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Phytophthora chlamydospora

Overview

Phytophthora chlamydospora Brasier and Hansen is found in streams and wet soil worldwide and is a pathogen of some riparian tree species as well as horticulturally valuable fruit and nut trees and nursery stock. It is self-sterile, and produces persistent non-papillate sporangia, usually on unbranched sporangiophores. Chlamydospores are formed most regularly at warmer temperatures. First isolated in 1971 from waterlogged roots of an ornamental *Prunus* in Gloucestershire, UK, it was tentatively assigned to *P. gonapodyides* Petersen (Buisman). Similar isolates from Britain and North America were collected and subsequently compared using DNA-based approaches. The UK *Prunus* isolate and some isolates from nurseries in Oregon and Washington, USA produced large thin-walled chlamydospores in culture and were considered to represent a separate taxon from the non-chlamydospore-forming *P. gonapodyides* (Brasier et al. 1993). The chlamydospore-forming group was informally designated *Phytophthora* taxon Pgchlamydo. *P. chlamydospora sp. nov.*, was formally named in 2015 (Hansen et al. 2015).

Etymology: "*Chlamydospora*" refers to the distinguishing chlamydospores formed especially at higher temperatures. The earlier informal name of "taxon Pgchlamydo" recalls its similarity in culture and habitat to *P. gonapodyides*.

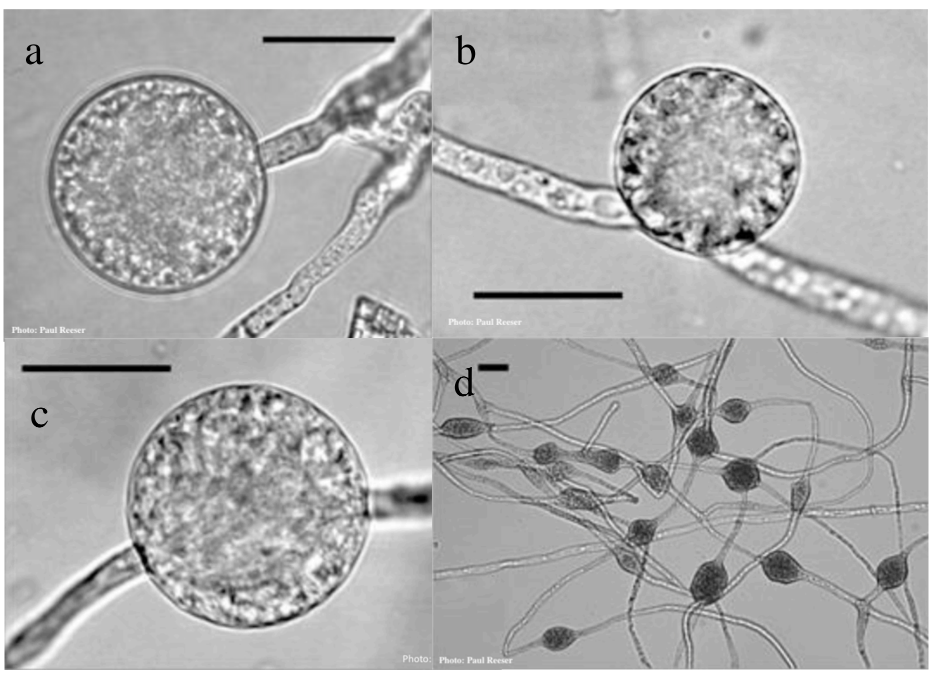

Figure 1. *P. chlamydospora* chlamydospores in agar (a, b, c) and hyphal swellings in water (d). Bar is 20 µm. Photos: Paul Reeser

Morphology

Chlamydospores formed in agar media may be scarce at 22° C but are usually abundant at 28° C. Chlamydospores are mostly intercalary but lateral, terminal and sessile chlamydospores are also observed (Figures 1 a,b,c). Clumps of large globose to subglobose hyphal swellings in branched chains are usually formed in water (Figure 1 d).

Sporangia are formed in water on simple, unbranched (occasionally sympodial) sporangiophores. They are obpyriform or ovoid, often somewhat elongated, non-papillate, persistent (non-caducous), with internal proliferation; average 56 µm by 36 µm, length: breadth ratios from 1.5 to 1.7 (Figure 2 a-d). Gametangia have not been observed in single isolate culture i.e. *P. chlamydospora* appears to be self-sterile. Some isolates exhibit a relic of heterothallism, remaining self-sterile but acting as a 'silent' A1 compatibility type, inducing gametangial formation in A2 isolates of other *Phytophthora* species when paired directly with them or via a polycarbonate membrane (Brasier et al 1993; 2003).

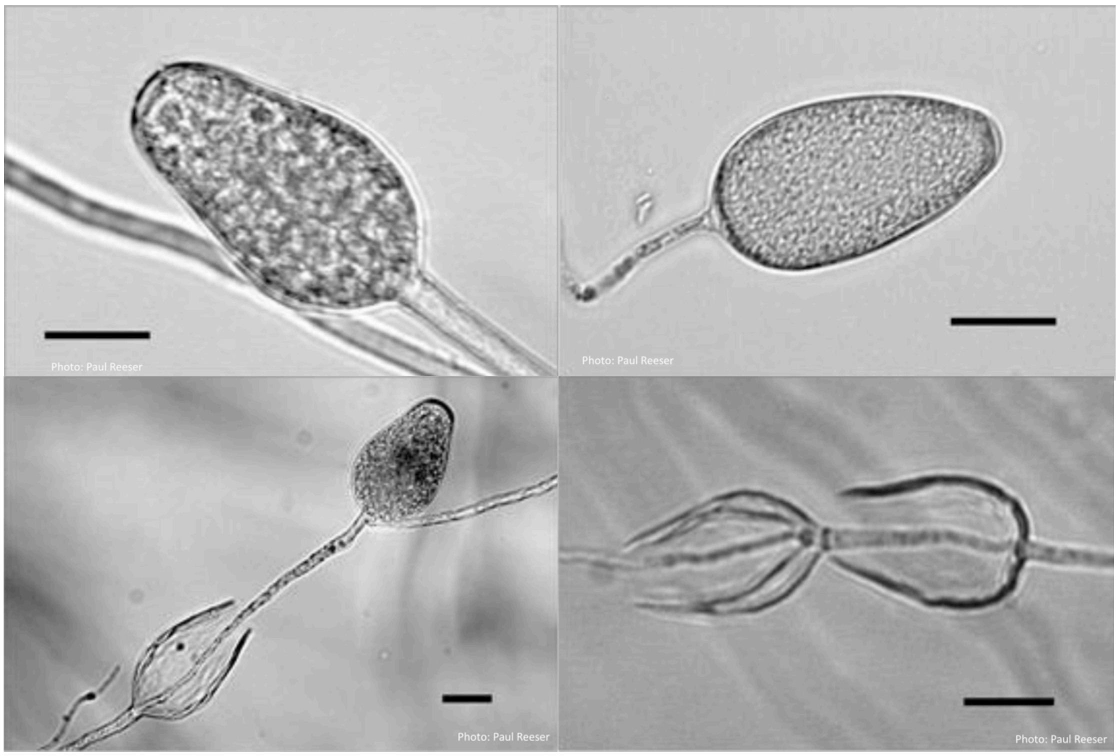

Figure 2. *P. chlamydospora* sporangia in water, showing subsporangial elongation (lower left) and internal proliferation (lower left and right). Bar is 20 µm. Photos: Paul Reeser

Growth in culture

Temperature optimum in vitro mostly ranges from 25–28° C. Maximum temperature for growth is 36° or 37° C. Growth rate on carrot agar at 25° C ranges from 3.2 to 4.1 mm/d (Brasier et al. 2003). Colonies on carrot agar are petaloid, very similar to *P. gonapodyides* (Brasier et al. 1993, 2003) (Figure 3).

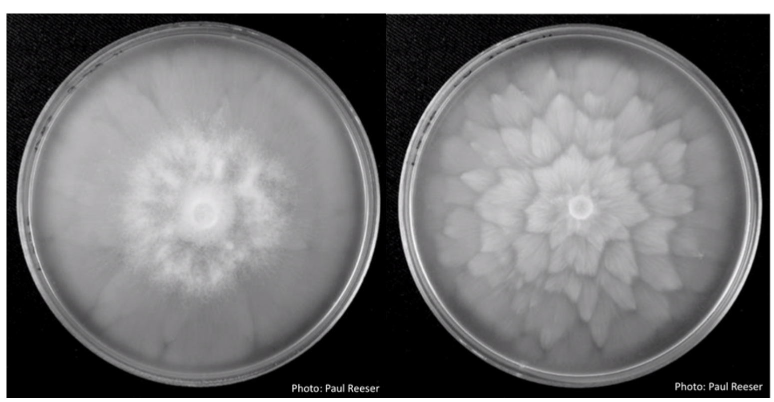

Figure 3. *P. chlamydospora* isolate P236 on V8 agar (left) and carrot agar (right). Photos: Paul Reeser

Distinguishing characteristics for identification

Phytophthora chlamydospora is rather nondescript in culture. It long has been confused with *P. gonapodyides*. Because chlamydospores may not form at lower temperatures this distinguishing feature is not always available. Sporangia usually form rapidly (within 24 hours) in water but are not easily distinguished from those of other non-papillate species. *Phytophthora chlamydospora* can be misidentified as *P. lateralis* because of its combination of large, sometimes laterally-attached chlamydospores and non-papillate sporangia, but it tolerates much higher growth temperatures. *Phytophthora chlamydospora* is itself sterile, although it may induce gametangia in A2 isolates of heterothallic species. Without carefully controlled mating tests to determine which isolate is producing gametangia, it often has been assumed to be heterothallic and consequentially misidentified as *P. drechsleri* or *P. cryptogea* because of its colony morphology and non-papillate sporangia. Clumps of large globose to subglobose hyphal swellings often are observed in water and can be a useful identifying feature. These clumps are sometimes large enough to be visible to the naked eye. Isolates examined from China, Europe, North America and Argentina have been indistinguishable morphologically.

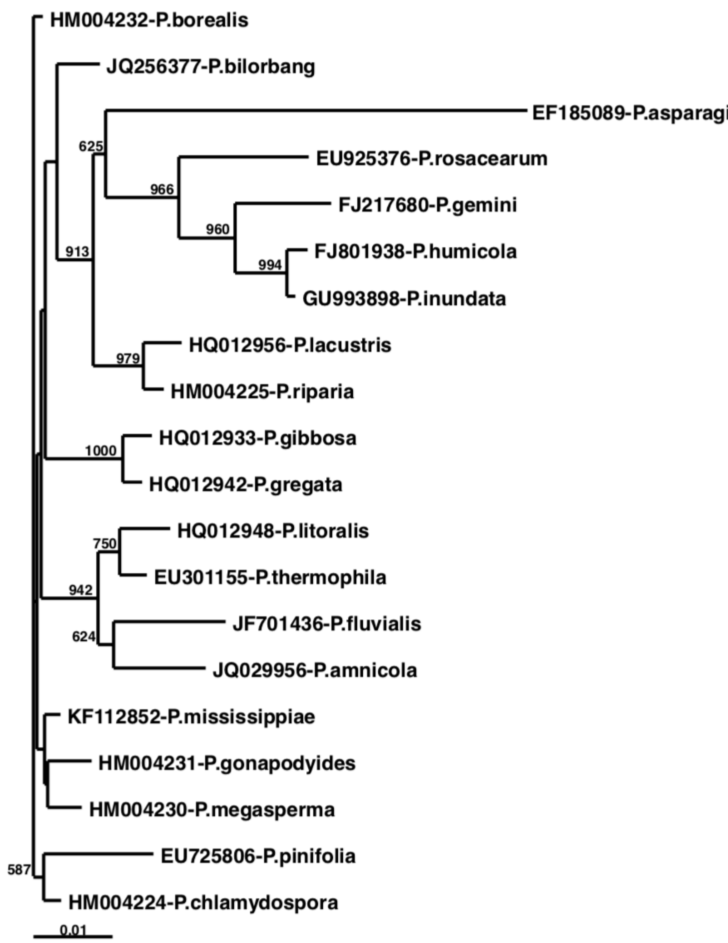

Figure 4. ITS phylogeny *of P. chlamydospora* in *Phytophthora* ITS Clade 6 aligned with ClustalX 2.1. The Neighbor Joining tree was generated by Clustal X and displayed with TreeView (Win32). Numbers on nodes represent bootstrap support values >500.

Genetics

Isolates of *Phytophthora chlamydospora* form a monophyletic clade within *Phytophthora* ITS Clade 6 (Figure 4) although with considerable variability expressed as “double peaks,” perhaps representing past hybridizations with other clade 6 species. Hybrid isolates are common in some situations. Nagel et al. (2013) have produced molecular and phenotypic evidence for local emergence of hybrid swarms between *P. chlamydospora* and *P. amnicola,* or between *P. chlamydospora* and *P. thermophila* in Australia and South Africa.

Several multilocus genotypes of *P. chlamydospora* have been identified. Isolates with sequences identical to the type isolate, which lacks double peaks in both ITS and β-tubulin gene regions, are most numerous and are present in both Europe and western North America. The second most frequently encountered multilocus genotype is also found in both Europe and North America. The third genotype was found in five isolates from Argentina. Despite this variation, *P. chlamydospora* can be distinguished from all other known *Phytophthora* species by the similarity of its DNA sequences of the ITS, COX spacer, and β-tubulin gene regions. *Phytophthora pinifolia* and *P. borealis* are sister species to *P. chlamydospora*. The three species are readily distinguished by growth rate, optimum and maximum temperature, and colony morphology, as well as chlamydospore formation. In addition, *P. pinifolia* exhibits a tendency to cauducity in culture, not observed in *P. chlamydospora*.

Disease History

P. chlamydospora is found in streams and wet soil worldwide (Table 1). It is occasionally recovered from cankers on trees and roots in forest situations (Reeser et al. 2008, Navarro et al. 2014, Sims et al. 2014). . It has been associated with root rot of Port-Orford cedar (*Chamaecyparis lawsoniana*) in German nurseries, where it was initially misidentified as *P. lateralis* (Hansen et al. 1999), and with root rot and stem cankers of *Abies* species in nurseries and Christmas tree plantations, where it was originally misidentified as *P. drechsleri* (Brasier et al. 1993). On horticultural hosts, *P. chlamydospora* causes root and crown rot of walnut, almond, and cherry trees (Dervis et al. 2016, Turkolnez et al. 2016, Kurbetli et al. 2017) and foliar lesions and shoot dieback on several ornamental species in nurseries (Jung and Blaschke 2004, Schwingle and Blanchette, 2008, Yakabe et al. 2009, Blomquist et al. 2012, Prospero et al. 2013, Ginetti et al. 2014).

Impacts in the forest

Apart from its riparian habitat *P. chlamydospora* has been associated with what may be largely opportunistic root infections of *Abies* and *Pseudotsuga* in Christmas tree plantations, root rot of ornamental *Prunus* and *Chamaecyparis*; and, in one instance, with stem cankers on tanoak (*N. densiflorus*) in a natural forest (Table 1). Artificial inoculations of several plant species have confirmed that *P. chlamydospora* can be pathogenic on stems and roots (Navarro et al. 2014, Reeser et al. 2008). However, true status of *P. chlamydospora* as a pathogen in forests has yet to be established. Where it is locally abundant in streams there is usually no visible evidence of disease in adjacent vegetation. In contrast, *P. chlamydospora* appears to be a pathogen of horticulturally valuable species in managed systems where it can cause both root and foliar disease on a range of woody hosts.

Source	Host Latin name	Host common name	Symptoms	Country	Reference
Streams	—	—	—	Argentina	Greslebin et al. 2005
Streams	—	—	—	Chile	Jung et al. 2018
Streams	—	—	—	China	Huai Wenxia et al. 2013
Streams	—	—	—	South Africa	Oh et al. 2013
Streams	—	—	—	Taiwan	Jung et al. 2017
Streams	—	—	—	USA	Brazee et al. 2016; Reeser et al. 2011
Water	—	—	—	France	Hansen & Delatour 1999
Soil	—	—	—	Australia	Burgess et al. 2009; Jung et al. 2012
Soil	—	—	—	South Africa	Oh et al. 2013
Soil	—	—	—	Germany	Jung & Blashke 2004
Forest	*Notholithocarpus densiflorus*	tanoak	bole canker	USA	Reeser et al. 2008
Nursery, Christmas tree plantation	*Abies procera*	Noble fir	root rot, stem canker	USA	Brasier et al. 1993
Nursery, Christmas tree plantation	*Pseudotsuga menziesii*	Douglas-fir	root rot	Canada	Hamm & Hansen 1987
Orchards	*Juglans regia* *Prunus cerasis* *Prunus dulcis*	walnut almond sour cherry	root and crown rot	Turkey	Dervis et al. 2016; Turkolmez et al. 2016; Kurbetli et al. 2017
Roadside	*Prunus*	ornamental cherry	root rot	UK	Brasier et al. 1993; 2003
Nursery	*Chamaecyparis lawsoniana*	Port-Orford cedar	seedling root rot	Germany	Hansen et al. 1999
Nursery	*Camellia*, *Rhododendron*, *Viburnum* and 9 others	various woody perennials	leaf lesions, shoot dieback	USA	Blomquist et al. 2012; Yakabe et al. 2009
Nursery	*Rhododendron* *Taxus*	rhododendron; yew	leaf lesions; dieback	USA	Schwingle & Blanchette 2008
Nursery	*Viburnum tinus*	laurustinus	shoot blight, root and collar rot	Italy	Ginetti et al. 2014
Nursery	*Rhododendron* *Viburnum*	rhododendron viburnum	leaf lesions, dieback	Switzerland	Prospero et al. 2013
Nursery	*Rhododendron*	rhododendron	leaf lesions	Spain	Moralejo et al. 2009

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