CHAPTER SIX

Phytophthora Root Rot

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Disease and hosts

Phytophthora root rot is caused by any of several *Phytophthora* species in Northwest nurseries. *Phytophthora megasperma* and *P. pseudotsugae* are the most common; *P. cactorum*, *P. cryptogea,* and *P. gonapodyides* are also regularly encountered. Two or more species may be present in a single nursery.

All these *Phytophthora* species have a wide range of hosts. Douglas-fir and the true firs are damaged in bareroot nurseries. Western and mountain hemlocks and sugar pine are also susceptible in inoculation tests and are likely to be damaged in the nursery if grown in high-hazard areas—places with poor drainage or a history of *Phytophthora* infestation. Western redcedar and incense cedar, lodgepole and ponderosa pine, western larch, and Sitka spruce sustain very little damage from *Phytophthora.* Port-Orford-cedar is resistant to most *Phytophthora* species, but is extremely susceptible to *P. lateralis*, which in fact attacks only Port-Orford-cedar.

Phytophthora root rot may be confused with:
Mechanical damage
Nematode damage
Other root diseases
Soil compaction

Phytophthora species are water molds; they produce swimming zoospores in water-saturated soils. They infect trees at any time between germination and lifting as 2+0 or 2+1 stock. Seedlings are most likely to be damaged during the winter after seeds are sown or in the season following transplanting. *Phytophthora* species attack the fine roots of seedlings of all ages wherever soils are saturated. The frequency of infection increases with the population of the fungus. Above-ground symptoms are seldom visible before the end of the first growing season. *Phytophthora* species can cause damping-off of newly germinated seedlings, but at most nurseries *Fusarium* and *Pythium* species are more damaging at this stage.

Figure 6-1. Root symptoms characteristic of Phytophthora root rot. Seedlings lack normal number and length of lateral roots, particularly in the lower areas, and the normally white cambial tissue becomes reddish-brown as the fungus advances upward.

Symptoms

1+0 AND 2+0 SEEDLINGS

In the first year root symptoms are normally confined to the lower one-third of the root system. Infected root tissue has a characteristic reddish-brown discoloration (Figure 6-1). There are usually no above-ground symptoms. Infected seedlings are most often confined to low-lying, poorly drained areas, but the infection may spread over large areas where heavy clay soils restrict drainage.

Above-ground symptoms generally appear in the spring of the second year. They consist of chlorosis, stunting, wilting, and browning of needles, followed by mortality. Branches show a stunted or "bottle-brush" appearance; this is due to delayed bud break and reduced elongation of branches and needles. Foliage symptoms follow a progression from chlorosis of the current year's needles and stunting of the shoots early in the growing season, to wilting and mortality by midsummer (Figure 6-2).

Root symptoms include discoloration of the cambium, root decay, and finally the absence of roots. If cortical tissue (bark) is carefully scraped from infected roots with a knife, red to dark brown discoloration of the cambium will be evident. The border between healthy and infected root tissue is usually distinct but sometimes irregular, with fine streaks of discoloration penetrating

Figure 6-2. Progression of symptoms of *Phytophthora* root rot. Healthy seedling at left is followed by a chlorotic seedling with poor branch elongation and root development. The third seedling shows wilting and browning of current year's needle flush. The fourth seedling has been killed.

the healthy areas of the root. In severely infected seedlings, the entire root system may be dead. In addition, most secondary roots may be missing and the border between healthy and infected tissue will be located at or above the root collar.

Symptomatic seedlings most frequently are found where soil is poorly drained—in low spots, bed ends, or drainage contours; in heavy clay soils or those with high water tables; and in areas that have been flooded (Figures 6-3 and 6-4).

TRANSPLANTS

Above-ground symptoms generally are not seen in fall-transplanted seedlings until late winter or early spring. In seedlings transplanted in the spring, symptoms appear in late spring or early summer. Lateral roots and taproots of severely infected seedlings are stubby and have no fine roots. Occasionally, new shoot growth begins only to wilt quickly and die. Generally, transplants are extremely susceptible as a crop type, presumably because of root-pruning and transplanting stresses and because large amounts of water are added after transplanting to prevent moisture stress.

The time symptoms appear and the distribution of affected seedlings in a field depend on whether seedlings were infected before or after transplanting. Seedlings infected before transplanting will show symptoms earlier and symptomatic seedlings will be more evenly distributed throughout the field, although they will be more prevalent in wet areas. Trees infected after transplanting will show symptoms somewhat later and will usually be confined to wet or compacted areas.

Fungus biology

Seedling roots are infected by motile zoospores (asexual swimming spores), which are attracted to root tips and wounds (Figure 6-5). Zoospores germinate and their hyphae penetrate the root epidermis and grow within phloem tissue. Infected tissue is killed. Growth of the fungus is usually restricted to the phloem below the root collar; above-ground stem tissue quickly dries out after the roots die and thus cannot support the fungus. Zoospores can move short distances (a few millimeters) in saturated soil and much longer distances in water flowing over land.

Figure 6-3. Phytophthora root rot most often occurs in low areas where surface or underground water can accumulate, as shown by this area of low stand density in a 2+0 bed. Seedlings not killed have developed poorly.

Oospores are formed in killed seedling tissue by some *Phytophthora* species (Figure 6-6). They are the result of sexual recombination (meiosis). Their role in the infection process is not known, but probably is similar to that of chlamydospores, which are formed by some species. Chlamydospores (thick-walled, asexual resting spores) and oospores can withstand relatively dry conditions, enabling the fungus to survive throughout the summer when soil temperature is high and moisture is low. Presumably both oospores and chlamydospores can produce sporangia, which release zoospores under conditions of abundant moisture (Figure 6-7). Chlamydospores and oospores are moved in soil and on the roots of seedlings, as well as on vehicles and other equipment.

Roots generally become infected when the soil is moist enough for zoospore production and movement. In Pacific Northwest nurseries these conditions exist in fall, after frequent rains begin, and in spring through mid-summer, before nurseries reduce irrigation. In winter, when the ground is cold or frozen, activity of *Phytophthora* probably is quite low; little or no new infection occurs.

Loss potential

Phytophthora root rot can ruin a nursery if it is ignored. Nursery blocks and even entire nurseries have been abandoned after infestation by *Phytophthora* species. Once established, the fungus is difficult, perhaps impossible, to eradicate. With careful disease management, however, and with special attention to maintaining good drainage, vigorous seedlings can be grown even in the presence of the fungus.

Where the disease is severe, many seedlings are killed outright, and more are infected to varying degrees even though they are still green at lifting. If lifting and storage conditions are not optimal, *Phytophthora* can spread throughout an entire bag of trees. Living but infected trees show reduced survival rates after outplanting, although the fungus itself does not develop further once seedlings are planted in forest soils. Seedlings that have sufficient healthy roots to become established in the first growing season will not be further damaged by *Phytophthora*.

Phytophthora root rot symptoms appear:
1+0
Summer
2+0, transplants
Late spring through late fall

Management

Phytophthora proliferates in saturated soils. Control strategies must be based on soil management that ensures good drainage. Fungicides are available to supplement cultural practices.

CULTURAL

If possible, nurseries should be located on light rather than heavy soils. Drainage can be improved by installing subsurface drainage systems and ditches to drain surface water, sloping fields towards drainage ways, subsoiling to break up hardpans, and building raised nursery beds.

If areas of a nursery or field cannot be adequately drained, then seedlings susceptible to *Phytophthora* should not be sown or transplanted in those areas. Growing such seedlings in chronic wet spots will result in large-scale losses or unsalable seedlings, or both, year after year.

Only resistant or tolerant tree species should be grown in high-risk areas—places where *Phytophthora* was present in the previous crop, or low, poorly drained, or flood-prone spots. Pathogenicity trials and nursery observations have led to this categorization of the resistance of species:

Resistant western redcedar

Tolerant: pine, spruce, larch, incense cedar

Highly susceptible: western and mountain hemlock, Douglas-fir, true firs

Figure 6-4. A distinct diseased area is defined by necrotic and chlorotic seedlings in rows where water has accumulated after transplanting.

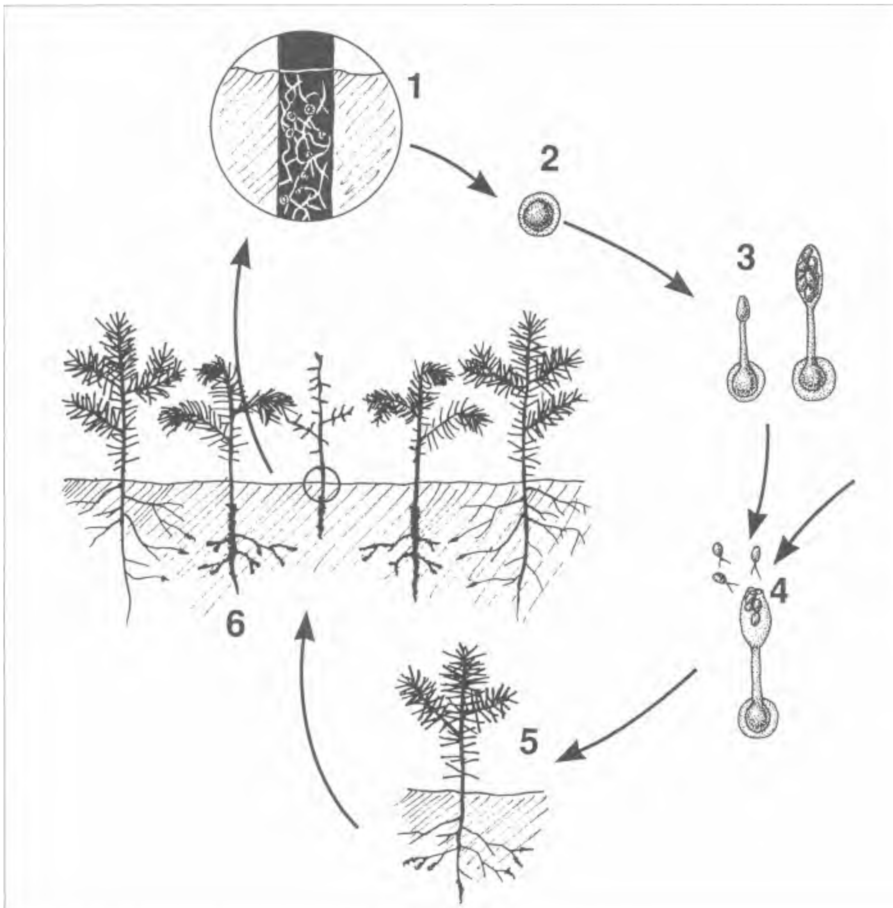

Figure 6-5. Life cycle of *Phytophthora.* Decomposition of dead roots (1) leaves chlamydospores or oospores (2) in soil and host tissue. Spores germinate during favorable periods, producing sporangia (3); zoospores are released (4) and migrate short distances through saturated soils or long distances in flowing surface water to infect seedling roots (5). Infected tissue is killed. More zoospores are produced on freshly killed tissue; they infect nearby seedlings (6).

Irrigation practices can be tailored to keep soils well drained. Routine irrigation schedules should be modified as extra water is applied for cooling, frost protection, fertilization, and pesticide treatments. Over-irrigation and periodic flooding of soils should be avoided, particularly in areas known to be infested or into which infected seedlings are to be transplanted.

Patches of diseased seedlings should be lifted separately from the main crop and disposed of. Removing infected root and stem tissue removes inoculum from the soil and prevents the mixing of diseased and healthy seedlings. Rogued seedlings and packing-house culls should not be returned to fields as organic matter or mulch because chlamydospores and oospores can survive in seedling tissues. Movement of stock between nurseries should be kept to a minimum to avoid initial or further *Phytophthora* contamination. Finally, careful observation of seedlings—particularly their root systems—will encourage early recognition and more-effective disease control.

CHEMICAL

Chemical soil and water treatments provide an important supplement to cultural control of *Phytophthora.* It is important to recognize, however, that they cannot replace proper soil and water management.

Fumigants—Fumigants significantly reduce soil populations of *Phytophthora*, but do not always prevent diseases caused by these fungi. The fumigant may not penetrate heavy, poorly drained soils sufficiently to kill all the spores. In addition, *Phytophthora* may easily be reintroduced accidentally into fumigated beds by means of contaminated water, soil, or seedlings.

Fungicides—Several fungicides are registered for use against Phytophthora root rot on conifers and woody ornamentals, but only metalaxyl has been shown in extensive field tests to be effective on conifers. Applying metalaxyl to *Phytophthora*-infected seedings will reduce their mortality and lessen the severity of the disease.

Metalaxyl is a systemic fungicide that can be applied to the soil in liquid or granular form. The fungicide is taken up from the soil by the roots. It halts the progression of the fungus through the root system; however, *Phytophthora* will remain viable in roots. Metalaxyl inhibits the formation of sporangia, oospores, and chlamydospores, and to a lesser extent mycelial growth and chlamydospore germination. It is also active against *Pythium*, but has little or no effect on other fungi. It does not harm mycorrhizae.

Metalaxyl must be used with discretion for two reasons: frequent use may cause naturally occurring tolerant strains of *Phytophthora* to become predominant, and repeated use in other crops has caused the buildup of organisms in the soil that quicken the breakdown of the chemical. The presence of *Phytophthora* in symptomatic seedlings should be confirmed by a pathologist before treatment.

One well-timed treatment of metalaxyl per year appears to adequately control the progression of Phytophthora root rot. The best times to treat seedlings are spring or fall when roots are active and can take up the fungicide. The fungicide is retained by the plant for a longer period during those seasons because

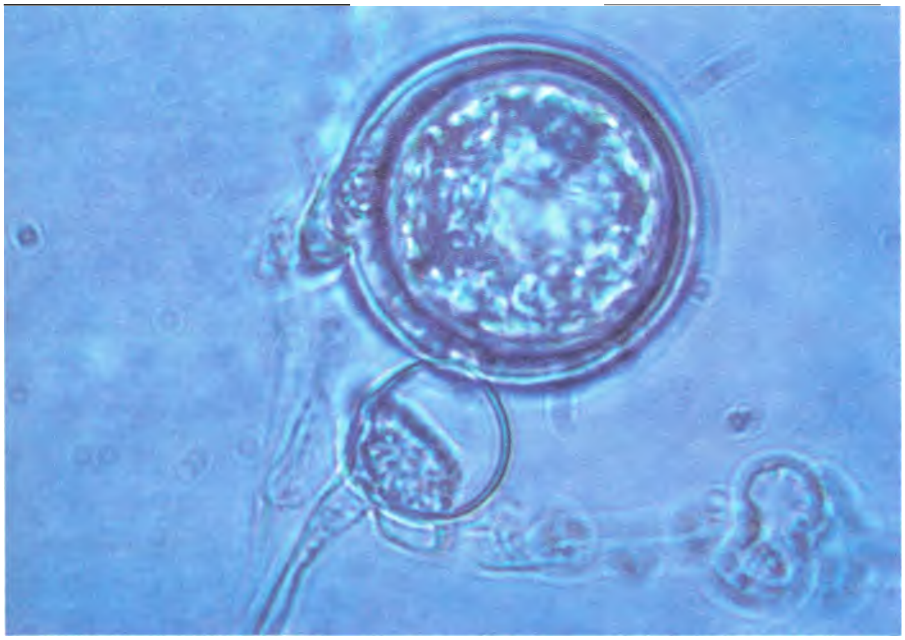

Figure 6-6. A *Phytophthora* oospore, microscopic in size, is thick-walled and therefore resistant to drying. With sufficient moisture and proper temperature, this structure will germinate to form a sporangium.

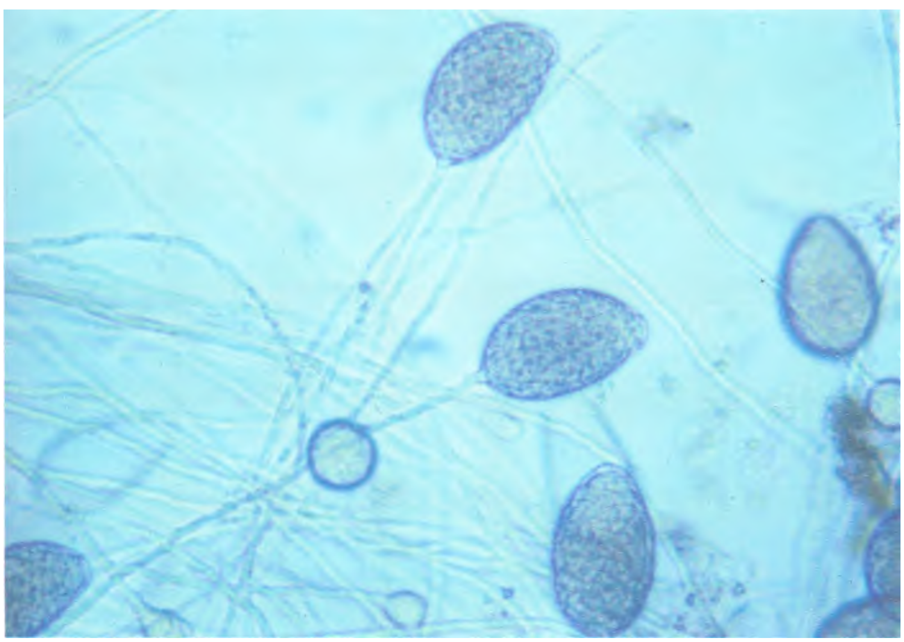

Figure 6-7. Sporangia produced by *Phytophthora.* In water, these structures each release many zoospores, which can cause infection.

soil temperatures are relatively cool. Metalaxyl can also be used as a preventive treatment, but this should be done only when seedlings or transplants must be sown in areas of known *Phytophthora* infestation.

Water chlorination—Chlorination of contaminated irrigation water can help check the spread of the disease. Water from agricultural districts and canal systems is more likely to be contaminated with *Phytophthora* than well water or municipal water.

Irrigation water can be tested for the presence of *Phytophthora* propagules. If it is contaminated, the nursery should switch to another source if possible. If no other sources exist, water can be chlorinated at the nursery. Various types of chlorination systems are available and can be adapted to each nursery's needs.

Selected references

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