



*Management of
Port-Orford-Cedar
and its Influence
on Phytophthora
Root Rot*

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**Management of Port-Orford-Cedar
and its Influence on Phytophthora Root Rot**

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Cover: Port-Orford-cedar snag in the Siskiyou National Forest.

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Management of Port-Orford-Cedar and its Influence on *Phytophthora* Root Rot

Abstract

Port-Orford-cedar (*Chamaecyparis lawsoniana*), one of the most valuable trees in Oregon, is found on national forest land, Bureau of Land Management O&C land, and some private land in Southwest Oregon and Northern California. For the past 30 years it has been under attack by *Phytophthora lateralis*, an introduced root rot. This disease, which is invariably fatal to the cedar, is spread from one infected tree to another by root grafts which the trees form with one another and by movement of spores through the groundwater.

However, long-distance spread of the pest mainly occurs with human assistance. Spores of the rot, living or dormant in mud and soil, are picked up by trucks and other machinery. They can then be carried to uninfested watersheds to create a new infection center. The main causes of spread of the disease in the past 30 years can usually be directly traced to new road construction.

Although the Forest Service is aware of the pest and how it spreads, little is done to prevent the spread of the disease. For example, although it has long been suggested that equipment be cleaned before entering uninfested watersheds, only one or two timber sales

in national forest lands have required such cleaning.

The disease can now be considered endemic in most of the natural range of Port-Orford-cedar. The main refuges for the tree are the roadless areas which have not been entered for timber harvest due to RARE II and other wilderness studies. Research now underway to protect the tree through breeding or other techniques will take many years before it is even known if it will be successful. In the meantime most of the natural gene pool of the tree could be wiped out.

The only course of action which will insure survival of the tree is the allocation of a number of uninfested watersheds to a roadless, non-timber management category. This can take place as a part of national forest planning procedures which are now underway on the Six Rivers and Siskiyou National Forests, where nearly all remaining uninfested stands are located. One planning regulation, which states that silviculture treatments which would make stands susceptible to disease shall not be applied, appears to mandate land use allocations of this sort.

Introduction

Phytophthora root rot, caused by *Phytophthora lateralis*, is the most damaging disease of Port-Orford-cedar. Since 1937, when the disease was first noticed, *P. lateralis* has damaged nurseries, windbreaks, and ornamental plantings throughout the Pacific Northwest. When it was found within the natural range of Port-Orford-cedar in the early 1950's, many thought it would destroy the species completely.

So far it has not. Yet plans are now

in preparation which may remove Port-Orford-cedar as a commercial species in its native habitat. Public forest managers must take into consideration the effects of their activities on the future viability of Port-Orford-cedar.

Port-Orford-cedar is the most valuable tree in Oregon. This paper will review the interactions of the host, pest, and management practices to provide insight in the management of threatened Port-Orford-cedar stands.

The Host: Port-Orford-Cedar (*Chamaecyparis Lawsoniana* (A. Murr.) Parl.)

Like all North American trees which are called "cedars," Port-Orford-cedar is not a true cedar. It might more properly be called a cypress -- and in fact one trade name for the tree as an ornamental is Lawson cypress. Because it is popularly called a cedar, botanists use the hyphen between "Orford" and "cedar" to designate that it is not a true cedar.

Even though Port-Orford-cedar has been transplanted all over the world with good success, its natural range is limited to a band no more than 40 miles wide along the Pacific Coast (Fowels 1965). This band extends only from Coos Bay, Oregon, south to the Mad River near Arcata, California. The eastern boundary of this band occurs on sites where the amount of precipitation is less and evaporation stress greater than Port-Orford-cedar can tolerate (Zobel and Hawk 1980). The tree also appears in two isolated pockets in northern California on the upper valleys of the Trinity and Sacramento Rivers, but the large commercial stands are along the coast (figure one).

Port-Orford-cedar grows well on many different sites. It can be found on sand banks near sea level and in moist coves at 1,360 meters (4,500 feet) in the Siskiyou Mountains (Whittaker 1960). It is a minor component of the Mixed-Evergreen (*Pseudotsuga-Schlerophyll*) vegetation zone in the Western Siskiyou and the *Picea sitchensis* zone of Southwest Oregon (Franklin and Dyrness 1973). In these zones it grows on the more mesic (moist) sites with Douglas-fir (*Pseudotsuga menziesii*), sugar pine (*Pinus lambertiana*), and grand fir (*Abies grandis*). It can even grow on serpentine soils, which are shallow and low in nutrients (Whittaker 1960).

But it experiences its best growth in the *Tsuga heterophylla* (western hemlock) zone along the coast (Fowels 1965). The

cool, moist winters and warm, dry Summers in this part of Oregon favor Port-Orford-cedar, as the same climate favors redwood in Northern California.

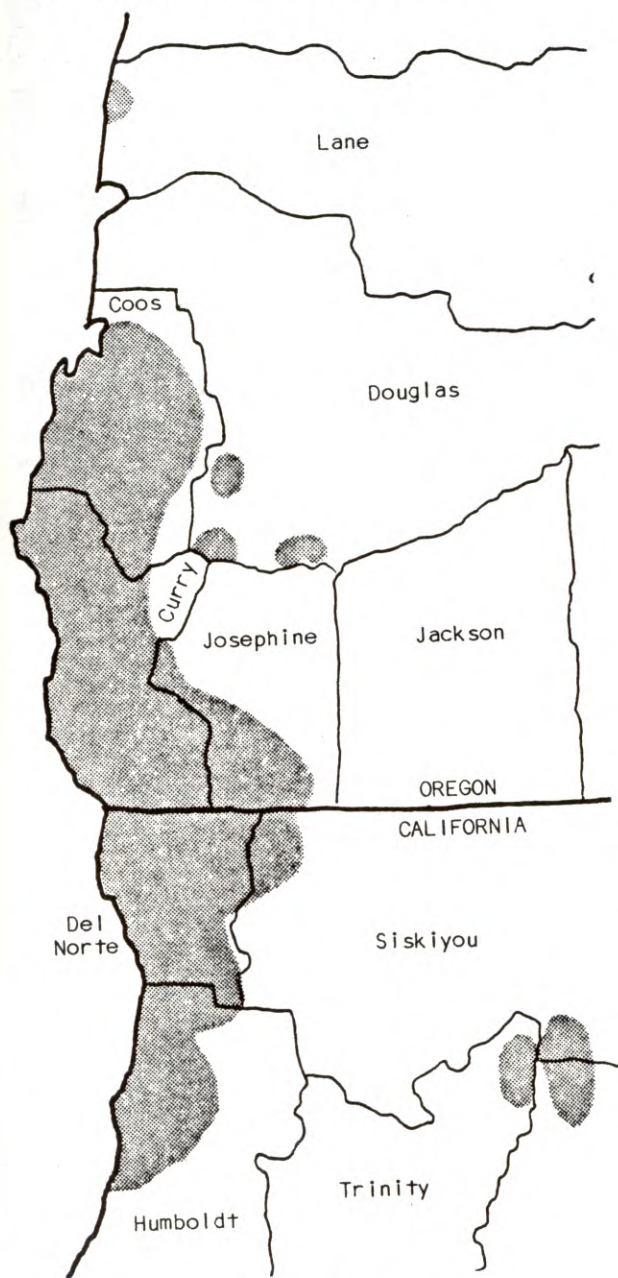
In this zone, the amount of annual precipitation ranges from 178 to 234 cm (70 to 100 inches) along the coast, with the majority falling during Winter and Spring (Minore 1973). Depth to the water table varies from 2 to 69 cm during the Winter, and an additional 1.5 to 50 cm during the Summer (Zobel and Hawk 1980). Air temperatures in this zone range from 4° to 10° C (40° to 50° F) in Winter to 24° C (75° F) in summer months. Soil temperatures range from 4° to 7° C (40° to 44° F) in winter to 13° C (55° F) in summer (Zobel and Hawk 1980) (see figure two). Its associates in this zone are Douglas-fir, western hemlock, grand fir, sugar pine, tan-oak (*Lithocarpus densiflorus*), Pacific madrone (*Arbutus menziesii*), and occasionally western red-cedar (*Thuja plicata*).

Port-Orford-cedar is a prolific seed producer. One study collected over 1.2 million seeds per acre in a cedar stand (Fowels 1965). Yet most are of poor quality. Seeds which do germinate cannot survive under a closed forest canopy, where it is typically replaced by grand fir and western hemlock. Natural regeneration is successful in openings in the stand.

In mixed stands, Port-Orford-cedar makes excellent growth when young and is usually dominant for the first 20 to 25 years (Anon. 1950). It is often then overtopped by other trees. Though tolerant to shade, growth is slowed when overtopped (Fowels 1965).

The dominant trees overtopping the Port-Orford-cedar often begin to die at around 250 to 300 years of age in natural stands. Even at this old age the Port-Orford-cedar will respond to release and again become a dominant. At 400 years, a stand protected from fire

Figure One
The Natural Range of Port-Orford-Cedar



(after Henley 1973)

and cutting will have Port-Orford-cedar and western hemlock as the climax species. On better sites Port-Orford-cedars will live over 500 years and reach 60 meters (180 feet) in height (Franklin and Dyrness 1973).

Port-Orford-cedar also has good growth potential in pure stands. Average height growth ranges from 25 to 35 centimeters (.83 to 1.15 feet) per year for the first 20 years. By age 40 diameters of 18 to 25 centimeters (7 to 10 inches) and heights of 15 to 21 meters (50 to 70 feet) are common in pure natural stands without overtopping (Fowels 1965).

As the tree grows it will often form root grafts with other Port-Orford-cedars. This union increases nutrient and water absorption and may prevent windthrow during Winter storms.

Because of the site versatility and beauty of Port-Orford-cedar it was once highly favored as an ornamental. In the 1930s and 40s the use of Lawson cypress in landscaping and windbreak plantings was common in the Pacific Northwest, California, British Columbia, Britain, Europe, and New Zealand (Evans 1968, Sutherland 1948, Torgeson *et al.* 1954).

The wood of this tree was equally prized. It machines well and was used as Venetian blind slats, in boats, interior finish, furniture, and for plywood and paper manufacture (Paul 1961). The oils in the wood make it resistant to certain acids, and strips of it were used for separators in early storage batteries. Today the only domestic use of Port-Orford-cedar is for shafts of arrows (Henley 1973).

The major market for Port-Orford-cedar today is in Japan. The wood resembles that of a Japanese hinoki cypress (*Chamaecyparis obtusa*), which has important spiritual values to the Japanese. Because the supplies of the native tree are severely depleted, there has been a high demand for Port-Orford-cedar as a substitute in housing and

other construction. The Department of Agriculture has declared Port-Orford-cedar "surplus" to U.S. needs, which allows raw Port-Orford-cedar logs to be exported to Japan.

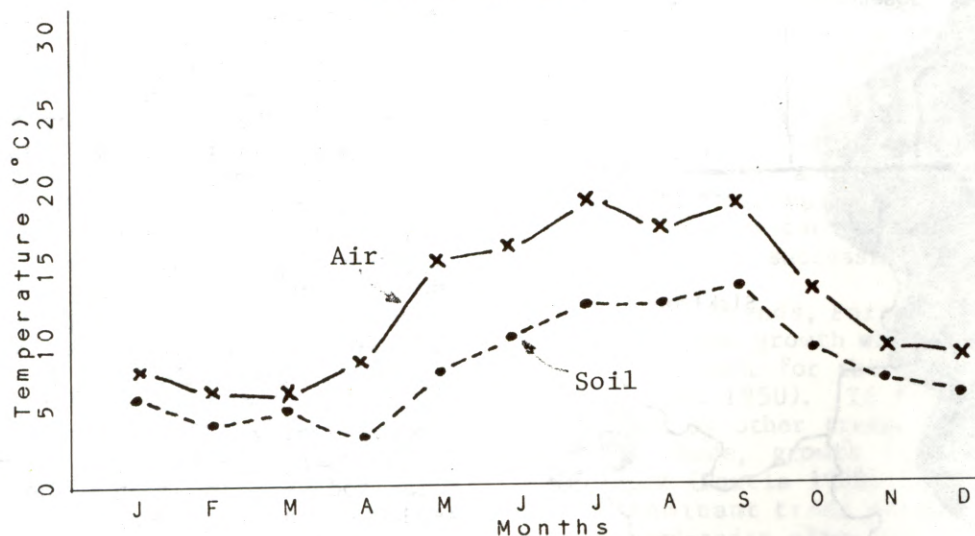
As a result, Port-Orford-cedar has become the most valuable timber species in Oregon. Many sales of Port-Orford-cedar top \$1,000 per thousand board feet (Ruderman 1982). In 1981, for example, the Siskiyou National Forest sold 7.6 million board feet of Port-Orford-cedar at an average price of \$1,126 per thousand (U.S.D.A. Forest Service 1982).

Most of the Port-Orford-cedar is on public land. The volume of growing stock has been estimated at 161 million

cubic feet in Oregon and 44 million cubic feet in Northern California (Ohmann in press). In 1981 an estimated 138 million cubic feet of Port-Orford-cedar grew on Federal commercial timberland. In 1979 a total of 12.7 million board feet (Scribner) were sold from national forests, primarily the Siskiyou (U.S.D.A. Forest Service 1982).

The Siskiyou and Six Rivers National Forests have a policy to manage for Port-Orford-cedar where it occurs. Cedar is also found on land managed by the Bureau of Land Management and on private land, chiefly Georgia-Pacific. Neither have any policies detailing the management of Port-Orford-cedar on their land.

Figure Two
Average air and soil temperatures on three
sites in the *Tsuga heterophylla* zone of
Southwest Oregon



(after Zobel and Hawk 1980, figures 2 and 3)

The Pest: *Phytophthora lateralis* Tucker and Mirb.

Fungi in the genus *Phytophthora* are known for their destructiveness. The potato blight which threw Ireland into famine in the mid-1800s and the root disease destroying eucalyptus forests in Australia today both belong to this genus. *P. lateralis*, a recently-observed fungus, causes a root rot of Port-Orford-cedar which is invariably fatal to the tree.

The origins of *P. lateralis* are not known, but its behavior in Port-Orford-cedar stands is like that of an introduced pest. Some Asian species of *Chamaecyparis* (cypress) display a resistance to it (Roth *et al.* 1972), so the fungus may be native to that part of the world.

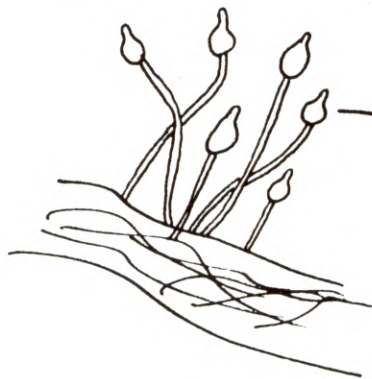
How it came to the Pacific Northwest

is also unknown, but the future of Port-Orford-cedar has been in doubt since its appearance. *P. lateralis* has only been found to infect species of *Chamaecyparis*, with *Chamaecyparis lawsoniana* being one of the most susceptible hosts (Torgeson 1951).

P. lateralis belongs to a class of fungi called phycomycetae. Members of this class are characterized as "lower fungi" and lack cross walls in their mycelium, the material which constitutes the fungal body. Spores are produced in structures on the mycelium called sporangia and released into the soil. These spores are washed up alongside the roots, germinate, and enter the Port-Orford-cedar through the root walls. After invading a root, *P. lateralis*

Figure Three
Formation and Release of Zoospores
from Sporangia on an Infected
Port-Orford-Cedar Root

Sporangia on infected
cedar root



Zoospores
after
release

moves up the roots towards the main stem, killing the root tissue as it advances. The wood material becomes dark and water-soaked after infection (Roth *et al.* 1972).

Once at the root crown the fungus spreads into the trunk. When all the tissues surrounding the trunk are killed the tree can no longer transport water and nutrients from the roots to the foliage, and the tree slowly dies. During this time the foliage turns light green and appears wilted on warm days. Later it turns yellow, bronze, light brown, and finally brown and withered (Tucker and Milbrath 1942).

The disease is usually not noticed until these foliar symptoms appear. By then few methods of control are available. Once girdled by the fungus large trees take two to four years to die.

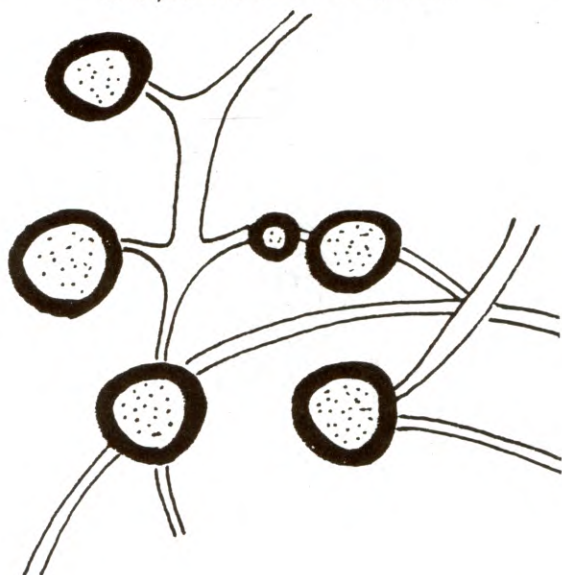
Small trees take only a few weeks (Roth *et al.* 1972).

P. lateralis has two distinctly different types of spores. As the mycelium grows along the root system it can form small lemon-shaped sporangia containing 25 to 40 zoospores (Trione 1974) (see figure three). These zoospores have a tail-like strand of cells used for locomotion. When the sacs open the zoospores are released and "swim" within the groundwater (Torgeson *et al.* 1954). The distance traveled may be short, but if they come up against another Port-Orford-cedar root they can germinate and invade its root tissues.

The other spore, called a chlamydospore, is a resting stage for *P. lateralis*. When environmental conditions are unfavorable for mycelial growth or zoospore production the thick-walled zoospores will form on the sides of the mycelium (figure four). The fungus survives adverse conditions, such as heat or lack of moisture, in this form (Englander and Roth 1980, and Trione 1974). When conditions become favorable again the chlamydospores germinate and invade the host. Although these spores cannot move by themselves, movement of root material and soil infested with chlamydospores can spread the fungus (Ostrofsky *et al.* 1977).

As with the host, temperature and moisture are important to the growth and survival of *P. lateralis*. The best growth occurs in mild, moist weather and the least growth during warm, dry weather. Zoospores can be produced in great quantities when soil and air are 10° to 20° C (50° to 68° F) (Trione 1974). Zoospore production and fungal growth are restricted at 25° C (77° F) and completely inhibited at 30° C (86° F) (Tucker and Milbrath 1942). As shown in table one,

Figure Four
Characteristic Development of Chlamydospores
on Mycelium of *P. Lateralis*



(after Tucker and Milbrath 1942, figure 5.)

chlamydospore production is optimal at 25° C (77° F) (Englander and Roth 1980).

Water plays a major role in the spread of *P. lateralis*. The motile zoospores are released into the free water of the soil. As the water drains away from infected Port-Orford-cedars these spores are carried with it and wash up against other roots. The water can also drain into streams and then carry the spores long distances down stream. Many infections begin along stream banks (Hunt 1959).

Long distance spread has mainly been the result of soil movement. Mud containing chlamydospores and infested plant debris can be picked up and deposited in another site by logs being skidded, on the tires of vehicles, and even on the hooves of cattle or elk (Roth *et al.* 1972).

Early examinations of this disease placed some emphasis on aerial spreading of *P. lateralis* (Trione 1959). As lower branches brushed across infested soil, zoospores present in the water droplets could be deposited on the foliage. The spores could then germinate and mycelium invade the twig conductive tissue. As the fungus progresses up the twig and kills the conductive tissues, the foliage displays the same symptoms as when the tree is girdled.

Within a crown, the zoospores would move as wind and rain splashed infested water droplets from twig to twig (Trione and Roth 1959). Spread from tree to tree would be accomplished when branches of neighboring Port-Orford-cedars are interlaced. As the rain and wind splashed droplets within a crown these droplets could also be deposited on branches of other trees.

The final method of spread is along root systems. When Port-Orford-cedars form root grafts the inner bark is also joined. This provides a continuous pathway for the fungus from tree to tree (Gordon and Roth 1976). Though it takes longer to spread in this manner, there

is always a suitable medium for growth.

These four methods of movement differ in their importance in the spread of *P. lateralis*. Aerial infections and movement along root surfaces are important only on a tree-to-tree basis. These two methods will cause the disease to move through a stand, but at a very slow rate. The movement of the fungus by water or soil are the more important methods of spread within stands and forests, since they allow long distance spread in a relatively short time. Movement of infested soil to previously uninfested stands can allow the fungus to cross over any natural barriers that would have contained the fungus within an area.

Once in a Port-Orford-cedar stand, *P. lateralis* can remain a threat for several years. Infected root material, organic matter, and resting chlamydospores all remain in the soil after the removal of infected or dead trees (Ostrowsky *et al.* 1977). If Port-Orford-

Table One

The survival of *Phytophthora lateralis* in moist particles of organic matter, collected from an infested greenhouse soil, during storage at different temperatures (after Ostrowsky, *et al.* 1977, table two)

Storage Time (weeks)	Storage Temperature (°C)						
	-5	5	10	15	20	25	30
0	4.7	4.7	4.7	4.7	4.7	4.7	4.7
2	1.3	5.0	4.9	4.7	5.0	4.3	0.2
4	0.6	5.0	4.8	5.0	4.9	1.8	0.0
8	0.0	4.9	5.0	5.0	4.6	1.6	0.0
12	0.6	5.0	5.0	4.9	5.0	1.6	0.0
16	0.1	4.9	5.0	4.8	4.2	0.0	0.0
20	0.0	4.6	4.8	4.8	2.8	0.0	0.0

Values are means of numbers of five cedar branchlet baits on which sporangia of *P. lateralis* were observed at x40 after flotation over particles of organic matter in 10 replicate dishes before and after storage.

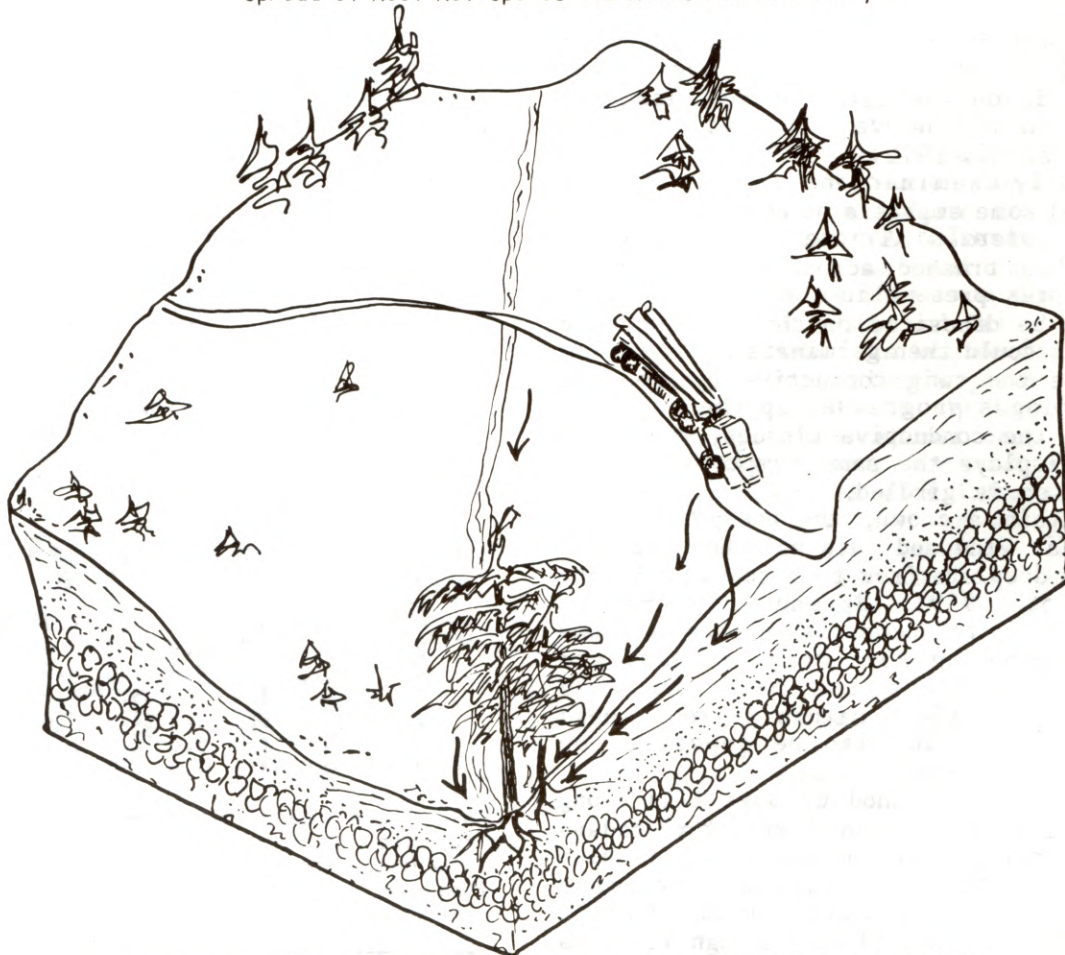
cedar seedlings regenerate on these sites infection can occur when their roots come in contact with infested material from the previous stand.

If infection does take place *P. lateralis* will remain on the site until the new trees are killed. This cycle of old material infecting new will continue as long as Port-Orford-cedar is introduced on diseased sites. Excluding Port-Orford-cedar from diseased sites for a period of time may break the cycle.

cle.

It is not certain how long the fungus can survive in the soil without a host. A study in progress shows a trend towards reduced survival over time, but after many months living spores can still be isolated from soil debris (Hansen interview). Loss of Port-Orford-cedar occurs as mortality and as lower growth rates of live, infected trees. These volumes have not been calculated.

Figure Five
Spread of Root Rot Spores via Roads and Machinery



After being deposited in mud or soil by a vehicle, spores can travel in streams or groundwater until they contact roots of a Port-Orford-cedar.

The History of *Phytophthora* Root Rot of Port-Orford-Cedar

P. lateralis was first introduced to Port-Orford-cedar in Northern Oregon and Washington. Planting of Port-Orford-cedars for ornamental and windbreak purposes began in the 1920s and became so popular that nurseries greatly expanded operations to meet the demand. Seedlings were grown close together in large blocks, often on abandoned farm land. The fields were usually depleted of nutrients and had poor drainage. As a result, parts of the nurseries became water-logged and root disease problems occurred (Hansen *et al.* 1979). It is probable that diseased seedlings were then sold along with healthy ones.

In the early 1930s some Port-Orford-cedars around Portland and Seattle began turning brown and dying. Similar trouble was noticed in the Willamette Valley around 1937, but it was blamed on poor cultural practices and the shock of transplanting Port-Orford-cedar (Milbrath and McWhorter 1938, Young 1954). As the problem increased dead trees were closely examined and a fungus was noticed on the roots and in the soil. C.M. Tucker and J.A. Milbrath studied the fungus, described its characteristics, and named it *P. lateralis* in 1942 (Tucker and Milbrath 1942).

By the mid-1950s warnings were being issued for this new disease of Port-Orford-cedar. Control was attempted in the nursery by the destruction of diseased trees, interplanting with hardwood seedlings, application of fungicides, and grafting Port-Orford-cedar onto the roots of non-susceptible conifers (Tehon 1942, Torgeson *et al.* 1954). Not all of these methods were effective.

Fungicides worked well in the laboratory, but not in the field. The fungus has been found in soil up to 76 centimeters (30 inches deep), too deep for many chemicals (Torgeson 1954). Soil drenches with fungicides stopped infections of established seedlings but

failed to prevent new infections when inoculum was reintroduced (Atkinson 1970).

About this time Port-Orford-cedar plantings in New Zealand, Britain, British Columbia, and Louisiana also began experiencing mortality (Newhook 1959, Evans 1968, Salisbury 1955, Campbell and Verrall 1963). Even though this was attributed to another fungus, *Phytophthora cinnamomi*, people became wary of Port-Orford-cedar as an ornamental. Because of this attitude and the continued incidence of *P. lateralis*, nurseries largely abandoned Port-Orford-cedar as an ornamental crop by 1960 (Roth *et al.* 1972).

How the fungus made it over the Coastal Mountains into the natural range of Port-Orford-cedar is unknown. The most likely possibility is that infected ornamental stock was introduced to the area.

The first sign of trouble was in 1944 when a few Port-Orford-cedars died at the Oregon Marine Biological Station just west of Coos Bay (Roth *et al.* 1957). The foliage showed symptoms similar to *P. lateralis*, but root samples were not taken and the cause was not determined.

In 1952, when a few seedlings died in Coos Bay, six dead seedlings were sent to Oregon State College for diagnosis. *P. lateralis* was isolated from four out of the six samples (Roth *et al.* 1957).

Annual surveys to monitor the spread of the fungus began that year (Hunt 1959). No more kills were noticed in 1952 but the next year *P. lateralis* was isolated from Port-Orford-cedars located 10 miles north and four miles south of Coos Bay (Roth *et al.* 1957). The trees were along the coastal highway, which may explain the rapid spread.

In 1954 Forest Service roadside surveys within the natural range of Port-Orford-cedar found the fungus to have

spread 75 miles along the coast and up to 20 miles inland. The fungus was mainly found along roadways and waterways and was linked to activities such as road construction and maintenance.

In 1957 and 1958 two spot infections were observed far inland. These were in a public campground and along a major road where, again, humans probably aided in the movement (Hunt 1959).

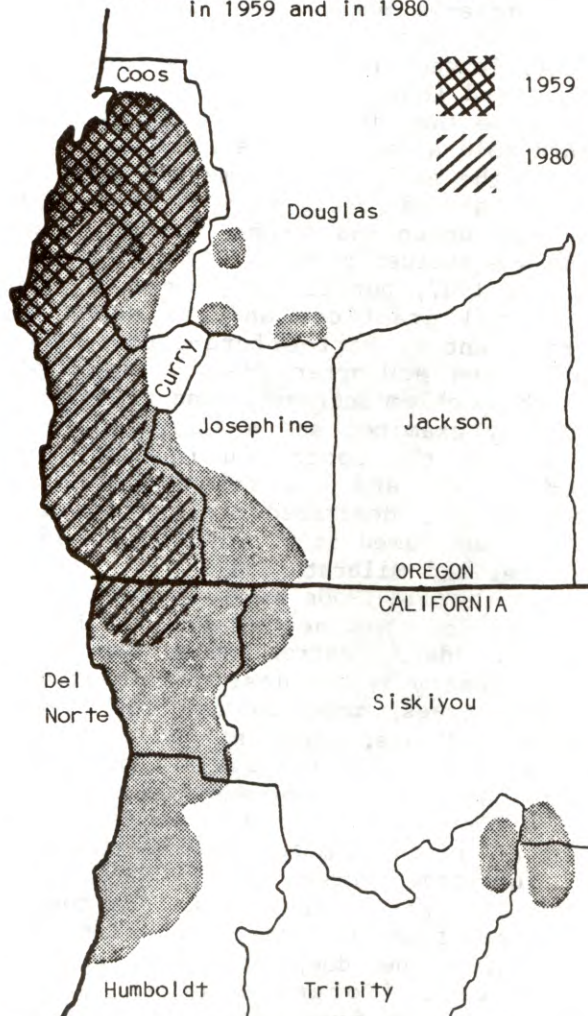
Facing a possible epidemic, the Forest Service recommended that managers discontinue the use of Port-Orford-cedar in reforestation projects outside its natural range (Hunt and Dimock 1957). Apparently it was thought the tree could best fight the disease in its native environment. Within the natural range officials attempted to screen all Port-Orford-cedar planting stock for infection and control the movement of planting stock into Southwest Oregon. Most commercial nurseries cooperated, but private individuals continued to plant Port-Orford-cedar into the area.

P. lateralis continues to move through the Port-Orford-cedar stands of Southwest Oregon. It can be found along streams and on flat land in both old growth and regeneration stands of Port-Orford-cedar.

In 1980, *P. lateralis* was discovered infecting Port-Orford-cedar on several sites in Northern California (Kliejunas and Adams 1981). Evidence on some sites indicated infections began in the mid-1960s, while other infections were only a few years old. The origins of these infections are unknown, but they are most likely from infected stands in Oregon. Once the fungus had become established, it was probably carried by equipment to other parts of the forest. One site, the Rock Creek subdivision on the Six Rivers National Forest, has had cedar dying on it since the mid-1960s. Another infected site was clearcut in the 1970s using equipment that was run and stored on the Rock Creek subdivision (figure six).

Although many stands of Port-Orford-cedar remain healthy, this is mainly because they have not been entered by road construction or logging equipment, the primary causes of long-distance spread. Once these stands are entered, early predictions of extirpation may be realized.

Figure Six
Approximate Location of Port-Orford-Cedar
Stands Infected with Root Rot
in 1959 and in 1980



Forest Service Programs for Control of *P. Lateralis*

The reactions by both forest managers and forest pathologists to the threat of *Phytophthora* root rot have changed over the past thirty years. At first the disease spread so quickly that most feared Port-Orford-cedar would be threatened with extinction, like the American chestnut. Hunt (1959) predicted that the fungus would "continue to spread and intensify until most of the natural range of Port-Orford-cedar is covered." Since human activity can cause the spread of the disease, Roth et al. (1972) warned that "present stand management practices are likely to accelerate losses" of the tree.

Writing in a draft report, Roth (1973) said:

We cannot retain existing commercial cedar through a normal harvest cycle nor keep aesthetic cedar reserves, much less stay in continuous cedar production, without a will to do so. If these trees are to be saved, we must develop a determination to save them that will quickly translate into firm policy and vigorous practice.

Two decades of witnessing conspicuously dying trees without any means of control have understandably resulted in an accelerated harvest by forest managers and a feeling of hopelessness in the public. The cedar cannot be saved if these attitudes remain. The prevailing pessimism must be replaced by confidence and determination to do the best that can be done with existing knowledge and knowledge must be increased.

Ostrofsky et al. (1977) wrote that "most harvestable stands probably will be destroyed during the next 30 years if steps are not taken to limit the damage" from *Phytophthora* root rot.

Now the Forest Service and others are less concerned with the potential damage

from this disease. Dr. Lewis Roth, who has studied this problem since the 1950's, is still concerned about damage, but feels that the fungus is on its way to becoming endemic in the forest -- a normal component of the site. Jim Hadfield, Forest Pest Management Group Leader in Portland, Oregon, considers the disease as a transient pest of the site: it will live only a short time in the absence of the cedar, and then die out. George Lottritz, Silviculturalist on the Six Rivers National Forest in northern California thinks the fungus is not controllable and tries only to slow the inevitable spread of the fungus.

It appears, then, that most forest managers think there is no way to prevent the continued spread of *P. lateralis*. To further complicate the issue, no data on the amount of mortality due to *Phytophthora* root rot is available. This makes it difficult to estimate the present threat to Port-Orford-cedar. In an October 1981 letter to Congressman Weaver, Robert Ethington, Director of the Pacific Northwest Forest and Range Experiment Station wrote "the species [Port-Orford-cedar] is not threatened [by *P. lateralis*] after recent extensive surveys of the species range."

Forest Service methods of controlling *P. lateralis* include (Roth et al. 1972):

- 1) Application of fungicides;
- 2) Breeding of Port-Orford-cedar resistant to *P. lateralis*;
- 3) Modifications in normal forest management.

Fungicides have produced encouraging results in nursery environments, but are impractical in the forest (Atkinson 1970, Torgeson et al. 1954). Because the fungus advances within the root system chemicals broadcast on the soil surface have little effect. Injections of fungicide into soils and trees might be more effective, but would be far too expensive. Fungicides are effectively

limited to nursery use in preventing infection of regeneration stock.

Breeding for resistance will not produce a resistant cedar for many years. While other *Chamaecyparis* species express some degree of resistance to *P. lateralis*, no evidence of resistance has been found in Port-Orford-cedar (Roth *et al.* 1972).

Oregon State University has recently completed a study developing the methodology for screening for resistant cedars. Once the methodology is fully developed, a breeding program would begin, involving the selection of "resistant" seed trees, collection of their seed, germination of those seeds, screening of seedlings displaying resistance, and attempts at hybrids of resistant seedlings.

Such a program would require about two years from germination of seeds to first screening, then another five to ten years to test seedlings and saplings for continued resistance. Even after this research program it is possible that the fungus -- whose breeding cycle is far shorter than the tree -- could adopt to and overcome any genetic expression of resistance in the hybridized Port-Orford-cedar.

Control of *P. lateralis* in the native habitat of Port-Orford-cedar therefore depends on the use of special management practices. The practices suggested by the Forest Service include (Greenup interview, Roth *et al.* 1972):

- a) wide spacing between Port-Orford-cedars;
- b) regulation of salvage and thinning operations;
- c) establishment of sale units in relation to drainage patterns;
- d) regulation of the final harvest;
- e) performing work in the dry Summer months with "clean" equipment;
- f) planting nonsusceptible species on infected sites; and
- g) restricting traffic through in-

fectured stands.

The Siskiyou National Forest precommercial thins Port-Orford-cedars to spacings of 7.5 to 12 meters (30 to 40 feet) between trees. This wide spacing isolates the Port-Orford-cedars, screening them with nonsusceptible vegetation and reducing the chances for root grafts. While this action would slow the spread by aerial infections and along root surfaces, Port-Orford-cedars downhill from infected trees will still run the risk of infection as infested groundwater moves through the stand.

Commercial thinning and salvage operations must be carefully regulated in infected stands. Traditional salvage operations enter the stand as often as practical to remove dead and dying trees. The cutting and skidding of scattered trees can cause a large amount of soil movement. Chlamydospores or infected organic material is thus spread to other parts of the stand and new pockets of infection can occur. It is better to enter stands as few times as possible and then only to remove groups of trees concentrated in small portions of the stand. Each such entry still runs a risk of spreading the disease.

Boundaries of harvest units containing infected timber should be drawn with drainage patterns in mind. Because water aids in zoospore movement Port-Orford-cedars within an infected drainage run the risk of future infection. Containing the unit this way not only focuses on the diseased cedars but also restricts the fungus to that area. Once cut the new stand can be monitored for infections.

Other practices may help restrict fungal movement during final harvest. Harvesting and skidding on slopes containing infected Port-Orford-cedars should begin downslope and work its way up the slope. If the Port-Orford-cedars are toward the top and along ridges this would allow much of the stand to be removed before disturbing soil near

infected trees.

However, Port-Orford-cedar is mainly found in the lower coves of the Coast Mountains and rarely along the ridges. The Forest Service recommends that landings and new roads be located so that water would drain away from uninfected stands of Port-Orford-cedar. The topography of the Coast Range does not always allow this to happen. Roads are located on the basis of many criteria and the tree species within a drainage pattern are rarely considered by project planners.

Shelterwood cutting may be a damaging practice. Living Port-Orford-cedar may maintain root grafts with the stumps and roots of harvested cedar. This would allow *P. lateralis* to move through a stand even when half the trees have been cut. When infected stands are harvested all Port-Orford-cedar -- from old growth to seedlings -- must be removed to break the cycle of infections.

Activities like road construction, thinning, and skidding in the warm, dry months when the fungus is least active may cause less damage than operations during other times of the year. Yet the fungus in the chlamydospore stage remains viable and can be moved to another site to infect Port-Orford-cedar when conditions become more favorable for fungal growth.

Humans and their vehicles are the most important means of spread of *P. lateralis*. All equipment that has operated within an infected stand, from road graders to skidders to logging trucks, should be cleaned before they leave the stand.

The cleaning of logging equipment operated in infected watersheds is one way to restrict long-distance spread and introduction of *P. lateralis* into new stands. As early as 1977 and again in 1981 the Forest Service recommended cleaning operations as simple as washing mud from the undercarriage and tires with water. But if the water used in

such washings is not collected and sterilized it will enter the groundwater and infect more trees. A more effective method is steam-cleaning: the high temperature kills the fungus and chlamydospores.

Similar cleaning operations are common in agriculture. In Australian eucalyptus stands infected with another species of *Phytophthora* rubber-tired skidders and log trucks are steam-cleaned before they leave an infected area.

Although the Forest Service recommends the use of "clean" equipment in road construction and logging operations it rarely enforces this guideline. The Forest Service first recommended steam-cleaning in Roth *et al.* (1972), but it has taken 10 years for a clause requiring steam-cleaning to be considered in a timber sale contract. The Shasta-Trinity National Forest's Devils Zoo sale in 1981 contained such a clause:

Cleaning of Equipment. To prevent the spread of *Phytophthora* root rot Purchaser shall clean before use on Sale Area any vehicles or equipment from the natural range of Port Orford Cedar in Oregon or the Smith River Drainage in California. Cleaning will consist of the removal of soil by steam cleaning or use of high pressure hose. Cleaning shall be inspected and approved by Forest Service before use on Sale Area.

Such a clause in sale contracts within the range of Port-Orford-cedar would help slow the spread of the fungus. Yet the Shasta-Trinity National Forest is outside the principle range of the tree, while cleaning activities on the Six Rivers and Siskiyou National Forests have been minimal.

Cleaning operations were tried for a short time in the 1960s on the Siskiyou National Forest, but they were soon abandoned as uneconomical. Mel Greenup, Silviculturalist on the Siskiyou, feels

it is too late for equipment cleaning requirements.

The Six Rivers National Forest may have a requirement of cleaning in some future sales, but the plans call for logging equipment to be cleaned at the mill. Log trucks and other equipment will still be allowed to travel through infested areas before reaching the sale areas.

Once an infected stand has been harvested the Forest Service recommends keeping Port-Orford-cedar off the site for several years. Remember that Port-Orford-cedar is a prolific seed producer and readily regenerates on disturbed sites free of a closed canopy. Preventing the tree from seeding into an infected site will therefore be difficult and costly. The Forest Service has an almost passive attitude toward Port-Orford-cedar. Greater efforts would be needed to monitor infested sites for Port-Orford-cedar regeneration and remove any seedlings that do appear.

Exactly how long Port-Orford-cedar should be kept off an infested site is still unknown. Kliejunas and Adams (1980) believe *P. lateralis* will only survive in the soil "a year or so" if Port-Orford-cedar is not present. The Forest Service believes that the fungus is short-lived and can only last up to three years without the host (Hadfield interview). The Forest Service feels that one rotation of nonsusceptible species such as sugar pine, western redcedar or Douglas-fir would be more than enough time.

Yet these ideas are speculations unsupported by research. Until research defines the longevity of *P. lateralis* in soil in the absence of a host it would be wise to keep Port-Orford-cedar off an infected site for more than one rotation. Port-Orford-cedar could then be reintroduced and grown through a rotation, provided that *P. lateralis* is not also reintroduced.

Infected stands should be disturbed

as little as possible prior to final harvest. Trione (1959) found that the rate of spread in disturbed stands is almost twice that of undisturbed stands. The exclusion of livestock and vehicles from infected stands will prevent soil movement. Unless the whole stand has died it should not be entered until final harvest.

Although these guidelines represent a minimal effort to slow the rate of spread of the disease they have yet to be adopted by all landowners. Even when used, fungicides, genetic breeding, and slightly altered management practices are incapable of eliminating the disease. Stronger actions are needed to successfully protect the tree.

One such action was recommended by Kliejunas and Adams (1980), who suggest that managers initiate quarantines to prevent or slow the spread of the fungus. Managers have looked upon this as only a suggestion, and it has never been implemented.

How would a quarantine work to prevent the spread of *P. lateralis*? Roth (1973) proposed a specific strategy to be incorporated in a forest plan to insure cedar production. He divided forests into protection units containing cedar production sites and surrounded by a "barrier forest" of non-susceptible tree species.

The cedar production sites would contain stands with Port-Orford-cedar as the major component. These stands would be located above roads and streams, along ridge tops, and separated from each other by stands without cedar. These sites would be managed intensively to replace cedars removed in unprotected sites.

The protection unit as a whole would "be located so as not to receive surface water from any land having a lower intensity of protection from root rot [and] accessible only by a road subject to effective traffic control." The protection unit should be composed of an

entire watershed and identified on a map and on the ground.

The barrier forest consists of non-susceptible species and was to be used to "buffer the protection units from heavily infected or unprotected cedar stands that are beyond the manager's resources or jurisdiction." However, Dr. Roth no longer feels that the barrier forest can be successful since the

fungus is wide-spread throughout the range of the cedar.

Instead, the strictures on activities within the protection units will have to be much greater than Roth originally suggested. While some areas might be experimentally managed as production sites, more areas will have to be protected from any management at all.



Forest Planning and *P. Lateralis*

The Siskiyou and Six Rivers National Forests are now preparing ten-year land and resource management plans as required by the National Forest Management Act of 1976. These plans should take into consideration the effects of timber and forest management on *Phytophthora* root rot and Port-Orford-cedar and propose strategies to protect the cedar.

However, the plans, which are soon to be submitted to the public in draft form, do nothing of the kind. Neither the cedar nor the fungus are more than mentioned in either plan. No disclosure is made of the relationship between timber management and the spread of the disease. No standards or guidelines are aimed at reducing that spread.

This is true in spite of the fact that Forest Service planning regulations include the following requirement:

Timber harvest and other silvicultural treatments shall be used to prevent potentially damaging population increases of forest pest organisms. Silvicultural treatments shall not be applied where such treatment would make stands susceptible to pest-caused damage levels inconsistent with management objectives [36 CFR 219.27 (c)(7)].

Another requirement of the National Forest Management Act is for diversity in the forest. The Act requires the Forest Service to provide

for steps to be taken to preserve the diversity of tree species similar to that existing in the region controlled by the plan [§6(g)(3)(B)].

This section makes clear that actions which reduce natural diversity, particularly the diversity of tree species, are allowed only under exceptional circumstances and when fully justified by a need to meet multiple-use objectives. The normal situation will be that natural diversity is preserved.

Port-Orford-cedar cannot be assured a place in the forest stand unless forest plans address the way management practices affect the incidence of *Phytophthora* root rot. Major steps to preserve Port-Orford-cedar in the forest are needed to meet the diversity requirement of NFMA.

In spite of these planning requirements, forest planners are doing little to solve the problem. Interviews with planners and silviculturalists on the Six Rivers and Siskiyou National Forests revealed that the Forest plans for those two forests will do little more than mention the problem.

The Forest Service and other land managers have opportunities to reduce damage from the disease. Commercial thinnings and salvage operations can be designed to minimize damage. Steam-cleaning of logging equipment and logging trucks can help slow the spread of the fungus into new watersheds. But, even the most careful operations run the risk of spreading the disease. Any road construction into new, uninfected watersheds is almost certain to lead to contamination of Port-Orford-cedar in those watersheds.

At the moment, no precautions are being taken to restrict the movement of *Phytophthora lateralis* into uninfected watersheds. After watching the steady movement of the fungus over the past thirty years, one would hope that measures have been taken to restrict any further movement. To date, none have been taken. The attitude of both the Six Rivers and Siskiyou National Forests is the disease cannot be stopped, and the only hope is the development of a resistant cedar. Such an attitude seems inconsistent with long range planning of what has been called the most valuable tree in Oregon.

At the same time, the Forest Service is going forward with activities which

will spread the disease to the remaining uninfected areas. A number of roadless areas identified during and prior to the RARE II planning effort contain uninfected stands of Port-Orford-cedar. None of these were proposed for Wilderness or Further Planning, and sales are now being planned in many of them.

For example, the Grassy Knob Roadless Area, in the Siskiyou National Forest, includes some relatively large drainages which contain Port-Orford-cedar and are unentered by roads or timber harvests. The largest of these is the Dry Creek watershed, of which perhaps 8,000 acres contain no roads and is likely to be uninfested. Although Grassy Knob was proposed for Wilderness in a bill introduced in Congress in 1982, the Forest Service is planning two sales in the area which will be almost certain to infect the entire drainage.

The Siskiyou and Six Rivers Forest Plans must do much more than simply mention the root rot. They must include standards and guidelines to insure that the rot will not spread. In addition, the planning process should allocate a number of uninfected areas to a roadless, non-timber management category to insure that these areas, at least, are not infected.

These areas should be well dispersed to insure protection of a wide variation of Port-Orford-cedar. As Silen (1982) has described, a species of tree is not genetically homologous throughout its range, but instead is precisely adapted to the local conditions found in each part of the range. "When local seed from a single locale of the native species is used to plant a large parcel of cleared land," says Silen, "the seed can theoretically be precisely adapted only to some single locale of the continuum."

This precise adaptation is important to forest managers because trees which are not precisely adapted to the site on which they are growing will have lower

survival and slower growth. Reconstitution of a lost gene pool will be very difficult if it is possible at all. In order to insure that the gene pool for Port-Orford-cedar, which grows on a wide variety of environments and thus must have a wide range of precisely adapted genotypes, is not lost, many diverse areas growing Port-Orford-cedar should be dedicated to protection of the species.

To insure protection from accidental infection the areas should be fairly large. They should include not only the stand of Port-Orford-cedar (or more likely, Port-Orford-cedar mixed with other species) but the entire subdrainage containing the stand. No roads should be allowed in or near the top of the subdrainage. The smallest subdrainages which may qualify on the Siskiyou and Six Rivers National Forests are generally about 500 to 1,000 acres in size.

Many such subdrainages would qualify for this status. These would include, for example, subdrainages of Dry Creek, Lawson Creek, Cedar Creek, and the Winchuk River in the Siskiyou National Forest.

Port-Orford-cedar protection areas would serve several purposes. First, they would provide a genetic storehouse available to the future. This storehouse could be tapped for planting precisely adapted genotypes in appropriate environments of previously infected areas which have been found to be no longer infected.

The Port-Orford-cedar protection areas could also play an important role in solving the root rot problem by providing a continuing source of genetic material which might prove resistant to the disease. Finally, if the root rot problem is ever solved through genetic or other means, the gene pool provided by the Port-Orford-cedar protection areas would be available to reestablish Port-Orford-cedar throughout its natural

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