Relative Heat Sensitivities of Certain *Phytophthora* spp. and the Potential for Soil Solarization to Disinfest Nursery Beds in West Coast States[1]

Jennifer L. Parke,[2] Fumiaki Funahashi,[2] Clara Weidman,[2] and Ebba K. Peterson[2]

Abstract

Soilborne *Phytophthora* spp. can be important for initiating disease through movement of inoculum with surface water to roots or splashing onto foliage. Nursery beds infested with *Phytophthora* spp. can contaminate container plants set on them, causing disease year after year and posing a risk of additional spread. Persistent sources of soilborne inoculum are especially problematic for quarantine pathogens such as *P. ramorum*. Unfortunately, infested nursery beds are challenging to disinfest because of restrictions on the use of soil fumigants and the difficulty of accessing equipment for soil steaming.

Soil solarization has been shown to be an effective strategy to kill *Phytophthora* spp. in the upper layer of soil in some locations. The effectiveness of solarization treatments will vary regionally, however, due to differences in day length, solar declination angle, and local climate. To predict the effect of soil solarization, lab trials were conducted under controlled conditions to determine parameters important for inoculum survival. Inoculum survival in field trials were then evaluated where these parameters were measured and a mathematical model to predict solarization efficacy was validated.

In lab experiments, rhododendron leaf disks infested with different *Phytophthora* spp. were placed in soil or polyethylene glycol (PEG) solution and subjected to constant high temperatures. For *P. ramorum*, the time to reduce survival by 99.9% ($LD_{99.9}$) was 3.9 days at 35°C, 0.9 days at 38°C, and 15 min at 50°C. For *P. pini,* the $LD_{99.9}$ was 6.9 days at 35°C, 2.5 days at 38°C, and 40 min at 50°C. Because *P. pini* survives longer at high temperatures than *P. ramorum, P. pini* could serve as a conservative surrogate for *P. ramorum* in field studies conducted outside quarantine facilities. Survival time at high temperatures was greater under drier conditions as compared to wetter conditions. For example, at 35°C, *P. ramorum* survived only 3.5 days at -0.001 kPa, but 10.6 days at -6.32 MPa. A similar trend was observed for *P. pini.* These results underscore the importance of maintaining high soil moisture to maximize the efficacy of soil solarization. Survival at constant high temperature was also compared to survival during intermittent heat. Despite equivalent total exposure time at high temperature, intermittent heat was found to be less damaging to *Phytophthora* inoculum than constant heat. Thus, reduced survival of *Phytophthora* at high temperature is not based solely on response to cumulative heat (Funahashi, 2015).

Soil solarization field trials with buried inoculum were conducted from 2012-2014 with *P. ramorum*, *P. pini*, and *P. chlamydospora* in San Rafael, California; *P. pini* and *P. chlamydospora* in Corvallis, Oregon; and *P. chlamydospora*, *P. plurivora*, and *P. gonapodyides* in Puyallup, Washington. Rhododendron leaf inoculum of each pathogen was buried at 0, 5, 15, and (occasionally) 30 cm. Solarization reduced

---

[1] A version of this paper was presented at the Sixth Sudden Oak Death Science Symposium, June 20-23, 2016, San Francisco, California.

[2] Oregon State University, Corvallis, OR 97331.
Corresponding author: Jennifer.Parke@oregonstate.edu.

inoculum survival most effectively in the upper soil layers, where soil temperatures were highest. For example, in a trial conducted at the National Ornamentals Research Site at Dominican University of California (NORS-DUC) in San Rafael, CA July 16-Aug. 13, 2013, inoculum at the surface and 5 cm depth was killed within 2 days, whereas inoculum buried at 15 cm survived 15 days of solarization. In another trial at NORS-DUC with *P. ramorum, P. pini,* and *P. chlamydospora*, all inocula except *P. chlamydospora* at the 15 cm depth were killed by 2 weeks of solarization. Soil temperatures during solarization were greater with anti-condensation plastic film as compared to regular plastic film. The presence of a crushed rock layer (2.5-7.5 cm thick) atop the soil significantly increased the maximum and average temperature at all depths (0-15 cm) relative to soil without the rock layer, indicating the feasibility of implementing soil solarization to disinfest container nurseries of *Phytophthora* species in the upper layers of soil.

A mathematical model was established to predict the survival of *P. ramorum* and *P. pini* during solarization. Inclusion of the factors soil temperature, soil matric potential, and constant vs. intermittent heat described solarization effectiveness in field trials. Survival of each pathogen in field trials largely agreed with survival as predicted from the model (Funahashi 2015).

To evaluate the potential for solarization efficacy within West Coast states, soil temperatures during soil solarization were measured in 43 nursery sites in CA, OR, and WA during the summers of 2013 and 2014. Soil temperatures were recorded during 4 weeks of solarization at 4 depths: 0 cm (surface), 5 cm, 10 cm, and 15 cm. Air temperature, wind speed, and solar radiation data were obtained from nearby weather stations. Solarization was successful in attaining temperatures lethal to *Phytophthora* spp. at most sites. Exceptions included sites in northwest WA, the coastal fog belt, or sites solarized in late summer.

With soil temperature data from the sites, a predictive model was developed that was the basis for a web-based forecasting tool created by L. Coop and D. Upper at the Integrated Center for Plant Protection at Oregon State University. The forecasting tool is intended for use by nursery managers in CA, OR, and WA to predict the length of time required to kill *P. ramorum* or *P. pini* at various soil depths. User inputs include target species (*P. ramorum* or *P. pini*), start date, location, thickness of a crushed rock layer, and choice of year for predicting the current year's weather. The model assumes use of clear, anti-condensation plastic film, a minimum treatment area of 2.5 m x 2.5 m, soil moisture at field capacity when covered with plastic, and full sun exposure. The initial version of the web-based forecasting tool is available at http://uspest.org/soil/solarize. Additional modules are being developed for application to raised bed agricultural systems and other target pathogens and weed species.

In summary, soil solarization appears to be a promising technique for disinfesting the upper layer of soil in West Coast container nurseries, particularly for relatively heat sensitive species such as *P. ramorum.*

Acknowledgments

We gratefully acknowledge funding for this project from the USDA Farm Bill, the Western Integrated Pest Management Center, and the Oregon Association of Nurseries. Many individuals contributed to the success of this project, including the entire staff of NORS-DUC, Kathy Kosta (California Department of Food and Agriculture), Brenten Reust, the Oregon State University (OSU) Botany and Plant Pathology Farm, the OSU Integrated Plant Protection Center, Gary Chastagner and Marianne Elliott (Washington State University-Puyallup), and undergraduate student workers in the Parke lab, particularly Eric Larson, Caleb Trammell, and Simon Fraher.

Literature Cited

Funahashi, F. 2015. Modeling survival of soilborne *Phytophthora* spp. and characterizing microbial communities in response to soil solarization and biocontrol amendment in container nursery beds. Ph.D. Thesis, Oregon State University. 180 pp.