Solarization

A Simple and Low Cost Method for Disinfesting Horticultural Containers

by Karen Suslow[1] and Kathy Kosta[2]

Introduction

The reuse of horticultural containers (hereafter collectively referred to as 'pots') by nursery growers is a beneficial and sustainable practice but has repeatedly been shown to serve as a mechanism for transfer of plant pathogens within a nursery. More critically, as a consequence, the risk of pathogen transport to natural or landscape plantings also increases. Infestation of habitat restoration sites by the out-planting of secondarily infested plant material has been documented and is a particular focus for preventive control measures. The transfer of water molds (Oomycetes), such as plant pathogenic *Phytophthora* species, is a major concern for restoration projects and should be a critical management control among nursery growers. Our research has established performance and efficacy criteria that demonstrate the risk can easily be avoided by the application of solarization techniques between uses of pots and other horticultural containers.

Solarization of used plant pots is an easily implemented and efficient way to eliminate *Phytophthora* from recycled pots and is considered a Best Management Practice (BMP) to prevent the spread of plant pathogens (such as *P. cactorum, P. ramorum* and *P. tentaculata*) within a nursery and to landscape plantings.

Background

In the summer of 2015, the National Ornamental Research Site at Dominican University of California (NORS-DUC) conducted two outdoor solarization experiments designed to determine the temperature and time requirements at which *P. cactorum* — a commonly found soilborne plant pathogen in the nursery industry — would be killed. Due to quarantine restrictions in the two counties in which the experiments were conducted, *P. cactorum* served as a surrogate for the quarantine pathogen, *P. ramorum*, the cause of Sudden Oak Death. Lab studies at NORS-DUC verified the time and temperature to be the same at which these two pathogens are killed.

Open-environment experiments were conducted in a hot climate and in a cool climate. Under both conditions, the pathogen was killed within the first week in the "clear", polymer-encased pots (Treatment) versus the Controls with no polymer sheet encasement. The clear polymer sheeting (4 mil thick and slightly opaque in appearance) was purchased off-the-shelf at a local mass merchant store. As an added control, samples of *P. cactorum* — held in the lab at room temperature and maintained in a similar fashion as those in the field — were sampled weekly and remained viable throughout the course of the experiment.

Methods and Experimental Design Setup

We chose two locations for the pot solarization experiment: one in a hot climate located in Winters, CA, where the ambient peak summer temperatures are typically in the 34–39°C range, and the parallel one in a cool, foggy climate located in Pacifica, CA, where the ambient summer/fall temperatures are typically in the 16–21°C range.

The isolate of *P. cactorum* used in these experiments was provided to us by the California Department of Food and Agriculture (CDFA) Plant Pest Diagnostic Laboratory and was propagated on rhododendron leaves on PARP, a highly selective media (Fig. 1).

The first experiment was conducted over a three-week period, beginning on 25 August 2015, in Winters, CA. Treatments and Controls were randomly arranged on the ground. CDFA Diagnostic Lab processed all samples in the hot climate trial including lab-maintained samples that were kept at room temperature during the course of the experiment. One sachet per week was extracted and the leaf disks plated out. At each weekly interval, viable *P. cactorum* grew from the disks of the lab-maintained sachets.

The second experiment was conducted over a six-week period, beginning 23 September 2015, in Pacifica, CA. Once again, the

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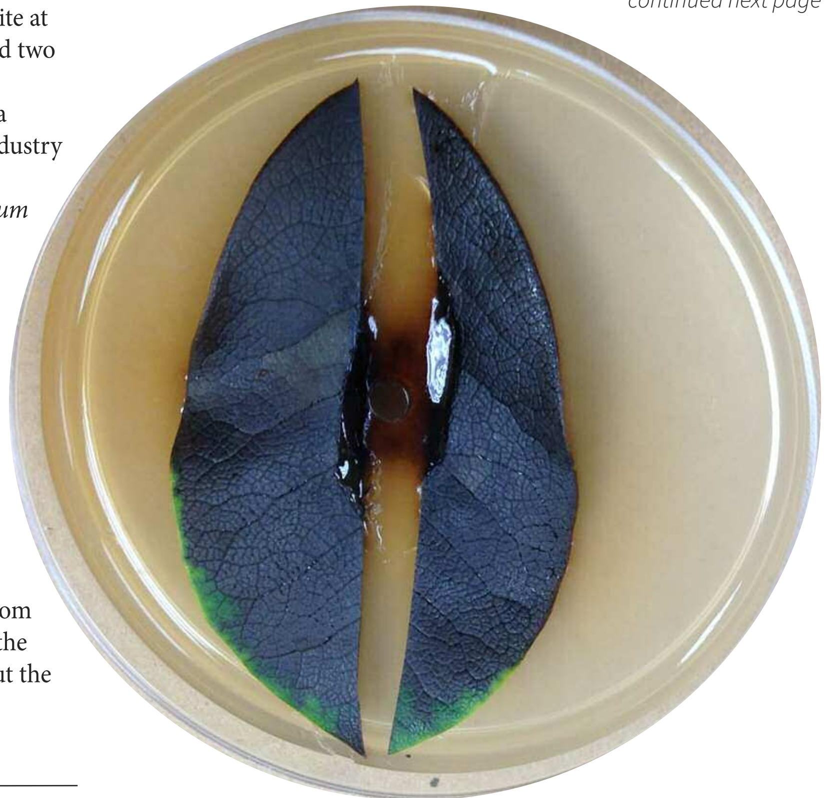

Fig. 1 *P. cactorum*-infected rhododendron leaf.

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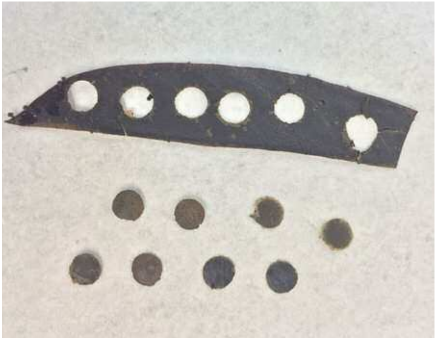

Fig. 2 Disks punched from *P. cactorum*-infected rhododendron leaf.

Fig. 3 Infected leaf disks and soil in sachets being inserted into hollow-core rope.

Fig. 4 Sachets in hollow-core woven rope coiled in the bottom of a 1G pot.

Fig. 5 Hole drilled in 1G pot which enables weekly extraction of sachet.

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Treatments and Controls were randomly arranged on the ground. NORS-DUC processed all samples in the cool climate trial. Retained lab control samples were kept at ambient temperature. One sachet per week was opened and the leaf disks plated out. Each week, across all time-points, *P. cactorum* grew from the disks of the lab-maintained sachets.

Leaf punches were extracted from the infected leaves (Fig. 2) and ten leaf disks were placed in 10ml of potting soil typically used by the Winters or Pacifica grower. The disks were then inserted into a 1" x 3" porous sachet bag (20 micron, Safar Nitex mesh), sealed with tape, and secured with a staple.

For the hot climate trial, in order to facilitate extraction of samples from the pots for each weekly sample, three sachets were inserted into a hollow-core, woven rope (Fig. 3) approximately 10" apart. The rope was then inserted into nested black plastic pots (Fig. 4). Each week, the rope was partially extracted through a small opening in the polymer sheet with minimal release of heat, and the rope excised just below one sachet. The sachet was returned to the lab whereupon the leaf disks were extracted and plated out onto PARP media to determine the pathogen viability. The lab-maintained samples in sachet bags under stable ambient conditions were also plated out each week to confirm continued viability of the pathogen over the course of the experiment.

In the cool climate trial, we inserted two ropes with three sachets each in order to sample weekly over the planned timeline.

The pot sizes selected for this experiment were those that are used extensively in the native plant nursery industry: black 1-gallon (1G) and the narrow D-40 pots. At the Winters location, we also included Tubex tubes, hollow tubes which are used to protect young plants in the native environment/restoration sites from destructive foraging by wildlife. The 1G black pots were nested in 3' high stacks (the number of pots varied in each stack because the used pots are not identical in shape and do not always nest tightly). Three stacks were placed together in the same alignment and secured with polymer gardening tape for the 1G and Tubex tubes. A 2cm diameter hole was drilled in the centrally located pot (Fig. 5) where temperatures had been demonstrated to be the coolest in a pre-trial experiment. Prior to inserting the rope into the drilled hole, the rope was sprayed with water in order to keep the soil sachets moist. (In the case of the D-40 pots, we secured five stacks each 3' high; hole drilling was required for neither the D-40 pots nor the Tubex tubes.) A temperature data logger (Spectrum Technologies, Inc., WatchDog B-series) was taped in the center pot on the side closest to the ground. The tied, wrapped pots were laid horizontally on the ground on top of a black plastic groundcover (Fig. 6). The Treatment stacks were sprayed with water, wrapped in the polymer sheeting, and securely sealed with strong adhesive clear tape. A small slit was made in the polymer over the drilled hole in order to facilitate removal of samples at weekly intervals. The slit was taped over to ensure complete enclosure. This setup was replicated three times. The Controls were identical to the Treatments; however, the pots were not sealed in polymer sheeting.

Results

I. Hot Climate Trials Field Sampling Results (Fig. 7)

Weekly collected field samples from all Treatments (1G, D-40, and Tubex tubes) yielded no *P. cactorum* growth. Additionally, *P. cactorum* was presumptively non-viable during the first week of the experiment in the Controls; however, other fungi and bacteria were isolated from the leaf disks of the Controls during the first two weeks. By week three, no micro-organisms were recovered from the Control samples.

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Fig. 6 Field layout at hot climate site in Winters, CA.

1G Pots — There was a temperature differential of 11°C between the Treatments vs Controls during the hottest interval of the day for 1G pots (1500–1600hrs): 57°C vs 46°C. Ambient shaded temperatures (as recorded by two data loggers located in a shaded area of the field plot, elevated 1 foot off the ground) were approximately 7–10°C cooler than the Control temperatures and 18-21°C cooler than the Treatment temperatures.

D-40 Pots — For the narrow D-40 pots, there was a greater magnitude difference between the Treatments and the Controls during the hottest time of the day (1500–1600hrs): 63°C vs 49°C (14°C difference). Ambient shaded positions were 6–9°C cooler than the Control temperatures and 20–23°C different from the Treatments temperatures.

Tubex Tubes — During the first week of the experiment, Treatment Tubex tubes achieved the hottest temperatures (compared to the 1G or D-40 pots), reaching a peak temperature of 68°C; they also showed the greatest difference between the Treatments and the Controls during the hottest time of the day: 68°C vs 47°C.

II. Cool Climate Trials Field Sampling Results (Fig. 8)

1G Pots — No *P. cactorum* was recovered from the Treatments. The pathogen was recovered from all three of the Control sachets in the first week; during the second week, the pathogen was recovered in only one of the three Controls, and continued to be recovered from each weekly sampling throughout the experiment for that particular Control. Another Control yielded other fungal growth (but not *P. cactorum*), on a weekly basis during the course of the experiment. There was a mean temperature difference of 14°C between the Treatments vs Controls during the hottest time of the day for 1G pots (1500–1600hrs): 45°C vs 31°C. Ambient shade temperatures (as recorded by two data loggers located in a shaded area of the field plot, and elevated 3 feet off the ground) were approximately 5°C cooler than the Control temperatures. Ambient shade temperatures were 19°C cooler than the Treatment temperatures.

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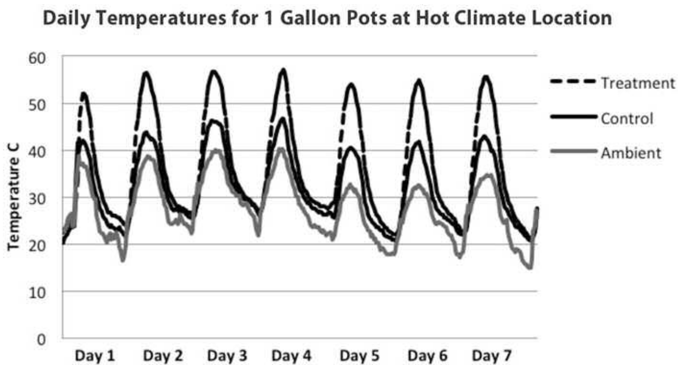
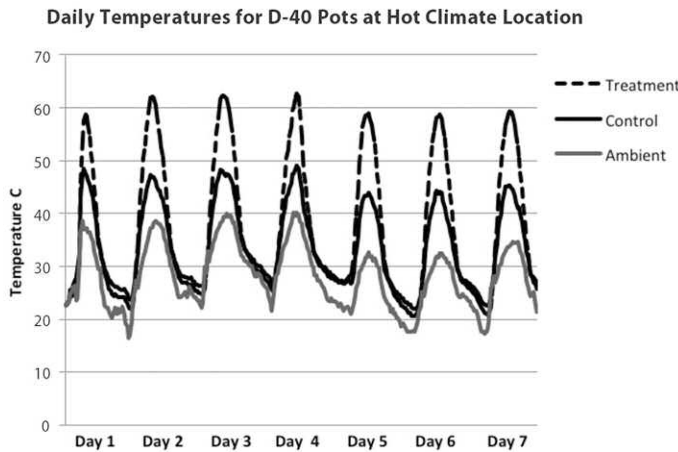




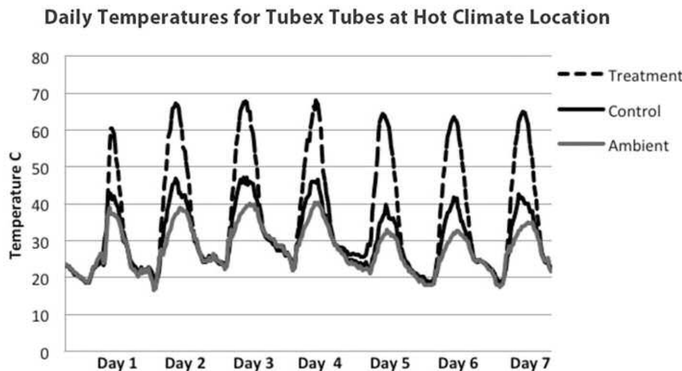
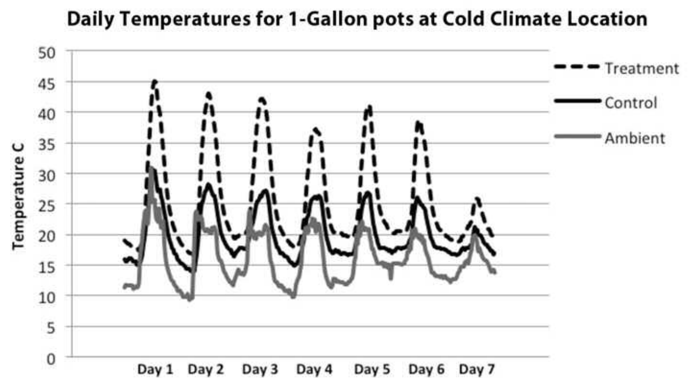


Figure 7 Daily temperatures during first week of experiment in the hot climate.



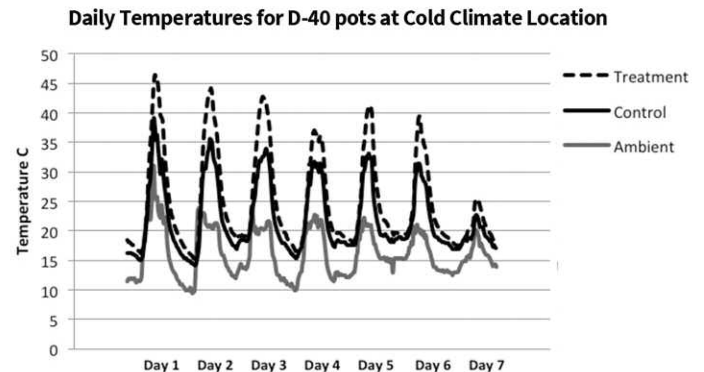


Figure 8 Daily temperatures during first week of experiment in the cold climate.

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D-40 Pots — No *P. cactorum* was recovered from the Treatments. Only one Control yielded *P. cactorum* during the first week's sampling, but thereafter, no *P. cactorum* was found in future weeks' samplings.

For the narrow D-40 pots, there was less of a difference between the Treatments and the Controls during the hottest time of the day (1500–1600hrs): 47°C vs 39°C. Ambient shade was 13°C cooler than the Control temperatures and 14–21°C different from the Treatments temperature. D-40 Controls were a few degrees warmer than the 1G Controls.

Conclusions

Solarizing horticultural containers is an effective method by which to eliminate high-priority soilborne plant pathogens from used pots. The ubiquitous nursery pathogen, *P. cactorum*, was killed within one week when summer solarization temperatures reached a peak temperature of 57°C in the sealed, clear polymer-wrapped 1G pots, D-40 pots, and Tubex tubes (Treatments) during which the cumulative hours above 50°C was sustained for 25 hours during the first week of the experiment (ambient temperatures ranged from 30–41°C). The pathogen was also killed in the Controls (non-polymer wrapped) within the same week during which the cumulative hours above 40°C was sustained for 30 hours (Table 1).

In lab studies, *P. cactorum* as well as numerous other *Phytophthora* and *Pythium* species, can be killed in 30 minutes at 50°C when exposed to moist heat (Baker and Cook). Reducing the temperature and extending the time has proven to be just as effective at killing *P. ramorum*. In infected rhododendron tissue, in loam soil, *P. ramorum* was not recovered after two days at 40°C nor at 4 days at 35°C (Tooley et al).

In the cool climate trial, the pathogen was killed within the first week of the experiment when the daily temperatures repeatedly reached 40–44°C for four hours within the Treatments. Research has shown that at these cooler temperatures, surviving bacteria may be acting as a preemptive biological control (Haas and DeFago) as was seen in the Controls of the hot and cool climate trials. The cool climate Controls never reached the lethal critical temperature threshold and *P. cactorum* survived in two of the three Controls. Bacteria and other fungi were found in the third Control, but no viable *P. cactorum* was present. Future studies will be investigating this potential biological control effect.

In the hot climate trial, Treatment D-40 pots, due to their long, narrow shape, reached a higher peak solarization temperature by approximately 6°C than did 1G pots; however in the cool climate trials, there was no significant difference between the Treatment groups. In contrast,temperatures in the Control D-40 groups were warmer than the Control 1G group, which may explain the data showing that all three 1G Controls had viable *P. cactorum* and other fungi isolated weekly while the D-40 Control pots only had one occurrence in the first week. Tubex tubes, because they are hollow and bottomless, reached the highest temperatures, frequently reaching 60–68°C daily.

Table 1. Cumulative hours attained during first week of Winters and Pacifica 1G trials.

		40-45°C	46-50°C	≥ 51°C
Winters, CA *Ambient temp: 30-41°C*				
	Treatment	12 hrs	14 hrs	25 hrs
	Control	30 hrs	2 hrs	
Pacifica, CA *Ambient temp: 19-26°C*				
	Treatment	18 hrs	0	0
	Control	0	0	0

For all pot sizes and in all trials, pots laid horizontally on the ground with black plastic under the pots yielded higher daytime and sustained nighttime temperatures than the ambient temperatures. Although reaching the required temperatures for solarizing is more easily attained in the summer months, in cooler climates and in the later fall months the radiant heat from the soil surface will aid in hastening the solarizing process. Additionally, when solarizing in a cool climate or a warm climate, encasing the containers in clear polymer can provide a heat capture differential of up to a 15–24°C as compared to pots not enclosed in polymer wrapping.

In order to achieve the highest temperatures and the quickest kill of *Phytophthoras*, solarize wet pots in the summertime, sealed in clear polymer, and laid horizontally on the ground with black plastic under the pots. Ideally, it is best to monitor your pot temperatures and correlate those temperature differentials with the ambient air temperature so you can determine when your pots have been sufficiently solarized. Alternatively, conservative time:temperature duration, as reported in this study and adjusted for climatic conditions, is an acceptable control point practice.

Future studies will include the nursery pathogen *P. tentaculata* and more frequent sample recovery periods in the hot climate trial.

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