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Ecology, Identification, and Management of Forest Root Diseases in Oregon

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Contents

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Root diseases are the most difficult type of disease to identify, measure, and manage in Oregon's trees and forests. The more common root diseases are caused by fungi, although root disease also can be associated with abiotic (nonliving) factors such as flooding or soil compaction.

Root disease fungi attack and destroy the tree's root system, resulting in growth loss, decay, death, or windthrow of infected trees. Trees with root disease also are more susceptible to pests, especially bark beetles. On the other hand, root diseases are a component of the forest ecosystem and play an important role in creating wildlife habitat and in cycling nutrients.

This publication is for woodland owners and managers interested in identifying and managing root diseases in trees or forests. It's intended to help identify the common root diseases and to understand the techniques used to reduce the damage they cause. Related publications are listed on page 11.

Ecologic roles of root diseases

Root diseases can cause widespread tree death in many forest ecosystems and, as a result, create gaps in the forest canopy. These gaps or openings change the light, moisture, and temperature in the forest and thus alter the habitat for plants and animals. Some plants and animals that require more light benefit from these openings; others prefer closed canopies. Root diseases provide a variety of canopy openings and thus create habitat for a wide variety of organisms.

Many animals and birds require dead standing trees (snags) or fallen trees (logs) for their habitat. Because root diseases kill trees of all sizes, snags are formed continually as the disease progresses over many decades. Snags that topple because of decayed root systems become logs, providing habitat for a different set of animals and plants than did the snags.

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Many root-disease fungi live in roots and stumps for 50 years or more after trees have died or been harvested. These fungi continue to decay the stump and major roots, thus returning nutrients to the soil and providing habitat for a wide variety of animals.

How to identify root diseases

You can identify root diseases by observing an infected tree's symptoms and signs (Table 1). **Symptoms** are the reactions of the host tree to the disease. Most root diseases cause foliar yellowing and thinning of the crown due to destruction of the root system and the subsequent reduced supply of water and nutrients to the foliage. Abundant, undersized cones, called a distress cone crop, often are produced by trees in advanced stages of decline. Trees with these symptoms usually die within 1 or 2 years.

Signs are the actual parts of the fungus on or near the diseased tree. The most obvious signs of root disease include conks or mushrooms on the tree or on the ground near the tree base.

Root diseases can infect a single tree but more commonly infect groups of trees. These groups of dead, dying, and windthrown trees are called disease patches or centers, or canopy gaps (Figure 1). Patches grow over time as the disease-causing fungi spread from tree root to tree root. Patches can range in size from a few trees to hundreds of acres.

Trees in a disease patch show a progression of symptoms; they do not all die at the same time nor will they be in the same stage of decline. Some trees near the middle of the disease patch will be dead, while those at the edge might show only a slight reduction in height growth or a slight yellowing of foliage. By contrast, groups of trees that have been burned or infected by bark beetles usually die at about the same time.

Aboveground symptoms can indicate the presence of root disease but not the type. In fact, a stand of trees and even a single tree can have two or more different root diseases. Only by examining the roots can you accurately identify specific diseases and determine the best management action.

Specific signs and symptoms of each root disease are summarized in Table 1 and discussed in more detail in the following pages.

***Table 1.*—Symptoms and signs of five important root diseases in Oregon.**

Symptoms	Laminated root rot	Armillaria root disease	Annosus root disease	Black stain root disease	Port-Orford-cedar root disease
Reduced tree height	√	√	√	√	
Crown thinning and yellowing	√	√	√	√	√
Distress cones	√	√	√	√	
Basal resin (sap)		√		√	
Brown stain in inner bark					√
Black stain in sapwood				√	
Laminated decay	√		√		
Yellow, stringy decay		√			
Signs					
White mycelial fans		√			
Leathery conks			√		
Mushrooms at base		√			
Setal hyphae	√				
Ectotrophic mycelium	√		√		

Laminated root rot

Laminated root rot is the most damaging root disease in Oregon from the standpoint of wood fiber production. Found in western and eastern Oregon, the disease is caused by the fungus *Phellinus weirii*. It affects all conifer species to some degree but is most damaging to Douglas-fir, grand and white fir, and mountain hemlock (Table 2, page 4).

Hardwoods are immune to this disease; they never become infected.

Figure 1.—Root disease patch showing a progression of symptoms such as stumps, snags, recently killed trees, and infected live trees.

The disease decays root systems, causing growth loss, death, and windthrow. One of the best indicators of laminated root rot is the presence of root balls. Root balls form when decayed roots break near the root collar, leaving an abnormally small "ball" of roots on fallen trees. By contrast, healthy trees blown over by wind have a large mat of mostly undecayed roots.

Root or stem wood with laminated root rot characteristically separates into sheets along annual growth rings, hence the term "laminated." The decayed wood is pale yellow-brown with numerous small oval holes or pits on both sides of the sheet. The pits are similar to shot holes and are about 1 millimeter in diameter. By using a magnifying lens to examine the wood sheet, you might see the key diagnostic indicator of laminated root rot—setal hyphae. Setal hyphae are small, wiry, reddish brown hairs of the fungus and are positive proof of laminated root rot.

Another good indicator of laminated root rot, especially on young living trees, grows on the surface of roots. Diseased roots are covered with a white to grayish crust of fungal growth called ectotrophic mycelium (Figure 2). It appears only on the outside of the root, not in the wood or between the bark and wood. Setal hyphae also can be mixed with ectotrophic mycelium on the root surface. The surface of healthy conifer roots is reddish brown.

Figure 2.—Ectotrophic mycelium (arrow) of *Phellinus weirii* on the root of an infected Douglas-fir.

Armillaria root disease

Armillaria root disease is caused by the fungus *Armillaria ostoyae* and is the most widespread root disease in Oregon. It is most prevalent and economically damaging in eastern and southern Oregon. In western Oregon, the disease commonly affects small groups of 10- to 30-year-old trees.

***Table 2.*—Relative susceptibility of Oregon trees to damage by root diseases.[1]**

Host trees	Laminated root rot	Armillaria root disease	Annosus root disease	Black stain root disease	Port-Orford-cedar root disease
Douglas-fir (coastal)	1	2	3	1	4
Douglas-fir (inland)	1	1	3	2	4
Ponderosa pine, Jeffrey pine	3	2	2	2	4
Lodgepole pine, knobcone pine	3	2	2	3	4
Sugar pine	3	1	3	4	4
Western white pine	3	2	3	4	4
Whitebark pine, limber pine	3	2	3	4	4
Grand fir, white fir	1	1	1	4	4
Pacific silver fir	2	2	1	4	4
Noble fir, Shasta fir	2	2	2	4	4
Red fir, subalpine fir	2	2	2	4	4
Western hemlock	2	2	2	3	4
Mountain hemlock	1	2	1	3	4
Western larch, subalpine larch	2	3	3	4	4
Engelmann spruce	2	2	3	4	4
Sitka spruce	3	2	3	4	4
Western redcedar	3	2	3	4	4
Alaska-cedar	3	2	3	4	3
Port-Orford-cedar	4	3	3	4	1
Pacific yew	4	3	?	4	2
Juniper	4	2	3	4	4
Coast redwood	4	3	3	4	4
Incense-cedar	4	3	3	4	4
Birch	4	3	?	4	4
Buckthorn	4	?	?	4	4
Cherry	4	3	?	4	4
Pacific dogwood	4	3	?	4	4
Willow	4	3	?	4	4
Giant chinkapin	4	3	?	4	4
Bigleaf maple	4	3	3	4	4
Red alder	4	3	3	4	4
White alder	4	?	?	4	4
Pacific madrone	4	3	2	4	4
Oregon ash	4	?	?	4	4
Tanoak	4	2	?	4	4
Quaking aspen	4	2	?	4	4
Black cottonwood	4	2	3	4	4
Oregon white oak	4	2	?	4	4
California black oak	4	3	3	4	4
California laurel	4	?	?	4	4

[1]Classes: 1 = severely damaged; 2 = moderately damaged; 3 = seldom damaged; 4 = not damaged

The disease affects all conifer species to some degree (Table 2) and can be damaging to hardwoods, especially white oak. Armillaria has a history of affecting conifers, hardwoods, and fruit trees throughout the world.

Infected conifers usually produce a flow of pitch or sap just above ground level. This flow is the tree's response to the fungus growing beneath the bark. Extensive growth of the fungus eventually girdles and kills the tree.

Chopping into the bark reveals white to cream-colored sheets of fungus called mycelial fans (Figure 3). These fans are inside the bark in the lower main stem of the tree or in roots. Mycelial fans have a rubbery texture and sometimes can be peeled from the wood like latex paint. They are a positive indicator of Armillaria root disease. Mycelial fans are closer to the ground in younger trees than in older trees.

Armillaria mushrooms occasionally appear in autumn, are edible to humans and wildlife, and can be a useful indicator of the disease.

Annosus root disease

Annosus root disease, caused by the fungus *Heterobasidion annosum*, is one of the more difficult root diseases to diagnose because often the only symptom is butt rot, and the disease signs are difficult to detect. In Oregon, the disease has two strains, one that affects primarily fir, hemlock, and spruce, and another that affects primarily pine. This fact is important to know when planting or favoring resistant tree species.

Besides causing root disease, *Heterobasidion annosum* also causes stem decay. The decayed wood contains silvery-white mycelium and small black flecks about the size of rice grains. In western Oregon, the fungus causes serious degrade in western hemlock and grand fir due to decay and stain in the valuable butt log.

Brown leathery conks with white undersides occasionally are found in rotten stumps (Figure 4, page 6) and among roots of windthrown trees. The conks produce spores that are the chief means of disease spread. The airborne spores need freshly cut stump surfaces or fresh tree wounds to infect and colonize the wood. After stumps are infected, the fungus grows through the root system and can infect living trees through root contacts.

In eastern Oregon, annosus root disease is most damaging to true fir and ponderosa pine. Stands that have been partially cut over many years show the most disease. In many areas, groups of pines die without showing substantial decay, especially on very dry sites. A progression of symptoms usually is evident—old dead trees near the center of the opening and recent kills near the perimeter.

Annosus root disease has been reported on bigleaf maple, red alder, and Pacific madrone but not on other hardwoods. Extensive surveys are needed to determine accurate host ranges.

Figure 3.—Mycelial fans of *Armillaria ostoyae* under the bark of an infected pine.

Figure 4.—A conk of *Heterobasidion annosum* in the hollow of an old infected fir stump.

Black stain root disease

Black stain root disease, caused by the fungus *Leptographium wageneri,* is unique among the root diseases affecting Oregon's forests because it is spread primarily by insects, mostly root-feeding bark beetles and weevils. Fungal spores form in the insect tunnels, stick to the insects, and are spread when the insects fly or walk to other trees.

These insects are attracted to low-vigor trees and freshly cut stumps where they feed and breed. Once the insects have introduced the fungus into a tree, it can spread to other trees across root grafts or by growing short distances through the soil. The fungus does not live long after the tree dies.

In Oregon, one form of black stain root disease attacks firs, mainly young (10- to 30-year-old) Douglas-fir, and the other attacks pines. In eastern Oregon, ponderosa pine is affected at any age. Other conifers seldom are affected (Table 2).

Similar to Dutch elm disease, black stain is a wilt disease that kills trees rapidly by plugging the water-conducting tubes of the root wood. Black stain is most severe in parts of southwestern Oregon, where it is considered epidemic; 25 to 50 percent of 10- to 30-year-old Douglas-fir stands in this region have the disease to some extent. In western Oregon, black stain is most common along roadsides, in stands that have been precommercially thinned, and in stands with a history of soil disturbance from tractor logging. Factors associated with black stain root disease in eastern Oregon are not well known.

As in Armillaria root disease, a black-stain-affected tree often produces resin at the base of its trunk. However, it does not have white mycelium on the root surface or inside the bark unless other root diseases also are present.

You can diagnose black stain by chopping into the wood of roots or the root collar of dying or recently killed trees to look for black to brown streaks in the most recent growth rings (Figure 5). This stain is the result of the dark fungus growing in the water-conducting tubes of the sapwood.

Port-Orford-cedar root disease

Port-Orford-cedar root disease, caused by the fungus *Phytophthora lateralis*, might have been introduced to Oregon around 1940 on ornamental cedars from Asia.

In southwestern Oregon, the disease is very damaging to Port-Orford-cedars, and in some areas the commercial status of the tree is threatened. Pacific yew and Alaska-cedar also are infected when growing with Port-Orford-cedar. The disease affects ornamental Port-Orford-cedars throughout Oregon.

Port-Orford-cedar root disease destroys the root system and discolors foliage, which turns from light green to yellow, red, and finally to brown. Look for a brown inner bark that abruptly joins white, healthy inner bark at the base of infected trees (Figure 6). This symptom is most apparent on trees with yellow foliage.

Roots are infected by special swimming spores, called zoospores, produced by the fungus. Zoospores spread downslope or downstream in water. Consequently, tree mortality often is apparent along water-courses or roadsides, especially on the downhill side (Figure 7, page 8).

Figure 5.—Black stain root disease caused by *Leptographium wageneri* in the wood of an infected ponderosa pine.

Figure 6.—Port-Orford-cedar killed by Port-Orford-cedar root disease. Note the darker, infected wood under lighter, healthy wood.

Animals and humans also can spread the disease. Machinery, tires, or transplanted seedlings can move infested soil and thus spread the fungus from one site to another. The disease also can spread upslope through root contacts.

Host susceptibility

Susceptibility to infection and to associated damage by root disease fungi varies with tree species (Table 2). **Susceptibility** is the likelihood that a tree species will be damaged if it contacts the root disease fungus. Damage susceptibility is rated on a scale of 1 to 4, based on field observations in Oregon.

Susceptibility of some tree species, hardwoods especially, is unknown for some fungi. Hardwoods are not affected by laminated root rot, black stain root disease, or Port-Orford-cedar root disease, three of the most important root diseases in Oregon. For this reason, hardwoods are recommended for planting or favoring in many areas affected by root disease.

How to manage root diseases

Management of root diseases is based on two important traits—the method of spread and fungus survival. All root diseases spread by root contact when the fungus grows from an infected tree or stump root to a healthy tree (Figure 8, page 9, and Table 3, page 8). In general, disease patches expand radially about 1 to 2 feet a year from root contacts.

Managing method of spread

One strategy to stop the spread of disease between healthy trees and infected trees is to break the connection of root contacts by cutting the "bridge tree." The bridge tree is the first healthy tree next to the infected tree. However, it is difficult to determine whether a tree is healthy or infected if it has no aboveground symptoms.

A better strategy to break the connection between root systems is to interplant or favor disease-tolerant tree species. Root disease fungi cannot spread as well on the roots of resistant or tolerant trees.

Figure 7.—Port-Orford-cedars killed by *Photophthora lateralis* as a result of waterborne spores along roadways.

Thinning, either precommercial or commercial, can affect the severity of root diseases. In the Cascade Range, precommercial thinning reduces mortality from Armillaria root disease in ponderosa pine (Figure 9) but has no effect on mortality in Douglas-fir, true fir, or hemlock.

Precommercial thinning in Douglas-fir stands can increase black stain root disease, especially if done in late winter or spring (before insect flight in July).

Annosus root disease can increase in stands that have been thinned, especially in commercially thinned true fir stands, because windborne spores spread to freshly cut stumps. Treatments such as a borax application to stump tops are recommended to prevent annosus spores from infecting stump surfaces and subsequently spreading to adjacent live trees. Salvage logging, especially of dying trees, can increase annosus and Armillaria root diseases in susceptible residual trees. For more information on thinning, see the publications list on page 11.

The effects of other silvicultural tools (pruning, fertilizing, and prescribed fire) on root disease are mostly unknown, but studies are underway.

***Table 3*.—Method of spread, major hosts, and management strategies for the major root diseases in the Pacific Northwest.**

Root disease	Method of spread	Major hosts	Management strategies
Armillaria root disease	Roots	All species	Prevent soil compaction. Prevent tree wounding. Favor resistant species.
Laminated root rot	Roots	All species (especially firs)	Favor resistant species.
Annosus root disease	Air, roots	True firs Hemlocks Pines	Treat stump surfaces. Prevent tree wounding. Favor resistant species.
Black stain root disease	Insects, roots	Douglas-fir Pines	Prevent tree wounding. Thin after July. Favor resistant species.
Port-Orford-cedar root disease	Water, mud, roots	Port-Orford-cedar	Avoid infested areas. Clean logging equipment. Favor resistant species.

Managing fungus survival

Fungus survival is the second trait that provides a basis for management. Many root disease fungi can survive in roots for decades after infected trees have died. If you harvest and replant a diseased stand without considering the disease, seedlings eventually will become infected. Damage in the new stand can be worse than in the preceding stand. Black stain root disease is one exception to long-term survival in roots; this fungus dies within 1 to 2 years after tree death.

Figure 8.—Infected trees and stumps spread root disease to healthy trees through root contacts and grafts.

Researchers and forest managers have excavated infected stumps and roots or have treated them with chemical fumigants in an attempt to control root disease. Stump excavation can be effective if done properly, but costs and potential soil damage must be considered. Stump fumigation requires special equipment and licensing and has been attempted only experimentally.

Planting and favoring resistant species

Based on our understanding of spread and long-term survival of root disease fungi, we recommend planting resistant species (Table 2) or favoring them during thinning or partial cutting as the preferred method of reducing root disease.

Some root diseases seriously affect only certain tree species—Port-Orford-cedar root disease on Port-Orford-cedar, and different forms of black stain root disease on Douglas-fir and on pines. Armillaria root disease, laminated root rot, and annosus root disease can cause severe mortality, especially for grand fir, white fir, and Douglas-fir.

You can favor disease-tolerant and disease-resistant species (classes 3 and 4, Table 2) during a variety of forest operations including planting, thinning, and partial harvesting. If tolerant or resistant tree species are planted or regenerated for 50 years or

Figure 9.—Thinning decreases mortality from Armillaria root disease in ponderosa pine.

more, and you periodically remove new seedlings of more susceptible species (classes 1 and 2), root disease fungi should die over most of the infected area.

If tree species in damage class 2 are used, many trees will become infected but at lower levels than if tree species in damage class 1 had been grown.

By planting or favoring hardwood species, especially on sites affected by laminated root rot, potentially you can sanitize sites.

Conclusion

Root diseases generally are much easier to prevent than to correct. By maintaining a healthy forest with mixtures of tree species, you can prevent economic damage from root disease.

If root disease is present, identify the type of disease and take appropriate steps during tree and stand maintenance to minimize the damaging effects of disease. These steps include favoring more resistant species when regenerating or thinning infested stands.

For more information

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Other publications

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Shaw, C.G. III and G.A. Kile, eds. *Armillaria Root Disease*, USDA Forest Service Agriculture Handbook No. 691 (USDA Forest Service, Washington, DC, 1991). Contact: C.G. Shaw, PNW Research Station, 2770 Sherwood Lane, Suite 2A, Juneau, AK 99801-8545.

Thies, W.G. and R.N. Sturrock. *Laminated Root Rot in Western North America*, USDA Forest Service/Canadian Forest Service, Resource Bulletin PNW-GTR-349 (USDA Forest Service, Portland, OR, 1995). Contact: W.G. Thies, PNW Research Station, 3700 SW Jefferson Way, Corvallis, OR 97331.

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