European and Mediterranean Plant Protection Organization
Organisation Européenne et Méditerranéenne pour la Protection des Plantes

Data sheets on pests recommended for regulation
Fiches informatives sur les organismes recommandés pour réglementation

Phytophthora lateralis

Identity

Name: *Phytophthora lateralis* Tucker & Milbrath
Taxonomic position: Chromista, Oomycota, Oomycetes, Pythiales, Pythiaceae
Common name(s) of the disease: root rot of *Chamaecyparis*
Special notes on taxonomy or nomenclature: *Phytophthora lateralis* belongs to Waterhouse group V and was in Clade 8a in the phylogenetic analysis of Cooke *et al*. (2000). Ribosomal DNA sequencing of the internal transcribed spacer region indicated that *P. lateralis* is most closely related to *Phytophthora ramorum* (Werres *et al*., 2001; Martin & Tooley, 2003)
EPPO code: PHYTLA
Phytosanitary categorization: EPPO A1 List no. 337.

Hosts

The main host of *P. lateralis* is *Chamaecyparis lawsoniana* (Lawson's cypress). *Taxus brevifolia* (Pacific yew) has also been reported as a host (DeNitto & Kliejunas, 1991). *P. lateralis* is thought to have been introduced, from an unknown origin, into North America, where it encountered the native *C. lawsoniana*; if this is so, it may have a native host, as yet unknown, in its area of origin (possibly another *Chamaecyparis* sp. or other member of the *Cupressaceae*). Although there are isolated records of infection of other *Chamaecyparis* spp. (*C. formosensis*, *C. obtusa*), it seems clear, from the absence of any published information, that these plants, which are also widely cultivated, do not suffer significant damage or loss due to *P. lateralis*.

There are reports of *P. lateralis* naturally infecting other hosts, including in particular other conifers, ornamental *Ericaceae*, and *Actinidia* spp. (Robertson, 1982). These are all considered to be misidentifications of other *Phytophthora* spp., notably *P. gonapodyides*. 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). This opens the possibility that *P. lateralis* might be carried latently by, and survive on, plants which are not natural hosts.

Geographical distribution[1]

EPPO region: France (found but not established), Netherlands (found but not established)
North America: Canada (British Columbia), USA (California, Oregon, Washington)
EU: France (found but not established), Netherlands (found but not established).
Note: *P. lateralis* was first reported in Washington State (US) in 1923, and described and named by Tucker & Milbrath (1942), by which time it had spread to other parts of Washington and to Oregon. By the 1950s, the pathogen was present in British Columbia (Atkinson, 1965) and by 1980 in North-Western California (Kliejunas & Adams, 1981). Though there have been reports in other parts of North America, the Pacific seaboard appears to be the only area in which the pathogen is established. Reports in Europe are believed to be incursions (of unknown origin), and in New Zealand misidentifications. Since *P. lateralis* is considered to be an exotic introduction to North America from an unknown source (Hansen *et al*., 2000), it may be presumed that it exists elsewhere, most possibly in some other area of the Pacific Rim.

Biology

P. lateralis parasitizes roots in the same way as other *Phytophthora* spp. In an established infection on a root of *C. lawsoniana*, *P. lateralis* 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 can swim a few cm autonomously, or also be carried by natural movement of soil water. The zoospores make contact with and attach to susceptible host rootlets, germinate and infect (Kliejunas, 1994). They may also encyst, and the cysts may be further transported by water and have a further opportunity to infect a susceptible root. *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 but temperatures of 15–20°C are optimal (Sinclair *et al*., 1987).

[1]An updated geographical distribution can be viewed on the EPPO website.

The foliage of *C. lawsoniana* is sometimes infected, if it comes into contact with the ground. Infection spreads upwards in an irregular triangle. Under favourable conditions, the pathogen produces sporangia on the foliage, and aerial spread is possible (Trione & Roth, 1957; Trione, 1959).

The mycelium of *P. lateralis* forms chlamydospores which persist in the soil and in leaf or root debris, ensuring the long-term survival and overland movement of the pathogen. *P. lateralis*, which is homothallic, sometimes also produces oospores, which can similarly survive. In buried pot tests, *P. lateralis* was recovered at a low frequency after seven years, but the pathogen was killed in days when infected roots were exposed to the sun on the soil surface (Hansen & Hamm, 1996).

The other known host, *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

The first above-ground symptoms of infection of *C. lawsoniana* are 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.

Infected roots appear water-soaked and are usually a deep cinnamon brown colour. Infection eventually spreads up to the trunk and causes girdling of the crown (Erwin & Ribeiro, 1996). 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 on 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 it can take several years for larger trees to die. Root infections kill the tree more quickly than aerial infection.

T. brevifolia shows similar but less severe symptoms. Hoitink & Schmitthenner (1974), who reported that they recovered *P. lateralis* from rhododendron crowns, found it to cause slight damage when they inoculated rhododendron roots, similar to that caused by other minor root pathogens of rhododendron such as *Phytophthora citrophthora*, *Phytophthora gonapodyides*, *Phytophthora megasperma* and *Phytophthora parasitica*. It is not now believed that the fungus they recovered was *P. lateralis*, but the possibility remains that *P. lateralis* can infect certain plants other than its major hosts, causing only slight damage.

Morphology

P. lateralis is readily isolated from pieces of root and stem tissue taken from the advancing edge of symptoms of the disease (Tucker & Milbrath, 1942). It has a slow growth rate but it can be grown on cornmeal agar, potato dextrose agar, oatmeal agar (Tucker & Milbrath, 1942) and V8 sterol agar (Englander & Roth, 1980). Production of chlamydospores is most abundant in the absence of light in V8 broth with 20 $\mu g\ mL^{-1}$ or β-sitosterol at 24–25°C (Englander & Roth, 1980). Maximum sporangial production is on V8 agar or broth containing 10 $\mu g\ mL^{-1}$ β-sitosterol in the light at 14 to 16°C (Englander & Roth, 1980).

The mycelium is colourless, usually smooth but occasionally gnarled, coenocytic and up to 8 µm wide, becoming septate in older cultures. The sporangia are ovoid, ellipsoid or obovoid, colourless, non-papillate, (20)-36-(60) µm long and (12)-15-(20) µm wide. Sporangia persist on simple sporangiophores and germinate to produce either zoospores or hyphae in water. Mature sporangia contain 25–40 zoospores. The laterally biflagellate reinform zoospores are 10–12 µm in diameter, germinate to produce hyphae and are capable of forming cysts. The chlamydospores are (20)-40-(77) µm in diameter, often sessile, lateral on the mycelium (in contrast to the clustered chlamydospores of other non-papillate species of *Phytophthora*). *P. lateralis* is homothallic and produces paragynous antheridia in single culture. Oogonia are smooth, spherical and terminal and 33–50 µm in diameter. Oospores are (28)-40-(46) µm in diameter and pigmented (Erwin & Ribeiro, 1996; Hall, 1991; Tucker & Milbrath, 1942).

Detection and inspection methods

Various baiting methods have been developed (Trione, 1959; Ostrofsky *et al*., 1977; Hansen *et al*., 1979; Hamm & Hansen, 1984; Tsao *et al*., 1995a, b), involving baiting with susceptible plant tissue, incubation and plating onto a selective media. Tsao *et al*. (1995a) developed a quantitative protocol of this technique. Ostrofsky *et al*. (1977) found baiting more efficient from organic matter than from soil.

Winton & Hansen (2001) developed a conventional PCR-based protocol that could detect the pathogen in water and plant tissue (including tissue used as baiting material, thereby allowing indirect testing of soil). However, this assay was shown to cross-react with the recently described *P. ramorum*. An ELISA test has been developed that shows promise but needs work to improve sensitivity (Greenup, 1998). Commercial ELISA kits have been used to detect *P. lateralis* several years after tree death (Hansen, 1997).

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). Above ground, foliage infection can be transmitted through contact between adjacent foliage. Aerial spread is thought to be primarily through zoospores, as mature sporangia remain attached to the sporangiophores and infection coincides with temperatures conducive for zoospore release (10 to 20°C) (Trione, 1959).

P. lateralis spread slowly through the Pacific states of the USA over several decades, and its progress was monitored throughout this period. 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. Trees in areas crossed by roads were more likely to be infected than those not crossed by roads. Vehicles on roads also spread inoculum further than foot traffic (both animal and human). Waterways were also 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*, or plants for planting of non-host plants with contaminated soil attached, or contaminated soil as such.

Pest significance

Economic impact

P. lateralis is a serious pest of *C. lawsoniana*, which is one of the most valuable commercially harvested conifer timbers in the world, commanding up to ten times the price of *Pseudotsuga menziesii* wood from the same site (Hansen *et al*., 2000). Hansen (1985) quoted prices of 1000–4000 USD per thousand board feet for living trees of *C. lawsoniana*, with wood from dead trees having little value. The greatest loss in commercial forestry results from the death of young trees at the lower size limits of merchantability. Presently, the disease continues to kill trees in forestry plantations but also hedgerow and landscape trees in the Pacific states of the USA and has resulted in the loss of wood export markets especially to Japan (Hansen *et al*., 2000). Trees of *C. lawsoniana* in parks in British Columbia generally experience significant annual losses due to root rot caused by *P. lateralis*, and the cost of replacing them has become prohibitive (Utkhede *et al*., 1997). *P. lateralis* is thought to have nearly destroyed the multi-million dollar industry for production of ornamental *C. lawsoniana* in Northwest Oregon and Western Washington (Hansen *et al*., 2000). 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 structure to waterways.

Control

Control measures can be applied in two situations, in the nursery and in the plantation. In the nursery, soil sterilization has been used in the past, and remains a possibility though it is not generally regarded as good practice. Various fungicides are registered as drench treatments against *Phytophthora* root rots of nursery plants. In the EPPO region, these mainly target *Phytophthora cinnamomi* but may have efficacy against *P. lateralis*. Hygiene measures are recommended for nurseries, including disinfection of materials, preventing the introduction or movement of infested soil or infected plant material, assuring adequate drainage, preventing plants in containers from becoming pot-bound, use of resistant cultivars (see below). Hunt & O'Reilly (1984) found that *C. lawsoniana* could be grafted onto non-susceptible hosts such as *Chamaecyparis formosensis* or *Chamaecyparis thyoides*, but it is not clear whether this was effective in protection from *P. lateralis*, or has been put into practice.

For control of *P. lateralis* in plantations, cultural measures were recommended by the US Federal Agencies managing *P. lateralis* in the Pacific forest areas 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 unfavourable 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.

In a resistance breeding programme for *C. lawsoniana* in the USA, promising results have been obtained (Hansen *et al*., 2000), though even the most resistant trees appeared to be susceptible as juveniles. Hansen *et al.* (2000) suggest that resistant trees still offer the best chance of re-establishing infested areas with *C. lawsoniana*, preferably in combination with cultural and biological control. Though Utkhede *et al.* (1997) investigated a strain of *Enterobacter aerogenes* as a soil drench to control *P. lateralis* in naturally infected *C. lawsoniana* trees, and obtained encouraging results over a four-year period, it is not clear that this, or any other biological control method, has been used in practice.

Phytosanitary risk

P. lateralis is extremely damaging to *C. lawsoniana* in nurseries, plantations and natural vegetation in the Pacific regions of USA and Canada where it has been introduced and spread. The disease takes the form of a root and crown rot leading to extensive tree mortality. In the EPPO region, the endangered area is mainly the Atlantic parts of Western Europe, having a wet maritime climate, but extends to conifer nurseries in any part of the region. The phytosanitary risk mainly concerns *C. lawsoniana,* which is grown as a valued ornamental, produced and sold by nurseries, especially as semi-dwarf cultivars for parks and gardens. It 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.

In practice, the risk of introduction 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 exists only in botanical collections in the EPPO region, and has no commercial importance in production or trade.

Phytosanitary measures

P. lateralis was added in 2006 to the EPPO A1 action list, and endangered countries are therefore recommended to regulate it as a quarantine pest. The main risk of its introduction is from the import of infested plants for planting of *C. lawsoniana*, of other plants which though not hosts might carry inoculum of *P. lateralis*, and of infested soil. The existing measures of the European Union (EU, 2000) already cover these risks by the prohibition of the import of plants for planting of *Chamaecyparis*, the severe restrictions applied to the import of trees and shrubs from non-European countries, and the measures concerning growing medium containing soil. Other EPPO countries are recommended to establish similar measures.

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