Evaluating the Efficacy of the Systems Approach at Mitigating Five Common Pests in Oregon Nurseries[1]

Nancy K. Osterbauer[2], Melissa Lujan, Gary McAninch, S. Lane, and Aaron Trippe
Oregon Department of Agriculture, 635 Capitol St. NE, Salem OR 97301

Abstract

In Oregon, the U.S. Nursery Certification (USNCP), Grower Assisted Inspection (GAIP), and Shipping Point Inspection (SPI) programs are used to certify nursery plants as pest free. To compare the programs' effectiveness for mitigating pest risk, potted plants grown within two USNCP, two GAIP, and two SPI nurseries were surveyed for Phytophthora root rot (*Phytophthora* spp.), Phytophthora foliar blight (*Phytophthora* spp.), bittercress (*Cardamine* spp.), snails and slugs (Class Gastropoda), and root weevils (*Otiorhynchus* spp.). A total of 1,635 plots were surveyed in the nurseries, with one or more pests detected in 1,003 plots. Based on the total percentage of plots found infested with a pest, significantly fewer were detected in the GAIP nurseries (55%) than in the USNCP nurseries (68%). However, bittercress incidence was significantly higher in GAIP nurseries (21%), while snails and slugs incidence was significantly higher in USNCP nurseries (49%), and Phytophthora root rot incidence was significantly higher in SPI nurseries (31%). Also, the plant families grown by the nurseries had a significant impact on pest incidence for two of the target pests, Phytophthora root rot and root weevils. While the GAIP seemed the best at mitigating pest incidence overall, none of the certification programs was consistently the most effective against all five target pests.

Index words: systems approach, *Phytophthora*, bittercress, snails and slugs, root weevils, pest risk mitigation.

Significance to the Nursery Industry

Three regulatory programs to certify nursery stock as pest-free, the audit-based U.S. Nursery Certification (USNCP) and Grower Assisted Inspection (GAIP) programs and the conventional shipping point inspection (SPI) program, were compared for their effectiveness against Phytophthora root rot, Phytophthora foliar blight, bittercress, snails and slugs, and root weevils. The effect of other factors, such as plant families grown and pathogen presence at previously identified hazards for pest introduction, were also considered. Based on our results, the nurseries in the GAIP had the lowest overall pest incidence. However, no single certification program was most effective against all five of the target pests. Also, the plant families grown had a significant impact on Phytophthora root rot and root weevil incidences within the nurseries participating in the study. This is the first study to evaluate the effectiveness of systems approaches at mitigating the risk from multiple pests in production areas for container-grown nursery plants. Our results indicate the systems approach shows promise, but more research must be done for such programs to be universally effective against multiple pests.

[1]Received for publication August 19, 2013; in revised form December 11, 2013. The authors wish to acknowledge the assistance of R. Ludy and C. Taylor with sample collection and processing. The authors would also like to thank K. Richardson for critical review of this manuscript prior to submission. This project would not have been possible without the cooperation of the six nurseries that participated in the study. The funding for this project was provided in part by USDA Cooperative Agreements 10-8100-1471-CA, 11-8100-1471-CA, and 12-8100-1471-CA.

[2]Corresponding author: nosterbauer@oda.state.or.us.

Copyright 2014
Horticultural Research Institute
1200 G Street NW, Suite 800
Washington, DC 20005

Reprints and quotations of portions of this publication are permitted on condition that full credit be given to both the HRI *Journal* and the author(s), and that the date of publication be stated. The Horticultural Research Institute is not responsible for statements and opinions printed in the *Journal of Environmental Horticulture*; they represent the views of the authors or persons to whom they are credited and are not binding on the Institute as a whole.

Where trade names, proprietary products, or specific equipment is mentioned, no discrimination is intended, nor is any endorsement, guarantee or warranty implied by the researcher(s) or their respective employer or the Horticultural Research Institute.

The *Journal of Environmental Horticulture* (ISSN 0738-2898) is published quarterly in March, June, September, and December by the Horticultural Research Institute, 1200 G Street NW, Suite 800, Washington, DC 20005. Subscription rate is $85.00 per year for scientists, educators and AmericanHort members; $130.00 per year for libraries and all others. For questions about subscriptions or changes to your contact information, call the Horticultural Research Institute at 202-789-2900, email hello@hri-research.org, or send to the Journal of Environmental Horticulture, 1200 G Street NW, Suite 800, Washington, DC 20005.

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-19 via free access

Introduction

The nursery industry has been implicated repeatedly as being a pathway for the movement of pests and diseases throughout the United States and the world (6, 14, 15). In response, the International Plant Protection Convention and similar organizations have promoted the adoption of a systems approach to pest risk mitigation within nurseries growing plants intended for international sale (11, 18, 28). With the systems approach, nurseries conduct a hazard analysis identifying the various points (hazards) in the production process where plant pests can be introduced (13, 24, 27). For each hazard, the nursery then identifies a critical control point where the application of one or more best management practices will mitigate the risk of a pest being introduced via that hazard (13, 24, 27). Other requirements, such as documentation of activities and traceability of nursery stock, must be met for nurseries to participate in officially sanctioned programs (4, 19). Regulatory officials then audit the nurseries to ensure they are complying with all official program requirements.

Two such audit-based programs that use the systems approach have been developed in the United States; these include the U.S. Department of Agriculture's U.S. Nursery Certification Program (USNCP) and the Oregon Department of Agriculture's Grower Assisted Inspection Program (GAIP) (16, 31). The USNCP is based on the requirements of the North American Plant Protection Organization's Regional Standards for Phytosanitary Measures No. 24 and was developed to mitigate pest risk in nursery plants bound for Canada (18). The program requires intensive documentation of business practices, including how the nursery tracks plant inventory, trains personnel, and manages pests of regulatory concern. The GAIP was developed to mitigate the presence of *Phytophthora* spp. in nursery plants shipped domestically. It is an outcome-based program that specifies goals for *Phytophthora* mitigation the nursery is expected to achieve, but also allows the nursery the flexibility to determine how best to achieve those goals. Both programs differ from the conventional shipping point inspection (SPI) program in that the nurseries participating in the GAIP and the USNCP are audited at various times during the growing season for compliance with program requirements; the plants produced by the audited nurseries may or may not be inspected on the loading dock prior to shipment (16, 31). The SPI program, which is the currently accepted standard for pest risk mitigation for plants moving through the nursery trade, requires plants be visually inspected for pests at the nursery immediately prior to shipment (e.g., 21); it does not require audits nor does it require nurseries to adopt or document a systems approach to pest risk mitigation.

While there has been a strong push for nurseries to participate in programs that use a systems approach, most research has focused on a single pest genus or class of pathogens rather than on the effectiveness of such programs for overall pest risk mitigation (e.g., 4, 24). The objective of this study was to quantify the incidence of five common nursery pests, Phytophthora root rot (*Phytophthora* spp.), Phytophthora foliar blight (*Phytophthora* spp.), bittercress (*Cardamine* spp.), snails and slugs (Class: *Gastropoda*), and root weevils (*Otiorhynchus* spp.), in nurseries participating in the USNCP, the GAIP, and the SPI program. The pest incidences were then compared to determine which certification program provided the greatest pest risk mitigation overall and for each specific pest. We also evaluated the effect of plant families grown by the respective nurseries and of pest presence at previously identified hazards on pest incidences.

Materials and Methods

Six nurseries in Oregon were surveyed: two were participants in the USNCP, two in the GAIP, and two in the SPI program. Both USNCP nurseries were located in Yamhill County. One GAIP nursery was located in Linn County and the other in Marion County. Both SPI nurseries were located in Marion County. All nurseries had participated in their respective programs a minimum of 3 years prior to the start of this study. The pest surveys were conducted on container-grown plants at each nursery. During each pest survey, the six nurseries were also assessed for common hazards associated with pest presence and for best management practices that had been adopted to mitigate those hazards (22). Pesticide application programs used by the nurseries were not assessed as part of this study because such programs are not a mandatory requirement for participation in the GAIP, USNCP, or SPI program (16, 21, 31). At four previously identified hazards [irrigation water, potting media, native soil (ground upon which containers were placed, with or without gravel), and used containers], samples were collected and tested for the presence of *Phytophthora* by baiting with susceptible leaf tissue and then plating onto a selective medium as previously described (23, 24). *Phytophthora* incidence at the four hazards was then analyzed using analysis of variance (ANOVA) for a randomized complete block design with $p \leq 0.05$ to identify the potential effect of the certification programs on pest incidence and Fisher's protected least significant difference to identify significant differences ($p \leq 0.05$) between means (26).

Each nursery was surveyed for the five target pests, Phytophthora root rot, Phytophthora foliar blight, bittercress, snails and slugs, and root weevils. These pests were chosen specifically because of their broad host ranges and common occurrence in nurseries (e.g., 2, 9, 10, 24, 34). To remove potential bias from the survey, nursery crops were inspected along random transects located within each nursery, with no attempt made to target a specific plant family, genus, or species. The number of transects walked within each nursery was based on the size of the nursery's container production area (Table 1) (30). Three survey plots, each with a radius of 1 m (39 in), were located equidistant along each transect. Within each survey plot, the plant species and family present was recorded and the presence or absence of bittercress, snails and slugs, and root weevils determined by visual identification in the field (2, 5, 10). Within each survey plot, presence of Phytophthora root rot was determined by collecting a root sample (a primary root or five secondary roots) from one symptomatic plant and then testing it in the laboratory. Root samples were initially tested for the presence of *Phytophthora* spp. using a commercial enzyme linked immunosorbent assay (ELISA) kit by following the manufacturer's instructions (Catalog No. SRA 92600, Agdia, Inc., Elkhart, IN) (1). Because of potential cross-reactivity with *Pythium* spp. (1), samples that tested positive with ELISA were then tested with real time polymerase chain reaction (qPCR) using the *Phytophthora*-specific 5.8S internal control primers of the USDA-approved Elicitin qPCR test to verify the presence of *Phytophthora* spp. in the sample (29). Within each survey plot, presence or absence of Phytophthora foliar

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-19 via free access

Table 1. **Total number of transects surveyed, survey plots inspected, and root and foliar samples collected from two nurseries in the Grower Assisted Inspection Program (GAIP), two nurseries in the U.S. Nursery Certification Program (USNCP), and two nurseries in the shipping point inspection (SPI) program over the course of the study.**

	Nursery size class[z]		Total number			
Nursery	hectares	(acres)	Random transects surveyed	Survey plots inspected	Root samples collected	Foliar samples collected
GAIP1	8–20	(20–50)	81	243	242	243
GAIP2	40–81	(100–200)	96	288	286	287
USNCP1	202–405	(500–1000)	144	432	430	430
USNCP2	81–202	(200–500)	120	360	359	359
SPI1	8–20	(20–50)	68	204	203	204
SPI2	0.5–2	(1–5)	36	108	107	107

[z]Numbers are based on the number of hectacres (acres) at the nursery dedicated to producing plants in containers only.

blight was determined by collecting a foliar sample (five leaves) from one symptomatic plant and then testing it in the laboratory. Testing was conducted with ELISA as described above. If the survey plots were unsafe to enter or contained no plants because of nursery cultural activities, root and/or foliar samples were not collected. Pest incidence for each of the five target pests was calculated by dividing the number of survey plots in which a pest was detected by the total number of survey plots inspected at the nursery during that survey period.

The nurseries were surveyed four different times. The first survey occurred from October 10, 2011, to November 17, 2011 (F2011), the second from March 15, 2012, to May 9, 2012 (S2012), the third from October 11, 2012, to November 19, 2012 (F2012), and the fourth from March 26, 2013, to May 8, 2013 (S2013). Surveys were conducted within these specified time frames to minimize potential differences in environmental conditions between the nurseries. Over the course of this study, a grand total of 1,635 plots were surveyed for the five target plant pests, with 1,627 root samples and 1,630 foliar samples collected for laboratory testing (Table 1).

To determine the effect of the certification program used, the data were combined by certification program (GAIP, USNCP, or SPI) and analyzed statistically as described above. To determine the effect of plant family on pest incidence, pest incidence data for each pest were combined by plant family regardless of nursery certification program and then analyzed statistically as described above. All determinations of statistical significance were made using the threshold $p \leq 0.05$.

Results and Discussion

The potential hazards and best management practices observed at the GAIP, USNCP, and SPI nurseries were very similar for soil drainage, general sanitation within production blocks, and sanitation within potting areas. All of the best management practices the nurseries had adopted (*data not shown*) were those recommended for pest risk mitigation at those potential hazards (13, 24, 27). However, there were differences noted elsewhere.

The GAIP and USNCP nurseries used river water and water from recycling ponds for irrigation throughout the study, adding irrigation with well water during later survey periods, whereas the SPI nurseries used well water throughout the study, adding river water for irrigation during the last survey period. The USNCP nurseries treated their irrigation water, but only during the F2011 and F2012 surveys. Well water and treated water, if treated using chlorine or sand filtration, are considered pest-free sources for irrigation (13, 24, 27). The USNCP requires nurseries to treat recycled water that is being used for irrigation, whereas the GAIP requires nurseries to either treat their recycled irrigation water or to adopt a water management program designed to minimize leaf wetness, overwatering, and standing water in production areas (16, 31). Nurseries in the SPI program have no such requirements.

All of the nurseries placed container-grown plants on gravel that was 10 cm (4 in) or less deep, although one GAIP nursery, one USNCP nursery, and both SPI nurseries also placed containers directly on native soil or on ground cloth over native soil. Placing containers directly on native soil or on a permeable surface reportedly places plants at risk for becoming infected by *Phytophthora* spp. (8, 24). All of the nurseries stored potting media components on concrete, although one GAIP nursery also stored components on native soil, again risking contamination of potting media by *Phytophthora* spp. (24). Lastly, the GAIP and USNCP nurseries used new or sanitized containers for potting, whereas the SPI nurseries potted plants into new and used containers. Used containers are a known source of *Phytophthora* spp. and bittercress contamination (2, 7, 17, 24, 33). Both the USNCP and the GAIP require participating nurseries to use new pots or to clean or sanitize used pots before re-use (16, 31). The SPI program has no such requirement.

Evaluating samples collected from irrigation water, used pots, potting media, and native soil, there was a statistically significant difference in *Phytophthora* incidence in irrigation water, with the highest incidence occurring in GAIP nurseries (Table 2). River water or water from recycling ponds comprised 76% of the samples collected from GAIP nurseries, 68% of the samples from USNCP nurseries, and 50% of the samples from SPI nurseries. Untreated river water and water from recycling ponds is a known source of *Phytophthora* contamination (24, 32). In contrast, well water, which comprised half of the samples collected from the SPI nurseries, is considered free of *Phytophthora* as is irrigation water treated with chlorine or sand filtration (24, 32). At the time of this study, neither GAIP nursery treated their irrigation water, although both had water management plans in place. When test results were combined with no regard to certification program, significantly more *Phytophthora* was detected in samples from irrigation water and soil substrate (Fig. 1). This is consistent with previous reports indicating the importance of these two known hazards as reservoirs for *Phytophthora* inoculum (8, 24, 32).

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-19 via free access

Table 2. **Average *Phytophthora* incidence at four known potential hazards for pathogen introduction in nurseries participating in the Grower Assisted Inspection Program (GAIP), U.S. Nursery Certification Program (USNCP), and Shipping Point Inspection (SPI) program.**

Nursery certification program	Average *Phytophthora* incidence (%)[z] Irrigation water	Potting media	Used pots	Native soil
GAIP	48b	1	10	30
USNCP	38ab	4	0	30
SPI	28a	13	15	36

[z]Different letters indicate statistically significant differences ($p \leq 0.05$) between means identified with Fisher's protected least significant difference test.

One or more of the target pests was detected in 1,003 of the 1,635 survey plots inspected. Of the 1,003 infested survey plots, 684 plots were infested with one target pest, 261 plots with two target pests, 53 plots with three target pests, 11 plots with four target pests, and one plot with all five target pests. Snails and slugs were detected in 652 of the infested survey plots, Phytophthora root rot in 334 plots, bittercress in 200 plots, root weevils in 130 plots, and Phytophthora foliar blight in 69 plots. The most common combination of target pests observed was snails and slugs with Phytophthora root rot (*data not shown*). Both pests benefit from moist, cool environmental conditions, a situation often found in container yards where pots are usually crowded close together (10, 24, 25).

Based on the total number of survey plots found infested with one or more target pests, the GAIP nurseries had significantly fewer infested plots than the USNCP nurseries, whereas the total number of infested plots found in the SPI nurseries was not significantly different from either the GAIP or the USNCP nurseries (Table 3). The GAIP is a goal-driven program, where each nursery is allowed to choose the best management practice to address an identified hazard that best fits their production practices (16). The USNCP is more prescriptive, where certain best management practices are dictated by the program requirements (31). The SPI has no specific requirements so that nurseries may adopt whatever best management practices they choose (21). This may have

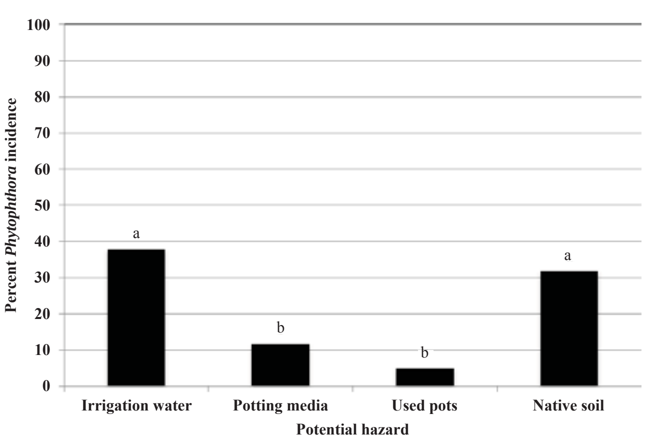

Fig. 1. **Average *Phytophthora* incidence at four known potential hazards for *Phytophthora* introduction into nurseries; different letters indicate statistically significant differences ($p \leq 0.05$) between means identified with Fisher's protected least significant difference test.**

played a role in the effectiveness of each program, although other factors may be contributing as well. For example, we did not assess the nurseries' pesticide application programs during this study; depending upon what was used, such programs would undoubtedly impact the incidence of certain pests.

Looking at each target pest individually, the average pest incidence for Phytophthora root rot was significantly higher in the survey plots inspected at SPI nurseries than in those inspected at nurseries participating in the GAIP and the USNCP (Table 4). Also, significantly more Phytophthora root rot was detected during the S2013 survey period (40% incidence) than during the other three survey periods (F2011 = 18%, S2012 = 20%, and F2012 = 11%), possibly due to an unusually dry weather pattern in early 2013 that required nurseries to begin irrigating earlier than normal (20). The SPI nurseries used well water, which should have helped protect against *Phytophthora* infections (13, 24, 27). However, these nurseries also placed pots directly on native soil and re-used containers without any sanitization, practices that can increase the risk of infection by *Phytophthora* (7, 8, 24). The GAIP and USNCP nurseries used non-treated water, which places plants at risk for *Phytophthora* infection (e.g., 24, 32), one GAIP nursery and one USNCP nursery placed pots directly on native soil, and one GAIP nursery stored potting media components on native soil (8, 24). Yet, significantly less disease was present in the GAIP and USNCP nurseries in spite of these risky practices. It is possible that the requirements for irrigation water treatment and/or a water management plan helped these nurseries be more successful mitigating Phytophthora root rot.

The average pest incidence for Phytophthora foliar blight was not significantly different between the GAIP, USNCP, and SPI nurseries (Table 4), suggesting all three certification programs were equally effective for mitigating the pest risk from Phytophthora foliar blight. There was also no significant difference in pest incidence between the four survey periods, with mean incidences of 3% in F2011, 2% in S2012, 3% in F2012, and 2% in S2013, suggesting this disease may be present at any time in the nurseries.

The average pest incidence for bittercress was significantly higher in survey plots inspected at GAIP nurseries than in those inspected at nurseries participating in the USNCP and SPI program (Table 4). This pest also appeared to be a seasonal problem, with significantly higher pest incidences during the fall survey periods (F2011 = 14% and F2012 = 17%) than during the spring survey periods (S2012 = 7% and

Table 3. **The percentage of survey plots identified as infested with one or more target pests over the four survey periods in this study are shown for nurseries participating in the Grower Assisted Inspection Program (GAIP), U.S. Nursery Certification Program (USNCP), and shipping point inspection (SPI) program.**

Nursery certification program	Survey plots found infested (%) Fall 2011	Spring 2012	Fall 2012	Spring 2013	Mean[z]
GAIP	58	40	58	63	55a
USNCP	75	48	76	71	68b
SPI	53	51	64	66	58ab

[z]Different letters indicate statistically significant differences ($p \leq 0.05$) between means identified with Fisher's protected least significant difference test.

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-19 via free access

Table 4. **The incidence of five nursery pests in nurseries participating in the Grower Assisted Inspection Program (GAIP), U.S. Nursery Certification Program (USNCP), and Shipping Point Inspection (SPI) program from the fall of 2011 to the spring of 2013.**

Nursery certification program	Pest incidence (%)[z]				
	Phytophthora root rot	Phytophthora foliar blight	Bittercress	Snails and slugs	Root weevils
GAIP	17a	4	21b	29a	7
USNCP	19a	7	9a	49b	7
SPI	31b	4	7a	34a	12

[z]Different letters indicate statistically significant differences ($p \leq 0.05$) between means identified with Fisher's protected least significant difference test.

S2013 = 10%). The GAIP has no specific requirements pertaining towards weed management; the program is focused on *Phytophthora* disease management only (16). Similarly, weed management in the SPI program is left entirely up to the nurseries. In contrast, participants in the USNCP are required to have a weed mitigation strategy in place (31). Herbicides, manual weeding, and sanitation are used to eliminate bittercress from nursery production systems (2, 3, 17, 33). Meanwhile, re-using pots without cleaning or sanitizing them and using untreated irrigation water are believed to contribute to weed establishment (2, 17, 33). The GAIP nurseries did sanitize used pots before re-use, but did not treat their irrigation water. The USNCP nurseries treated pots similarly, but also treated their irrigation water. The SPI nurseries, which used a clean water source but re-used pots without sanitizing them, also had few problems with bittercress. This suggests the lack of water treatment may have played a role in the bittercress issues in the GAIP nurseries; this and some other factor, such as contamination of tools and equipment by seeds, may be contributing to the higher pest incidence (2, 17, 33).

The average pest incidence for snails and slugs was significantly higher in survey plots inspected at USNCP nurseries than in those inspected at nurseries participating in the GAIP and SPI program (Table 4). This pest may also be more of a seasonal problem, with a significantly lower pest incidence during the S2012 survey period (23%) and a lower pest incidence during the S2013 survey period (36%), although the latter was not significantly different from the pest incidences detected during the fall survey periods (F2011 = 43% and F2012 = 48%). Slugs and snails are favored by mild climates, cloudy or foggy weather, and lots of ground cover (10, 25). We are unable to suggest a specific reason why pest incidence was so much higher at USNCP nurseries. However, this may be a situation where the nurseries' pesticide application programs, a factor we did not assess, may have affected pest incidence. The horticultural industry has been implicated as a primary pathway for the spread of exotic snails and slugs (6); our data suggest that adjusting the implementation timing of mitigation measures may help minimize spread through the shipment of nursery plants.

The average pest incidences for root weevils were not significantly different for the GAIP, USNCP, and SPI nurseries, suggesting all three certification programs are equally effective for mitigating the pest risk from root weevils (Table 4). There was also no significant difference in pest incidence between the four survey periods (F2011 = 12%, S2012 = 3%, F2012 = 14%, and S2013 = 5%), indicating this pest could be present at any time in the nurseries. This is consistent with previous reports that state the pest may be present in nursery stock year-round, although the life stage may differ depending upon the time of the year (9, 12).

Overall, plants from 78 different families were inspected during the course of this study (Table 5). Based on the total number of survey plots inspected, eight plant families were most commonly inspected (Fig. 2), although the families grown by the nurseries varied considerably (Table 5). When analyzing pest incidences within the eight most common

Table 5. **The plant families grown by nurseries in the Grower Assisted Inspection Program (GAIP), the U.S. Nursery Certification Program (USNCP), and the Shipping Point Inspection (SPI) program from the fall of 2011 to the spring of 2013.**

Nursery certification program	Plant family
GAIP	Aceraceae, Adoxaceae, Anacardiaceae, Agavaceae, Apocynaceae, Aquifolicaceae, Asteraceae, Berberidaceae, Betulaceae, Bignomiaceae, Boraginaceae, Buddlejaceae, Buxaceae, Caprifoliaceae, Caryophyllaceae, Celastraceae, Clusiaceae, Cornaceae, Cupressaceae, Dryopteridaceae, Ericaceae, Fabaceae, Fagaceae, Grossulariaceae, Hamamelidaceae, Hydrangeaceae, Lamiaceae, Lauraceae, Lythraceae, Magnoliaceae, Malvaceae, Myricaceae, Oleaceae, Paeoniaceae, Passifloraceae, Pinaceae, Poaceae, Ranunculaceae, Rhamnaceae, Rosaceae, Salicaceae, Saxifragaceae, Scrophulariaceae, Taxaceae, Thymelaeaceae
USNCP	Aceraceae, Actinidiaceae, Adoxaceae, Alliaceae, Anacardiaceae, Apocynaceae, Aquifoliaceae, Araliaceae, Asteraceae, Berberidaceae, Betulaceae, Boraginaceae, Buddlejaceae, Buxaceae, Caprifoliaceae, Celastraceae, Cercidiphyllaceae, Cistaceae, Clethraceae, Clusiaceae, Cornaceae, Crassulaceae, Cupressaceae, Dryopteridaceae, Elaeagnaceae, Ericaceae, Fabaceae, Fagaceae, Fumariaceae, Geraniaceae, Gingkoaceae, Grossulariaceae, Hamamelidaceae, Hippocastanaceae, Hydrangeaceae, Lamiaceae, Lauraceae, Liliaceae, Magnoliaceae, Malvaceae, Myricaceae, Oleaceae, Onagraceae, Paeoniaceae, Pinaceae, Pittosporaceae, Poaceae, Podocarpaceae, Polemoniaceae, Ranunculaceae, Rhamnaceae, Rosaceae, Rutaceae, Saxifragaceae, Scrophulariaceae, Taxaceae, Thymelaeaceae, Tiliaceae, Ulmaceae, Verbenaceae, Violaceae, Winteraceae
SPI	Aceraceae, Acoraceae, Aizoaceae, Apocynaceae, Aspleniaceae, Asteraceae, Begoniaceae, Berberidaceae, Blechnaceae, Brassicaceae, Buxaceae, Campanulaceae, Caryophyllaceae, Celastraceae, Cornaceae, Crassulaceae, Cupressaceae, Dryopteridaceae, Ericaceae, Euphorbiaceae, Fabaceae, Geraniaceae, Juncaceae, Lamiaceae, Liliaceae, Malvaceae, Oleaceae, Oxalidaceae, Pinaceae, Poaceae, Polemoniaceae, Polygonaceae, Rosaceae, Saxifragaceae, Scrophulariaceae

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-19 via free access

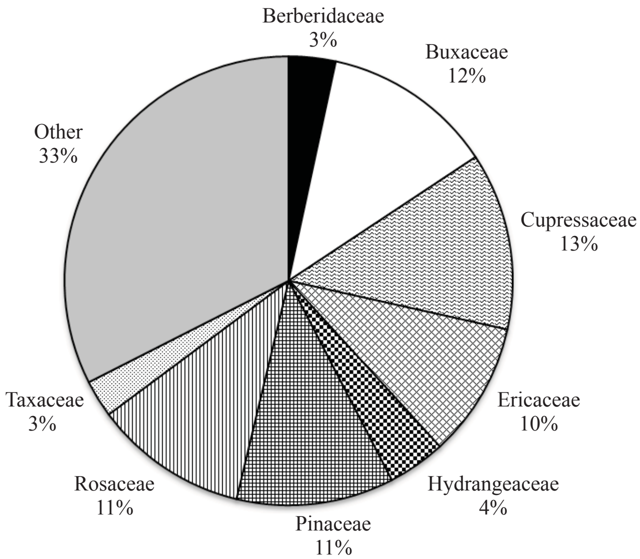

Fig. 2. The eight most common plant families grown in six Oregon nurseries from the fall of 2011 to the spring of 2013.

factor. Regardless, our results indicate that the plant families grown does affect Phytophthora root rot and root weevil incidence. Nurseries should consider adjusting their production practices accordingly.

In this study, we compared the effectiveness of two audit-based, systems approaches to pest risk mitigation in nursery stock to the current regulatory standard. When looking at overall pest incidence without regard to the specific pest(s) found, the audit-based GAIP provided the greatest pest risk mitigation for nurseries growing plants in containers. However, none of the certification programs included in this study was consistently the most effective against all five of the pests surveyed for. Bittercress incidence was highest in the GAIP nurseries, snails and slugs incidence highest in the USNCP nurseries, and Phytophthora root rot incidence highest in the SPI nurseries. We also identified an additional factor, or hazard, that may play a role in the effectiveness of certification programs, the plant families grown by the nursery. Other unidentified hazards may be important as well. Also, our study focused only on plants grown within containers. It is likely the potential hazards for plants grown under other conditions, for example in the field, and the associated best

Table 6. The incidence of five nursery pests in the eight most common plant families grown in six Oregon nurseries from the fall of 2011 to the spring of 2013.

	Pest incidence (%)[z]				
Plant family	Phytophthora root rot	Phytophthora foliar blight	Bittercress	Snails and slugs	Root weevils
Berberidaceae	16ab	2	3	38	6ab
Buxaceae	10a	2	7	38	11b
Cupressaceae	32c	3	3	33	12b
Ericaceae	6a	8	5	32	2a
Hydrangeaceae	3a	5	15	42	8ab
Pinaceae	38c	8	11	48	8ab
Rosaceae	26bc	4	8	42	7ab
Taxaceae	30c	0	2	38	27c

[z]Different letters indicate statistically significant differences ($p \leq 0.05$) between means identified with Fisher's protected least significant difference test.

plant families, significant differences were observed for Phytophthora root rot and root weevils, with Phytophthora root rot most common in the Pinaceae, Taxaceae, Cupressaceae, and Rosaceae and root weevils most common in the Taxaceae (Table 6). Of all the plots surveyed within each nursery, 56% in nursery SPI1 were made up of members of the Pinaceae, Cupressaceae, Taxaceae, and Rosaceae, 2% in nursery SPI2, 34% in nursery GAIP1, 28% in nursery GAIP2, 50% in nursery USNCP1, and 34% in nursery USNCP2. Because plant family was a significant factor for Phytophthora root rot incidence and because two nurseries apparently specialized in producing nursery stock from those four plant families, we also statistically analyzed this pest incidence data by nursery. When analyzed this way, SPI1 and USNCP2 had significantly higher pest incidences for Phytophthora root rot than the remaining nurseries (Fig. 3). However, USNCP1 had significantly less Phytophthora root rot, despite members of the Cupressaceae, Pinaceae, Rosaceae, and Taxaceae comprising 50% of the samples tested. This suggests differing practices within the nurseries may be affecting the incidence of Phytophthora root rot. As stated before, we did not assess the nurseries' pesticide application programs in this study, but that may have been a

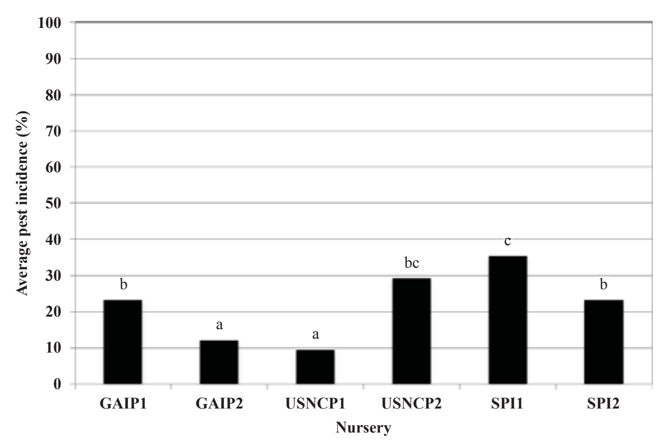

Fig. 3. Average pest incidence of Phytophthora root rot over four survey periods in two nurseries participating in the Grower Assisted Inspection Program (GAIP), two nurseries participating in the U.S. Nursery Certification Program (USNCP), and two nurseries participating in the Shipping Point Inspection (SPI) program; different letters indicate statistically significant differences (p ≤ 0.05) between means identified with Fisher's protected least significant difference test.

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-19 via free access

management practices will differ from those discussed here. Finally, we excluded nursery pesticide application programs from this study; such practices were not mandatory for inclusion in either of the systems approach-based certification programs we surveyed. As nurseries and regulatory agencies move toward using the systems approach for pest risk mitigation, more research must be done to identify potential hazards to field-grown nursery stock, to identify the appropriate best management practices to mitigate overall pest risk, and to determine the role of pesticide application programs in the systems approach.

Literature Cited

1. AgDia, Inc. Phytophthora reagent set: DAS-ELISA alkaline phosphatase label Catalog No. SRA 92600. M39.6, AgDia, Inc., Elkhart, IN, 7 pp.

2. Bachman, G.B. and T. Whitwell. 1998. Hairy bittercress seed production, dispersal, and control in propagation beds. Department of Horticulture, Clemson University, Clemson, SC, 3 pp. http://www.clemson.edu/cafls/departments/horticulture/research/ornamental/nursery/hairy_bittercress_control.html.

3. Briggs, J., T. Whitwell, M.B. Riley, R. Smith, and G. Legnani. 2001. Preemergent bittercress control on a gravel groundcover. J. Environ. Hort. 19:104–108.

4. Canadian Food Inspection Agency. 2011. Canadian Fruit Tree Export Program (CFTEP) for *Malus*, *Pyrus*, *Chaenomeles*, *Cydonia*, and *Prunus*, 2nd Revision. D-08-05, Canadian Food Inspection Agency, 21 pp.

5. Carmean, D. 1986. Identifying common root weevils. Ornamentals Northwest Archives 10:8–9.

6. Cowie, R.H., K.A. Hayes, C.T. Tran, and W.M. Meyer III. 2008. The horticultural industry as a vector of alien snails and slugs: Widespread invasions in Hawaii. Int. J. Pest Manage. 54:267–276.

7. Dart, N.L. and G.A. Chastagner. 2007. High recovery of *Phytophthora* from containerized nursery stock pots at a retail nursery highlights potential for spreading exotic Oomycetes. Plant Health Progr. DOI: 10.1094/PHP-2007-0816-01-BR.

8. Dart, N.L., G.A. Chastagner, E.F. Rugarber, and K.L. Riley. 2007. Recovery frequency of *Phytophthora ramorum* and other *Phytophthora* spp. in the soil profile of ornamental retail nurseries. Plant Dis. 91:1419–1422.

9. Fisher, J.R. and D.J. Bruck. 2008. Biology and control of root weevils on berry and nursery crops in Oregon. p. 345–352 *In*: P. Bañados and A. Dale (editors). Proc. IXth Int. Rubus and Ribes Symposium. Acta Hort. 777.

10. Flint, M.L. and C.A. Wilen. 2009. Pest notes: Snails and slugs. Publication no. 7427, Univ. California Statewide Integrated Pest Management Program, 4 pp.

11. Food and Agricultural Organization of the United Nations. 2012. International Standards for Phytosanitary Measures 36: Integrated measures for plants for planting. Int. Plant Protection Convention, 20 pp., https://www.ippc.int/core-activities/standards-setting/ispms.

12. Green, J.L. and J. Capizzi. 1985. Root weevils: Some adults overwintered, others are still emerging. Ornamentals Northwest Archives 9:12–14.

13. Griesbach, J.A., J.L. Parke, G.A. Chastagner, N.J. Grünwald, and J. Aguirre. 2012. Safe procurement and production manual: A systems approach for the production of healthy nursery stock. Oregon Association of Nurseries, Wilsonville, 98 pp. http://www.oan.org/displaycommon.cfm?an=1&subarticlenbr=861.

14. Koch, F.S. and W.D. Smith. 2010. Advances in threat assessment and their application in forest and rangeland management. GTR802, USDA Forest Service, p. 421–443.

15. Liebhold, A.M., E.G. Brockerhoff, L.J. Garrett, J.L. Parke, and K.O. Britton. 2012. Live plant imports: The major pathway for forest insect and pathogen invasions of the US. Front. Ecol. Environ. 10:135–143.

16. Lujan, M., G. McAninch, and N. Osterbauer. 2010. Oregon's Grower Assisted Inspection Program: An audit-based system to manage *Phytophthora* diseases. p. 340–343 *In*: S. Frankel, J. Kliejunas, and K. Palmieri (technical coordinators). Proceedings of the Sudden Oak Death Fourth Science Symposium. PSW-GTR-229, USDA Forest Service, Albany, CA.

17. Norcini, J.G. 2004. Control of bittercress in Florida container nurseries. Publication ENH 985, University of Florida Coop. Ext. Serv., 5 pp.

18. North American Plant Protection Organization. 2005. Regional Standard for Phytosanitary Measures No. 24: Integrated pest risk management measures for the importation of plants for planting into NAPPO member countries. Secretariat of the North American Plant Protection Organization, Ottawa, Ontario, Canada, 22 pp.

19. Nursery and Garden Industry Australia. 2008. BioSecure HACCP: Guidelines for managing biosecurity in nursery production. Nursery and Garden Industry Australia, Sydney, 139 pp.

20. Oregon Climate Service. 2013. March madness: Dry weather continues, year off to driest start on record. Oregon Climate Service, Oregon State Univ., Corvallis, 4 pp.

21. Oregon State Legislature. 2011. Oregon Revised Statute Chapter 571: Nursery stock; crops; Christmas trees. Oregon State Legislature, Salem, 31 pp.

22. Osterbauer, N.K., S. Lewis, J. Hedberg, and G. McAninch. 2013. Assessing potential hazards for *Phytophthora ramorum* establishment in Oregon nurseries. J. Environ. Hort. 31:133–137.

23. Osterbauer, N.K., M. Lujan, G. McAninch, A. Trippe, and S. Lane. 2013. Verifying critical control points for *Phytophthora* introduction into nurseries. p. 149–153 *In*: S.J. Frankel, J.T. Kliejunas, K.M. Palmieri, and J.M. Alexander (technical coordinators). Proceedings of the Sudden Oak Death Fifth Science Symposium. PSW-GTR-243, U.S. Department of Agriculture, Forest Service, Albany, CA.

24. Parke, J.L. and N.J. Grünwald. 2012. A systems approach for management of pests and pathogens of nursery crops. Plant Dis. 96:1236–1244.

25. Speiser, B., D. Glen, S. Piggot, A. Ester, K. Davies, J. Castillejo, and J. Coupland. 2001. Slug damage and control of slugs in horticultural crops. IACR Research Institute of Organic Agriculture (FiBL), 8 pp.

26. Steel, R.G.D. and J.H. Torrie. 1980. Principles and procedures of statistics: A biometrical approach, 2nd Edition. McGraw-Hill, Inc., San Francisco, CA, 633 pp.

27. Suslow, K. 2008. Recommended industry best management practices for the prevention of *Phytophthora ramorum* introduction into nursery operations. p. 115–128 *In*: S. Frankel, J. Kliejunas, and K. Palmieri (technical coordinators). Proceedings of the Third Sudden Oak Death Science Symposium. PSW-GTR-214, USDA Forest Service, Albany, CA.

28. Thompson, J.P. 2011. Certified: Feasibility of audit-based certification to prevent invasive plant pests in the horticulture industry. Washington: Northeast-Midwest Institute, 112 pp.

29. USDA APHIS Center for Plant Health Sciences and Technology. 2009. Elicitin quantitative multiplex real-time PCR (qPCR) for detection of *Phytophthora ramorum* using a TAqMan system on the Cepheid SmartCycler®. WI-B-T-1-7, USDA APHIS CPHST, Beltsville, MD, 10 pp.

30. USDA APHIS National Seed Health System. 2001. Reference Manual B: Seed health testing and phytosanitary field inspection methods manual, p. 44–51.

31. USDA APHIS Plant Protection and Quarantine. 2008. Standards for phytosanitary measures: Requirements for the certification of nurseries under the United States Nursery Certification Program. USDA APHIS PPQ, Riverdale, MD. 111 pp.

32. Werres, S., S. Wagner, T. Brand, K. Kaminski, and D. Seipp. 2007. Survival of *Phytophthora ramorum* in recirculating irrigation water and subsequent reinfection of *Rhododendron* and *Viburnum*. Plant Dis. 91:1034–1044.

33. Wilen, C.A. Bittercress (*Cardamine* spp.) biology and control for nurseries. University California Coop. Ext., San Diego, 2 pp.

34. Yakabe, L.E., C.L. Blomquist, S.L. Thomas, and J.D. MacDonald. 2009. Identification and frequency of *Phytophthora* species associated with foliar diseases in California ornamental nurseries. Plant Dis. 93:883–890.

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-19 via free access