7. Major Greenhouse Diseases

Regulated Diseases

This chapter describes the most common disease problems in greenhouse ornamental production. However, it is important to realize that some of the most destructive diseases are very infrequently found but when they are, the impact can be devastating. Some diseases, because they are known to be a potential risk to large segments of Canadian agriculture, are regulated by the Canadian Food Inspection Agency (CFIA). Other diseases may have no known potential for damage until they occur, at which time the CFIA will decide on the risk they present. When found, regulated diseases must be reported to the CFIA. A decision will then be made by CFIA as to what action must be taken to address the disease or disease pathogen. Although this action can have serious financial impacts on individual growers, it is important to the industry that growers report suspected problems. Failure to do so could threaten the export of ornamental plants to countries such as the United States. Known quarantine diseases as of June 2014 are noted within this chapter and include chrysanthemum white rust, Ralstonia bacterial wilt of geranium and Ramorum blight and dieback (sudden oak death). For more information and the most up-to-date listing of regulated pests and diseases, visit the CFIA website at *www.inspection.gc.ca* or contact your local CFIA office (see Appendix D. *Other Contacts* on page 155).

Fungus Diseases

Botrytis (grey mould)

The fungus known as *Botrytis cinerea* causes many common diseases of greenhouse ornamental and vegetable crops. “Grey mould” is often used to describe the disease because of the prolific sporulation of grey or brown spores, a characteristic symptom that occurs on infected tissues under appropriate conditions.

Botrytis disease symptoms appear as flower spotting and blight, leaf blights, bud and cutting rot, stem cankers, and corm or bulb rots.

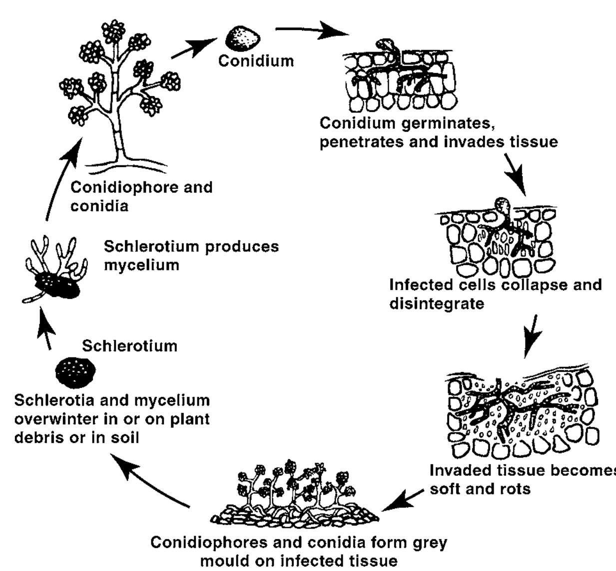
Infections occur when germinating conidia (spores) penetrate healthy succulent leaf or flower tissue, stomata, or wounds, or when pieces of fungal mycelium or infected plant tissue come in contact with healthy host tissue. See Figure 7-1. *Botrytis Life Cycle* on this page.

Botrytis readily attacks healthy or senescing, soft, nutrient-rich flower or bract tissues of most flowers including cyclamen, geranium, rose and poinsettia. Mycelial infections typically occur when infected flowers or leaves fall onto healthy tissues below and stick to wet leaf surfaces.

Latent infections occur as described above but show no visible symptoms because of unfavourable environmental conditions. When environmental conditions change, symptoms may appear. This typically occurs with cut flowers, which appear healthy when cut and packed but have tan-brown spots on the petals when unpacked at the retail destination.

Botrytis is ubiquitous – the spores are always present. The conidia disperse very readily in air currents and in or on water droplets. Fluctuating relative humidity levels trigger the release of spores. Spore germination can occur in less than three hours, with sporulation occurring within eight hours of initial infection.

Figure 7-1. *Botrytis* Life Cycle



Botrytis infections usually occur during cool, wet or humid weather conditions, which favour infection and sporulation. Free moisture containing dissolved nutrients in combination with air temperature determine the severity of the initial infection and subsequent lesion development. Optimal conditions for *Botrytis* growth are temperatures between 15–23°C and relative humidity (RH) greater than 90%, or when microscopic free moisture forms on plant tissue as a result of cooler plant tissue temperature compared with the surrounding air temperature.

Cultural strategies to manage Botrytis

Botrytis is often considered a "disease of bad management." Use appropriate crop management techniques and manipulation of the greenhouse environment to minimize its impact. For example, reduce the relative humidity at night by maintaining warmer night temperatures and proper ventilation practices.

Use computer-controlled humidity monitoring programs. Avoid formation of free moisture, which occurs at night whenever the leaf or plant temperature is lower than the air temperature or the air cools below the dew point. This happens frequently in the evening with a clear sky or early in the morning when the air heats up more quickly than the plant surface. Computer controlled energy/shading curtains can be effectively used to manage plant temperature under the conditions described above. Use minimum pipe temperatures in summer when nights are warm and humid.

Calibrate RH sensors regularly. Keep RH below 85%. Do not allow leaves to stay wet more than 3–4 hours.

Air circulation that maintains smooth, laminar flow is also critical for maintaining dry plant surfaces by eliminating the high-moisture boundary layer around the leaf surfaces. Proper plant spacing is important to allow air movement throughout the plant canopy. Remove excessive foliage in crop canopy if necessary.

Sanitation before and during crop production is essential. Remove senescing flowers and leaves.

Avoid overhead watering wherever possible. When using overhead irrigation, water early in the day to allow foliage and canopy to dry before evening.

Fungal leaf spots and blights

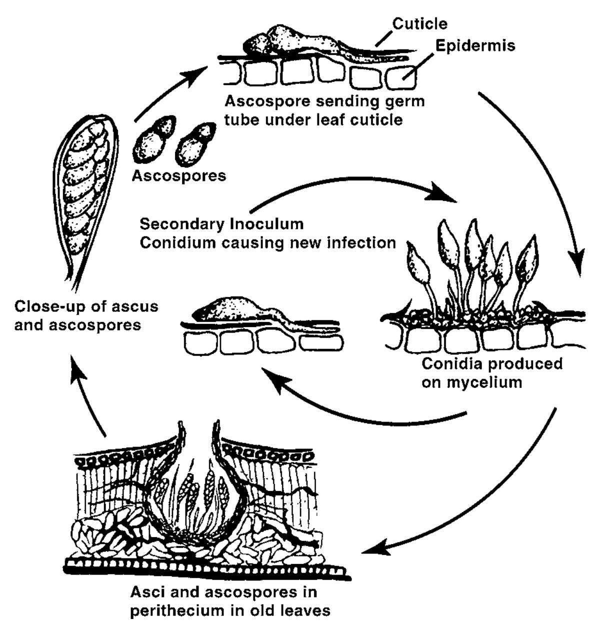
Fungi cause all of these diseases, with symptoms varying greatly. See Figure 7-2. *Leaf Spot Disease Life Cycle* on this page.

The more common fungi causing leaf spots include *Alternaria, Ascochyta, Cercospora, Phyllosticta, Gloeosporium,* and *Septoria,* all part of the ascomycetes group of fungi. Most produce abundant conidia. Spores of these fungi are wind-borne and can be splashed around when watering. Some of these leaf spot fungi can be seed-borne.

Blights or spots can appear on leaves, stems or flowers depending on the organism present. Many attack all three of the plant parts, but none attack the roots or crown. Leaf blights and spots usually appear on the lower foliage and work their way up through the plant canopy. Many of the pathogens produce characteristic spots or lesions, such as "bull's-eye" spots with a reddish border or tan-coloured spots with concentric rings. Spots may be circular, angular or irregular.

Leaves must be wet for a period of time (3–8 hours depending on pathogen) for infection to occur.

Figure 7-2. Leaf Spot Disease Life Cycle



Cultural strategies to manage fungal leaf spots and blights

- Keep foliage and flowers as dry as possible.
- Avoid overhead watering late in the day.
- Provide good air circulation.
- Remove infected plant material from the greenhouse.
- Use disease-free propagating material.
- Most broad spectrum fungicides will provide effective control. Check the label for registered uses.

Powdery mildews

These common fungal diseases cause an easily recognized white powdery growth on leaves, stems, petioles and floral parts of infected plants, quickly making plants unmarketable. Several genera are involved, including *Erysiphe, Leveillula, Microsphaera* and *Sphaerotheca*. It is important to note that the fungus that causes powdery mildew on one plant species generally does not affect another. Because powdery mildews are obligate parasites, they require living plants for completion of their life cycle. Each of these fungi forms a network of hyphae over the leaf or stem surface, from which it penetrates epidermal cells to derive its nutrients via nutrient pegs known as haustoria.

Growth may begin as small, discrete spots but can spread to cover the entire upper surface of the leaves. On many plants, the fungal growth becomes felt-like. This happens when ideal conditions produce abundant superficial mycelia bearing many colourless conidia (spores). In some plants, the leaves develop a reddish discolouration where the infection occurred. Severe infections will cause leaf stunting, yellowing and curling.

In the greenhouse, powdery mildew fungi have a simple life cycle. Single-celled conidia form in a long chain on short, erect fungal stalks. See Figure 7-3. *Powdery Mildew Life Cycle* on this page. This creates the "fluffiness" usually associated with powdery mildew. Under favourable environmental conditions, conidia chains are produced and released typically at a rate of one conidium per day or diurnal cycle. Conidia mature and are ready for release in 24 hours. A drop in relative humidity and the heating and drying effect of solar radiation promote spore release.

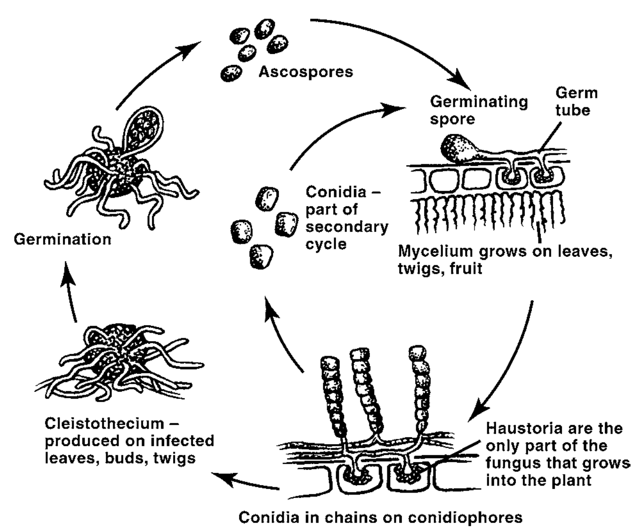
Conidia need a RH of 95% or a near-zero vapour pressure deficit for more than 3–4 hours to germinate and penetrate the host's leaf or stem epidermal cells. The mycelium produces haustoria or nutrient pegs, which provide a constant nutrient supply for fungal growth and conidial stalks as it grows over the leaf surface. Within 48 hours of inoculation, mature conidia can be released to infect other leaves or plants.

Relative humidity, temperature, light, leaf wetness and air movement (e.g., drafts) all influence the severity and spread of powdery mildew infections. Because of these interrelated environmental factors, use an integrated approach.

Excessive and turbulent air movements, such as drafts near open doors, improper spacing of HAF (horizontal airflow) fans, forced air furnaces or improper fan sizing or speed, promote infection and spread.

Leaf wetness episodes promote fungal development. The occurrence and persistence of leaf wetness are affected by leaf-to-air temperature gradients, the degree of leaf radiant energy loss, solar radiation and leaf transpiration.

Figure 7-3. Powdery Mildew Life Cycle



Cultural strategies to manage powdery mildew

Avoid drafts by keeping walkway doors closed. Automate the opening and closing of doors if possible. Reduce speed of horizontal airflow fans (HAF) if they have variable-speed motors. Maintain smooth airflow patterns over leaf surfaces. This prevents localized areas of high relative humidity (RH) and reduces air and leaf temperature fluctuations.

Using computer technology, establish reasonable environmental parameters to maintain the desired RH levels through heating and ventilation to provide buoyancy to the air that will allow for efficient purging of excess moisture in the air. Avoid sudden changes in either temperature or RH due to venting. High RH on its own does not necessarily promote powdery mildew.

Rely on the radiant heat from both the crop zone and above crop heating lines to maintain a drier, warmer crop environment. Establish a higher minimum pipe temperature if using hot water, or apply short pulses of steam into the above-crop heating lines to create a source of radiant heat to maintain a warmer leaf temperature than the surrounding air. See additional comments on plant temperature on page 86 regarding management of Botrytis.

Maintaining minimum crop heating is important because during the evening in late summer, the dew point is often reached in the greenhouse as temperatures drop. Closing shading or energy curtains and/or using high-pressure sodium lighting during the winter months will help prevent radiant energy loss from leaf surfaces by keeping them warmer.

Downy mildews

Peronospora, Plasmopara and *Bremia* are the three downy mildew genera that commonly attack ornamental plants. The downy mildews have become more common in the past several years and are difficult diseases to control. These fungi are primarily foliage blights but will attack and spread rapidly into young green tissues of growing tips and flower buds, causing stunting and distortion. Some of the most commonly attacked crops include rose, snapdragon, impatiens (New Guinea impatiens not included), *Lisianthus,* sunflower, *Coleus, Cineraria, Argyranthemum,* pansy, basil, cucurbit vegetable transplants and numerous herbaceous perennials.

For most crops, masses of tan, white or purple fuzz (spores) can be found on the under-surface of the leaves. Leaves of most plants will tend to cup along the margin and curl downward. Upper leaf surfaces show chlorosis (yellowing) where the infection is located. Leaf abscission (drop) typically occurs in most plants when infections become severe.

The development and spread of downy mildews depend on the presence of water films on the plant tissues and by air movement, especially during cool nights when the RH is very high.

Rose leaves develop purplish-red spots on upper leaf surfaces. They become distorted, have symptoms typical of pesticide phytotoxicity, turn yellow and abscise in great numbers. Rose downy mildew produces very few visible spores unless optimal conditions exist.

Downy mildew of snapdragons produces masses of grey-brown spores that resemble thick velvet. Foliage becomes distorted and if infection occurs in the seedling stage, it quickly becomes systemic and infects the growing tip or developing flower spike. Losses can be severe.

On *Impatiens walleriana,* yellow blotching or general leaf yellowing occurs with downward leaf cupping of the upper leaf surface and with masses of white spores on the under surface. Since 2011, downy mildew has become a serious disease in residential landscapes because there are no control strategies for use outdoors.

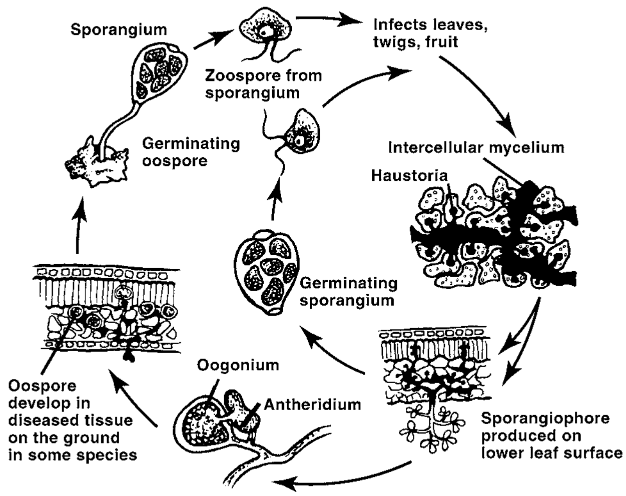
Symptoms on sunflower are very similar to that of impatiens.

Downy mildew of coleus and basil are often the same pathogen because both plants belong to the same plant family. In both cases, symptoms include leaf yellowing, irregular necrotic brown lesions, plant stunting, and masses of purplish grey brown spores on the lower leaf surface.

Downy mildew fungi survive for long periods of time on infected plant debris in the soil, or as oospores within the greenhouse and outdoors in landscape beds.

Sexual reproduction results in oospore production, which is a thick-walled spore that carries the fungus through long periods unfavourable for its growth and development. See Figure 7-4. *Downy Mildew Life Cycle* on this page.

Figure 7-4. Downy Mildew Life Cycle



Cultural strategies to manage downy mildews

Manipulating the environment combined with fungicide applications can prevent further spread to non-infected plants. Fungicides will not cure systemic plant infections. Downy mildews become resistant to many fungicides very quickly. It is important to rotate between fungicides of different Fungicide Resistance Action Committee (FRAC) group numbers. Alternating or combining a broad spectrum fungicide with registered systemic fungicides reduces the potential for resistance development. See Table 8-6. *Fungicide Groups Based on Sites of Action* on page 110 and Table 10-2. *Pesticide Registrations by Pest* on page 133 for FRAC code numbers, mode of action and crop usage patterns for products registered as of June 2014.

Control humidity and temperature fluctuations to prevent moisture condensation on the plants. This is often difficult when growing cool-season crops. However, increasing night temperatures using both crop and overhead heating lines and raising minimum night temperatures to reduce the radiant energy loss from leaf surfaces can be effective.

Avoid wetting the foliage when irrigating, although this is usually impossible when growing bedding plants. Spores are spread by splashing water and air currents. Watering early in the day when possible will provide time for drying of the plant canopy.

Clean up all crop debris and infected plants and remove from the greenhouse, as the organism survives between crops on plant debris, particularly as thick-walled oospores.

Many epidemics begin during extended periods of cool, damp weather, when growers attempt to economize on fuel consumption by adopting low-temperature set points or by not operating the heating system during the late spring or early fall.

Fungal wilts

Wilt diseases cause a whole plant, a portion of a plant or a major branch to wilt. Other symptoms include vascular discolouration, stunting, and varying degrees of leaf yellowing. Infectious wilts can be divided into two broad categories:

- Fungal, caused by *Fusarium solani, Fusarium oxysporum* and *Verticillium albo-atrum*.
- Bacterial, caused by *Erwinia chrysanthemumi, Erwinia carotovora, Xanthomonas campestris* and *Ralstonia solanacearum*. For discussion on bacterial wilts, see *Bacterial Diseases* on page 97.

Most fungal wilt pathogens are soil-borne, attacking through roots or the crown area. Root hairs and root tips exude nutrient-rich compounds like proteins and enzymes into the media as they grow through the media. These can stimulate fungal germination and are the first nutrient source for potential pathogens until they are established within the plant host.

Fungal wilt pathogen growth is limited to the vascular tissue, while bacterial pathogens spread rapidly into adjacent tissues through maceration (breakdown) of all cell tissue. Both groups of pathogens can be carried in the stems and/or roots of symptomless cuttings.

Symptoms of *Fusarium* and *Verticillium* are almost identical in some plants and these diseases can only be accurately differentiated through laboratory examination. These pathogens plug the xylem vessels, interfering with the translocation of water and nutrients. Symptoms include wilting, marginal necrosis and yellowing (eventually browning) of older leaves. Plants are usually stunted, bloom production is reduced, and the vascular tissue often has a brownish or reddish-brown discolouration. Plants usually die, particularly from an early infection. Many weeks can pass between the initial infection and the appearance of symptoms.

Fusarium can cause stem and crown rots that result in wilting and collapse. The dark-brown to black lesions develop on the stem at or just below the soil line, with the leading edge often pinkish or reddish. Infection occurs inward. There is usually no external stem discolouration.

Fusarium is a very common pathogen of a wide range of greenhouse crops. *Verticillium* is much less common, and usually attacks only chrysanthemum, aster and dahlia.

The fungal pathogens persist for long periods as thick-walled resting spores in soil or plant debris. The spores form when plant tissue begins to dry up.

Host plant stress makes plants susceptible to a fungal wilt pathogen attack and strongly influences attack severity. Stress for a particular crop can include high or low air or media temperatures, improper watering, fertilization, media pH or EC.

Pathogen spread during propagation is very common. Fungal pathogens are readily spread by water movement through media, splashing, and the physical movement of infected media and plant material within and between greenhouse operations.

Fungus gnat larvae readily spread *Fusarium* spp. spores.

Cultural strategies to manage fungal wilts

To minimize the development and spread of wilt pathogens, maintain good horticultural practices:

- Use pathogen-free cuttings and seeds.
- Remove and destroy all infected plants.
- Sanitize benches and used trays. See Chapter 4, page 50 for section on Disinfectants and cleaners of greenhouse surfaces.
- Do not reuse pots.
- Thoroughly pasteurize beds for soil-grown crops.
- Maintain appropriate temperature and growing media moisture levels for each crop.

Damping-off of seedlings

Rhizoctonia solani, Pythium spp. and *Phytophthora* spp. are the primary causes of this seedling disease complex, which describes a condition affecting germinating seeds and young seedlings rather than a specific pathogen. See Figure 7-5. *Disease Cycle of Damping-off and Seed Decay* on page 91. *Fusarium, Botrytis* and *Sclerotinia* are also occasionally responsible for damping-off.

Pre-emergence damping-off

Pre-emergence damping-off kills the emerging radicle (developing root) and hypocotyl during germination or soon after emerging from the seed coat. The young plants never emerge from the media. Growers often mistakenly blame this loss on poor quality seed. Pre-emergence damping-off is rarely observed today because of good moisture and temperature control in the seedling plug trays during germination and establishment.

Post-emergence damping-off

Most growers are familiar with post-emergence damping-off. Typically, the stem is invaded at or near the soil surface. The seedling wilts or stunts, the stem collapses and the plant topples over. Stem lesions may appear somewhat water soaked. Other variations of post-emergence damping-off include top rot or top damping-off and root rot.

Wire-stem damping-off

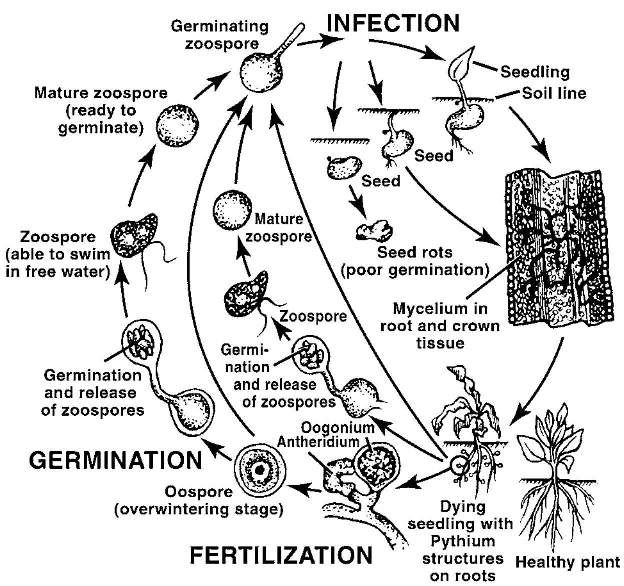
Wire-stem damping-off is usually associated with older seedlings that have been hardened off. Stems are partially girdled with dry black lesions and have a wire-like appearance. Infected plants are stunted and eventually die. *Rhizoctonia solani* is associated with this condition. High media moisture and poor air circulation within the plant canopy of seedlings increase the likelihood of attack.

Rhizoctonia often spreads in a circular pattern in a seedling tray, with fine grey-brown strands of mycelium visible on the surface of the growing media or as an aerial blight infecting the above-ground plant parts.

Water moulds like *Pythium* and *Phytophthora* can attack seeds, but commonly induce rot from the tips of the young roots. This is most severe at high moisture levels and cool temperatures.

Wet media, poor sanitation, poor ventilation, high humidity, cool temperature, thick stands of seedlings or overgrown seedlings provide ideal conditions for damping-off fungi.

Figure 7-5. Disease Cycle of Damping-off and Seed Decay



Cultural strategies to manage damping-off caused by Rhizoctonia solani

- Sanitation is important. Only use new flats or plug trays for disease-susceptible crops.
- Avoid splashing water, which will spread the pathogens.
- Use a porous, well-drained pathogen-free seedling mix.
- Maintain proper temperatures throughout the various phases of seedling germination and growing on.
- Provide good air circulation.
- Do not contaminate media used for seeding with dust or used media.
- Reduce misting as soon as possible after seedling emergence, or germinate in high-humidity germination chamber.

Crown and root rots

The fungi that most commonly cause crown and root rots are, in order of importance, *Pythium, Rhizoctonia, Phytophthora, Fusarium, Thielaviopsis* and *Sclerotinia*. Crown and root rot fungi are soil-inhabiting pathogens that constantly threaten commercial greenhouse crops. Note that each of these disease-causing fungi has unique environmental needs.

"Root rot" is a general term for the killing and then rotting of roots by various fungi. Root rot begins when the cortical roots become dysfunctional. They appear water-soaked and have a brown to black discolouration. New root development is reduced. As the rot progresses, the leaves become yellow and stunted, and eventually wilt.

Root rots debilitate individual plants and groups of plants. They compromise crop uniformity and often cause symptoms of nutritional imbalance. This is a serious issue with crops being grown in closed sub-irrigation systems.

Root pathogens are more difficult to diagnose visually than most foliar diseases.

Cultural strategies to manage crown and root rots

All fungal root rot pathogens can survive in growing media or on infected tissues as mycelium or spores. Most soilless media are considered pathogen-free, and as such have few naturally occurring fungi or bacteria to act as suppressive agents. They can also exist in soil and growing media as oospores, chlamydospores or sclerotia (resting structures with thick cell walls), which remain viable for long time periods. When they contact roots of a susceptible host, they become active (germinate) and begin infecting root tissues. Completely eliminating the inoculum source is difficult, so preventing their activity is the key to control.

All root rot fungi can be spread in or by splashing irrigation water. Fungi can also be carried over in contaminated media, soil under benches, infected plant residues, reused growing containers, dust, used capillary mats and recirculated irrigation water. Irrigation water from storage ponds collected from runoff may contain root rot pathogens. For disease-susceptible crops being grown in a closed system, treat the recirculation solution with UV, ozonation, heat pasteurization, chlorination or hydrogen peroxide.

Healthy plants resist root rot infection. Crop stress is an important contributing factor to crown and root rots, predisposing plants to attack. Factors contributing to crop stress include fertility level, high EC and media pH, watering practices, air and media temperature, light level, and pesticide and growth-retardant drench applications. Each root pathogen has a different optimum temperature, pH and moisture requirement.

Using growing media drenches effectively

Soil drenches are typically used for the control of root- or crown-attacking disease pathogens and involve the application of the pesticide to the root zone. The amount of pesticide added varies depending on the pot size and volume of the growing medium, but to thoroughly wet the growing medium in a 15-cm pot requires approximately 150–180 mL. For soil beds, apply 12 L of drench/m². Be aware that not all pesticides require the medium to be completely wet, so follow the label directions carefully. Treatment of young plants preventatively just prior to transplanting to a larger container is a way of reducing the amount of pesticide used.

Application of soil drenches for crops being sub-irrigated is a challenge because the roots are concentrated at the bottom of the pot, while the fungicide applied as a drench, by its very definition, is being applied from the top. Also, by applying from the top, the accumulated salts in the top zone of the media are pushed down into the active root zone area, potentially compounding the problem. Application of fungicides by sub-irrigation is very effective. Discuss available options with a greenhouse floriculture specialist.

Growing media should be moist when fungicides are applied to avoid further damage to the root systems of the crop.

For disease control, drenches should not replace a thorough greenhouse sanitation or soil pasteurization program, but they are useful for preventing recontamination or eliminating pathogens in the soil or the basal parts of the plant during the cropping cycle.

Some fungicides are taken up from the soil by plant roots and distributed throughout the plant. This is described as systemic action, and the whole plant is effectively treated against the disease being targeted. Aliette is the only fungicide for control of a root and crown pathogen that is often more effective when applied to the foliage and translocated downward in the phloem.

Pythium spp.

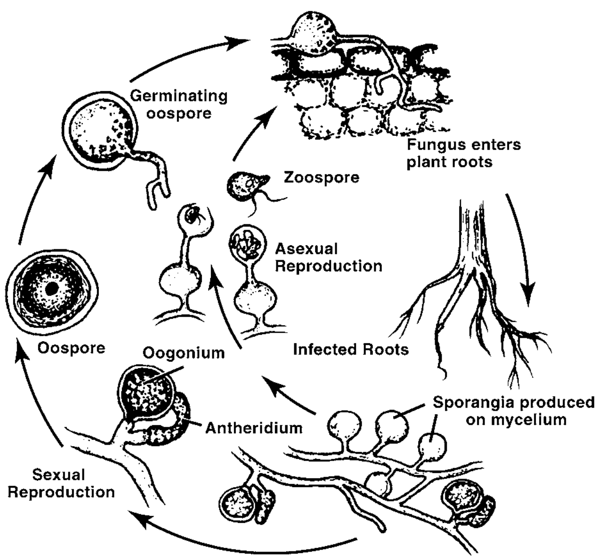
Pythium root rot is the most common root rot found in greenhouse production. Several different species including *P. ultimum* (the most common), *P. aphanidermatum* and *P. irregulare* attack many crops.

Symptoms vary with the age and development stage of the affected plant. Older-plant infections are usually limited to roots and root hairs. Infected roots are soft, mushy and various shades of brown. The rot begins as water-soaked brown rot of the root tips and cortex. Usually the cortex sloughs off, leaving the vascular cylinder (which remains thread-like). Lesions can occur on crowns of more succulent crops such as gloxinia. Above-ground symptoms include stunting, wilting and yellowing due to nutrient and water deficiencies. *Pythium* black leg of cuttings is generally very black and often shiny.

Pythium spores germinate in response to root exudates. These provide food until the white, slender, profusely branching and rapidly growing mycelium penetrates the roots. See Figure 7-6. *Pythium Root Rot Life Cycle* on page 93. *Pythium,* depending on the species, quickly produces two types of spores:

- Asexual zoospores, which, when released, can swim in films of water until they contact healthy host tissue. There, they germinate and start a new infection.
- Sexual oospores, which are thick-walled, resist both high and low temperatures, and remain viable for long periods of time.

Figure 7-6. *Pythium* Root Rot Life Cycle



Regardless of species, spores are moved around rapidly within a greenhouse in sub-irrigation water.

Cultural strategies to manage Pythium root rot

Pythium ultimum infections are most common at temperatures below 18°C, while other species favour high temperatures. Maintain temperatures favourable for plant growth, particularly root growth. High media temperature causes considerable root stress and is of concern during the summer months when growing on concrete floors and metal troughs.

Avoid over watering and fertilization when the crop is young or not growing actively. Use a porous, well-drained media. Keep the EC of the media low during the summer. Check regularly for high salts. Avoid excess nitrogen fertilization.

Monitor and control fungus gnat populations. Both fungus gnat larvae and adults can spread the pathogen.

Rhizoctonia

Rhizoctonia solani is commonly associated with damping-off but can also occur in rooted cuttings and well-established plants of most commercial floriculture crops.

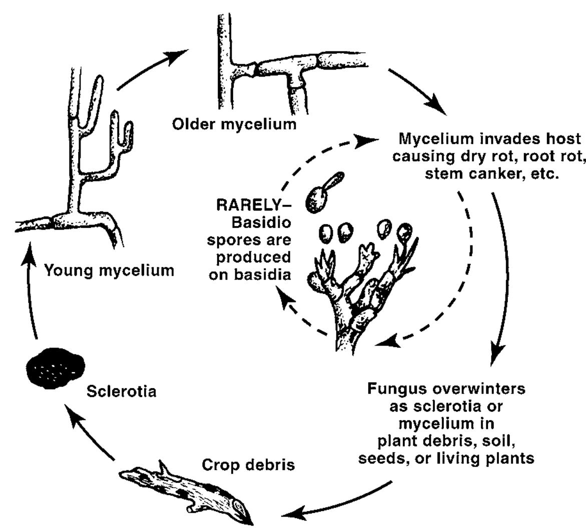
The symptoms vary with the host and development stage, but generally cause reddish-brown or black lesions on the below-ground stem and roots of infected plants. Under favourable conditions, the lesions increase in size and number to include the whole base of the plant. See Figure 7-7. *Rhizoctonia Life Cycle* on this page.

This pathogen is slow to girdle the crown and root area of established plants. As a result, the grower may not observe this disease until long after the initial infection, when plants begin to wilt or appear stunted with yellowing leaves. Lower leaves of infected plants usually become chlorotic and plants may break off at the soil line.

Potted plants propagated by cuttings are susceptible, such as geranium, poinsettia and New Guinea impatiens. It appears as a brown basal rot and stems may have longitudinal cracking. Crown rot can occur as a crown infection in the absence of root rot.

On fleshy, succulent stems, bulbs, and corms, the brown or black sunken lesions are often dry. Stem cankers can occur on lower branches where infested media have been splashed.

Figure 7–7. *Rhizoctonia* Life Cycle



Cultural strategies to manage Rhizoctonia root rot

High media and air temperatures and/or high RH promote *Rhizoctonia* in most greenhouse crops. Avoid wet and dry extremes in the growing media. Ensure good air circulation to quickly dry media surfaces. A temperature range of 17–26°C, which includes typical plant propagation and production regimes, is optimal for this pathogen.

Phytophthora spp.

Phytophthora causes root and crown rots (similar to *Pythium),* although not typically beginning at the root tips and occasionally as leaf blights. In Ontario, these pathogens are most commonly observed during the summer growing period.

Two common species, *P. cryptogea* and *P. parasitica,* will attack many crops but the symptoms observed are similar. *Phytophthora,* like *Pythium,* is a water mould. The asexual spores and mycelium spread quickly in films of water.

Typical symptoms include necrotic brown to black lesions on larger roots and on the crown of the plant. Basal cankers with black streaking often appear. Leaves can become infected by contact with infested media.

Zoospore production and development are stimulated by saturated media and root exudates.

Cultural strategies to manage Phytophthora crown and root rots

Avoid over-watering when the crop is young or not actively growing. Use a porous, well-drained, pathogen-free growing medium. Avoid saturated media conditions. Water management is very important.

Avoid media temperatures above 26°C.

Ramorum blight and dieback (sudden oak death)

Ramorum blight and dieback is a serious disease caused by *Phytophthora ramorum* that has killed hundreds of thousands of oak trees in California and Oregon since first being detected in the mid-1990s. It has a wide host range with dozens of genera of plants (all species in each genus), including many common nursery-grown woody ornamentals, currently regulated by the CFIA. The disease has been detected in British Columbia and is subject to an eradication program by the CFIA. Strict regulatory control measures are in place to ensure the disease does not become established in Canada. A wide range of symptoms are caused by the pathogen depending on the host, ranging from rapid decline and dieback of oak to foliar blights and leaf spots on rhododendron and camellia.

Evidence suggests that *P. ramorum* spreads by airborne spores and wind-blown rain. Cool temperatures with relatively high moisture favour disease development.

Two mating types are known to exist: the A1 or European strain and A2 or North American type.

To view the latest phytosanitary regulations to prevent entry of this disease into Canada, visit the CFIA website at *www.inspection.gc.ca* or contact your local CFIA office (see Appendix D. *Other Contacts* on page 155).

Fusarium spp.

Several *Fusarium* species cause stems, crowns, corms, bulbs and tubers to rot. The primary culprits are *F. solani* and *F. oxysporum*.

With root rots, the infected tissue is usually dark red to brown and may appear as streaks up to the soil line. Plant growth is usually retarded. As infection increases, the oldest leaves begin to yellow and younger leaves are often stunted before becoming flaccid. *Fusarium* is often not apparent until near flowering because of the length of time required for plugging of the vascular tissue.

In stem rots affecting plants such as chrysanthemum and carnation, the infected plants wilt and die from a dry stem rot at the base of the plant. The lesions that develop at or just below the soil line often have pink or red edges leading to the infections. The lesions develop inward. There is usually no external stem discolouration.

Bulb and corm rots can occur in the field and in storage. The rot usually begins at a wound or at the base of these organs and may not produce visible symptoms. However, the basal plate and fleshy scales will be brown and decaying, with mats of mycelium. The foliage often turns purple or yellow and dies prematurely.

Cultural strategies to manage Fusarium crown and root rot

Crop stress, which is the leading environmental cause of Fusarium disease, predisposes plants to attack by this fungus. Standard disease control strategies apply. Review production practices and modify them as needed to minimize crop stress.

Maintain proper temperatures, avoiding high air and substrate temperatures. Avoid over-fertilization when crops are under stress.

Irrigate consistently. Wet or dry extremes enhance *Fusarium* development. Drought stress can result in the rapid onset of symptoms.

Use pathogen-free media. Use only new pots and trays to avoid contamination. Pasteurize the soil for effective control in soil-grown crops and use healthy, disease-free stock for vegetative propagation purposes.

Finally, use suppressive bio-fungicides and/or preventative fungicide applications during periods of unavoidable crop stress.

Thielaviopsis basicola

Thielaviopsis basicola causes a severe, black root rot of a number of major greenhouse flower crops. These include cyclamen, fuchsia, geranium, kalanchoe, primula, petunia, pansy, poinsettia and vinca.

Infected roots usually develop black lesions covering all or part of the root. Root tips may turn black. Plants are often stunted, with yellow or white leaves typical of a severe nutritional deficiency. The roots die rapidly, causing plant death.

Cultural strategies to manage Thielaviopsis root rot

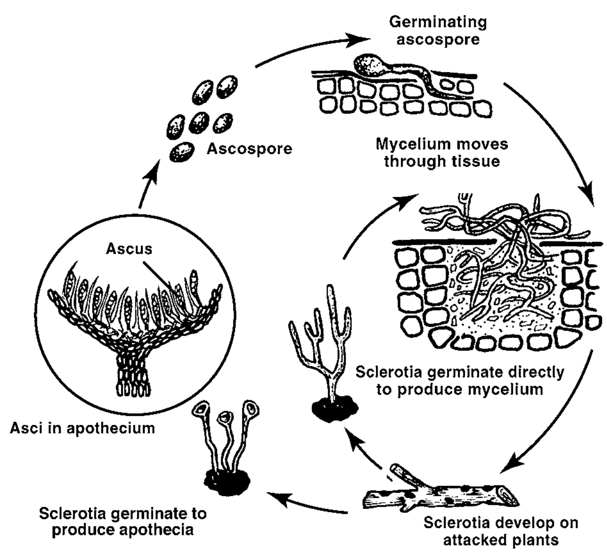
- Monitor the growing medium. *Thielaviopsis* thrives with high media moisture and a high pH. Cool media temperatures (15–16°C) typically favour development of this pathogen in most crops, although optimum temperatures of 25°C have been reported for its development in cool-season crops like pansy.
- Avoid temperatures too high or too low for the crop. For example, do not grow vinca below 20–21°C or pansy above 18°C whenever possible.
- Avoid high ammonium nitrogen fertilization because the promotion of softer growth tends to make susceptible crops more prone to attack.
- Maintain proper sanitation practices and use only new containers for growing highly susceptible crops.
- Use pathogen-free media and maintain pH below 5.5. Avoid high moisture levels in growing media.
- *Thielaviopsis* is difficult to eradicate when crops are grown on the ground or wooden benches. Fortunately, this disease is not common.

Sclerotinia

Sclerotinia sclerotiorum attacks many herbaceous ornamental and vegetable crops, including chrysanthemum, snapdragon, salvia, dahlia, delphinium, marigold, tomato, pepper and eggplant. The disease is most common outdoors but is observed occasionally in the greenhouse.

Symptoms vary with the host, the affected host part, and the environmental conditions. The most obvious early symptom is fluffy, thick, white mycelium on the stems of plants near the soil surface. See Figure 7-8. *Sclerotinia Life Cycle* on this page. Relatively large, hard, charcoal-black, resting fruiting structures (called sclerotia) soon appear. These are embedded in the mycelium or in the pith of plant stems. The fungus causes a stem rot, which eventually leads to wilting and death of the plant.

Figure 7-8. Sclerotinia Life Cycle



During the early infection stages, no visible signs of infection appear on the foliage until the fungus grows completely through the stem. The exception is when the initial infection occurs through a leaf.

Sclerotinia fungus survives either as sclerotia in the soil or on plant debris for at least three years, or as mycelium in dead or living plant material. Sclerotia are very resistant to extreme temperatures and moisture.

Cultural strategies to manage Sclerotinia stem rot

Pasteurize the soil for effective control in soil-grown crops. For bench-grown crops, control can be difficult. Maintain dry foliage by minimizing overhead watering and dripping, and provide good air circulation through the crop canopy by ensuring good spacing.

This disease is most problematic in spring and summer because day length influences its activity.

Rusts

Rust fungi are obligate parasites and as such are specific to the greenhouse crop on which they are found. Some rusts found outdoors require an alternative host to complete their life cycle, but this is not the case for rusts found on greenhouse crops. Their life cycle is complex, producing up to five different spore types. Rust may occur on carnation, chrysanthemum, fuchsia, geranium, poinsettia, snapdragon and many outdoor perennials including columbine, daylily and rose.

Rust diseases produce masses of white, yellow, orange or brown to reddish-brown uredospores on the under surface of leaves and stems. These appear when the pustules erupt to release the mature spores. First symptoms usually appear within 5–7 days of infection, depending on environmental conditions.

The various rusts can produce concentric ring patterns. These rings are due to a series of environmental conditions conducive to secondary and tertiary infections. The leaf surface directly above the pustule is usually yellow and may be sunken. Numerous infection sites on a leaf will cause yellowing and eventually senescence of the leaf. The lower leaves are usually infected first. Plants are rarely killed.

Cool temperature, high canopy relative humidity and plant density are critical to initial disease development and for secondary and tertiary infection that can typically occur.

Rust spores spread via air currents and by splashing water within a greenhouse. Spores can travel long distances on the leaf surfaces of cuttings. A film of water must remain on upper leaf surfaces for at least 3–4 hours for spore germination and infection. However, sporulation is on the lower leaf surface.

Rust fungi survive as spores, as systemic mycelium on or in dormant plants and in plant debris.

Cultural strategies to manage rust diseases

Chrysanthemum white rust is the only quarantinable rust disease of greenhouse ornamentals. Chrysanthemum white rust appears as creamy-coloured pustules on the lower surface of the older leaves, and over time moves upward throughout the plant canopy if conditions are favourable. For further information on the disease and the latest policy directive, visit the CFIA website at *www.inspection.gc.ca* or contact your local CFIA office (see Appendix D. Other Contacts on page 155).

Growers who receive imported chrysanthemum planting stock from the United States that they suspect is infected must contact the Canadian Food Inspection Agency immediately. Chrysanthemum planting stock cannot be imported into Canada from Europe.

Controlling rust diseases is difficult. Most produce more than one type of spore, and infected plant residue (e.g., under benches) can harbour the spores for long periods.

A temperature range of 10–25°C favours spore production of most rusts, and spores are released into the air more readily with diurnal relative humidity fluctuation.

Infections are often severe near fans and in corners of the greenhouse. Severe infections also occur under conditions of poor air circulation and temperature stratification due to crowding or a heavy canopy.

Avoid overhead watering or late-afternoon watering. Space plants to allow better air movement within plant canopies.

Prevent dew formation on plants by providing adequate heating, ventilation and air circulation at night to control relative humidity around and through the plant canopy.

Destroy all infected plants to reduce the level of inoculum.

Bacterial Diseases

Bacteria are single-celled organisms that multiply rapidly under ideal temperature conditions, with the rate of development and spread increasing with temperature, moisture availability and food supply. Bacterial pathogens also need a wound or natural opening, including stomata or hydathodes of leaves, for invasion.

Some plant pathogenic bacteria attack only one or two plant species, while others attack a wide range of plants. Plants commonly attacked by bacteria include geranium, begonia, chrysanthemum, calla lily and hibiscus.

Bacterial infections may appear as wilts, stem and root rots, leaf spots, galls and fasciation of plant parts. Although bacterial diseases are less common than fungal diseases, they can be very destructive and difficult to control. *Erwinia, Pseudomonas, Ralstonia* and *Xanthomonas* are the most common disease-causing bacteria affecting greenhouse crops. The bacteria can live on or in roots, on leaves and stems of hosts, and in non-host plants.

Bacteria do not produce spores. Most bacteria survive in the greenhouse in a semi-dehydrated state, infecting plant debris for extended periods of time. However, *Ralstonia* survives in soil without association with plant tissues for long periods of time. See more details in *Ralstonia solanacearum* on page 98.

Bacteria enter wound sites and natural plant openings such as stomata and hydathodes or root hairs. A film of water is usually required for a bacterial infection to begin on above-ground plant parts.

With bacterial wilt infections, wilting of entire leaves or leaf margins is the first symptom. Infections typically become systemic very quickly, moving through the leaf veins and petioles. Entire leaves yellow or develop large V-shaped yellow lesions. When bacteria invade the stems, the outside of the stem usually appears grey-black and water-soaked, while the internal stem tissue appears black.

Bacterial disease development is enhanced by high air and media temperature and by high relative humidity. All bacteria can survive in living or decaying plant material.

Pathogen spread during propagation is very common. Bacterial pathogens are spread by water movement through the media, water splashing, and the physical movement of infected media and plant material within and between greenhouse operations.

Cultural strategies to manage bacterial wilts

No chemical controls will eradicate bacterial diseases from infected plants in a production environment. Prevention and exclusion are key. Good cultural practices and careful sterilization procedures reduce the chance of bacterial infection.

Purchase disease-free stock from the plant breeder for propagation purposes and isolate stock plants in a thoroughly disinfected area. Disinfect cutting tools and propagation areas frequently.

In general, warm temperatures (above 25°C) are required for bacteria to develop rapidly and for plants to express symptoms.

Bacteria are spread on leaves and stems by condensation, splashing water, and during pruning or harvesting of cuttings. These pathogens also spread very rapidly from plant to plant on propagation benches and in sub-irrigation systems.

Both fixed and organic copper sprays provide reasonable protection against bacterial diseases. They are not eradicants, however, and may cause phytotoxicity.

Erwinia carotovora

Erwinia carotovora causes soft-rot symptoms that first appear to be simply water-soaked, but quickly break down into a foul-smelling, mushy rot, resulting in complete collapse of the plant. This disease thrives in warm, humid conditions. Increased irrigation and high levels of both phosphorus and nitrogen promote its development. *Erwinia* is a ubiquitous bacterium in the natural environment.

Erwinia chrysanthemumi

Erwinia chrysanthemumi attacks a wide range of floral crops including all foliage crops, chrysanthemum, poinsettia and begonia. Its symptoms include root rots, leaf blights and wilts.

Ralstonia solanacearum

Ralstonia solanacearum is a bacterial plant pathogen that causes bacterial wilt. It has a very wide host range. Known previously as *Pseudomonas,* the bacterium is not really a new disease. Because of its diversity, it has been classified into various groupings known as races and biovars based on the host range and biochemical reactions. Of most concern is Race 3 Biovar 2 (known as the "potato race") that was found on vegetative geranium cuttings originating from tropical or sub-tropical regions. It is of special concern because it has been shown to survive in soil in temperate climatic regions. *Ralstonia solanacearum* Race 3 Biovar 2 is a regulated, quarantinable pathogen in Canada and the United States. It was placed on the United States Department of Agriculture (USDA) *Agricultural Bioterrorism Act* of 2002, Select Agents and Toxins list. It is a regulated disease because it is not known to exist in North America and because its host range includes two important food crops, potato and tomato.

> Growers who suspect this disease must notify the Canadian Food Inspection Agency immediately.

Ralstonia enters plants through the roots and through stem wounds. Race 3 is most severe or virulent between 24–35°C, and decreases in virulence at very high or very cool temperatures.

Early symptoms are similar to bacterial blight. Lower leaves typically wilt first when infection has entered through the roots. Sectorial leaf yellowing may be present and stems may show brown to black discolouration near the soil line. Eventually, the entire plant wilts and dies.

The bacterium will survive for long periods of time in soil without plant residue. Under greenhouse conditions, the bacterium can be spread on cutting knives, in soil or in contaminated recirculating sub-irrigation systems.

It is thought that the disease is easily spread via recirculating irrigation systems where the solution is not being pasteurized. In addition, the bacteria are spread by splashing water, plant-to-plant contact, and tools and from clothing and hands of employees contaminated with bacteria.

For the latest CFIA policy directives and disease factsheet regarding *Ralstonia,* visit the CFIA website at *www.inspection.gc.ca* or contact your local CFIA office (see Appendix D. *Other Contacts* on page 155).

Controlling this disease consists of quarantine and crop destruction.

Xanthomonas campestris

Xanthomonas campestris and its various strains cause leaf spots and stem rots on a wide range of plants including begonia, geranium, zinnia and dieffenbachia. Symptoms range from small, well-defined spots with yellow margins on leaves to systemic activity where leaf veins become grey-green.

Infected leaves wilt and eventually turn yellow and die. Stems turn dark green as the bacteria block the vascular tissue. In geranium and begonia, distinctive yellow V-shaped areas bounded by major veins usually appear in many leaves. Initially, one branch of the plant may exhibit the symptoms.

Some hosts show no clear symptoms but may simply lack vigour.

Xanthomonas campestris pv *pelargonii* (commonly known as "bacterial blight") is very destructive in geranium. It infects all cultivars of zonal, ivy, seed and Martha Washington types. It is a systemic disease that can quickly kill zonal and seed geraniums. Other types are usually not killed but grow poorly and have an unthrifty appearance.

Viral Diseases

Viruses are disease-causing agents that multiply only within living plant cells. They tend to spread throughout the host plant through the vascular system. Many of the important horticultural crops belong to major plant families that are susceptible to viral attack.

With the introduction of many new vegetative annuals to the bedding plant industry, viruses have become of greater importance, particularly for those growers who also grow vegetable transplants. Viruses can be spread by sucking insects, such as aphids and leafhoppers, by tools, or by crop handling such as plant cleaning, disbudding or taking cuttings. Many viruses spread via infected cuttings.

Viral infection symptoms may include vein banding, flecking or necrotic lesions, ring spots, mosaic (irregular areas of dark and light green on the leaf), mottling or growth abnormalities (twisting/curling or strap-like growth) of the leaves. The specific symptoms depend on the type of virus. Symptoms do not always increase in severity. Some viruses cause stunting. In severely infected plants, the growing point of the plant may die.

The extent of the visible symptoms depends on the duration of the infection, the age of the plant at the time of infection, and the crop growing conditions.

Cultural strategies to manage spread of viruses

No chemical controls will eradicate viral diseases. Prevention is the key. Good cultural practices and careful sterilization procedures reduce the chance of viral infection.

Purchase disease-free stock or cuttings from the plant breeder for propagation purposes. Isolate stock plants in a thoroughly disinfected area or screen vents and doors to prevent insect entry. Disinfect cutting tools and propagation areas frequently.

Crop stress predisposes plants to a virus attack. Symptoms will be more apparent in stressed plants.

Tobacco Mosaic Virus (TMV)

This virus can be problematic in many bedding plants because there are many different strains with not all species showing similar symptoms. Petunia and calibrachoa are the most common, but other susceptible crops include impatiens, torenia, lobelia, osteospermum, nicotiana, tomato and pepper as garden transplants.

Symptoms vary depending on the strain, host and environmental conditions. Typical symptoms include leaf curling and twisting, yellowing of veins, stunting and flower colour break.

TMV is very stable and will survive on benches, tools and dried plant tissue for years. TMV is easily transmitted mechanically by workers when transplanting, pinching and spacing plants.

Cultural strategies to manage TMV

Because no chemical control exists, all incoming cuttings or young plants should be inspected. Suspicious plants should be isolated and samples sent to your local diagnostic laboratory for testing. All TMV-infected varieties including media and containers should be removed and sent to landfill. Carefully disinfect benches and equipment after removing infected plant material. All gloves should be discarded after handling infested plants. Milk is one of the most effective products to degrade virus particles and should be used to disinfect tools and between plants or varieties.

Cucumber Mosaic Virus (CMV)

CMV is one of the most common plant viruses, with most bedding plants and herbaceous perennials susceptible. Symptoms are usually a mild mosaic on the leaves and colour breaking in the flowers. Green peach and melon aphid are the common vectors.

Tomato spotted wilt virus (TSWV)/ impatiens necrotic spot virus (INSV)

Tomato spotted wilt virus and impatiens necrotic spot virus are both tospoviruses, which are very unusual among plant viruses. The virus particles are quasispherical and are unique in that they are enveloped by a membrane composed of both lipid and protein. They are spread by only a few thrips species and have a broad host range. INSV is the most common in floricultural crops, with TSWV usually affecting only chrysanthemum.

In Ontario greenhouse production, TSWV and INSV are transmitted only by western flower thrips. Unlike other insect vectors, thrips must feed on infected plant tissue as first instar larvae to acquire the virus. Virus transmission occurs when infective adults feed, and continues for as long as the thrips are alive.

Characteristic symptoms vary depending on the host species and age. For many hosts, large brown or black circular concentric ring spots appear on the foliage. In many hosts, the virus becomes systemic, with black streaking of the major leaf veins, petioles and (in some plants) the stem.

In cyclamen, 8–10 weeks may pass between the initial infection and the first symptoms. Symptoms generally appear more quickly when plants are growing vigorously. However, when young gloxinias are infected, the virus rapidly develops systemically. Symptoms appear similar to Phytophthora crown rot. In other crops, such as petunia, the viral symptoms appear as small, discrete, tan-coloured spots. In petunia, the infection does not become systemic and this plant can be used as an early warning indicator of the disease.

Sometimes the symptoms mimic pesticide phytotoxicity.

Cultural strategies to manage TSWV/INSV

A simultaneous, multi-pronged approach is necessary for successful control. It is impossible to control the virus during warm weather if viruliferous thrips populations are not controlled.

- Rogue virus-infected plants, stock plants and finishing plants to prevent first instar larvae from acquiring the virus.
- Control thrips populations to prevent viral spread. See Chapter 5, *Major Insect and Mite Pests* on page 63 for detailed information on the life cycle of western flower thrips.
- Purchase only clean cuttings from reputable propagators.
- Isolate stock plants in a thrips-free area.
- Screen vents.
- Weed control is important, both inside and outside the greenhouse, as many weeds are reservoirs of the virus and western flower thrips.