The Future Looks Bright for Port-Orford-Cedar

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Abstract

Port-Orford-cedar (*Chamaecyparis lawsoniana* [A. Murr.] Parl.), also known as Lawson cypress, is native to a small area in Oregon and California, and is highly valued in many areas of the world for its wood and as an ornamental. Unfortunately, it is affected by a lethal root disease caused by *Phytophthora lateralis*. Because of the efforts of many individuals and agencies, heritable resistance to the disease has been confirmed and a breeding program to produce disease-resistant plant material is underway. This article describes these efforts and provides recommendations for obtaining and planting disease-resistant seedlings and preventing spread of the root disease.

Introduction

Port-Orford-cedar (*Chamaecyparis lawsoniana* [A. Murr.] Parl.), also known as Lawson cypress, is a large and attractive conifer that is native to a small area of southwestern Oregon and northwestern California (figure 1). The species is found in the coastal ranges and Klamath Mountains, from the Oregon Dunes in Coos County, Oregon, and south to the Mad River in Humboldt County, California. A disjunct population occurs in the Trinity and Scott Mountains near the headwaters of the Trinity and Sacramento Rivers in California (figure 2).

Although geographically limited, within its small range Port-Orford-cedar is found in a wide variety of plant communities and environments, from sea level up to 6,400 ft (1,950 m), and in many soil types, including ultramafics (serpentine). Port-Orford-cedar is more drought tolerant than western hemlock (*Tsuga heterophylla* [Raf.] Sarg.) or Sitka spruce (*Picea sitchensis* [Bong.] Carr.), but less drought tolerant than most of its other conifer associates. The limiting factor in the natural distribution of Port-Orford-cedar is most likely its requirement for consistent moisture during the summer (Zobel and others 1985). Port-Orford-cedar seed germinates late in the spring, and its seedlings are small and shallow-rooted. Natural seedling success is dependent on moisture near the surface and high water potential in summer. Thus, natural stands of Port-Orford-cedar are limited to locations with consistent groundwater, including high water table and seep areas, along rivers and streams, lakeshores, slumps, cool microsites, and upper slopes in areas with summer fog.

Port-Orford-cedar is moderately high in shade tolerance, but also grows well in the open. This species is the most shade tolerant of all its conifer associates with the exception of western hemlock. Port-Orford-cedar is also tolerant of repeated fire. This species is less fire resistant than Douglas-fir (Mirb.) Franco, but more resistant than true firs or hemlock. Pole-sized trees generally are able to survive light to moderate ground fires (Jimerson and others 2001, Zobel and others 1985).

Port-Orford-cedar plays a significant role in riparian zones within its range. This species provides streamside shade,

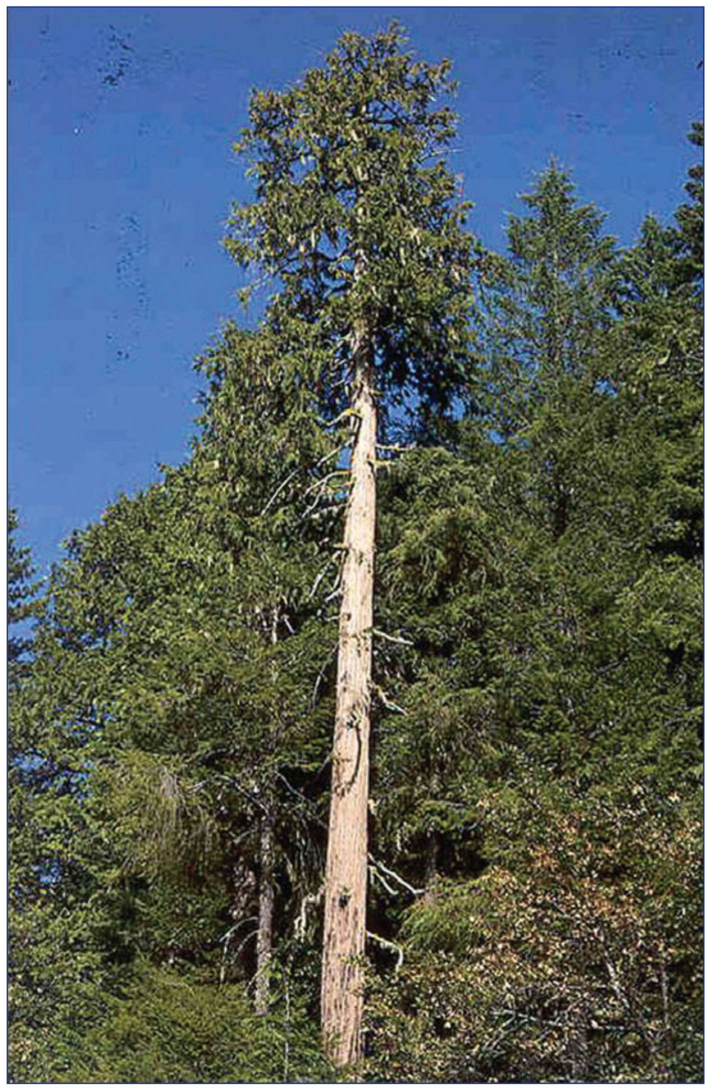

Figure 1. A large healthy Port-Orford-cedar (Photo source: Forest Service Pacific Northwest Region archives).

Figure 2. The native range of Port-Orford-cedar (Map source: Zobel 1990).

bank stability, and decay-resistant large woody material for in-stream structure. Along streams on ultramafic sites where Port-Orford-cedar is often the only large conifer, these functions are particularly critical. On ultramafic sites, rare and unique plants are often found in association with Port-Orford-cedar (USDA and USDI 2004).

Port-Orford-cedar has been highly prized as an ornamental since it was first collected and propagated by early botanical explorers in the Pacific Northwest. At least 250 named varieties have been propagated for a diversity of size, color, branching habit, and foliage. Port-Orford-cedar performs well in many areas outside its natural range. This species has been planted in residential gardens, hedges, and parks around the world. Port-Orford-cedar is also valued for its decay-resistant, fine-grained, white wood. Native Americans use the wood in traditional plank houses, for storage boxes and regalia items; and the shoots, bark, and twigs for medicinal purposes, as well as for baskets, clothing, and mats. Euro-Americans began large-scale harvesting of Port-Orford-cedar to provide lumber for the building booms of the Gold Rush. Harvest for lumber and many other uses continued through two world wars. Old-growth Port-Orford-cedar is highly valued in Japan and was the basis of a thriving export market until old-growth Port-Orford-cedar became much less available. Today, Port-Orford-cedar is harvested primarily for domestic uses. This species is milled for lumber, paneling, decking, fencing, and arrow shafts. The essential oil is used in organic insect repellents and a large market exists for the boughs, which are used in wreaths and floral arrangements.

Port-Orford-cedar is affected by a lethal root disease, which was first reported in a nursery in Seattle, WA, in 1923. At the time, the disease had already been observed killing planted specimens in area gardens (Zobel and others 1985). The root disease was widespread and had already devastated the horticultural trade in Port-Orford-cedar in the Northwest before the causal agent was identified and named *Phytophthora lateralis* by Tucker and Milbrath (1942). By 1952, the pathogen had spread south into the natural range of Port-Orford-cedar, where it moved rapidly along roads and streams with devastating results. The most severe effects have been on privately owned land along the coastal plain and farther inland on both public and private land in wet areas, riparian zones, and ultramafic sites.

Port-Orford-Cedar Root Disease

Port-Orford-cedar and Pacific yew (*Taxus brevifolia* Nutt.) are the only species known to be affected by *P. lateralis*. Nearly all Port-Orford-cedar are very susceptible, and most of the infected trees are quickly killed. Yew is much less susceptible and becomes infected only when growing in close proximity to diseased Port-Orford-cedar (Murray and Hansen 1997).

Like other members of the genus *Phytophthora*, *P. lateralis* is a water mold, more closely related to brown algae than to fungi, which it superficially resembles. *Phytophthora* species, including *P. lateralis*, produce swimming zoospores that infect the fine roots of their hosts. Growth of *P. lateralis* in the roots of infected trees cuts off the flow of water and nutrients, resulting in rapid mortality. Aboveground symptoms are typical of water stress, and include reduced growth, wilting, and fading of the entire crown from green to yellow to bronze. Until the cambium dries out, a cinnamon-orange stain (figure 3) with a distinct margin is visible under the bark in the phloem of the roots and root collar of diseased trees (Hansen 1997).

P. lateralis is a cool-climate *Phytophthora* species. This species is active during mild, wet weather and is inactive when conditions are hot and dry. Spread of the pathogen over long distances is accomplished by resting spores transported in infested plant material and soil, primarily by humans. This is the most common means of introduction into new areas.

Within an infested area, *P. lateralis* spreads mainly by waterborne spores in ditches, streams, and overland flow. Movement of the pathogen along root-to-root contacts between infected and uninfected trees is also an important mechanism of spread between adjacent trees, although it appears to be less important than spread by movement of spores in water or soil (Zobel and others 1985).

The risk that trees on a site may become infected is largely based on factors that aid or inhibit the movement of infested water and soil. High-risk sites for infection include low-lying wet areas downslope from already infested areas, sites below open roads and trails, areas within the high water mark of stream channels and riparian areas, as well as ditches, gullies, swamps, seeps, ponds, lakes, and concave slopes where water collects.

Low-risk sites for infection are upland sites, sites on convex slopes, areas above the high water mark of stream channels, and areas away from roads and trails where topography provides protection from the introduction of the pathogen into soil or water.

After trees become infected, *P. lateralis* survives in their roots and root fragments until the roots decompose, which may take at least 7 years under cool moist conditions (Hansen and Hamm 1996). Under less favorable conditions, survival of the pathogen is greatly reduced. If all the host trees, including natural regeneration, can be eradicated from an infested site, the pathogen will be eliminated from the site after the roots have decomposed.

Breeding Port-Orford-Cedar for Resistance to Root Disease

Hansen and others (1989) confirmed the existence of heritable resistance to Port-Orford-cedar root disease. As a result, the Forest Service and the U.S. Department of the Interior, Bureau of Land Management began an operational breeding program in cooperation with Oregon State University in 1996. The goal of the program is to develop durable resistance to *P. lateralis* while maintaining broad genetic diversity within the species (USDA 2004). The first phase of the program was selection of phenotypically resistant trees from diseased populations throughout the range of Port-Orford-cedar. Small branches from approximately 12,000 trees were screened for disease resistance using a stem dip test that artificially inoculated stem tissue with the pathogen. The results of this test identified approximately 1,600 potentially resistant parent trees. Seedlings and rooted cuttings propagated from these trees were subjected to additional testing by artificial root inoculation in the greenhouse (figure 4) and by outplanting in naturally infested field sites. In short-term greenhouse trials, seedlings from disease-resistant parents had between 50 and 100 percent survival compared with less than 10 percent survival of seedlings from susceptible parents (Sniezko and others 2006). In a long-term field test, seedlings and rooted cuttings of disease-resistant families had 20 to 80 percent survival after 16 years compared with 0 to 8 percent survival of susceptible families (Oh and others 2006). Several disease-resistant individuals have survived for 22 years on an infested site at Oregon State University.

Figure 3. Stem of a young Port-Orford-cedar with diagnostic stain caused by Phytophthora lateralis (Photo source: Forest Service Pacific Northwest Region archives).

Figure 4. Testing rooted cuttings for resistance to Port-Orford-cedar root disease by artificial root inoculation in the greenhouse (Photo source: Richard Sniezko, Forest Service).

Short-term greenhouse trials have shown that at least two types of disease resistance exist: major gene and slow dying resistance. In addition, McWilliams (2000) found that isolates of *P. lateralis* from Western North America have only limited genetic variability. The possibility of several resistance mechanisms, coupled with uniformity in the pathogen, increases the chance that resistance to the root disease will persist over time (USDA and USDI 2004). Both short- and long-term field trials are continuing (Sniezko and others 2009). The durability of disease resistance in long-term field trials will determine the ultimate success of the program.

The first containerized breeding orchards of disease-resistant Port-Orford-cedar were established in 2001 (figure 5). The long-term objective is to have 30 disease-resistant selections per breeding zone. The resistance level of parent trees in the orchards is continually increasing as new parents are added following the results of ongoing trials, as orchards are rogued to meet new selection criteria, and as second generation breeding increases disease resistance (USDA 2006). Orchard development and the entire breeding program are greatly benefitted by the fact that Port-Orford-cedar can be induced to flower, and produce cones and seed at a very young age.

Figure 5. A containerized orchard for breeding root disease-resistant Port-Orford-cedar (Photo source: Richard Sniezko, Forest Service).

The orchards are propagated and organized according to breeding blocks, which were determined by studies of the genetic variability in Port-Orford-cedar. Within the blocks, breeding zones were delineated that further subdivide the blocks into elevational bands (figure 6). The purpose of breeding blocks and breeding zones is to guide breeding activities, and specify where seeds and other reproductive material are gathered and then deployed (table 1). This approach ensures that nursery stock is adapted to the outplanting site, and conserves the natural genetic structure of Port-Orford-cedar (USDA and USDI 2004).

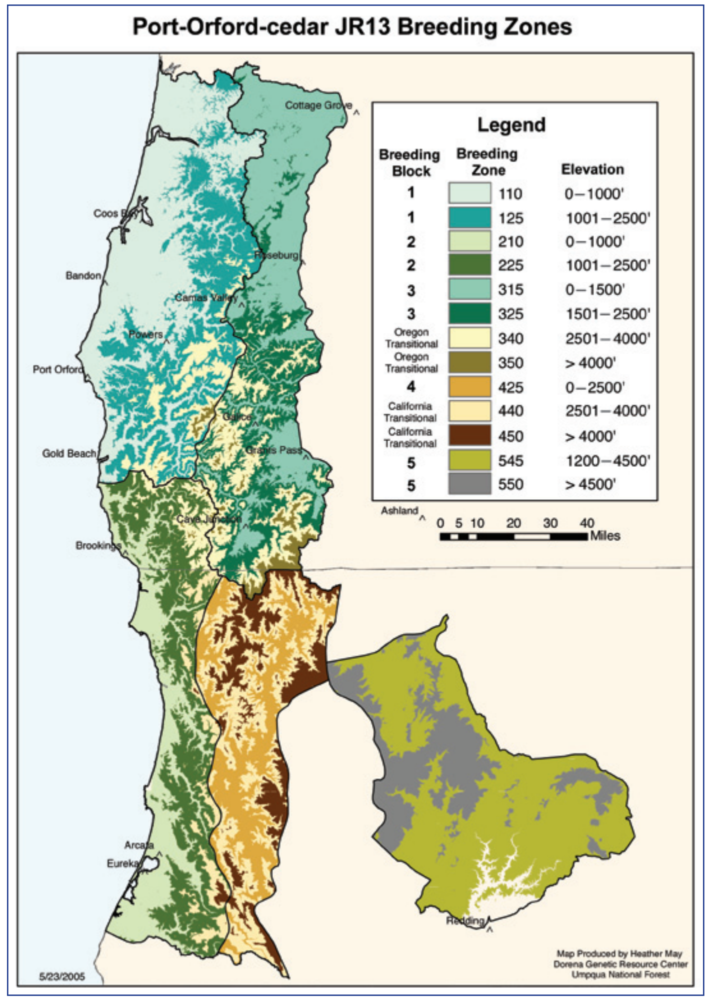

Figure 6. Breeding zones for Port-Orford-cedar. Note: "JR13" refers to Jim Hamlin and Rod Stevens, Geneticists, respectively, Forest Service and U.S. Department of the Interior, Bureau of Land Management (retired), who determined the boundaries of the 13 breeding zones (Map source: Heather May, Forest Service).

Table 1. Seed zones for Port-Orford-cedar

Breeding block	Breeding zone[a]	Elevation ft (m)
1	110	0–1,000 (0–304)
1	125	1,001–2,500 (305–762)
2	210	0–1,000 (0–304)
2	225	1,001–2,500 (305–762)
3	315	0–1,500 (0–457)
3	325	1,501–2,500 (458–762)
OR transitional[b]	340	2,501–4,000 (459–1,219)
OR transitional	350	> 4,000 (> 1,219)
4	425	0–2,500 (0–762)
CA transitional	440	2,501–4,000 (763–1,219)
CA transitional	450	> 4,000 (> 1,219)
5	545	1,200–4,500 (366–1,372)
5	550	> 4,500 (> 1,372)

[a] The first digit represents the breeding block, and the second and third digits represent the upper limit of the elevational band.

[b] Seed and seedlings from transitional zones may be planted anywhere in the State within the respective elevation band.

Why Plant Disease-Resistant Port-Orford-Cedar?

On many currently infested and previously infested sites, few large Port-Orford-cedar remain. Planting disease-resistant Port-Orford-cedar will increase the probability that the trees will survive to a large size and regain their ecological role as a source of shade and decay-resistant wood, particularly important in riparian areas. On ultramafic soils, the reintroduction of Port-Orford-cedar will restore a primary source of shade and soil stability. Planting disease-resistant Port-Orford-cedar will also provide a source of resistant genes for future natural regeneration. Disease-resistant Port-Orford-cedar will be a particularly valuable addition on sites where increased species diversity would benefit forest management. For example, disease-resistant Port-Orford-cedar may be an appropriate alternative in areas along the southern Oregon coast where Swiss needle cast (caused by the fungus *Phaeocryptopus gaeumannii* [Rohde]Petrak) is causing significant reductions in the yield of Douglas-fir (Duddles 1999), or on sites where Douglas-fir is affected by laminated root rot. Even where the performance of Douglas-fir is not an issue, Port-Orford-cedar may be a bonus in stands, adding to total yield, because it does not significantly compete with Douglas-fir (Zobel and others 1985). Since it performs well in the understory, Port-Orford-cedar can add structural diversity and would be a valuable addition where uneven-age management is preferred.

The pond value of Port-Orford-cedar logs, compares favorably with Douglas-fir logs and prices for Port-Orford-cedar logs have remained more stable than Douglas-fir log prices during the past 10 years (Huff 2011). Port-Orford-cedar may also be a desirable component of managed stands because of its value for boughs and specialty wood products. Carefully controlled bough harvest can provide intermediate income, while individual trees can be selectively harvested for specialty products. Planting disease-resistant Port-Orford-cedar will also ensure its availability for traditional tribal uses.

Port-Orford-cedar was once widely planted and highly valued as an ornamental in the Pacific Northwest and around the world. This species is seldom damaged by foliage diseases, stem decay, or insects. The bark of mature trees is thick and resistant to damage. The species resists moderate air pollution and recovers well when the terminal leader is lost (Zobel 1990). The availability of these new disease-resistant varieties should encourage renewed planting of Port-Orford-cedar in parks, gardens, and other urban settings.

Where To Plant Port-Orford-Cedar

Current recommendations for planting disease-resistant Port-Orford-cedar are to plant on sites that are low risk for root disease, in riparian areas, in adjacent uplands up to 100 yd (91 m) upslope from previously known locations of Port-Orford-cedar, on concave slopes, and in areas with an open or partially open canopy. Sites where all Port-Orford-cedar (including natural regeneration) have been eradicated by treatment or by the root disease for at least 7 years are also good candidates for planting.

In addition to planting on sites where Port-Orford-cedar loss has occurred because of fire or root disease, disease-resistant Port-Orford-cedar can also be planted on new sites within its natural range. Containerized seedlings or bareroot seedlings with a large root mass may perform well on drier sites that would be marginal for natural regeneration of Port-Orford-cedar (Lucas 2011). On upland sites, seedlings should be planted in moist microsites, such as on the north side of stumps or snags, and in areas where brush or other regeneration will not hinder seedling growth. In general, sites with red alder (*Alnus rubra* Bong.) are considered suitable for planting Port-Orford-cedar (USDA and USDI 2004).

The current focus of Port-Orford-cedar planting on Federal land is on sites where its ecological function is most critical, such as along streams on ultramafic soils, or where the species has been lost to wildfire. The largest operational planting of disease-resistant Port-Orford-cedar on Federal land was in 2010. Approximately 48,000 seedlings were planted on 1,470 acres (595 hectare) on the Six Rivers and Klamath National Forests that burned in a 2008 wildfire. Seedlings were planted in areas where Port-Orford-cedar grew before the fire, as well as in adjacent areas where it had not been present (Angwin and others 2010). Disease-resistant stock has been planted in smaller amounts on Federal land in Oregon since 2004.

In landscape settings, disease-resistant Port-Orford-cedar is best suited for areas with well-drained (but not droughty) soil, on high ground, away from areas where water runs off or puddles, and away from roads, parking lots, trailheads, and other heavily trafficked areas.

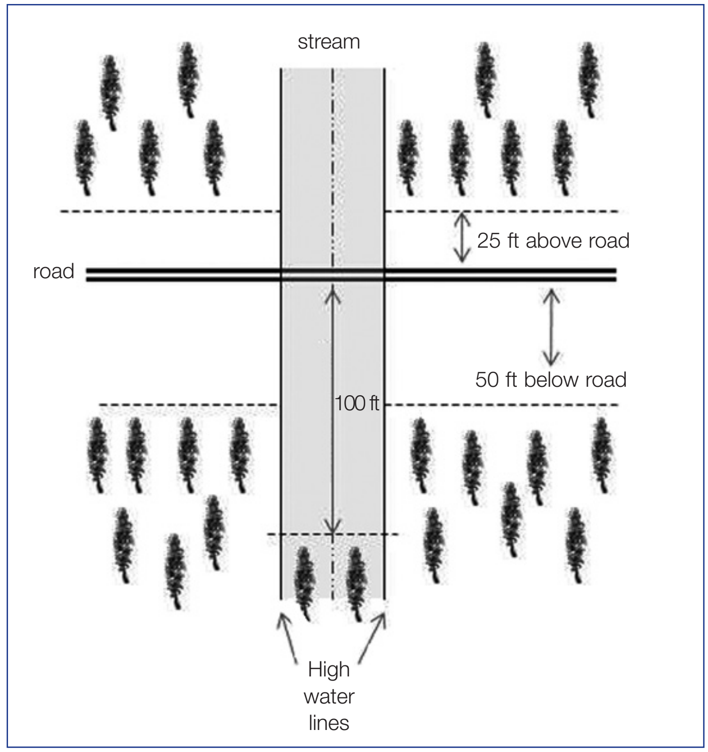

Figure 7. Guidelines for planting resistant Port-Orford-cedar along roads and streams (Graphic source: Katy Mallams, Forest Service).

Where Not To Plant Port-Orford-Cedar

Seedlings that are resistant to Port-Orford-cedar root disease are not completely immune to the disease. Therefore, disease-resistant Port-Orford-cedar should not be planted where vehicle, foot, or animal traffic is likely to introduce soil infested by *P. lateralis*. Port-Orford-cedar should not be planted within 50 ft (15 m) of the downhill side of roads that are open to vehicles, or within 25 ft (8 m) of the uphill side of open roads, or within the high water line of stream channels within 100 ft (30 m) of roads (figure 7).

Port-Orford-cedar should not be planted in areas where the root disease has caused recent mortality, as indicated by the presence of brown needles or fine branches on the dead trees, or where eradication treatments are under way. Planting in these areas would provide new host material for the pathogen, allowing it to persist on the site. In addition, the resulting selective pressure would provide an opportunity for the pathogen to mutate to a new, possibly more virulent strain. Port-Orford-cedar should also not be planted in unstocked areas between infested and uninfested sites to avoid creating a bridge for movement of the pathogen into uninfested areas.

In landscape settings, Port-Orford-cedar should not be planted near recently dead Port-Orford-cedar, anywhere water runs or puddles, in low spots, or along roads, driveways, or trails, or other areas frequented by people.

Preventing Introduction of *P. lateralis* During and After Planting

A number of measures can be taken to exclude *P. lateralis* from uninfested sites, and prevent its reintroduction to previously infested sites during and after planting and other activities. These measures include choosing entry and exit routes to avoid infested areas; planting uninfested sites before those with a history of root disease; washing and inspecting vehicles, planting tools, and planter's (and inspector's) footwear before entering planting areas; and rewashing and reinspecting vehicles and equipment leaving the area before they return.

Wash vehicles, equipment, and footwear with uninfested water or with water treated with Clorox® bleach according to the label instructions (mix at a ratio of one part Clorox® to 1,000 parts water at least 5 minutes before use). A stiff brush or vigorous stream of water is usually sufficient to remove potentially infested soil. Take care that wash water does not drain into watercourses or areas with uninfected Port-Orford-cedar. Whenever possible, limit visits to planted areas, bough collecting, and other harvest activities to the dry season when conditions that favor pathogen spread are limited.

Availability of Disease-Resistant Plant Material

Seed and seedlings from disease-resistant parents are available to Federal agencies from the Forest Service J. Herbert Stone Nursery in Central Point, OR (phone: 541–858–6100). Non-Federal agencies and private landowners in Oregon interested in purchasing seed can contact the Oregon Department of Forestry (ODF), Private Forests Program (http://www.oregon.gov/ODF/privateforests/index.shtml). Several commercial forest tree nurseries in the region have experience growing Port-Orford-cedar. These nurseries can purchase the seed from ODF and will grow specific amounts on contract. For individual plantings around homes, gardens, parks, and other landscaped settings, named varieties of Port-Orford-cedar that are propagated on disease-resistant rootstock are available from retail nurseries.

Summary

Port-Orford-cedar has been recognized as a beautiful and highly valuable tree species since humans first encountered it in the forests of southwest Oregon and northern California. In the early 20th century, introduction of a nonnative pathogen, *Phytophthora lateralis*, devastated the Port-Orford-cedar horticultural and timber industries, and led to significant changes in forest structure and function, particularly in riparian and ultramafic ecosystems. For many years, it appeared that no resistance to the root disease existed, and that the future of Port-Orford-cedar was uncertain at best. Fortunately, some people refused to give up hope and, in 1989, it was shown that heritable resistance exists in a small number of families. Since then, an active search has identified disease-resistant parent trees from many areas in the natural range of Port-Orford-cedar. An ongoing breeding program provides seed from disease-resistant parents to public agencies and private landowners, and continues efforts to increase the level of resistance. These efforts have renewed interest in Port-Orford-cedar by the horticulture industry and named varieties of Port-Orford-cedar on disease-resistant rootstock are now available.

The availability of disease-resistant stock, awareness of how *P. lateralis* moves, and commitment to using the best management practices to prevent disease spread are more important than ever. Given these means, there is renewed hope that Port-Orford-cedar will survive and flourish again in many of the places where it once thrived.

Acknowledgments

The author thanks Pete Angwin, Frank Betlejewski, Ellen Goheen, Tristan Huff, and Sunny Lucas for reviewing the draft of this manuscript and providing many helpful suggestions. The author also thanks Dr. Donald Zobel and the late Dr. Lewis Roth for their pioneering contributions that have increased understanding of Port-Orford-cedar and *Phytophthora lateralis*.

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