Understanding and Managing *Phytophthora* Root Rot in Doug and True Firs
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What's Killing My Trees?!

Phytophthora root rot is one of several soil-borne disease organisms that have been found infecting Christmas tree species in the Sierra foothills. *Phytophthora* used to be classified as a fungus belonging to the "water mold" group or Oomycetes- because it produces, under the right conditions, a swimming spore called a zoospore. (Recently this organism has been reclassified by the taxonomists so that it is more closely related to brown algae, due to its cell wall structure!)

Phytophthora forms several different spore types in the soil-chlamydospores are formed under dry conditions, often in infected roots, and serve as a survival mechanism for this organism. The chlamydospores can survive for several years. Oospores are formed under lower temperatures and are another type of survival spore. Both oospores and chlamydospores can "germinate" when there is moisture and warm temperatures to form the sporangia, which in turn produce the zoospores. The zoospores then "swim" to a new root and infect it. So, soil moisture is key for new infections.

Phytophthora cinnamomi Rands (hereafter referred to as *P.c.*) was first isolated from cinnamon trees in Sumatra in about 1922 and has since been reported from over 70 countries. It has a HUGE host range including peach, pear, walnut, avocado, ornamentals such as rhododendron and camellia, eucalyptus, and conifers including pine, true firs and Doug Fir. It is considered one of the most virulent species of *Phytophthora*, which means it is very good at infecting and causing rapid death of its host. In El Dorado, we have found *P. cinnamomi* to be the species often infecting Christmas trees.

P.c. likes warm soil temperatures (some other species of *Phytophthora* show up in cooler temperatures). Therefore, this disease becomes active in late spring-summer, we think when the soil temperatures warm up to about 70 degrees or so.

Symptoms. Trees with root rot turn yellow-red and die, often apparently suddenly. In Christmas tree species, we have observed "bleeding" or gummosis- heavy pitch bleeding from the trunk-in trees that were positively diagnosed as having *P.c.* Roots from these infected trees will be minimal-often brown and rotting with a lot of "sloughing" of the root cortex. This deterioration of the roots is what causes the trees to become suddenly wilted-turn yellow, lose needles- collapse and die. The trees are unable to get water.

Although water is key for infection, (and often we see *Phytophthora* root rot in areas that are over watered or too wet), **stress** on trees can also weaken roots and make them susceptible to infection. **This includes drought stress**, which makes it difficult to gauge how to use irrigation to manage *P.c.* We sometimes see trees collapse and die in situations where they have been under watered (and therefore subject to drought stress)-

growers can be confused how a "water mold" can cause disease in these conditions. What sometimes happens is that infection occurs earlier, the roots are weakened, and when high heat comes along, and the tree is stressed, it collapses.

Other things can also cause similar symptoms to *Phytophthora* root rot, and so a proper diagnosis is very important in managing this disease. Other culprits with similar symptoms include:

- *Armillaria* (Oak Root fungus): this fungus will often form a white mycelial "fan" under the bark of the tree. It also sometimes forms "honey mushrooms" in November or so.

- *Annosus* Root Rot: this fungus infects either by root-to-root contact or by infecting a freshly cut stump. When the trunk is cut-the darkly stained older wood is often diagnostic of this disease.

- Gophers: destroy roots, cause drought like symptoms. Look for the tell tale mounds and holes of these pests to rule them out.

- J-root or poor planting: Twisting roots while planting them, or shoving roots in a too small hole, can strangle young trees and cause collapse and death.

Managing *Phytophthora*. We are still learning how to manage this disease, but there are several things a grower can do to lessen the chance of *Phytophthora* root rot.

- Plant a "resistant" species, if possible. Nordmann, Turkish Fir, and to a lesser extent Douglas Fir, appear to confer resistance-these may be good choices if you know you have an area that has *P.c.* These species may have other cultural requirements so experiment with a few trees if they are new to you.

- Choose your trees from a reputable nursery and choose bigger (older) seedling trees with stronger root systems.

- Chemical Control: Subdue Maxx™, Syngenta (mefenoxam) is currently registered for use on Christmas trees in California, however, in a pilot study conducted in Camino, Ca., White Fir and Noble Fir seedlings treated with Subdue Maxx during the season still became infected with *Phytophthora cinnamomi*.

- Avoid over watering your trees-especially when more mature. Younger trees need more water than trees 5 years (or so) and older. If you have a mixed planting, use of drip irrigation will allow you to "plug" the irrigation on trees that don't need the water while enabling you to keep moisture on the young trees when needed.

- Don't stress your trees. Anything that stresses your trees: heavy fertilizer on young tender roots, herbicide damage to roots, too much or too little water, can make them susceptible to *P.c.* infection.

- Increase soil organic matter and "tilth". *Phytophthora* thrives in "heavy" soils like our clay soils. Increasing organic matter in your soil, such as by incorporating a cover crop or mulch, will increase the aeration of your soil and make it less likely to remain wet and conducive to *P.c.* infection.

- Avoid compaction of your soil. Avoid heavy equipment, such as ATV or truck driving, or even walking paths, in areas where trees are being planted.

- Perhaps consider planting on a raised bed. Results with susceptible species are not conclusive, however, a raised bed will provide more aeration to roots.

- Consider "cooling" your soil with a drought tolerant cover in between tree rows such as Sheep Fescue.

- Avoid moving soil from root rot areas to "new" areas. *Phytophthora* lives in the soil and can be moved with equipment-shovels, planting augers, even boots. Disinfect your tools if you have been working in a root rot area with a solution such as 50% Clorox. Don't allow customers to walk in root rot areas-keep these cordoned off.

Identifying chemical and cultural management strategies for *Phytophthora cinnamomi* in California's Sierra foothill Christmas trees: an on-farm pilot study.

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Introduction

Agriculture in the Sierra foothill region of California is characterized by small family farming operations that rely mainly on direct marketing for sales. Christmas trees present a lucrative crop for these growers as sales from "choose and cut" operations have increased in recent years. However, root rot caused by *Phytophthora cinnamomi*, (*P.c.*), has been identified as a serious problem for Christmas tree growers in this region. This pilot study begins to investigate potential tools to help manage *P.c.* in California's Sierra foothill Christmas tree farms.
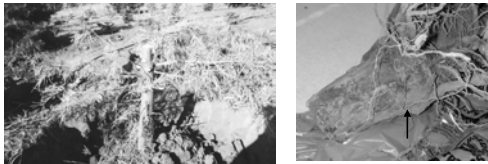
A White fir exhibiting the typical signs of *Phytophthora* infection: "bleeding" on the trunk at and just above the soil line. When cut into, the canker under the bark appears red-brown in color.

Goal: To identify promising management strategies for root rot, *Phytophthora cinnamomi*, in naturally infested Christmas tree farm soils.

Objectives:

1. To identify Christmas tree species which may confer some resistance to *P.c.* infection.

2. To evaluate the effect of mefenoxam, (Subdue Maxx™, Syngenta), applied either as a root dip prior to planting or as a soil drench during the season, on *P.c.* infection.

3. To evaluate the effect of fenamidone, (Bayer- not yet registered in California), applied as a soil drench during the season, on *P.c.* infection.

4. To evaluate the effect of planting Christmas trees on raised beds on *P.c.* infection.

Methods

Christmas trees were planted on February 21, 2003 in two adjacent blocks with a history of *P.c.* located on the same Christmas tree farm in Camino, CA. Four species were planted. Table 1. shows the species, size and root health of the trees planted.

Table 1: Christmas tree species planted in 2003 *Phytophthora* trial.

Species planted	Obtained from*	Size (plug-bed)	Notes
Douglas Fir *(Pseudotsuga menzieii)*	U.S.F.S nursery, Placerville, CA. (local)	P0-2	Large root system-strong trees
White Fir *(Abies concolor)*	CDF nursery, Magalia, CA.	P2-0	Weaker root system-smaller trees
Nordmann Fir *(Abies nordmanniana)*	Lawyer nursery, Olympia, WA.	P1-2	Large root system-strong trees
Noble Fir *(Abies procera)*	Weyerhaeuser Co., Tacoma, WA.	P1-1	Weaker root system-smaller trees

* All trees were donated from growers and from the local U.S.F.S. nursery. These contributions are gratefully acknowledged.

The following treatments were applied:

♣ Control-untreated.

♣ Subdue Maxx™ at planting at a rate equivalent to10x the labeled 2-0 transplant rate: 0.5 pt. Subdue/gal. One gallon of solution was mixed and tree roots were soaked in the solution for 30 minutes prior to planting.

♣ Subdue Maxx™ during the season using the labeled rate for 2-0 transplants of .05 pt. Subdue/gal. A volume of 2 pints solution per tree was hand-applied at the base of each tree on three dates: March 31, June 4 and July 18.

♣ Fenamidone during the season at a rate equivalent to 14 oz./100 gal. A volume of 2 pints of solution per tree was hand applied at the base of each tree on three dates: March 31, June 4 and July 18.

♣ Raised beds. Prior to planting, a mound approximately six inches in height was created and the tree was planted into the middle of the mound.

Five replicates of the Doug Fir and White Fir, and three replicates of the Nordmann and Noble Fir were blocked and treatments were randomly applied in two sections of the field.

Trees were inspected for visual symptoms of *P.c.* infection (browning of entire seedling) on June 3, June 11, July 15, and August 27. In order to confirm *P.c.* infection as the cause of seedling death, trees with visual symptoms were dug up on June 11 and July 15 , examined for signs of J rooting or other obvious damage, and taken to the State Dept. of Forestry lab in Davis, Ca. for culturing. Tissue from roots were plated on to specialized media (PARP) for *Phytophthora* fungi. Cultures were maintained at room temperature in the dark for one to three weeks until potential fungal growth appeared.

Soil samples were collected from each irrigation line where trees were planted in the study. A composite of three samples approx. 6 inches in depth was collected, mixed and pear baited for *P. cinnamomi*. Samples were placed in labeled plastic bags containing a firm pear and sterile water. After three to five days the pears were removed and tissue from along the margins of any areas of discoloration was plated on specialized media and incubated in the dark for approximately one week.
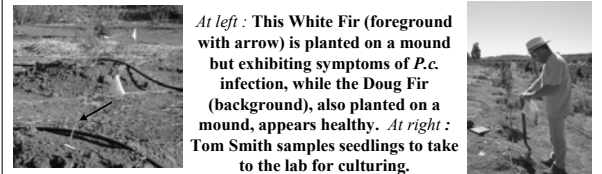
At left : **This White Fir (foreground with arrow) is planted on a mound but exhibiting symptoms of *P.c.* infection, while the Doug Fir (background), also planted on a mound, appears healthy.** *At right :* **Tom Smith samples seedlings to take to the lab for culturing.**

Table 2. Percent of Christmas trees (by species) exhibiting visual signs of *Phytophthora* infection in treated and untreated plots across both experimental blocks.

Species	Untreated Control	Subdue™ dip	Subdue™ drench	Fenamidone drench	Planted on mound
Doug Fir	0% (n=5)	0% (n=5)	0% (n=5)	0% (n=5)	0% (n=5)
White Fir	100% (n=5)	80% (n=5)	40% (n=5)	60% (n=5)	60% (n=5)
Nordmann Fir	0% (n=3)	0% (n=3)	0% (n=3)	0% (n=3)	0% (n=3)
Noble Fir	67% (n=3)	33% (n=3)	67% (n=3)	0% (n=3)	33% (n=3)

Table 3. Results of lab culturing of seedling tissue to confirm *P.c.* infection from treated and untreated plots. n=number of trees in each treatment with visual symptoms of *P.c.* (+) indicates number of trees positively cultured for *P.c.*; (-) indicates number of trees that did not culture *P.c.*; (*lost) indicates number of cultures lost due to contamination; (! NS) indicates number of trees that show visual signs of infections but have not yet been sampled.

Species	Untreated Control	Subdue™ dip	Subdue™ drench	Fenamidone drench	Planted on mound
White Fir	n=5 1 (+) 1 (-) 3 (*lost)	n=4 1 (+) 1 (*lost) 2 (!NS)	n=2 1 (+) 1 (!NS)	n=3 1(+) 1 (-) 1 (!NS)	n=3 1 (+) 1 (-) 1 (!NS)
Noble Fir	n=2 2 (+)	n=1 1 (!NS)	n=2 1 (-) 1 (!NS)	-	n=1 1 (!NS)

Results to date (Sept. 2003): Of the twelve soil samples taken, seven cultured positively for *P.c.* using the pear bait assay. Table 2 shows the percent of each species in each treatment that showed visual signs of *P.c.* Only White Fir and Noble Fir seedlings died, although it should be noted that these seedlings had the weakest root structure at planting. None of the trees sampled exhibited J-rooting, although lack of fibrous roots was noted in some. Table 3 shows the results of culturing to confirm death due to *P.c.* Culturing for *P.c.* was difficult and slow: all seedlings sampled June 11 were lost due to contamination of lab cultures. Those seedlings exhibiting symptoms on August 27 have not yet been cultured. Therefore, it is difficult to evaluate the effects of the treatments at this time. Doug Fir and Nordmann Fir appear to offer some "resistance" to *P.c.* and this should be further investigated.