Forest Insect & Disease Leaflet 131

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Port-Orford-Cedar Root Disease

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Port-Orford-cedar (*Chamaecyparis lawsoniana* (A. Murr.) Parl.) is the largest and most impressive tree in its genus (Figure 1). It is native to a limited area along the Pacific Coast from Coos Bay, Oregon to the mouth of the Mad River near Arcata, California. Its range extends from the coast to about 50 miles inland. There is a small disjunct population in the Scott Mountains of California (Figure 2). For a variety of reasons, including its ability to tolerate ultramafic (serpentine) soils and live along streams and other wet areas, it plays a very significant ecological role in certain forest communities.

Wood properties that make Port-Orford-cedar desirable are its precise machining capability, decay resistance, resistance to chemical corrosion, and aromatic quality. Port-Orford-cedar supplies forest products, including decking, siding, and flooring. Specialty products include wooden arrow stock, aromatic storage boxes for American Indian ceremonial materials, and long-lasting cedar boughs. Port-Orford-cedar is milled into cants for export to Japan where it is used for

Classic whole crown discoloration due to Port-Orford-cedar root disease.

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Figure 1. Mature healthy Port-Orford-cedar.

soaking tubs, in traditional construction, and in reconstruction of temples and shrines. Port-Orford-cedar has horticultural value; it is planted in many areas around the world as an ornamental and for windbreaks.

By far, the most serious disease of Port-Orford-cedar is a root disease caused by the non-native pathogen *Phytophthora lateralis* (Tucker and Milbrath). Nursery stock, ornamentals, and forest trees are all subject to attack. Pacific yew (*Taxus brevifolia* Nutt.) is also infected and killed by the pathogen on infrequent occasions. Observations and laboratory trials show that Pacific yew is much less susceptible than Port-Orford-cedar. Where it has been found infected, Pacific yew was growing in close association with groups of infected Port-Orford-cedar.

Distribution

The high susceptibility of most Port-Orford-cedar and the general absence of significant unexplained mortality in natural stands prior to 1952 strongly suggests that the pathogen evolved outside the native range of the host species, Port-Orford-cedar. While its origin remains unknown, recent investigations suggest *P. lateralis* evolved in Taiwan or Japan.

Port-Orford-cedar root disease was first reported on ornamental host seedlings near Seattle, Washington in 1923. It was not until 1942, in the Willamette Valley of Oregon that the causal pathogen was identified and described again from hosts used in landscaping. Losses became so severe among ornamentals in northwest Oregon and western Washington that, within a decade, production of the valuable horticultural varieties of Port-Orford cedar was mostly abandoned.

The Port-Orford-cedar root disease pathogen spread south, apparently via infected nursery stock and infested soil, and was first reported in the natural range of Port-Orford-cedar in 1952 near Coos Bay, Oregon. Since that time, the pathogen has spread into high risk sites across much of the range of Port-Orford-cedar, killing its host, and threatening to reduce its ecological function and commercial potential. Although *P. lateralis* is widespread, it is not all pervasive in its host range; it does not threaten

Port-Orford-cedar with extinction. Approximately 92% of federal land within the range of Port-Orford-cedar in Oregon and California is not currently infested.

Life Cycle

Phytophthora lateralis is a water mold (oomycete) that superficially resembles a fungus, but is more closely related to the brown algae. It reproduces via sporangia, which are minute, lemon-shaped fruiting bodies that develop at the mycelial tips, and by chlamydospores, which are thick-walled, spherical, resting spores that develop along the sides of the mycelium. Swimming spores, called zoospores, are produced in the sporan-

Figure 2. The natural range of Port-Orford-cedar.

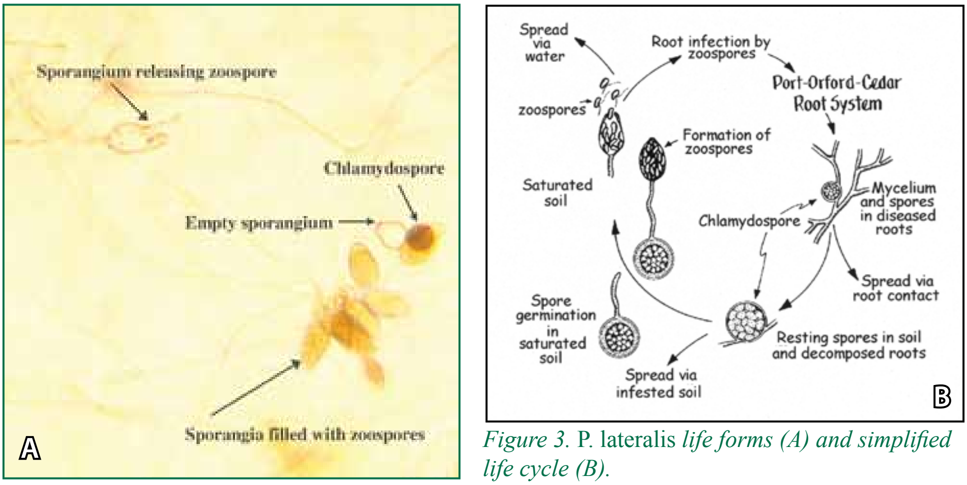

Figure 3. P. lateralis *life forms (A) and simplified life cycle (B).*

gia. They burst forth when the soil is saturated and move with the surface water. Chlamydospores spread as they are moved about with soil on vehicles or other carriers (Figure 3).

When a tree is infected and *P. lateralis* colonizes its tissues, the inner bark and root cambium discolor to a deep cinnamon brown, contrasting strongly with the rich cream color of healthy inner bark (Figures 4a and 4b). This is useful for disease diagnosis particularly at early stages of infection.

Foliage of infected trees first appears lighter in color than that of healthy trees and, on warm spring days, wilts slightly. Later, the foliage withers, turns yellow-bronze, red, and finally, light brown. Discoloration occurs simultaneously throughout the crown. The final browning is concurrent with drying and darkening of all of the inner bark. Large trees die within two to four years after infection; seedlings within a few weeks.

Pathogen Spread

Phytophthora lateralis is spread via water and soil. Most long distance spread of this pathogen occurs in the cool, rainy months of the year (approximately October 1 through May 31) when conditions are optimal for the pathogen. It can spread rapidly if preventive actions are not taken to slow or stop it. The primary means of long distance spread is through soil movement in construction, road maintenance and use, and logging operations. A typical spread scenario involves transport of infested soil into non-infested areas on vehicles (including all terrain vehicles), equipment, or by foot traffic. In addition to the boots of forest users, this pathogen can be carried on the feet of cattle and game animals, particularly elk. Rarely, aerial infection can occur when detached sporangia and possibly zoospores carried by moisture laden air or splashing water land on the foliage, branches, or main stem of the tree.

When infested soil falls off of a vehicle or other carrier in a situation where conditions favorable for the pathogen prevail, Port-Orford-cedars near the site of introduction are infected first. New spores produced by that infection are washed downhill in surface water, infecting additional hosts. This infection pathway is especially lethal along drainages and creeks where infested water is channeled and flows near concentrations of healthy Port-Orford-cedars. Port-Orford-cedars growing in upland situations often escape infection even when *P. lateralis* is established in nearby low-lying areas or drainages because conditions on upland sites are not favorable for the pathogen. The pathogen can spread via root grafts between adjacent trees. This source of infection is only significant in relatively dense stands of Port-Orford-cedar where root systems are closely associated.

Impacts

Port-Orford-cedars of all ages and sizes may be killed by this pathogen on sites with conditions favorable for infection. Though some Port-Orford-cedars are resistant to the pathogen, levels of resistance in natural populations are very low. Port-

Figure 4. View of infected tree (A) and close-up view of inner bark infected and discolored by P. lateralis*.*

Orford-cedar root disease frequently kills ninety percent of the hosts on newly infested high risk sites (and more in larger size classes). Mortality often progresses rapidly.

Root disease progression along streams can lead to loss of shade canopy, and depending on topographic shading, can potentially contribute to increases in stream temperature during summer months. Increases in stream temperature can negatively impact coldwater aquatic species, including salmon.

Port-Orford-cedar mortality has resulted in loss of commercially valuable products, including timber, floral greens and plants for the horticulture industry. Port-Orford-cedar root disease has been confirmed in high value Port-Orford-cedars along roadsides and in hedgerows in France and Scotland, and in native forests in Taiwan.

Management

High Risk Sites

High-risk sites are low-lying wet areas (infested or not) that are located downslope from infested areas or are below likely sites for introductions, especially roads. They include streams, drainage ditches, gullies, swamps, seeps, ponds, lakes, and concave low-lying areas where water collects during rainy weather. Above a road, areas within 25 feet of the road are considered high risk. Below a road and away from streams, areas within 50 feet of the road are considered high risk. Below a road and near a stream, areas within 50 feet on either side of the steam are considered to be high risk (Figure 5). The absence of streamside Port-Orford-cedar within 100 feet of a road greatly reduces the risk of infection from any individual patho-

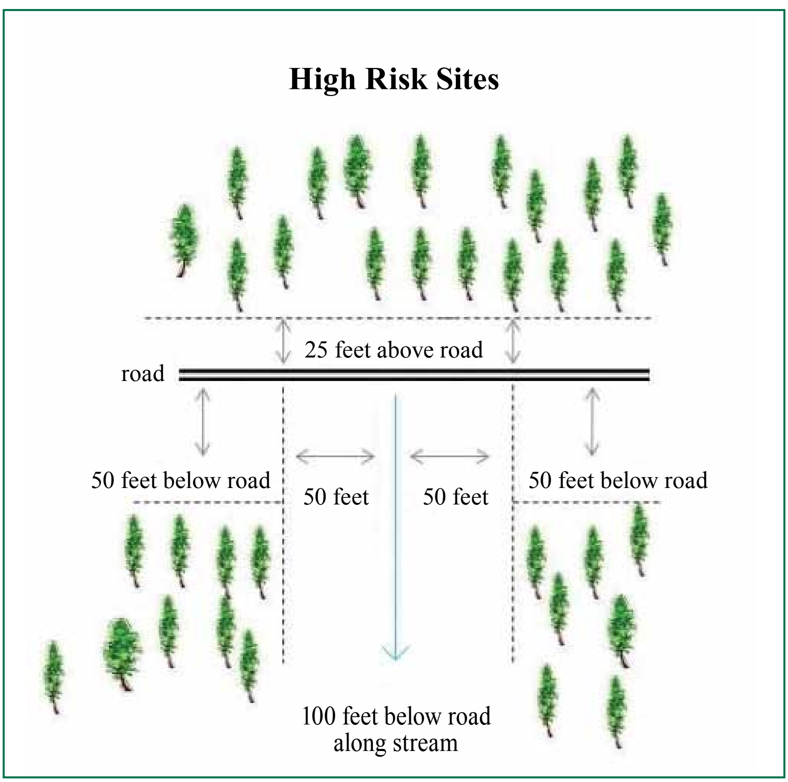

Figure 5. Remove Port-Orford-cedars from high risk sites along roads and streams.

gen introduction event to streamside Port-Orford-cedar more than 100 feet below the road.

Low Risk Sites

All sites not considered high risk are considered to be low risk. Management of Port-Orford-cedar should be especially focused on sites that are at low risk for infection.

The proportion of low risk sites varies by location within the range of Port-Orford-cedar, depending on Port-Orford-cedar distribution on the landscape relative to the avenues of pathogen spread along water and roads. In the northwest portion of its range (roughly the area from Powers to Coos Bay in Oregon), Port-Orford-cedar is widely distributed across the landscape because of favorable moisture conditions. *P. lateralis* has been in this area more than 50 years, so most of the high-risk sites have already been infested. Due to the fact that spread is limited almost exclusively to high-risk sites, this area is approaching disease saturation and the rate of new infestations has substantially declined from previous decades. Chronic mortality continues in previously infested areas as new hosts seed in and are subsequently infected and killed.

Further south and east, Port-Orford-cedar becomes more concentrated along streams. This higher tree density, along with proximity to roads that tend to be situated close to streams, increases the proportion and amount of Port-Orford-cedar that is at high risk of infection. Because the pathogen has not been in these areas for as long as it has further to the northwest, the potential for rapid increase of new infested acres is still high.

Management Practices

Several management practices are recommended for Port-Orford-cedar root disease. The best management strategy involves a combination of appropriate techniques tailored for use in a specific site or landscape. Techniques to consider include:

1) Project Scheduling: Schedule projects during the dry season or incorporate area scheduling (see Practice #3) and vehicle and equipment washing into project design.

2) Use Non-infested Water: Use non-infested water sources for activities such as equipment washing, road watering, fire control treatments and other uses, or treat water with Clorox® to prevent/reduce the spread of *P. lateralis* (1 gallon of Clorox® per 1,000 gallons of water). Clorox® is EPA registered for this use in Oregon and California.

3) Area Scheduling: Conduct work in areas where the pathogen is not present before working in areas infested with the pathogen.

4) Access: Designate access and egress routes to minimize exposure to the pathogen.

5) Routing Recreation Use: Route new recreation trails (off-highway vehicle, motorcycle, mountain bike, horse, and foot) away from areas with Port-Orford-cedar – especially if the root disease is present – or provide other mitigation such as seasonal closures.

6) Road Management Measures: Implement disease-prevention measures including seasonal or permanent road closures, road maintenance, and/or sanitation removal of roadside

Port-Orford-cedar to reduce the likelihood of new infestations – especially to high risk areas. Favor road design features such as using pavement rather than other surfacing, applying surfacing rather than no surfacing, removing low water crossings, designing drainage structures that divert water to areas unfavorable to the pathogen, and disposing infested waste soil and other debris in areas not conducive to pathogen spread. In the absence of other management practices, avoid use of existing roads in significant non-infested areas and avoid building new roads in such places.

7) Washing Project Equipment: A large reduction in pathogen spores occurs when vehicles, equipment, and footwear are washed. Wash equipment prior to working in non-infested areas, when leaving infested areas to work in non-infested areas, and when leaving the area at the end of the project. Washing will minimize movement of infested soil to non-infested areas (Figures 6a, 6b, and 6c). Equipment includes maintenance and harvest equipment, trucks, crew vehicles, boots and hand tools coming in contact with infested soil. Project areas should be compartmentalized by road system. A road system with infested areas and non-infested areas should be considered infested. Washing stations should be placed at optimum locations to minimize pathogen spread, such as at entry/exit points of the road system. Washing should take place as close as possible to infested sites. Wash water should be from non-infested water sources or treated with Clorox®. Wash water should not drain into watercourses or into areas with healthy Port-Orford-cedar. Ideally, equipment should not travel for any substantial distance prior to being washed, unless transported on surfaced roads. Equipment moving into non-infested areas may be washed miles away as long as it does not travel through infested areas before reaching its destination.

8) Spacing Objectives for Port-Orford-cedar Thinning: Port-Orford-cedar spacing during commercial or precommercial thinning projects should be designed to fragment the continuity of Port-Orford-cedar across the area. Leave more Port-Orford-cedar on low-

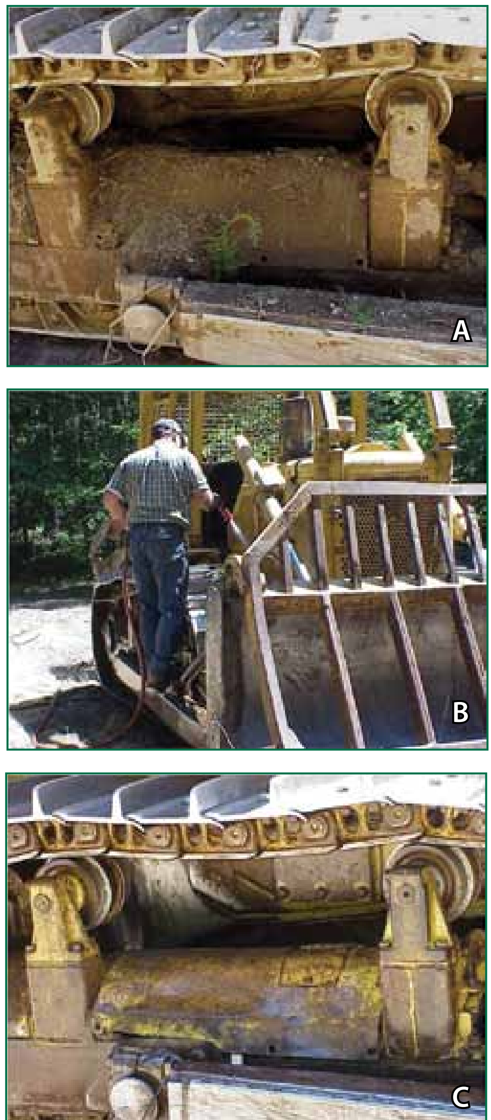

Figure 6. Infested soil on heavy equipment -- pre-washing (A), being washed (B), and post-washing (C).

risk sites and discriminate against the species on high-risk sites.

9) Summer Rain Events: Cease operations when puddles in the roadway or water running in roadside ditches increase the likelihood of spreading the pathogen even when operating in the dry season.

10) Roadside Sanitation: Remove Port-Orford-cedar along both sides of the road in high-risk sites. Recommended minimum width of the sanitized area is 25 feet above the road, and 50 to 100 feet below the road depending on whether or not it is along a stream (see Figure 5). Roads that are open year-round and are heavily used generally pose the highest risk and benefit most from sanitation treatment. Effectiveness of sanitation is based on the fact the pathogen does not infect dead host trees.

11) Disease-resistant Port-Orford-cedar Planting: Plant disease-resistant Port-Orford-cedar on low risk sites, including other suitable low risk sites not currently occupied by Port-Orford-cedar.

To assist land managers in choosing the most genetically adapted seed for reforestation or restoration, the range of Port-Orford-cedar has been divided into thirteen Breeding Zones (Figure 7) on the basis of a short-term genetic common garden study and general knowledge of Port-Orford-cedar genecology. Based on initial indications of genetic resistance in the late 1980s and subsequent confirmation during cooperative work among the USDI Bureau of Land Management, the USDA Forest Service, and Oregon State University in the early 1990s, an operational program to develop resistance was begun in 1997. Over 12,500 trees have gone through the first round of resistance testing. In greenhouse testing, two types of disease resistance appear to be present: (1) reduced mortality (the top seedling families have 50 to 100% survival compared to 100% mortality in the most susceptible seedling families, and (2) slower disease progression (other families with some level of resistance show slower progression of the disease, leading to delayed mortality and/or lower mortality).

Resistant seed is now available for several breeding zones. Seed and seedlings from disease-resistant parents are available to federal agencies from the Forest Service J. Herbert Stone Nursery in Central Point, Oregon. Non-federal agencies and private landowners in Oregon interested in purchasing seed can contact the Oregon Department of Forestry, Private Forests Program.

Field tests now underway will continue to assess the efficacy of resistance under a variety of field conditions, and the durability of resistance. The use of resistant seedlings is meant to complement, not replace, other prudent management activities.

12) Eradication: Remove all live Port-Orford-cedar from in and around infested sites. The only way to eliminate the pathogen from an infested area is to remove the host for several years. The exact length of time that is needed is not known, but is suspected to range from a minimum of four years (in the drier parts of the range) to as much as ten years (in the wetter parts of the range).

13) Site-Specific Port-Orford-cedar Management: Where possible, emphasize management of Port-Orford-cedar on sites where conditions make

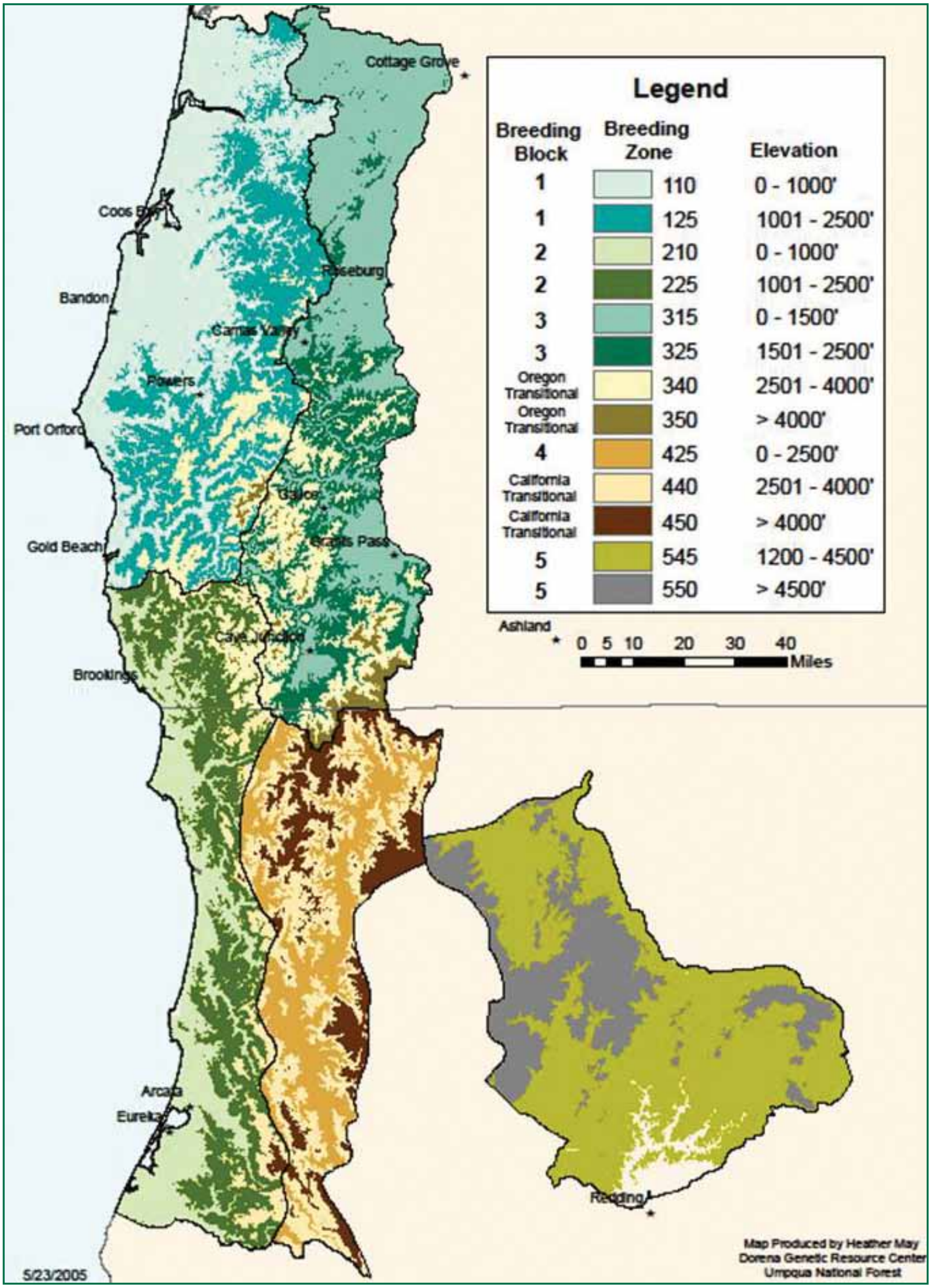

Figure 7. Port-Orford-cedar breeding zones.

it likely that they will escape Port-Orford-cedar root disease, even if the pathogen has already been established nearby or may be introduced in the future. Port-Orford-cedar above roads, uphill from creeks, on ridgetops, and on well-drained sites is less likely to become infected.

Assistance

Private landowners can get more information from County Extension Agents, State Forestry Departments, or State Agriculture Departments. Federal Resource Managers should contact Forest Health Protection specialists in the Pacific Southwest Region (www.fs.usda.gov/main/r5/forest-grasslandhealth) or the Pacific Northwest Region (www.fs.usda.gov/goto/r6/fhp).

Acknowledgments

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NOTE: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the Federal Environmental Protection Agency, consult your county agricultural agent or State extension specialist to be sure the intended use is still registered.

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