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Phytophthora tentaculata

Overview

Phytophthora tentaculata Kröber & Marwitz was described in 1993 in Germany on greenhouse-grown nursery ornamentals. It has since been found in Italy, Spain, China and the U.S. (California) causing a root and stem rot of many different plant species including nursery-grown native species used for habitat restoration. *P. tentaculata* is homothallic and is classified in Stamps group I which is characterized by the production of mostly paragynous antheridia, papillate sporangia and the production of both hyphal swellings and chlamydospores in culture. *P. tentaculata* is placed in phylogenetic Clade 1 (Cooke et al., 2000) with species such as *P. cactorum, P. nicotianae, P. clandestina*, *P. iranica*, *P. hedraiandra* and *P. pseudotsugae*.

Etymology: refers to the spider web-like growth habit of the mycelium in culture.

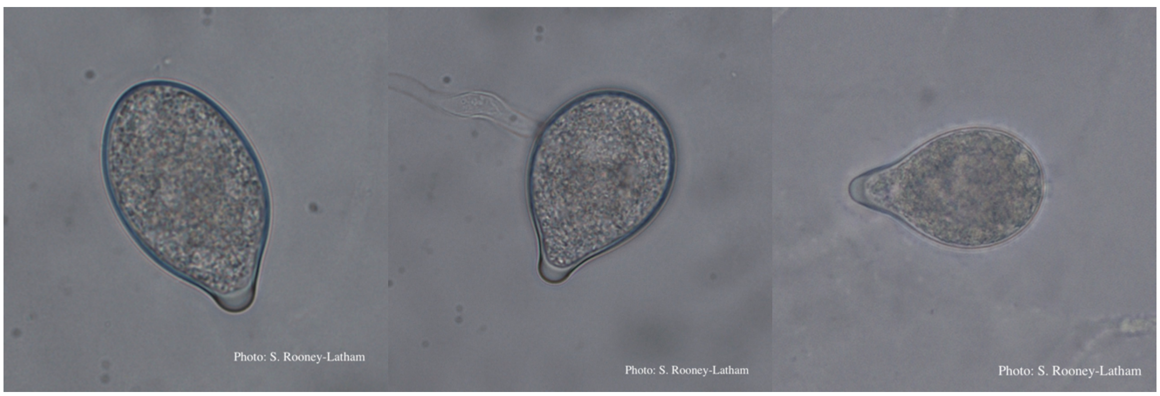

Figure 1. Papillate sporangia of *P. tentaculata*. Sporangium on the far right has an elongated neck or beak.

Morphology

Sporangia of *P. tentaculata* are spherical or ovoid to obpyriform, papillate to occasionally bipapillate and measure 10-81 x 13-52 µm (average 35.7 x 27.4 µm). They are primarily noncaducous, rarely caducous with a short pedicel, and often have elongated necks or beaks (Fig. 1). Small hyphal swellings are intercalary and often occur with hyphal branching (Fig. 2). On PARP and V8 juice agar, the hyphal growth pattern resembles a non-organized web spun by spiders in the family Theridiidae; hyphae often grow forming loops in the agar (Fig. 3). Chlamydospores are intercalary to terminal, thin-walled, measuring 10-45 µm (average 26.6 µm), occasionally with a short hyphal projection (Fig. 4). *P. tentaculata* is homothallic, with mostly paragynous antheridia (Fig. 5). Antheridia are diclinous and often form tooth-like projections when they encircle the oogonia. Oospores are spherical, aplerotic, and measure 14-38 µm (average 28.1 µm) (Fig. 6) (Erwin and Ribeiro, 1996; Kröber and Marwitz, 1993).

Figure 2. A: Hyphal swellings at branching points of mycelium. B: Intercalary hyphal swellings. C: Chlamydospore. D: Sporangium.

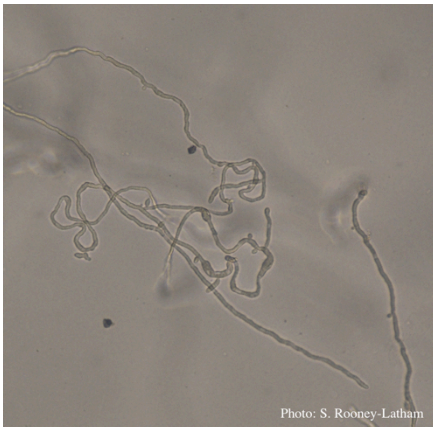

Figure 3. Looping hyphae commonly seen with *P. tentaculata* on PARP media.

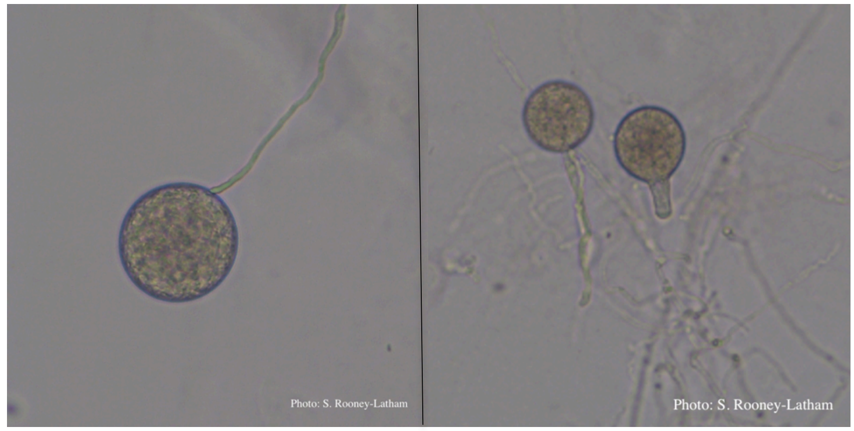

Figure 4. Chlamydospores of *P. tentaculata*. Left: Terminal chlamydospore. Right: Chlamydospore with short hyphal projection.

Figure 5. Paragynous antheridium attached to oogonium with oospore.

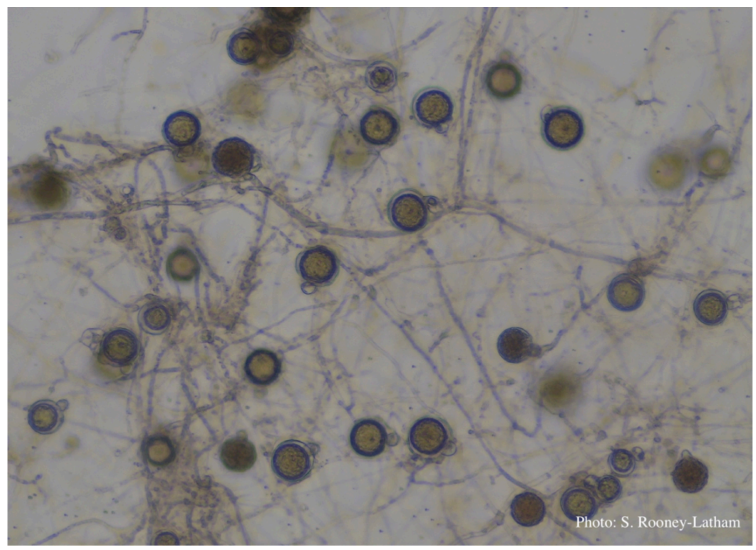

Figure 6. Oospores and oogonia with mostly paragynous but some amphigynous antheridia of *P. tentaculata*.

Genetics

P. tentaculata is placed in phylogenetic Clade 1 (Cooke et al., 2000) along with *P. cactorum, P. nicotianae, P. clandestina*, *P. iranica*, *P. hedraiandra* and *P. pseudotsugae,* among others (Fig. 7) (Blair et al., 2008).

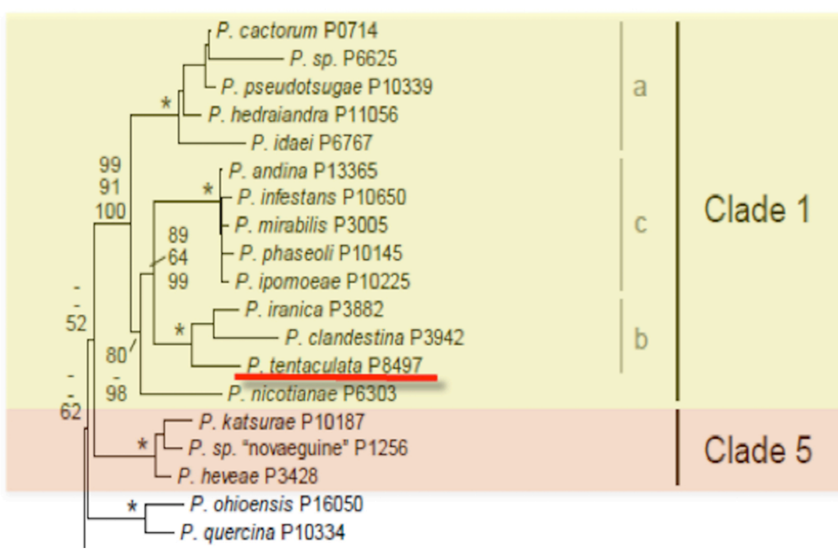

Figure 7. Phylogenetic tree from http://www.phytophthoradb.org/species.php

Growth in culture

The optimum temperature for *P. tentaculata* is 15-25°C, while the minimum and maximum temperatures are 7°C and 32°C. At optimum temperatures, the growth rate is 2-5 mm/d. This slow growth rate contributes to the difficulty of isolating *P. tentaculata* from infected plants. Colony growth pattern on V8 juice agar is fluffy with a regular margin (Fig. 8).

Figure 8. Culture of *P. tentaculata* on V8 juice agar.

Distinguishing characteristics for identification

P. tentaculata is classified in group I based on its primarily paragynous antheridia and papillate sporangia (Stamps et al., 1990) and is a member of phylogenetic Clade 1 (Cooke et al., 2000) along with *P. cactorum, P. nicotianae, P. clandestina* and *P. pseudotsugae*, among others. It differs from *P. cactorum* by the production of hyphal swellings, larger oogonia and oospores, higher minimum temperature and slower growth rate. It differs from *P. nicotianae* by being homothallic and producing mostly paragynous antheridia. It is distinct from *P. clandestina* and *P. pseudotsugae* by the production of chlamydospores and has a faster growth rate than *P. clandestina*.

Disease History

P. tentaculata was first discovered causing a stem and root rot of greenhouse-grown ornamentals in Germany in 1993 (Kröber and Marwitz, 1993), before being found in Spain and Italy (Moralejo et al., 2004; Álvarez et al., 2006; Cristinzio et al., 2006; Martini et al., 2009). It was detected in China in 2007 in field-grown medicinal plants and again in 2012 in field-grown celery (Meng and Wang, 2006; Wang and Zhao, 2014). In a USDA risk assessment, *P. tentaculata* was listed in the top 5 *Phytophthora* species of concern to the U.S. due to its potential environmental and economic impacts (Schwartzburg et al., 2009). In 2012, it was first found in North America in a California native plant nursery on sticky monkey flower (*Diplacus aurantiacus* syn=*Mimulus aurantiacus*) (Rooney-Latham and Blomquist, 2014). It has since been detected in numerous other California native plant nurseries and in outplanted nursery stock in a few restoration sites (Frankel et al., 2015). The origin of *P. tentaculata* is unknown.

Susceptible hosts include members of the Asteraceae, Ranunculaceae, Lamiaceae, Rhamnaceae, Phrymaceae, Rosaceae, and Verbenaceae plant families (Table 1). In Europe, the disease has been detected on marguerite daisy (*Argyranthemum frutescens*), chicory (*Cichorium intybus*), larkspur (*Delphinium* sp.), Gerbera daisy (*Gerbera jamesonii*), oxeye daisy (*Leucanthemum vulgare*), oregano (*Origanum vulgare*), lavender cotton (*Santolina chamaecyparissus*), and verbena hybrids (*Verbena* spp.). In China, it has been reported on celery (*Apium graveolens*) and costus root (*Aucklandia lappa*). In California it has been reported on nursery-grown native plant species including California mugwort (*Artemisia douglasiana*), tarragon (*Artemisia dracunculus*), California sagebrush (*Artemisia californica*), buckbrush (*Ceanothus cuneatus*), sticky monkey flower (*Diplacus aurantiacus*), coffeeberry (*Frangula californica*), toyon (*Heteromeles arbutifolia*), coyote mint (*Monardella villosa*), and sage (*Salvia* sp.). *P. tentaculata* has not been detected from any tree species.

In California, the pathogen appears to have been spread within and between nurseries by the use of infested pots and potentially by infected plants. Very little research has been done on specific control strategies. Like other *Phytophthora* diseases spread by zoospores in water, the use of strict sanitation and planting practices (i.e. use of clean soil, media, pots and propagation materials, proper irrigation, and keeping plants off the ground to prevent standing in water and water splash) are recommended to reduce the risk of pathogen spread. In addition, strict isolation of newly acquired plants from other sources must be maintained until the health of the plants is confirmed. Soil solarization and steam injection are being investigated as means to eradicate spot infestations resulting from the planting of infested nursery stock.

Impacts in the Forest

In Europe, *P. tentaculata* has been detected mostly in ornamental nurseries (Kröber and Marwitz, 1993) though there have been a few detections in commercial fields, usually associated with transplants (Garibaldi et al., 2010, Cristinzio et al., 2006). In California, *P. tentaculata* has only been detected in the environment on plants that have been grown in a nursery and planted out for restoration purposes. However, it has persisted on infected stock in the field for at least 4.5 years in northern California. The fact that both infected plants and the pathogen can survive for years after outplanting increases the potential for eventual spread from infected stock into native wildlands. Because the pathogen is reported to cause severe root and crown rot on a wide range of woody and semi-woody hosts, its introduction with infected nursery-grown plants could threaten key components of native plant communities being restored.

Forest and Wildland Hosts and Symptoms

P. tentaculata causes a moderate to severe root and crown rot, depending on the host species (Figs. 9 and 10). It has not been shown to be a foliar pathogen. The pathogen is known to cause high mortality in heavily infected plants (Kröber and Marwitz, 1993).

Figure 9. Crown and root rot of a sticky monkey flower plant *(Diplacus aurantiacus)* infected with *P. tentaculata* (right) compared with a healthy plant (left).

Figure 10. Nursery grown California mugwort plant (*Artemisia douglasiana*) infected with *P. tentaculata* and exhibiting severe root and crown rot.

Amongst Californian hosts, sticky monkey flower (*Diplacus aurantiacus*) appears to be highly susceptible (Rooney-Latham and Blomquist, 2014). Artificially inoculated plants wilted and showed severe crown and root symptoms two weeks after root and crown exposure to *P. tentaculata* zoospores (Fig. 11). More than two thirds of the California detections of *P. tentaculata* to date have been on sticky monkey flower.

Field-planted nursery stock infected with *P. tentaculata* exhibits varying symptoms. Infected sticky monkey flower plants are stunted, with dull, yellowish leaves that turn red as the disease progresses. Roots and stem collars have necrotic, sunken lesions with few feeder roots. Plants have shown poor growth and eventual collapse within the first season in some situations (Fig. 9). In other cases, plants have grown for a year or more before developing extensive dieback with the onset of high evaporative demand in summer (Fig. 12). Transplanted *Artemisia douglasiana* plants infected with *P. tentaculata* were stunted and somewhat chlorotic more than 4.5 years after planting, but did not show obvious dieback (Fig. 13).

Figure 11. Crown and root rot of sticky monkey flower plant (*Diplacus aurantiacus*) artificially inoculated with *P. tentaculata* (right) compared to the control (left).

Figure 12. Outplanted sticky monkey flower *(Diplacus aurantiacus)* 1.5 years after outplanting. Plant shows severe stunting and dieback.

Figure 13. Outplanted California mugwort plant (*Artemisia douglasiana*) infected with *P. tentaculata,* 4.5 years after planting. Plant shows stunting and chlorosis. (*P. cryptogea* and *P. lacustris* were also baited from the same plant.)

Table 1. *Phytophthora tentaculata* hosts, symptoms, and locations.

Host Latin name	Host common name	Symptoms	Habitat	Region
Apium graveolens	celery	Stem and root rot	Field	China - Bengbu, Anhui Province
Argyranthemum frutescens (=Chrysanthemum frutescens)	marguerite daisy	Root and stem base	Nursery	Germany
Artemisia douglasiana	California mugwort	Root rot	Nursery, outplanted nursery stock	USA - California
Artemisia dracunculus	tarragon	Root rot	Nursery	USA - California
Artemisia californica	California sagebrush	Root rot	Nursery	USA - California
Aucklandia lappa	costus root	Stalk rot	Field	China - Yunnan Province
Ceanothus cuneatus	buckbrush	Root rot	Nursery	USA - California
Cichorium intybus	Witloof chicory	Collar and root rot	Field	Italy - Tarquinia
Delphinium sp.	larkspur	Root and stem base	Nursery	Germany
Diplacus aurantiacus (=Mimulus aurantiacus)	sticky monkey flower	Root and crown rot	Nursery, outplanted nursery stock	USA - California
Frangula californica	coffeeberry	Root and crown rot	Nursery, outplanted nursery stock	USA - California
Gerbera jamesonii	Gerbera daisy	Crown and stem rot	Field	Italy – Torre del Greco
Heteromeles arbutifolia	toyon	Root rot	Outplanted nursery stock	USA - California
Leucanthemum vulgare (=Chrysanthemum leucanthemum)	oxeye daisy	Root and stem rot	Nursery	Germany
Monardella villosa	coyote mint	Root rot	Nursery	USA - California
Origanum vulgare	oregano	Root and stem rot	Nursery	Italy - Liguria
Salvia sp.	sage	Root rot	Nursery	USA - California
Santolina chamaecyparissus	lavender cotton	Root rot	Nursery	Spain - Valencia Province
Verbena sp. and hybrids	verbena	Root, stalk and collar rot	Nursery	Germany; Spain - Balearic Islands

Management and education resources

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