Diseases Affecting Shoots

Gray mould

This disease occurs in container nurseries throughout the province and provides a classic example of how new pest problems can arise with technological change – the change from bareroot seedling production, where the disease seldom occurs, to growing seedlings in containers. Earlier problems with the disease have decreased with improved cultural conditions.

Hosts and damage

*Botrytis cinerea* is a ubiquitous fungus with a wide host range; locally, it is very damaging to western hemlock, spruce, and Douglas-fir seedlings. Western redcedar is also attacked, often on the tips of the terminal shoot and lateral branches. Pines seem to be less affected than other species. Some reasons for this are: (i) that they are usually smaller and have a more upright growth habit, both of which limit within-canopy conditions favoring the disease, and (ii) that they are usually grown in nurseries in interior British Columbia where the climate is drier.

Symptoms appear from late summer onward, until stock is shipped for outplanting. Initial symptoms include watery-moulding and killing of lower needles, brown mycelium (Figure 30) and spores of the pathogen are present on dead tissue thus the name “gray mould.” The disease does not seem to harm roots. Besides affecting seedlings in the nursery, the disease can continue to develop if affected seedlings are cold-stored. This topic is discussed in the chapter on moulding of stored seedlings.

Life history (Figure 31)

The pathogen overwinters as mycelium or sclerotia in old plant debris, but the exact sequence of events is not known for local container nurseries. *Botrytis* conidiospores, which are usually air-borne, are probably produced on dead plant material within the nursery or adjacent fields and forests, and are either drawn or blown into nurseries by ventilation fans or wind. The fungus may also be introduced on seeds, as it can easily be isolated from them. Irrigation water could also contain gray mould spores.

*Botrytis cinerea* normally becomes parasitic after establishing a food base on dead or dying plant material. Tissues damaged by fertilizer or frost are known avenues for infection. *Botrytis* may also enter seedlings early in the growing season via senescent needles. Disease development and spread are favored by moderate temperatures, high moisture, dense foliage, and crowded seedlings. The disease usually starts on and spreads from senescent, dead, injured, or lower needles. When succulent leaders are attacked, the disease can move downward.

Management

Cultural and fungicidal controls are presently used, alone or combined, against gray mould. The former are aimed mostly at making greenhouse conditions unfavorable for disease development: e.g. (i) lowering humidity, by decreasing or ceasing watering or by watering in the morning so that foliage dries off quickly, (ii) improving ventilation by spacing of containers so that there is a space between each one, (iii) regulating temperature, or (iv) using any
Rosellinia blight

Rosellinia minor has recently been identified on container-grown seedlings in British Columbia. Previous reports of R. herpotrichoides on bareroot Douglas-fir in the province are now attributed to R. minor. The moist, mild falls and winters of coastal British Columbia are ideal for Rosellinia.

Hosts and damage
Locally, R. minor has occurred on 1+0 container-grown Douglas-fir and Englemann spruce and 2+0 bareroot Douglas-fir. It also affects bareroot Douglas-fir and Sitka spruce in California and Washington, respectively. Damage occurs in the center of densely sown seedbeds, container-nursery benches, or individual containers where prolonged high humidity, free water on stems and needles, and dense foliage favor the disease (Figure 32). The fungus forms dense mats of whitish brown mycelium (Figure 33) on the lowermost stems and needles of seedling shoots, sometimes binding them together.

Superficially, Rosellinia can resemble gray mould, Botrytis cinerea, which thrives under similar conditions, and sometimes the two occur together. The two fungi differ in that R. minor forms sexual fruiting structures (perithecia). Rosellinia also has the tendency to grow upward and cover the shoot. Needles beneath the mycelium become chlorotic, die, and are cast, resulting in the seedlings being culled. Few seedlings die. Defoliation can reach 80% on heavily attacked seedlings. After needle death, the mycelium loses its mould-like appearance and becomes flattened against twigs and needles, exposing the small black, perithecia (Figure 34).

Life history
The life history of Rosellinia is unknown. Infection may result from airborne conidiospores, mycelium from contaminated soil, ascospores, or all three. Generally, perithecia produce ascospores after the decayed host material is subjected to winter temperatures. Conidiospores are produced during summer. Under fa-

---

**Figure 31. Life history of gray mould.**

combination of these. Dead, especially Botrytis-infected seedlings or other plant material (including weeds), should be removed from within and near container nurseries to reduce gray mould inoculum. Greenhouse ventilation can also be improved by the removal of side and roof coverings. The latter also improves lighting, thus preventing excessive shoot growth which is particularly favorable to gray mould.

Other factors that may contribute to gray mould include seedling moisture stress and, although not yet defined, certain fertilizer regimes. Gray mould that becomes established during the growing season may develop further on stored seedlings. Storing seedlings at -1 to -2°C prevents such damage. However, the stock should be handled carefully after storage to prevent subsequent gray mould damage.

Protectant and eradicant (systemic) fungicides are also used in gray mould management. Factors related to their efficiency include timing of application, thoroughness of coverage, and, in the case of certain systemic fungicides, buildup of Botrytis strains with fungicide tolerance. No fungicide, however, will completely control the disease unless the environmental conditions favoring disease development are also changed.

Selected References

---

Because little is known about the life history of R. minor, a diagram is not included here.
vorale growing conditions this may vary, with ascospores produced and released to start new infection centers the same growing season, while mild winters may result in conidiospore production.

Management

Cultural practices are important in R. minor management as the fungus requires long periods of high humidity and free moisture. Humidity can be reduced by spacing containers to improve aeration, decreasing irrigation, and increasing ventilation. Growing media should have good drainage to avoid water accumulation. Sanitation is important, so diseased plant material should be removed from the nursery. In bareroot nurseries, bare fallowing during summer will expose the pathogen to the sun’s heat and desiccation.

Selected References


Figure 32. Rosellinia on container-grown spruce.

Figure 33. Container-grown spruce showing the dense mat of Rosellinia mycelium.

Figure 34. Perithecia of Rosellinia.

<table>
<thead>
<tr>
<th>Rosellinia blight</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Principal, locally grown hosts</strong></td>
</tr>
<tr>
<td><strong>Host age and season when damage appears</strong></td>
</tr>
<tr>
<td>Age</td>
</tr>
<tr>
<td>Douglas-fir, all spruces</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Nursery type and location</strong></td>
</tr>
<tr>
<td><strong>Bareroot</strong></td>
</tr>
<tr>
<td>Coastal</td>
</tr>
<tr>
<td>Yes</td>
</tr>
</tbody>
</table>
Sirococcus blight

This disease, caused by the fungus Sirococcus stroblinum, affects conifers throughout the North Temperate Zone, including all of British Columbia. Since being found on lodgepole pine seedlings at the Red Rock nursery in 1970, Sirococcus blight has appeared in nurseries throughout the province. It is more prevalent on container-grown stock than bareroot stock.

Hosts and damage

Seedlings of Sitka, white and Engelmann spruce, lodgepole and ponderosa pine, Douglas-fir, and, very rarely, western hemlock are affected. On Douglas-fir the disease has been found only on bareroot seedlings. Disease symptoms and time of their appearance differ for container-grown and bareroot seedlings. Although 2-year-old, container-grown spruce are sometimes affected, Sirococcus most often attacks very young seedlings in container nurseries (Figures 35 and 36) where killing of the primary needles from the base upward is a common symptom.

Depending upon how far the disease has progressed, the upper portion of diseased needles may be green. Killed needles are light to reddish brown. Dead seedlings remain upright. Examining the base of diseased needles with a hand lens often reveals the small, irregularly rounded, light butterscotch-colored pycnidia (Figure 37); these darken with age. In container nurseries, the disease affects random seedlings (Figure 38), usually within specific seedlots because the pathogen is seed-borne. In germination tests, 1-2% of the spruce germniantons often become diseased from seed-borne inoculum. In container nurseries, mortality from secondary spread sometimes reaches 30% in some spruce seedlots.

In bareroot nurseries, symptoms usually appear in late summer through the fall on 1+0 bareroot seedlings or in the spring on 2+0 trees. The fall symptoms may be confused with early frost damage. Generally, the pattern of symptom development, color of diseased tissues, presence of pycnidia, and the random distribution of affected trees is the same as for container nurseries.
seedlings. The susceptibility of lodgepole pine varies among provenances. Whereas Sirococcus blight normally results in mortality of container-grown seedlings, it usually kills only part of the shoot on bare-root trees. A lateral branch then takes over as the terminal shoot (Figure 39). The desiccated terminal shoot of dead seedlings may assume a crozier-shape. In lodgepole pine, the pathogen's spread can often be traced from the primary needles, where infection may have occurred, to the base of the epicotyl and upward on the stem and secondary needles.

**Life history (Figure 40)**

Because *S. strobilinus* is seed-borne, initial disease centers in container nurseries develop from this inoculum and occasionally from spores from outside the nursery. The latter inoculum is probably most important in bareroot nurseries. Secondary spread is via pycnidiospores produced on diseased tissues and disseminated in rain and irrigation water. Infection occurs through young needles and is favored by cool, moist conditions and low light intensity, all of which often occur simultaneously in the spring and early summer in coastal British Columbia. This probably accounts for the higher *Sirococcus* incidence in coastal container nurseries. Because the pathogen has no other known spore forms, it is assumed that each new disease out-

**Management**

Because infested seedlots are probably the major source of *Sirococcus* inoculum in container nurseries, records should be kept of all seedlots with blight history. When infested seedlots are sown, a fungicide should be applied as soon as symp-
Figure 40. Life history of Siroccus blight.

toms appear, to prevent spread of the disease. Prudent use of fungicides will help prevent the subsequent development of fungicide-resistant strains of pathogenic fungi such as Botrytis. Diseased seedlings should be rogued and burned when practical. Disease spread can be alleviated by reducing humidity in greenhouses, and perhaps by increasing temperatures. Increasing illumination may be helpful, as light-stressed seedlings are most susceptible. Disease severity usually decreases with the advent of bright, warm growing conditions. Bareroot seedlings should be sprayed with the appropriate fungicide when the disease first appears.
Moulding of stored seedlings

Moulding of seedlings in storage has become a major problem in British Columbia because of the growing length in storage periods. The need for longer storage has occurred primarily because the recent increase in seedling production has prevented the lifting and shipment of all trees precisely when they are needed for outplanting; and the greater demand for high elevation provenances often means storing the stock until snow melt is complete in late spring. Another contributing factor has been the increased production of container-grown stock, which may contain incipient grey mould that can develop further in storage. Moulding of stored seedlings is a concern because stored trees are the nurseryman’s final product, and they are at their maximum pre-shipping value.

Hosts and Damage

Moulding of bareroot seedlings affects all species, although pines apparently less so than others. Initial evidence (Figure 42) of the disease includes cottony mould on the lower needles, especially on seedlings within the storage bundles. These symptoms gradually progress upward on the shoots. Mould may be most noticeable around string holding seedlings in bundles. As the disease moves upward, stems and needles become watery and decayed, and affected needles fall off. Sometimes, after prolonged storage, moulding appears at numerous points scattered over entire seedlings.

Other symptoms that may appear on all or part of the stem and branches include water-soaked lesions, bark that strips off easily, and dead, butterscotch-colored cambium. Bundles of diseased seedlings may emit a musty odor and small clouds of mould spores. Symptoms can appear any time after storage begins, but usually the amount and probability of damage occurring are proportional to the length of the storage period. Sometimes mycorrhizal fungi proliferate on roots of stored seedlings, but they should not be confused with storage moulds that rarely occur on roots.

The moulding of stored container-grown seedlings differs from that of stored bareroot seedlings in that only one or two fungi are involved (i.e., usually the grey mould pathogen Botrytis cinerea and sometimes Rosellinia). These fungi can become established during the growing season and continue to develop after the seedlings are stored. Hosts, symptoms, and damage of these diseases are described in separate chapters. Certain root fungi such as Cylindrocarpon and Fusarium, can be acquired by container-grown seedlings in the nursery and carried over into storage; see earlier sections on these diseases.

To date, in British Columbia, the amount of moulding damage on either bareroot or container-grown seedlings has not been correlated with subsequent outplanting survival. However, trees with advanced stem and branch decay and defoliation (Figure 43) probably survive poorly, and seedlings with low to moderate damage may be more affected by site, weather, and other factors than would healthy seedlings.

Life History

Fungi such as Fusarium, Rhizopus, Aspergillus, Penicillium, Epicoccum, Cylindrocarpon, and numerous non-spore-lating forms, are common on mouldy bare-root stock. Ordinarily, they live on dead or dying organic matter and only become

<table>
<thead>
<tr>
<th>Moulding of stored seedlings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Principal, locally grown hosts</td>
</tr>
<tr>
<td>All species, pines least affected</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

3 Because of the variation in the life histories of the pathogens involved, a diagram is not included here.
pathogenic under favorable conditions. These fungi are ubiquitous, thus inoculum is on foliage prior to storage, in soil particles deposited onto shoots during lifting, or in soil adhering to seedling roots. None of these fungi occurring on barroot seedlings have any specialized spores for survival, reproduction, or inoculation related specifically to their role in moulding.

Management

Storage moulds of both container and barroot-grown seedlings are better prevented than controlled. Some practices that help reduce losses include: (i) storing stock for the shortest period possible, (ii) periodically examining a sample of each stored seedlot, and (iii) immediately shipping stock with initial moulding. The latter should receive special care to prevent further moulding in transit and prior to outplanting.

Seedlots containing significant quantities of dead organic matter (e.g., frost-killed or fertilizer-burned foliage) should be monitored closely because moulding fungi become established on this material before moving to healthy tissues. Transplants are very prone to moulding, especially if they have been lifted and stored as 2+0 stock—not shipped, transplanted late, then lifted and re-stored as 2+1 transplants. Such seedlings are likely to be in a weakened condition and thus more susceptible to moulding.

There is some evidence that moulding risk decreases as seedling frost hardiness increases. The best control for storage mould on container seedlings is to prevent establishment of gray mould or Rosellinia blight on the stock prior to storage. Infested stock should be inspected frequently once it is stored. Storing seedlings at 1-2°C reduces damage by severely limiting growth of most storage moulds. Their growth can be completely stopped by dropping the storage temperature to -2 to -3°C. Storing stock at these temperatures provides excellent control for stock that can withstand frozen storage. To date, species originating from the Interior seem best suited to sub-freezing storage. Frozen stock is usually thawed gradually, thus it should be watched closely for mould development during thawing and also after-

ward during shipping and prior to outplanting.

Most attempts at fungicidal control of storage moulds have involved either systemic or protective fungicides, or both at various pre-storage intervals. However, the results, especially with the protectants, have been erratic. Removing trees from storage, dipping them in fungicide, and re-storing them is not recommended because it is too time-consuming, expensive, and potentially hazardous to nursery workers.

Selected References


Phomopsis canker and foliage blight

In British Columbia nurseries, Phomopsis occulta (perfect state = Diaporthe conormum) and P. lokoyae (perfect state = D. lokoyae) occasionally cause cankers and foliage blight.

Hosts and damage

These two fungi are widely distributed, occurring on many conifers, particularly western larch and spruces. Needle loss and shoot blight (Figure 44) can occur on 1+0 and 2+0 seedlings. Older seedlings may develop stem or branch cankers resulting in dieback of laterals, seedling death, or culling due to terminal shoot death. Cankers appear to be sunken, because of the growth of healthy tissue surrounding the dead tissue. Foliage and branches distal to the infection become yellow and die quickly. Sometimes seedlings die (Figure 45), but most losses are due to culling.

Life history (Figure 46)

These fungi are common saprophytes occurring on dead tissues of living seedlings, fallen cones, and dead stems and needles. Phomopsis occulta may be seedborne on western larch. CANKERS form on young stems and branches of winter-dormant seedlings and grow for one season. If the stem is not girdled, lesions eventually heal and no permanent damage results. Small, black spherical pycnidia develop in cankers during spring or summer, producing spores that are spread by rain or irrigation water. Under favorable conditions, spores germinate on young branches or stems in late summer and infection results. The fungus moves through the bark to the cambium where it develops during the winter. The fungus' perfect state may occur in the fall on infected branches, releasing wind-borne spores that lead to within-nursery spread of the fungus.

Management

Several cultural practices are important in Phomopsis management. Thinning seedlings and decreasing watering reduces humidity. Removing diseased seedlings decreases the amount of inoculum for spread of the fungus. Top pruning, which creates infection courts, should be avoided and stressed seedlings (e.g., from drought or frost) should be kept under careful surveillance as they are prone to infection. Under extreme conditions, applying a fungicide regularly to protect new growth from the time of germinant emergence through the fall has also proven to be effective.

Selected References

Melampsora foliage rusts

Only two foliage rusts occur in British Columbia forest nurseries: conifer-aspen rust (Melampsora medusae) and conifer-cottonwood rust (M. occidentalis). They derive their common names from the fact that they require at least one coniferous and one Populus spp. host to complete their life cycle. Since susceptible Populus are rarely grown in local forest nurseries, emphasis in this handbook is on how these diseases affect conifers. Both rusts occur predominantly in bareroot nurseries. Other foliage rusts, such as fir-willow rust (M. abieti-capraeaeum) and larch-willow rust (M. paradoxa), could be bothersome, especially if bareroot production of their coniferous hosts is increased.

Hosts and damage

Coniferous hosts for M. medusae are Douglas-fir, western larch, tamarack, and ponderosa and lodgepole pines; the Populus host is trembling aspen. Douglas-fir, black cottonwood, and balsam poplar are hosts for M. occidentalis. The rusts occur throughout the province wherever their hosts are present.

Both rusts produce yellow-orange, spore-producing pustules on foliage of their hosts (Figures 47-49). On coniferous needles or stems, these appear in late spring through mid-August and on Populus leaves in early summer to late fall. On the latter, the rust is most abundant on the underside of the leaf; corresponding chlorotic spots are present on the upper leaf surface. On conifers, symptoms are confined to the current year’s foliage and often to the primary needles of rising 1+0 seedlings. Affected needles are usually killed and shed in the fall. Shoots of severely affected seedlings are killed. Disease intensity on individual seedlings and within nurseries is greatest near diseased Populus hosts. The scarcity of such trees near local nurseries probably accounts for the low level of Melampsora damage.

Life history (Figure 50)

Melampsora medusae and M. occidentalis both require their Populus and coniferous hosts to complete their life cycles. The rusts overwinter as teliospores on dead...
Populus leaves on the ground. These spores germinate in the spring, producing windborne basidiospores, which results in infection of coniferous foliage. About 2 weeks later (late spring), masses of yellow-orange aeciospores are produced on needles of the coniferous host. They serve as inoculum for infection of live Populus leaves during the summer. Approximately another 2 weeks later, urediniospores (in yellow-orange pustules) are produced on the Populus leaves. These spores serve as inoculum for rust spread and intensification on Populus throughout the summer. In late summer, teliospores (the overwintering spores) are again produced on Populus leaves, completing the rust's life cycle.

Management
Elimination of Populus hosts in the immediate vicinity of conifer nurseries usually gives adequate disease control. When Populus cannot be eliminated, and where feasible, the fallen leaves can be raked and destroyed to eliminate the overwintering spores - i.e., the inoculum for coniferous seedlings. If neither of these procedures is practical, germinants and new growth of 2+0 seedlings can be protected with fungicidal sprays.

Selected References

Figure 47. Aecia of Melampsora occidentalis on Douglas-fir needles.

Figure 48. Aecia of Melampsora medusae on a lodgepole pine seedling.

Figure 49. Uredinia of Melampsora occidentalis on black cottonwood leaves.
Figure 50. Life history of *Melampsora* foliage rusts.
Western gall rust

This disease is caused by the fungus *Endocronartium harknessii*. The term "rust" designates both the disease and causal fungus. To date, the rust has been found in most bareroot nurseries in British Columbia where its hosts are grown. Although recent disease losses have been small, infected nursery stock can disseminate the rust to disease-free areas. Infec-
tion of nursery seedlings often occurs on the main stem; thus, if diseased stock is outplanted, the gall continues expanding and the tree dies, or may suffer wind-breakage.

Hosts and damage

Hosts are two- and three-needle (hard) pines, of which only lodgepole and ponderosa pines are grown locally. Since there is an interval between infection and development of conspicuous galls (Figure 51), the disease is rarely noticed on stock until late in the second growing season, or it may go undetected until the lifted trees are graded or after they are outplanted. Locally, in recent years, seldom more than 1%, and often none, of the stock has been affected. Since seedlings are not killed, the only direct losses are the culling of lifted stock. Because these losses have been inconsequential, the disease has been largely ignored; however, western gall rust epidemics are cyclical and the potential for serious losses always exists.

Life history (Figure 52)

In spring and early summer, masses of orange-yellow spores are produced by and released from galls on diseased trees. When these wind-dispersed spores land on succulent current year’s shoots or needles, they germinate — especially during rainy periods — and penetrate. The rust stimulates proliferation of the host’s tissue so that 1.5-2 years later, irregular, rounded to pear-shaped swellings appear. These woody, perennial galls grow and release spores (Figure 53) annually, which can re-infect pines. Consequently, no alternate hosts are involved in this rust’s life cycle. Eventually the stem or branch dies. Since the interval between infection and sporulation exceeds the usual period that most seedlings are in the nursery (except perhaps some transplants), there is no danger of disease spread among nursery seedlings. Instead, all inoculum originates from older infections on trees outside the nursery (Figure 54).

Because of the interval between infection and sporulation, it is obvious that (i) the galls seen on 2-year-old trees originate from infections occurring early in the first growing season, and (ii) trees infected during the 2nd year will be symptomless while in the nursery. The concern with these seedlings is that they mask the true incidence of the disease in the nursery, with the result that infected trees get out-planted unknowingly.

### Western gall rust

<table>
<thead>
<tr>
<th>Principal, locally grown hosts</th>
<th>Host age and season when damage appears</th>
<th>Nursery type and location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lodgepole and ponderosa pines, other hard pines</td>
<td></td>
<td>Coatal Interior Coastal Interior</td>
</tr>
<tr>
<td>Age</td>
<td>Season</td>
<td>Bareroot</td>
</tr>
<tr>
<td>2 + 0</td>
<td>Mid- to late summer</td>
<td>Yes</td>
</tr>
</tbody>
</table>
FUNGUS SURVIVES AS PERENNIAL GALLS ON LARGE TREES (E.G. WINDBREAKS) WITHIN OR ADJACENT TO NURSERY; EACH YEAR IN SPRING TO EARLY SUMMER GALLS PRODUCE MASSES OF ORANGE-YELLOW TELIOSPORES

IF INFECTED SEEDLINGS NOT CULLED AT LIFTING THEY DISSEMINATE DISEASE TO YOUNG PLANTATION(S)

TELIOSPORES ARE WIND-BORNE TO SUCCULENT SHOOTS AND NEEDLES OF SEEDLINGS WHERE THEY GERMINATE (ESPECIALLY DURING RAINY PERIODS) AND INFECT

RUST STIMULATES INFECTED SEEDLING TO PRODUCE PEAR-SHAPED GALL 1.5 TO 2 YEARS AFTER INFECTION

Figure 52. Life history of western gall rust.

Management
Because spores are blown into the nursery from outside, all gall rust infected pines should be cut for 275 m around the nursery. The unreliability of current prediction techniques makes fungicidal spraying of nursery seedlings impractical. Diseased seedlings should always be culled to lessen spread of the disease to new areas.

Selected References

Figure 53. Western gall rust on 2+1 lodgepole pine. Note masses of spores which can vary in color from white to yellow.

Figure 54. Globose galls on trees in windbreaks or adjacent to the nursery produce western gall rust inoculum (courtesy of Forest Insect and Disease Survey, P.F.C., Victoria, B.C.).
**Colletotrichum blight**

In the early 1980’s *Colletotrichum acutatum* and *C. gloeosporioides* caused blights on container-grown western hemlock (Figure 55) in British Columbia. Experiments showed that *C. gloeosporioides* affects several conifers, especially western and mountain hemlock. *Colletotrichum* blights are favored by high humidity and temperature. Symptoms include blanching of young needles, progressing from bases upward, followed by affected needles becoming brown. Advanced symptoms include needle browning on the entire shoot, crooking of lateral branch and terminal shoot tips, and stem and needle lesions. The disease spreads from infection centers, quickly affecting all seedlings within large, circular areas.

Both fungi overwinter as mycelium, sclerotia, and perithecia in diseased host tissue on living plants or soil debris. Culling and destruction of infected seedlings are recommended. Because spore production, spread, and germination all require high humidity and free water, cultural practices that reduce moisture are important in managing the disease. Where possible (e.g., in greenhouses) temperature should be reduced. Often it is necessary to apply fungicide sprays in conjunction with these cultural practices.

**Selected References**


---

**Fusarium top blight**

*Fusarium* top blight, caused by *F. oxysporum*, can cause severe losses of 1+0 Douglas-fir and pines in bareroot and container nurseries. In containers, the problem is often traced to seed-borne inoculum. Bareroot inoculum carries over on bits of old roots and organic matter, including sawdust mulch. On seedlings, rot appears at the junction of the seedcoat and cotyledons and spreads down the stem. Seedling mortality follows.

Both bareroot and container-grown seedlings are attacked from mid-to late growing season. Symptoms consist of purplish, then brownish discoloration near the base of the succulent terminal leader, the terminal bud, or adjoining needles. The pathogen progresses downward (Figure 56) killing all or part of the stem and the needles.

In bareroot culture, the disease is most likely to occur on seedlings in older nurseries with heavier soils, because the pathogen builds up over the years and heavy soils favor pathogen survival. Situating nurseries on lighter soils alleviates this problem. Bare fallowing and frequent cultivation of bareroot soils between crops also helps reduce inoculum. The practice

---

**Table: Colletotrichum blight**

<table>
<thead>
<tr>
<th>Principal, locally grown hosts</th>
<th>Host age and season when damage appears</th>
<th>Nursery type and location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western and mountain hemlock, other species susceptible</td>
<td>Age</td>
<td>Season</td>
</tr>
<tr>
<td></td>
<td>1+0</td>
<td>Summer</td>
</tr>
</tbody>
</table>
of roguing and culling diseased seedlings in both barefoot and container nurseries will help reduce pathogen spread. Fungicide sprays are sometimes used.

Selected References


Hypocotyl rot

Hypocotyl rot caused by Fusarium and Phoma species affects 1+0 Douglas-fir, lodgepole and ponderosa pine, and Engelmann and white spruce in container and barefoot nurseries. Although either of these fungi can cause the disease, they often occur together on seedlings. Laboratory assays are necessary to determine if one or both are causing the disease.

Initial symptoms include stunting, chlorosis, and wilting, followed by the development of a crook at the terminus of the leader, and death. Mortality occurs from July through October, affecting random seedlings throughout the nursery. Diseased seedlings are often predisposed by stress, such as drought.

The pathogen may also enter through wounded stem tissue (Figure 57). Inoculum may be seed-borne, wind-borne, or soil-borne. Bare falling in barefoot nurseries reduces pathogen populations.

Early sowing may enable seedlings to mature and reach a more resistant stage before environmental conditions favor the disease. Using practices such as regulating watering, or mulch application, which prevent soil moisture stress and high soil temperatures, may alleviate disease losses. Although seldom warranted, fungicide drenches can begin after seedling emergence, but effectiveness varies with environmental conditions and cultural practices.

Selected References


Hypocotyl rot

<table>
<thead>
<tr>
<th>Principal, locally grown hosts</th>
<th>Host age and season when damage appears</th>
<th>Nursery type and location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Douglas-fir, hard pines, and all spruces</td>
<td>Age 1 + 0</td>
<td>Coastal Interior Coastal Interior</td>
</tr>
<tr>
<td></td>
<td>Season Summer through fall</td>
<td>Container</td>
</tr>
</tbody>
</table>

Fusarium top blight

<table>
<thead>
<tr>
<th>Principal, locally grown hosts</th>
<th>Host age and season when damage appears</th>
<th>Nursery type and location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Douglas-fir and pines</td>
<td>Age 1 + 0</td>
<td>Coastal Interior Coastal Interior</td>
</tr>
<tr>
<td></td>
<td>Season Summer through fall</td>
<td>Container</td>
</tr>
</tbody>
</table>

Figure 57. Fusarium hypocotyl rot on a true fir seedling. Note masses of spores on stem.
Needle dieback

Needle dieback, which primarily affects container-grown Douglas-fir seedlings, is not fully understood. Similar symptoms have occurred to a lesser extent on true fir, spruce, and western larch. Symptoms (Figure 58), which first appear when seedlings are 1-2 cm in height, include stunted root and shoot growth, needle chlorosis, twisting and wilting of shoot tips, and needle tip dieback. Distribution of affected seedlings within seedlots is patchy, but often the disease is more prevalent in individual batches of growing medium. Plants affected during germination and early growth stages rarely reach end-of-season growth standards. Seedlings affected later suffer some needle damage but few other effects.

Studies indicate that a complex of Pythium species in association with unfavorable cultural practices, such as high growing medium temperatures and imbalanced ammonium-to-nitrate ratios, may be associated with needle dieback. To date, little information is available on dieback management, but apparently growing medium sterilization reduces dieback incidence.

Selected References


Figure 58. Needle dieback of Douglas-fir.

Phoma blight

Phoma species cause needle dieback on western hemlock, western redcedar, and several pine and spruce species in bareroot and, particularly, container nurseries (Figure 59). Cotyledons, lower needles, and buds are affected by this soil-borne fungus, resulting in defoliation. Infected needles become chlorotic, turn golden brown, and are cast. Other symptoms include dieback or tip blight which progress down the stem. Symptoms develop in the fall through early spring following the first growing season.

In bareroot seedbeds, cultural practices such as mulching, which reduces soil splashing, help reduce pathogen dispersal. Decreasing sowing densities improves air circulation and results in drier foliage, which inhibits the disease. Although Phoma losses in British Columbia have not justified soil fumigation, it has been used in western U.S. nurseries.

Selected References


Smothering fungus

The smothering fungus, *Thelephora terrestris*, is a mycorrhizal fungus associated with many coniferous species. It has a wide distribution and readily invades fumigated soils. It can occasionally grow up the stems of bareroot or container-grown seedlings, particularly where dense growth shades seedling bases. This habit gives it the name, "smothering fungus." The fruiting body of the fungus initially forms a collar around the lower stem and, in serious infestations, grows upward (Figure 60), smothering the seedling. It develops and matures on the seedling or surrounding surfaces such as styroblocks. The fungus does not rot tissue; however, severe smothering could result in mortality. Management practices that reduce humidity are important. These include growing seedlings at lower densities, carefully managing irrigation, and increasing ventilation in greenhouses.

Selected References


<table>
<thead>
<tr>
<th>Pathogen (and disease caused)</th>
<th>Hosts</th>
<th>Type of nursery</th>
<th>Season</th>
<th>Remarks</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoot tip blight <em>Diplodia pinea</em></td>
<td>Ponderosa pine</td>
<td>Interior, container</td>
<td>Summer</td>
<td>Other hosts possible, could affect seedlings of all ages in all nurseries.</td>
<td>Plant Dis. Rep. 60: 269-270.</td>
</tr>
<tr>
<td>Shoot blight <em>Pestalotia</em> spp.</td>
<td>Amabilis fir Larch</td>
<td>Coastal, bareroot Interior, container</td>
<td>Fall Summer</td>
<td>As above.</td>
<td></td>
</tr>
</tbody>
</table>