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FOREST Pest LEAFLET

Pacific Forestry Centre

Laminated root rot of Douglas–fir

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Introduction

Laminated root rot, caused by the fungus *Phellinus weirii* (Murr.) Gilbertson, is one of the most damaging root diseases in the forests of British Columbia. It belongs to a group of fungi called pathogenic root inhabitants. These are parasitic fungi which can reside in both living and dead roots for extended periods of time.

Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco, is the most economically important host of *P. weirii* and, along with true firs, *Abies* spp., is highly susceptible to the fungus. Western hemlock, *Tsuga heterophylla* (Raf.) Sarg., spruces, *Picea* spp., and western larch, *Larix occidentalis* Nutt., are considered moderately susceptible to *P. weirii*; pines, *Pinus* spp., have a low susceptibility. Western redcedar, *Thuja plicata* Donn:D.Don, is resistant to infection, and deciduous species are immune. Tree mortality and reduced height and radial increment growth occur primarily in stands of second-growth Douglas-fir; annual wood volume losses in British Columbia are estimated to be 1.4 million m^3.

Advanced decay caused by *P. weirii*: the wood separates along annual rings as laminations – hence the common name “laminated root rot”.

The distribution of *P. weirii* in British Columbia closely follows that of Douglas-fir across the southern third of the province, from Vancouver Island east as far as the Purcell Mountains. On the coast it is prevalent in the Coastal Douglas-fir (CDF) and drier portions of the Coastal Western Hemlock (CWH) biogeoclimatic zones, and in the interior, in the Interior Douglas-fir (IDF), Interior Cedar-Hemlock (ICH) and Montane Spruce (MS) zones.

Although the northern range of Douglas-fir extends beyond McLeod Lake, records of *P. weirii* extend only as far north as Williams Lake. Laminated root rot is also prevalent throughout the range of Douglas-fir in Washington, Oregon, northern California, western Montana and northern Idaho.

A second variety of *P. weirii* found in British Columbia causes butt rot of western redcedar, but its effect on other species is thought to be negligible. This leaflet will address only the Douglas-fir variety of the fungus.

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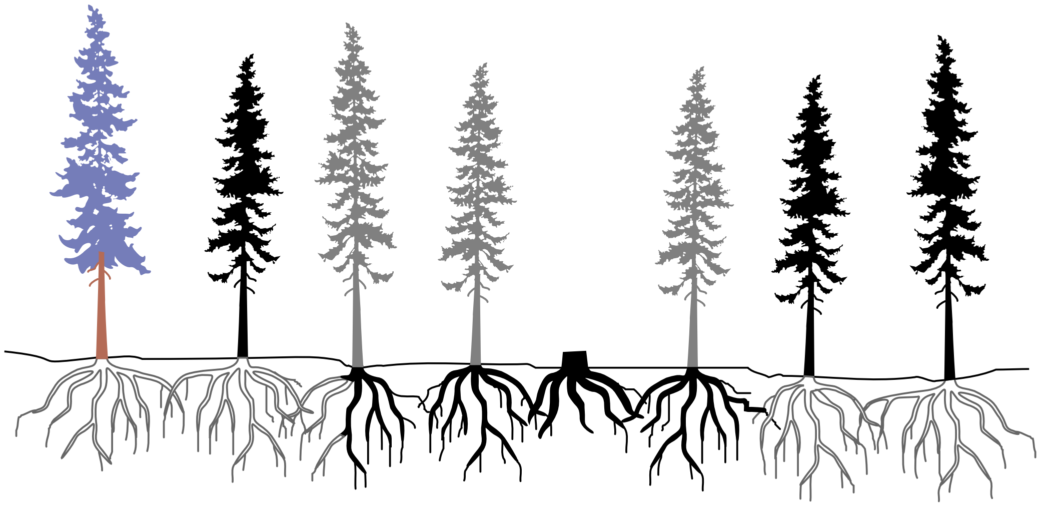

The disease spreads when healthy roots of susceptible species contact infected roots.

Life history

Infection by *P. weirii* starts when healthy roots of susceptible tree species contact infected roots of an adjacent tree or infected stumps and roots (residual inoculum sources) from the previous stand. Surface (ectotrophic) mycelium spreads from infected roots onto the surface of healthy roots. Ectotrophic mycelium eventually penetrates to the interior of host roots, likely gaining entry through both intact and injured bark. Once inside the root (as endotrophic mycelium), the fungus progressively destroys root tissue, depriving the tree of water and nutrients and weakening its structural support.

The interval between initial infection, the expression of crown symptoms, and mortality depends upon tree age and size. Trees under 15 years of age show crown symptoms and often die within two years of initial infection. In older and larger trees, crown symptoms may develop for 10 or more years before trees die standing or are windthrown. Some older trees survive infection, harbouring the fungus strictly as a butt rot. In yet other cases, trees with crown symptoms appear to overcome the disease and return to normal growth.

As *P. weirii* spreads from an initial inoculum source and kills trees, infection centers are created. Centers expand at an average rate of about 30 cm per year, normally in some variation of a radial pattern; over time infection centers may grow to cover one or more hectares. When the boundaries of expanding adjacent centers meet they coalesce and appear as one. Larger openings caused by root rot, probably were initiated from more than one inoculum source.

The distribution of laminated root rot centers within stands varies considerably. In many stands they are distributed in a clumped pattern; in others, patterns may be diffuse and discrete centers may be difficult to detect.

The persistence and potential for carry-over of *P. weirii* into subsequent rotations is largely dependent on the presence and extent of living ectotrophic mycelium remaining on the stump roots left over from the previous stand. While *P. weirii* is a virulent parasite, it is not a strong saprophyte; following the death of a host the amount of residual inoculum decreases with time. After 20 to 30 years, at most only small scattered patches of living ectotrophic mycelium remain on host roots. In contrast, viable endotrophic mycelium has been recovered from within stumps and large roots up to 50 years after harvest. In both circumstances the likelihood of healthy roots contacting this inoculum is negligible.

A member of the Basidiomycete class of fungi, *Phellinus weirii* disperses basidiospores from brown crustlike fruiting bodies or sporophores which are sometimes produced on the undersides of fallen trees. There is no evidence, however, that these spores play a significant role in the spread of the fungus.

Detection and identification

Detection

Before mounting detection and assessment surveys it is often possible to determine from forest cover maps whether laminated root rot is likely to occur in a particular area. Douglas-fir is the major host of the fungus, and these maps can identify Douglas-fir cover types. In addition, polygons of age class three or older (i.e., older than 41 years) that have significant deciduous components, or an average height or stocking class lower than expected, may signal the presence of root rot. Aerial photographs can also be used to identify stand openings or telltale coniferous/deciduous mosaics.

In young stands, root rot centers are often detected during routine silviculture surveys prior to juvenile spacing, brushing and weeding, and commercial thinning.

Crown of a Douglas-fir infected by laminated root rot. Note the rounded top, bushy branch ends, and thinning foliage of this tree which contrasts greatly with the healthy firs in the immediate background.

Uprooted Douglas-firs with compact root wads are characteristic of laminated root rot.

In mature stands, centers are often detected during preparation of the preharvest silvicultural prescription.

A ground-based survey is the only way to confirm the presence of *P. weirii* and to accurately assess disease distribution and intensity within a stand. Ground survey designs range from regularly or randomly spaced transects to systematically spaced variable-radius or fixed-radius plots. In British Columbia, a transect sampling system developed by the Canadian Forest Service is the most commonly used survey method for laminated root rot.

The type and intensity of a root disease survey will be determined largely by information requirements. In a root-diseased stand scheduled for harvest where Douglas-fir is the major species, an intensive[1] root rot survey is recommended as part of a preharvest silviculture prescription. This survey will also determine whether the stand can be stratified into areas of high and low disease incidence for delineating areas to be treated for root rot. For broad-scale resource planning, a simple walkthrough to determine the presence or absence of disease damage may be sufficient.

Regardless of the survey method used, crews must be well trained in identifying signs and symptoms of the disease before entering the field.

Recognition

Phellinus weirii root rot is recognized first by the symptoms it induces in its hosts. Reduced terminal growth is usually the first symptom to appear, followed by yellowing (chlorosis) and thinning of crowns. On hosts that are killed quickly (young trees or diseased trees with secondary agents like bark beetles) foliage turns red or brown as it dries. Diseased trees may also produce a large crop of small cones one or two years before they die.

The crown symptoms described above may be caused by other agents, most notably by *Armillaria ostoyae*

[1] An intensive survey is defined as follows:
i) 100% of the block is covered using a 50 m interval grid, and
ii) a sketch map, identifying visible infection center boundaries, is drawn at a scale of 1:2,000-5,000.

(Romagn.) Herink, the fungus causing Armillaria root disease in British Columbia (see Forest Pest Leaflet 35). Environmental stresses such as drought can also cause similar needle loss, discoloration, and stress-induced cone crops. Crown symptoms, therefore, should be used only to identify trees in which *P. weirii* is suspected; the presence of the pathogen can only be confirmed by observing specific signs of the fungus.

Trees planted near *P. weirii* inoculum sources may be killed within a few years, but because these dead trees are small and tend to be scattered, a laminated root rot center may go unnoticed. By the time plantation trees reach 15 to 20 years of age, some root contact is still occurring with residual inoculum but more is occurring between infected and healthy plantation trees. At this stage, scattered individual and small groups of dead trees become evident.

Disease centers in older *Phellinus*-infested stands are often characterized by an opening in the stand canopy containing some standing and fallen dead trees. The fallen trees tend to lie in a random pattern of crossed stems, or they occur as "leaners," hung-up in the crowns of adjacent trees. These characteristics readily distinguish root disease trees from storm blowdown trees which tend to all fall in one direction. Standing dead or symptomatic trees can usually be seen scattered within and around the periphery of infection centers. Clumps of hardwoods or non-susceptible conifers often grow in disease centers.

The major roots of fallen trees typically break off close to the root collar due to extensive decay, resulting in compact root wads; these root wads are characteristic of laminated root rot. Callus[2] tissue may be evident on the stubs of broken roots. Adventitious roots developing from this callus may help to prolong the lives of infected trees.

[2] tissue which develops as a result of wounding or infection

Prior to death, the foliage of a tree infected by *P. weirii* turns yellow and falls. A crop of stress-induced cones is also commonly present.

Identification of laminated root rot

Symptoms

- reduced terminal growth
- thinning and chlorosis of crown
- stress-induced cone crop
- stand openings containing standing dead and randomly - directed fallen trees
- compact root wads on fallen trees

Signs

- dense white-tawny-light mauve mycelium at root collar and on major roots
- red-brown stain in heartwood of lower bole
- laminated decay with wood separating along annual rings
- reddish brown setal (hair-like) hyphae

Confirmation

Phellinus weirii can be positively identified in living suspect trees by examining the root collar and lateral roots for grey-white to tawny to mauve colored ectotrophic mycelium. Brown crustlike mycelial mats commonly form over surface mycelium below the duff layer, particularly in the crotches of roots. Reddish brown hair-like structures called setal hyphae may be seen with the aid of a hand lens, scattered in surface mycelium or in pieces of wood with advanced decay. Setal hyphae, in conjunction with these other signs, are diagnostic of *P. weirii*. Confirmation of laminated root rot in a stand is easier before harvest.

Post-harvest surveys for laminated root rot should focus on detecting signs of the fungus on the cut surfaces of stumps. Incipient or initial decay appears as reddish brown irregular patches or crescent-shaped stains on fresh stump tops or cross sections of major roots. Root disease surveys are best conducted within three weeks of harvest before the stain fades. Examination of infection columns in stumps with more advanced decay or broken roots of windthrown infected trees will reveal oval pits about 1 mm x 0.5 mm and decayed wood will separate along annual rings as laminations – hence the common name "laminated root rot." Between the laminations lie the characteristic brown tufts of setal hyphae visible to the naked eye. Stumps with advanced decay caused by *P. weirii* are often hollow, with remnant wood reduced to a stringy mass.

Young fruiting bodies of *P. weirii* are a light grey-brown with light buff sterile margins. Later they turn a uniform chocolate brown. Because of their inconspicuous, resupinate (flattened) growth habit, and uncommon occurrence, they are of limited diagnostic value.

Fresh cut stump surface of a Douglas-fir infected by *P. weirii*; note the incipient decay (red-brown stain) caused by the fungus.

Treatment options for laminated root rot

Harvest–regeneration phase	Immature stands
• stump extraction	• start again with immune or low-susceptibility species
• push-falling	• selective removal of susceptible species during spacing or commercial thinning
• plant low-susceptibility or immune species	• bridge tree removal around infection centers

Management

Phellinus weirii is endemic to western North America and is an integral part of many forest ecosystems. The effects of this fungus may be desirable in some stands, particularly where wildlife habitat, visual quality objectives, and other factors predominate. In these instances no management strategy for *P. weirii* would be considered. Where the primary use for forest land is timber production, management strategies for laminated root rot should be considered.

The goals for the management of any root disease are to regenerate infested areas which have been harvested, improve timber production, and reduce losses to the disease during the rotation. Currently there are two distinct strategies which can be used to achieve these goals in areas infected with laminated root rot. The first is inoculum reduction, the second is species manipulation. Although it is possible to reduce damage caused by *P. weirii* at any stage of stand management, the best opportunity occurs at the harvest-regeneration phase when management strategies are most easily implemented.

The harvest-regeneration phase

Inoculum reduction

Stump removal (stumping) using a wide-tracked excavator significantly reduces mortality due to *P. weirii* and is currently accepted as the most effective management strategy against the disease on many sites. Removal of infected stumps and large roots from the soil eliminates most of the inoculum, and minimizes carry-over of the fungus into the new stand. Small-diameter roots and pieces of large-diameter roots which remain in the soil after stumping are invaded relatively quickly by competing soil-borne organisms and rarely serve as long-term sources of *P. weirii* inoculum. To minimize site disturbance, and maximize cost-effectiveness, stumping should be limited to high-quality sites with light soils and slopes of less than 30%. Such treatment should only be considered where Douglas-fir or grand fir are the preferred species for subsequent planting.

Push-over harvesting or push-falling has been developed and tested in British Columbia as an alternative to stumping. With this method, whole trees are pushed over causing root systems to pull up and out of the soil. Harvesting and the removal of diseased stumps and roots is thus achieved with one stand entry. The treatment has the same site limitations as stump removal, and, though the long term efficacy is not yet known, preliminary results from trials indicate it will be as effective as stump removal in reducing *P. weirii* inoculum.

Species Manipulation

Species resistant or immune to *Phellinus weirii*, such as western redcedar and red alder on the coast, and pine spp., poplars and white birch in the interior, can be planted on diseased sites to hold the effects of the disease within acceptable limits. The choice of alternate species will be limited by the suitability of these species to particular sites.

Laminated decay in Douglas-fir caused by *P. weirii*.

Preliminary results from sites where alternate species have been encouraged or planted indicate that mortality from laminated root rot has been reduced or eliminated.

Immature stands

Managed Douglas-fir stands are normally entered at age 8 to 12 years for a free-to-grow assessment, and at age 12 to 20 years for juvenile spacing. Commercial thinning is also practised in some intensively managed stands between 30 and 40 years of age. Forest managers can take action to reduce losses from laminated root rot at each of these stages.

If root disease centers are numerous and widely distributed at the time of juvenile spacing, consideration should be given to destroying the plantation and either replanting with immune or low susceptibility species, or removing the inoculum and replanting with any suitable species. The lost time and added costs may be more

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Hydraulic excavator push-falling second-growth Douglas-fir infected by *P. weirii*.

than compensated for by increased yields from a healthy stand. If a short-rotation deciduous species such a red alder (on the coast) is established, the site can be replanted to Douglas-fir after 30-40 years with little or no disease loss in the subsequent rotation.

Commercial thinning is not recommended in stands with a moderate to high incidence (>15% of area infested) of laminated root rot because asymptomatic infected trees will probably be retained as crop trees.

If a root disease survey shows that centers are relatively small and discrete, immune and resistant species should be retained during spacing to create barriers to the spread of *P. weirii.* Dead and symptomatic trees in disease centers should be removed along with any susceptible tree that is likely to have root contacts that could bridge infected portions of the stand to healthy portions. By cutting bridge trees, *P. weirii* inoculum can be isolated in the centers. Openings could be replanted with immune or resistant species. These or related treatments can be applied both during juvenile spacing and commercial thinning.

Management options under investigation

Chemical

Despite the efficacy of fumigants in reducing *P. weirii* inoculum in experimental treatments, public policies and high costs will likely limit fumigation to the treatment of high-value trees in parks and urban settings.

Biological

Research continues on the use of competing fungi such as *Trichoderma* spp. (see Nelson and Thies 1985) and other potential biological control agents against *P. weirii.*

Prompted largely by observation of individual Douglas-firs which show differential resistance to *P. weirii* infection, researchers in British Columbia are investigating natural resistance to laminated root rot. Families of these resistant trees could in future be planted on diseased sites where Douglas-fir is the preferred species.

Ineffective management options

Over the years several experimental strategies have been applied to *P. weirii* control and found ineffective.

- On infested sites where broadcast burning of slash and stumps has been conducted, temperatures were not high enough to kill inoculum.

- Applications of nitrogen fertilizers to infested sites increases seedling growth but does not reduce mortality due to *P. weirii* . However, fertilizers may shorten the time that the fungus can survive in roots.

- The application of borax to kill fungal spores on cut stump surfaces does not prevent *P. weirii* infections, as spores are not important in the spread of the disease.

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