Threats to oaks and other native plants from root-rotting *Phytophthora* species

California Oak Health Virtual Workshop-April 2020

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Root and crown rots caused by *Phytophthora* are an under-recognized threat to the health of native habitats and urban forests.

- Root rots and other diseases caused by *Phytophthora* species have long been recognized as serious diseases in agriculture, nurseries, various landscape plants, and forests (Erwin and Ribeiro 1995).
- Even so, the impacts of these pathogens on the health and sustainability of urban forests have been largely overlooked.
- Recent research suggests that introduced *Phytophthora* species pose an increasingly important threat to both urban forest and their surrounding native forests and plant communities (Beckerman et al 2014, Brasier 2008, Barber et al. 2013, Jung et al. 2015, Scanu et al. 2015, Swiecki et al. 2011).
- A large and increasingly diverse contingent of *Phytophthora* species identified in nursery stock present an expanding threat to urban and native forests alike.

Phytophthora root rot can be difficult to diagnose in trees and shrubs in both landscapes and nursery stock.

- In many woody plants, Phytophthora root rot symptoms are not distinctive and are commonly attributed to other factors such as drought, flooding, or aboveground pests and pathogens that secondarily attack affected trees.
- Irrigated nursery stock of drought-tolerant trees and shrubs commonly will not show top symptoms until almost the entire root system is decayed, or a crown canker develops.
- In landscapes, infected trees and shrubs may grow for years in the presence of these root pathogens, because only a portion of the root system is infected. When conditions favor more extensive infection, infected plants may decline rapidly.

Phytophthora species are commonly introduced into landscapes through planting of infected nursery stock.

- Conventional nurseries provide near optimal conditions for survival, reproduction, and spread of root-rotting *Phytophthora* species, leading to high infection rates in nursery stock.
- Use of *Phytophthora*-suppressive chemicals (aka fungicides) by nurseries does not eradicate *Phytophthora*, but may help mask symptoms, increasing acceptance of infected nursery stock.
- Once planted, *Phytophthora*-infected stock may be short-lived or may survive for an extended period, usually with reduced growth and vigor.
- Persistent *Phytophthora* inoculum remains in the soil after affected plants are removed and can infect subsequent plantings.
- Planting or holding nursery stock in the rootzones of trees and other susceptible hosts can initiate new infections.

Planting of infected nursery stock and subsequent soil and water movement from infested areas can spread *Phytophthora* into nearby native plant habitats.

- Multiple infestations of root-rotting *Phytophthora* have been identified in native forests and shrub-dominated natural communities in California.

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- Some rare species (e.g., *Arctostaphylos myrtifolia, A. pallida*) are threatened with extinction in their native habitats due to *Phytophthora* infestations.
- In tests by us and others (Bourret et al 2016, Rooney-Latham et al 2016, 2019) about 60 different *Phytophthora* taxa have been identified in restoration planting sites and native plant nurseries in California.
- A number of these detections are first known occurrences of *Phytophthora* species in California or the US.
- Several undescribed *Phytophthora* species or hybrids have recently been detected in sampling of California nursery stock.
- *Phytophthora* from planted landscapes at the wildland interface has spread into adjacent native vegetation, causing decline and mortality.

Phytophthora infestations expand across landscapes through both primary introductions and secondary spread.

- Once *Phytophthora* has been introduced and becomes established in host vegetation, these infested areas serve as sources of inoculum that can be spread to other locations.
- Activities that move contaminated soil can spread infestations widely around an area via movement of roots and soil on equipment.
- Most planted landscapes should be considered potential sources of soil-borne *Phytophthora* species.
- Even within planted landscapes, infestations are commonly spotty, and additional pathogen spread can still occur within a property.

What can be done?

Prevent *Phytophthora* introductions and avoid spreading *Phytophthora* by following phytosanitary working practices.

- Use only nursery stock grown under Best Management Practices (BMPs) for producing nursery stock free of *Phytophthora* – the *Working Group for Phytophthoras in Native Habitats* (calphytos.org) and CNPS have adopted effective BMPs.
- Not all BMPs are equal: many nursery BMPs are inadequate to ensure that plants will be free of *Phytophthora* to the greatest degree possible.
- Availability of clean nursery stock is currently limited to some native plant nurseries – consider cooperative arrangements to contract for clean plant production by willing nurseries.
- Follow clean working practices to minimize potential for spread of soil and plant debris by footwear, tools, equipment, and vehicles – start clean and clean up before you leave, especially for operations that involve soil contamination.
- Avoid soil-intensive activities under wet conditions that favor spread of contamination and make cleanup more difficult.
- Consider where *Phytophthora* infestations are more likely to occur on the local scale and work from clean areas toward infested areas, not the reverse.
- You can make a bad situation worse: introducing additional *Phytophthora* species or strains to an area already infested by one or more species can expand the effective range of susceptible hosts, leaving fewer or no good replanting options.

Eradication may be an option for dealing with small infested areas

- Moist heat is the most effective means of eradicating *Phytophthora* from infested soil.

- The minimum time/temperature combination needed to ensure mortality of *Phytophthora* with moist heat is at least 30 minutes at 50 C (122 F) (Baker 1957). To allow for some margin of error, a better target is at least 55 C [131 F] for 1 hour.
- Heat can be applied via steam or dry heat sources; methods that agitate soil during heating attain target temperatures faster and more efficiently than methods that apply heat to a static soil mass.
- Where feasible, solarization is another option for heating soil to lower elevated temperatures for longer periods to attain pathogen eradication.
- Heat treatments need to extend to the depth of *Phytophthora* contamination in the soil, which is related to rooting depth.

Suppression is the last and least desirable option

- If a site is infested, suppression may be the only viable option for management in the infested area, but preventing secondary spread is still critical.
- *Phytophthora* reproduction and spread is greatly curtailed under dry conditions, so minimizing periods of soil saturation can slow disease development and spread.
- The absence of susceptible hosts will prevent additional inoculum production in infested areas, but a host-free period may need to extend for many years to completely eliminate *Phytophthora*.
- Chemical control using materials that are active against *Phytophthora* (e.g., potassium phosphites) can suppress disease development, but the plant will remain diseased and infection levels will increase when chemical residue levels decrease. (Note: these chemicals are not really "fungicides" despite their classification; *Phytophthora* is not a fungus, and the chemicals only suppress rather than kill the pathogen at normal use rates).
- In some areas, increasing soil organic matter can increase the activity of microorganisms antagonistic to *Phytophthora* and suppress disease development. Antagonism is related to microbial cellulase activity; *Phytophthora* cell walls are cellulosic.

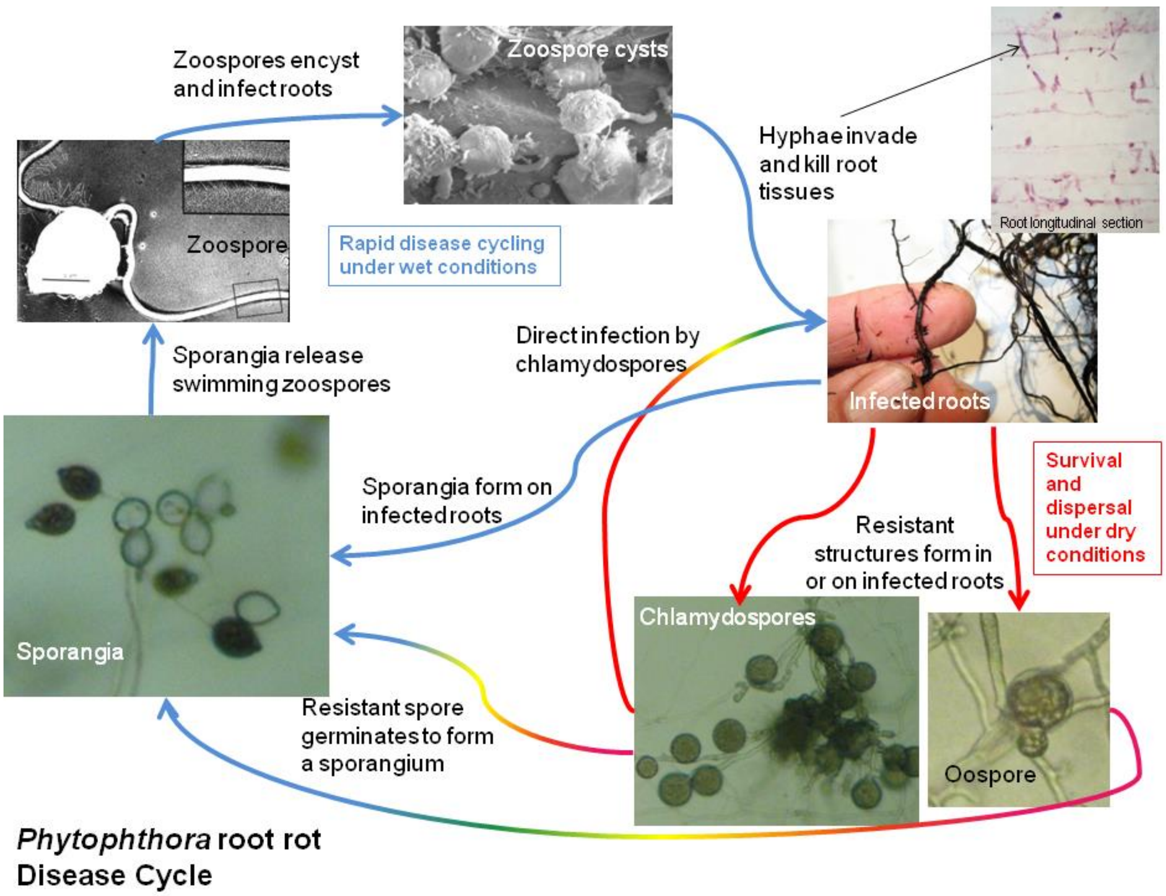
Can I just test my nursery plants to see if they are free of *Phytophthora*?

Various assays can be used to detect and identify *Phytophthora* species associated with nursery plants. Tests vary in difficulty, cost, sensitivity, and suitability for particular applications. All testing methods can give false negative results, i.e., *Phytophthora* is not detected when it is present. All testing methodologies (e.g., immunoassay [ELISA], culturing, baiting, DNA-based methods) have limits in sensitivity and are subject to factors that can interfere with the tests. The quality, quantity, size, and condition of the sample, as well as the training of the sampler, can affect whether a pathogen is detected in a sample. False negative results may be obtained due to any of the following conditions:

- sample size is too small to capture detectable levels of the pathogen for the test being used
- infection levels in the sampled plants are below the level of detection, e.g., because plants were recently infected
- sampled plant(s) or roots are not infected, even though other roots or plants are infected
- infected roots are too decayed by secondary organisms that interfere with detection
- *Phytophthora* species present does not infect baits being used or does not grow well on media used
- pathogen growth is suppressed by *Phytophthora*-suppressive chemicals ("fungicides") applied to the plant or potting soil
- improper sample handling has degraded the pathogen to undetectable levels
- the test is run incorrectly or under conditions that reduce its efficacy.

Due to logistical, cost, and test sensitivity issues, it is not practical to individually test large numbers of plants to reliably assess the infection status of each plant. To obtain a reliable supply of *Phytophthora*-

free nursery stock, the stock needs to be produced under conditions that exclude *Phytophthora*. This is analogous to the way that the food service industry prepares food that is safe for consumption. Food safety relies on a system of clean handling and standardized safe preparation processes rather than testing every serving that is produced.



General disease cycle for root-rotting *Phytophthora* species. Upper loop (solid blue arrows) illustrates rapid disease cycling that occurs under generally moist conditions, with at least intermittent soil saturation. Cycling that enables pathogen survival and dispersal under drier conditions is shown with red and multicolored arrows.

Resources

- Phytophthoras in Native Habitats Work Group (PWG) website – http://calphytos.org - includes nursery BMPS and other guidelines adopted by PWG
- Phytosphere Research Phytophthora root rot site - http://phytosphere.com/onlinelist_soilphytophthoras.htm - includes links to background materials, nursery BMPs, phytosanitary procedures, testing procedures, other presentations, and other resources
- Forest Phytophthoras website - http://journals.library.oregonstate.edu/ForestPhytophthora
- CNPS Phytophthora Resources - https://sites.google.com/site/cnpsphytophthoraresources/

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