Phytophthora Diseases in Native Plant Production: Why Should I Care and What Can I Do About It?

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Outline

- What is *Phytophthora*?
- Why the concern about plant diseases in native plant nurseries?
- Results of sampling for *Phytophthora* in OR and WA native plant nurseries

- What is a systems approach to preventing disease?
- What are the most common sources of contamination in nurseries?
- What management practices will help prevent disease?
- Resources for more information

Phytophthora – the plant destroyer

"Perhaps no other single plant disease has resulted in such widespread human suffering and sociological impact."

More than 100 species identified

P. infestans – responsible for the Irish potato famine in 1845

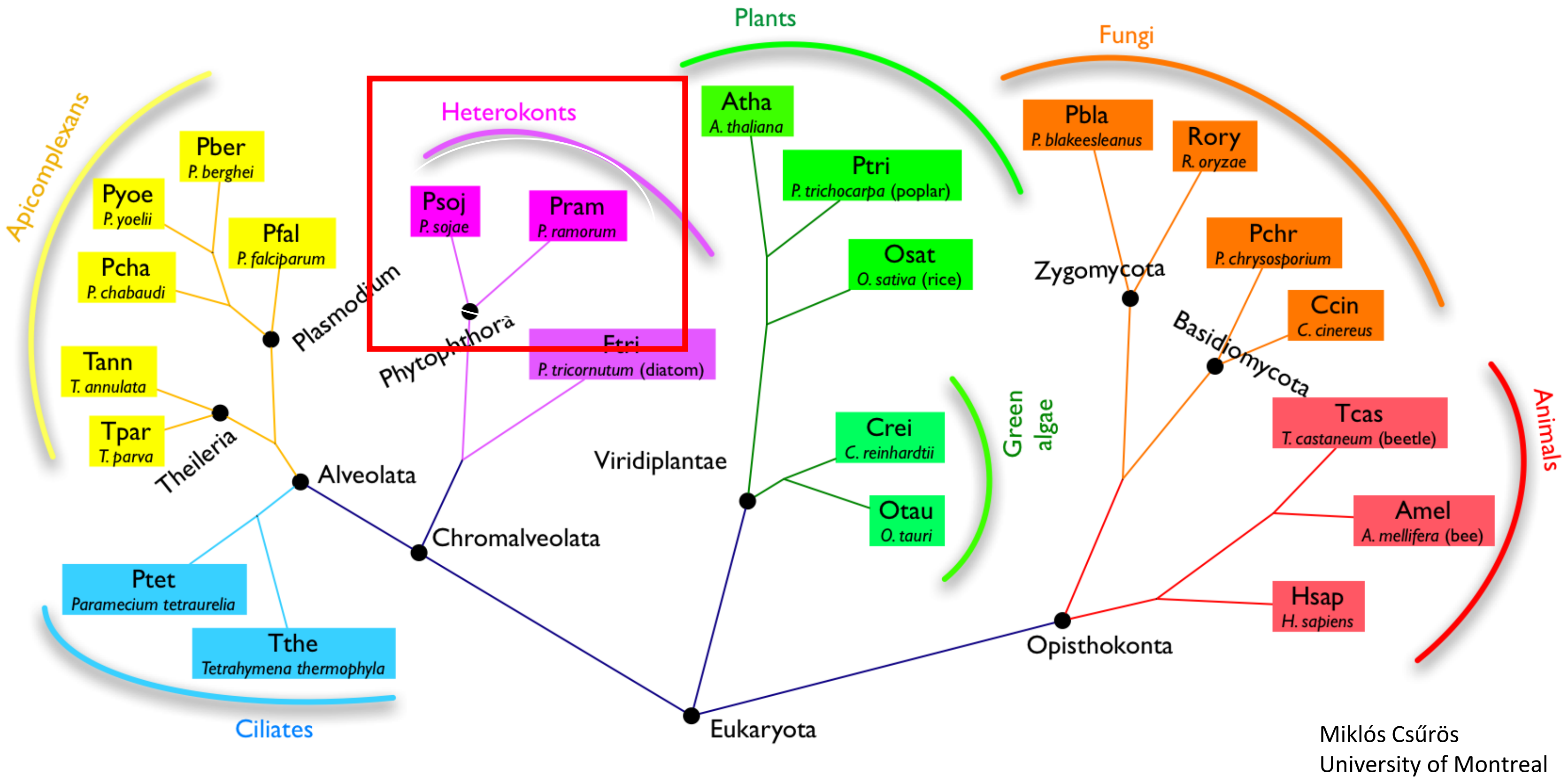
P. sojae - soybean stem and root rot

Several *Phytophthora* spp. cause disease on cacao

P. cinnamomi – causes damage to forest ecosystems worldwide

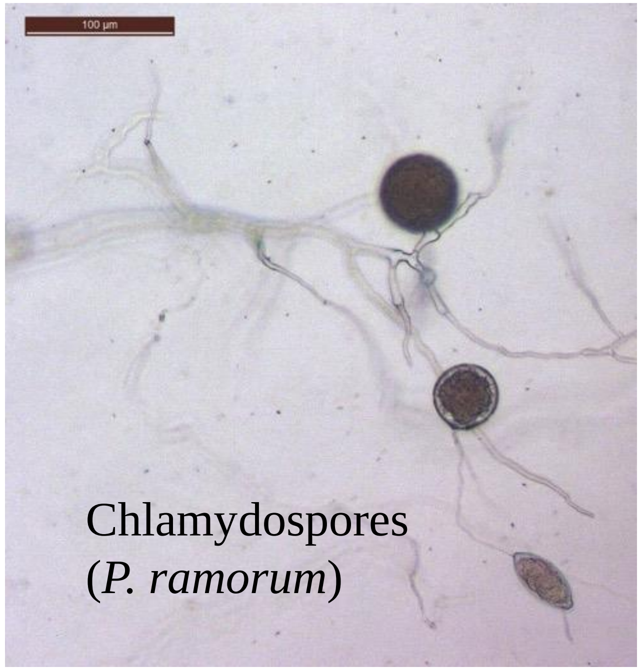
P. ramorum – causes Sudden Oak Death (SOD)

Phytophthora is not a fungus

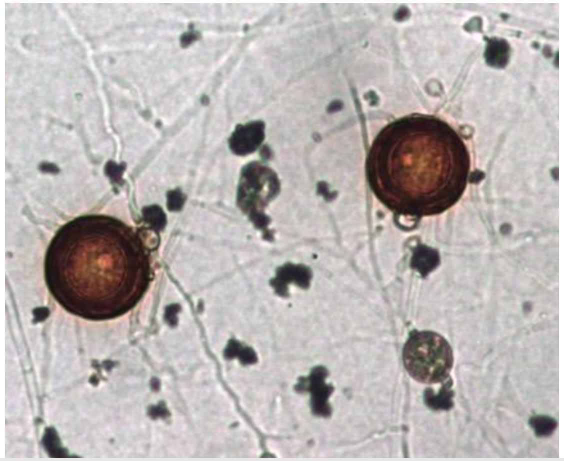


- Oomycetes (aka "water molds") were once considered to be fungi
- Fungi and Oomycetes have similar growth forms – convergent evolution
- Control agents for fungi may not work for Oomycetes and vice-versa

Phytophthora



Chlamydospores (*P. ramorum*)



Oospores of *P. megasperma*

Sporangia containing swimming zoospores (*P. ramorum*)

P. alni oospore

Phytophthora is microscopic and species can be identified by spore stages and/or DNA sequencing

Damage caused by *Phytophthora* spp.


P. cinnamomi root disease on Pacific madrone


P. ramorum foliar and shoot blight on *Vaccinium* at a nursery

Bleeding cankers cause by *P. alni ssp. alni* on Alder

Root disease
Bleeding cankers
Shoot blight
Foliar lesions

Movement of plant diseases

Some examples of exotic *Phytophthora* spp. most likely spread from nurseries to wildlands

Source	Approx. Year	Pathogen	Nursery host(s)	Threatens
???	1990s	*P. ramorum*	Rhododendron, viburnum, camellia, Mahonia, salal	Forests, urban landscapes
Taiwan, OR, CA, EU	1925	*P. lateralis*	Port-Orford cedar, yew	Forests, hedgerows, ornamentals
EU	Late 1900s	*P. alni* ssp. *alni*	Alder	Forests, riparian areas, urban landscapes
CA	Early 2000s	*P. cinnamomi*	Many (Arctostaphylos, Arbutus, chinquapin)	Native landscapes, ornamentals
CA	2012	*P. tentaculata*	Mimulus (Diplacus) aurantiacus, toyon	Native landscapes
OR	2015	*P. occultans*	Ceanothus, salal, boxwood, rhododendron	Native landscapes, ornamentals


Sudden Oak Death
Phytophthora ramorum

Sudden Oak Death

Rhododendron infected with *Phytophthora ramorum*

Phytophthora lateralis
Port-Orford cedar root rot OR, CA;
Now in France, UK

Photo by Cecile Robin

P. alni ssp. *alni*

Alder decline, Europe

Phytophthora cinnamomi
Arctostaphylos myrtifolia, A. viscida - CA

Photo by Phytosphere Research

Phytophthora occultans on Ceanothus spp.- OR

+ *P. occultans* Control

Ceanothus sanguineus

+ *P. occultans* Control

Ceanothus velutinus

Photos from Reeser, Sutton and Hansen (2012); First Report Reeser et al. 2015

+ *P. occultans* C Control

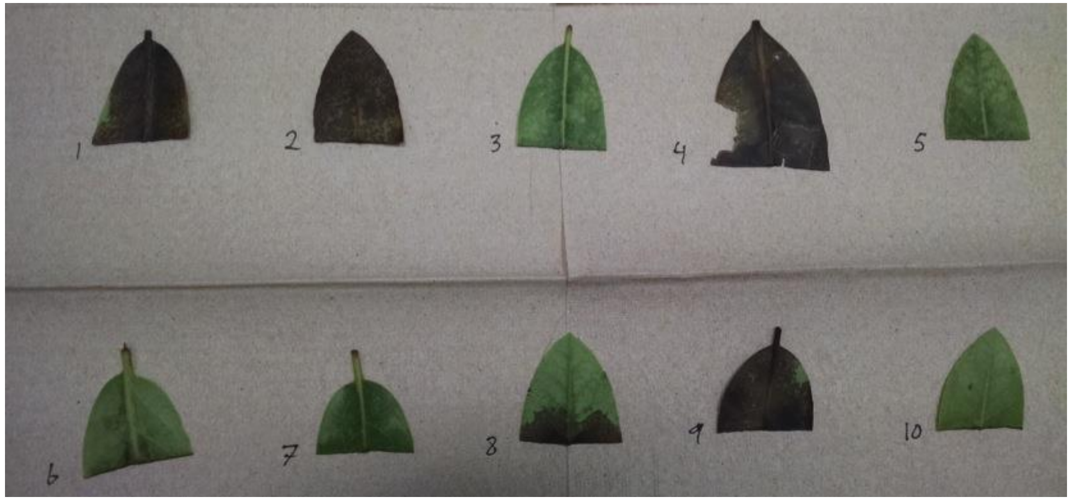
Ceanothus sanguineu *lutinus*

Photos from Reeser, Sutton and Hansen (2012); First Report Reeser et al. 2015

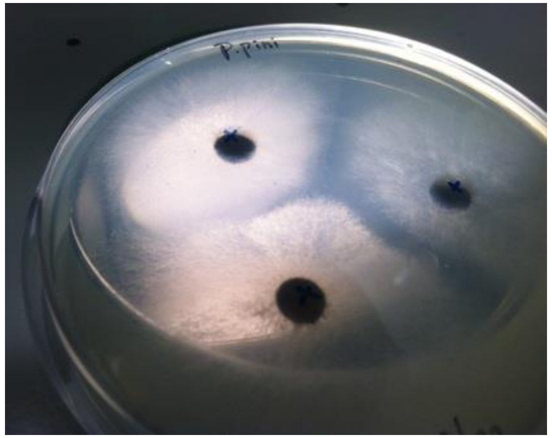
Phytophthora incidence in native plants purchased in Oregon and Washington

1. Pour-through test:
For each plant species, leachate collected from 30 plants
(10 from each of 3 nurseries)

2. Leachate baited with rhodo leaves



3. Baits plated onto PARPH



4. Pure cultures sequenced and examined in microscope to i.d. species

Host	Code	Genus species	Family	*Phytophthora* spp. present OR	WA
Forest					
Kinnickinnick	ARUV	*Arctostaphylos uva-ursi*	Ericaceae	*cinnamomi*	*cinnamomi*
[a]Ceanothus spp.		*Ceanothus spp.*	Rhamnaceae	*cambivora, **occultans***	n/a
Western red cedar	THPL	*Thuja plicata*	Pinaceae	*chlamydospora, citricola, pini*	*citricola, pini*
Oregon grape	MAHO	*Mahonia spp.*	Berberidaceae	*syringae*	*cactorum, citricola, **occultans***
Riparian					
Red alder	ALRU	*Alnus rubra*	Betulaceae	*cambivora, cinnamomi, cryptogea, plurivora, siskiyouensis*	***alni ssp. uniformis**, cactorum, citricola, **occultans**, pini, plurivora*
Pacific crabapple	MAFU	*Malus fusca (a.k. Pyrus fusca)*	Rosaceae	*cambivora*	*cactorum, cambivora, citricola, cryptogea, plurivora*
Red osier dogwood	COSE	*Cornus sericea*	Cornaceae	*cambivora, cinnamomi*	***gallica, occultans**, plurivora, pini*
Prairie					
Bigleaf lupine	LUPO	*Lupinus polyphyllus*	Fabaceae	*borealis, cactorum, cinnamomi, cryptogea, **hedraiandra***	*cryptogea, pini, plurivora*
Mimulus spp.	MIMU	*Mimulus cardinalis*	Phrymaceae (Scrophulariaceae)	***occultans***	*citricola*
[b]Yarrow	ACMI	*Achillea millifolium*	Ranunculaceae	n/a	***occultans***
Slender cinquefoil	POGR	*Potentilla gracilis*	Rosaceae	*cryptogea, plurivora*	*cactorum, citricola, plurivora*

[a]Not available in WA
[b]Substituted for *Delphinium* spp.

Soilborne Phytophthoras in potted native plants at nurseries

- *Phytophthora* spp. not previously reported in WA State include *P. occultans*, *P. alni* ssp. *uniformis*, and *P. gallica*.
  New to OR – *P. hedraiandra*

- Several new host/pathogen combinations

- 10 homothallic and 5 heterothallic species

Plants in gallon pots are stacked for shipping

Oospore of a homothallic *Phytophthora* sp.

Why should we be concerned about exotic *Phytophthora* spp. in nursery stock used for habitat restoration?

-Introduced *Phytophthora* species have already been shown to affect a wide range of plant communities in varying climates and soils

-Both rare and common native plant species affected

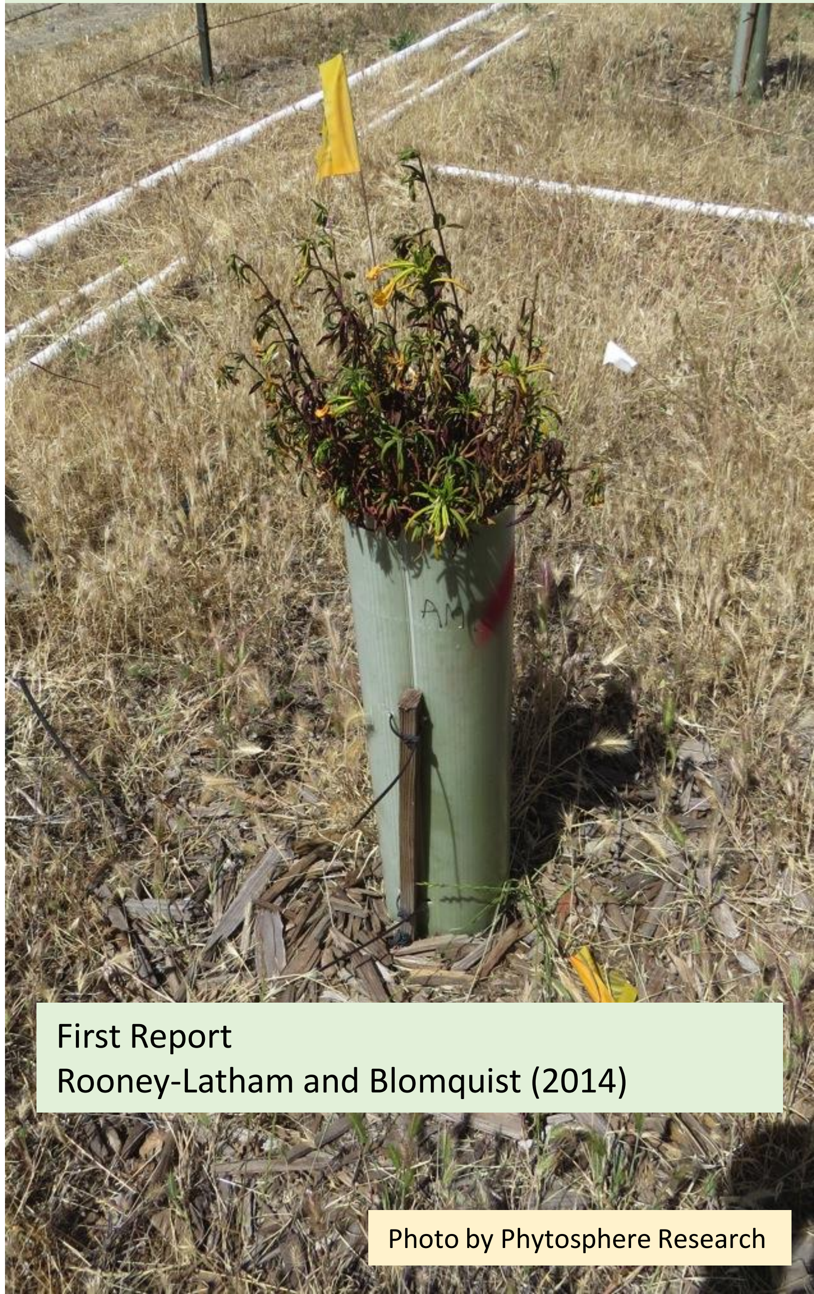
-Increasingly wide variety of *Phytophthora* species in nurseries

-Contaminated soil moved via vehicles, bikes, and foot traffic -*Phytophthora* moves quickly downhill with flowing water

-Very persistent in soil, not possible to eradicate over large areas

-Contaminated nursery stock is probably the most direct and efficient means of introduction

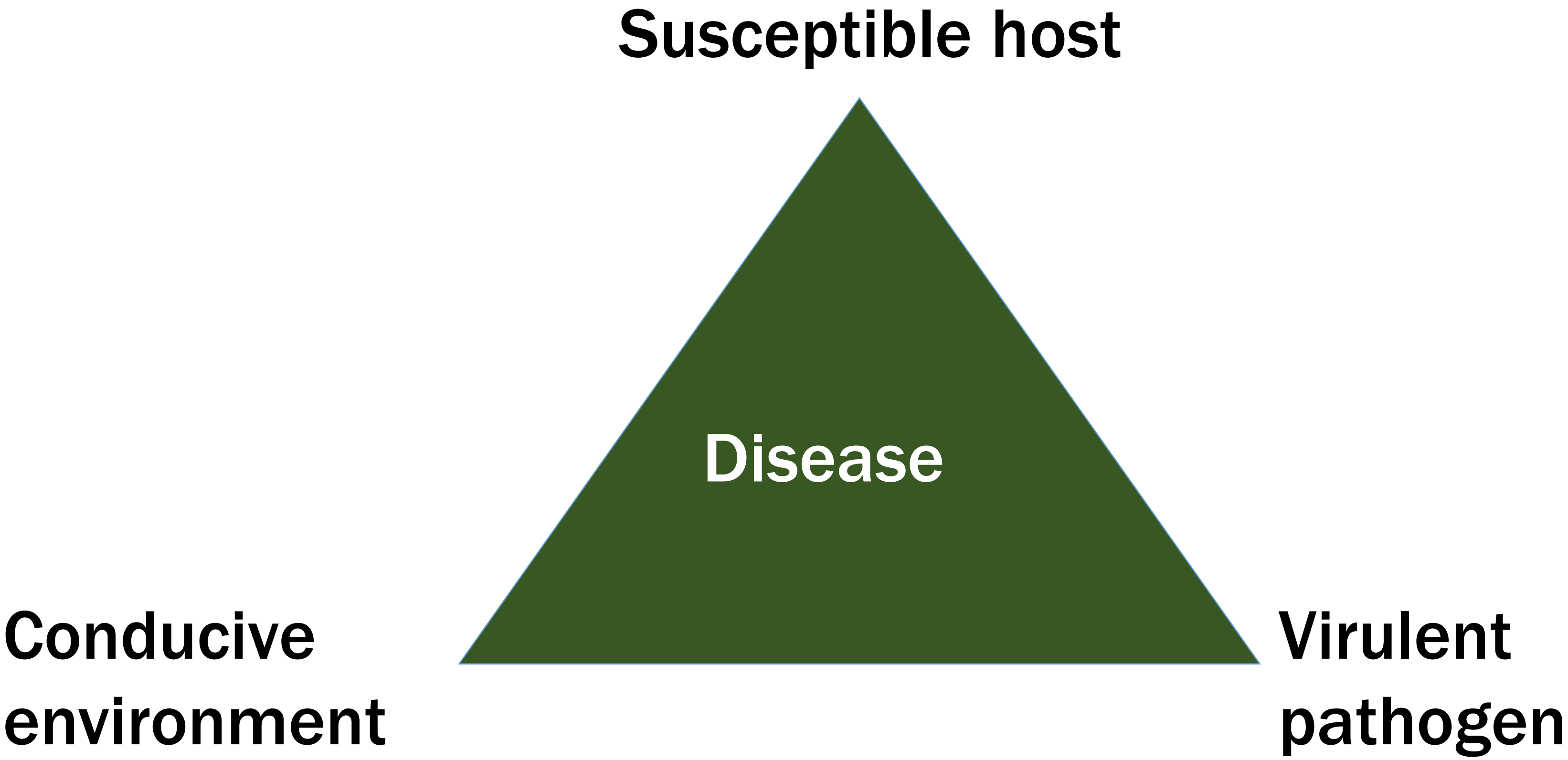
Phytophthora tentaculata on *Mimulus (Diplacus) aurantiacus* - CA



First Report
Rooney-Latham and Blomquist (2014)

Photo by Phytosphere Research

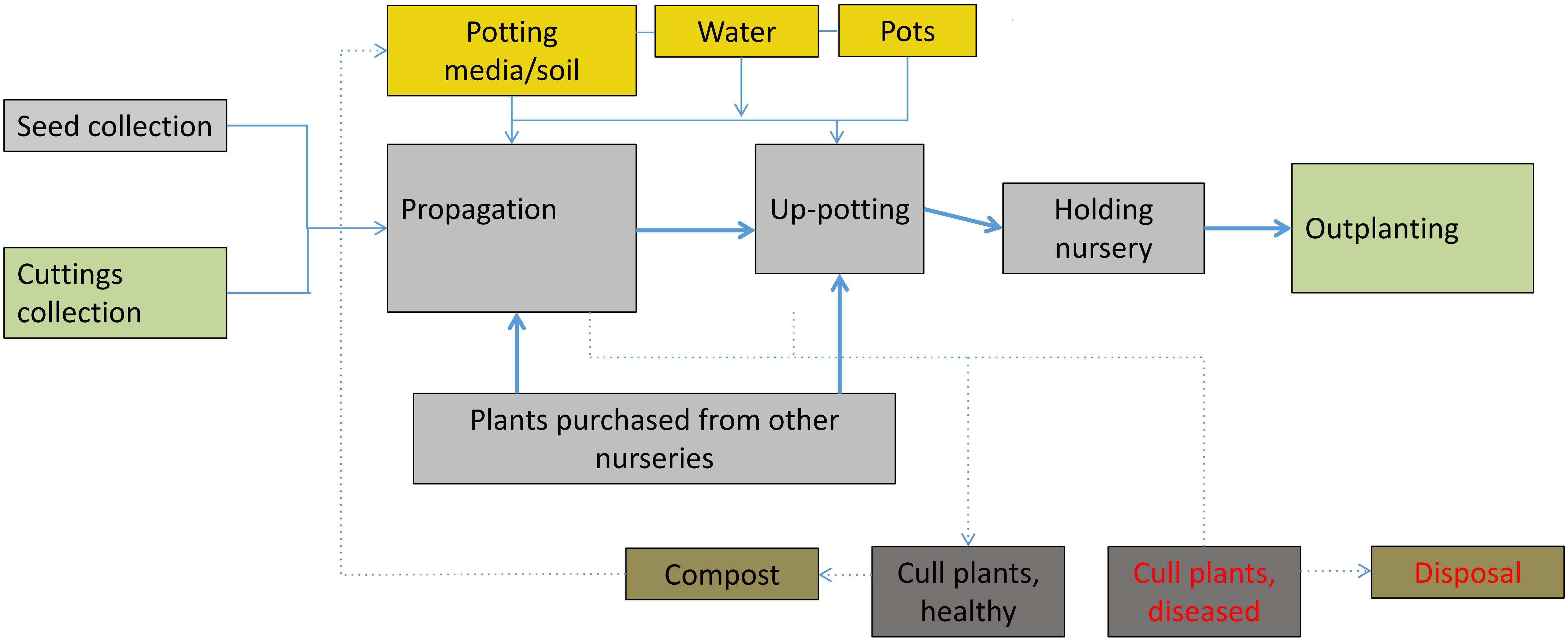
The disease triangle



A Systems Approach for Growing Healthy Plants

- Considers the entire system of plant production from start to finish
- Identifies greatest hazards of contamination
- Leads to correction of any unsafe practices; development of Best Management Practices
- Reduces risk of disease
- Proactive
- Preventative

A systems approach for producing healthy native plants



Components of a Systems Approach in Nurseries

- Site selection, preparation, and maintenance
- Plant sources
- Plant propagation and greenhouse production
- Water management
- Container production
- Field production
- Potting media and containers
- Disposal and composting
- Training
- Scouting
- Recordkeeping

Site selection

A beautiful native plant nursery

But it’s surrounded by a forest infested with Sudden Oak Death.

Oregon myrtlewood infested with *P. ramorum*

Locate your nursery away from known sources of pests and pathogens

Propagation

Maintain ultraclean propagation houses

Disinfectants for cleaning hard surfaces, tools, and equipment

For best results, clean soil or plant debris from objects or surfaces before applying the disinfectant. Use labeled rates and minimum contact time.

Chemical name	Trade name
peroxides	ZeroTol, TerraCyte, Virkon
sodium hypochlorite (bleach)	Chlorox
quaternary ammonia	Physan, Greenshield

Wood is impossible to clean

Photo by Phytosphere Research

Placement of containers

Never put containers in direct contact with the ground

Get containers up and off the ground

•

Prevent leafy debris from accumulating on the ground

Collect and dispose of leafy debris between crops.

Keep your greenhouses free of leafy debris

Water management

Prevent standing water

A well-drained outdoor growing area

Assume all surface water is contaminated with *Phytophthora* spp. and do not use it for irrigation.

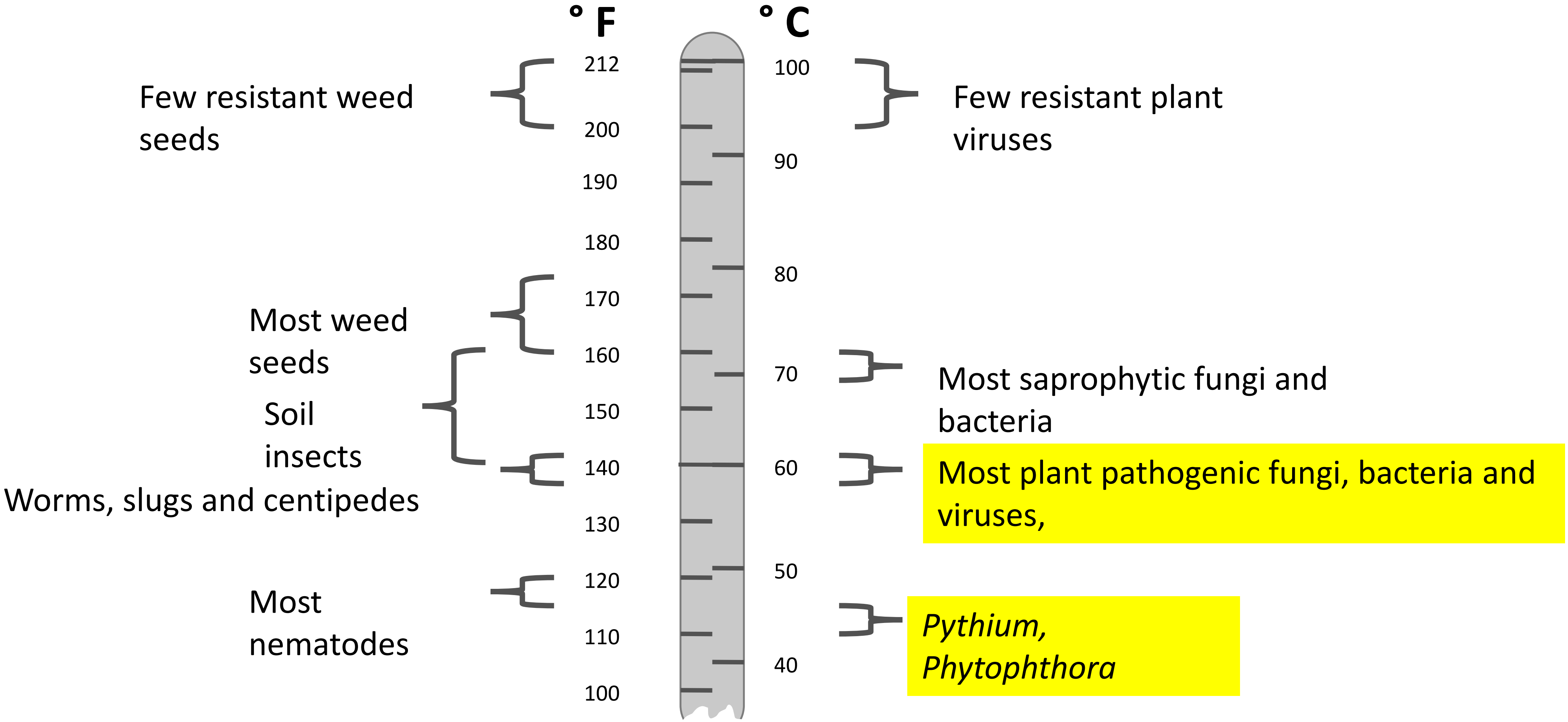
Municipal water and well water do not contain plant pathogens.

Soil and potting media

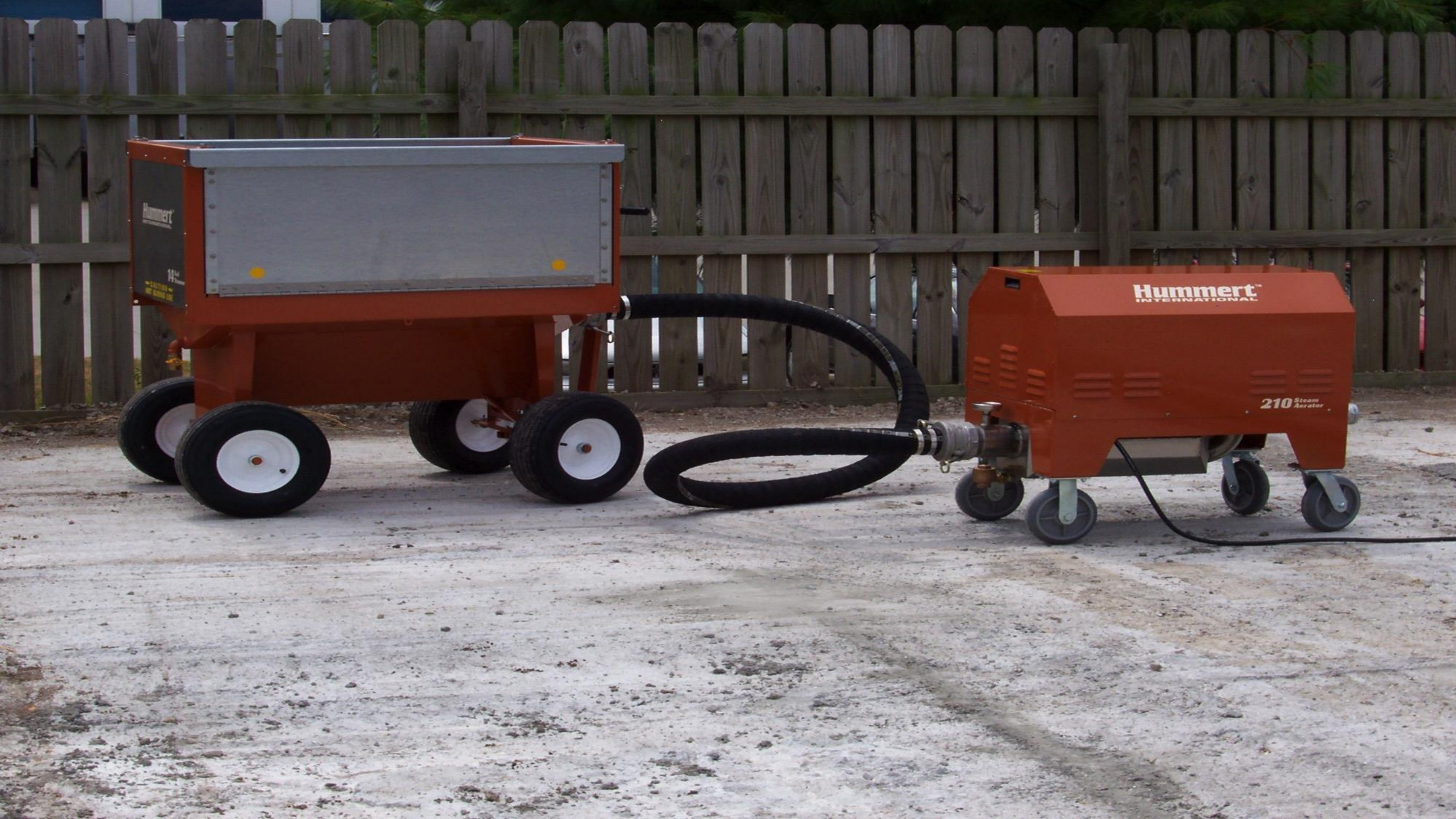
Soil is teeming with microorganisms and most of them are “good guys”

….but some of them aren’t.

Temperatures necessary to kill various groups of soil organisms – 30 min. aerated steam



Steamer cart to pasteurize soil at 140° F for 30 min once soil has come up to temperature


Hummert
INTERNATIONAL
210 Steam Aerator

Solarize

To eliminate pests and pathogens, maintain:
≥158°F for 30 min, or ≥140°F for 60 min

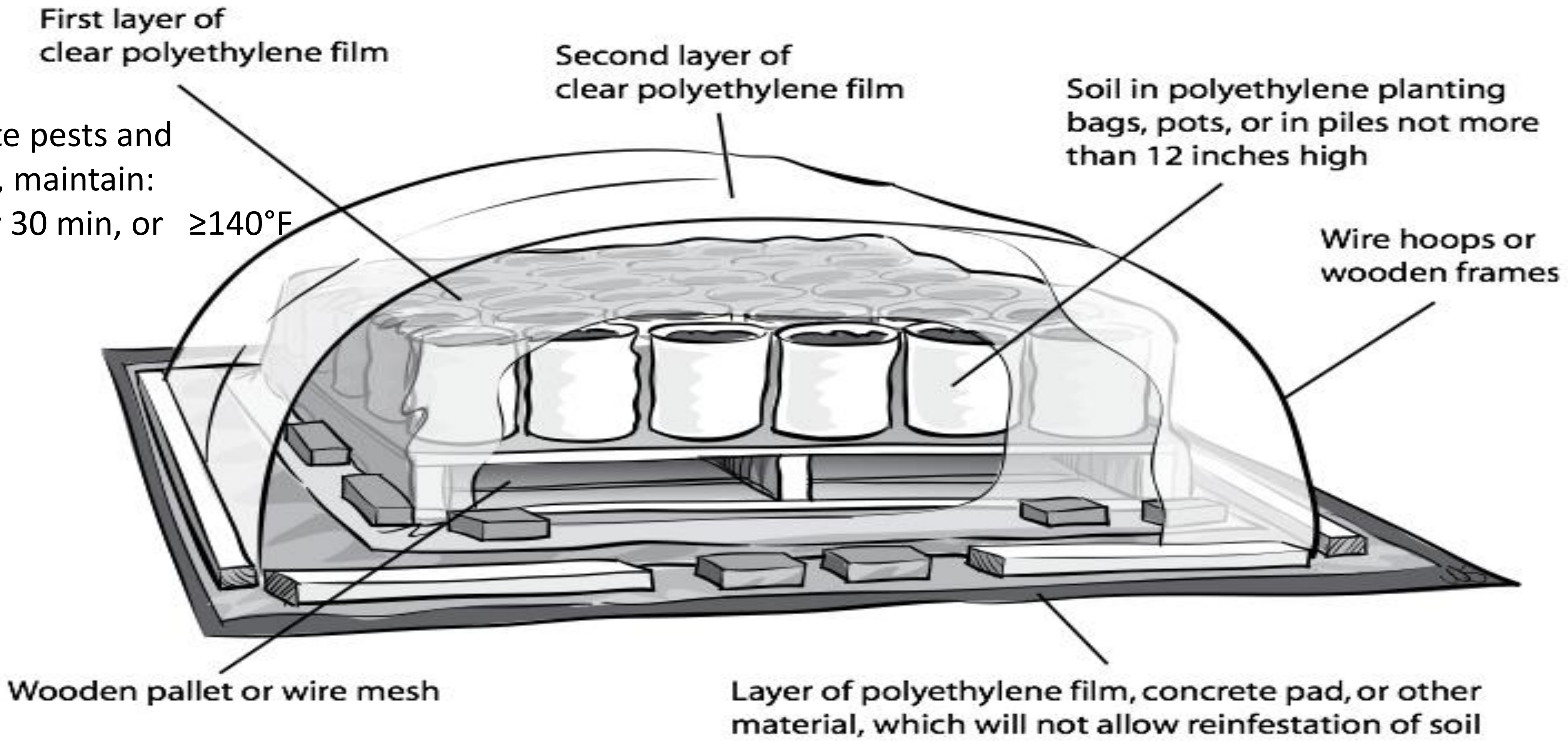


Figure 3. To solarize soil in containers, place soil in buckets or bags on an elevated surface and cover with a double tent of two layers of clear polyethylene film.

http://www.ipm.ucdavis.edu/PDF/PESTNOTES/pnsoilsolarization.pdf

Solarization of fallow soil for 4-6 weeks is very effective at killing many soilborne pathogens and also weeds.

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Soil Solarization Model | Soil Solarization Model

uspest.org/soil/solarize

uspest.org/soil/solarize

Input Options: Species: Phytophthora ramorum and P. pini | Start: Jun 23 | End: Jul 23 | Start year: 2016

Location: WDAC1 Woodacre CA (Marin) | Prior year to use as a forecast: 2015

Crushed rock depth (inches): 0 | Soil temperature (°F) 20 inches below surface: 84

RUN SOLARIZE MODEL

Soil Solarization Program - for using transparent anti-condensation plastic film to manage two soilborne plant pathogens: *Phytophthora ramorum* and *Phytophthora pini*, developed for nursery beds.

Instructions - how to use the "SOLARIZE" soil solarization program.
See also model documentation (pdf).

1. Select all options starting with species.
2. For Start Date, default is today.
3. For End Date, default is 50 days from today.
4. Select a prior year to be used as a forecast past the available 7-day forecast (subject to available data; default is last year's data).
5. Locations currently limited to Western OR, WA, CA stations with solar radiation data (RAWS, AGRIMET, AGWEATHERNET, and CIMIS networks).
6. For Crushed Rock Depth, default is 0 inches (no crushed rock on surface of soil).
7. For Lower Boundary Temp. default is 80 Degrees Fahrenheit.
8. Click "RUN SOLARIZE MODEL" button to view graph results.
9. To re-run model just change settings and click button again.

[Home] [Intro] [Data Access Maps] [DD Calc & Models] [Links]

Integrated plant protection center ippc OSU Western IPM Center NIFA

This project funded by USDA-NIFA Western IPM Center Initialization & Signature Program grants, and by the statewide Integrated Pest Management Program of IPPC at Oregon State University.

Potting media options

Purchase bagged soilless potting media from a reliable supplier, OR

Potting media options (cont'd)

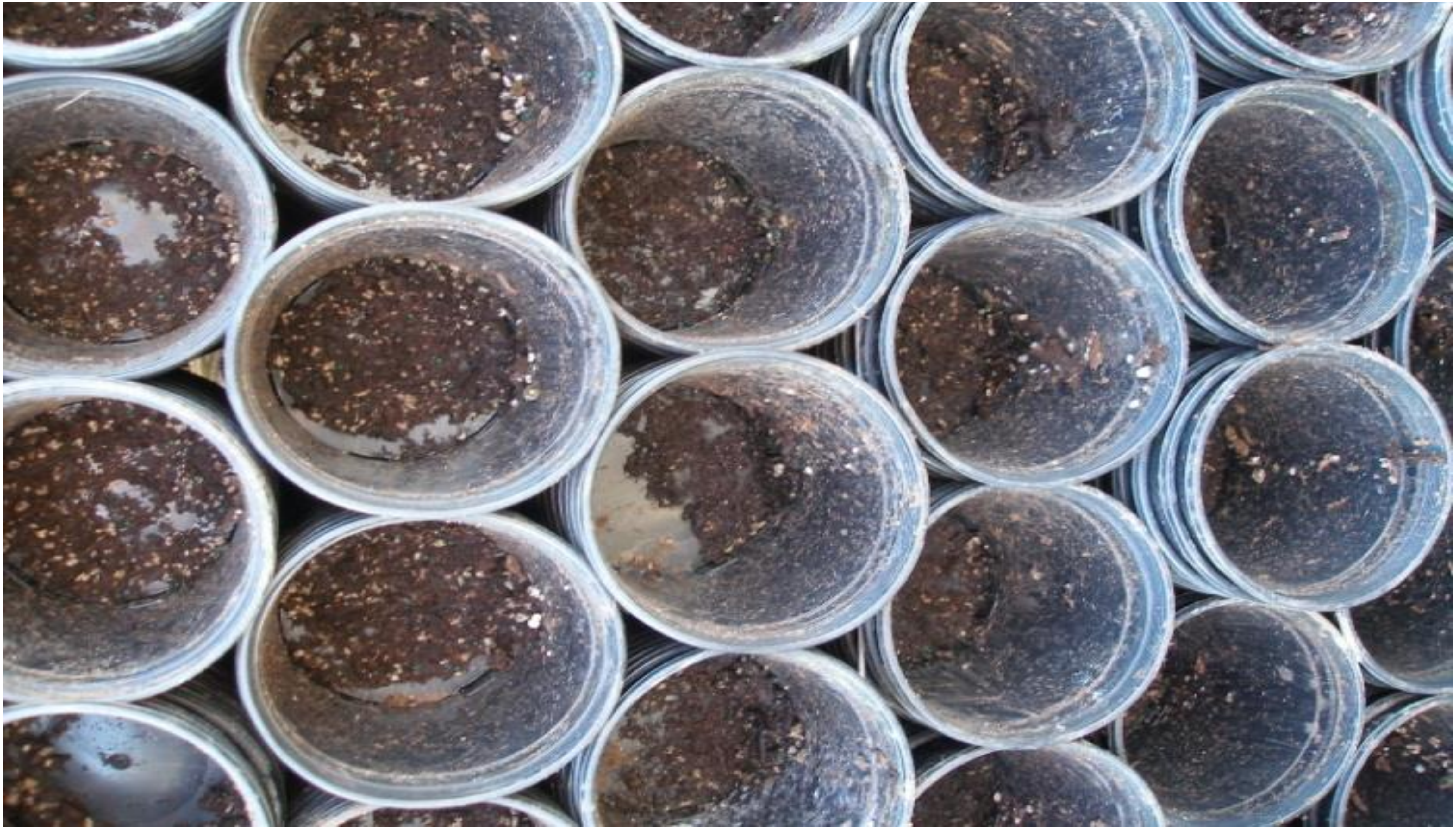
- Prepare your own media from raw materials free from pathogens: bark, compost*, sand*, pumice, vermiculite, perlite; do not let it become contaminated during storage or mixing
- Can add to treated soil or potting media: inoculum of mycorrhizal fungi (granular, powder, liquid) or biocontrol products available commercially

Store media ingredients on a well-drained, paved surface,

Dirty potting media

Containers

Do not reuse dirty pots without cleaning them first!



How to disinfest pots, trays, racks, and cones

1. Steam (no washing necessary) 140-180° F for 30 min

OR

2. Wash to remove soil, roots, and organic debris

Then sanitize:

- Soak in hot water bath 180° F for 30 min.

OR

- Soak in a 10% bleach solution for 30 min., then rinse

OR

3. Solarize

Pot and conewashing stations

Steam

Mobile Steam Unit

Hot water dip

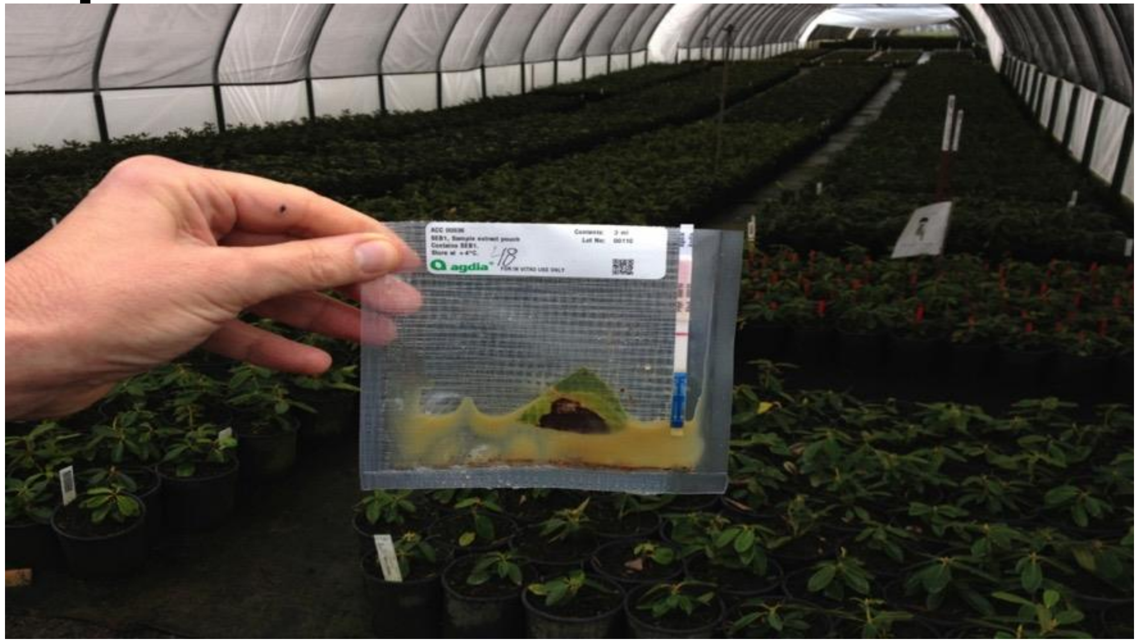
Scouting and monitoring

Regularly scout your plants for pests and diseases


If you find a sick or dead plant, dispose of it.

Know what a healthy plant should look like.

Use ELISA diagnostic kits to test suspect plants



Phytophthora Immunostrips
Agdia, Inc. USA
Strips with SEB1 buffer-filled mesh bags
ISK 92601/0025= 25 strips

25 strips = $150 ($6.25 each)

Two ways to bait the root ball

In the pot

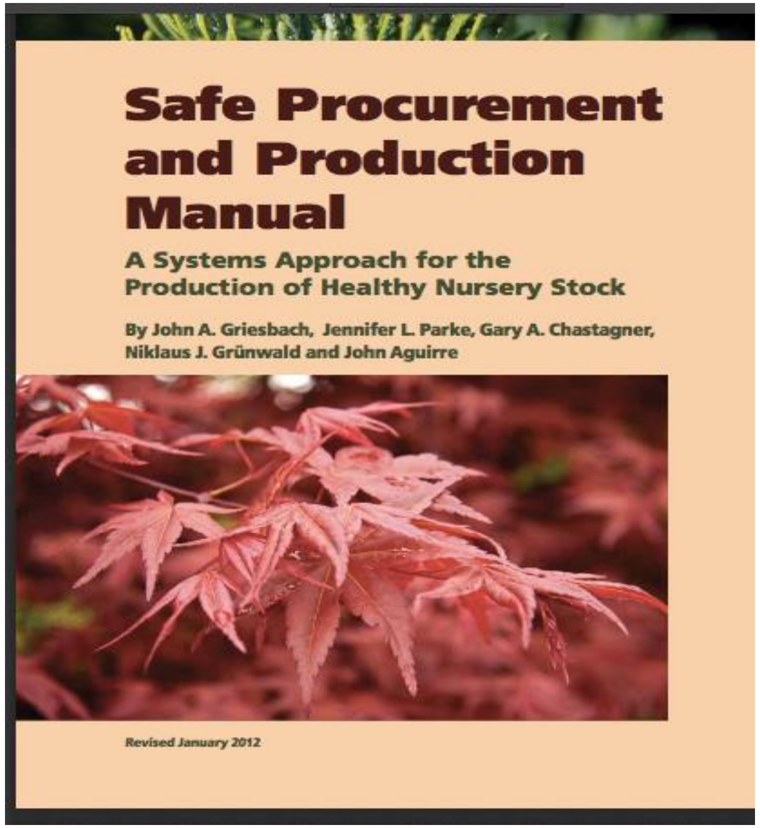
Or under the pot

Send the leaf bait to a plant diagnostic lab

Then flood the saucer

Education, diagnostics, tools for early detection

Systems Approach Manual



Griesbach, Parke, Chastagner, Grünwald, & Aguirre, 2012

Available for free download from the OAN website http://oan.org/associations/4440/files/pdf/SafeProduction.pdf under Publications

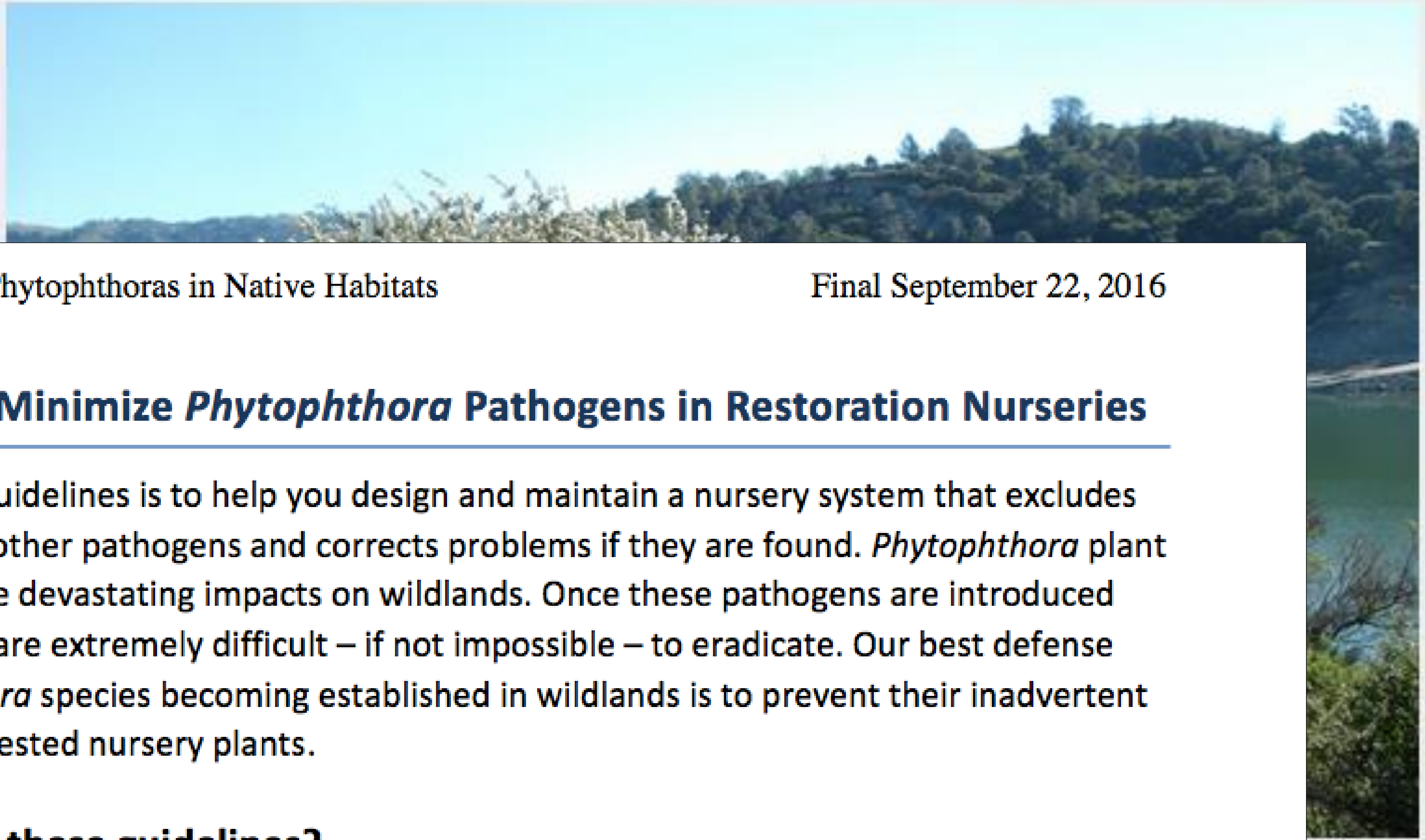
Welcome to CalPhytos.org – Phytophthoras in Native Habitats

Several first-in-the-USA detections and newly identified species of *Phytophthora* in both native plant nurseries and restoration areas have occurred in recent years. Many of these *Phytophthora* species appear to have wide host ranges, capable of causing disease on plants across many families and in many different habitats. The **Working Group for Phytophthoras in Native Habitats** has formed to determine steps needed to protect wildlands and assist the restoration industry.

Read more in "*In Brief… Phytophthora* plant pathogens in California native plant nurseries and habitats. Why the concern?" (May 2015) and in the links below.

Photo by Janell Hillman, Santa Clara Valley Water District

Welcome to CalPhytos.org – Phytophthoras in Native Habitats



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Working Group for Phytophthoras in Native Habitats — Final September 22, 2016

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. *Phytophthora* plant pathogens can have devastating impacts on wildlands. Once these pathogens are introduced into the wild, they are extremely difficult – if not impossible – to eradicate. Our best defense against *Phytophthora* species becoming established in wildlands is to prevent their inadvertent introduction via infested nursery plants.

Who should use these guidelines?

The intended audience is professional growers managing California native plant nursery businesses that supply to wildland restoration projects. Given the importance and sensitive nature of these habitats, these guidelines support the highest standards and best practices to exclude *Phytophthora* and other soil-borne pathogens from nursery stock to the greatest extent possible.

Department of Horticulture

Nursery, Greenhouse, & Christmas Trees

Phytophthora Online Course: Training for Nursery Growers

Submitted by Erin Martin on Thu, 04/17/2014 - 12:53pm

Authors: Jennifer Parke, Jay Pscheidt, Richard Regan (Oregon State University); Jan Hedberg (Oregon Department of Agriculture); Niklaus Grunwald (USDA ARS)

In this course, you will learn about *Phytophthora* so that you can reduce the risk of *Phytophthora* disease in your nursery. The course is divided into three modules:

Module 1: Biology, Symptoms, and Diagnosis

Module 2: Disease Management

Module 3: *Phytophthora ramorum*

Phytophthora root rot on rhododendron. Photo by C. Lewis.

It is best to go through each module in order. Each module should take 1-2 hours to complete, although you may start and stop as often as you like. A glossary of scientific words is accessible from anywhere in the course. There are practice questions at the end of each module so you can test yourself on what you have learned. There are also links to further information.

The course is free, but there is an optional online exam which you may take for $100.

If you pass the test, you will receive a Certificate of Mastery on *Phytophthora* from Oregon

DECEMBER 14th 9 AM to 1 PM

NORTH WILLAMETTE RESEARCH & EXTENSION CENTER

15210 NE MILEY ROAD, AURORA, OR

ODA PESTICIDE APPLICATORS RECERTIFICATION – 3 CREDITS

Dr. Jennifer Parke, Plant Pathologist, Oregon State University, Corvallis
Dr. Marianne Elliott, Plant Pathologist, Washington State University, Puyallup
Dr. Luisa Santmaria, Extension Specialist, Oregon State University, NWREC

Agenda

- Background: Phytophthoras in Native Plant Nurseries
- BMPs to Prevent Phytophthora Contamination
- Hands-on Methods to Recognize, Detect & Prevent Phytophthora

REGISTRATION REQUIRED - $35

online or contact 541-753-7208

WASHINGTON STATE UNIVERSITY | Oregon State UNIVERSITY | OSU College of Agricultural Sciences | BENTON SOIL AND WATER CONSERVATION DISTRICT

Come to our workshop!

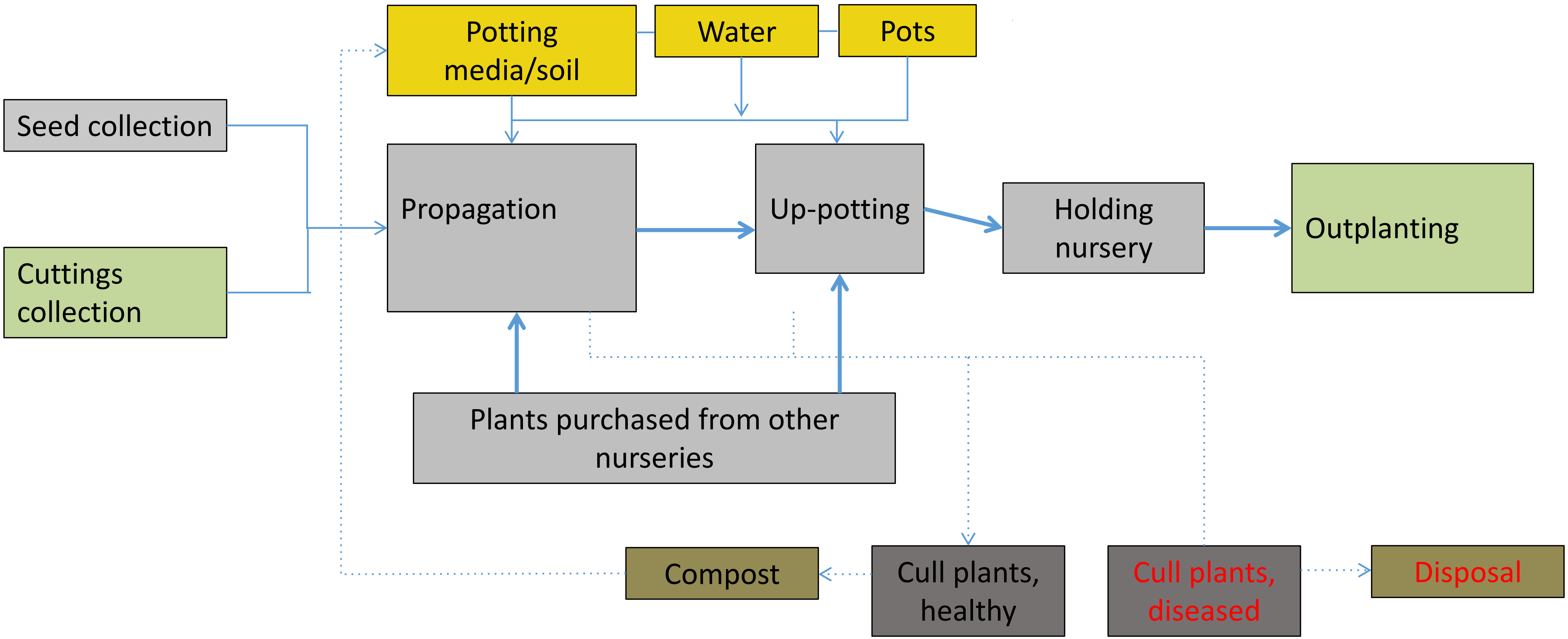
Acknowledgements

- U.S. Forest Service
- USDA-APHIS
- WSDA
- OSU
- WSU
- Benton Soil and Water Conservation District

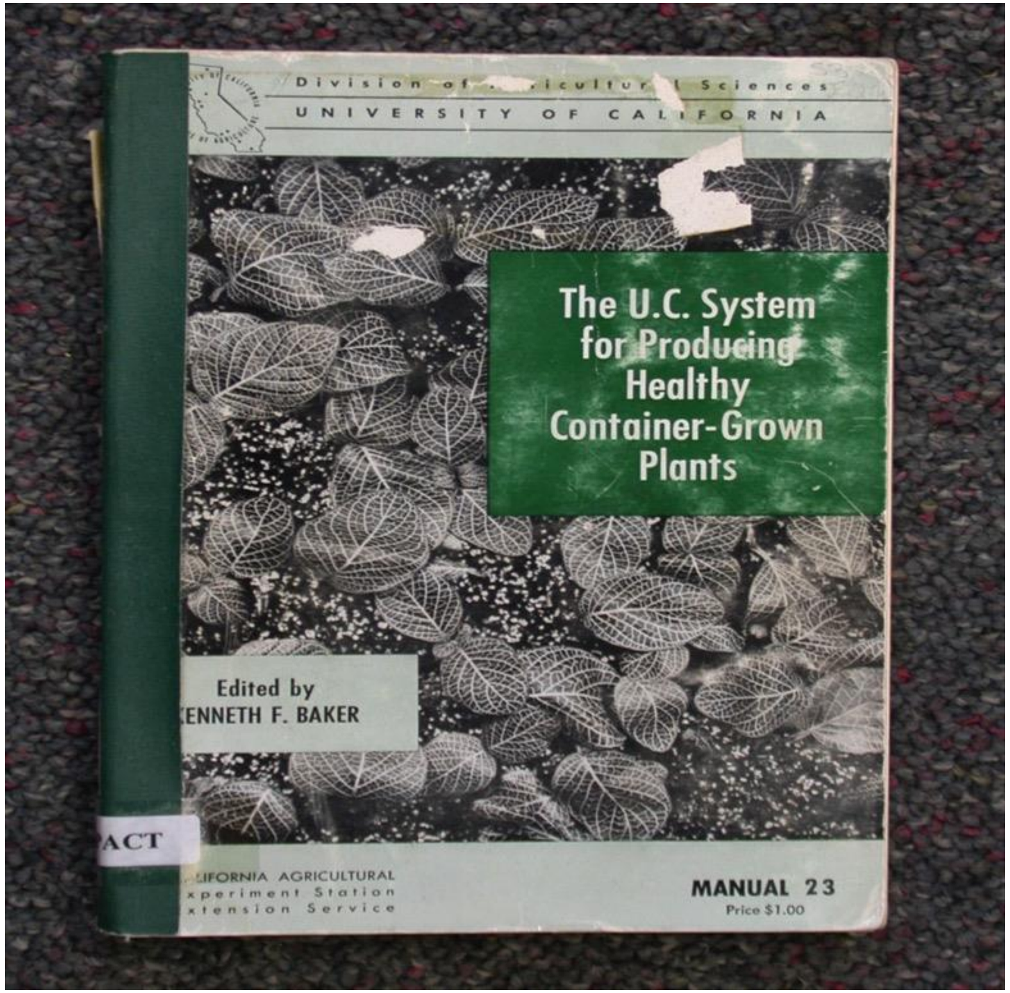
5 Principles of Plant Disease Control

- Exclusion: quarantines, inspections, certification
- Avoidance: planting site, time of year
- Eradication: sanitation, heat treatment
- Protection: biological control, chemical control
- Resistance: innate genetic resistance, induced resistance

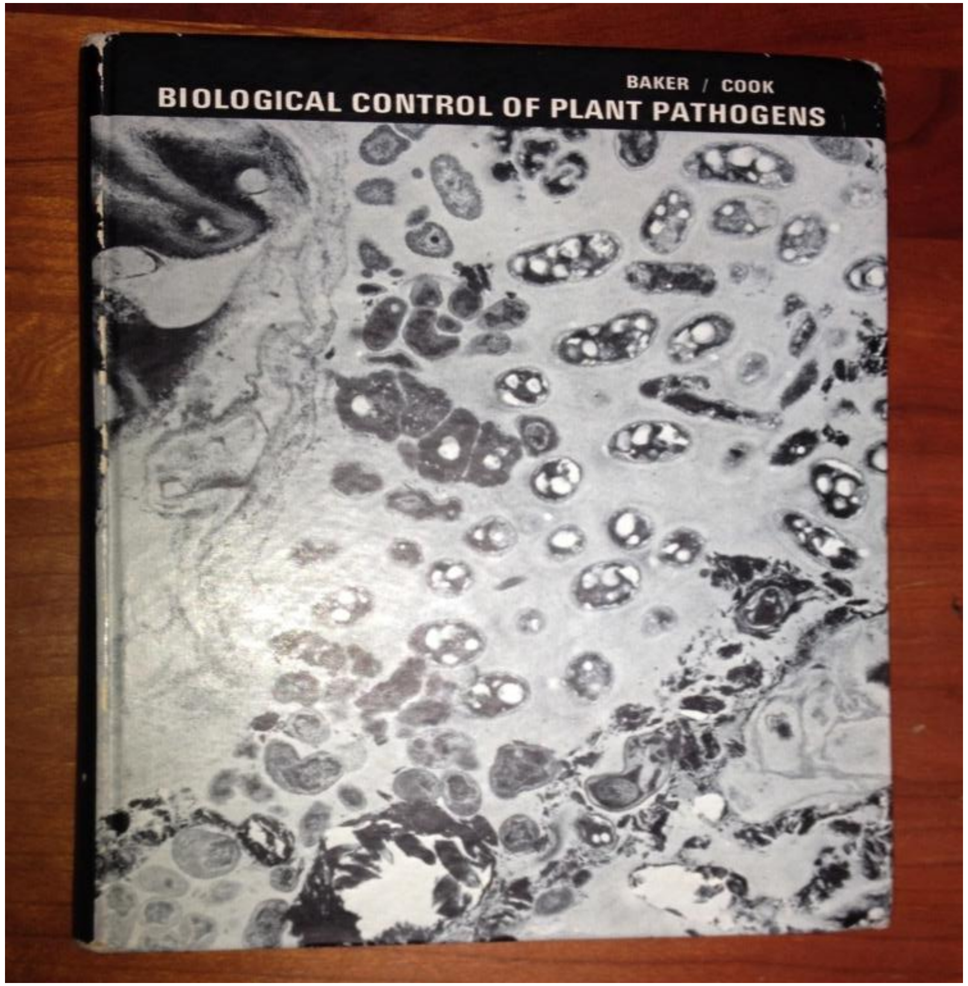
Production flow chart for native plant nurseries



Principles of soil treatment to avoid soilborne plant diseases



K. F. Baker (1957)



Baker and Cook (1974)

Clean potting media

Clean pots

Dead and dying plants

Healthy plants

Get containers up and off the ground

Avoid standing water

Ways to disinfest irrigation water

A summary of treatment options for waterborne pathogens in nursery and greenhouse irrigation systems (Page 1 of 2)

Treatment	Active ingredient	Readily soluble	Injection method	How It Works	Usual range in concentration[1]	Notes
Bromine Example: Agribrom™	1-Bromo-3-chloro-5,5-dimethyl-2,4-imadazolidinedione	No	Tablets or granules are placed in a container with water. The supernatant solution is injected into the irrigation water.	Oxidizing agents listed in this table interact with reactive chemical groups on organic matter. The oxidation of organic matter results in a change in the chemical structure of the organic matter, and death of the pathogen. The oxidizing agent itself is also "used up" during sanitation because the agent changes chemical form as it reacts with organic matter. Plant pathogens vary in their susceptibility to the agents listed in this table. Some plant pathogens and types of resistant inoculum structures may require higher rates of oxidizing agents and/or exposure times than those listed. The material being oxidized can include pathogens, peat, and fertilizer salts. Because all organic matter in the water will absorb and deplete oxidizers, good pre-filtration is essential.	5–35 ppm bromine	Because of low solubility, some time is required for the undissolved tablets or granules to replenish the bromine in the stock solution. Difficult to maintain a constant concentration of bromine over the course of the day, especially with high flow rates. Requires a special injector resistant to corrosive chemicals.
Chlorine gas	Cl_2	Yes	Chlorine gas is bubbled through the water, where it combines with the water to form hypochlorous acid (HOCl) and hydrochloric acid (HCl).		0.5–2 ppm free chlorine. Hypochlorite is a weak acid and can be found in solution in two different forms: OCl^- and HOCl. Because the HOCl form is much more effective at disinfecting than the OCl^- form, the water pH should be controlled, as sanitizing reactions tend to be slower at higher pH.	Hazardous gas requires special equipment, ventilation, and handling. As with all chlorine application methods, higher than recommended concentrations can be toxic to plants.
Sodium Hypochlorite	NaOCl	Yes	Liquid NaOCl solutions (5–15 percent chlorine) are injected directly into irrigation water.			Requires a special injector that is resistant to very corrosive chemicals and has a very high injection ratio. Has a limited shelf life. Warm temperatures and sunlight speed up breakdown. Never combine with fertilizers or other chemicals containing ammonium.
Calcium Hypochlorite	$Ca(OCl)_2$	Yes	Granules may be dissolved in water, or tablets can be eroded in a flow-through feeder for more automatic chlorination, at chlorine concentrations up to 10,000 ppm, depending on the feeder and operating conditions.			Calcium hypochlorite solutions of up to approximately 21 percent can be prepared, but due to the presence of insoluble materials such as calcium carbonate solutions of above 200 ppm tend to be cloudy. Sediment forms with very concentrated solutions. At less than 100 ppm available chlorine there should be no apparent cloudiness or sediment.
Chlorine Dioxide Examples: Ultra-Shield™, Selectrocide™	ClO_2	Yes	Dry packet or tablets placed in water, ClO_2 solution generated in stock tank.		Injected into irrigation lines. Continuous injection of residual concentration of 0.25 ppm or less. Twice a year shock treatment at 20 to 50 ppm depending on product.	Stock solution should be used within 15 days to minimize loss due to volatilization. Maximum stock concentration of 500 or 3,000 ppm, depending on product.
Ozone	O_3	No	An electrical arc is used to produce the ozone from bottled or atmospheric oxygen. The ozone is then bubbled through the water.		Residual effect from reaction products (peroxides, organic radicals). Breaks up biofilm. 10 grams/hr/m³.	Requires professional design based on water analysis. Proper design prevents ozone from escaping into the atmosphere in hazardous concentrations.
Activated Peroxygen Examples: ZeroTol™, SaniDate™	Hydrogen dioxide/ hydrogen peroxide (H_2O_2) and Peroxyacetic acid/peracetic acid (CH_3COO-OH)	Yes	A stabilized H_2O_2 and peracetic/peroxyacetic acid solution that is injected directly into irrigation water. Peroxyacetic acid is a more effective biocide than H_2O_2 alone.		27 to 540 ppm H_2O_2	Requires a special injector that is resistant to very corrosive chemicals and has a very high injection ratio, or the material must be diluted before injection.

Ways to disinfest irrigation water (cont'd)

A summary of treatment options for waterborne pathogens in nursery and greenhouse irrigation systems (Page 2 of 2)

Treatment	Active ingredient	Readily soluble	Injection method	How it works	Usual range in concentration[1]	Notes
Ultraviolet (UV) radiation		N/A	Water is exposed to high doses of UV light in tubular chambers. Most common are low pressure mercury vapor lamps with a wave length of 254 nm, close to the optimum range for killing pathogens.	UV radiation disrupts the genetic material in the cell, effectively killing it. Dose, exposure time and turbidity determine effectiveness.	250 mJ/cm² eliminates most pathogens. No residual effect on pathogens downstream of treatment.	The effectiveness of the lamp decreases with age. Any particulate matter in the water will disperse the light, making the application of UV radiation less effective. Good pre-filtration is essential. Often used with other disinfecting material to get some residual effect.
Copper ionization	Cu^{++}	Yes	An electrical charge is passed between copper bars or plates, releasing copper ions into the water.	Copper ions are a toxin to most pathogens, including *Pythium*, *Phytophthora*, *Xanthomonas*, and algae. Recent advances in controls produce consistent copper levels and reliable results.	0.5 to 1 ppm Cu for pathogens. 1 to 2 ppm for algae and biofilm.	Less effective if water pH is above 7.5. Choose a system which actively controls copper output according to flow and EC. Applied copper concentrations are within U.S. drinking water standards and a fraction of plant toxicity levels.
Heat treat-ment/pas-teurization		N/A	Water is heated to specific temperature, and waste heat is recovered to pre-heat incoming water.	Pathogen resistance to heat varies. Effect largely independent of water quality.	An example treatment is 203 F for 30 seconds. No residual effect on pathogens downstream of treatment.	High energy use makes it expensive for large flow. To prevent scaling of heat exchangers from hard water, pH needs to be reduced to 4.5, then raised again as needed for irrigation. Best for low-flow, high-sanitation applications.
Slow sand filtration	N/A	Water moves passively through sand bed that supports a biologically active layer (*Schmutzdecke* or biofilm crust) on the filter surface. Clean, filtered water is stored in a covered reservoir until use.	Sand filtration works through a combination of physical removal of particles and biological activity of the biofilm crust. Effective at eliminating *Phytophthora* spp. from water.	An example rate of filtration is 30-90 m³/hr. A filter bed area of 260 m² and 1 m deep can yield approximately 40,000 m³ filtered water/mo.	While the biofilm crust or *Schmutzdecke* is important for the functioning of the filter, it must be maintained by periodic raking or the filter can become clogged. Slow sand filtration may not be rapid enough to supply the volume of water during periods of peak irrigation demand. Space limitations may also limit the size of the sand filter and the volume of water that can be treated.	

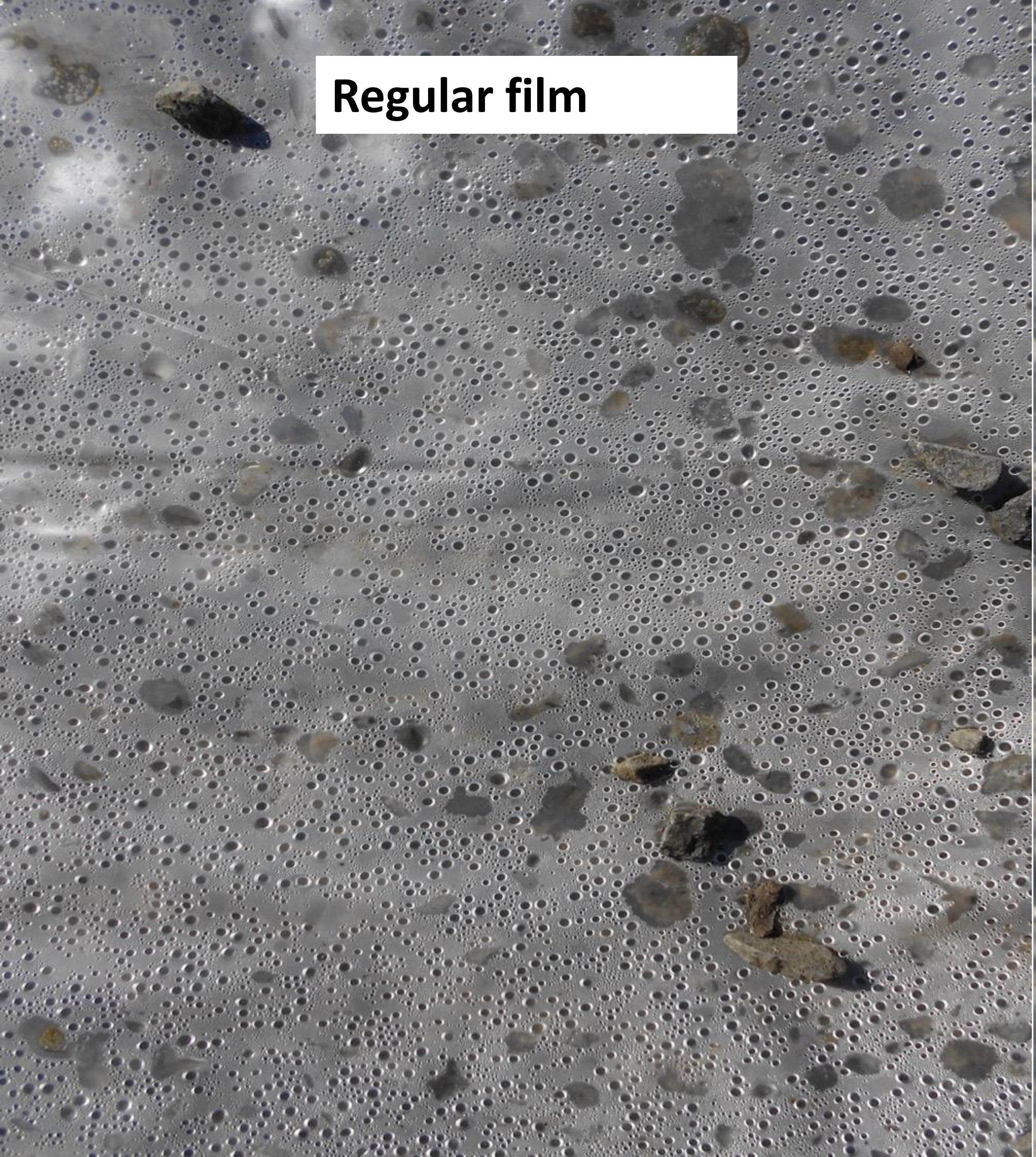
Notes

1. Desired concentration depends on the application (e.g. shock treatment versus continuous treatment of clean water, and the specific pathogens targeted). See product label and manufacturer's instructions for your application.
2. All the methods mentioned above are non-specific and will react with any type of organic matter, whether it is a pathogen, algae, or a particle of peat. In all cases, the cleaner the water is before the application, the more effective the disinfection method is at removing pathogens.
3. Bromine, chlorine products, ozone, peroxyacetic acid, and hydrogen peroxide are strong oxidizing agents. Metal micronutrients (copper, iron, manganese, and zinc) are easily oxidized (particularly iron). It is likely that long-term exposure (greater than 2 minutes) of metal micronutrients to these oxidizing agents will decrease their solubility. Chelated micronutrients should be only slightly less affected than sulfates.
4. Ultraviolet radiation is a photo-oxidizing agent. Research by Cornell University on photo-oxidation of iron in fertilizer solutions indicates that the greater the light exposure, the less iron that will remain in solution.
5. Quaternary ammonium compounds such as Green-Shield®, Physan 20™, or Triathlon™ are listed for disinfection of walkways, benches, tools, flats, etc., but are not for use with irrigation water.
6. Liquid hydrogen peroxide/hydrogen dioxide (H_2O_2) solutions (35–50 percent H_2O_2) are not EPA-registered for water treatment in greenhouses, and are less effective and stable compared with registered activated peroxygen products.

Chemical names and trade names are included in this publication as a convenience to the reader. The use of brand names and any mention or listing of commercial products or services in this publication does not imply ndorsement, nor discrimination against similar products or services not mentioned. Individuals who use chemicals are responsible for ensuring that the intended use complies with current regulations and conforms to the product label. Be sure to obtain current information about usage and examine a current product label before applying any chemical. For assistance, contact your state pesticide regulating authority.

Table modified by J. Parke, Oregon State University, with permission from Fisher, P. (ed.) 2009. *Water Treatment for Pathogens and Algae.* Water Education Alliance for Horticulture. 57 pp.

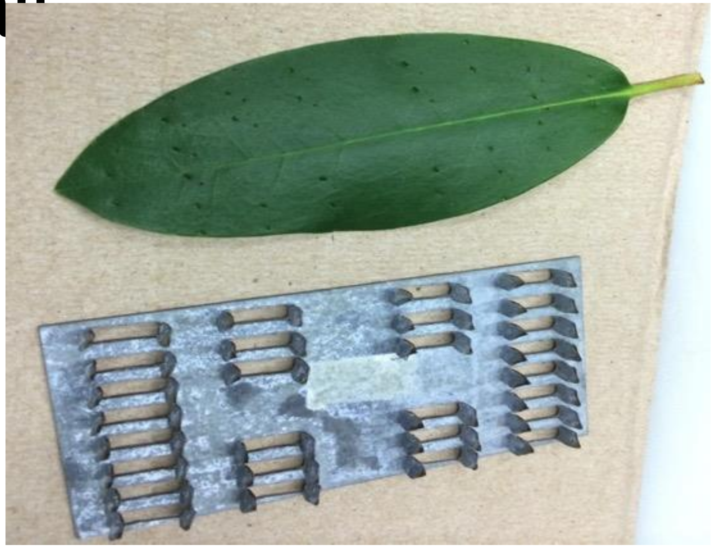
Parke and Fisher, 2012


Regular film


Anti-condensation film

Bait the root ball

- Collect fresh leaves of Rhododendron catawbiense 'Grandiflorum' from greenhouse-grown plants not treated with fungicides.
- Wound leaves with wounding device
- Place 4 leaves leaf in pot under root ball
- Fill saucer under container with water
- Incubate 3-5 days.



Disinfectants for treating cuttings

Chemical name	Trade name
Hydrogen dioxide	ZeroTol
Chlorine dioxide	

ZeroTol is labeled for use on ornamental plants in greenhouses and nurseries as a preplant dip and foliar spray. Chlorine dioxide is labeled for use on vegetable and fruit processing.

Optimize drainage.