secondary inoculum during the current growing season. The fungus survives as microsclerotia from season to season on seed and in plant debris from infected crops. Microsclerotia can produce both hyphae and conidia. Soil- borne microsclerotia and conidia can be splashed onto foliage and fruit where appressoria are formed, with the infection peg penetrating the fruit cuticle. The pathogen penetrates green fruit and stems and remains latent until these tissues begin to mature. Leaf infection and some fruit infection takes place by at least mid-July in southern Ontario, depending on the weather. Conditions that favor plant infection are temperatures from 10 to 30°C (with an optimum of 20 to 24°C), together with free moisture. Splashing water and extended periods of leaf and fruit wetness encourage the spread and development of anthracnose. The longer the period of free moisture on tomato fruit the greater the disease severity. The fungus can also enter through wounds caused by sand blasting or other diseases, such as early blight.

Management

Cultural practices — Growers should use disease-free, fungicide-treated seed or seed that has been disinfested (see bacterial canker, 18.1). Infested crop residues may take three years to decompose completely. Keep fields free of weeds. Uncontrolled weed populations can support increased inoculum levels between rotations. Tomato crops should be rotated with non-solanaceous crops. Field sorting will lower the percentage of defects delivered to processors.

Resistant cultivars — Sources of resistance exist and promising new tomato cultivars are being evaluated but many are small-fruited and late maturing.

Chemical control — Registered fungicides are available. A weather-timed fungicide spray program called TOM- CAST is available to assist growers in scheduling sprays (see early blight, 18.8).

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(Original by L.M. Tarder and R.E. Pitblado)

▶ 18.7 Damping-off *Fig. 25.7*

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

Damping-off (see Greenhouse tomato, damping-off, 25.7) can be a serious problem in newly seeded or transplanted tomato, pepper and eggplant crops. The effect of this disease has been significantly reduced in commercial production with the introduction of plug transplants. With proper water management and the use of disease-free, soilless mixtures, damping-off has almost been eliminated as a production concern. However, the collar rot phase of damping- off remains a problem in hydroponically grown transplants.

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(Original by R.E. Pitblado)

▶ 18.8 Early blight (target spot) alternaria fruit rot *Figs. 18.8a-g; 25.9a,b*

Alternaria solani Sorauer
Alternaria alternata (Fr.:Fr.) Keissl.

Early blight can cause serious defoliation of tomato crops. It is often associated with septoria leaf spot, and these two fungal diseases, either separately or together, are responsible for most of the defoliation caused by diseases in field tomato crops in Canada. The pathogen also infects potato (see Potato, early blight, 16.8) and solanaceous weeds. Pepper and eggplant are rarely affected. See also Greenhouse tomato, early blight, 25.9.

Symptoms Early blight can affect all above-ground plant parts throughout the growing season. In unusual cases, a collar rot can girdle the base of the stem at the time of emergence. In greenhouse plug production of seedlings, a stem blight phase with black, elongate lesions on the stems is often noted under hot, moist growing conditions. Early blight is more commonly known as a leaf spotting or foliar blight disease *(18.8a).* Initially, the small circular spots have characteristic dark concentric rings (target spots) *(18.8b, 25.9a).* The spots later become irregular in shape, and affect both the central portion and the edges of the tomato leaf. Early blight lesions produce a characteristic yellow blighted area around the dead tissue similar to the spring symptoms of bacterial speck and bacterial spot under especially dry soil conditions. Spots first appear on the older leaves, progressing upward to the new growth. This disease may be confused with septoria leaf spot *(25.9b),* the lesions of which also produce a black wavy appearance somewhat similar to the concentric rings of early blight. However, septoria lesions have a lighter tan center with pycnidia therein, giving a black-dot appearance under magnification. Under conditions of extended leaf wetness and high temperatures, tomato plants can be completely defoliated by early blight, thereby exposing fruit to sunscald and anthracnose while reducing yield. Brown concentric circles are also found on stems and flower parts. On fruit, symptoms are common when extended wet periods occur at harvest. A blackened area, similar in appearance to blossom- end rot, can develop at the stem end of the fruit *(18.8c).* Dark, leathery sunken areas *(18.8d-g)* occasionally form around wounds or fruit cracks.

Causal agent (see Potato, early blight, 16.8) In addition to *Alternaria solani, A. alternata* is often isolated from typical early blight lesions, especially on fruit. Conidia of the two species differ in morphology and length (see Greenhouse tomato, early blight, 25.9).

Disease cycle (see Potato, early blight) The pathogen survives between crops mainly in diseased plant residues. Spores can be carried for several kilometres by the wind. The early blight fungus also can be seed-borne in tomato. Its relatively short disease cycle allows for numerous, repeated infections, resulting in rapid defoliation under favorable conditions. Plant susceptibility increases with age, heavy fruit load and inadequate nutrition. *Alternaria alternata* is a weakly virulent pathogen that typically infects wounded or senescent tissues. It is sometimes found in early blight lesions on tomato leaves and fruit. In addition, it is known to colonize tissues damaged by frost, growth cracks, sunscalded areas, and wounds caused by mechanical injury, chemical phytotoxicity or other diseases on both green and ripe fruit. The fungus is able to grow through exposed epidermal layers, resulting in small black lesions. In time, even during cold storage, these lesions may coalesce and cover large areas of the fruit, especially on the shoulders. Diseases caused by *Alternaria alternata* are often referred to as black shoulder, black mold rot or alternaria fruit rot *(18.8f,g).* The general environmental conditions favoring infection and disease development on tomato are the same as for potato.

Management

Cultural practices — Control can be achieved by extending crop rotations to three or four years, using disease-free transplants, minimizing plant injury, and maintaining plant vigor. When irrigation is required, morning watering will allow the leaves to dry before a new dew period begins in the evening.

Resistant cultivars — Varying levels of genetic resistance exist among currently grown field cultivars. HY 9478, Malinta and Medalist are tolerant to early blights.

Chemical control — Properly timed foliar fungicides are effective in reducing losses caused by early blight. TOM- CAST, a weather-timed fungicide spray program, is available to commercial tomato growers to help determine when applications are warranted. Daily disease severity values (DSV) are calculated from surface wetness and temperature data. Fungicide sprays are recommended only when specified accumulated DSVs have been reached.

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(Original by R.E. Pitblado and R.J. Howard)

▶ 18.9 Fusarium crown and root rot *Figs. 25. 10a d*

Fusarium oxysporum f. sp. *radicis-lycopersici* W.R. Jarvis & Shoemaker

Fusarium crown and root rot is primarily a disease of greenhouse tomato (see Greenhouse tomato, fusarium crown and root rot, 25.10), but it also has been reported in field tomato in Ontario. Fusarium crown and root rot contamination of seedling tomato has occurred where tomato and pepper seedlings have been grown in close proximity to or within the same greenhouse complex as full-season greenhouse tomato production. Growers should avoid this practice. The use of soilless mixtures in seedling trays placed on racks above the soil surface lessens the opportunities for fusarium crown and root rot infection. Piles of crop residues are an important source of spores of the pathogen and should be eliminated.

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(Original by R.E. Pitblado)

▶ 18.10 Fusarium wilt *Figs. 25.11a-c*

Fusarium oxysporum f. sp. *lycopersici* (Sacc.) W.C. Snyd. & H.N. Hans.

Fusarium wilt (see Greenhouse tomato, fusarium wilt, 25.11) is a minor disease of field tomato. Since the introduction of the *I-1* gene, which provides resistance to race 1 in most tomato hybrids grown in Canada, losses from this disease have been minimal. Race 2 of *Fusarium oxysporum* f. sp. *lycopersici* has been identified throughout the southern United States but has not yet become established in Canada. Excellent monogenic resistance is available in germplasm having the *I-2* gene, which is now routinely being used in tomato breeding programs throughout the world.

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(Original by R.E. Pitblado)

▶ 18.11 Gray mold (ghost spot) *Figs. 18.11a-c; 25.12a-d*

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

Gray mold (see gray mold of Greenhouse tomato, 25.12; Greenhouse pepper, 24.3; and Lettuce, 11.10) occurs in the field under conditions of prolonged high humidity. The extent of damage is usually minor but it can be a problem in newly- planted soft-grown transplants in cool, wet springs. Roughly handled transplants are particularly susceptible. Affected tissues are tan-colored *(18.11a),* soft and often occur on plant parts close to the ground. Field symptoms are mainly ghost spots on fruit (*18.11b*) and fruit rotting *(18.11c).* Ghost spots appear on the fruit as a superficial pale halo or ring with a brown to black pinpoint spot in the center. On green fruit *(25.12d),* the halo may be pale green or silvery and the tissue inside the halo is generally paler green. On ripe fruit, the halo is usually pale yellow. Ghost spots rarely develop further, but they can reduce market quality. (For management strategies, see Lettuce, gray mold, 11.10.)

(Original by R.E. Pitblado)

▶ 18.12 Late blight *Figs. 18.12a-d; 25.13a,b; 16.11T1*

Phytophthora infestans (Mont.) de Bary

Late blight (see Potato, late blight, 16.11) can infect tomato, especially when plantings are close to blighted potato crops. The disease causes severe defoliation and fruit rot *(18.12a-d).* From 1946 to 1948 and in 1957 and 1976, late blight was epidemic in the tomato-growing areas of southern Ontario. However, with dry weather patterns and effective fungicide spray programs, late blight is no longer considered to be a serious disease in southern Ontario.

Selected references

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(Original by R.E. Pitblado)

▶ 18.13 Septoria leaf spot *Figs. 18.13a-c*

Septoria lycopersici Speg.

Septoria leaf spot is a common disease of field tomato in central Canada and often is found in association with early blight. The disease usually does not become prevalent until late in the season. Rapid defoliation and heavy crop losses can occur. Tomato is the only crop attacked by *Septoria lycopersici.*

Symptoms Under conditions favorable for infection, temperatures between 20 and 25°C and extended periods of leaf wetness, lower leaves are peppered with small dark circular spots. As the spots enlarge, the centers of the lesions turn light tan with dark margins *(18.13a).* Within the lesions, black, pinhead-sized pycnidia can be seen (*18.13b*) that help distinguish septoria lesions from those of early blight. Septoria leaf spots often have several wavy black lines at the edge of each lesion, which may result in the disease being misidentified as early blight. The disease spreads from lower leaves and stems (*18.13c)* to upper leaves on affected plants. There is seldom direct fruit damage; however, yield loss can occur as a result of reduced fruit size and an increased susceptibility to anthracnose and sunscald. Septoria leaf spot does not produce the degree of foliage yellowing that early blight does. Defoliation can occur rapidly under favorable conditions for disease development.

Causal agent (see Greenhouse tomato, septoria blight, 25.15)

Disease cycle *Septoria lycopersici* is seed-borne and also can overwinter in decomposing tomato residues in fields. Spores can be spread by water, workers, equipment, insects, wind-blown soil, and infested plant debris. Extended periods of leaf wetness and temperatures above 18°C favor disease development. Epidemics are usually delayed under normal spring conditions and the disease is seldom observed in the field until late July.

Management

Cultural practices — Control measures for septoria leaf spot are similar to those for early blight and anthracnose. Growers should use disease-free seed and transplants and provide balanced nutrition to promote healthy, vigorous growth.

Resistant cultivars — Resistance to septoria leaf spot is available in several breeding lines and is being incorporated into commercial tomato cultivars.

Chemical control — Registered fungicides are available. The TOM-CAST forecasting system is available to help growers time their foliar fungicide applications (see early blight, 18.8).

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(Original by R.E. Pitblado)

▶ 18.14 Verticillium wilt *Figs. 18.14a-c; 25.16a*

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

Verticillium wilt can affect tomato, pepper and eggplant. It is caused by two species of soil-inhabiting fungi. In general, *Verticillium dahliae* prefers warmer soils and is commonly encountered in southern Ontario and British Columbia. It is also the main cause of verticillium wilt in greenhouse tomato. *Verticillium albo-atrum* is mostly present in cooler areas; in particular, it is found in Quebec and the Maritime provinces. These two fungi are often found together in the same field. They can attack potato and other solanaceous plants (see Potato, verticillium wilt, 16.20), strawberry, raspberry and certain stone fruits. They are also found on many weeds, which thus aid in their carry-over from crop to crop (see also Greenhouse cucumber, 22.17).

Symptoms Symptom expression is similar for tomato, eggplant and pepper. The first symptom on leaves is yellowing followed by wilting *(18.14a).* Lesions on leaves of *Verticillium*-infected plants have a characteristic V-shaped yellowing pattern *(18.14b)*, which is widest at the leaf margins, narrowing to a small V toward and sometimes including the leaf midrib. The deep brown tissue within these lesions is always surrounded by a large, yellow, irregular area *(18.14c; 25.16a).* In tomato, this leaf symptom is often confused with those of early blight. A further diagnostic feature is that several of the surrounding leaves also may show the distinctive yellow coloration without any dark or necrotic tissue, the initial sign of the systemic leaf toxin. The disease affects lower leaves first, then moves upward. The fungus affects the vessels, so symptoms often appear only on one side of the plant and sometimes only on one side of the leaf. For the same reason, symptoms are more pronounced during drought periods. Leaf wilting is followed by necrosis and stunting. When the stem of an infected plant is cut lengthwise, the vascular tissue is brown, another characteristic symptom of the disease. Infected pepper and eggplant usually collapse rapidly and eventually die.

Verticillium wilt can be confused with fusarium wilt. Both diseases affect vessels within the vascular system of plants. In seedlings, verticillium wilt causes tan necrosis, while fusarium wilt produces a mahogany discoloration of the vascular tissues. In questionable situations, the two diseases can be distinguished only by isolating the causal organism.

Causal agent (see Potato, verticillium wilt, 16.20)

Disease cycle (see Potato, verticillium wilt) In tomato fields, *Verticillium* species survive on infected crop residues in the form of microsclerotia in *V. dahliae* and as resistant mycelium in *V. albo-atrum.* Weeds often serve as symptomless hosts. Infection takes place in the roots; the fungus invades the vessels and interferes with water transport either by obstructing the vessels or by producing a toxin that causes wilt. Hastened entry occurs when accompanied by plant parasitic nematodes. Combinations of nematodes and *Verticillium* cause a decline and loss in yield similar to that found in potato.

Management

Cultural practices — Growers should follow a four- to five-year crop rotation to allow infested plant residues to decompose in the soil. Long rotations help reduce the level of fungal inoculum in fields; however, *Verticillium* spp., especially *V. dahliae,* can survive for many months in the absence of susceptible plants. Grain crops should be included in the rotation. Whenever possible, infested plant material should be gathered and destroyed after harvest.

Resistant cultivars — Most commercial tomato cultivars have the *Ve*-gene that confers a level of resistance. However, a second race of *V. dahliae,* first reported from Ohio in 1962 and since observed in Ontario, has resulted in the decline of several popular tomato cultivars. Resistance to *Verticillium* spp. in pepper and eggplant is poor. As with tomato, genetic resistance is available, but it is specific only for certain races of *Verticillium.* One control measure is the grafting of eggplant onto *Verticillium*-resistant tomato rootstocks. The grafting is done in a greenhouse and the plants are then transplanted to the field.

Biological control — Toxin-producing or antagonistic organisms are being evaluated, but none is commercially available.

Chemical control — Growers should fumigate fields before transplanting if soil tests indicate high levels of *V. dahliae* or plant parasitic nematodes.

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(Original by L.M. Tarder and R.E. Pitblado)

▶ 18.15 White mold *Figs. 18.15a-e*

Sclerotinia minor Jagger
Sclerotinia sclerotiorum (Lib.) de Bary

(syn. *Whetzelinia sclerotiorum* (Lib.) Korf & Dumont)

White mold, caused mainly by *Sclerotinia sclerotiorum,* and rarely in Canada by *S. minor*, can be a destructive disease of field tomato in Ontario. Either species can cause a collar rot of transplants and a stem and fruit rot of mature plants. Both species of *Sclerotinia* have a wide host range, particularly in vegetable crops such as bean, carrot, cauliflower, cabbage, celery, cucurbits, pea and rutabaga. Weeds and refuse piles are potential sources of inoculum.

Symptoms In young transplants, the hypocotyl can be infected by mycelial growth from senescent cotyledons. Lesions are water-soaked at first, though the rotted area usually remains fairly firm. The affected tissue appears bleached, and there is almost invariably a prolific, pure white fungal growth on the stem (*18.15a,c,e*). The fungus may also infect stems at the soil line, especially if senescent tissue is present. This can result in collar rot *(18.15b),* a condition in which the stem rots and causes the affected plant to wilt and die. In the case of *S. minor,* small, flat, black sclerotia about 1 to 2 mm in size appear on the outside of the stem, often coalescing into masses *(18.15b).* In *S. sclerotiorum,* the sclerotia are black, larger (5 to 8 mm) and irregular in shape *(18.15d).* They are formed mostly inside the stem.

On older plants, lesions may be initiated anywhere on the shoot, usually at the site of a leaf scar or where fallen flower has lodged. Lesions may attain several centimetres in length and girdle the stem *(18.15b,c)*\ all of the tissue above a large lesion dies. Fruit becomes infected from colonized, senesc- ing tissue adhering to it and sometimes from latent infections in the senescent flower parts. Infected fruits rot completely *(18.15a).*

Black sclerotia lying in a mass of white mycelium inside hollow stems are diagnostic of *S. sclerotiorum,* while smaller sclerotia, aggregated in masses and always external, are typical of *S. minor.* Pale, beige-colored apothecia, 1 to 3 mm in diameter, are produced at the soil surface in spring and throughout cool, moist summers; careful searching may reveal an abundance of small, inconspicuous apothecia on the soil surface.

Causal agent (For a description of *Sclerotinia sclerotiorum,* see Bean, white mold, 15B.9, and for *S. minor,* see Lettuce, drop, 11.9.)

Both fungi grow readily on a variety of agar media. The mycelium is always pure white and abundant, and both species produce typical sclerotia in culture. The sclerotia usually produce abundant apothecia when placed on damp sand or floated on water in diffuse light at about 25°C.

Disease cycle (see Bean, 15B.9, and Lettuce, 11.9)

Management

Cultural practices — The sclerotia are long-lived and germinate whenever they are brought to within 2 to 3 cm of the soil surface by cultivation. Control by a short rotation usually is not very successful. An interval of at least three or four years of cereal cropping is needed to reduce their numbers appreciably in the field. Weeds should be eradicated because many of them also are hosts, and they serve to maintain a humid microenvironment in the crop. Refuse piles should be removed and buried deeply or composted properly to ensure the destruction of sclerotia. Field crop rows should run parallel to the prevailing wind so that plants dry out quickly after rain. Excessive overhead irrigation should be avoided where white mold is a potential problem.

Resistant cultivars — No resistant cultivars of any vegetable are known, but those with a more open habit are less susceptible than those with a dense habit in which water is slow to evaporate.

Biological control — Sclerotia are damaged by sciarid flies and are parasitized by a number of other fungi. There has been limited success in biological control with one or two of these fungi but not on a commercial scale.

Chemical control — Dicarboximide and benzimidazole fungicides may be used, but fungicide tolerance may develop quickly. Efficacy should be monitored closely and spraying stopped at the first sign of resistance to the fungicides.

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(Original by W.R. Jarvis)

VIRAL AND VIRAL-LIKE DISEASES

Viral diseases can adversely affect tomato and pepper crops in Canada. Symptoms vary depending on the virus type, virus strain, host plant, time of year and environmental conditions, and often go unrecognized or are misdiagnosed. Seven viruses have been identified as attacking field tomato and pepper in Canada, but those affecting eggplant have not been studied. Several other viruses are known to attack these crops worldwide.

▶ 18.16 Aster yellows

Aster yellows mycoplasma-like organism

Aster yellows is a minor disease of tomato, eggplant and pepper. Affected plants are stunted, chlorotic and may have a stiff growth habit. Fruits from yellows-infected tomato plants may be catfaced (see catface, 18.23). Aster yellows is a more important disease in crops such as lettuce (see Lettuce, aster yellows, 11.15) and celery (see Celery, aster yellows, 7.8). Management of this disease centers on controlling the aster leafhopper (see Lettuce, 11.23), which vectors the aster yellows pathogen.

(Original by R.J. Howard)

▶ 18.17 Cucumber mosaic *Figs. 18.17; 25.18a,b*

Cucumber mosaic virus

Cucumber mosaic is often misdiagnosed as tomato mosaic, and they both occur commonly in tomato crops. Cucumber mosaic virus can attack a large number of plant species (see Greenhouse cucumber, cucumber mosaic, 22.20).

Symptoms Cucumber mosaic causes a distinct narrowing ("shoestring") of young tomato leaves (*25.18a)* and conspicuous mosaic symptoms (*25.18b*) similar to those produced by tomato mosaic virus. The shoestring leaf symptoms sometimes resemble injury caused by growth-regulating herbicides, such as 2,4-D. Shoestring is often confused with "fern- leaf," a symptom caused by tomato mosaic virus (*18.18a, 25.21c)* (see Greenhouse tomato, 25.21), but shoestring often can be distinguished by its narrower, tendril-like leaflets. Plants with severe shoestring often are stunted and produce little or no marketable fruit.

In pepper, severe foliar mosaic may occur and older leaves sometimes exhibit large, necrotic rings *(18.17).* Fruit may be malformed, with conspicuous, yellow, concentric rings and/or spots on immature fruit.

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

Disease cycle (see Greenhouse cucumber, cucumber mosaic) Limited spread of cucumber mosaic virus may occur in the field through handling plants. The green peach aphid is the most widespread and efficient vector, but potato and melon aphids also may spread the pathogen.

Management (see Cucurbits, cucumber mosaic, 9.15)

Selected references
Francki, R.I.B., D.W. Mossup 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 R.E. Pitblado and R.J. Howard)

▶ 18.18 Tomato mosaic, single streak, double streak *Figs. 18.18a-e; 25.19a,b; 25.21 a-e*

Tomato mosaic virus

Tomato mosaic is widespread on field tomato in Canada but often goes unnoticed or is not diagnosed accurately. The names "tomato mosaic" and "tobacco mosaic" are often used interchangeably (see Greenhouse tomato, 25.20 and 25.21). The extent of crop losses from this virus in field tomato, pepper and eggplant in Canada is not well documented. The virus occurs in many strains and its effect on susceptible cultivars can range from none to severe. Tomato mosaic virus has a wide host range (see Greenhouse tomato, tomato mosaic, 25.21).

Symptoms Light and dark green mottling (mosaic) of the leaves *(25.21b),* distortion, and a reduction in the size of the leaflets *(18.18a)* are the most characteristic symptoms of tomato mosaic in tomato. Plants attacked early in the season may be slightly stunted *(25.21a),* while later infections have little or no noticeable effect on plant growth (see also symptoms of "femleaf," *25.21c,* and "shoestring," *25.18a).* Fruit set may be severely reduced. Internal browning of the fruit wall, yellow blotches and necrotic spots may occur on both green and ripe tomato fruit *(18.18b-e; 25.21d,e).*

At least one strain of tomato mosaic virus is also involved in another distinct disease of tomato called "streak" or "single streak." This disease is characterized by longitudinal brown streaks on the leaves and petioles, and dark blemishes on the fruit. A more severe disease, "double streak" *(25.19a,b),* is the result of a combined infection of tomato mosaic virus and potato virus X (see Greenhouse tomato, double streak, 25.19).

On pepper, very prominent mosaic symptoms appear on the foliage accompanied by leaf puckering and reduction in leaf size. Vein clearing of the young leaves becomes extremely pronounced. Older leaves fall prematurely. Yield is reduced because fewer fruit are set and those that do are small and misshapen.

Causal agent (see Greenhouse tomato, 25.21) Tomato mosaic virus differs only slightly in host, serological and cross-protection reactions from tobacco mosaic virus. Strains of tomato mosaic virus have been classified by their ability to induce symptoms in plants of certain *Lycopersicon* spp. or in isogenic tomato lines.

Disease cycle (see Greenhouse tomato, 25.21) Tomato mosaic virus can be spread by anyone who handles or brushes against diseased plants then handles healthy ones in operations such as tying, pruning, cultivating and harvesting. The virus also can be spread on tools and machinery.

Management (see Greenhouse tomato, 25.21)

Cultural practices — Growers should keep seedling production areas free of weeds and ornamentals. Young seedlings should not be clipped. Diseased plants should be pulled and left to die in the field as soon as virus symptoms are noticed; this practice minimizes the spread of the virus by direct contact between plants. Cultivators, tools and other equipment should be disinfested before moving from diseased to healthy crops.

Resistant cultivars — Tomato and pepper cultivars with some resistance to tomato mosaic virus are commercially available in Canada.

Chemical control — Suitable herbicides should be used to eliminate weeds that may harbor viruses within tomato, pepper and eggplant crops and in borders and fence rows that surround production fields. Insect pests should be controlled with insecticides where populations warrant.

Selected references

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Hollings, M., and H. Huttinga. 1976. Tomato mosaic virus. CMI/AAB Descriptions of Plant Viruses, No. 156. Commonw. Mycol. Inst./Assoc. Appl. Biol., Kew, Surrey, England. 6 pp.
Zaitlin, M., and H.W. Israel. 1975. Tobacco mosaic virus. CMI/AAB Descriptions of Plant Viruses, No. 151. Commonw. Mycol. Inst./Assoc. Appl. Biol., Kew, Surrey, England. 6 pp.

(Original by R.E. Pitblado and R.J. Howard)

▶ 18.19 Tomato spotted wilt *Figs. 24.8b,c; 25.22a-d*

Tomato spotted wilt virus

Tomato spotted wilt (see Greenhouse tomato, 25.22, and Greenhouse pepper, 24.8) is a viral disease that was relatively uncommon in field tomato and pepper crops in Canada before 1989. However, greenhouse tomato and pepper crops have been affected by this disease since 1984, when tomato spotted wilt became an important problem in the greenhouse floriculture industry in Canada. In the spring of 1989, tomato spotted wilt was observed extensively throughout Ontario wherever tomato and pepper crops were grown. The virus and its thrips vector (see western flower thrips, 18.42) were imported into Ontario with vegetable transplants from the southern United States. A protocol to produce virus-free transplants has been developed for use by Canadian growers. The virus has a very wide host range.

Symptoms Moderate to heavily infected transplants, once planted in the field, appear stunted but seldom die. They remain unproductive, never growing beyond the seedling size. Transplants only slightly infected at planting time initiate growth, but later show characteristic leaf symptoms. Pepper leaves become mottled *(24.8b)* and often have circular, raised, yellow zones. Tomato foliage turns purplish- brown (bronzing) *(25.22a,b).* Fruits are irregular in shape and color with circular markings of alternate red and yellow bands *(25.22c,d; 24.8c).*

Causal agent (see Greenhouse tomato, tomato spotted wilt, 25.22)

Disease cycle (see Greenhouse tomato, tomato spotted wilt)

Management

Cultural practices — Management of tomato spotted wilt should emphasize exclusion of the insect-disease complex. Field-grown transplants imported from the USA often require repeated applications of insecticides to control the thrips vector. Locally grown transplants require stringent sanitation strategies to produce disease-free plants. The practice of growing vegetable transplants with bedding plants often leads to transplants becoming infected with the virus.

Using an effective protocol for managing thrips and tomato spotted wilt virus in vegetable seedling greenhouses will provide healthy, disease-free transplants. Recommended practices include:

- providing a break in cropping for at least one month before vegetable seedlings emerge; temperatures should be set at 22°C or warmer to accelerate the hatching of any thrips eggs that are present;
- monitoring for thrips and disease using blue sticky traps and growing petunias as indicator plants;
- not growing vegetable transplants in close proximity to houses used for flower production;
- maintaining weed-free greenhouses;
- restricting visitors;

- using appropriate insecticides when necessary.

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(Original by R.E. Pitblado)

▶ 18.20 Other viral diseases *Figs. 18.17; 25.19a,b; 25.21b*

Alfalfa mosaic virus
Potato virus X
Potato virus Y
Tobacco etch virus

Alfalfa mosaic has been observed in field pepper in Ontario. The symptoms depend on the virus strain and the environmental conditions under which the crop is growing. Yellow blotches or sometimes mosaic mottling, chlorotic rings, spots and other patterns appear in affected leaves. Severe leaf necrosis also may occur. Alfalfa mosaic virus overwinters in alfalfa crops and it is commonly transmitted by green peach aphids. (For information on the virus, see Potato, calico, 16.24.)

Potato virus X On tomato foliage, potato virus X causes a distinct light and dark green mottle similar to that produced by tomato mosaic *(25.21b).* Small dead spots sometimes appear on the affected leaves. Plants infected by both potato virus X and tomato mosaic virus exhibit symptoms of the disease known as double streak (*25.19a,b*) (see tomato mosaic, 18.18, 25.19). Pepper shows a mild mosaic symptom with leaf puckering. Leaf size may be slightly reduced. The virus is spread by contact between diseased and healthy plants and during handling. Grasshoppers reportedly are vectors. Potato virus X may carry over in potato tubers (see Potato, potato virus X, 16.27), and it also can infect a large number of other solanaceous plants.

Potato virus Y (see Potato, 16.27) is found more frequently in pepper than in tomato. The virus causes mild to severe mottling depending on the strain involved. The virus is not seed- transmitted but is spread by several aphid species, of which the green peach aphid is probably the most efficient vector.

Tobacco etch Tomato plants infected with tobacco etch virus appear somewhat stunted with mildly mottled, slightly distorted foliage. In pepper, the virus causes a very mild chlorotic mottle with some foliar distortion. Large, concentric rings and line patterns may be produced on both leaves *(18.17)* and fruit. Fruit often becomes misshapen. Root necrosis occurs, causing some wilting. Wilted plants recover but they are usually stunted and bushy. Stems of older plants sometimes show reddish-brown spots and streaks. Bud drop may occur. Tobacco etch virus overwinters in weeds of the family Solanaceae and is spread mostly by the green peach aphid and occasionally the potato aphid.

Management

Cultural practices — Most of the minor viral diseases of tomato, pepper and eggplant can be kept at low levels by using virus-free seed and transplants, by controlling insect vectors and weed hosts, and by employing strict sanitation programs in propagation greenhouses and with field equipment.

Selected references

De Bokx, J.A. 1981. Potato virus Y. CMI/AAB Descriptions of Plant Viruses, No. 242. Commonw. Mycol. Inst./Assoc. Appl. Biol., Kew, Surrey, England. 6 pp.

Jaspars, E.M.J., and L. Bos. 1980. Alfalfa mosaic virus. CMI/AAB Descriptions of Plant Viruses, No. 229. Commonw. Mycol. Inst./Assoc. Appl. Biol., Kew, Surrey, England. 7 pp.

Koenig, R., and D.-E. Lesemann. 1989. Potato virus X. AAB Descriptions of Plant Viruses, No. 354. Assoc. Appl. Biol., Inst. Hort. Res., Wellesbourne, Warwick, U.K. 5 pp.

Purcifull, D.E., and E. Hiebert. 1982. Tobacco etch virus. CMI/AAB Descriptions of Plant Viruses, No. 258. Commonw. Mycol. Inst./Assoc. Appl. Biol., Kew, Surrey, England. 7 pp.

(Original by R.E. Pitblado and R.J. Howard)

NON-INFECTIOUS DISEASES

▶ 18.21 Blossom-end rot (bottom rot) *Figs. 18.21 a-d; 24.9; 25.23*

Blossom-end rot affects tomato, pepper and eggplant. It generally occurs on the first fruit clusters and sometimes causes significant economic losses. It is caused by a localized deficiency of calcium in the fruit and is induced by unfavorable growing conditions, especially drought. Blossom-end rot develops when there are fluctuations in water supply such as result from long periods of hot, dry weather followed by heavy showers. The cause is a failure of the plant to absorb calcium quickly enough, even though it may be abundant in the soil. This disorder affects the first fruit clusters on tomato most severely. Clusters developing later may not be affected. Rapid plant growth, low potassium and calcium levels in plant tissue, large quantities of magnesium and nitrogen in the soil, high soil salinity, damage to the roots, and high relative humidity all serve to predispose plants to blossom-end rot.

Symptoms The first symptoms usually appear on young fruits that are a third or more developed but the disorder can occur at any stage. Initially, light brown patches appear at the blossom end of the fruit, although they can occasionally appear on the sides as well *(18.21c,d).* These patches darken and an area of sunken black tissue forms, sometimes affecting up to half the fruit *(18.21a; 24.9; 25.23).* These dead tissues may be invaded by secondary organisms that can cause the fruit to rot. In tomato, an internal rot symptom can also occur. Black areas throughout the fruit often go unnoticed until it is cut open *(18.21b).*

Management

Cultural practices — The best way to prevent blossom-end rot is to ensure steady plant growth through careful irrigation. This promotes the uptake and assimilation of calcium by the plant. In addition, providing balanced fertilization and avoiding root damage while cultivating will encourage deep root development and enable the plant to obtain adequate water during drought periods. Mulches that aid in conserving soil moisture may help to prevent blossom-end rot. Applications of lime to the soil well before planting and the use of calcium chloride or calcium nitrate sprays on the foliage during the growing season, prior to the onset of symptoms, also may be helpful.

Resistant cultivars — Cultivars differ in their susceptibility to blossom-end rot, but this has not been well documented.

Selected references

Banuelos, G.S., G.P. Offermann and E.C. Seim. 1985. High relative humidity promotes blossom-end rot on growing tomato fruit. *HortScience* 20:894-895.

Bradfield, E.G., and C.G. Guttridge. 1979. The effects of night-time humidity and nutrient solution concentration on the calcium content of tomato fruit. *Sci. Hortic.* 22:207-217.

DeKock, P.C., A. Hall, R. Boggie and R.H.E. Inkson. 1982. The effect of water stress and form of nitrogen on the incidence of blossom-end rot in tomatoes. *J. Sci. Food Agric.* 33:509-515.

Pill, W.G., and V.N. Lambeth. 1980. Effects of soil water regime and nitrogen form on blossom-end rot, yield, water relations, and elemental composition of tomato. *J. Am. Soc. Hortic. Sci.* 105:730-734.

Spurr, A.R. 1959. Anatomical aspects of blossom-end rot in the tomato with special reference to calcium nutrition. *Hilgardia* 28:269-295.

(Original by L.M. Tartier)

▶ 18.22 Blotchy ripening *Figs. 18.22a,b*

Blotchy ripening is most often encountered in the greenhouse and damage can be significant. It is also found in the field in fresh-market, processing and staked tomato crops. The cause of this disorder and its relationship to “graywall” are uncertain. It has been linked to potassium or boron deficiency and to high nitrogen levels, which favor excessive growth. Blotchy ripening also has been attributed to infection by tomato mosaic virus, but this does not appear to be the definitive cause. Weather conditions also seem to play a role in the development of blotchy ripening; the disease is more frequent when temperatures are very high and is less prevalent during sunny, mild conditions.

Symptoms Affected fruit ripens at an uneven rate. Large patches of hard, grayish or yellowish tissue are immediately visible on the green fruit. The fruit does not turn a uniform red; the patches remain gray or turn yellow *(18.22a).* This gives the characteristic appearance of poorly ripened fruit. When affected fruits are cut in half, the vascular tissues may appear brown *(18.22b).*

Management

Cultural practices — Growers should ensure that a well-balanced fertilizer program is followed.

Resistant cultivars — Some cultivars appear to be less susceptible to this problem than others.

Selected references

Dangler, J.M., and S.J. Locascio. 1990. External and internal blotchy ripening and fruit elemental content of trickle-irrigated tomatoes as affected by N and K application time. *J. Am. Soc. Hortic. Sci.* 115:547-549.

Geraldson, C.M. 1960. Nutritional factors affecting the incidence and severity of blotchy ripening of tomatoes. *Proc. Florida State Hortic. Soc.* 73:111-113.

Matsumoto, T., and C.A. Hornsby. 1974. Influence of weekly changes in temperature and light regimes on the incidence of blotchy ripening of tomatoes. *Can. J. Plant Sci.* 54:129-133.

Picha, D.H., and C.B. Hall. 1981. Influences of potassium, cultivar, and season on tomato graywall, and blotchy ripening. *J. Am. Soc. Hortic. Sci.* 106:704-708.

(Original by L.M. Tarder)

▶ 18.23 Catface (stylar cork) *Fig. 18.23*

Catface originates during the early stages of flower bud development, approximately two or three weeks before blossoming. It results from abnormal development of tissues at the junction of the style and ovary, and the resulting fruit is misshapen. Unfavorable growing conditions, such as several days of temperatures below 15°C when the plants are young, seems to be the main cause of this disorder, although other impediments to flower bud development also can result in catfacing. High levels of soil nitrogen and excessive pruning aggravate the problem. Aster yellows and injury from hormonal herbicides, such as 2,4- D, also can lead to the production of malformed fruit, but foliar symptoms can be used to distinguish these problems from true catfacing. Catface is generally most prevalent on large-fruited, fresh-market tomatoes.

Symptoms Affected fruits are generally flattened on the blossom end. Large bands of cork-like, malformed scar tissue cover the whole end of the fruit *(18.23).* The scars often criss-cross and the fruit seems to consist of lobes. Cavities sometimes form in healthy tissue. This problem is sometimes confused with injury caused by hormonal herbicides.

Management

Cultural practices — Good growing practices, especially temperature control, should be followed in greenhouse production of field transplants. High levels of soil nitrogen, excessive pruning and accidental exposure to phenoxy herbicides should be avoided in tomato crops.

Resistant cultivars — Large-fruited tomato cultivars are more susceptible to catface and should be avoided if this disorder is a persistent problem.

(Original by L.M. Tartier)

▶ 18.24 Cold injury

Exposure to low temperatures can reduce seed germination, retard growth, and damage tomato foliage and fruit. Chilling injury to tomato fruit can occur when temperatures of 0 to 10°C persist for prolonged periods, either before or after harvest. Chilling injury is likely to occur if there is an accumulation of 120 hours below 15°C during the week before harvest.

Freezing damage to tomato begins when temperatures drop to -1 or -2°C. Injury is caused by ice crystals that form in the plant tissue, thereby rupturing the cells. Plants are generally more susceptible to frost when the soil is dry, rather than moist. One factor that can affect the temperature at which injury occurs is the presence of ice-nucleation bacteria on the plant surface. When these bacteria are not present, ice does not form until the temperature reaches about -5°C.

Chilling injury to fruit frequently occurs in the home when it is stored in the refrigerator, in stores where it is put in cold storage over the weekend, and in trucks when being transported over long distances.

Symptoms Fruits not fully ripened at the time of exposure to chilling temperatures fail to ripen normally. Affected tissues may become soft and water soaked. As the tissue breaks down, it becomes increasingly susceptible to decay. When fruit is exposed to low temperature in the field, injury may not be apparent at harvest but may appear after five to seven days during storage or shipping. Frozen leaves, fruit surfaces and other tissues quickly become water soaked, then turn black. Tomato plants can usually recover from a brief exposure to frost but damaged fruit is unmarketable.

Management

Cultural practices — Growers should plant early-maturing cultivars, and avoid excessive use of nitrogen fertilizers that may delay maturity. Hotcaps or tunnels help to protect newly transplanted seedlings.

Selected references

Patterson, B.D., and L.A. Payne. 1983. Screening for chilling resistance in tomato seedlings. *HortScience* 18:340-341.

(Original by R.J. Howard)

▶ 18.25 Growth cracks *Fig. 18.25*

Growth cracking is a physiological disorder that occurs as the fruit is sizing and is the result of variations in soil moisture and temperature. Growth cracks may occur during periods of rapid fruit growth when relative humidity and air temperatures are high or after a drought period when water becomes abundantly available after a rain storm or irrigation. Growth cracks are easily invaded by secondary organisms such as *Alternaria* spp. and soft rot bacteria that promote fruit rot.

Symptoms There are several types of growth cracks *(18.25).* Radial cracks cover the fruit, beginning at the stem end; concentric cracks encircle the stem end. As the fruit grows, these cracks deepen and expose the flesh but seldom the locules. Severe cracking or “bursting” also can occur, exposing the locules.

Management

Cultural practices — The problem can be minimized by irrigating tomato plants regularly. Since ripe fruit is more susceptible to growth cracking, irrigation should be avoided once the fruits ripen. Excessive application of fertilizers should be avoided.

Resistant cultivars — Cultivars differ in their susceptibility to growth cracking, but this has not been well documented.

(Original by L.M. Tartier)

▶ 18.26 Leafroll, herbicide injury *Figs. 18.26a-d*

Leafroll is a common physiological disorder of tomato. It also can occur on pepper, eggplant and potato. The edges of the leaves roll upward and inward to the extent that they may appear tubular *(18.26a).* This rolling appears to be a moisture conservation measure by the plant and is often permanent. Affected leaves also may have a leathery texture. The lower leaves are generally the first to exhibit leafroll symptoms, but the entire plant eventually may be affected. Overall growth and fruit production usually are not impaired. The onset of symptoms is greatest following hot, dry growing conditions. Some cultivars appear to have a genetic predisposition to this disorder. Leaf rolling and other abnormalities *(18.26b-d)* can also occur as a result of exposure to hormonal herbicides, such as 2,4-D.

Management

Cultural practices — Growers should ensure that tomato plants receive adequate moisture, especially during drought periods.

(Original by R.J. Howard)

▶ 18.27 Nutritional disorders *Figs. 25.24a,b*

Field tomato, pepper and eggplant crops are subject to a number of nutritional disorders, principally deficiencies of nitrogen, phosphorus, potassium, calcium and magnesium. Yield and quality of fruit are reduced when serious toxicides and deficiencies occur (see Greenhouse tomato, 25.23, 25.24, for descriptions of calcium and magnesium deficiencies; also see blossom-end rot, 18.21).

Selected references

Besford, R.T., and G.A. Maw. 1975. Effect of potassium nutrition on tomato plant growth and fruit development. *Plant Soil* 42:395-412.

(Original by R.J. Howard)

▶ 18.28 Puffiness *Fig. 18.28*

Puffiness affects both greenhouse and field tomato. Affected fruit loses its commercial value. Puffiness results when unfa

vorable weather conditions adversely affect pollination or fertilization of the ovule. Temperatures above 35°C or below 13°C may result in poor pollination. Extreme variations in soil moisture, genetic factors, over-fertilizing with nitrogen, and the use of fruit-setting hormones also may play a role in the development of this disorder.

Symptoms Fruit affected with puffiness is bloated, light in weight and soft. In some cases, the locules are only partially filled with gel. When the fruits are cut in half, the locules may be empty, sunken and have few seeds *(18.28).*

Management

Cultural practices — Fertilizer programs should be balanced to avoid excessive levels of nitrogen. Fruit-setting hormones should be used with caution.

(Original by L.M. Tartier)

▶ 18.29 Sunscald *Figs. 18.29a,b*

Sunscald primarily affects fruit tissue; however, leaves and stems also can be scalded, resulting in collapse of the mesophyll. Sunscald results when fruit and young foliage are exposed to the direct sunlight. The disorder is aggravated by high humidities and temperatures. This problem appears on fruit that is suddenly exposed to the sun because the foliage no longer offers protection. This can result from defoliation through diseases, such as early blight, septoria leaf spot, bacterial and wilt diseases, excessive heat, excessive leaf loss caused by fruit-ripening chemicals or insect feeding, or when vines are trained, alleys are made through fields or fruit is picked for the fresh market. Sunscalded fruit is unmarketable.

Symptoms Sunscald symptoms appear on the part of the fruit that is exposed to the sun. Affected areas are sunken and light brown to white *(18.29a,b).* These areas are often invaded by secondary organisms that can cause the fruit to rot. Early in the season, tender leaf and stem tissues can also be sunscalded and may turn a light gray to brown. The underside of the upper foliage has irregular bands across the leaf, while the stems turn whitish on the exposed side.

Management

Cultural practices — This problem can be partially avoided by keeping the foliage healthy so that the fruit is sheltered from the sun.

Resistant cultivars — None is currently available, but growers might use varieties that have sufficient foliage to protect the fruit.

(Original by L.M. Tartier and R.E. Pitblado)

NEMATODE PESTS

▶ 18.30 Northern root-knot nematode *Fig. 18.30*

Meloidogyne hapla Chitwood

Tomato, eggplant and pepper are highly susceptible to damage from the northern root-knot nematode *(18.30)*. Infected plants become stunted and chlorotic and senesce early. Fruit set and size are reduced. For a complete description and management strategies, see Carrot, 6.20; see also Management of nematode pests, 3.12.

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

Pratylenchus penetrans (Cobb) Filip. & Stek.

Symptoms Plant growth is stunted in heavy infestations. Affected plants occur in patches, usually extending along the rows, or elongated in the direction of cultivation. Plants wilt readily on hot days and leaves become progressively yellow. Older leaves may die prematurely. Secondary roots are necrotic with dried areas. See Potato, 16.38; see also Management of nematode pests, 3.12.

Selected references

Potter, J.W., and T.H.A. Olthof. 1977. Analysis of crop losses in tomato due to *Pratylenchus penetrans. J. Nematol.* 9:290-295.

▶ 18.32 Stubby-root nematodes

Paratrichodorus allii (Jensen) Siddiqi
Paratrichodorus pachydermus (Seinhorst) Siddiqi
Paratrichodorus spp.
Trichodorus spp.

See Potato, 16.39, and Management of nematode pests, 3.12.

INSECT PESTS

▶ 18.33 Aphids *Figs. 16.40-16.43*

Green peach aphid *Myzus persicae* (Sulzer)
Potato aphid *Macrosiphum euphorbiae* (Thomas)
Other aphids

The same species of aphids that attack potato (see Potato, 16.40-16.43) also attack field tomato, eggplant and pepper. These aphids form colonies on the undersides of leaves, and often in or around flowers. In hot, dry weather, aphid populations increase rapidly. High populations sometimes follow the early-season use of insecticides to control the Colorado potato beetle, resulting in reduced numbers of aphid predators and parasites. Aphids and their effects on crop yields and fruit quality are often overlooked. However, the ability of aphids to transmit viruses is the greatest concern.

Damage Aphids transmit several viruses that can be devastating to solanaceous vegetable crops; these include cucumber mosaic virus, alfalfa mosaic virus, potato virus Y and tobacco etch virus. Moderate to heavy aphid infestations can cause the foliage to turn yellow, resembling symptoms that can be mistaken for fungal blights. However, the foliage is covered with whitish, molted skins (aphid exuviae) and the bodies of parasitized aphids, which appear swollen and bronzed.

Aphids do not cause significant losses in production except under dry conditions, when they can reduce plant growth, thereby lowering yields. Leaves become twisted and cupped as a result of feeding by clusters of aphids on the underside of the foliage. Additional damage results from honeydew, which supports the growth of sooty mold that reduces the marketability of the fruit.

Identification (see Potato, 16.40-16.43)

Life history (see Potato, 16.40-16.43)

Management

Resistant cultivars — A number of tomato, eggplant and pepper cultivars carry a level of resistance to some virus diseases transmitted by aphids, but there is no apparent resistance to aphids.

Biological control — Growers often rely on lady beetles and other predators (see Beneficial insects, mites and pathogens, 3.7) to keep aphid populations low.

Chemical control — In most years, chemical control of aphids is not warranted and is difficult to achieve because of poor under-foliage coverage when insecticides are applied with conventional sprayers. Other factors mitigating the efficacy of chemical control are the development of resistance to chemical insecticides by aphids and rapid increases in aphid populations once initial control has been achieved. Products with activity against aphids and the European corn borer or Colorado potato beetle are preferred. Chemical insecticides should only be applied when they are required, and control can be improved by using a systemic insecticide.

(Original by R.E. Pitblado)

▶ 18.34 Colorado potato beetle *Figs. 16.44a-d; 16.44T1*

Leptinotarsa decemlineata (Say)

The Colorado potato beetle occurs in all tomato-growing regions of Canada. In Essex and Kent counties in southwestern Ontario, where 80% of the Canadian field-tomato crop is grown, the Colorado potato beetle is of particular concern to growers, especially early in the growing season at the time of transplant establishment. High beetle populations are present because of the numerous potato fields in that area and the high proportion of insecticide-resistant beetles found in southwestern Ontario. The tendency for both tomato and eggplant crops to be grown on lighter, sandy soil-types, where high overwintering populations of adult beetles occur, coupled with the lack of crop rotation, also have played a role in the Colorado potato beetle populations with which tomato growers now have to contend.

Eggplant and pepper are not seriously affected by this insect.

Damage Adults and larvae of the Colorado potato beetle are capable of defoliating young tomato seedlings. Damage is scattered throughout a field wherever the in-field overwintering adults emerge and begin to feed, or it is concentrated along field borders when adults from neighboring fields move in and later where mated females have laid their eggs. Severely defoliated plants may have only the stem and larger leaf mid-ribs remaining, causing a 50% loss in yield. If 50% of the foliage remains after a beetle attack, a tomato seedling may often outgrow this early season damage with no subsequent loss in yield. Colorado potato beetles also cause feeding damage to tomato fruit.

Identification (see Potato, 16.44)

Life history (see Potato, 16.44) Overwintered adults of the Colorado potato beetle emerge from the soil in early spring. They immediately seek and begin to feed on host plants. Both the adults, popularly called "hard shells," and the larvae or "soft shells" feed on tomato foliage early in the season. Adults that emerge after mid-July often fly to nearby potato crops.

Management

Monitoring — Emerging adults within a tomato field begin to feed, mate and lay eggs immediately after transplants are planted. Therefore, early detection is important. There are no established action thresholds, but the presence of 10 larvae or adults per 100 plants is a useful guideline for timing application of an insecticide to young transplants. Populations of Colorado potato beetle in tomato fields are clumped and spotty, and extensive sampling is required to monitor populations accurately. Monitoring field edges gives an indication of beetle populations moving into vegetable fields. Growers while cultivating should take note of areas that are moderately or heavily damaged by beetles.

Cultural practices — Crop rotation is only moderately effective as a management strategy because beetles that overwinter in nearby potato fields readily fly into tomato fields in the spring. Eggplant transplants or, preferably, potato rows planted strategically in a tomato field act as trap crops, reducing Colorado potato beetle damage to the tomato crop.

Resistant cultivars — Tomato cultivars with substantial anti-feeding resistance, which results from an increase in glyco-alkaloid content, are being developed but few of these are available commercially. There is concern about the safety to humans of these high glyco-alkaloid cultivars. Other resistance mechanisms are being evaluated.

Biological control — Foliar application of the bacterium *Bacillus thuringiensis* Berl., San Diego strain, which is effective against larvae of the Colorado potato beetle, is an alternative to the use of chemical insecticides.

Chemical control — Insecticidal applications are effective in reducing damage caused by Colorado potato beetle. However, in contrast to the range of insecticides available for potato, only a few foliar insecticides are recommended for tomato. These may be "spot-sprayed" onto heavily infested areas of fields where beetle numbers warrant. If possible, growers should not apply insecticides to entire fields and should avoid over-treating, because most of the insecticides used against the Colorado potato beetle kill beneficial insects, such as aphid predators and parasites, resulting in high populations of aphids in late July and

August. If adult Colorado potato beetle populations are low, microbial insecticides can be used to control the larvae after eggs have hatched, rather than applying chemical insecticides to kill the adults. Overwintered adults, if abundant, must be treated to prevent defoliation of young transplants. The use of insecticides in transplant water helps in early season control.

Colorado potato beetle was reported in 1971 to have developed resistance to endosulfan and other organochlorine insecticides but organophosphate and carbamate insecticides remained effective. Since then, widespread resistance to insecticides has been documented, limiting the choice of chemical insecticides available to tomato growers in Canada. Carbamates are not very effective against adult potato beetles in comparison to the synthetic pyrethroids and organophosphates, which still have fast knock-down capabilities. Resistance to azinphos-methyl, an organophosphate, has been demonstrated in the major tomato-growing areas of Canada. Endosulfan, an organochlorine that was once ineffective because of resistance and was thus not used for many years, now appears to be effective against the Colorado potato beetle population in some areas.

Selected references

Jaques, R.P., and D.R. Laing. 1989. Effectiveness of microbial and chemical insecticides in control of the Colorado potato beetle (Coleoptera: Chrysomelidae) on potatoes and tomatoes. *Can. Entomol.* 121:1123-1131.

(Original by R.E. Pitblado)

▶ 18.35 Cutworms *Figs. 18.35a-g; 6.25a-c; 11.26*

Variegated cutworm *Peridroma saucia* (Hübner)
Other cutworms (see Table 18.35)

Cutworms cause problems to tomato, eggplant and pepper transplants by feeding on the plant stems at or near ground level (see also Carrot, cutworms, 6.25).

Cutworms are solitary feeders and many are subterranean. They have been known to cause serious damage to vegetable crops, especially in the second year after sod or pasture. However, cropping after sod is no longer a common practice. Early cutworm damage now is observed only at field edges along ditch banks or hedgerows, or within fields where weeds are present.

The variegated cutworm is a sporadic pest of tomato in southern Ontario and across Canada. High moth catches are frequent, beginning in the second week of July. Whether the moths are transitory, flying into Canada from more southern overwintering sites, or local, is open to question.

In years when natural biocontrol agents are ineffective, variegated cutworm larvae may cause substantial losses in fruit quality and yield. The variegated cutworm has an extremely wide host range and does not confine itself to tomato.

Damage Damage to foliage and fruit of tomato is common during late July and throughout August. Foliar damage consists of scattered leaf feeding, particularly along the leaf edges, but sometimes the entire leaf is eaten, leaving only the midrib. Fruit damage may consist of light surface feeding or feeding that produces holes deep into the fruit *(18.35a,b).* Injured fruit is often invaded by soft rot organisms.

Table 18.35 Cutworms commonly found in Canada

Common name	Scientific name
Army cutworm	*Euxoa auxiliaris* (Grote)
Black army cutworm	*Actebia fennica* (Tauscher)
Black cutworm	*Agrotis ipsilon* (Hufnagel)
Climbing (spotted) cutworm	*Xestia adela* Franclemont
Dark-sided cutworm	*Euxoa messoria* (Harris)
Dingy cutworm	*Feltia jaculifera* (Guenée)
Glassy cutworm	*Crymodes devastator* (Brace)
Granulate cutworm	*Agrotis subterranea* (Fabricius)
Pale western cutworm	*Agrotis orthogonia* Morrison
Redbacked cutworm	*Euxoa ochrogaster* (Guenée)
Sandhill cutworm	*Euxoa detersa* (Walker)
Striped cutworm	*Euxoa tessellata* (Harris)
Variegated cutworm	*Peridroma saucia* (Hübner)
White cutworm	*Euxoa scandens* (Riley)

On tomato transplants and other vegetable crops, cutworm larvae may chew partly or completely through the stem or petioles at ground level or, in the case of climbing cutworms, somewhat higher on the plant.

Identification Larvae of the variegated cutworm (family Noctuidae) are brown with longitudinal stripes *(18.35b,c).* They have mottled, diamondshaped markings along the back and sides of the body. Other cutworm larvae (*18.35d; 6.25a-c; 11.26)* are similarly marked and difficult to distinguish from the variegated cutworm without rearing to the adult stage. Adult identification should be confirmed by a specialist.

Feeding damage is accompanied by large, brown or black droppings (frass) on the soil surface.

Life history Moths of the variegated cutworm appear in mid-July and their numbers peak during the first to second week of August. Eggs are laid on the foliage and hatch within 5 to 10 days. The young larvae begin eating the tomato foliage and later attack the fruit. They often chew a feeding hole into the side of the developing tomato fruit. The larvae of the variegated cutworm often remain curled inside the feeding holes in the fruit, feeding mostly at night. The larvae complete their development and pupate in the soil. The variegated cutworm pupae overwinter in British Columbia, especially in the coastal areas, but whether they overwinter in Ontario is uncertain.

Management

Monitoring — Moths of the variegated and other cutworms can be monitored by black-light or pheromone traps, starting early in the season. Once observed, routine field inspection is necessary.

Biological control — Naturally occurring predators, parasites and pathogens usually exert significant influence because in most years cutworm populations cause little damage. Wherever feasible, growers should try to preserve these natural biocontrol agents.

Chemical control — Growers are advised to apply foliar insecticide treatments in the evening when larval activity is greatest, particularly early in the season when natural biocontrol agents are insufficient to suppress cutworm populations. Good spray coverage with penetration into the lower canopy is essential for adequate control.

Selected references
Rockburne, E.W., and J.D. Lafontaine. 1976. *The Cutworm Moths of Ontario and Quebec.* Can. Dep. Agric. Publ. 1593. 164 pp.

(Original by R.E. Pitblado and J.A. Garland)

▶ 18.36 European corn borer *Figs. 18.36a,b*

Ostrinia nubilalis (Hübner)

The European corn borer overwinters in pepper- and eggplant-growing areas throughout Canada except British Columbia, where this insect does not occur. Crops also may become infested by adults that fly in or are blown in during the growing season.

Field pepper is an important host of the European corn borer, more so than eggplant, potato and snap bean.

However, pepper is not as attractive to the corn borer as is sweet corn, its preferred host. Tomato is not affected by this insect.

Damage In areas having single-generation corn borer populations, damage to pepper occurs from mid-July to early August. Where two generations are produced, damage occurs during late July, then again throughout August and September. Corn borer populations are heaviest in southwestern Ontario and Quebec, which are also the areas of highest pepper production in Canada.

Larvae (*18.36a*) usually enter the fruit under the calyx stem-cap. A yellowish-brown, sawdust-like residue of droppings (frass) (*18.36b*) may be noticeable around the entry hole. If the larva enters directly through the side of the fruit during early pepper development, the fruit becomes dimpled in that area.

Severe loss in field pepper crops can be caused directly by fruit damage by the feeding corn borer larvae, or indirectly by rotting caused by pathogens introduced by the larvae. Fungi or bacteria often gain entry through the entrance holes created by the larvae, causing the fruit to collapse or rot. Losses are greatest for farmers who grow processing peppers because of a contractual load-rejection clause controlled by the processors, by which they can reject an entire load with more than 1 to 5% borer-damaged fruit.

Identification (see Maize, 12.16)

Life history (see Maize, 12.16) Overwintering corn borer larvae occur mainly in the stalks of field corn where they pupate and emerge as adults in the spring. Adults invade pepper fields in the spring, congregating in “hot spots” in response to the stage of pepper growth and the proximity of grassy areas, which they use as daytime refuges. Corn borer eggs are laid in masses on the leaves of pepper plants or on the pepper fruit-cap. Soon after the eggs hatch, larvae feed on the foliage, causing visual damage, and soon move toward the fruit, boring into the side or under the calyx stem-cap.

Management ***Monitoring*** — Field pepper crops are susceptible to corn borer attack as soon as the fruit is 3 cm in diameter. From then until harvest, the crop must be monitored and protected if corn borers are present. Adult corn borers can be monitored with black-light traps or commercial pheromone traps. Difficulties with sampling preclude the determination of a threshold value for corn borer egg masses on pepper.

Resistant cultivars — All bell-type peppers are susceptible to corn borer. Only the pepper cultivar known as Sweet Hungarian and the hot-type cultivars, such as Hungarian Wax and Long Thick Red, have high levels of resistance to corn borer attack. Pepper cultivars grown in Ontario show corn borer resistance in descending order, as follows: Hungarian Wax (Hot), Long Thick Red (Hot), Sweet Hungarian (Yellow Banana), Super Set 19, Staddon’s Select, Super Shepherd, MA 79252, Greenboy, Early Niagara Giant, Golden Bell, Lady Bell, Midway, Romanian Wax (Hot), Gedeon, Vinedale, Jupiter, Bell Boy, Emerald Giant 38, California Wonder, Keystone Resistant Giant and Yolo Wonder 43.

Chemical control — When corn borer populations are present, pepper growers should follow a preventive foliar spray program once the fruit has attained 3 cm in diameter (walnut size). Insecticidal applications then should begin when adults are trapped for three consecutive days and should be repeated every 7 to 10 days, depending on temperature and subsequent moth catches. Once eggs hatch, larvae quickly move under the fruit cap and bore into the fruit. This limits exposure, reducing the likelihood of an insecticide contacting the larvae, and makes early spray coverage essential for good control of European corn borer.

(Original by R.E. Pitblado)

▶ 18.37 Other caterpillars *Figs. 18.37a-c; 8.40; 12.13*

Cabbage looper
Trichoplusia ni (Hübner)
Corn earworm
Helicoverpa zea (Boddie)
Hornworms
Manduca spp.

Other caterpillars are observed occasionally in commercial tomato fields. In southern Canada, these include the cabbage looper (see Crucifers, 8.40), the corn earworm (see Maize, 12.13), and two *Manduca* species of hornworms (*18.37a-c*).

Tomato hornworms occur in the warmer, southern areas of Canada. They are particularly prevalent in southwestern Ontario and southern British Columbia. The large, green larvae are easily diagnosed by the seven or eight oblique white lines along the sides of the body and a prominent caudal horn *(18.37b).* Hornworm larvae feed on the foliage and may strip an entire leaf, leaving only the midrib. Although larvae feed on green fruit *(18.37c),* damage is rarely extensive.

In some years, hornworms and other caterpillars require control measures, but naturally occurring predators, parasites and pathogens usually keep them under control. Late- season damage to foliage in August and September by the cabbage looper and hornworms is usually of little concern. Fruit damage by the corn earworm is minor.

(Original by R.E. Pitblado)

▶ 18.38 Pepper maggot *Figs. 18.38a-g*

Zonosemata electa (Say)

The pepper maggot is native to and occurs throughout the eastern United States and southwestern Ontario. In Essex County, Ontario, it is an important but sporadic pest of field pepper. Horse nettle-infesting populations have been found as far north as London, Ontario.

The pepper maggot confines itself to solanaceous plants. The primary crop-host is pepper but larvae have been collected from eggplant and tomato. Several solanaceous weeds, including ground cherry *(Physalis* spp.), serve as hosts. Horse nettle, *Solanum carolinense* L., *(18.38a)* a particularly persistent, perennial weed in soybean and corn fields in southwestern Ontario, is thought to have been the original wild host of the pepper maggot.

Damage The first sign of damage on pepper is the small egg puncture formed by the female's ovipositor *(18.38b).* Egg punctures usually occur when fruit is about 1 to 3 cm in diameter. When pepper fruit increases in size, the area around the egg puncture becomes depressed, forming a shallow dimple. Most larval activity occurs in the soft placental tissue, or core, of the pepper fruit *(18.38c).* Damage appears as a brown, mined area and can be distinguished from corn borer damage by the absence of droppings (frass) *(18.36b).* Sometimes larval mines are visible beneath the epidermis of the pepper fruit, particularly after harvest. Pepper usually has only one larva per fruit, but eggplant commonly contains several larvae that mine the fruit extensively.

Pepper maggot has little impact on production of field pepper in Canada, because it is restricted to southern Ontario. However, in the absence of controls, growers of fresh-market crops in southern Ontario experience losses as high as 90% in some years. The zero tolerance for pepper maggot in processing peppers means that this insect can be devastating.

Identification Pepper maggot (family Tephritidae) adults are brightly colored, yellow-striped flies with banded wings and green eyes (*18.38d*). The head, thorax and abdomen are pale yellow, with two black dots on the dorsal side of the last abdominal segment. The legs are yellow with short black bristles ventrally. Males are about 6.5 mm and females about 7.5 mm long. The egg is 2.0 to 2.2 mm long and opaque white with a striated shell and a distinctive, narrow stalk *(18.38e).* Larvae reach 11 to 12 mm in length at maturity. They are legless, white maggots that turn yellow as they mature *(18.38f).* Pupae (puparia) are about 8 mm in length, 4 mm at the widest point, and medium buff-brown (*18.38g*). The above measurements are based on individuals reared on pepper. When reared on horse nettle, all life stages are about 10% smaller.

Egg punctures often go undetected early in the season. Frequently, the stalk of the egg protrudes from the skin of the fruit and may be seen with the unaided eye, but detection often requires at least 10X magnification. Pepper fruit suspected of containing pepper maggot should be cut open to expose the internally feeding larva. Infested eggplant fruits usually feel very spongy.

Previously, populations of pepper maggot infesting horse nettle and pepper were thought to be distinct host races with different biologies. However, recent work has shown that the life history and behavior of the pepper maggot on each of these hosts are similar. Thermal requirements, phenologies and activity periods also are similar. In the laboratory, females collected from horse nettle, pepper and eggplant will oviposit in fruits of pepper, eggplant, tomato and ground cherry, regardless of the plant from which they originated.

Life history The pepper maggot has the typical fly life stages of egg, larva, pupa (puparium) and adult. The pupa overwinters in a state of arrested development (diapause) in the top 15 cm of soil, the majority at depths of 5 to 10 cm. Diapause development requires about 150 days below 5°C; adults begin to emerge when soil at the 10-cm depth has accumulated 475 degree-days (range 409 to 541) above 9.5°C, measured after January 1. Peak emergence occurs near the end of June, and 50% of adults will have emerged when the soil at the 10-cm depth has accumulated about 600 degree-days above 9.5°C. Emergence extends over a period of 10 to 12 days, depending on the weather. Males and females emerge at the same time. They fly to host plants where they mate. The dispersal range is unknown; however, new infestations have occurred at least 1 km from known populations. The first mating may occur within 24 hours of emergence. Both sexes may mate several times in their lifetime. The pre-oviposition period lasts about six to seven days or until accumulating 180 degree- days above 9.5°C (air temperature).

Females live about 23 days and lay an average of 54 eggs, but some females live as long as 45 days and are capable of laying up to 200 eggs. Females seem to prefer small fruit (1 to 3 cm diameter) for oviposition, but this may reflect the size of fruit available during egg laying. Small fruits usually harbor single eggs while large fruits may contain several eggs. Larvae hatch within 10 days and young larvae may feed in the wall of the fruit, but most move directly to the core of soft placental tissue and remain there. When mature, the larvae move to the lower third of the fruit, bore through the fruit wall, drop to the ground and enter the soil to pupate. There is one generation per year in Canada.

Management

Monitoring — Detecting pepper maggot damage on pepper before the larva leaves the fruit is often difficult, although larvae are present until harvest when their exit holes become visible. Sampling for adults must be done visually or with a sweep net. Adults are most commonly observed resting on small fruits (1 to 3 cm diameter) in the early morning. Despite a zero tolerance for pepper maggot in pepper fruit destined for processing, there are no reliable traps for monitoring adult populations and no threshold is available.

Cultural practices — Horse nettle near plantings of pepper or eggplant should be removed, because this plant is a potential reservoir and source of pepper maggot infestations. Destruction of horse nettle in the first year of a rotation may not decrease damage to crop plants because pepper maggot flies emerging from horse nettle sites will continue to infest pepper and eggplant. Weed control must be practiced for several years. Fruit known to be infested with pepper maggot should be harvested early and buried deeply to reduce the next year's population.

Resistant cultivars — In fields and regions with a history of damage from pepper maggot, infestations can be reduced by planting the less preferred or more resistant pepper cultivars. Females prefer to oviposit on dark green, fleshy peppers, particularly the bell and cherry types. Thin- walled Yellow or Red Banana, Cayenne, Jalapeno, Tabasco, and Serrano pepper cultivars are the least preferred for oviposition by pepper maggot females, and these cultivars are highly resistant to larval feeding. Late-maturing cultivars also sustain less damage, because few flies are present after early August; any fruit that develops at that time is not likely to be infested.

Biological control — A wasp, *Opius sanguineus* (Ashmead), has been recorded in low numbers in pepper maggot larvae infesting horse nettle in Ontario, but never from larvae from pepper or eggplant. Predatory beetles likely cause some pupal mortality.

Chemical control — The pepper maggot is very susceptible to most chemical insecticides, and resistance has not been documented to any of the insecticides currently used in production of field pepper in Ontario. Because the eggs and larvae are protected within the fruit, foliar sprays for control of pepper maggot are effective only against adults. Insecticides used against European corn borer provide good control of pepper maggot and preclude the need for additional sprays. For optimum control of pepper maggot, the first application should be when 180 degree-days above an air temperature of 9.5°C have accumulated after the actual or predicted 50% emergence date for pepper maggot adults. An additional spray should be applied seven days later.

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(Original by G.J.R. Judd)

▶ 18.39 Sap beetles *Fig. 18.39*

Various species of sap beetles (family Nitidulidae) are attracted to cracked or squashed tomato fruits in the field or on wagons, hoppers or trucks standing in the field. Eggplant and pepper fruit also attract sap beetles but to a lesser extent than tomato. Although the transport system used in machine harvesting of processing tomato greatly reduces the need for concern of sap beetles, these insects remain a problem when tomatoes are hand-picked.

Life history (see Maize, four-spotted sap beetle, 12.19)

Management Growers must rely on cultural practices to reduce the occurrence of sap beetles in the field, because practical methods for the use of insecticides to control these beetles are not available.

Cultural practices — Roadways should be provided in the field at suitable intervals to allow movement of farm vehicles without squashing fruit. Growers should harvest as close as possible to the time of delivery, avoid leaving picked tomatoes in the field for long periods, and expose loaded wagons to air circulation if the load is not to be delivered promptly.

(Original by R.E. Pitblado)

▶ 18.40 Stink bugs *Figs. 18.40a,b; 3.7k,m*

Various species of stink bugs occur throughout the tomatogrowing areas of Canada. Until recently, they have not been considered seriously as pests. However, recent changes in cultivar selection and cultural practices have enhanced stink bug presence and their damage to tomato fruits.

Stink bugs have a wide host range, which includes alfalfa, cereals, soybean, bean, pea, tomato, and many weeds.

Damage As weedy areas dry out or mature during the summer, stink bugs move into tomato fields, presumably in search of their liquid diet. Consequently, damage to tomato fruit is often limited to the edge of the field nearest weedy areas. The piercing-sucking mouthparts of the stink bug adults and nymphs inflict damage to the surface of the tomato fruit, causing development of cloudy yellow blotches just below the skin of the fruit as a result of enzymes injected by the feeding insect (*18.40a,b).* Surface depressions also can form at the feeding sites. Stink bug feeding causes fruit distortion and defects, such as peel "tags" remaining on the fruit and a yellow blemish in the tomato flesh. As fruits enlarge, sites of early feeding expand and may rupture the thin epidermis over the wound, permitting entry of secondary organisms. Increase in sorting costs or rejection of the entire load at the factory may result from stink bug injury to tomato fruit. Losses can be significant for the wholepack and fresh- market industries.

Identification Stink bugs (family Pentatomidae) are 10 to 15 mm long and vary in color from green to brown. Their wings are folded flat over the abdomen with the membranous outer halves of the wings directed toward the rear of the body. The adults have pointed "shoulders" on the front part (pronotum) of the thorax (*18.40a; 3.7m).* Nymphs are similar in appearance but lack fully developed wings and the pronotum is not as pointed *(3.7k).*

Life history Stink bugs overwinter as adults in protected areas, such as fencerows, ditches, windbreaks or other areas where plant litter is abundant. In early spring, when temperatures reach 21°C or above, the adults become active. They feed initially on weeds. A single female may lay an average of 30 egg clusters during a month or more. Each egg cluster may contain 300 to 500 eggs. The nymphs hatch within a week and develop through five instars. The adult stage is attained after about six weeks. Repeat generations occur at five- to six-week intervals during the summer. Adults and nymphs spend much of their time deep within the plant canopy and, at times, slightly below ground. Adults move out of weedy areas in search of moisture in tomato fruits, especially during dry summers.

Management

Cultural practices — Stink bug damage has increased with the introduction of programs that include conservation tillage, extensive use of cover crops, and preventive practices to control wind erosion. These practices inadvertently favor stink bugs by increasing the availability of hosts and hiding places. Tomato cultivars that have an extensive foliage cover can be damaged severely. Increased damage during relatively dry years suggests a greater and earlier dispersal from the weed hosts to secondary, crop hosts. Growers are advised to eliminate weedy patches near field edges.

Chemical control — Treatment thresholds and reliable sampling methods have not been developed for stink bugs on tomato, so growers are wise to adopt a conservative approach in countering stink bug damage. Moreover, a proportion of some stink bug populations usually remains either on or in the soil where spray coverage is poor, resulting in inadequate control. Chemical insecticides normally would be applied in the latter part of July but may not be economical for an entire acreage. Spray applications, if necessary, should be directed around the field borders.

(Original by R.E. Pitblado)

▶ 18.41 Wireworms *Figs. 12.21a,b,T1; 16.50*

Wireworms (see Maize, 12.21) are found in all soil types and in all crop-production areas of Canada. Many different species cause damage to vegetable and field crops. Among vegetables, all root crops are susceptible, as well as potato, sweet corn and transplanted crops, such as cole crops, tomato, eggplant and pepper.

Damage Wireworms cause damage to plant roots and stems just below the soil surface. Plants attacked by wire- worms wilt, and the top 1 to 2 cm of plant tissue "flags" and eventually dies. Wireworms can be observed burrowing into the underground stems and roots of transplants, which eventually results in above-ground death of the plant. Damage is more severe in years when soils are cool and wet, conditions which retard plant growth but not insect feeding. Under good growing conditions, transplants often outgrow minor wire- worm damage. Pepper plants, however, do not compensate as well as tomato and eggplant, and each pepper plant lost represents an important loss in total yield.

Identification (see Maize, 12.21; Potato 16.50)

Life history (see Maize, 12.21)

Management (see also Potato, 16.50)

***Monitoring* —** Wireworms remain in a field for several years, so problem areas must be treated or managed for consecutive seasons.

Cultural practices — In the past, growers were advised to protect vegetable crops, especially after sod. However, wireworms have caused significant damage whether sod preceded the crop or not. Weed control to eliminate grasses reduces the availability of egg-laying sites within fields. Rotation with alfalfa is beneficial but not always practical.

Chemical control — Growers will become aware of areas of fields that must be treated, because wireworms remain in the soil for several years. Insecticides applied in the transplant water effectively reduce the damage caused by wireworms. Some insecticides may be phytotoxic under cool, wet spring conditions.

(Original by R.E. Pitblado)

▶ 18.42 Other insect pests *Figs. 18.42a-m*

Crickets and grasshoppers
Flea beetles
Greenhouse whitefly *Trialeurodes vaporariorum* (Westwood)
Tarnished plant bug *Lygus lineolaris* (Palisot de Beauvois)
Vinegar flies *Drosophila* spp.
Western flower thrips *Frankliniella occidentalis* (Pergande)

Crickets and grasshoppers

Crickets (family Gryllidae) and grasshoppers (family Acrididae) migrate into tomato fields in August and September from nearby weedy or grassy areas. These insects may damage foliage, and crickets also often eat the skin of tomato fruits. If crickets begin to move into commercial tomato fields, one or two insecticidal applications directed around the border of the field usually will protect the crop.

Flea beetles

Flea beetles (not the same species as those on cabbage and other crucifers) are not serious pests of tomato, eggplant or pepper, although they may act as vectors of fungi, such as the early blight pathogen *Alternaria solani.* The existing schedules for fungicidal applications, using the weather-timed spray program TOM-CAST, have all but eliminated concern about flea beetle transmission; the small, circular leaf damage caused by the adult flea beetles is easily compensated for by the newer, rapidly growing tomato cultivars. Flea beetle damage to emerging, direct-seeded tomato seedlings has led to the development of control recommendations. However, direct seeding of tomato is no longer practiced commercially in Canada.

Greenhouse whitefly

The greenhouse whitefly (see Greenhouse tomato, 25.27) can be found on field tomato in significant numbers, mainly in southern Ontario and southwestern British Columbia. Their sucking method of feeding and honeydew deposits result in stickiness to foliage and fruit. This is not a problem in tomato crops that are machine harvested for processing, but the stickiness resulting from high whitefly populations can be a nuisance for pickers in hand-harvested operations and for fresh-market crops.

Tarnished plant bug

The tarnished plant bug (see Celery, 7.21) (*18.42b-e*) feeds on the flowers and stems of tomato, eggplant and pepper, causing flower drop which reduces yield in some years. Fruit also may be attacked *(18.42a)*, leading to indentations and yellowing of the flesh where the fruit is "stung" by the piercing-sucking mouth- parts of the plant bug nymphs and adults. Early damage often is not noticed by growers and control measures are seldom used.

Injury by tarnished plant bug is likely to increase as cultural practices within the vegetable-growing areas of Canada shift toward reduced tillage, which increases plant residue on soil surfaces and thereby improves the available habitat for these insects (see stink bugs, 18.40).

Vinegar flies

are also known as vinegar fruit flies (family Drosophilidae) (*18.42f,g*). They are only a minor problem in fruits wounded in the field by equipment, birds or insects, such as crickets and variegated cutworms. These so-called “fruit flies” hardly merit consideration except when fruit is damaged or bruised at harvest, or when it is kept or stored for an extended period, in which case their impact is greatest on fresh-market tomatoes.

Western flower thrips

The western flower thrips (see Greenhouse cucumber, 22.34) (*18.42h-m*) has recently expanded its range as a field pest to eastern Canada from western Canada and the southern United States. It can be a serious problem in the production of tomato and pepper because it transmits tomato spotted wilt virus. In 1989, both the western flower thrips and tomato spotted wilt virus were recorded for the first time in Canada on field tomato and pepper in southern Ontario. The western flower thrips and the virus are thought to have been imported on transplants from the southern United States and may continue to be imported because both pests are endemic in the southern United States, which is the source of a large portion of the transplants used to establish the tomato and pepper crop each year in Canada. As the local plug-transplant industry expands in Canada, fewer transplants will be obtained from the southern United States, reducing the importation of the virus and the thrips. The western flower thrips is difficult to control because the immature and adult thrips prefer to feed in flower blossoms, which shelter them from predators and where they often escape the lethal effects of chemical insecticides. (For more information about the western flower thrips, see Greenhouse cucumber, 22.34.)

(Original by R.E. Pitblado)

OTHER PESTS

▶ 18.43 Slugs *Figs. 18.43; 11.27a-c*

During wet conditions, slugs may shred leaves of pepper plants and attack young pepper and tomato fruit. Feeding holes made in the fruit can serve as entry sites for bacteria. (For more information on slugs, see Crucifers, 8.49; Lettuce, 11.27.)

(Original by R.E. Pitblado)

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