



## ***Phytophthora* Species in Native Plant Nursery Stock: Issues and Implications**

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Ted Swiecki and Elizabeth Bernhardt, Phytosphere Research

Recent research has documented the presence of multiple *Phytophthora* (pronounced: fie-TOF-tho-ra) species in California native plant nurseries, restoration sites, and native landscapes. The interdisciplinary **Working Group for Phytophthoras in Native Habitats** is actively involved in expanding efforts to prevent further spread of these serious plant pathogens, which threaten both rare and common native species in the wild and in cultivated landscapes. This group includes plant pathologists, restoration ecologists, native plant nursery operators, and federal, state and local agency and district staff, and CNPS representatives. CNPS is actively involved in expanding efforts to prevent further spread of these serious plant pathogens, which threaten both rare and common native species in the wild and in cultivated landscapes.

### **The problem: Plant diseases caused by introduced *Phytophthora* species**

*Phytophthora* species are microscopic water molds. Previously considered fungi, these microorganisms are now placed in the Stramenopila. They are more closely related to the brown algae than to true fungi. Diseases caused by *Phytophthora* species include root rot, stem cankers, and blights of fruit and leaves. Host ranges of individual *Phytophthora* species vary, but some species can infect hundreds of plant species across many plant families.

When introduced into native ecosystems, various exotic *Phytophthora* species have proven to be serious to devastating pathogens. In California, native populations of the endangered endemics Ione manzanita, pallid manzanita, and Coyote ceanothus are threatened by *Phytophthora* root diseases. Introduced root-rotting *Phytophthora* species have also caused decline and mortality of oaks, madrones, California bay and other woody natives in native stands. Sudden oak death, caused by the introduced pathogen *P. ramorum*, has caused extensive mortality of oaks and tanoaks in forests of the coast ranges from central California to southern Oregon. *Phytophthora ramorum* is dispersed through the air and kills oaks and tanoaks trees by killing above-ground living bark (phloem).

*Phytophthora* species are serious pathogens of native vegetation, commercial forests, agricultural and horticultural crops, and cultivated landscapes worldwide. A disturbing recent trend has been the rapid dispersal of new *Phytophthora* species worldwide, facilitated by international movement of nursery stock and other plant material. These connections extend to California native plant nurseries. All of the detections of *P. tentaculata* in the US to date are in California native plant nurseries and restoration plantings. This pathogen was recently described and was previously known only from nursery and agricultural situations in Europe and China. It was ranked as a top-five priority threat by USDA in a recent review of *Phytophthora* species not present in the US.

### **Plant nurseries as sources of diseased material**

#### **Nurseries are favorable for *Phytophthora***

Diseases caused by both aerial and soil-borne *Phytophthora* species are common in plant nurseries. Plant nurseries provide nearly optimal environments for the development and spread of *Phytophthora* diseases. Production and dispersal of *Phytophthora* sporangia and swimming zoospores are favored by the wet and humid conditions found in nurseries. High root density within containers, close spacing of plants, plant handling, and frequent rearranging of containers

all enhance opportunities for pathogen spread and reproduction. See also PLANT NURSERY CONDITIONS FAVOR *PHYTOPHTHORA* ROOT ROTTS.

#### **Practices increase infection risk**

Even with highly favorable conditions for disease development risk, *Phytophthora* diseases will not develop if the pathogen is not present. However, production practices in most nurseries provide many opportunities for *Phytophthora* introduction, through poor sanitation practices, using nonpasteurized potting media, reusing nonsanitized containers, or simply inadvertently buying infected (but possibly asymptomatic) plants from other sources. These unsafe practices have been facilitated by the widespread use of systemic fungicides that are active against *Phytophthora*. Using these chemicals in the nursery suppresses symptoms but does not eliminate these pathogens, allowing nurseries to sell infected plants that may appear healthy. See also HOW USING FUNGICIDES IN NURSERIES CAN INCREASE THE RISK OF MOVING *PHYTOPHTHORA* TO PLANTING SITES

#### **Diseased plants are difficult to detect**

Unfortunately, it is often difficult to detect *Phytophthora*-infected plants in the nursery. Symptoms caused by aerial, foliar infecting species such as *P. ramorum* may be confused with symptoms of insufficient water or fertilizer burn. Root rot symptoms can be even harder to detect. Many drought-tolerant California natives will not show obvious above-ground symptoms under nursery conditions until root rot is severe (Figure 1). At earlier disease stages, healthy-appearing roots will still be present. Also, roots of many woody species are dark-colored, making it difficult to recognize infected roots.

Various tests can be used to detect and identify *Phytophthora* species associated with nursery plants. However, because of various logistical, cost, and test sensitivity issues, it is not currently practical to individually test large numbers of plants to reliably assess the infection status of each plant. Research is being conducted to develop fast and reliable methods for screening large numbers of plants for *Phytophthora* infections. See also *PHYTOPHTHORA* TESTING PROCEDURES FOR CNPS BMPs FOR PRODUCING CLEAN NURSERY STOCK.

#### **Detections associated with California native plant nursery stock**

*Phytophthora* root rots are currently as pervasive in California native plant nurseries as they are in horticultural plant nurseries. Root-rotting *Phytophthora* species have been detected at every California native plant nursery that has been professionally sampled specifically to look for these pathogens over the past two years. Many different plant species have tested positive for *Phytophthora*, including many that were not previously known to be *Phytophthora* hosts.

A long and growing list of *Phytophthora* species and likely hybrids (currently at least 25) have been detected in native plant nurseries in California. Multiple *Phytophthora* species have been found in many nurseries. Some detected species are relatively uncommon or not previously documented in California (e.g., *P. tentaculata*). Others (e.g., *P. cinnamomi*, *P. cactorum*, *P. cambivora*) are pathogens that have been associated with death and decline of cultivated plants in California for many years. Both 'new' and 'older' *Phytophthora* species are of concern because of their potential to permanently infest and spread from areas where they are introduced.



Figure 1. Shoots (top) and corresponding root systems (bottom) of three live nursery-grown toyons with *Phytophthora* root rot. All plants tested positive for *P. cactorum*, which attacks a wide range of woody plants. The foliage of the left plant was somewhat off-color and appeared water stressed; the plant had few, if any, live roots. The tall healthy-appearing plant on the right also had nearly complete root rot. The center plant, also healthy-appearing, had some apparently healthy roots on the outside of the root ball (upper center root image), but most of the remaining roots were rotted (lower center root image). Pots had been reused and had various intact paper labels, suggesting that the pots had not been washed prior to reuse.

#### **Wildland infestations have been initiated through nursery stock**

Infected nursery stock has been shown to be the source of various *Phytophthora* introductions. The pathogens that cause sudden oak death (*P. ramorum*) and Port Orford cedar root disease (*P. lateralis*) are among the better known introductions that have become widespread in parts of California, but recent research has demonstrated many more examples. In particular, we recently documented that a restoration planting conducted over 20 years ago in Santa Clara County was clearly associated with a widespread infestation involving multiple *Phytophthora* species in a mix of native hosts, including the endangered *Ceanothus ferrisiae*.

Most root-rotting *Phytophthora* infestations in native habitats have been detected because they cause decline and mortality of native species. In California, they have been found in a variety of State Parks, public open space lands, botanical preserves, private properties, and elsewhere over

the past 14 years. The introduction of one or more virulent *Phytophthora* species can result in "sick" landscapes in which the most susceptible species suffer high levels of mortality and do not successfully regenerate. More tolerant species show reduced growth and vigor and may die during periods of drought or be attacked by opportunistic pest and pathogens. Ironically, many invasive weed species are unaffected by *Phytophthora* and may become more dominant in infested areas.

Continued introduction of exotic pathogenic *Phytophthora* species poses a significant threat to the conservation and sustainability of our native flora. Many of the most destructive *Phytophthora* species have wide host ranges and may persist in the soil for years after their hosts have been killed. Because there are limited options for managing *Phytophthora* diseases once they are established in native ecosystems, preventing introduction is of the utmost importance. *Phytophthora* propagules in soil may be spread to new areas by movement of soil on shoes, tires, and tools. Overland water flow along slopes, drainages, and streams can also disperse *Phytophthora* spores large distances.

### **The solution: Clean plant production**

The principles of producing nursery plants that are free of these and other pests and pathogens can be summarized in five words: start clean, keep it clean. *Phytophthora* diseases cannot develop if these pathogens are not present. Though this sounds simple, it requires a diligent approach to:

- (1) **use clean materials**, including pathogen-free plant propagules, sanitized or new containers, pasteurized potting media, and uncontaminated water;
- (2) **prevent contamination** throughout nursery production by setting up the nursery and managing it in a way that excludes these pathogens.

This can be accomplished by using a systems approach to sanitation similar to the HACCP (hazard analysis and critical control point) systems that are used in food manufacturing to prevent contamination.

A key point of the systems approach is that it is comprehensive. Many of the native plant nurseries where multiple *Phytophthora* species have been detected were using some of the best management practices (BMPs) that are part of a systems approach to clean plant production. However, these nurseries invariably failed to follow a complete systems approach addressing all critical pathways for contamination, with predictably poor results. Plants cannot be "cured" of *Phytophthora* infections. Following selected BMPs on plant material that is already infected will not eliminate established *Phytophthora* infections and may not prevent spread. Conversely, plants that are initially clean can be contaminated by poor practices at many points during production.

A number of native plant nurseries have taken steps to adopt a complete systems approach, and work is underway to develop a certification system that would allow consumers, including CNPS chapters, to purchase clean native plants with confidence. CNPS supports the development of pathogen-free certification programs. Unfortunately, it will take some time to establish a certification process. In the meantime, some agencies have suspended the use of nursery stock for restoration projects and/or are developing specifications that would be used to certify plants that they purchase. CNPS has supported the development of propagation guidelines for disease-free nursery production for use by Chapter and other native plant nurseries (CNPS BEST MANAGEMENT PRACTICES (BMPs) FOR PRODUCING CLEAN NURSERY STOCK)..

## Implications

A sizeable but unknown percentage of existing native plant nursery inventory is likely to be infected with a number of exotic *Phytophthora* species. These infections can eventually debilitate and kill infected plants after they are planted in either native or horticultural landscapes. Beyond this, the pathogens can permanently infest sites where the plants were installed and then be spread unwittingly to other locations. Although it may be possible to identify and avoid some of the stock with the worst symptoms, it is not yet possible to identify all infected plants. This is the rather unfortunate situation that currently exists and has existed for years. Due to recent detections of *P. tentaculata*, many other organizations are now more aware of the extent and implications of this problem.

The spread of *Phytophthora* and other plant pathogens via infected nursery material is a long-established problem that cannot be solved quickly. It will take a sustained effort by many parties to assure that native plant nurseries are reliably clean systems. The industry is currently in a transitional phase in this effort and must work with restoration practitioners so the entire growing cycle is clean. Some native plant nurseries have undertaken substantial efforts to improve sanitation, but certifiable production and testing standards are not yet validated. Other nurseries have not yet acted or have not implemented enough changes to produce clean plants.

In the absence of certification standards and testing protocols, it is difficult to verify whether plants are free of *Phytophthora*. Nurseries may also be involved in CDFA's voluntary clean nursery program. This is a positive step, but this program focuses on reducing rather than eliminating *Phytophthora*, and does not provide any guarantee that the nursery produces clean plants. Plants free of *Phytophthora* and other exotic pathogens and pests are requisite for habitat restoration; habitat is not being "restored" if long-lived exotic pathogens are being introduced with plantings. Public lands managers and others that have long-term stewardship responsibility over restored habitats have been among the first to support a verifiable clean plant certification system.

The suggestion has been made that most landscaped yards are likely to be infested with *Phytophthora* from previous nursery stock plantings. This may be true for portions of an existing landscape, but such contamination is usually not uniform across an entire property. Using infected material in uncontaminated areas, such as previously unplanted portions or former turf areas that are undergoing conversion, can introduce contamination to these areas. Furthermore, the host ranges of *Phytophthora* species vary widely. Increasing *Phytophthora* diversity by introducing additional *Phytophthora* species can more seriously restrict future planting options. These introductions also increase the risk that additional *Phytophthora* species will be inadvertently spread into native plant landscapes. CNPS's clean nursery initiative has the potential to provide *Phytophthora*-free plants to native plant buyers.

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