Assessing Potential Hazards for *Phytophthora ramorum* Establishment in Oregon Nurseries[1]

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Abstract

In 2011 and 2012, nurseries that ship plants interstate were surveyed for hazardous conditions that may contribute to *Phytophthora ramorum* establishment within plant production areas. Four-hundred-forty-three nurseries were surveyed for issues related to irrigation water, soil drainage, general sanitation, handling of potting media, potting practices, and the surface on which containerized plants were placed. While most nurseries used best management practices to address those potential hazards, potentially risky conditions were observed at several nurseries. Seventy-nine nurseries used untreated water from rivers and ponds to irrigate their plants. One-hundred-thirteen nurseries had standing water present in greenhouses and/or in plant production areas. Heavy amounts of plant debris were observed in 39 nurseries, while 36 nurseries placed cull piles in risky locations. One-hundred-thirteen nurseries placed containerized plants on native soil and 157 nurseries stored potting media on native soil. Re-using pots was a common practice, although 207 nurseries did not clean or sanitize containers before re-use. Adopting or changing management practices to address these hazardous conditions would help mitigate the risk of *P. ramorum* becoming established in the nurseries.

Index words: *Phytophthora*, hazard assessment, systems approach, best management practices.

Significance to the Nursery Industry

This study describes hazardous conditions and practices observed within wholesale and greenhouse production nurseries that may contribute to the survival, spread, and establishment of the federally regulated pathogen *Phytophthora ramorum* within containerized plant production facilities. The results may also be applied to other *Phytophthora* species. Such hazards include irrigating with potentially contaminated water sources, re-using containers without cleaning them, placing cull piles in poor locations (i.e., near plant production areas, potting media piles, and irrigation water sources), placing potted plants onto native soil, and storing potting media on native soil. The study also identifies some common best management practices currently used by nurseries that help mitigate the risk of *Phytophthora* pathogens infecting their plants. These practices include using pathogen-free water sources for irrigation, cleaning or sanitizing pots before re-use, placing containerized plants on surfaces with adequate drainage, storing potting media on surfaces that prevent commingling with native soil, and using cleaned or dedicated tools to pot plants. The nursery industry and university extension specialists may find this information helpful for planning educational workshops on best management practices and adoption of the systems

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approach to address *P. ramorum* and other *Phytophthora* pathogens in nurseries that grow containerized plants.

Introduction

The federally regulated pathogen *Phytophthora ramorum* was first detected infecting *Rhododendron* and *Viburnum* plants in European nurseries in 1993 (25, 27) and infecting tanoak trees (*Neolithocarpus densiflorus*) in California forests in the mid-1990s (16). Since then, the pathogen has been detected infecting plants in nurseries in several states and Canadian provinces (6, 11, 12, 23, 29). Initially, it appeared the pathogen might have spread from wild tanoak trees into *Rhododendron* plants grown in a neighboring California nursery (10). However, subsequent analyses have shown *P. ramorum* has been moving quite readily throughout North America on infected nursery stock (5, 6, 15).

Studies conducted in retail and wholesale nurseries have identified several sources of *Phytophthora* contamination that could be contributing to the spread and establishment of *P. ramorum* within nurseries. Dart et al. identified *P. ramorum* and other *Phytophthora* species in the soil profile at a retail nursery (3), while other studies have shown *P. ramorum* may infect and spread through a plant's roots into its foliage (14, 17). Other researchers have shown *Phytophthora* species, including *P. ramorum*, may infest and spread from potting media to healthy plants (8, 14, 21). Studies in Washington and Oregon have identified used stock pots as a source of *Phytophthora* inoculum within nurseries (2, 13), while others have demonstrated the ability of *P. ramorum* to survive in and be spread by irrigation water (22, 28). Thus, there are several factors contributing to the ability of *P. ramorum* to survive, spread, and become established within nurseries once it is introduced.

Parke and Grünwald recently discussed the so-called systems approach for management of pests and pathogens in nursery crops, focusing on their research into potential hazards for the establishment of *Phytophthora* species within nurseries growing containerized plants (13). In this study, we surveyed wholesale and greenhouse production nurseries in Oregon for several of those potential hazards for *Phytophthora* establishment. We also identified best management practices currently in use that may help mitigate *Phytophthora* risk at these known hazards.

Materials and Methods

Wholesale and greenhouse production nurseries were assessed for potential hazards for *P. ramorum* establishment by trained Oregon Department of Agriculture inspectors. Assessments were conducted using a standardized form that focused upon the following potential hazards: irrigation water, soil drainage, general sanitation, handling of potting media, potting practices, and the surface on which containerized plants were placed. For each hazard, unique criteria were established. For irrigation water, inspectors identified the source of water used (well, municipal, river, recycling pond, other) and if the water was treated (yes, no). For soil drainage, inspectors verified the presence or absence of standing water within the nursery and the areas affected (plant blocks, greenhouses, roadways, media piles, other). To evaluate general sanitation, the inspector assessed the loading dock (clean, muddy, debris present, other), cull pile (isolated, no drainage, off-site, other), and amount of plant debris within the nursery blocks (heavy, medium, light, other). For the surface on which containerized plants were placed, the type of surface (gravel, soil, benches, other) and amount of gravel, if applicable ($\geq$ 10 cm, $<$ 10 cm, compacted, other), were recorded. Inspectors noted how potting media was stored (on concrete, on asphalt, on soil, other) and if it was treated (yes, no). Potting practices were also recorded, including how the plants were potted (by machine, by hand, by both, other), sanitation practices in the potting area (shared tools cleaned, traffic limited, dedicated tools, other), and the sanitary condition of the pots (new, cleaned, sanitized, other).

The nurseries assessed grew plants only in containers, in containers and in the field (ball and burlap, bare root, or in field soil), and only in the field. For the purposes of this study, only assessment forms from nurseries that grew plants in containers or grew plants in containers and in the field were used. Data from forms that were submitted with incomplete or illegible information were excluded. All nurseries assessed grew *P. ramorum* host or associated host plants (26). The assessments were conducted in the nurseries during their annual *P. ramorum* certification inspection (25). Assessments were conducted from March to October in 2011, and again in 2012.

Preliminary statistical analyses using analysis of variance and least significant difference indicated there were no significant differences between the assessment results from 2011 and from 2012 ($p > 0.05$, data not shown) (4). Thus, results from both survey years were combined for this report.

Results and Discussion

In 2011, 1,603 wholesale and greenhouse production nurseries were licensed with the State of Oregon, with 544 of those nurseries assessed for potential hazards. In 2012, 1,426 nurseries were licensed, with 528 assessed for potential hazards. Of the 1,072 nurseries assessed in 2011 and in 2012, data from 443 nurseries met the criteria for inclusion in this study. Thus, the sample size provided a 95% confidence level that our survey results were representative of the nurseries growing containerized plants within Oregon, with a ±3.6% margin for error (4). Of the 443 nurseries, 188 grew *Rhododendron* and/or *Camellia*, two plant genera known to be highly susceptible to *P. ramorum* (23, 26).

Almost all nurseries assessed used some form of irrigation; only four depended solely upon rain for watering their plants (Fig. 1). Of the 443 nurseries surveyed, 382 used well or municipal water for irrigation; both are considered *Phytophthora*-free and are touted as safe sources for irrigation (7, 13, 19). Eighty-eight nurseries used water from multiple sources, with 77 of those nurseries using water from a river or recycling pond as one of their sources. *Phytophthora* species are commonly detected in untreated river water and untreated water from recycling ponds (22, 28). Nurseries also used rainwater, springs, seasonal creeks, and lakes or ponds as other water sources for irrigation. Thirty-seven nurseries treated their water prior to irrigation. Treatment methods noted by the inspectors included using copper, an algaecide, an insecticide, chlorine, aeration, acid to adjust pH, or sand filtration. Of those methods, chlorine and sand filtration are known to be effective treatments for *Phytophthora* (1, 24).

About half of the nurseries did not have standing water anywhere within their production facilities (Fig. 2). Standing water facilitates the movement of water-borne pathogens

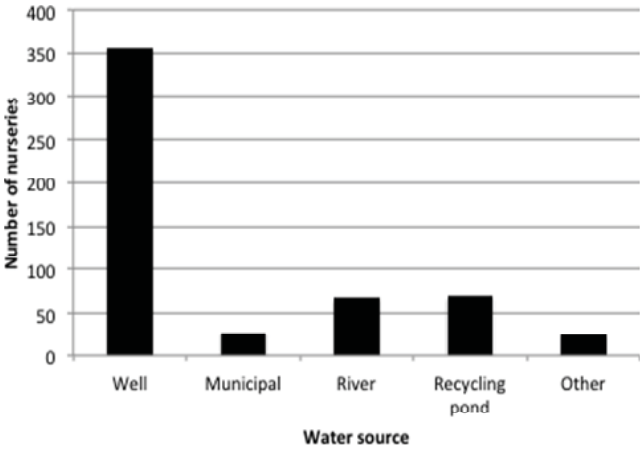

Fig. 1. Sources of irrigation water used by nurseries during the 2011 and 2012 survey periods.

from plant to plant (7, 13, 19) and water has been demonstrated as a means of spread for *P. ramorum* (22, 28). Of the 268 nurseries that did have standing water present, 68 had this problem in multiple locations. Sixty-five of those 68 nurseries had standing water present in plant production blocks or within greenhouses as well as in other locations (Fig. 3). Five had standing water near their cull piles. Cull piles often include diseased or unhealthy plants removed from plant blocks and, as such, may be reservoirs for pathogens like *Phytophthora* (7, 13, 19).

Seventy-two of the 443 nurseries did not have a formal loading dock or loading area. Of the remaining nurseries, the majority (326 nurseries) kept their loading docks clean with no issues noted. The loading docks at 28 nurseries were muddy, while 20 nurseries had plant debris present and another nine nurseries had a different sanitation issue, usually weeds present. Multiple conditions were observed at the loading docks of 12 nurseries, including a combination of clean and muddy areas at six nurseries, clean and weedy areas at three nurseries, and debris and other issues at three nurseries. Incoming plants and associated debris can be sources of *Phytophthora* contamination (7, 13, 18, 19), thus maintaining a clean loading dock is considered a key component of biosecurity for nursery production facilities (7, 13, 19).

Plant debris is a known reservoir for *P. ramorum* within plant production blocks (7, 13, 18, 19). Thus, regular removal of plant debris is encouraged to maintain low pest levels. Of the 443 nurseries assessed, 349 had no debris or a light level of debris in amongst their plants, 70 had a medium level, and 39 had a heavy level. Fifteen nurseries had higher levels of debris in one part of their nursery and lower levels elsewhere. This may have been indicative of recent pruning activities or plant movement within the nursery.

As noted before, cull piles may be a reservoir for *Phytophthora* species and other plant pests within nurseries. Best management practices recommended for handling of cull piles include isolating the pile from production and potting areas, and preventing runoff from the pile into production or potting areas (7, 13, 19). Three-hundred-sixty-six nurseries kept their cull piles isolated or located their cull piles off-site. Meanwhile, 27 allowed no runoff from their piles, which would limit the potential spread of waterborne pathogens like *Phytophthora*. Eight stored culls in dumpsters, semi trailers, or trash bins, while six nurseries had no cull piles. Thirty nurseries used multiple best management practices, including regular burning of their culls, to manage pest risk. Thirty-six nurseries located their cull piles in or near production or potting areas, loading docks, or irrigation water sources. These nurseries may be placing their plants at risk.

Nurseries usually placed their potted plants on gravel (Fig. 4). The gravel was at least 10 cm (4 in) deep at 80 nurseries, less than 10 cm (4 in) deep at 197 nurseries, and compacted at 87 nurseries. In 49 nurseries, the gravel was of multiple depths. Once crushed rock or gravel has become compacted by sinking into the mud, it no longer provides a barrier between plants and the native soil (7, 13). Drainage is also poorer in these areas, which can create an ideal situation for *Phytophthora* species (7, 13). One-hundred-eighty-eight nurseries placed their potted plants on multiple surfaces; at 79 of those nurseries, at least one of the surfaces was native soil. Placing pots in direct contact with native soil or on a permeable surface placed over native soil puts plants at risk for becoming infected by *P. ramorum* and other *Phytophthora* species (13). One nursery placed pots on sheet metal.

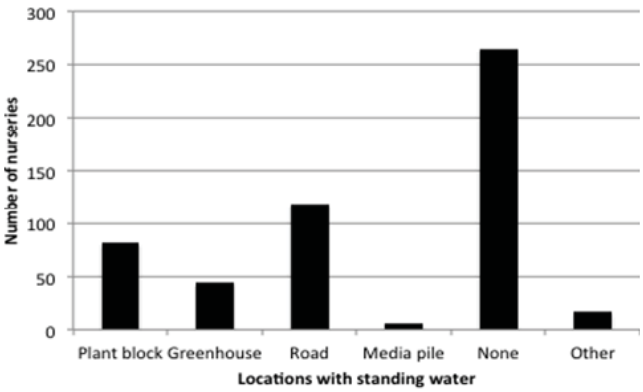

Fig. 2. Locations where standing water were observed within nurseries during the 2011 and 2012 survey periods.

Fig. 3. Standing water within a block of containerized *Rhododendron* plants being grown in a greenhouse (image by J. Hedberg).

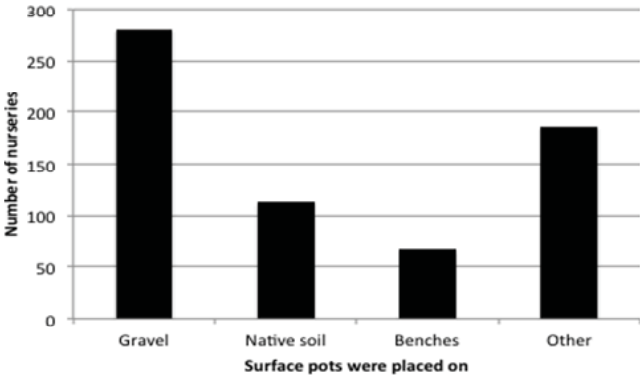

Fig. 4. Surfaces used by nurseries for propagation of potted plants during the 2011 and 2012 survey periods.

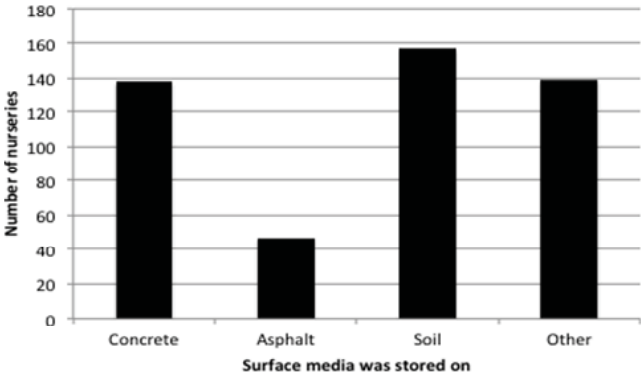

Fig. 5. Surfaces used by nurseries for storing potting media during the 2011 and 2012 survey periods.

Most nurseries stored their potting media components on a non-permeable surface, although an almost equal number stored components on soil or using another method (Fig. 5). Alternative storage methods included storing media components on gravel, on landscape fabric or a tarp, on wood chips, underneath a tarp, inside a building, and inside a container or bag. Forty-five nurseries used multiple methods to store their potting media components and of those nurseries, 28 used native soil as one of the surfaces for media storage. Eighteen nurseries purchased media as needed. *Phytophthora ramorum* has been recovered from native soil and from contaminated potting media (3, 8). Potting media should be stored in containers or on a non-permeable surface to minimize the chances of *Phytophthora* contamination from native soil (7, 13, 19). Fifty-six nurseries treated their potting media prior to use; most treated with pesticides, while others used composting or pasteurization. Composting, if done correctly, and pasteurization have both been shown to effectively eliminate *P. ramorum* from potting media (9, 20).

Three-hundred-twenty-five nurseries potted their plants by hand, while 34 used machines and 84 a combination of hand- and machine-potting. Three nurseries had someone else do the potting for them. Most nurseries used one or more best management practices within their potting area; 91 cleaned shared tools after use, 152 limited traffic within potting areas to authorized personnel only, 171 used tools dedicated to potting only, and 69 used multiple best management practices. For nurseries using multiple best management practices, using dedicated tools or cleaning shared tools was one of the multiple practices employed by 62 of the nurseries. Forty nurseries used another best management practice, such as bleaching floors, sanitizing tools, or having a routine cleaning schedule. Seventy-two nurseries practiced no sanitation within their potting areas. Lack of sanitation within the potting area may result in contamination of the potting media by *Phytophthora*, particularly if the contamination is by native soil (7, 13, 19).

Used containers have been identified as a source of *Phytophthora* contamination within nurseries (2, 13). In Oregon, 271 nurseries potted plants in new containers, while 377 nurseries re-used their containers. Of the latter, 63 nurseries cleaned their containers prior to re-use, 83 sanitized their containers, and 24 used a combination of those two methods. The remaining 207 nurseries did not clean or treat their containers prior to re-use, which places their plants at risk for *Phytophthora* introduction (2, 7, 13, 19).

Overall, most nurseries had implemented best management practices to mitigate the risk of *P. ramorum* and other *Phytophthora* species becoming established within their production sites. However, some did engage in hazardous practices that may place their nurseries at risk, such as irrigating with untreated water, allowing standing water within production areas, allowing heavy amounts of debris within plant production areas, placing cull piles in risky locations, placing potted plants or storing potting media on native soil, and re-using pots without any sanitation. Changing or adopting management practices to address these hazards will help reduce the likelihood of *P. ramorum* and other *Phytophthora* species becoming established within their nurseries.

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