Guidelines to minimize *Phytophthora* species pathogens in restoration nurseries: rationale and review

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Outline

1. Big picture rationale
   - Why the concern?

2. Overview major points of the Phytophthora Working Group doc.:
   “Guidelines to Minimize Phytophthora Pathogens in Restoration Nurseries”
   brief reasoning behind each

3. A closer look at specific aspects of guidelines:
   - Table height (Section 6.3. Benches and growing areas)
   - Buy-ins (Section 8. Special note)
   - Soil pasteurization (Section 4, and 10.4.)

4. Example of how well Phytophthora does *without* Best Practices as a rationale for use:
   - Real examples from two California nurseries that provides restoration nursery stock
1. Big Picture Rational: Importance of Maintaining CA Biodiversity

Threats to biodiversity loss

1. Habitat loss from urbanization and overexploitation
2. Climate Change
3. Invasive species (includes Phytophthora)

Mediterranean biomes are considered particularly at risk to biodiversity loss especially in area with high human activity (2000, Sala et al. 2000, Science)

Threats from forest pathogens in particular Garbelotto & Pautasso (2012 Eur. Journal Plant Path.)
Phytophthora pathogens increasingly in production
Greater species richness & diversity in nurseries sources than wildlands sources

Jung et al. 2016, Forest Pathology

Parke et al. 2014, Phytopathology

Sims et al. 2015, Mycologia
How Phytophthora gets around Example- Industry related movement of *Phytophthora ramorum*

Grünwald & Garbelotto et al. 2012
Costs to manage once they are in wildlands are very high

- In just one 19,000 hectare watershed
- Estimated to cost $45 million to clean up and start over
- And we are planting them in wildlands with nursery stock!

**Phytophthora tentaculata:** A New Exotic and Invasive Disease

A new plant pathogen in the genus *Phytophthora* (pronounced菲-TOF-ther-uh) has recently been found in several California native plant nurseries. Pathogens of agricultural, ornamental, and forest plants.

Similar to other members of the *Phytophthora* genus, *P. tentaculata* exhibits a broad host range. In addition, species and one additional genus have been found infected, all common in the native plant nursery trade and in wildlands. These include *Artemisia douglasiana*. 

*Bay Nature* An Exploring a Nature in the San Francisco Bay Area

*Killer Plant Pathogen Is Widespread at SFPUC’s Alameda County and Peninsula Restoration Sites*

By Alisa Newtons on July 16, 2015

*UC IPM*

Retail Nursery and Garden Center

*IPM News*

Vol. 6, No. 3. December 2016
Phytophthora- Microscopic fungal-like organism that produces spores and hyphae (unrelated to true Fungi)

![Image: Oospore](image)

![Image: Chlamydospore](image)

![Image: Zoospore producing sporangia](image)

Zoospore image: Judelson 2005
All others: Laura Sims
(2) Document Overview- “Guidelines to Minimize Phytophthora Pathogens in Restoration Nurseries”

• The goal of these guidelines is to help you design and maintain a nursery system that excludes *Phytophthora* and other pathogens and corrects problems if they are found.

• From beginning to end- start clean and stay clean.

• CalPhytos.org
Clean planting materials (Section 2)

Objective: Start with propagative material that is free from infection or external contamination by *Phytophthora* species as well as other pathogens.

Don’t bring in pathogens to the sites
  Once they are there difficult or impossible to remove

Make sure propagation collection site material is healthy and free from debris
  Diseased material brought from the field will allow pathogens to thrive in your nursery if propagated in the nursery

- Increase chance of crop success
- Decrease chance of growing contaminated crop from the start
- Keep source sites healthy

Used clean tools, new bags, and have my clean shoes on so I don’t bring disease from the nursery
Clean containers (Section 3)
Objective: Use only clean containers
Why? Eliminate this as a source of pathogens

• Dirty containers can have pathogen ‘seed’ source (spores)
• Dirty containers can start epidemics in nurseries if used to grow plants in
  • Spores remaining in containers act as a disease source
Clean potting media (Section 4)

Objective: All potting media must be pathogen free and be handled and stored in a manner that precludes contamination

- Pathogens do **not** spontaneously generate
- Resting spores of survive years in soil / debris making it extremely important to remove before use, or to be from a source that does not contain pathogens

![Chlamydomare](image1.png)

![Oospore](image2.png)

Boiler used to generated steam
Clean water (Section 5)

Objective: Use only uncontaminated, appropriately treated water for irrigation

Untreated water may contain *Phytophthora* sporangia and swimming zoospores
Know your water source: Watering plants with *Phytophthora* zoospores and sporangia can lead to infestation problems
Irrigation practices and management (Section 6.5)

• How much water are you using?
  • Excessive water provides a favorable environment for *Phytophthora* to grow and reproduce by zoospores
  • Overwatering can help to spread Phytophthora by creating more opportunites by splash contact and runoff
  • Underwatering stresses plants making them susceptible to even weak pathogens
  • Grouping plants on benches based on watering needs can help to reduce waste, improve plant growth and discourage *Phytophthora*
  • Water moving from plant to plant can move *Phytophthora* and *Pythium* too
  • Over wet conditions support other plant pathogens like *Fusarium* and support an enviroment that is good for fungus gnats which grow and move fungi including plant pathogenic ones like *Phoma, Fusarium* and *Pythium*
Nursery design layout and workflow (Section 6.2)

• Layout is really important, think about beginning, end and movement through the nursery

• Water from outside nursery should not flow into your nursery
  • water can carry pathogen propagules like zoospores

• Outside plants should not overhang nursery building
  • overhanging material may contain vectors or the pathogen itself spreading it into the nursery – or vice versa a contaminated nursery can move disease outside of the nursery this way

• Propagation and growing areas need to be away from cull pile and discard areas
  • if there was any pathogen in your plant material they may grow in the dead and dying material and then produce resting spores. This material can help to start epidemics in your nursery

• Growing materials need to be separated from discard materials
  • discarded materials that come into contact with growing materials combine with that material and can bring pathogens with them

• Dirty containers should be away and separated from new materials
  • assume dirty containers have the pathogen and mixing may accidentally lead to the use of dirty instead of clean containers in nursery production
Sanitation (Sect. 10.3., pg. 25)

Objective: Keep it clean—benches, work areas, tools, surfaces, and the nursery environment

- Past infestation can come back to ‘life’ by presence of spores if re-introduced into the system from dirty benches, tools etc.
- Debris can be a great source of pathogens
- Surfaces and tools can hold debris if not cleaned and sanitized

Prevent epidemics and don’t let past epidemics come back to haunt you!
Delivery of finished plant material (Section 8., pg. 19)

The process is not over until it is over
Plants need to be delivered clean
Where are they stored before delivery
How are they delivered
What happens while they are being loaded
What is the condition of the truck bed
Is the water source used in transport Phytophthora free?
(3) A closer look at specific guidelines

A. Table height (Section 6.3. Benches and growing areas; pg. 13)
B. Buy-ins (Section 8. Special Note; pg. 19)
C. Soil pasteurization (Section 4. & Section 10.4 Heat treatment of potting media; pg. 25)
Why is it a problem that plants are grown on open ground? Why should benches be three feet high?

**Practical Advantages:**
Good working height reduces worker strain and accidents
Less likely to drop or damage materials if working at a good height

**How it works. Principle of Plant Health Management called Protection:**
Establishing a barrier between the pathogen and the host plant or the susceptible part of the host plant
Usually a chemical barrier, e.g., a fungicide, bactericide or nematicide – but this not recommended for restoration
Protection also physical, spatial, or temporal barrier - spatial barrier probably most practical for restoration plants grown in nurseries

The specific strategies employed assume that pathogens are present and that infection will occur without the intervention of protective measures. Assume the ground is where the pathogen is and the distance acts (three feet modest and sufficient) as a spatial barrier between the pathogen and the host.

In general 1 foot may suffice and even eight inches is better than zero – however in cases of driving rain, storms irrigation breaks, heavy irrigation by fatigued/untrained staff risk of spread is still strong

Three feet still possible but very unlikely

**Splash is the most important factor in the spread of epidemics of many plant pathogens.**
Splash height is highly dependent on the kinetic energy of impacting drops. The lower the height the less predictable splash height becomes and (generally more frequent) this may be due to the effects of secondary splash

Splash can move and spread soil particles, pathogens and water
When and where would three foot high benches not provide any added protection

• If there is no splash or if splash does not contain pathogens, if the ground does not have pathogens and the plants do not have pathogens
• If the splash height were reduced
  • Perhaps develop a screen system to prevent splash- soft surface absorbs and does not puddle evaluated for this purpose
  • Examples- Splash guards, silicone surfaces, absorbent ground covers, thirsty concrete

In what circumstance are three foot high benches not practical

• Large plant stock
• Greatly reduce the chance the floor has the pathogen – excluding from the nursery as best as possible

• Then decreasing barrier distance is possible and will offer as much protection as a three foot distance

• reduce the chance of splash by protecting from extremes and careful irrigation
  • It is possible that ground cloth and a much lower surface plastic or steel pallet stacked could work better than high tables esp. for large plant stock
  • Double sided plastic pallets provide an environmental alternative to wood pallets or skids.
  • One-piece, high pressure injection molded plastic is used for food processing, meat, poultry and pharmaceutical applications.
  • Could be used for nursery plants
  • 100% recyclable pallets offer a unique rib reinforced design to minimize dirt and dust collection.
  • Easy to clean and washable pallets do not hold or trap water for fast drying.
  • Stackable pallets high load capacities.

Are there options?

48” x 40” and 6” height
Special note: Buy-ins commercial nurseries use fungicides to reduce damage caused by pathogens in nursery production, does not usually kill the pathogens can act as a pathway into your nursery. Are you sharing pathogens?

Buy-in plant root system 3 months after purchase. *Phytophthora* alive and well! Plant roots beginning to rot and produce witches brooms of fine roots.
Soil pasteurization (Section 10.4 Heat treatment of potting media; page 25)

- Without heat treatment spores that are present can survive years
- Biocontrol usually only works as long as it is continually added NOT a replacement
  - used to suppress not eliminate
- Heat treatment if done correctly kills Phytophthora and other pathogens
- What is killed depends on the temperature that is reached
Where are there short falls/complications with heat treatment

• Are you heating uneven soil? If yes then heat distribution is uneven as well
• Are you using dry heat then the temperature must be higher and heated for longer may cause increased phytotoxic effects
• Are you heating solid material like old root pieces. No I hope that you are not or else you have a specific protocol for that
• Solarization is tricky if you continually get just below the right temperature may promote the organism that you are trying to get rid of
• Are you monitoring the temperature. Temperature is key
(4) Example of how well Phytophthora does without Best Practices as a rationale for use: real examples from two California nurseries that provides restoration nursery stock
Wild West of Restoration Nursery Management

Yee haw Let’s look at some poor management!

• Help to understand how poor practices support Phytophthora
• Rationale for why best practices are so important
• Answer question: Does making small changes make a difference?
Compare two nurseries that supply restoration plant stock in California

- We call them the red and yellow nursery
- Similarities – both have Phytophthora problems, but one less so than the other

Red Nursery = Stop! Lots of *Phytophthora*

Yellow Nursery = Watch it! *Phytophthora* still doing well!
Major drivers of contamination problems evidenced at both nursery

• At least some plants grown on open ground
• Improper watering observed during evaluation
• Potting mix contains potential contamination source
• Potting mix stored in the open near dirty containers, cull pile
• Planting in dirty container
## Problems specific to each nursery

### Red Nursery
1. Most plant production on open ground
2. Excessive weeds and mud on site
3. Improper watering observed during evaluation – mid day (overhead) in already very wet condition
4. Broken irrigation with flooding
5. Contaminated species placed all around nursery grounds near other plant species (mixed with)
6. Mixing potting waste with new potting material and ‘new ‘ mix stored adj. to dirt road and not seperated from potting material
7. No tracking of propagation dates/information

### Yellow Nursery
1. At-least some production on open ground
2. Overwatering during propagation
3. Older potting mix placed with new
4. Various piles of mix many of questionable quality
5. Main mix obtained from unverified mix of sources because it was free or cheap, and not treated before use
Yellow nursery drivers toward plant health

• Some areas at-least (focus on restoration project plants) ground cover used to protect plants from splash
• Effort to train staff about pathogens and manage problems as they arise, willingness to learn and adapting to improve practices
• General good management and horticultural knowledge
• Access to at-least some Phytophthora “free” propagation materials
• Working on getting plants up on benches, had moved some plants at-least a few inches off the ground
Nursery red and yellow comparison of diseased crops worst to best

Conclusion: The yellow nursery has less of a problem than the red nursery. Both have far to go.

Percent Positive by nursery and rank

X axis: Worst Crop
Y axis: % Positive

Crop Rank from worst to best for the red nursery and the yellow nursery.
**Isolate totals:** 47 *Phytophthora* species isolates  
**Taxa totals:** 10 identified taxa based on consensus ITS  
**ITS clade totals:** 1 clade 1 isolate from 1 sample, 1 taxa; 13 Clade 2 isolates from 6 samples, 3 taxa; 4

<table>
<thead>
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<th>ITS Clade</th>
<th>Phytophthora species (taxon)</th>
<th>host₁</th>
<th>host₂</th>
<th># of isolates</th>
<th># of plants, n=10</th>
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<td>1</td>
<td><em>Phytophthora cactorum</em></td>
<td>Acer circinatum</td>
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<td><em>P. multivora</em></td>
<td>Acer circinatum</td>
<td>Frangula californica</td>
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<td><em>P. pini/citricola clade</em></td>
<td>Arctostaphlos uva-ursi</td>
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<td><em>P. crassamura</em></td>
<td>Diplacus aurantiacus</td>
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<td>Arctostaphlos uva-ursi</td>
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<td><em>P. cryptogea/pseudocryptogea clade</em></td>
<td>Diplacus aurantiacus &quot;trish&quot; type</td>
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<td><em>P. pseudocryptogea</em></td>
<td>Diplacus aurantiacus &quot;trish&quot; type</td>
<td>Arctostaphlos uva-ursi</td>
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<td>Unidentified clade 8 species</td>
<td>Diplacus aurantiacus</td>
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Red Nursery: 44% of plants were *Phytophthora* species positive

<table>
<thead>
<tr>
<th>ITS Sequence Species Results</th>
<th>Host₁</th>
<th>Host₂</th>
<th>No. of isolates</th>
<th>No. of plants, n=10 per plant species</th>
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</thead>
<tbody>
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<td>1 <em>P. cactorum</em></td>
<td>Heteromeles arbutifolia</td>
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<td>Ceanothus thyrsiflorus</td>
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<td>8 <em>P. cryptogea</em></td>
<td>Frangula californica</td>
<td>Aesculus californica</td>
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<td>2 <em>P. multivora</em></td>
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</tbody>
</table>

Yellow Nursery: 15% of plants were *Phytophthora* species positive

Species List: From each nursery 50 plants were evaluated: 10 plants from each of 5 known susceptible crops
Answer question: Does making small changes make a difference?

• Yes. Small changes do make a difference in the amount of crop plants that are infested
• And makes a difference regarding the number and type of Phytophthora species found
• Small changes are not enough – just a beginning moving in the right direction
• Evaluating the population provides evidence of effort
References (author, source, date):

Thank you! Questions?

• Thanks to: Phytophthora Working Group, My Lab: Forest Pathology and Mycology Lab at UC Berkeley, My Boss: Matteo Garbelotto, ANR: For funding, To you: For listening