Phytophthora lateralis **System:** Terrestrial

Kingdom	Phylum	Class	Order	Family
Fungi	Oomycota	Peronosporea	Peronosporales	Peronosporaceae

Common name Port Orford-cedar root disease (English), cedar root disease (English), root rot of *Chamaecyparis* (English), Port-Orford cedar root rot (English)

Synonym

Similar species

Summary *Phytophthora lateralis* is the causal agent of a serious root disease of Port Orford-cedar (*Chamaecyparis lawsoniana*), an ecologically and economically important tree. It advances quickly and can kill large trees within several years. The disease has devastated the ornamental planting and timber industry of Port Orford-cedar throughout the Pacific Northwest causing losses of millions of dollars. In natural ecosystems *P. lateralis* reduces populations of this important tree in riparian areas, which may have flow on effects to terrestrial and aquatic life. Control efforts are focused on reducing spread of this pathogen via roads, and the development of resistant populations.

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Species Description
Phytophthora lateralis is a water mould (Oomycetes) that infects the root system of Port Orford-cedar, also known as Lawson's cypress (*Chamaecyparis lawsoniana*). Young hyphae lack cross-walls (coenocytic), but may become septate in older cultures. Mycelium is usually smooth but occasionally snarled or tuberous. The sporangia are ovoid, ellipsoid or obovoid, colourless, non-papillate, 20-60 µm long, 12-20 µm wide. Sporangia are borne on simple sporangiophores and germinate to produce either zoospores or hyphae in water. Mature sporangia contain 25-40 zoospores, which are laterally biflagellate and 10-12 µm in diameter. Zoospores form cysts, which germinate to produce hyphae. Asexual chlamydospores which arise as lateral swellings on the hyphae (a distinctive feature in contrast to the clustered chlamydospores of other non-papillate species of *Phytophthora*, and hence the species Latin name) are 20-77 µm in diameter and often sessile. *P. lateralis* is homothallic and sometimes produces oogonia with paragynous antheridia in single culture. Oogonia are rare, but when observed are smooth, spherical and terminal and 33–50 µm in diameter. Oospores are 28-46 µm in diameter and pigmented (Erwin & Ribeiro, 1996 in EPPO, 2009; Tucker & Milbrath, 1942).\r\n
The first symptoms of the disease in *C. lawsoniana* involve gradual colour changes in the foliage: to yellow, bronze and finally a light brown to tan colour as the foliage dries out. In cool, damp weather this colour change sequence may take two to three months, whereas in hot and dry weather it may only take two to three weeks (Tucker & Milbraith, 1942). These symptoms are uniform throughout the tree if the infection begins in the roots, but localized on individual branches in the case of aerial infection (Erwin & Ribeiro, 1996). The pathogen generally invades the roots, killing tissues as it advances, and causing a brown and water-soaked appearance. The infection eventually spreads to the root crown of the tree and causes girdling of the trunk and ensuing foliar changes described (Tucker & Milbraith, 1942). Removal of the outer bark from the infected root collar shows a sharp line of demarcation between the white healthy tissue and the dark brown dead tissue; a black resinous line can sometimes be seen on the cambium (Tucker & Milbraith, 1942). Eventually plants die; infected seedlings die rapidly but it may take several years for larger trees to die. Pacific yew (*Taxus brevifolia*) shows similar but less severe symptoms (EPPO, 2009).

Notes
Direct isolation of *Phytophthora lateralis* from soil, even on selective media, is generally not successful probably due to low numbers of propagules (Hamm & Hansen, 1984). However various baiting methods have been developed (e.g. Hansen & Hamm, 1984; Tsao et al. 1995a in EPPO, 2009), using plant tissue of its host *Chamaecyparis lawsoniana*. Infected tissue is then plated onto selective media, from which *P. lateralis* can be isolated from (Hamm & Hansen, 1984). More recently PCR-based protocols have been developed for rapid identification of the pathogen (Winton & Hansen, 2001; Schena *et al*., 2008) and ELISA tests have been developed, but need refining (Greenup, 1998 in EPPO, 2009).

Lifecycle Stages
Phytophthora lateralis infects roots of its hosts in the same way as other *Phytophthora* spp. Zoospores are produced in sporangia, and are released under suitable conditions (moist and temperatures of 10 to 20 °C). Zoospores are flagellated and can travel short distances autonomously, or may be dispersed by water. Zoospores may also encyst, and the cysts may be further transported by water and have a further opportunity to infect a susceptible root (EPPO, 2009). \r\n
Zoospores initiate the infection in the fine roots (Kliejunas, 1994 in EPPO, 2009). The mycelium then spreads throughout the inner bark and cambium of the root system to the root collar. Infection spreads upwards in an irregular triangle. Under favourable conditions, the pathogen may be splashed from soil onto foliage, and produce sporangia on the foliage. These sporangia may be dispersed by wind and rain, and aerial spread is possible (Trione & Roth, 1957; Trione, 1959 in EPPO, 2009). *P. lateralis* also forms chlamydospores, thick walled resting spores, which persist in the soil and in leaf or root debris, allowing long-term survival and overland movement of the pathogen (EPPO, 2009). *P. lateralis*, which is homothallic, sometimes also produces oospores, which are similarly hardy and can survive long distance travel (Kauffmann & Jules, 2006).\r\n\r\n
P. lateralis can survive and remain infectious in absence of living host tissue for at least 7 years in a range of natural environments (Hansen & Hamm, 1997).

Habitat Description
In its invasive range in North America the main host of *Phytophthora lateralis* is Port Orford-cedar (*Chamaecyparis lawsoniana*: Cupressaceae). It was originally thought to be host specific to this species, but Pacific yew (*Taxus brevifolia*: Taxaceae) was reported as a host in 1991 (DeNitto & Kliejunas, 1991 in EPPO 2009). However Pacific yew is less susceptible to *P. lateralis* than Port Orford-cedar (Murray & Hansen, 1997). There have also been one off reports of it occurring on other *Chamaecyparis* species. Its native host has not been confirmed but recent evidence suggests its native range is Taiwan (Brasier *et al*., 2010).
Artificial infection has also been achieved in inoculation experiments with *Rhododendron* species (Hoitink & Schmitthenner, 1974 in EPP0, 2009), *Pseudotsuga menziesii* (Pratt *et al*., 1976 in EPPO, 2009) and *Chamaecyparis nootkatensis* (Kliejunas, 1994 in EPP0, 2009). This suggests that *P. lateralis* may be carried latently by some plants which hare not natural hosts (EPPO, 2009).
There are a number of published reports of this oomycete infecting other species. However reports on hosts other than cedars (*Chamaecyparis* spp.) and *T. brevifolia* are considered to be misidentifications of other *Phytophthora* spp. (CSL, 2006; EPPO, 2009).
Infection can occur at temperatures of 3-25 °C, but temperatures of 15-20 °C are optimal. Growth is restricted at 25 °C and inhibited entirely at 30 °C (Sinclair *et al*., 1987 in EPPO, 2009; Tucker & Milbraith, 1942).

General Impacts
Ecosystem change: Port Orford-cedar is an important tree in its native range (coniferous forests of southwestern Oregon and northern California) where it is found along streams and in areas with year-round seepage, and is often the dominant riparian tree especially in the southern part of its range. It tolerates ultramafic soils in the region, recycles calcium to surface soils and is often associated with rare plant species. In riparian areas it is important for providing shade to streams and stabilising banks. Wood from dead trees provides diverse habitat for salmonid fish and other aquatic life (Hansen *et al*., 2000). \r\n
Port Orford-cedar has been drastically reduced or eliminated from large portions of riparian environments and wetlands by *P. lateralis*. Reduction of this important tree can have catastrophic impacts on streamside plant communities and aquatic ecology. Particularly on ultramafic soils, where Port Orford-cedar may be the only tree species able to grow, consequences to stand structure can be particularly pronounced (Hansen & Hamm, 1997; Hansen, 1999; Hansen *et al*., 2000). Loss of old-growth stands of Port Orford-cedar can have negative impact on wildlife species that require old-growth characteristics (Hansen *et al*., 2000). Additionally, the size and age class of cedar has shifted as a result of the disease and forest harvest, with large old trees being replaced by smaller, young trees (Hansen *et al*., 2000).\r\n
While Pacific yew is also an important forest species, providing food and cover for wildlife and shade and stability for streams, it is less susceptible to *P. lateralis* and mortality is low (Hansen *et al*., 2000).\r\n\r\n
Economic: Port Orford-cedar or Lawson's cypress is grown as an ornamental tree in Europe and the Pacific Northwest. Since the incursion of *P. lateralis* the multi-million dollar ornamental nursery production in Washington and Oregon has largely been destroyed (Hansen & Hamm, 1997; Hansen *et al*., 2000). Port Orford-cedar trees in parks in British Columbia experience significant annual losses due to *P. lateralis* with a high cost of replacement (Utkhede *et al*., 1997). \r\n
Port Orford-cedar has been one of the most valuable commercial timbers in the world, with a value on the export market of up to ten times that of Douglas-fir (*Pseudotsuga menziesii*) (Hansen *et al*., 2000). \r\n\r\n\r\n
Pacific yew is less susceptible to *P. lateralis*, and the pathogen is likely to have only limited impact on this tree. Unusual morality of Pacific yew has only been observed in areas where it grows in close proximity to Port Orford-cedar (Murray & Hansen, 1997).\r\n\r\n
Other: Social impacts include loss of business in nursery and forestry sectors, and effects on tourism and fishing due to forest closures (Hansen *et al*., 2000).

Management Info
Legislative: *Phytophthora lateralis* is on the EPPO A1 action list, meaning that countries at risk of invasion are recommended to regulate it as a quarantine pest. The European Union prohibits the import of *Chamaecyparis* plants. Other EPPO countries are recommended to establish similar measures (EPPO, 2009).
Preventative: The US Forest Service has established permanent and wet season road closures in areas with Port Orford-cedar. These closures are an important tool to stop the spread of *P. lateralis*, as transportation via roads has been identified as the primary method of spread. Other preventative methods include confining harvesting, road maintenance and other activities to the summer dry season; sanitation of vehicles and equipment before they reach uninfested areas; altering and diverting roads away from cedar areas; growing cedar on sites unfavourable for disease spread (Hansen *et al*. 2000; Hansen & Hamm, 1997; Jules *et al*., 2002).
In nurseries preventative measures include soil sterilisation, use of fungicides registered for use against *Phytophthora* root rots, disinfection of materials and preventing the introduction or movement of infested soil (EPPO, 2009).\r\n
Cultural: Methods that have been suggested to reduce *P. lateralis* infection include growing disease-free stock in uninfected soil, avoiding monocultures of Port Orford-cedar in windbreaks or hedges and ensuring adequate drainage (Utkhede *et al*., 1997). However the most commonly suggested and employed technique is the reduction of cedar density, especially in infected sites near roads (Goheen, 2000 in Jules *et al*., 2002). \r\n\r\n
Genetic resistance:\r\nFollowing observations of healthy trees in the midst of dead neighbours led Hansen *et al*. (1989) to demonstrate that heritable resistance to *P. lateralis* occurs in Port Orford-cedar. Since then a resistance breeding programme for Port Orford-cedar has been underway with the goal of providing resistant seedlings for forest regeneration.The programme has produced promising results and first generation resistant seedlings are now available (Oh *et al*., 2006; Sniezko, 2003; Sniezko, 2006). Resistance to *P. lateralis* offers the best chance of re-establishing Port Orford-cedar in areas where the pathogen is established and is important in long-term disease management. However, genetic resistance offers no protection for surviving stands of the cedar, and it will be hundreds of years before the resistant seedlings can replace the large old trees (Hansen *et al*., 2000). \r\n\r\n
Biological: Treating Port Orford-cedar with drench applications of the bacteria *Enterobacter aerogenes* (Strain B8) has shown some success. Diseased trees treated over four years in Vancouver, British Columbia had lower disease ratings and higher growth rates than water-treated controls (Utkhede *et al*., 1997). However this, or any other biological control method, have not been used in practice (EPPO, 2009).

Principal source: European and Mediterranean Plant Protection Organization (EPPO) 2009. *Phytophthora lateralis*. Bulletin OEPP. 39(1). APR 2009. 43-47.

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ALIEN RANGE

[1] CANADA
[1] FRANCE
[1] NEW ZEALAND
[4] UNITED STATES
[1] EUROPE
[1] NETHERLANDS
[3] UNITED KINGDOM

Red List assessed species 1: VU = 1;

Chamaecyparis lawsoniana **VU**

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