13 Onion, garlic, leek, shallot, chives

BACTERIAL DISEASES

▶ 13.1 Slippery skin *Fig. 13.1*

Pseudomonas gladioli pv. *alliicola* (Burkholder) Young, Dye & Wilkie

Slippery skin occurs sporadically in all onion-producing areas of Canada, but it is a greater problem in the southern United States and other areas with warm climates. Affected bulbs may be unmarketable, especially for processing. At harvest, there are often no external symptoms of the disease and the bulbs must be cut to detect symptoms. In Ontario, truckloads of onions have been declared unmarketable and entire fields abandoned because there is no practical method to grade out the affected bulbs. *Pseudomonas gladioli* pv. *alliicola* is not a problem on other *Allium* crops.

Symptoms In the field, onions with severe slippery skin may have one or two wilted leaves in the middle of the leaf cluster. Later, the wilted leaves turn pale yellow to off-white and die back from the tips. Older and younger leaves generally remain green. Lifted bulbs usually are soft and watery; squeezing them at the base will cause the rotted inner portions to slide out through the neck, hence the name slippery skin.

Usually, the disease progresses slowly so that affected bulbs appear sound at harvest. However, the inner scales of horizontally cut bulbs often appear water-soaked. The neck of these bulbs may become softened, after which rot spreads from the neck through the inner scales to the base *(13.1).* The pathogen can then spread throughout the bulb and into the central scales, which become watery and develop a cooked appearance.

Causal agent *Pseudomonas gladioli* pv. *alliicola* forms a diffusible, non-fluorescent, pale yellow to yellow-green pigment on nutrient-dextrose agar and King's B medium. It is a motile, Gram-negative rod that has one to several polar flagella. This bacterium is oxidative, reduces nitrates to nitrites, and will grow at 41°C, giving a weak oxidase reaction. It is able to utilize nicotinate, (+)-tartrate, (-)-tartrate, meso-tartrate, mesaconitase, gamma-aminovalerate, citraconate and laevulate, but not putresceine, glutarate, erythritol or glycollate. In one report, all isolates tested caused considerable degradation of pectate gels at pH 4.9 to 5.1 and pH 6.9 to 7.1, but not at pH 8.3 to 8.5.

Disease cycle Slippery skin occurs most frequently during seasons with high rainfall and in fields that are heavily irrigated. The disease usually appears during the last half of the growing season. The pathogen is soil-borne and is probably transferred to the leaves by splashing water. Infection of the seed stalks and leaves has been reported in Hungary and India. Not all attempts to reproduce the symptoms by re-inoculation have been successful. Plants appear to become more susceptible with age.

Wounds on the leaves may be important points of entry for the pathogen. Accumulation of water in the neck of the onion also may favor infection. After infection, the bacteria spread down the leaf to the corresponding bulb scale, then progress down the scale to the base of the bulb before spreading throughout the bulb. Infection usually takes place while the crop is actively growing, shortly before harvest, or when the onions are topped. High temperatures and slow drying of the bulbs favor infection.

The bacteria grow in the range of 5 to 41 °C, with an optimum of 30°C. In warm weather, a bulb can decay in 10 days. Infected bulbs begin to rot within four weeks when stored at 25°C, but not at 15°C. In storage, the disease may take up to three months to destroy a bulb completely.

Management

Cultural practices — Overhead irrigation should be avoided late in the season and leaf damage kept to a minimum. Onion should be harvested only when the bulbs are fully mature and when the weather is dry. Unnecessary damage at harvest should be avoided and bulbs should be quickly and thoroughly cured (see neck rot, 13.7). Only dry bulbs should be stored and the storage environment should be maintained as close as possible to 0°C and 65 to 75% relative humidity. The high temperatures associated with artificial curing may temporarily encourage rotting, but heat curing is necessary for successful longterm storage. Subsequent cold storage will halt further multiplication of the bacteria.

Resistant cultivars — Spanish onion is more susceptible to slippery skin than common onion.

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(Original by M.R. McDonald)

▶ 13.2 Soft rot (bacterial soft rot) *Figs. 13.2a,b*

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

Soft rot can affect onion in both storage and transit, especially when proper grading or storage procedures have not been followed. Soft rot bacteria are secondary invaders but nevertheless can cause major crop losses. Soft rot affects many vegetable crops including most cultivated *Allium* species.

Symptoms When the bacteria enter onion necks through injured or dying leaves they may spread directly into one or more of the bulb scales without moving from scale to scale.

Affected scales first become spongy, water-soaked and pale yellow to light gray. As the rot develops, the scales become progressively softer and the whole interior of the onion breaks down to form a sticky mass inside the dry outer scales *(13.2a,b).* When the bulb is squeezed, it is soft and a watery. A foul-smelling liquid usually oozes out at the neck. When infection occurs at the site of an injury, the rot can progress through several scales from the infection site and the bulb will decay.

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

Disease cycle Soft rot may develop in the field, especially after heavy rains and when the leaves are drying near the end of the season. The bacteria require a wound or an infection site of another organism to gain entry to the plant. Once established, soft rot can cause far greater damage than the original injury or disease.

Soil is a major source of bacterial contamination. The pathogen survives on infested crop residues in the soil and may be transferred to neighboring plants by splashing water. Direct contact with infested soil can also result in infection. Onion maggot damage to bulbs is an important entry point for soft rot bacteria. Once the bacteria have entered a bulb, they multiply very rapidly at high temperatures. The temperature range for growth is 6 to 37°C, with the optimum between 24 and 32°C in culture and between 18 and 27°C in plants.

In the field, disease develops quickly during warm, wet weather. In storage and transit, the bacteria continue to multiply at temperatures greater than 3°C. High relative humidity and liquid water also promote the reproduction and spread of soft rot bacteria when temperatures are favorable. One infected bulb can stain several surrounding bulbs in a pallet box or bag, thereby reducing onion marketability.

Management (see onion maggot, 13.26)

Cultural practices — Disease management is based on reducing all types of injury to the bulbs and providing good storage conditions. Growers should avoid using overhead irrigation on onion, especially Spanish types, when the crop is approaching maturity. Onion should be harvested only when the bulbs are fully mature and dry. Efforts should be made to reduce sunscald, bruising and mechanical damage during harvest. Wherever possible, diseased or damaged onions, especially those with onion maggot damage, should not be put into storage. Bulbs should be stored at 0°C and 65 to 75% relative humidity. Adequate ventilation must be provided during storage so moisture is not allowed to condense on the bulbs.

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(Original by M.R. McDonald)

▶ 13.3 Sour skin *Fig. 13.3*

Pseudomonas cepacia Burkholder

Sour skin is not a major problem, but like the related disease slippery skin, it can occasionally cause significant losses. Sour skin was first described in 1950 in New York where it has become prevalent. In Ontario and Quebec, sour skin is usually less common than slippery skin. This disease affects only onion.

Symptoms Affected onion plants usually have one or two leaves that turn light brown. Later, a watery rot develops at the base of the leaf in the bulb neck. Affected leaves can easily be pulled out of the bulb. When disease is advanced, in the field or in storage, the bulb scales become yellow and viscous but not watery *(13.3).* The central scales and scales near the outside of the bulb may be infected in the absence of symptoms on the bulb. Diseased scales may separate from adjacent healthy ones. Squeezing the base of an affected bulb may push the central portion out through the neck; however, it is not watery and remains firm unlike bulbs affected by slippery skin. Secondary organisms such as yeasts are often associated with this disease and may be responsible for the acrid, vinegar-like odor from which the name “sour skin” was derived.

Causal agent *Pseudomonas cepacia* is a motile, Gram-negative rod with rounded ends. It does not form spores. It has one to three polar flagella and averages 0.8 to 1.9 µm in size. These bacteria do not form fluorescent pigments (i.e., no fluorescence at 254 nm), but they do produce a variety of yellowish and greenish pigments. These pigments may diffuse into the culture medium or remain bound to the cells. *Pseudomonas cepacia* is an obligate aerobe.

When transferred to pectate gels, strains of *P. cepacia* cause pitting at pH 4.9 to 5.1 and at 6.9 to 7.1, but not at pH 8.3 to 8.5. This reaction is the same as that of *P. gladioli* pv. *alliicola. Pseudomonas cepacia* macerates onion slices and causes the acidity of the juice to drop from pH 5.5 to about 4.0. When isolations are made from necrotic tissue of onions with sour skin, the pathogen is usually present in low numbers compared to the quantity of saprophytic bacteria present.

Disease cycle *Pseudomonas cepacia* has been isolated from organic soils and irrigation water. Overhead irrigation and splashing rain are probably the most common means by which the bacteria are spread. They do not infect unwounded plants, but enter young leaves through wounds or gain entry to bulbs when the onions are topped. High rainfall and moderately high temperatures may be necessary for infection. In New York State, the disease always occurs in conjunction with rainstorms and warm weather.

When infection of young leaves occurs, the bacteria progress downward, causing a watery rot, and then infect the corresponding bulb scales. The bacteria spread more quickly in water-soaked tissues than in those that are not congested. Infection of the bulbs may also occur at harvest through the cut surfaces created by mechanical toppers. Disease is more severe when the weather is warm and humid and the leaves have not completely dried down.

Management

Cultural practices — Methods used to reduce losses caused by sour skin are similar to those for other bacterial diseases, such as soft rot and slippery skin. Overhead irrigation has been shown to favor sour skin development, especially when applied from bulbing until harvest. Furrow or drip irrigation is less conducive to the development of sour skin. Growers should try to keep damage to the leaves at a minimum during the growing season. To avoid infection at harvest, onions should be lifted when fully mature, cured properly and stored at 0°C and 65 to 70% relative humidity.

Resistant cultivars — Spanish onion is more susceptible to sour skin than common onion.

Selected references

Burkholder, W.H. 1950. Sour skin, a bacterial rot of onion bulbs. *Phytopathology* 40:115 -117.
Kawamoto, S.O., and J.W. Lorbeer. 1972. Multiplication of *Pseudomonas cepacia* in onion leaves. *Phytopathology* 62:1263-1265.
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(Original by M.R. McDonald)

FUNGAL DISEASES

▶ 13.4 Basal rot *Fig. 13.4*

Fusarium oxysporum f. sp. *cepae* (H.N. Hans.) W.C. Snyder & H.N. Hans.

Basal rot occurs in most areas of the world where onions are grown. It has been found in only a few fields in the major onion-producing areas of Canada. Most yield losses result from disease development in the field, but basal rot can also progress in storage. The pathogen attacks only members of the genus *Allium.* Onion, garlic, shallot, chives and leek are susceptible, but the disease is economically important only on onion.

Symptoms The first symptoms on onion in the field are tip dieback and yellowing of the leaves. The disease may progress until the entire foliage is yellow and withered, which is an indication that decay has already started at the basal plate. Infected onions can be pulled easily out of the ground and often appear lopsided because only one side of the basal plate is infected. The roots decay and a firm, pinkish-brown rot develops at the base of the bulb and later progresses upward *(13.4).* Under moist conditions, white mycelium develops on the rotted area.

When infection occurs late in the crop season, symptoms are not visible until the onions are in storage. However, early signs of infection may be detected by cutting the bulb vertically and looking for a discoloration of the basal plate that begins at the outermost layer and extends upward.

Causal agent *Fusarium oxysporum* f. sp. *cepae* produces chlamy- dospores, microconidia and macroconidia, both on the host and in culture. Isolations from onion bulbs and soil indicate that the pathogen exists in soil primarily as a sporodochial type. The many *formae speciales* of *F. oxysporum* are differentiated by the ability of the specific pathogen to infect a host (see Celery, fusarium yellows, 7.5, for a description of *Fusarium oxysporum*).

Disease cycle The fungus persists in soil in the form of chlamydospores that can be spread in water, soil or air. It can penetrate roots directly or infect roots and bulbs previously injured by other onion diseases or by onion maggots. Disease development occurs between 15 and 30°C with an optimum of 29°C. The requirement for high soil temperatures is a chief reason that this disease is not a major problem in Canada. Soil moisture levels that will support onion growth are adequate for infection and disease development.

In storage or transit, rot develops rapidly between 20 and 30°C. Below 15°C, the rate of decay is very slow but premature sprouting is still likely to occur. High relative humidity in storage promotes rotting.

Management

Cultural practices — Growers should follow a three-year rotation with non-susceptible crops, such as carrot, lettuce, celery or beet, and grow onion in well-drained soils. Disease-free sets and recommended production practices help to reduce stress on the crop. Bulbs should be cured properly before harvest (see neck rot, 13.7) and damaged or diseased bulbs should be culled before storage. Maintain storage temperature at 0°C and relative humidity at 65 to 70%.

Resistant cultivars — Many commercial onion cultivars have field tolerance to fusarium basal rot, examples being Canada Maple, Granite and Valiant. Growers should check provincial recommendations for up-to-date lists.

Selected references

Abawi, G.S., and J.W. Lorbeer. 1972. Several aspects of the ecology and pathology of *Fusarium oxysporum* f. sp. *cepae. Phytopathology* 61:1042-1048.
Kehr, A.E., M.J. Obrien and E.W. Davis. 1962. Pathogenicity of *Fusarium oxysporum* f. sp. *cepae* and its interaction with *Pyrenochaeta terrestris* on onions. *Euphytica* 11:197-208.
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(Original by M.R. McDonald)

▶ 13.5 Botrytis leaf blight *Figs. 13.5a,b*

Botrytis squamosa J.C. Walker
(teleomorph *Botryotinia squamosa* Vien.-Bourg.)

Botrytis leaf blight is one of the major foliar diseases of onion in cool climate areas. The disease has been reported in North America, Britain, Europe, Japan and New Zealand. In Canada, it ocurs annually in most areas where onions are grown. The severity of epidemics depends on local weather conditions. Botrytis leaf blight severely affects only common onion.

Levels of disease affecting less than 11% of leaf area do not decrease yield, but when disease is severe and leaves die back the bulbs may be small and fail to mature properly. Severely affected bulbs may not dry down enough for proper storage. They may also have fleshy leaf tissue at the neck rather than dry papery scales and are therefore more susceptible to storage rots. Rapid senescence of the leaves may also interfere with the application of sprout inhibitors, thus reducing the storage life of bulbs.

Symptoms The first symptom is discrete, circular to elliptical, grayish white leaf spots, about 1 by 3 mm, which later become brownish-white and desiccated. Some lesions may extend through the wall of the leaf and split open with age, exposing the inside (lacuna) of the leaf. Newly formed lesions are often surrounded by an area where the epidermis has separated from the underlying leaf tissue giving the appearance of a silvery-white “halo” with uneven margins (7*3.5a, b).* This is characteristic of *Botrytis squamosa* infection on onion. The gray mold fungus *Botrytis cinerea* may also infect onion leaves, but the resulting lesions are smaller, do not penetrate to the inside of the leaf and do not develop halos. *Botrytis aclada* (see neck rot, 13.7) can cause limited foliar spotting, but it usually remains in a latent state until the bulb is mature or the leaf has senesced. Whitish flecks and spots caused by ozone injury lack the distinct margin and silvery halo characteristic of botrytis leaf blight.

Under favorable conditions, the number of lesions on a leaf increases, the lesions expand and merge, and the leaves begin to die back. Dieback usually begins at the leaf tip and may extend down the entire leaf. The lower, older leaves are usually the first to die. Sporulation occurs on necrotic leaf tips and occasionally on large lesions. Several species of *Botrytis* are associated with neck rot symptoms; that caused by *B. squamosa* is known as small sclerotial neck rot (see neck rot, 13.7).

Causal agent Important diagnostic features of *Botrytis squamosa* include the shape of the conidiophores, which shrink back into accordionlike folds after sporulation, and the size of the obovoid to globose conidia, which are larger (9 to 18 by 14 to 24 µm) than those of the other *Botrytis* spp. found on onion. *Botrytis cinerea* has smaller conidia, 4 to 11 by 6 to 18 µm, and has long conidiophores that are darker than those of *B. squamosa. Botrytis aclada* has the smallest conidia, 4 to 8 by 6 to 16 µm.

Sclerotia of *B. squamosa* are flat, scale-like structures, 0.5 to 4 mm, white at first, but turning black with age. The sclerotia often produce tufts of conidiophores and, in certain locations, apothecia in the spring. The apothecia are stipitate, cupulate and 0.5 to 2.5 mm in diameter. Wild-type isolates are heterothallic. Microconidia are hyaline, unicellular, 2 to 3 µm in diameter, produced in chains from phialides and function as spermatia. Asci are 163 to 200 by 13.8 to 16.5 µm and contain eight ascospores ranging from 15.9 to 17.5 by 10.0 to 12.5 µm. The ascus has an iodine-positive ring.

Botrytis squamosa can be cultured from conidia or sclerotia obtained from onions. The pathogen often sporulates on infected leaves kept in a moist chamber at room temperature for a few days. Conidia will form on the lesions or on necrotic leaf tips. Conidia can then be transferred to and maintained on potato-dextrose agar. To stimulate the production of conidia in culture, transfer mycelium to the basal agar medium described by Bergquist *et al.(see* Selected references), which contains mineral salts, vitamins and dextrin (10 g/L). The plates should be incubated at 22°C and provided with a 12-hour photoperiod using a combination of cool-white fluorescent and near-ultraviolet (“black”) lamps. Conidia will form in 7 to 13 days.

Disease cycle *Botrytis squamosa* is a polycyclic pathogen with the potential to cause very rapid disease development. Sclerotia overwinter in the soil, on onion debris, and on bulbs in cull piles. In the spring, these produce conidia that serve as the initial inoculum. Conidia are produced at temperatures ranging from 3 to 27°C, with maximum production at 9°C. Apothecia also have been observed on sclerotia in onion fields.

Sclerotia may survive at least 21 months when buried in organic soil, but conidia usually survive for less than three months. The mycelium of *B. squamosa* does not survive long in plant residues. Infection of seedlings from seed- borne conidia probably occurs rarely in nature.

The conidia of *B. squamosa* are released during the daytime with peaks of spore release between 0900 and 1200 hours promoted by declining relative humidity. A smaller peak may occur in the evening and large releases of spores are associated with rain showers. The conidia are dry and are dispersed in turbulent air. Disease distribution in a field is usually general rather than focal. Germination of conidia and infection require liquid water and temperatures over 6°C. The optimum conditions for infection are 12 hours of leaf wetness at 15 to 18°C. Infection is reduced above 27°C.

Management

Cultural practices — The initial inoculum can be reduced by rotation with carrot, lettuce, celery and other crops unrelated to onion. The removal of onion cull piles and the reduction of overwintering cull onions in the field also reduce inoculum levels.

Chemical control — Disease management depends largely on fungicide applications. Protectant fungicides provide adequate control when applied before infection takes place. The best control has often been achieved by applying mixtures of broad-spectrum (e.g. dithiocarbamate) and single-site-specific (e.g. imide) fungicides.

Three different systems are used in North America to forecast botrytis leaf blight and to time fungicide applications. These are the sporulation index incorporated into the PREDICTOR (also called the PESTCASTER) developed by M.L. Lacy; BOTCAST developed by J.C. Sutton *et al:,* and BLIGHT-ALERT developed by P.C. Vincelli and J.W. Lorbeer. Each of these programs predicts the need for fungicide applications by different means.

The PREDICTOR is based on vapor pressure deficit, which is determined using relative humidity and temperature over the previous 72 hours to arrive at an index that indicates the probability and intensity of spore release. This program utilizes an instrument that measures temperature and relative humidity and can also record leaf wetness, rainfall and soil temperature. It provides a read-out of the sporulation index for that day. A grower or scout checks the sporulation index each day and determines whether the risk is sufficient to warrant chemical control. Fungicides need not be applied more than once every five to seven days. This system is used in Michigan and Quebec. It can be grower-operated and does not depend on field scouting. In Quebec, good control of botrytis leaf blight has been achieved by spraying when the sporulation index is over 50.

The other two programs are based on starting the fungicide spray program when a critical disease level of one lesion per leaf is reached. BOTCAST is designed to use accumulated microclimatic data to predict when this critical level has been reached in the field, using duration of leaf wetness, temperature, relative humidity and rainfall data to provide an inoculum value (0 or 1), and temperature and leaf wetness data to provide an infection value (0, 1 or 2).

These values are multiplied to give a disease severity index for each day. Cumulative disease severity indices (CDSI) indicate two thresholds. Threshold 1 (CDSI = 2) triggers the recommendation to spray before the next rainfall. Threshold 2 (CDSI = 30-40) indicates that a fungicide should be applied as soon as possible. Once the control program has started, fungicides should be applied every 7 to 10 days. Research in Ontario has shown that using microclimatic data to lengthen the spray interval when weather is not favorable for botrytis leaf blight only saves an average of one spray.

The BLIGHT-ALERT program is designed specifically to time fungicide sprays following the first application. Under this system, the threshold of one lesion per leaf is determined by pest management scouts walking the fields and counting lesions on leaves. A sequential sampling method is used and scouts count lesions on the three oldest green (80% green) leaves on 15 to 50 plants per field. Once the one lesion/leaf threshold is reached and growers begin spraying, subsequent sprays are recommended on the eighth day after spraying if the probability of rain is greater than 30% or if the "Inoculum Production Index" is greater than 7. An index of less than 7 indicates that spore release is unlikely. Fungicide protection is considered to last for seven days. If no fungicide application is recommended for day eight, the index and probability of precipitation are checked for day nine and each day thereafter until the next spray is needed.

The Inoculum Production Index, which is based on weather conditions conducive for spore production, is calculated using average temperature, hours of relative humidity above 90% and days after planting. The index ranges from 0 to 25. Significant spore releases usually occur on days where the index is greater than 7. A probability of precipitation greater than 30% indicates that conditions will be favorable for infection if spores are released. In New York State, growers using the spray threshold and BLIGHT-ALERT program have saved two to three sprays per season.

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(Original by M.R. McDonald)

▶ 13.6 Downy mildew *Figs. 13.6a-d*

Peronospora destructor (Berk.) Casp. in Berk.

Onion downy mildew occurs sporadically in the onion-producing areas of British Columbia, Ontario and Quebec. Epidemics in onion fields are potentially explosive and destructive, given favorable weather. In some instances, the disease destroys all of the foliage in just four or five weeks. Severe downy mildew reduces bulb size and can result in bulbs being downgraded for market. Necks of diseased onions often remain succulent and difficult to cure at harvest. Downy mildew can affect dry bulb, pickling, Welsh, Egyptian and multiplier onions, as well as garlic, shallot, leek, chives and several other *Allium* species.

Symptoms The first sign of downy mildew is velvetlike growth of the pathogen on the otherwise green leaves *(13.6a,b).* Early in the morning, the fungal growth appears purplish due to pigment in the fungal spores (sporangia), which form overnight just above the leaf surface. Later, most of the spores are dispersed in the air and a whitish fungal growth remains on the leaf. During the next two to four days, the diseased leaves turn pale green, then yellow, and finally collapse and die *(13.6c).* Blackish growth of other fungi, especially *Stemphylium botryosum* Wallr., is common on the dead leaves. Small green leaves often emerge from the cluster of dead top growth within a week or two. Necks of affected plants remain succulent. Affected areas on seed stems tend to remain yellow, but may bend over and break when the seed head enlarges. The downy mildew fungus may also invade flowers and seeds.

Causal agent *Peronospora destructor* produces aseptate mycelium, asexual sporangia borne on sporangiophores, and sexual oospores. The mycelium develops only within living host tissues. Sporangia form on sporangiophores that emerge through the stomata of green host leaves and become dichotomous with primary and secondary branches and curved sterigmata *(13.6d)*. The sporangia develop in an acropetal sequence on pointed ends of the sterigmata. Mature sporangia are thin-walled, sub-hyaline, pyriform, papillate at the distal end, and measure 18 to 29 by 40 to 72 µm. They are easily detached from the sporangiophores. Oospores form intercellularly within the host tissues, usually late in the growing season, and are released after the tissues die and decompose. The oospores are thick-walled, spherical and 40 to 44 µm in diameter. Oospores survive in the soil for four or five years and germinate by a germ tube.

The pathogen is readily identified from the symptoms and from microscopic examination of sporangia and sporangiophores scraped from the surface of diseased onion leaves. Isolates of *P. destructor* may be stored conveniently for five to six months in inoculated onion sets kept at 1 to 3°C. The sets may be inoculated by injection with a spore suspension of the fungus. To recover the pathogen, the sets are planted in pots, allowed to grow until about 15 to 20 cm high, then placed in a dark, moist chamber to promote sporulation. The pathogen also may be maintained in green onion leaves, but must be transferred every two to three weeks.

Disease cycle The mildew fungus overwinters in infected onion bulbs or sets and on other host plants. In spring, it invades new leaves as they emerge. Invaded leaves usually are paler green than healthy ones. Spores produced on these leaves initiate mildew epidemics in onion and other hosts grown from seed. Infected seeds and oospores in crop residues are possible, but unlikely, sources of inoculum for mildew epidemics. The main sources of inoculum for spring-seeded crops are volunteer onion plants, onion cull piles, onion seed crops, fall-seeded onion plants and perennial onion plants grown in home gardens.

Only a few spores are needed to initiate a destructive epidemic in an onion field. After infection, the fungus grows extensively within the leaf, which remains symptomless until the fungus sporulates. Generations of spores (sporangia) are produced every 10 to 16 days. Disease increase is stepwise, each step coinciding with sporulation and subsequent collapse of the leaves. Successive steps usually increase in size. Given favorable weather, most of the foliage is destroyed after three to four cycles of sporulation and infection, which can occur over a period of about 34 to 45 days.

The relationship of weather and downy mildew is well established. The fungus sporulates on heavily colonized onion leaves between midnight and sunrise. Weather conditions required for spore production at night are: relatively low to moderate temperatures during the preceding day (average of less than 24°C between 0800 and 2000 hours), temperatures between 4° and 24°C at night, continuous high relative humidity (about 95%) between midnight and sunrise, and no rain after 0100 hours.

High daytime temperature and short or interrupted humid periods at night commonly prevent sporulation. Under favorable conditions, as many as 100000 or more spores are produced on each square centimetre of leaf. The spores mature near dawn and are released into the air mainly during the morning. A few spores may be released before the dew dries, but most are dispersed as the relative humidity declines. Some of the spores deposited on onion leaves survive and infect the leaves during the first or second night after dispersal. The spores germinate and infect the leaves within three to six hours when dew is present, except when dew deposition is slow or erratic or temperatures are near freezing or above 26°C.

Management

Cultural practices — Cull onions should be destroyed and not left in piles near onion fields. It is very important not to grow winter onion and other host crops in fields and home gardens near summer production fields. Seed onion should be grown far away from any bulb crops.

Chemical control — Foliar fungicides suppress downy mildew effectively when spray applications are suitably timed. Fungicides should be used when mildew is present in the area and when weather favors disease increase. The downy mildew forecaster DOWNCAST may be used to identify periods when weather favors sporulation and infection by the mildew fungus. DOWNCAST requires weather monitoring in the field and indicates optimal times to look for early signs of mildew and to apply fungicide sprays. Protectant fungicides are effective only when applied before infection.

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(Original by J.C. Sutton)

▶ 13.7 Neck rots *Figs. 13.7a-d*

Neck rot (gray mold neck rot)
Botrytis aclada Fresen.
(syn. *Botrytis allii* Munn)

Mycelial neck rot
Botrytis byssoidea J.C. Walker
(teleomorph *Botryotinia allii* (Sawada) Y. Yamamoto)

Small sclerotial neck rot
Botrytis squamosa J.C. Walker
(teleomorph *Botryotinia squamosa* Vien.-Bourg.)

Neck rot is one of the most common storage diseases of onion and also can occur on shallot, leek, garlic and chives. Disease incidences of up to 50% of the bulbs in storage have been reported. Additional losses can result from secondary infections of bacterial soft rot.

Symptoms Neck rot is most commonly found on bulbs after harvest, although in wet seasons it may appear before harvest. The first symptom is the softening of the affected neck scale tissue, which takes on a sunken, cooked appearance. There is a definite margin between the diseased and healthy tissue, which remains distinct even when the rot is advancing toward the base of the bulb *(13.7a).* As the lesions age, the tissue becomes grayish and later a dense, grayish *(13.7b),* cottony growth of mycelium appears on the surface of the scales. This growth gives rise to a gray- brown powdery mass of spores that can spread the fungus for considerable distances through the air. Still later, small, whitish, kernel-like sclerotia, less than 3 mm in length, appear in the mycelium and soon turn black and hard *(13.7c).* Symptoms usually appear first in the neck *(13.7d)* and spread downward to the base of the bulb, but symptoms may develop first around the basal plate at the base of the bulb and progress toward the neck. Eventually the whole bulb may become dry and mummified, but it can still serve as a source of inoculum.

Causal agent Neck rot is caused chiefly by two closely related species *Botrytis aclada* and *B. byssoidea.* A third species, *Botrytis squamosa*, also infects white onion (see botrytis leaf blight, 13.5) and causes a disease known as small sclerotial neck rot.

Botrytis aclada, the most common species in Ontario, may produce a dense mat of conidiophores near the sclerotia on infected bulbs. Neck rot caused by *B. aclada* is sometimes referred to as gray mold neck rot, but this can be confused with the name “gray mold,” which usually refers to diseases caused by *Botrytis cinerea,* which often can be isolated from onion leaves and bulbs.

Botrytis byssoidea infection of onion, sometimes called mycelial neck rot, can be distinguished from gray mold neck rot by the presence of more surface mycelium and sparse sporulation.

Botrytis conidiophores are straight, alternately branched and may proliferate. The conidia are usually one-celled, gray to brown, globose to ovoid, and are botryoblastospores. The teleomorph of *B. aclada* has not been identified.

Both *B. byssoidea* and *B. aclada* can be cultured from mycelium, conidia or sclerotia aseptically transferred from infected bulbs to potato-dextrose agar. In culture, *B. byssoidea* produces few conidia and they are larger, 5 to 11 by 8 to 20 µm, than those produced by *B. aclada,* which measure 4 to 8 by 6 to 16 µm. *Botrytis aclada* conidia sometimes overlap the size range of *B. cinerea* conidia (see Lettuce, gray mold, 11.10).

Disease cycle The sclerotia that form on infected bulbs serve as the primary overwintering structures, and in some soils and in cull piles, they may survive for several years. The sclerotia germinate under suitably moist conditions to produce successive crops of conidia that spread on air currents to neighboring onion fields as well as to those some distance away. In Britain, *B. aclada* was shown to survive on debris in a sandy loam soil for two years, but sclerotia failed to germinate and produce conidia after only six months in soil. In Canada and the northeastern United States, sclerotia in cull piles and on onion debris and unharvested bulbs in the field are the main source of initial inoculum.

Botrytis aclada is also seed-borne and seed lots have been found with as much as 20% infestation. Direct seedling infection has been observed with mycelium from the seed coat penetrating the tip of the cotyledon leaf. However, infected seed lots do not appear to be a major source of neck rot in North America. Virtually all of the onion seed planted in Canada is treated with a systemic fungicide to control onion smut and this chemical also provides some control of seed-borne *B. aclada.*

The air-borne spores of *B. aclada* can infect onion leaves during periods of cool (15 to 20°C), wet weather, but symptoms may not be visible. Either the fungus can grow within the leaf without causing symptoms or it remains quiescent in the epidermis and grows only when the leaf starts to senesce. Conidiophores are produced only on senescent or necrotic leaf tissue. The pathogen can spread rapidly during wet growing seasons and can spread downwind from a diseased to a healthy crop. Cool, wet weather during the ripening and harvest periods also can increase the incidence of neck rot.

Infection can take place during harvest if the bulbs are bruised or damaged. Onions with thick necks or broken outer scales may be infected through these sites, especially if the relative humidity in storage is high. Neck rot rarely spreads from bulb to bulb. It may become more severe the longer onions are stored because bulbs that were infected, but symptomless when harvested, eventually develop the disease.

Management

Cultural practices — The elimination of onion cull piles and crop rotations of at least two years with carrot, beet, corn and other crops unrelated to onion help to reduce the overwintering inoculum. Crop rotation is most effective where onion fields are widely separated from each other. Proper curing and storage of mature bulbs is the most important means of reducing neck rot. Onions with thick necks, nicks or bruises should be graded out before storage. Onions for long-term storage should have two or three layers of dry outer scales and the neck should be narrow and composed of papery-dry scales.

Onion bulbs should be prepared for storage by maturing or "curing" them. This usually is done by leaving the lifted bulbs in windrows until the necks are thoroughly dry. Onions produced in humid areas should be cured artificially by passing dry outside air through piles of onions in storage for two days. The air should be heated sufficiently to reduce the relative humidity to 60% for 14 days or until the onion skins turn a rich golden brown. Once onions are cured thoroughly, storage conditions should be maintained just above 0°C at a relative humidity of 65 to 75%.

Resistant cultivars — Most commercial onion cultivars grown in Canada are susceptible to neck rot, especially white-skinned common and Spanish onions. Red-skinned onion and cultivars that are strongly pungent are less susceptible to infection.

Chemical control — Foliar fungicides are registered in Canada, but the level of control achieved is usually low.

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(Original by M.R. McDonald and W.R. Jarvis)

▶ 13.8 Pink root *Figs. 13.8a, b*

Phoma terrestris E.M. Hans.
(syn. *Pyrenochaeta terrestris* (E.M. Hans.) Gorenz, J.C. Walker & R.H. Larson)

Pink root is common but usually of minor importance on *Allium* crops in Canada. It also occurs in the United States, Australia, Europe and South Africa. Losses are difficult to document because only bulb size is reduced by this disease. The pathogen is a common soil inhabitant and can infect the roots of common and multiplier onion, shallot, garlic, leek, chives, and many other monocotyledonous and dicotyledonous crops.

Symptoms Symptoms of pink root are frequently seen on onion roots. The disease is recognized most easily by the distinctive, dark pink to maroon color of infected roots *(13.8a).* Infected roots are also partially to totally collapsed and later turn reddish brown as the root dies. In contrast, healthy roots are cylindrical and white. Diseased roots break off easily when the bulb is pulled from the soil. When disease is light and growing conditions are favorable, onion bulbs may have only two or three pink roots and no above-ground symptoms. Under these conditions, no reduction in yield has been observed and bulb sizes are similar to those of uninfected plants. Plants with severe pink root are stunted, have a high proportion of infected roots, are easily pulled from the soil, and fail to produce marketable bulbs. When disease is moderate, the leaves die back from the tip, turning yellow-white or yellow-red. The color is more reddish than when the leaves die from environmental stress. Infected plants rarely die back completely *(13.8b);* they usually remain stunted with only a small area of green leaf tissue remaining near the neck of the bulb.

The disease is not usually observed on seedling onion but can become noticeable by mid- to late season, often showing first when the plants begin to form bulbs. The pathogen is widely distributed within fields but diseased plants often appear in patches, either near the headlands, where the soil is shallow, or on knolls or over drainage tiles where the soil is poorer or drier. Often, the disease appears so late in the season that it has the beneficial effect of reducing moisture uptake by the plant, thereby allowing the bulbs to dry and mature in preparation for harvest.

Causal agent Pycnidia of *Phoma terrestris* form singly within infected roots and later burst through the surface. The pycnidia are globose, dark brown to black, up to 400 pm in diameter, and darkly pigmented around the ostiole. There are usually a number of brown setae, 60 to 180 µm long, around the ostiole. Conidia form inside the pycnidia and are unicellular, hyaline, ovoid to allantoid with rounded ends, and have a guttule at each end.

Isolation of the pathogen is often difficult because fast-growing *Fusarium* species frequently co-inhabit pink root-affected plants. *Fusarium* species do not cause pink root symptoms on their own. To isolate *P. terrestris,* plate symptomatic, surface-sterilized onion roots onto water agar and incubate at 20°C with a 12-hour photoperiod for four to five days. Discard all cultures producing *Fusarium* conidia. Subculture suspected isolates of *P. terrestris* to plates of cornmeal agar amended with 500 ppm of chloramphenicol and incubate for 10 to 14 days at 24°C. Once again, discard any *Fusarium* cultures. The remaining cultures will be *P. terrestris,* which grows slowly on this medium; the colonies will be pinkish, circular, appressed and have smooth margins.

Disease cycle *Phoma terrestris* is a soil inhabitant that can survive and multiply indefinitely in soil. It is only weakly pathogenic and attacks the roots of plants that are under stress or that have previously been injured. On onion roots inoculated with conidia, symptoms can be seen within 7 to 21 days. The hyphae penetrate the roots and grow through the cortical tissue; pycnidia form in both the epidermal and cortical cells. The pycnidia erupt through the epidermal tissue and release the conidia into the soil.

The fungus can develop at all soil moisture levels that will support the growth of onion. The optimum temperature for infection is 26°C. In organic soils, temperatures this high usually are associated with dry conditions. High levels of soil moisture moderate the soil temperature. Yield losses usually occur when onion is stressed by high temperature and dry soil conditions. This makes it difficult to determine the proportion of yield loss caused by the disease versus that due to environmental stress.

The fungus is spread by infested onion sets and soil. Machinery, dust storms and surface run-off can move soil from one area to another and spread the pathogen. However, the fungus is often so widespread that it is futile to try to prevent its spread from one field to another.

Management

Cultural practices — Long rotations with unrelated crops, such as carrot, lettuce, celery and beet, are suggested. However, cereals, grasses, parsnip, radish and spinach are not recommended for rotations because the pathogen can infect their roots. When onion is grown in infested soil, adequate moisture, fertilizer and pest control encourage vigorous crop growth. Healthy plants are able to tolerate the disease by producing abundant roots.

Resistant cultivars — Leek and chives are resistant to pink root. Several of the early Japanese hybrid onion cultivars suffer from a combination of high temperature and moisture stress at bulbing and may become heavily infected. Many commercial onion cultivars have some tolerance to pink root, examples being Capable, Paragon, Copper King and Granite.

Chemical control — Soil fumigation is not economical, though it will reduce the population of *P. terrestris* and may result in increased onion yields. Fumigation is more effective on sandy soils.

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(Original by M.R. McDonald)

▶ 13.9 Purple blotch *Figs. 13.9a,b; 13.5b*

Alternaria porri (Ellis) Cif.

Purple blotch is a common onion disease that can be very destructive. It is usually secondary, affecting leaves that already have been attacked by other pathogens or by abiotic factors such as hail or ozone. *Alternaria porri* also can infect leek, shallot, Egyptian and Welsh onion, and false shallot.

Symptoms Lesions are initially small, whitish, sunken and elongate *(13.9a);* some may have purplish centers *(13.5b).* Under favorable conditions, the lesions soon expand to become large, oval, purple blotches with concentric rings *(13.9b).* The blotches may merge and become covered with the dark brown spores of the fungus. Diseased leaves eventually die. Older leaves are more susceptible to purple blotch than are younger leaves.

Purple blotch can cause heavy losses in onion seed crops by infecting and destroying the flower stem. The fungus also may infect the onion bulb at harvest through wounds or fleshy neck tissue. In storage, *A. porri* causes a dark yellow or deep-red spongy bulb rot.

Causal agent Conidiophores of *Alternaria porri* form singly or in clusters on diseased leaves. They are pale to medium brown, 10 to 15 pm thick, up to 120 pm long, and may have one to several well-defined conidial scars. Conidia are smooth or minutely verrucose, pale to golden brown, and are borne singly. When they detach, they leave a distinct scar. The conidia are straight or slightly curved, 100 to 300 µm long, 15 to 20 µm thick, and club-shaped with a long beak. The beak is often as long as the main body of the conidium, and is flexible and tapered. The conidia have 8 to 12 transverse septa and none to several longitudinal or oblique septa. Each cell is capable of germination. A teleomorph is not known.

Disease cycle The mycelium and conidia of *A. porri* overwinter on infested onion residues in the field or in cull piles. Conidia are produced in the spring and disperse by wind or splashing water to onion leaves. Liquid water is necessary for the conidia to germinate. Germination can occur in 45 to 60 minutes at 28 to 36°C. Penetration can take place directly through the uninjured epidermis or through wounds or stomata. Lesions may appear one to four days after penetration and conidia are produced shortly thereafter. Long periods of leaf wetness favor infection. Almost no infection occurs at temperatures below 13°C. In culture, the fungus grows between 6 and 34°C. The optimum for sporulation is 25°C at 90% relative humidity. On calm days, the maximum number of conidia is trapped between 0800 and 1400 hours. Wind, rain, irrigation and spraying may promote spore release. A forecasting system to predict spore release is being developed at Michigan State University.

Management

Cultural practices — To reduce initial inoculum, residues from infected crops should be destroyed and onions should be grown in rotation with non-host crops, such as carrot, celery, lettuce or potato. Culled onions should not be piled near onion fields. To prevent disease development in storage, onions should be harvested during dry weather when the bulbs are fully mature and the tops are dry. Bulbs should be stored at 0°C and 65 to 75% relative humidity.

Resistant cultivars — Yellow cooking onion is not as susceptible as Spanish onion.

Chemical control — Broad-spectrum protective fungicides applied to onion foliage prior to spore deposition provide effective control of purple blotch.

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(Original by M.R. McDonald)

▶ 13.10 Smudge *Fig. 13.10*

Colletotrichum circinans (Berk.) Voglino
(syn. *Colletotrichum dematium* f. sp. *circinans* (Berk.) Arx)

Smudge occurs mainly on white-skinned common and Spanish onion and has been observed sporadically in Canada. It also has been reported on shallot and leek. Infection is mostly superficial, but the formation of black fruiting bodies of the pathogen on the outer scales gives the onions a dirty or “smudged” appearance. Infected bulbs are downgraded or rejected for sale.

Symptoms Smudge can appear on maturing bulbs in the field, usually just before harvest, and on bulbs in storage. The small fruiting bodies of the fungus are dark green at first but turn black when mature. They characteristically occur in groups or in concentric rings near the neck and on the outer scales of the bulb *(13.10).* The black fruiting bodies are covered with stiff black bristles that can be seen with the aid of a hand lens.

When infected onions are stored under moist conditions, small yellow lesions form on the inner layers of the bulb. These enlarge and coalesce and the bulb may shrivel and sprout prematurely. The pathogen can cause damping-off in moist soils and leaf spotting during warm weather.

Causal agent *Colletotrichum circinans* produces septate mycelium that is hyaline at first but becomes darker and thicker with age. Stromata are formed from the thick-walled hyphae, and saucer-shaped acervuli develop from the stromata within the host cuticle. These acervuli contain hyaline conidiophores and numerous dark setae that are triseptate and 80 to 315 µm long. Eventually, the acervulus ruptures the host cuticle and releases the conidia, which bud off the conidiophores individually. Conidia are fusiform, nonseptate, hyaline to pale yellow, and slightly curved with a rounded top. They measure 3 to 4 by 18 to 18 µm. Under moist conditions, they appear as a creamy-colored, gelatinous mass on the dark acervuli. A sexual state is unknown.

Disease cycle *Colletotrichum circinans* can survive in soil for several years, either as a saprophyte or as stromata. The fungus can also be introduced into fields when infected bulbs are planted.

Warm, wet weather is conducive to disease development and spread. High relative humidity is essential for the formation of conidia. They are spread most often by splashing rain, but also can be dispersed by wind and on clothing. The optimum temperature for the germination of conidia is 20°C. No infection occurs below 5°C. The optimum for mycelial growth and symptom development is 26°C. Conidia require free moisture in order to germinate. Germinating conidia produce one to three germ tubes, which develop appressoria on the surface of the plant. An infection hypha pushes through the cuticle by mechanical pressure, and the fungus becomes established between the cuticle and the epidermis. Enzymatic degradation of the host tissue allows further colonization to take place. The fungus can complete an infection cycle within a few days under warm moist conditions.

Management

Cultural practices — It is critical to use disease-free seed and sets. Proper curing of white-skinned onions is essential. Growers should use artificial curing methods if the weather is rainy or very humid. Dry onions should be stored at 0°C and a relative humidity of 65 to 70%. Crop rotation and good drainage also may help to reduce disease incidence.

Resistant cultivars — Yellow- and red-skinned onion cultivars are resistant to smudge because phenolic compounds present in the outer scales inhibit spore germination. White-skinned types are susceptible.

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(Original by M R. McDonald)

▶ 13.11 Smut *Figs. 13.11a-c*

Urocystis magica Pass, in Thüm.
(syn. *Urocystis cepulae* Frost)
(syn. *Urocystis colchici* var. *cepulae* Cooke)

Onion smut has a worldwide distribution and is a major disease of onion in Canada. It occurs in every region where onion is produced, except on newly cleared land. Stand reductions of 50 to 80% have been reported where onion is grown in infested fields and the seed had not been treated with a systemic fungicide.

Urocystis magica infects only *Allium* species. Common and Welsh onion, leek and shallot are very susceptible, whereas garlic and wild leek *(A. tricoccum* Ait.) are only moderately susceptible. Several *Allium* species are resistant to smut, including Winterbeck onion, common and Siberian chives, certain ornamental *Allium* species, and the wild species *A. altaicum* Pall., *A. obliquum* L., *A. nitans* L., and *A. ramosum* L.

Symptoms The first symptoms of smut occur on the cotyledon (flag leaf) and first true leaf of the onion seedling *(13.11a).* A thickening and darkening of these leaves is visible as soon as they emerge from the soil. Long, dark blisters or pustules containing powdery black spores of the smut fungus form within the leaves. The leaves may become bloated and distorted as they grow and often split open, releasing the spores.

Smut infection may kill the seedlings during the first three to four weeks. Sometimes, however, the pathogen remains isolated in the first leaf and, when this leaf dies, the plant continues to grow free of infection. In most instances, however, when the seedling is not killed, the smut fungus continues to grow with the plant, colonizing it systemically. The pathogen progressively invades the leaf bases and bulb scales of successive leaves. Some of these plants die during the growing season, while others survive and produce bulbs with the characteristic elongated dark pustules *(13.11b,c).* Pustules on onions in the field and in storage may be invaded by secondary organisms that can cause soft rot.

Causal agent *Urocystis magica* is heterothallic and produces multi- celled teliospores. The distinctive teliospores are an important taxonomic feature of this pathogen. Each teliospore consists of a central, smooth, spherical to ellipsoidal, thick-walled cell that is dark brown and 12 to 15 µm in diameter. The central cell is surrounded by numerous colorless, thin-walled cells that are 4 to 6 pm in diameter. Only the central cell is capable of germination.

The teliospores develop from the terminal cells of sporogenous hyphal branches. The mature teliospore is diploid and produces a short basidium when it germinates. No basidiospores are formed; instead, the mycelium formed from the basidium fragments to produce new thalli.

The teliospores of *U. magica* will germinate on potato-dextrose agar, but mycelial growth following germination is very slow. The fungus also grows on Dow and Lacy culture medium, which contains malt extract, peptone and inorganic salts. The optimal pH is 5.5 to 6.5. After storage under refrigeration in sterile water for three or four months, the teliospores will germinate readily once transferred to the culture medium.

Disease cycle The teliospores of *Urocystis magica* can persist in soil for 15 years and are the primary overwintering and infective form of this fungus. The mycelium does not play an important role in persistence or infection. The teliospores must undergo a resting phase before germination can occur. Spore germination may be stimulated by root exudates from *Allium* species. However, if germination occurs when no hosts are present, the mycelium can derive nutrients from organic matter in the soil. The seedling is susceptible to infection from about the second day after germination until the first true leaf emerges, a period of about 12 to 15 days, depending on weather conditions. The spore germinates by means of a germ tube, which directly penetrates the epidermis of the cotyledon without forming an appressorium. Infection takes place before the leaves emerge from the soil. Each new onion leaf goes through a growth phase during which it is susceptible to infection. However, developing onion leaves remain enclosed within the preceding leaf until they emerge above ground, so if the preceding leaf has not been infected, the succeeding one will not become infected. Thus, if the cotyledon and first true leaf emerge uninfected, the plant is then resistant to infection. There are two mating types of this pathogen; teliospores of both must be present for infection to take place.

Smut spores germinate at 13 to 22°C. The optimum range for germination on agar is 20 to 24°C. Soil temperatures of 29°C completely inhibit fungal growth. Low soil temperatures result in increased infection levels by slowing seedling emergence, thereby lengthening the time that the seedling is susceptible to infection. Deep planting of onion seed can also result in increased infection levels by delaying seedling emergence. Soil moisture levels have no direct effect on the germination of teliospores or infection, but high soil moisture can result in lower soil temperatures and delayed seedling emergence which, in turn, can increase the incidence of infection.

The pathogen can be spread in infested soil and water and in infected plant parts. In the field, the smut pustules burst and release the teliospores, recontaminating the surrounding soil. Onion smut was most likely introduced into the oniongrowing regions of Ontario and Quebec through infected onion sets. There are no reports of seed transmission.

Management

Cultural practices — Growers should avoid contaminating smut-free fields with infested soil or crop residues. If onion sets are to be grown, they should be closely inspected and any that are diseased should be discarded. Smut-free sets or seedling onions for transplanting are immune to infection and can safely be grown in smut- infested fields.

Resistant cultivars — Some success in breeding for resistance has been achieved by hybridizing the common onion with the Welsh onion, but the commercial cultivars grown in Canada are very susceptible to smut.

Chemical control — Where onion is grown from seed, seed dressing with a suitable systemic fungicide is effective in protecting seedlings. The fungicide can be applied in the coating process by commercial seed companies or to raw seed by individual growers. When applying fungicide to raw seed, the use of a sticker, such as 1 % methyl cellulose solution, increases the retention of the fungicide on the seed. A drench or granular application of non-systemic fungicide into the open seed furrow at planting is not as effective as a seed dressing.

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(Original by M.R. McDonald)

▶ 13.12 White rot *Figs. 13.12a-e*

Sclerotium cepivorum Berk.

White rot is a very destructive disease of common onion and related species. The pathogen is widespread in Canada and cannot be controlled by quarantine measures. It occurs sporadically in British Columbia, Manitoba, southern Ontario and eastern Quebec. In southern Ontario, several onion fields in the Bradford and Thedford marshes are infested, and surveys between 1962 and 1968 recorded the presence of white rot in the muck soils south of Montreal.

Sclerotium cepivorum attacks edible *Allium* species, including onion, garlic, leek, shallot and chives. Wild and ornamental species are susceptible to varying degrees; *Allium aflatunense* Fedtsch. and *A. stipitatum* Regel, are ornamental species that are highly resistant to the pathogen.

Symptoms The first above-ground symptoms, which usually are yellowing and dieback of leaf tips, can progress down the leaf blades until the affected leaves finally collapse *(13.12a).* However, these symptoms are not diagnostic and can be confused with onion maggot damage.

Identification of white rot in the field is mainly by visual examination of roots and bulbs. The characteristic symptoms are white fluffy mycelium and soft rot around the base of the bulbs *(13.12b).* Masses of tiny black sclerotia form on the mycelium and in infected bulb tissues *(13.12c).* In advanced stages of infection, diseased plants are easily pulled because the bulbs and roots are destroyed *(13.12d).*

When infection occurs late in the crop season, the disease may not be noticed at harvest time and symptoms may appear only in storage. The pathogen may also cause preemergence death of seedlings, a stage of the disease that is not always detected.

Causal agent *Sclerotium cepivorum* has no sexual state. The only known survival structures of this pathogen are sclerotia, which are formed on diseased bulbs. These structures are black, spherical, hard, and 0.2 to 0.5 mm in diameter (*13.12e*). They can remain dormant in the soil for several years in the absence of host plants. Sclerotia are held dormant by the soil microflora, since they germinate readily in sterile soil. Their germination in the field is triggered specifically by organic sulphur compounds exuded by the roots of *Allium* species. In mineral soil, sclerotia have been reported to survive for up to 10 years. In contrast, in organic soil in the Fraser Valley of British Columbia, substantial decay of sclerotia occurs in less than a year. This rapid decay is attributed to environmental factors such as prolonged periods in winter when soils remain saturated. The fungus occasionally forms small secondary sclerotia, either within the parent sclerotium before germination or outside of it from germinating hyphae. The quantity of secondary sclerotia formed in soil and their pathogenicity are unknown.

Sclerotium cepivorum may also produce conidia on sporodochia. These spores seem to be sterile and appear to play no part in the disease cycle. The fungus does not grow in soil as a saprophyte. Mycelial growth in the soil is negligible unless the fungus is sustained from a foodbase, such as a sclerotium or an infected bulb.

Disease cycle Primary infections originate from sclerotia in soil, which germinate any time after onion is seeded. The optimum temperature for germination is between 10 and 18°C. The fungus usually penetrates the host through the roots. It also can infect wounded bulbs, but there is little evidence that it enters unwounded leaves or bulbs. Once the fungus has penetrated the host, the most favorable temperature range for disease development is 10 to 20°C. Above 20°C, there is a marked reduction in infection. The disease is favored by moderate moisture levels (-45 mbars to -3 bars). While mycelial growth of *S. cepivorum* in soil is restricted, secondary spread from plant to plant within rows may occur, but this requires close proximity of roots and stem bases. White rot often develops in patches in the field due to the non-uniform distribution of sclerotia in the soil. In contaminated fields, there usually are areas of high, low or no inoculum. Areas of high concentration are found where infected bulbs were left to decay after harvest. The movement of infested soil by wind, water or equipment can spread the fungus within or between fields. The use of infected onion sets or transplants can introduce the pathogen to non-infested areas. White rot occurs in a variety of soils ranging from light sands to heavy clays with acid to alkaline reactions.

Management

Cultural practices — Good sanitation is essential to avoid an increase in sclerotial populations in infested fields and also to prevent the spread of the fungus to non-infested fields. Recommended practices include the use of clean machinery, tools and pallet boxes, irrigation water free of sclerotia, and healthy onion sets or transplants, together with the removal of infected onions from the field, and the prevention of field-to-field movement of flood water carrying crop debris and soil.

In fields where white rot has developed, a four- to five- year rotation with crops other than *Allium* species is suggested. However, even after four to five years, there may still be viable sclerotia in the soil, and precautions should be taken to prevent an increase in inoculum concentration by using extended rotations and other control measures such as roguing.

In organic soil, flooding for four weeks during the spring promotes sclerotial decay. Flooding is more effective when used in combination with crop rotation because aged sclerotia (two to three years old) are more susceptible than younger ones to decay during flooding.

Biological control — The antagonistic bacterium *Bacillus subtilis* (Ehrenberg) Cohen is a potentially effective biocontrol agent for *Sclerotium cepivorum* but is not yet commercially available in Canada.

Chemical control — Erratic results may occur with the use of fungicides, especially in organic soil. Fungicides registered as pre-planting treatments, when applied according to label recommendations, often do not provide satisfactory control. This may be due to soil adsorption, leaching and microbial degradation.

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(Original by E. Banks)

VIRAL AND VIRAL-LIKE DISEASES

▶ 13.13 Aster yellows *Fig. 13.13*

Aster yellows mycoplasma-like organism

Aster yellows is a widespread disease that affects a large number of cultivated and wild plants, including vegetables such as carrot, lettuce, celery and onion. Onion is less often affected than carrot or lettuce. Onion seed crops can suffer much greater damage than bulb crops.

Symptoms On seeded onion, the symptoms begin with a yellowing at the base of the youngest leaves that spreads toward the top *(13.13).* The leaves then flatten and become marked with yellow and green streaks, although they do not twist. Seed crop plants show yellowing and abnormal elongation of the flower stem and pedicels, causing malformation of the floral cluster and sterility of the umbels.

Causal agent (see Lettuce, aster yellows, 11.15**)**

Disease cycle (see Lettuce, aster yellows)

Management Growers should control leafhopper populations.

Cultural practices — Biennial and perennial weeds on headlands and ditchbanks should be destroyed because the mycoplasma-like organism may overwinter in them.

(Original by R. Crête)

▶ 13.14 Viral diseases *Fig. 13.14*

Garlic mosaic (yellow streak) virus
Leek yellow stripe virus
Onion yellow dwarf virus
Shallot latent virus
Tobacco mosaic virus
Tomato black ring virus

Onion yellow dwarf occurs in several countries, but it is not widespread in Canada because it affects mainly onion seed crops and sets, which are not commonly grown in this country. It also occurs on shallot, garlic, leek, and certain species of narcissus. The disease reduces the bulb yields of onion grown from seed if the infections occur in early spring, and it may lower seed production of onion seed crops by up to 50%. Diseased bulbs keep poorly in storage.

Onion yellow dwarf has been known since the 1920s. The mucilaginous character of *Allium* leaf sap has made characterization of viruses from these crops difficult, so there has been a tendency to associate most viruses of *Allium* spp. with onion yellow dwarf virus. Recent work reveals at least two additional viruses: leek yellow stripe virus, which has been definitely identified only in Europe, and shallot latent virus. In most regions, garlic often harbors more than one virus. The relationship of garlic viruses to other *Allium* viruses remains unclear.

Symptoms Virus infections cause streaking or striping of monocotyledonous leaves; such symptoms are more or less analogous to virus-caused “mosaics” in dicotyledonous species.

Garlic mosaic (yellow streak) —

Symptoms *(13.14)* are generally similar to those of onion yellow dwarf, although leaves may show more curling and distortion. Garlic bulbs often fail to differentiate properly into cloves and produce only small onion-like “rounds.”

Leek yellow stripe virus —

This virus causes striping of the entire leaf, most apparent at the leaf base, and general stunting. Infected plants are more sensitive to frost damage.

Onion yellow dwarf —

Leaf symptoms generally appear as pale green, chlorotic streaks or stripes that develop into variable amounts of yellowing, ranging from irregular striping to nearly complete yellowing of leaves. Infected leaves also may curl downward, appear limp or wilted, and show flattening or crinkling. Infected plants are usually stunted. Bulbs from infected plants store poorly and sprout prematurely.

Shallot latent virus —

This virus is widespread but causes no apparent symptoms in shallot.

Tomato black ring virus and tobacco mosaic virus —

These viruses are reported occasionally in *Allium* crops. Both are soil-borne. Symptoms are fairly characteristic when infections by these potyviruses are encountered. They also typically cause fibrous or granular inclusion bodies to form in leaf epidermal cells, often associated with the nucleus, that can be detected with a light microscope. Electron microscopy is required for positive identification of virus particles. Serological procedures are generally not available because relatively few laboratories have produced antisera against *Allium* viruses.

Causal agents Onion yellow dwarf virus is a member of the potyvirus group. The virus particles are flexuous filaments, approximately 15 to 16 nm in diameter and 700 to 800 nm long. Leek yellow stripe virus is also a potyvirus, approximately 820 nm long. Shallot latent virus is a member of the carlavirus group and its particles are straight to slightly curved filaments approximately 650 nm long.

There has been considerable confusion regarding the number and identity of viruses infecting garlic. Garlic “mosaic” (various regions), “yellow stripe” (California), and “yellow streak” (New Zealand) are usually attributed to potyviruses, but other workers have associated symptoms in garlic with a carlavirus. Both a potyvirus and a carlavirus with straighter, shorter particles have been found in several lines of infected garlic in Canada and also in California; most garlic probably contains a “complex” of more than one virus.

Disease cycle Most of the important viruses infecting *Allium* crops have a narrow host range and are restricted to these crops. Reports that onion yellow dwarf virus can be seed-borne have not been verified. The main sources of infection are other *Allium* species grown nearby, overwintering volunteer plants, and vegetatively propagated material of the crop species. In Europe, leek yellow stripe virus becomes prevalent only in areas of year-round leek production.

In addition to transmission through the use of vegetatively propagated material, the *Allium* viruses are transmitted in a non-persistent manner by various aphids. Onion yellow dwarf virus is transmitted by several aphid species that migrate through onion crops but do not colonize them. The shallot aphid can transmit both onion yellow dwarf virus and shallot latent virus among stored bulbs and sprouts. Leek yellow stripe is transmitted in Europe by the black bean aphid and the green peach aphid. Garlic viruses are also aphid-transmitted.

Management Aphid vectors should be controlled with registered insecticides where populations warrant.

Cultural practices — Most control measures against viruses center on prevention or avoidance strategies. Growers should plant onion sets and mother bulbs in disease-free areas and remove any volunteer onion plants. Early removal of infected plants and early harvest of planting stock also should be practiced. In some countries, certified planting stocks are produced some distance from crops grown for consumption. Crops grown from seed are less likely to have virus problems, particularly if isolated from other crops.

Much of the imported garlic sold as planting material is of variable quality. Growers are advised to obtain planting material from an experienced producer. Efforts to obtain “virus-free” garlic by *in vitro* meristem tip culture have been made in various countries. In California, garlic was freed of a symptom-causing virus in this manner, but not of a latent virus. The relationship between garlic virus(es) causing mosaic and onion yellow dwarf virus remains unclear. Some investigators maintain that onion yellow dwarf virus is not very infectious in garlic and that garlic “mosaic” is not very damaging to onion, while others disagree. Viruses have been transmitted from garlic to onion in mechanical inoculation trials. It is likely that aphids can also transmit from garlic to onion, so it would be wise to grow onions some distance from garlic, as the latter is usually infected.

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(Original by J.F. Peterson)

NON-INFECTIOUS DISEASES

▶ 13.15 Herbicide injury *Figs. 13.15a-c*

Herbicides can cause temporary or permanent injury to ***Allium*** crops. Damage can occur when these products are applied at excessive rates, during unfavorable weather conditions, or at the wrong stage of growth. With contact herbicides, burns and necrotic spots are produced (*13.15a*) and leaf tips may wither (*13.15b,c*); with translocated herbicides, the plants may turn yellow. Generally, the plants recover and the symptoms disappear over time. However, if the application rate is too high, the damage will be irreversible. Damage may also be observed if *Allium* crops are grown where the previous year’s crop was treated with a residual herbicide to which they are susceptible.

Management

Cultural practices — To avoid injury, growers should follow recommendations concerning rates, volume of water, and growth stage for proper application. Records of weather conditions and stage of the crop when applying herbicides are useful in case of injury.

Chemical control — Growers should tank-mix herbicides only with recommended spreader-stickers and other pesticides specified on the label. Excessive wetting of onion foliage with unsuitable mixtures can lead to severe crop injury. Identifying herbicides that were used on the crop that previously grown in the field may help to pinpoint the cause of a chemical injury.

(Original by R. Crête and M.R. McDonald)

▶ 13.16 Ozone injury *Fig. 13.16*

Ozone injury occurs sporadically in the major onion-producing areas of Ontario and Quebec. Ozone alone causes increased leaf necrosis and reduced bulb size, but the injury is also of concern because it can predispose leaves to botrytis leaf blight and purple blotch.

Symptoms Ozone injury first appears as minute whitish flecks on the onion leaves, especially between the veins. If there are large numbers of flecks, they may coalesce to form whitish spots of varying sizes and shapes with diffuse margins *(13.16).* The flecks do not penetrate to the inside of the leaf but larger spots may. Ozone injury can be distinguished from the symptoms of botrytis leaf blight by the lack of distinct margins and silvery halos. Both ozone injury and botrytis lesions may be present on the leaf at the same time (see also tipburn, 13.19).

When ozone injury is severe, the leaves become pale green to yellowish overall and die back from the tips

(13.16). Damage is usually apparent one to three days after an ozone episode, which occurs in conjunction with warm, hazy, humid weather when air pollution levels are high. Ozone levels of 15 parts per hundred million in the ambient air are considered major episodes and usually cause flecking on onion leaves. Generally, the youngest and the oldest leaves are more resistant to ozone injury.

Causal agent Ozone is a powerful oxidant that exists naturally at very low levels in ambient air. Ozone can be produced by the action of light on air pollutants such as hydrocarbons and nitrous oxide, which are formed when fuel is burned in internal combustion engines. Ozone can also be produced during electrical storms. The levels of ozone generated as a result of air pollution can be high enough to cause injury to onion leaves and to the leaves of other plants.

Management Other than locating onion fields in areas of low air pollution, no control measures are available.

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(Original by M.R. McDonald)

▶ 13.17 Sprout inhibitor injury *Fig. 13.17*

Applying the sprout inhibitor maleic hydrazide too early in the growing season results in spongy bulbs of poor quality. Maleic hydrazide is the only sprout inhibitor registered for use on onion in Canada and it is used widely on crops destined for long-term storage. Without the application of a sprout inhibitor, onions will begin to sprout after three to four months in storage, even under ideal storage conditions. Onion bulbs that are starting to sprout become soft, even before the green leaves emerge at the neck, and are unmarketable.

Symptoms Onions that have received maleic hydrazide too early in the season may be full size at harvest but will feel soft and spongy when squeezed. Sponginess occurs because the rings in the bulb have separated from each other *(13.17)* and are not pressed tightly to the adjacent rings as they are normally. The spaces between the rings are most obvious near the neck. Maleic hydrazide inhibits sprouting by suppressing cell division. If applied before the cells in the bulb have stopped growing and dividing, cell division will be halted but the cells will continue to grow larger, causing the bulb scales to change shape and pull away from one another.

Management

Cultural practices — Correct timing of maleic hydrazide application based on the growth stage of the onion is the key to achieving effective sprout inhibition while avoiding injury. Maleic hydrazide should be applied when the onion has stopped producing new leaves. When this occurs, the neck becomes hollow and weak, and the top lodges as the bulb matures. The ideal time to apply maleic hydrazide is when 50% of the plants in the field have lodged, but the plants still have an average of five to eight green leaves. If the onion plant does not have at least five fairly healthy green leaves, the uptake and translocation of maleic hydrazide will not be sufficient to provide good sprout inhibition.

For maximum effectiveness, maleic hydrazide should be sprayed when temperatures are in the range 10 to 24°C and the relative humidity is high. Low humidity may cause maleic hydrazide to crystallize on the leaves, thereby inhibiting uptake. Rain within 24 hours after application will also reduce uptake.

Selected references

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(Original by M.R. McDonald)

▶ 13.18 Sunscald

Sunscald is a minor disorder in onion crops. On a hot sunny day during warm, dry springs, particularly on dark organic soils, the temperature at the soil surface may rise to as high as 65°C. The heat damages the sensitive young plants, killing the cells at the neck level. Injured tissues shrivel, strangling the neck, and the plant wilts and withers. The seriousness of the damage depends on the temperature at the soil surface and the tenderness of the plant tissues.

The only way to avoid sunscald is to seed as early as possible so that the plants outgrow the sensitive stage before the soil temperatures become too hot.

(Original by R. Crête)

▶ 13.19 Tipburn (tip dieback) *Fig. 13.19*

Tipburn is a physiological disorder that affects mainly onions. It is a widespread phenomenon in onion-growing areas and has been reported on other monocotyledenous crops. However, it is not related to tipburn of cole crops and lettuce, which is associated with reduced calcium uptake.

Symptoms Tipburn usually starts at the tips of the oldest leaves. These turn yellow and then white because of the loss of chlorophyll. Eventually the affected leaf tissue dies. Tipburn may extend down the entire leaf and affect several leaves on a plant. In most cases, the symptoms appear at the same time over an entire field *(13.19)* or in all the plantings of a particular cultivar growing in the same region. Tipburn most often occurs when the plant is starting to bulb and nutrients are being translocated from leaf to bulb, but it can also occur earlier in the growth of the plant. Onion cul- tivars have been observed to differ in their susceptibility to tipburn. The tipburn symptoms that occur when onions are bulbing often appear quickly in a field and may be mistaken for the symptoms of herbicide injury or botrytis leaf blight. Ozone injury also may be confused with tipburn.

Causal agent The cause of tipburn is not well defined. In general, any factor that puts the plant under stress is likely to result in this disorder. Drought and saturated soil have both been implicated.

Management

Cultural practices — Balanced fertilization and constant moisture levels help to reduce stress.

Resistant cultivars — Some cultivars are commonly afflicted with tipburn and should be avoided if the problem is serious.

Chemical control — Fungicides may help to protect senescent leaf tissues from diseases such as botrytis leaf blight, purple blotch and blackstalk rot (*Stemphylium botryosum* Wahr.).

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(Original by M.R. McDonald)

▶ 13.20 Translucent scale *Fig. 13.20*

This disorder is occasionally seen on onion crops, most often on Spanish onion.

Symptoms This disorder is characterized by a grayish, watery appearance of one or more layers of scales, which makes them look translucent *(13.20).* Sometimes the condition affects all of the layers, but most often only the second and third fleshy scales exhibit symptoms. The affected scales are brownish in cross section.

Causal agent The cause of translucent scale is unknown. The problem seems to be connected with storage, because it appears after harvest and worsens after three or four months of storage. Onions kept at 5 to 10°C for a few weeks before final storage at 0°C are more subject to this disorder. Excessive relative humidity could also predispose onions to this problem.

Management

Cultural practices — Growers should heat-cure onion bulbs well, then store them at 0°C and a relative humidity of 65 to 70%.

(Original by R. Crête)

▶ 13.21 Wind, hail, pelting rain injury *Fig. 13.21*

Allium crops are very prone to wind damage at the seedling stage. Young leaves can be desiccated by hot, dry winds or sandblasted by drifting soil, especially in exposed field locations. The force of raindrops in a heavy storm may also injure leaves, causing whitish spots with irregular margins *(13.21).* These spots can develop quickly, often within 24 hours of the rainfall, and they usually occur on the side of the leaf that was facing the wind. The impact of hailstones may cause similar spots or may cut or shred the leaves, depending on the size of the stones and the intensity of the storm.

Wind and hail can seriously damage *Allium* crops and may necessitate replanting. Pelting rain usually does not cause enough harm to reduce yield, but the spots may be confused with botrytis leaf blight or herbicide injury. The injury may also make the plants more susceptible to infection by fungal pathogens by allowing nutrients to leak out onto the leaf surface.

Management

Cultural practices — To protect seedling onions from wind injury, growers should plant a cereal crop, such as barley, on the same day that the onions are seeded. The barley may be seeded in rows (one row of barley for every four to eight rows of onions) at a rate of 40 barley seeds per metre of row. Even better protection is afforded by broadcast seeding the barley at a rate of 50 to 80 kg/ha. Once the onion plants are established, the barley can be killed with a selective herbicide. Timing of the herbicide application is critical. If the barley is seeded in rows, it should be sprayed when the plants are approximately 15 cm tall. If broadcast seeded, the barley should be killed when it is 10 to 14 cm high.

Chemical control — The application of a broad-spectrum fungicide may help to protect the injured leaves from subsequent infection by fungal pathogens.

(Original by M.R. McDonald and R.J. Howard)

NEMATODE PESTS

▶ 13.22 Northern root-knot nematode *Fig. 6.20*

Meloidogyne hapla Chitwood

Bulb crops are usually quite sensitive to infestations of this nematode.

Symptoms include conspicuous yellowing, stunting and early senescence. Prolific branching of rootlets, and production of small, spherical galls on roots are characteristic *(6.20).* Bulbs are not invaded. Onion sustains less damage than carrot under light infestations. For a complete description and management strategies, see Carrot, 6.20; see also Management of nematode pests, 3.12.

▶ 13.23 Root-lesion nematode *Fig. 13.23*

Pratylenchus penetrans (Cobb) Filip. & Stek.

Symptoms include wilting and stunting in patches in heavy infestations; leaves become yellow. Secondary roots become necrotic, with dried areas. Bulb size may be reduced *(13.23).* For a complete description, see Potato, 16.38; see also Management of nematode pests, 3.12.

▶ 13.24 Stem and bulb nematode *Fig. 13.24*

Ditylenchus dipsaci (Kühn) Filipjev

This nematode attacks mainly onion and allied crops. The onion strain that is found in Canada has three races; these affect alfalfa, narcissus and onion, respectively. It has been confirmed from Newfoundland, Quebec, Ontario, Saskatchewan and British Columbia. The main crops of concern are chives, garlic, leek, onion and pea. Other strains found in Europe but not in Canada parasitize bean, beet, carrot, lettuce, parsnip, potato and spinach.

Symptoms Plants are infected during or shortly after germination. Seedling bases become swollen and leaves appear twisted and malformed. Leaves yellow and die. Young roots and bulbs may rot. Plants that do not die have badly deformed bulbs and shorter leaves that senesce prematurely *(13.24).* Bulbs are very susceptible to secondary infection by fungi and bacteria. Bulb scales are discolored and bloated. Malformed bulbs may sprout or double. A slight infection in the field may pass unnoticed, but the nematode can multiply in stored bulbs if they are not kept at low temperatures.

Identification *Ditylenchus dipsaci* (order Tylenchida, family Anguinidae) has a delicate labial framework, a thin short stylet with small knobs that are difficult to see under a microscope, and a rounded median bulb with large valves. The adult female has one, very long, anterior ovary and a long slender tail.

This nematode can survive extremely dry conditions for years. Large aggregates of desiccated nematodes can be found in dried, infested plant residue. In the dormant state, they are also able to survive freezing temperatures. Many strains of *D. dipsaci* are recognized and cannot be separated on the basis of morphology. Each strain is more or less specialized with respect to its pathogenicity to a restricted number of hosts.

Nematode extraction from soil, leaf or bulb samples and microscopic examination are needed to diagnose this species.

Life history Nematodes migrate toward the seedling roots and penetrate stems at the soil level, or they may migrate up the stem and infect young leaves. They feed on parenchyma cells and, in the process, release digestive enzymes containing pectinases and cellulases. These chemicals dissolve the middle lamellae between cells and digest the tissues around the nematodes. Small cavities are formed where the mature females lay their eggs. The nematodes reinfest the soil when infested leaves and bulbs are left in the field. In the soil, the fourth-stage juveniles can become quiescent and, as such, are able to survive extreme temperatures and dry conditions for several years. Stem and bulb nematodes are spread with infected plants, seeds and soil.

Management

Cultural practices — Rotation to non- *Allium* vegetables for at least three years, while also avoiding legumes, should reduce numbers of infective juveniles adequately. Where infestation of soil is confirmed, cull bulbs and crop residue should be removed from the plot completely; this may be more practical for home gardens and small field plantings. Growers should avoid buying or planting onion sets from contaminated sources; infected sets are often discolored (dark brown) and lighter in weight. Questionable sets should be diagnosed or discarded.

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(Original by T.C. Vrain)

INSECT PESTS

▶ 13.25 Onion bulb fly *Fig. 13.25*

Eumerus strigatus (Fallén)

The onion bulb fly was introduced from Europe and is sometimes called the lesser bulb fly or small narcissus fly. It is a minor pest of dry bulb onion grown from sets, bulbs or multipliers and, most importantly, of onion grown from bulbs for seed production throughout western Canada.

The onion bulb fly also commonly infests bulbs of amaryllis, hyacinth, iris, narcissus and shallot. There are anecdotal accounts of onion bulb flies infesting carrot, parsnip and potato. While there is no doubt that healthy daffodil bulbs are attacked, most other plants are subject to attack only when decaying from some other cause.

Damage A single, withered leaf growing from a bulb usually indicates that the bulb is infested with onion bulb fly larvae. Bulbs infested with onion bulb fly may contain as many as 10 to 30 larvae. After harvest, infested bulbs are soft to the touch and soon become a rotting mass in storage. The onion bulb fly has little or no economic impact on commercial production of dry bulb onion crops grown from seed. Damage is restricted to onion plants growing from sets, bulbs or multipliers already damaged by other causes. Seedling onion crops are rarely, if ever, attacked and chemical controls for more important pests maintain populations at low levels. However, the onion bulb fly can be a serious problem for home gardeners who grow onion from bulbs, sets or multipliers, and for commercial growers of onion seed who grow onion from bulbs.

Identification Onion bulb fly (family Syrphidae) has the typical fly life stages: egg, larva, pupa (puparium) and adult. Adults are hover flies, about 8 mm long, and black-green with several white, lunate markings on an almost hairless abdomen (*13.25).* They resemble beneficial species of hover flies (see Beneficial insects, mites and pathogens, 3.7). The eggs are chalk-white, more elongate than oval, and less than 1.5 mm long. The legless larvae are gray-yellow with a markedly wrinkled surface. The maximum larval length is about 1.3 cm. Pupae are similar in color to pupae of the onion maggot, but they are more heavily sclerotized, about 1.5 times larger, and blunter at the ends.

Life history The onion bulb fly overwinters as a larva in soil down to depths of 8 cm but more commonly in infested onion bulbs left in the field. In the spring the mature larva crawls out of the bulb to the soil surface and usually pupates at the base of the developing bulb stem. The adults from overwintered larvae appear in late spring and early summer. They are most active on warm sunny days, feeding for about a week on pollen and nectar from the blossoms of numerous plants and sap from rotten onions before laying eggs. Eggs are laid on leaves near the stem collar, in leaf axils, and on the ground around damaged onion bulbs. Females may lay 40 or more eggs in their lifetime and it is not unusual to find 10 or more eggs on a single bulb. The structural formation of the larval mouthparts prevents them from feeding on healthy, intact bulbs. Thus, only onions damaged from some other cause are infested with onion bulb flies. Larval entry usually occurs at the basal plate. There can be up to two summer-generations of onion bulb fly each year. However, some slow-feeding larvae may require up to two years to develop. The first generation of adults is active during August.

Management

Monitoring — Monitoring procedures and thresholds specific to the onion bulb fly have not been developed. However, the flies are attracted to a number of food baits, particularly decomposing oatmeal, which stimulate oviposition. Such baits may be useful in monitoring adult activity.

Cultural practices — Growers should plant onion in areas where there is air movement (but see wind injury, 13.21); soil-borne diseases, especially basal rot, should be controlled. Also, it is best to discard or otherwise destroy all soft and rotting bulbs, and to lift and destroy all transplanted bulbs that fail to grow. Bulbs that are soft should not be planted. Dormant bulbs can be immersed in hot water for one hour at 40°C before planting. Cultivation too close to the bulbs should be avoided, as injury provides sites for flies to oviposit.

Biological control — There is little if any documentation of the role of natural enemies in the control of onion bulb fly.

Chemical control — No insecticides are registered specifically for control of onion bulb fly in Canada, but many of the insecticides recommended for control of onion maggot and onion thrips will control onion bulb fly, which is not known to be resistant to any of the currently used insecticides.

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(Original by G.J.R. Judd)

▶ 13.26 Onion maggot *Figs. 13.26a-e*

Delia antiqua (Meigen)

The onion maggot is the most serious insect pest of onion in temperate regions. It was introduced into eastern North America from Europe around 1875 and is now present throughout all commercial onion-growing areas of Canada.

Onion is the preferred host of the onion maggot. Related crops, such as bunching onion, chives, garlic, leek and shallot are occasionally infested. Onion maggot flies will oviposit on wild *Allium* species in a laboratory, but none of the wild onions growing in North America or Europe has become important as a host.

Damage The greatest economic damage to commercial onion is caused by first-generation larvae in the spring, when the plants are small. The larvae can destroy 20 to 30 onion seedlings in the loop stage, because they readily move between adjacent plants. Also, because females lay eggs in batches, damage appears clumped within onion beds. Damage from the first-generation larval attack usually can be seen by early June in British Columbia or by mid- to late June in eastern Canada. Above-ground damage symptoms depend on the growth stage of the plants. When damage occurs at the loop stage or earlier, onion may simply wilt and disappear. Plants that are attacked in the two- to three-leaf stage develop a gray cast, wilt, turn pale green to yellow, and usually remain in place within the row (*13.26e*). When these wilted plants are pulled, they often break just below the soil surface, exposing the feeding maggot inside the rotting stem *(13.26a).* Onion plants attacked in late June or early July are not killed and above-ground symptoms are difficult to detect. Fewer plants are damaged at this time because maggots no longer migrate between onion bulbs. However, plants damaged at mid-sea- son will have misshapen bulbs that often are secondarily infected with fungi and bacteria. Damage from later generations of larvae causes little economic loss to growers because most onions will already have been lifted for curing in windrows in the field by the time the females are ovipositing. Eggs are often laid on windrowed onions or in the surrounding soil but very few maggots enter healthy, undamaged bulbs at that time of year. Annual losses to commercial onion crops average about 2 to *5%* across Canada, despite heavy use of costly insecticides. In the absence of insecticidal treatments, average yearly losses to onion maggot would be in the order of 40 to 45% in commercial fields and could reach 100% in small plots or home gardens.

Identification The onion maggot (family Anthomyiidae) has an egg, larval, pupal (puparium) and adult stage. The adult is a pale gray fly (*13.26b*) that resembles the common house fly but is smaller (6 mm long) and has longer legs. Eggs are about 1 to 1.5 mm long and are white, with a striated surface (chorion). Larvae are legless, cream-colored maggots that taper toward the anterior end, with a pair of black mouthhooks (*13.26c).* Fully grown larvae are about 6 to 8 mm long. Pupae (puparia) are 5 to 7 mm long, chestnut-brown (*13.26d),* and resemble grains of wheat.

Life history The onion maggot overwinters as a pupa, usually in the top 15 cm of soil. When spring soil temperatures rise above 4°C, overwintering pupae begin to develop. Precise timing of adult emergence in the spring depends on the distribution of pupae in the soil and the temperatures to which they are exposed. Emergence usually begins when 300 degree-days above 4°C have accumulated after March 1; this occurs from late April to early May in coastal British Columbia. In Ontario and Quebec, adults may not emerge until mid- to late May. The adults disperse randomly until they are reproductively mature, when they fly upwind in response to onion odors. Although adults are capable of dispersing several kilometres, many remain within a few hundred metres of their emergence sites, sometimes aggregating and feeding on flowering weeds surrounding last season's onion fields.

The adults mate after they are five to seven days old. Mating is thought to occur in or near onion fields, because both males and females become responsive to the odor of onion when they are reproductively mature. Once having located onion fields, many adults remain in or near the field borders. Adults of later generations, which emerge in onion fields during the summer, disperse very little.

Egg laying begins about three to four days after mating, or 7 to 10 days after emergence. Each female fly may live about 30 days and lay up to 200 eggs. Eggs are laid in batches just below the soil surface around the stem of onion plants. They hatch in a few days, and the young larvae crawl toward onion roots where they feed. Mature larvae leave the onion plants and pupate in the soil.

There can be up to three generations of onion maggot each year. Seasonal phenology of the generations varies among growing areas, largely because of differences in temperature. In Ontario and Quebec, adults from overwintered pupae are present from mid-May to late June, first- generation adults from early July until early August, and second-generation adults from late August until early October. These periods are at least three to four weeks earlier in British Columbia.

Management (See also control of soil-borne pathogens, especially those that cause onion smut, 13.11, and basal rot, 13.4.)

Monitoring — Onion maggot adults can be monitored with a variety of traps, depending on local preferences and requirements. White sticky traps are used in British Columbia, both yellow sticky traps and interception traps are commonly used in Ontario, while in Quebec cone traps baited with a volatile onion derivative, dipropyl disulfide, are used. Sticky traps are best used in areas with little wind, otherwise they quickly become covered with dust, which makes them ineffective. For most onion-growing areas, action thresholds based on trap catches are impractical, because of extremely high endemic populations of onion maggot. Instead, trap catches are used to time sprays during peak population activity. In British Columbia, where onion maggot populations are several times lower than in Ontario, an action threshold of one fly per 10 traps per day, using a 300 cm^2 white sticky trap, provides the basis for timing foliar sprays.

Cultural practices — Prevention and good sanitation are extremely important in controlling the onion maggot. Both second- and third-generation female adults prefer to lay their eggs on diseased or damaged onion plants and larval survival is higher on such plants. Ineffective treatments against first-generation maggots result in greater onion maggot injury at harvest, as does mechanical damage from cultivation or damage due to onion smut. Because damaged onion bulbs are the major food source for late-summer larvae, which in turn become the overwintering pupae, every effort should be made to minimize mechanical damage to onions, especially during uprooting for drying and harvest. Onions uprooted by a potato digger, and then windrowed, sustain less damage than those that are uprooted by undercutting. Removal of cull onions from the field in the fall, before onion maggot adults lay eggs, will reduce the next year's populations. Cull onions should not be disced in the fall until after the last summer-generation of flies has had its flight-period. Discing promotes larval survival by increasing the number of sites available for larval entry into onions.

Biological control — Several parasites, predators and diseases of the onion maggot life-stages have been identified but most are relatively ineffective in chemically treated commercial plantings. Ground beetles, primarily *Bembidion* spp., are important predators on eggs of the onion maggot, while the rove beetle *Aleochara bilineata* (Gyllenhal) attacks onion maggot eggs in its adult stage and onion maggot pupae in its larval stage. Also, the fly *Coenosia tigrina* (Fabricius) attacks onion maggot adults. Perhaps the most important agent against larvae of the onion maggot is a parasitic wasp, *Aphaereta pallipes* (Say). The fungus *Entomophthora muscae* (Cohn) is the most important agent against the adult, and it is the only natural agent that has a substantial impact on onion maggot populations during the production season; however, its activity is limited to a great extent by fungicides used to control pathogens. Despite documented evidence that *E. muscae* is a major mortality factor of onion maggot adults, very little is known about this fungus as a biocontrol agent in managed onion fields.

Chemical control — Proper application of a granular insecticide at seeding is the most important feature of onion maggot control with pesticides. Granular insecticides ensure good control of first- and very often second-generation larvae, provided that the dosage is correct and the insecticide is placed in the furrow on top of the seed at planting time. Very often, chemical control of third-generation larvae is unnecessary, especially in British Columbia and Quebec, where populations of this generation tend to be extremely low and where onions are often in the process of being harvested when oviposition begins. Foliar insecticides are effective only if applied on the foliage, not on the soil. Late-season control may be accomplished by applying foliar sprays early in the evening or just before dusk, directed against the adults. Sprays should be applied during population peaks on the basis of trap catches or degree-day accumulations. Because degree-day estimates for emergence of the adults vary among areas, growers should consult extension agents for the proper timing of spray treatments.

In some areas of Canada, particularly southwestern Ontario, the onion maggot has developed resistance to some organophosphorus and carbamate insecticides. Although resistance to these materials has not been documented in other areas of Canada, degradation of carbofuran (a carbamate) by soil microorganisms has reduced the effectiveness of this granular, furrow-incorporated insecticide in British Columbia.

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(Original by G.J.R. Judd)

▶ 13.27 Onion thrips *Fig. 22.35c*

Thrips tabaci Lindeman

The onion thrips is found in diverse habitats and on a variety of plants. It is common in all commercial onion-growing areas of Canada.

The onion thrips is an extremely polyphagous species, infesting forage and vegetable crops as well as numerous weeds. Onion thrips has been collected from most *Allium* crops (see hosts of the onion maggot, 13.26), as well as bean, cole crops, cucumber, pea, pepper, squash and tomato.

Damage Onion thrips feed on onion leaves by piercing the plant tissue with their mouthparts and sucking up the plant juices. This feeding behavior causes silver streaks to appear on the leaves. As the feeding areas coalesce, the silver streaks develop into white patches. If the infestation is severe, the leaves die back from the tips and become distorted. In hot, dry summers, the whole crop may have a “blasted” appearance. Plants may ripen prematurely and produce smaller bulbs, or they may die. Damage is less likely to be serious in cool, moist seasons and infestations are often reduced by a drenching rain. Although thrips rarely destroy a crop, reductions in yield are fairly common. Very often the grower will not recognize the extent or the cause of these yield reductions. In most years and in most areas of Canada, onion thrips is not considered as important a pest of onions as onion maggot. However, onion thrips will likely become a greater threat to onion production under reduced onion maggot spray programs, especially in arid regions and in dry years. While there is a negative relationship between feeding by onion thrips and yield in dry-bulb onion crops, the economic impact of this insect on Canadian onion production has not been established.

Onion thrips has been shown to transmit several plant pathogens, including tomato spotted wilt virus and the causal agent of powdery mildew on other crops, but no diseases of *Allium* crops are known to be transmitted by this thrips. However, onion thrips is one of many thrips suspected of predisposing plants to infection by pathogenic bacteria and fungi as a result of their feeding punctures.

Identification Onion thrips (family Thripidae) adults (*22.35c*) are pale yellow to brown, 1 to 1.2 mm long and slenderly elongate. They have four narrow wings fringed with delicate hairs (setae). The eggs are too small to be seen without magnification, but they can be seen by clearing leaf tissue with alcohol washes, when they appear as translucent, oval structures just beneath the leaf epidermis. The immature, nymphal stages, sometimes referred to as larvae, are pale yellow and resemble wingless adults. Propupae and pupae are rarely seen because they develop in the soil, but they can be distinguished from nymphs by the presence of wing buds. *[Note:* The genus *Thrips* is characterized by laterally paired “combs” on abdominal segments five to eight and antennae with seven or eight divisions (annuli). Identification should be confirmed by a specialist. — Eds.]

Life history The onion thrips overwinters as an adult in a variety of habitats and on various plants. Overwintering females are often found on onion plants or refuse left in the field after harvest, on onion bulbs in storage, or in standing alfalfa and winter wheat crops and weedy vegetation surrounding onion fields. In some areas of Canada a small overwintering reservoir of thrips is maintained on greenhouse crops. As the weather warms in the spring, females lay their eggs in leaf tissue of onion or other host plants. Very often, onion thrips will reproduce on other favored hosts before migrating into onion fields. Infestations usually begin at the field borders and gradually spread in the direction of the prevailing wind through the rest of the crop. Initially, thrips nymphs stay in clusters at the base of the plant, where the leaves are close together. As the nymphs mature, they move over the leaves, feeding like adults by rasping the plant tissue with their mouthparts and sucking up the plant juices. Mature nymphs enter the soil to pupate. The rate of development, and the duration of various stages are temperature dependent. In Michigan, the developmental threshold is 7.4°C for the entire life cycle, from egg-hatch to adult. The same threshold probably is applicable to thrips populations in Canada. The mean development-time from egg-hatch to adult at 20°C is about 14 days. In some areas of Canada, there can be several generations per season.

Thrips are among the weakest of flying insects, yet their finely fringed wings enable them to remain air-borne long enough for the wind to carry them great distances. Airborne dispersal from breeding sites is a regular event in the life cycle of the onion thrips. Many times, onion thrips will invade onion crops when infested adjacent hosts, such as alfalfa or weeds, are removed.

Management

Monitoring — Onion thrips populations are best sampled by removing all leaves from 10 to 20 plants at ground level and washing or shaking them over a suitable trapping surface in the laboratory. Adult onion thrips also can be trapped with yellow, white or blue sticky traps. Color is probably irrelevant because no relationship is known between trap catches and population levels of thrips or their damage on plants. Monitoring programs being developed are based on counts of thrips on plants in the field. There is a negative relationship between the seasonal mean number of thrips per plant and onion yield, yet there is no established spray threshold for onion thrips. However, as few as five thrips per plant per season can have a significant impact on yield. In Quebec, a mean of three thrips, either as nymphs or adults, per onion leaf in a random sample of 20 plants per five hectares of onion is a tentative spray threshold. Sampling is done twice a week in Quebec.

Fields should be sampled at least once per week during hot, dry weather, particularly during mid- to late season and following nearby harvest of hosts.

Cultural practices — Prevention and sanitation will help to reduce damage. Onion should be grown as far as possible from fields of alfalfa, wheat and other crops that may harbor onion thrips because harvesting of those crops before onion will result in invasion of nearby onion crops by migrating thrips populations. Heavy irrigation will often reduce thrips populations, eliminating the need for chemical control. In the fall, overwintering sites, such as tops of onion plants and cull bulbs, should be buried. In the spring, grasslands and headlands bordering onion fields should be cultivated to kill overwintered onion thrips by burying them.

Biological control — The onion thrips has several parasites, predators and pathogens, but there is little documentation of their effect on onion thrips populations in onion fields in Canada. The effectiveness of predaceous mites, which are used to control thrips in greenhouses (see Greenhouse cucumber, western flower thrips, 22.34), has not been evaluated in the field.

Chemical control — In most onion-growing areas, onion thrips have been, or are controlled by foliar sprays directed at onion maggot adults. However, since 1980, the use of granular insecticides and greater dependence on monitoring programs to manage onion maggot have resulted in fewer foliar sprays and greater damage attributable to onion thrips. The onion thrips is not known to be resistant to any of the insecticides currently used in onion production in Canada.

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(Original by G.J.R. Judd)

▶ 13.28 Other insect pests

Shallot aphid *Myzus ascalonicus* Doncaster

This aphid occurs in Canada and can transmit viruses; see onion yellow dwarf and shallot latent viruses, 13.14.

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