EPPO Datasheet: *Phytophthora lateralis*

Last updated: 2021-10-18

IDENTITY

Preferred name: *Phytophthora lateralis*
Authority: Tucker & Milbrath
Taxonomic position: Chromista: Pseudofungi: Oomycetes: Peronosporales: Peronosporaceae
Common names: root rot of Chamaecyparis
view more common names online...
EPPO Categorization: A2 list
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EPPO Code: PHYTLA

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Notes on taxonomy and nomenclature

Phytophthora lateralis is a rather uniform and distinctive species and its taxonomy has not been complicated by name changes. Unrelated species have been misidentified as *P. lateralis*, especially in work completed before molecular diagnostics were available (Hansen *et al.*, 1999; 2000; CABI 2021).

HOSTS

The evolutionary and geographic origins of *P. lateralis* were investigated in a number of studies. Four lineages were identified, the origins of which are not fully elucidated. Two of the lineages are considered to be indigenous in cloud forests of Taiwan on *Chamaecyparis obtusa* (Brasier *et al.*, 2010, 2012; Vettraino *et al.*, 2016).

The main host of *P. lateralis* is *Chamaecyparis lawsoniana* (Port Orford cedar). Other *Cupressaceae* such as several false cypresses (*Chamaecyparis* spp.), *Taxus brevifolia* (Pacific yew), *Thuja occidentalis* (Eastern white cedar), Common juniper (*Juniperus communis*, see FERA unpublished record, 2014; Peterson *et al.*, 2020) and Siberian cypress (*Microbiota decussata*), have also been reported as hosts (Brasier *et al.*, 2010; DeNitto & Kliejunas, 1991; Green *et al.*, 2013; Murray & Hansen, 1997; Peterson *et al.*, 2020; Schlenzig *et al.*, 2011, 2014) however, infections of such hosts usually occur in the vicinity of heavily infected Port Orford cedars (CABI, 2021). Further naturally infected host plant species are periwinkle (*Vinca* spp.) and petunia (*Petunia* spp., Forestry Research, 2021). Reports of *P. lateralis* naturally infecting some other hosts (Robertson, 1982) are considered to be misidentifications of other *Phytophthora* spp. such as *P. gonapodyides* (E. Hansen, Oregon, USA, 2006, pers. comm.). Artificial infection has been obtained in inoculation experiments with *Rhododendron* spp. (Hoitink & Schmitthenner, 1974), *Pseudotsuga menziesii* (Pratt *et al.*, 1976) and *Chamaecyparis nootkatensis* (Kliejunas, 1994). A comprehensive list of hosts including some doubtful species can be found in FERA, 2015.

Host list: *Chamaecyparis lawsoniana*, *Chamaecyparis obtusa*, *Chamaecyparis pisifera*, *Juniperus communis*, *Microbiota decussata*, *Petunia sp.*, *Taxus brevifolia*, *Thuja occidentalis*, *Vinca sp.*

GEOGRAPHICAL DISTRIBUTION

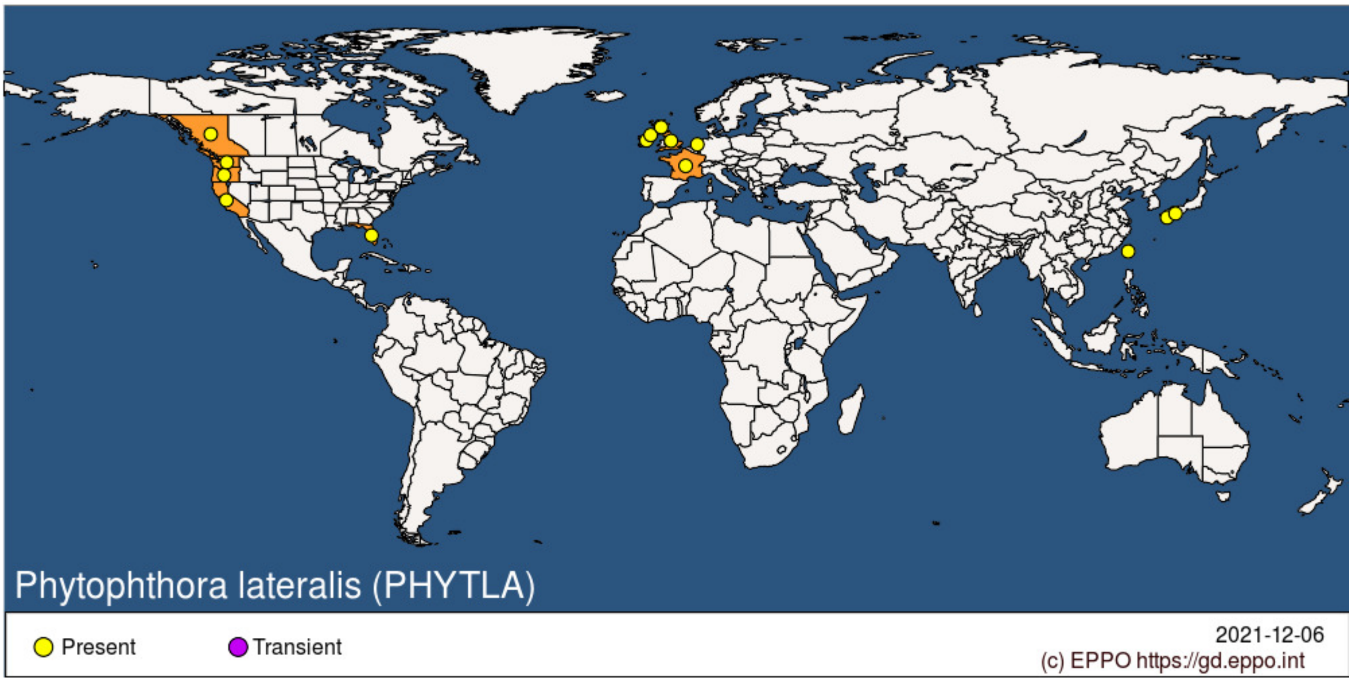
P. lateralis was first reported as causal agent of Port Orford cedar root disease in Washington State (USA) in 1923, and described and named by Tucker and Milbrath (1942), although by that time it had spread to other parts of Washington and to Oregon. By the 1950s, the pathogen was present in British Columbia, Canada (Atkinson, 1965). It also had reached the native range of *C. lawsoniana* in southwest Oregon. The pathogen was reported in California in 1981 (Kleijunas and Adams, 1981), and is now present in all parts of the Port Orford cedar range in these two states. Localized outbreaks were recorded in other regions of the North American continent (Washington, Florida; CABI 2021).

Since Asiatic species from the genus *Chamaecyparis* are resistant to the pathogen, the origin of the species was considered to be Asia (Sinclair *et al.*, 1987). Following this assumption expeditions to South East-Asian cloud forests resulted in the recovery of the species in forests of Taiwan from leaf litter of two native *Chamaecyparis* species (Brasier *et al.*,2010). Later on, the pathogen was isolated from symptomatic leaves of *C. obtusa* var. *formosana* in Taiwan (Webber *et al.*, 2012). Recently *P. lateralis* was identified from leaf litter of *Chamaecyparis* in evergreen forests of Japan (Jung *et al.*, 2021).

The introduction from Asia into North America during the first half of the 20^{th} century was therefore considered likely to be the reason for the impact of the pathogen to the highly sensitive Port Orford cedar (Brasier *et al.*, 2012).

In Europe *P. lateralis* was first recorded in 1998 in France, where it likely had been introduced with *C. lawsoniana* nursery plants (Hansen *et al.*, 1999). From 2005 on mortality of *C. lawsoniana* was observed in Brittany and in 2009 thousands of shelterbelts of this species over a 400-km^2 area were affected by the pathogen (Robin *et al.* 2010). In 2004 and 2010 the pathogen was recorded in the Netherlands, again on *C. lawsoniana* nursery stock (Meffert 2007; J. Meffert pers. comm.). In 2010 *P. lateralis* was identified from dying *C. lawsoniana* in Western Scotland (GB) and from 2010 on numerous outbreaks of the pathogen were recorded on woodland and amenity plantings of *C. lawsoniana* in England, Ireland as well as in Northern Ireland (Green *et al.*, 2013; O'Hanlon *et al.*, 2016). In Scotland *P. lateralis* was isolated from nursery plants of *C. lawsoniana* as well as *Thuja occidentalis* imported from continental Europe (Schlenzig *et al.* , 2011).

Four distinct lineages of *P. lateralis* are known, two of them from Taiwan J (TWJ), Taiwan K (TWK), one from North America (Pacific Northwest) and one from the United Kingdom (Brasier *et al.*, 2012). The American strains represent a further lineage originating from strains that are likely to be from an unknown Asian source (Vettraino *et al.*, 2016). From North America, the pathogen was introduced into Europe (same lineage). The lineage found in the United Kingdom could have originated from hybridisation (Vettraino *et al.*, 2016).



EPPO Region: France (mainland), Ireland, Netherlands, United Kingdom (England, Northern Ireland, Scotland)
Asia: Japan (Kyushu, Shikoku), Taiwan
North America: Canada (British Columbia), United States of America (California, Florida, Oregon, Washington)

BIOLOGY

P. lateralis initially parasitizes roots. In roots of *C. lawsoniana*, the pathogen is present as mycelium, from which sporangia are formed. Under suitable conditions (i.e. available moisture and temperatures of 10 –20°C), the sporangia release zoospores that swim autonomously, or can also be carried by natural movement of soil water. Sporangia are mainly not caduceus however a small proportion are able to break off (Brasier *et al.*, 2010, Hansen *et al.*, 1999, Webber *et al.*, 2012). The zoospores are subject to chemotactic attraction by susceptible host rootlets, to which they attach, then, germinate and infect (Kliejunas, 1994). They may also encyst, and the cysts may be transported by water to infect further roots. *P. lateralis* mycelium spreads through the inner bark and cambium of the root system to the root collar, which can result in the eventual death of the host. Infection can occur at temperatures of 3–25°C (optimum 15–20 °C, Sinclair *et al.,* 1987).

Sometimes foliage is infected. This refers to *C. lawsoniana* but also to *C. obtusa* (Webber *et al.*, 2012). Under favorable conditions (high humidity and mild temperatures), the pathogen produces sporangia on the foliage, and aerial spread is possible (Robin *et al.*, 2010; Trione & Roth, 1957; Trione, 1959; Webber *et al.*, 2012).

P. lateralis mycelium is able to grow at temperatures between 3 and 25 °C and able to survive at low levels in frozen organic matter for at least 16 weeks (Hall, 1991; Ostrofsky *et al*., 1977).

Vegetative growth is inhibited above 30 °C however chlamydospores of *P. lateralis* are likely to enable survival at these temperatures (Tucker & Milbrath, 1942).

Chlamydospores persist in the soil and in leaf or root debris, ensuring the long-term survival and overland movement of the pathogen. The homothallic species sometimes also produces oospores, which can survive in a similar manner.

T. brevifolia is less susceptible (Murray & Hansen, 1997). Surveys have shown that *T. brevifolia* is only killed by *P. lateralis* where it was growing along streams in close association with dead or dying *C. lawsoniana* (Hansen *et al.*, 2000). This suggests that a high level of zoospore inoculum is needed to obtain infection of this host.

DETECTION AND IDENTIFICATION

Symptoms

P. lateralis causes symptoms which are typical for the genus *Phytophthora*. The first above-ground symptoms of infection of *C. lawsoniana* are a slight wilting of the foliage, which undergoes a gradual colour change to yellow, bronze and finally to a light brown or tan colour as it dries out (Erwin & Ribeiro, 1996). These symptoms are uniform throughout the foliage if only the roots are infected, but localized in the case of aerial infection.

P. lateralis primarily infects the roots of Lawson cypress and necroses eventually extend up into the lower stem causing girdling of the crown. This leads to yellowing, browning and drying of the foliage (Erwin & Ribeiro, 1996). At the root collar, apart from some resin bleeding, hardly any shape and colour changes of the bark surface are visible, so detection requires cutting into the bark to track phloem necroses below it (EPPO, 2015).

Infected roots appear water-soaked and are usually deep cinnamon brown. Removal of the outer bark from the infected root collar can show a sharp line of demarcation between the white healthy tissue and the dark brown dead tissue; a black resinous line can be seen in the cambium (Kliejunas & Adams, 2004). This symptom distinguishes the disease from otherwise similar symptoms caused by *Phytophthora cinnamomi* (Erwin & Ribeiro, 1996). Trees weakened through infection are commonly attacked by bark beetles (*Phloeosinus* spp.). Infected seedlings die rapidly, but with larger trees this can take several years. Root infections kill the tree more quickly than aerial infections.

Aerial infections also cause a discoloration of the foliage, as well as death of branches sometimes with small cankered areas (resin bleeding) and brown cortical lesions (Robin *et al.*, 2010; Green *et al.*, 2013).

T. brevifolia shows similar but less severe symptoms. Hoitink & Schmitthenner (1974) found *P. lateralis* to cause slight damage when they inoculated rhododendron roots. Thus a certain possibility remains that *P. lateralis* can infect certain plants other than its major hosts, causing only minor damage.

On *C. obtusa*, which is very likely to be one of the native hosts, infections from *P. lateralis* cause only mild symptoms on leaves and roots (Webber *et al.,* 2012).

Morphology

P. lateralis can be isolated from pieces of root and stem tissue taken from the advancing edge of a necrosis (EPPO, 2015; Tucker & Milbrath, 1942). Media for isolation of *Phytophthoras* are usually semi-selective. A commonly used medium is V8 agar (EPPO, 2015, modified by Jung *et al.*, 1996). Depending on the medium used, growth rate of the mycelium differs see EPPO (2015).

The mycelium is colourless, usually more or less smooth, composed of hyphae up to 8 ?m width becoming septate in older cultures. Production of chlamydospores (resting spores) is abundant in many media (Englander & Roth, 1980; Erwin & Ribeiro, 1996). The chlamydospores are on average 40 ?m in diameter. For zoosporangia-production duration of at least 12 hrs light exposure is essential (EPPO, 2015). The sporangia are ovoid, ellipsoid or obovoid and colourless. They are non-papillate and measure on average 26 ?m x 15 ?m. Sporangia show preformed pedicels and a slight tendency to become detached (caduceus) which indicates the adaption to aerial dispersal. In water they produce either zoospores or hyphae. The laterally biflagellate kidney-shaped zoospores are 10–12 ?m in diameter, produce hyphae and can form cysts. *P. lateralis* is homothallic and produces paragynous antheridia in single culture. Oogonia are smooth, spherical and terminal and 33–50 ?m in diameter. Oospores are on average 40 ?m in diameter and pigmented (Erwin & Ribeiro, 1996; Hall, 1991; Tucker & Milbrath, 1942). For oospore-production in culture see Erwin & Ribeiro (1996).

Detection and inspection methods

Detection of foliage symptoms in a stand should be followed by the search for a tree in a slight to medium stage of decline. A careful inspection of the bark of this tree for lesions at the root collar should then be performed. For this, the outer bark is cut off using a mallet or chisel to expose the inner bark tissues. Several samples should be taken at the leading edge of a necrosis, containing both dead and living bark tissues. The samples should contain both bark and the outermost wood layers and measure 5-10 cm². Small parts of these samples can be taken for an ELISA-test (lateral flow device), however this gives only information on the presence or absence of the genus *Phytophthora* in the tissue. In addition, cross-reactions with some *Pythium* species are possible. The latter especially concerns samples taken from tissues near the soil level (stem base).

Samples should put in a sealed plastic bag, preferably with a moist tissue, labelled and sent or brought as quickly as possible (not later than the next day) to a diagnostic laboratory (Forestry Research, 2021).

Detection of *P. lateralis* in the rhizosphere requires soil sampling. The procedure follows the one used for many Phytophthoras (Jung *et al.*, 1996). Various baiting methods are available for *Phytophthora*, the one developed by ANSES is described in detail in the EPPO diagnostic protocol for *P. lateralis* (EPPO, 2015).

Identification of *P. lateralis* can be achieved by morphological and molecular methods.For morphological identification, the laterally-attached chlamydospores can be considered as a main criterion. Molecular techniques, preferably performed if morphological methods yield unclear results, comprise conventional and real-time PCR. The EPPO diagnostic protocol for *P. lateralis* provides further information and recommendations on how to detect and identify the pathogen (EPPO, 2015).

PATHWAYS FOR MOVEMENT

Natural short-distance dispersal can be plant-to-plant, aerial, or through soil and water. Below-ground movement is primarily by zoospores, which may be carried down slopes by water movement. Plant-to-plant contact can be above or below ground. Cases are known where *C. lawsoniana* has undergone abundant intraspecific root grafting, which has served as a path for vegetative spread of *P. lateralis* (Gordon & Roth, 1976). Aerial spread is the reason for foliage infections, and this is typical for rainforests in Taiwan. It can be the result of contact between adjacent foliage or by wind- or rain splash-spread of caduceus sporangia and spores (Webber *et al.*, 2012). Occurrence of lesions on the upper branches and stem at outbreaks of *P. lateralis* on *C. lawsoniana* in France and the United Kingdom is further evidence of aerial dispersal (Robin *et al.* 2010).

A comprehensive study of the disease in Southwest Oregon and Northwest California by Jules *et al.* (2002)

concluded that dispersal by vehicles had the greatest effect in spreading the pathogen to uninfested areas. This refers especially to logging trucks and off-road vehicles according to the high volume of soil sticking to the wheels. Spread on boots and mountain bike tires has also been suggested and probably contributes to new infections locally. Waterways were also observed to be pathways of spread, since hosts at sites with large or persistent streams were more likely to become infected (Jules *et al.*, 2002). Long-distance movement of inoculum, particularly human-mediated movement of infested soil; mainly involves chlamydospores and oospores. Zoospores are more important for short-distance dispersal.

In international trade, the most likely pathways for *P. lateralis* would be plants for planting of *C. lawsoniana*. The pathogen very likely reached the USA and later Europe via this pathway (Hansen *et al.* 1999, Webber *et al.*, 2011).

However, plants for planting of non-host plants with contaminated soil attached, or contaminated soil alone, and even footwear of tourists should be considered as potential pathways (EPPO, 2006).

PEST SIGNIFICANCE

Economic impact

In the United States decline from *P. lateralis* caused a serious impact to trade of one of the most valuable commercially harvested conifer timbers in the world. By the end of the last century, Port Orford cedar timber yielded prices ten times higher than the wood of *Pseudotsuga menziesii* (Hansen *et al.*, 2000). At present, main timber exports from the United States go to Japan for production of coffins, toys and for repair and construction of houses, shrines and temples. However, timber production is minor in economic importance compared to the value of nursery stock. The Port Orford cedar is produced in many countries in the Northern hemisphere as well as in New Zealand mainly for ornamental purposes. Therefore, the greatest loss in commercial forestry results from the death of young trees. In addition to social impacts through loss of business in nursery and forestry sectors, tourism and fishing have been affected due to forest closures (Hansen *et al.*, 2000). In addition, *P. lateralis* has destroyed large numbers of *C. lawsoniana* within the natural range of the species, where it grows in riparian habitats, with large trees providing shade and long-lasting protection to waterways. *C. lawsoniana* is on the International Union for Conservation of Nature (IUCN) red list of worldwide endangered species (Farjon, 2013).

Control

Control of *P. lateralis* comprises preventive and curative measures. In nurseries, the first focus should be prevention of the introduction or movement of infested soil or infected plant material. Plants should be produced using *Phytophthora*-free substrate, preferably in containers. Irrigation with contaminated water must be avoided by methods also used for other *Phytophthora* species. Hygienic measures should involve also surface-sterilisation of equipment, placement of potted plants above ground to avoid contamination from surrounding soil and separation of the plantlets from other plants being produced. For field-grown plants, in addition a good soil drainage system to prevent stagnant wet soil is required. All measures should be accompanied by regular and repeated checks for contamination with *Phytophthora* spp.

For curative purpose, a range of fungicides is available for use on nursery stock in ornamental plant production. Several active ingredients are registered for use as drench treatments against *Phytophthora* root rots. However, the main problem is that the use of fungicides may only result in symptom suppression instead of pathogen eradication and resistance may arise (FERA, 2015).

For control of *P. lateralis* in plantations, cultural measures were recommended by the Federal Agencies of the United States managing *P. lateralis* in the forests of the Pacific coast in order to prevent further spread of the pathogen (Greenup, 1998; Hansen *et al.*, 2000). These include: conducting forestry operations in summer months; cleaning of vehicles and equipment before leaving infested areas and entering areas that are not infested; wide spacing of susceptible hosts and growing susceptible hosts on sites unfavorable for pathogen spread (i.e. at raised elevations, away from waterways and roads); regulating the harvesting of *C. lawsoniana* timber; road closures in infested areas. In addition to these measures, roads were engineered in ways to reduce their risk as a pathway for spread of the pathogen, and logging systems were modified to reduce the need for and extent of new roads.

Promising results have been obtained in a resistance breeding program for *C. lawsoniana* in the United States (Hansen *et al*., 2000). Recent trials with plants of *C. lawsoniana* resistant to *P. lateralis* showed that progeny of trees showing natural resistance can be used to establish resistant forest and ornamental stands (Sniezko *et al*., 2020).

Phytosanitary risk

P. lateralis is extremely damaging to *C. lawsoniana* in nurseries, plantations and natural vegetation in the Pacific regions of United States and Canada where it has been introduced and spread. The disease results in extensive tree mortality. In the EPPO region, the endangered area is mainly the Atlantic parts of Western Europe, which have a wet maritime climate, but extends to conifer nurseries in any part of the region. The phytosanitary risk mainly concerns *C. lawsoniana*, which is one of the most important ornamental conifer species for the nursery trade. In contrast to the situation in North America, *C. lawsoniana* is infrequently grown as a timber tree in the EPPO region, though there are plantations in Northern Spain and Portugal which would be at risk. From this, it can be concluded that risk for spread is likely to be relatively slow through natural processes but rapid when associated with plants for planting. Expected economic, environmental and social impacts from *P. lateralis* are regarded as small to medium, with economic impacts likely to be highest for producers of ornamental plants of *Chamaecyparis* (FERA, 2015).

In practice, the risk of new introductions of *C. lateralis* into the EPPO region is reduced, because the endangered area mainly falls within the European Union, which prohibits the import of plants of *Chamaecyparis*, and also restricts the import of growing medium, and of trees and shrubs generally, from non-European countries.

Although it is recognized that *T. brevifolia* is also a (less susceptible) host of *P. lateralis*, this species is only found in botanical collections in the EPPO region, and has no commercial importance in production or trade.

PHYTOSANITARY MEASURES

In 2006 *P. lateralis* was added to the EPPO A1 list of pests recommended for regulation, and endangered countries are therefore recommended to regulate it as a quarantine pest. The main risk of its introduction is from the import of infected plants for planting of *C. lawsoniana*, of other plants which through not hosts might carry inoculum of *P. lateralis*, and of infested soil. The existing measures in the European Union (EU, 2000) include prohibition of the import of plants for planting of *Chamaecyparis*, severe restrictions applied to the import of trees and shrubs from non-European countries, and the measures concerning growing medium containing soil. EPPO Standard PM 8/2 *Coniferae* recommends to EPPO Member Governments the phytosanitary measures which they should use or require for *Coniferae* plants and plant products moving in international trade in order to prevent the introduction and spread of pests including *P. lateralis*. (EPPO, 2018).

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