7-14-2023

A Modified Delphi Study on Boxwood Blight Disease Management in the US Nursery Industry

Bhawana Ghimire

Kumuditha Hikkaduwa Epa Liyanage

Charlie Hall

Fulya Baysal-Gurel

HortScience 58(8):898–906. 2023. https://doi.org/10.21273/HORTSCI17210-23

A Modified Delphi Study on Boxwood Blight Disease Management in the US Nursery Industry

Bhawana Ghimire and Kumuditha Hikkaduwa Epa Liyanage
Department of Agricultural and Environmental Sciences, College of Agriculture, Tennessee State University, Otis L. Floyd Nursery Research Center, 472 Cadillac Lane, McMinnville, TN 37110, USA

Charlie Hall
Department of Horticultural Sciences, Texas A&M University, College Station, TX 77843-2133, USA

Fulya Baysal-Gurel
Department of Agricultural and Environmental Sciences, College of Agriculture, Tennessee State University, Otis L. Floyd Nursery Research Center, 472 Cadillac Lane, McMinnville, TN 37110, USA

Keywords. boxwood blight, boxwood production practices, *Calonectria pseudonaviculata*, nursery production, ornamental

Abstract. **Boxwood is one of the most popular evergreen shrubs in the United States, the production of which is currently challenged by boxwood blight, an emerging threat that has spread across 30 states. A thorough understanding of boxwood production, plant health, management practices and economic impact could aid in answering the needs of the nursery industry in managing this disease. An online modified Delphi survey was conducted to identify grower perceptions on processes, programs, and practices to limit or prevent the entry and spread of boxwood blight disease. The expert panel consisted of 29 nursery producers who represented a significant portion of boxwood production nationally. The panel members rated boxwood blight as the third most problematic disease with a potential to be number one in the future. Boxwood transplants were perceived as the main source of boxwood blight outbreak, followed by cutting tools, nursery equipment, containers, plant debris, irrigation water, worker hygiene, and other crops. According to the panel responses, cultural control methods, inspection, and quarantine of incoming plant material, scouting, and sanitization were the most important practices that can limit or prevent plant diseases during boxwood production. The panel members did not agree that the composted manure could influence the spread of plant disease in boxwood production, although this has been verified by the findings of various previous research experiments. Panel members were very familiar with scouting and employee training, best management practices, and the boxwood blight cleanliness program. This study documents the key components, practices, and procedures in boxwood production that could influence the spread of boxwood blight in nurseries and could be further verified by sampling and laboratory assays to specify the critical control points in the production process.**

Boxwood (*Buxus* sp. L., Buxales, Buxaceae) is an evergreen shrub with a high market value (Kramer et al. 2020), increasing from $102.9 million in 2009 to $126.5 million in 2014 (Hall et al. 2021) and increasing again from 2014 to 2019 to $140.9 million as reported in the Census of Horticultural Specialties (US Department of Agriculture, National Agricultural Statistics Service 2020). Until 2014, the top three states involved in nursery operations that sold boxwood were Oregon, Ohio, and California, which represented 36% of the total US boxwood sales, and this reached 40% by 2019. North Carolina, Maryland, Illinois, New Jersey, Virginia, Connecticut, and Tennessee were in the top 10 boxwood-producing states. However, a major difference in the production trends of boxwood sales from 2009 to 2014 vs. 2014 to 2019 was the replacement of Connecticut and Tennessee by Florida and Louisiana in the top 10 list. Both states were negatively affected by boxwood blight as reflected by the decrease in sales by 50.5% and 46% in Connecticut and Tennessee, respectively (Hall et al. 2021). North Carolina, which was number four among the top producers/sellers of boxwood, declined to number seven as it was also impacted by the boxwood blight.

Boxwood blight caused by *Calonectria pseudonaviculata* Lombard, Crous, and Wingfield (*Cps*) disease severely defoliates susceptible boxwood plants which, in turn deteriorates the marketability of the plants, resulting in significant economic losses to boxwood growers (Bika 2021; Dhakal et al. 2022). Boxwood blight has a 29-year history in Europe and 12-year history in North America but is projected to change the composition of boxwood used in gardening irreversibly, as it has been documented to be devastating to susceptible English boxwood (*Buxus sempervirens* L.) in gardens internationally (LeBlanc et al. 2018). The disease has spread to 30 states (Daughtrey 2019; Hall et al. 2021) in the United States and has been an urgent scientific challenge to plant pathologists and horticulturists.

Boxwood is sold in the form of liners, cuttings, containerized products, balled and burlapped products, field-grown and bagged for sale, bare root, and balled and potted (process balled) plants (Hodges et al. 2015). Producing and selling boxwood blight-free plants from the nursery based on the principle of minimization of primary inoculum could be the fundamental process instrumental in decreasing the spread of boxwood blight (Filho et al. 2016). It is therefore crucial to understand what steps (or cultural practices) in nursery operations are followed to produce boxwood. It is also important to know what resources, materials, and tools are commonly used during production (e.g., potting media, containers, bags, shovels, shears, irrigation water) that could be a source of entry for the further spread of *Cps* (Hall et al. 2011). An understanding of how boxwood blight enters nurseries and spreads during nursery production will be useful in managing boxwood blight. The disease management of boxwood blight is a decision-making process that combines interdisciplinary research such as social sciences and plant pathology. In this study, we investigated the status of boxwood production, the state of knowledge of the factors related to plant health, and the socioeconomic impact of boxwood blight management.

The Delphi method used in this study was developed by RAND Corporation (Santa Monica, CA, USA) in 1950s (Linstone and Turoff 1975, 2002) and is based on using a series of data collection questionnaires and conducting several rounds of surveys to gain consensus from selected participants who have expert knowledge of the discipline (von der Gracht 2012). Also, the Delphi method is a structured communication process used to predict outcomes based on the past knowledge and experience of a group of experts (Mitroff and Turoff 2002). Delphi surveys are different from other types of surveys, as the expert panel has an opportunity to reconsider their answers anonymously based on the overall group responses (Mitroff and Turoff 2002). Conventionally, the Delphi technique has been used

Received for publication 17 Apr 2023. Accepted for publication 2 Jun 2023.
Published online 14 Jul 2023.
We thank Boxwood Blight Insight Group scientists and the advisory board members for their support on this study. This work was supported by the National Institute of Food and Agriculture (NIFA), US Department of Agriculture (USDA) Evans-Allen grant, under award number TENX-S-1083; NIFA, USDA Specialty Crop Research Initiative grant, under award number 2020-51181-32135.
F.B.-G. is the corresponding author. E-mail: fbaysalg@tnstate.edu.

as a forecasting method, communication improvement, or policy analysis technique. In recent studies, however, the Delphi technique has been used to understand complex problems and identify critical issues within various industries such as agriculture, business, life sciences, information technology, and education. Specifically, in the agriculture industry, the Delphi method is used in agronomy, animal and food production, agricultural education, food systems, extension education, and crop management areas (Lamm et al. 2021). Plant pathology or plant disease management is still a novel area to explore with the Delphi method (Miller et al. 2015). Also, this technique has been modified in recent studies, with various types of questions such as multiple choice, rating, Likert scale, demographic, and closed-ended questions (Raudales et al. 2014) being used in addition to traditional open-ended questions.

The primary objective of this study was to obtain baseline information on boxwood production in nurseries across the United States using the modified Delphi survey method. We focused on topics regarding the nature of boxwood production, the knowledge and status of parameters affecting plant health, critical steps in production that could introduce *Cps*, current boxwood blight management practices, the economic impact of boxwood production, the most effective information dissemination measures, and nursery demographics in this survey study.

Materials and Methods

A list of panel growers was selected from the members of Boxwood Blight Insight Group (BBIG) who were directly or indirectly working with those growers to mitigate boxwood blight in those regions and were deemed to be leaders in the nation in terms of boxwood production (Boxwood Blight Insight Group 2023). Twenty-nine nursery growers/companies were selected as panel members based on their reputation and involvement in boxwood production as propagators, growers, or owners of nurseries located across the nation. Participation of these panel members was voluntary, and no incentives were provided when they completed the survey. Dillman's (2011) tailored design method was used to obtain an acceptable response rate for the survey. The survey questionnaire was approved by the Tennessee State University, Texas A&M University, and Virginia Tech University institutional review boards. All 29 potential panelists were contacted via e-mail and invited to participate in the first round of the survey. The survey was first sent via e-mail in Feb 2022, and data were collected until Oct 2022. Reminders to participate in the survey were sent on 21 Mar, 31 Aug, and 9 Sep. If the respondents accepted the invitation to participate, they were allowed to click on the link embedded in the e-mail and be directed to the Qualtrics (Provo, UT, USA) website that was hosting the questionnaire.

The survey was constructed to elicit expert opinion regarding boxwood disease management for several topics. The Boxwood Production section (p 2–6) covered information on nursery sales, categories of boxwood, types of operation, and the proximity of operation, and management practices related to boxwood production. The Plant Health section (p 7–15) solicited information related to diseases and pathogens of boxwood. The Management and Economic Impact portion (p 16–18) covered the timeline of operations, yield, total area of production information, and market channel information of boxwood. The Demographics section (p 19–22) requested information on their preferred media for receiving disease management information, nursery sales information, employment, and preferred language. The survey had 30 questions (including a consent agreement) and was developed by the members of BBIG which was established as part of a Specialty Crop Research Initiative grant to prevent boxwood blight and safeguard boxwood.

Survey responses were recorded as multiple choice, open-ended, close-ended, and rating scale questions. Extent of the boxwood blight was ranked from 0 = nonproblematic to 10 = most problematic and the threat of the disease was ranked from 1 = no threat to 5 = extreme threat. Also, ordinal 5-point Likert-type scale (Likert 1932) questions were used to record the level of agreement in the modified Delphi survey (Ab Latif et al. 2016; Mitroff and Turoff 2002) with the statements regarding the sources of plant pathogens and practices that limit and prevent plant diseases in boxwood production using a ranking from 1 = disagree to 5 = agree. The panel members were asked to rate their familiarity of processes and programs using a scale from 1 = not familiar to 5 = very familiar and additionally asked whether they currently follow those to control plant diseases to justify their responses. The data were coded, tabulated, and analyzed using Microsoft Excel spreadsheet software (Redmond, WA, USA) and SAS statistical software (SAS Inc., Cary, NC), and the results were expressed as graphical summaries, percentages, and mean frequencies. Consensus was achieved on Likert-type questions if at least 70% of the respondents agreed and the mean frequencies were interpreted as "important" or "not important" (von der Gracht 2012). In the first round of the survey, open-ended responses were also expected from the members with comments about their practices, yields, and values of boxwood production.

Results and Discussion

Boxwood production. Of 29 nurseries in the sample frame, a total of 25 clicked the link and 20 agreed to participate in the survey. Of these 20 responses, two were incomplete and 18 (62%) were completed in the first-round instrument. Members of the panel were from the states of Connecticut, Georgia, Illinois, Kansas, Minnesota, Oregon, Tennessee, Texas, and Virginia. Boxwood represented 14% of average total nursery sales for all the nurseries in the panel, which is higher than the percentage of boxwood share of total US broadleaf evergreens sold (7%) reported in the 2019 Census of Horticultural Specialties (US Department of Agriculture, National Agricultural Statistics Service 2020). As far as the types of boxwood operations, 80% of the panel members were involved in boxwood propagation, 55% were involved in field production, and 80% were involved in containerized boxwood production. Several respondents were involved in all three types of operations.

Asiatic boxwood was the most grown category (35%), followed by other hybrids (30%), less susceptible cultivars (23%), and American/English boxwood (11%). Common cultivars such as Golden Dream, John Baldwin, Baby Gem, Wedding Ring, Sprinter, Green Pillow, Hohman's Dwarf, Grace Hendricks Phillips, Peergold, Cole's Dwarf, Big Leaf Wintergreen, and Green Pillow fall into Asiatic boxwood category (Baysal-Gurel and Liyanapathiranage 2017; Ganci 2014; Ganci et al. 2013; Miller et al. 2016; Yoder et al. 2022). The results of this study are comparable to a previously published literature which indicates that the growers are shifting toward cultivating less susceptible boxwood (Omolehin et al. 2022). Asiatic boxwood category includes high to moderately resistant cultivars whereas American/English boxwood category includes cultivars highly susceptible to boxwood blight. The cultivars such as Aurea-pendula, Justin Brouwers, Vardar Valley, Suffruticosa, Scupi, Rotundifolia, Northland, Denmark, Handsworthiensis, Pendula, Newport Blue, Graham Blandy, Dee Runk could be included in English/American boxwood category (Baysal-Gurel and Liyanapathiranage 2017; Ganci 2014; Ganci et al. 2013; Shishkoff et al. 2015). Cultivars that could be included in the less susceptible category are National, Jim Stauffer, Gregem, Green Beauty, Nana, Winter Beauty, Wintergreen, Pinchusion, and Winter Gem (Baysal-Gurel and Liyanapathiranage 2017; Ganci 2014; Ganci et al. 2013; Miller et al. 2016). NewGen boxwood, included in the less susceptible category, was developed from the resistant cultivar breeding efforts as a response to the boxwood devastation caused by boxwood blight (Daughtrey 2019; McClellan 2019). The category of other hybrid cultivars could include Chicagoland Green® Glencoe, Green Velvet, Green Ice, Green Mound, Green Gem, and Green Mountain (Baysal-Gurel and Liyanapathiranage 2017; Ganci et al. 2013; Ganci 2014; Miller et al. 2016; Shishkoff et al. 2015).

The proximity of the boxwood propagation facility to container or field production areas were compared and 50% of panel members responded that they had their propagation and production areas in the same nursery, 45% had the nearest boxwood container or field production area between 100 yards and 1 mile of the propagation facility, 10% had the nearest boxwood container or field production area within 100 yards of the propagation facility, and 5% had the nearest boxwood container or field production area more than 1 mile from the propagation facility. *Cps* conidia can sporulate on fallen or infected tissues and disperse to nearby crops during boxwood operations, whereas infected leaves blown into nearby fields also have the potential to germinate and cause further disease spread (Weeda and Dart 2012). The accidental movement of infected plant materials by the workers from production to propagation area or movement of pathogen inoculum via tools and equipment used in production, worker boots, gloves, or clothes (Bika et al. 2021; Daughtrey 2019; Gehesquière 2014) could potentially occur if propagation or production area are in close proximity. For this reason, the nurseries that had propagation and cultivation in the same area were at a higher risk of rapid disease spread and higher economic losses, whereas nurseries that maintained a greater distance (100 yards to 1 mile or more than 1 mile between production and propagation facilities) were comparatively at a lower risk.

Pachysandra (*Pachysandra* sp. Michx., Buxales, Buxaceae) and sweet box (*Sarcococca* sp. Lindl., Buxales, Buxaceae) are alternate hosts of *Cps*, and even if disease management measures are adopted to manage the *Cps* in boxwood, these alternate hosts can harbor the pathogen to establish a new infection cycle (Kong et al. 2017; LaMondia and Douglas 2015). Fifteen percent of the survey respondents grew sweet box, 20% grew pachysandra, and the majority of the respondents (70%) did not grow any of these plants with boxwood in the same nursery.

Twenty percent of the growers used smaller blocks to grow boxwood, whereas a majority (80%) did not produce boxwood in blocks. These smaller blocks of boxwood were separated by various tree and shrub species, grasses, Azalea (Ericales, Ericaceae), and Ilex (Aquifoliales, Aquifoliaceae) plants. It is recommended to produce boxwood in small blocks separated by a distance of 10 ft rather than using the whole available production area as a single block (Baysal-Gurel 2023; Dart et al. 2014; LaMondia et al. 2023).

The movement of infected plants, accidental spread of the sticky conidia by human factors such as use of contaminated cuttings tools, workers clothes, gloves, boots, equipment used in production are considered the main mechanisms of pathogen spread, but the spread could also occur by splashing rain, rainy storm, or irrigation from one plant to another plant (Baysal-Gurel and Liyanapathiranage 2017; Bika et al. 2021; Castroagudín et al. 2020; Douglas 2011; Henricot 2006; Kodati et al. 2022; LaMondia et al. 2021). The pathogen transmission via water could be minimized if a barrier of nonhost plant is used between each block of boxwood plants, which increases the diversity of plant species that will have a negative impact on the pathogen load. This lessens the rate of disease spread in the field and the disease does not spread as easily or quickly if the boxwood blocks were located next to each other without a barrier (Baysal-Gurel 2023; Hantsch et al. 2013; Mitchell et al. 2002). It is important to note that eradication measures are recommended when the boxwood blight is detected (Bush et al. 2016; Dart et al. 2014). Boxwood growers who do not use small blocks to grow boxwood are at higher risk of economic losses due to boxwood blight if *Cps* is accidentally introduced compared with growers who use blocking approach or use a single large block (production area). If smaller blocks are used in production and disease is detected in one block, only the plants from that block must be eradicated, which lessens the economic losses associated with boxwood blight.

Also, from these respondents, 42% followed a rotation plan after boxwood production, and 58% did not follow a rotation plan. When planting consecutive crops during a crop rotation program, 95% always completely cleaned out after each crop whereas 11% interplanted (planted another crop after boxwood) in the rotation program. A total of 63% of growers removed plant debris located under the plant rows immediately after each pruning, and 16% used other methods and 21% never removed any debris from the nursery. This indicated that panel members were aware of the potential of plant debris or pruned plant materials to be a source of new infections in healthy crops and aid in increased disease pressure. Sanitation is crucial in boxwood blight management as it helps to remove the *Cps* inoculum which could be surviving in the fallen plant debris (Palmer and Shishkoff 2014).

Unsanitized cutting tools could also spread *Cps* from one plant to another or, more specifically, cuttings prepared using unsanitized tools could carry the pathogen (Bika et al. 2021). When taking cuttings for propagation or pruning boxwood plants, 47% used a new or sanitized cutting tool after each block whereas 37% sanitized or used a new tool after each row, 5% used at each cut, 5% used at each plant, and 6% did not sanitize cutting tools. Forty-two percent of the growers treated boxwood cuttings with a sanitizing agent to eliminate plant pathogens and 58% did not use sanitizing agents. Additionally, 26% of members sanitized clothing, equipment, and vehicles between boxwood blocks, whereas 74% did not sanitize. The risk of spread of boxwood blight between fields of production within a production business is higher as the transmission of the pathogen could occur via human and animal movement and unsanitized cutting tools (Bika et al. 2021; Daughtrey 2019; Gehesquière 2014). The majority of the panel members did not sanitize clothing, equipment, and vehicles between blocks, which could be due to various reasons such as lack of awareness among the growers about the overall steps in sanitation that include cleaning the production area, and then using disinfecting agents to kill the plant pathogens (Hansen 2020), cost, and time associated with the sanitation (The HC Companies, Inc. 2023).

Diagnosis is a crucial first step in plant disease management (Castroagudín et al. 2020; Fry 2012). A majority of the panel members were involved in pathogen testing to reduce the further spread of the disease. Twenty-six percent of growers tested boxwood cuttings/plants within their company for the presence of plant pathogens, 58% sent them to a laboratory for testing, and only 26% did not test. Pathogen testing or diagnosis could be helpful in accurate diagnosis, early detection, monitoring the levels of disease or pathogen load, and applying necessary curative and quarantine measures that ultimately help in integrated plant disease management to minimize crop loss (Castroagudín et al. 2020; Malapi-Wight et al. 2016).

Plant health. Phytophthora root rot, Volutella blight, boxwood blight, Fusarium root rot, and Pythium root rot were rated as the most problematic diseases faced by the panel members. Boxwood dieback, Macrophoma leaf spot, and nematodes were the least problematic in current boxwood production (Table 1). *Phytophthora* species are one of the most problematic and widely studied phytopathogens in nursery production which justifies the growers' selection of *Phytophthora* as one of the current most problematic diseases in their production system (Mihajlovic et al. 2017; Parke et al. 2019).

Boxwood blight and Phytophthora root rot were rated as moderate to high threats to future boxwood production whereas Volutella blight, Pythium, Fusarium, Macrophoma, boxwood dieback, and other diseases were rated to be a low-to-moderate threat to boxwood production in the future (Table 2). The rapid spread of boxwood blight within the US states justifies the grower's perception of boxwood blight being the worst threat they will encounter in the future (Daughtrey 2019; Ivors et al. 2012). In addition, *Phytophthora* is a soilborne pathogen often associated with water and is hard to manage, which justifies panel members' anticipation of this being one of the problematic pathogens in the future (Parke et al. 2019; Redekar et al. 2019).

As listed in Table 3, a list of 17 items that could serve as sources of plant pathogens during boxwood production were assessed to better understand grower perceptions using the 5-point Likert scale. Twelve of 17 items had an average perception rating >3.5, with the highest rating for "boxwood transplants" (4.9 ± 0.2) compared with other sources such as cutting tools, nursery equipment, nursery bench, floor and sidewall surfaces, plant debris and culled plants, media and soil, trays, pots or containers, irrigation water, work clothing and shoes, visitors and nonemployees, worker hygiene, and other crops. The sources such as irrigation water, incoming plants, pots, potting media, and production field are already established critical control points in nursery crop production and have the potential to be the critical control points to decrease the spread of boxwood blight in nurseries (Parke and Grünwald 2012). Five lower ranked attributes

Table 1. Disease rating during current boxwood (*Buxus* sp.) production with 0 = no problem at all, 1 = least problematic to 10 = most problematic.

Disease	N	Mean	*SD*[i]
Phytophthora	17	3.2	2.6
Volutella blight	15	2.3	1.9
Boxwood blight	9	2.2	3.4
Fusarium	7	2.0	2.9
Pythium	10	2.0	1.9
Boxwood dieback/Anthracnose	9	1.8	2.5
Macrophoma	6	1.3	0.8
Nematodes	3	0.7	1.1

[i] Standard deviation of the disease rate.

Table 2. Extent of the diseases that pose a threat to boxwood (*Buxus* sp.) plant health in future production with 1 = no threat, 2 = low threat, 3 = moderate threat, 4 = high threat, and 5 = extreme threat.

Disease	N	Mean	*SD*[i]
Boxwood blight	19	3.3	1.4
Phytophthora	19	3.2	1.4
Other	19	2.6	2.4
Volutella blight	19	2.6	1.0
Pythium	19	2.5	1.8
Fusarium	19	2.5	1.9
Macrophoma	19	2.4	1.8
Boxwood dieback/Anthracnose	19	2.3	1.4

[i] Standard deviation of the extent of diseases.

of sources (rating below than 3.5) were animals (pets, rodents, and livestock), composted manure, pesticide applications, insects and bumblebees, and weeds. Interestingly, worker hygiene and animals are important factors in boxwood blight spread in production (Daughtrey 2019; Gehesquière 2014), whereas infected boxwood used in composted manure could be a source of new infections in healthy plants (Dart et al. 2014; Harvey et al. 2019; Lamondia et al. 2023; May 2023).

Of the 31 boxwood production practices evaluated for their ability to limit/prevent plant disease introduction and spread, all had an average perception rating ≥3.5, indicating that these perceptions were important in the boxwood blight management practices (Table 4). The highest perception rating of 5.0 was recorded for cultural control methods, isolation and quarantine of incoming plants, inspection of incoming plant material, scouting for diseases, and removing infected and damaged plants. Although the panel members perceived that these practices could limit the pathogens in production, not all (100%) of them had fully adopted these practices as listed in Table 4, which could be due to a number of factors impacting adoption such as availability, accessibility, and cost-effectiveness (Balehegn et al. 2020; Senyolo et al. 2018). Majority of the panel members (≥50%) had adopted elimination, exclusion, and sanitation practices, promotion of worker hygiene, water management, and chemicals to manage diseases (Table 4). Some of the panel members (≥40% to 50%) had adopted provision of handwashing stations, limitation of vehicles at entry in production areas, using clean water all the time, and small-sized blocks for production (Table 4). The least adopted practices (<40%) were provision of crop-free period; provision of sanitary facilities; sanitization of carts, equipment, containers, and other items; provision of gloves/coats to the workers; provision of tire baths and foot bath at entry; treating water for plant pathogens; using certified cuttings; and use of biopesticides (Table 4).

The panel members provided the highest ratings to the practice they were already conducting in their production system to be able to limit or prevent the plant disease. They were adopting the practices that in their opinion are helpful in preventing/limiting disease. The cultural control methods such as sanitation of cutting tools, containers, nursery equipment, and surfaces, along with chemical fungicide applications, biopesticides, and planting of resistant hosts are recommended for prevention of spread of boxwood blight (Bika et al. 2021; LaMondia et al. 2021; Palmer and Shishkoff 2014). Inspection, isolation, and quarantine of incoming plants, using certified pathogen-free cuttings are crucial for lowering the spread of boxwood blight because the infected plant material is the main mode of long-distance movement of boxwood blight. An example of this was the speculation of first introduction of boxwood blight to North America from infected plant material (Bartíková et al. 2020; Kong and Hong 2019; LaMondia 2015; LaMondia and Maurer 2020; Palmer and Shishkoff 2014). Sending samples for disease diagnosis in laboratory as early as possible is important to prevent further spread of the disease and recommended boxwood blight management measure (Castroagudín et al. 2020). Water in the production system contaminated with plant pathogens plays a significant role in disease outbreaks in the nurseries (Ristvey et al. 2019) and water mediated short-distance transfer of *Cps* has been verified by previous studies (Dart et al. 2014; LaMondia and Maurer 2020). *Cps* sporulates in the presence of moisture and the conidia are spread to neighboring plants by water splash, hence removing plant debris from production area and providing a crop-free period in the nursery are important to limit the further spread of *Cps* in production nurseries (LaMondia et al. 2021; LaMondia and Maurer 2020). Using clean water all the times, avoiding standing water in the production area, avoiding runoff water from holding areas, culling diseased plants from production areas, using smaller-sized blocks, monitoring/testing irrigation water for pathogens, and treating irrigation water for pathogens are important to prevent/limit the entry or spread of the pathogen. The stickiness of the conidia of *Cps* favors human/animal/equipment-mediated pathogen spread, thus excluding animals from the production area and providing worker gloves and clothes, vehicle tire baths at entry, handwashing stations, employee sanitation training, and sanitation facilities are important (Baysal-Gurel and Liyanapathiranage 2017; Bika et al. 2021; Dart et al. 2014; LaMondia 2015).

Members of the expert panel were familiar with processes and programs in boxwood production. Their mean ratings of familiarity of these practices were higher than 4.0 (on a 5-point scale), a value indicating that they were either familiar or very familiar (Table 5). Scouting and employee training was the highest practiced process (94%) among the panel members. Pesticide applicator training and certification were practiced by 89% of the panel members, whereas standard operating procedures for sanitations, best management practices and boxwood blight cleanliness program were practiced by 83% of the panel members. Tracing products or processes from initial to final stage was practiced by 67% of the panel members. Finally, 28% of the panel members practiced irrigation testing for plant pathogens (Table 5). As expected, the growers were extremely familiar with the processes/programs, which were already practiced by the majority of the respondents. Logically, processes/programs not familiar to the growers were not practiced. According to the methods and frequency of disease management techniques used in boxwood production in the past 12 months, 56% of growers had performed scouting and inspection activities 16 or more times, and 53% of growers had used sanitizers 16 or more times. Thirty-three percent used chemical control 16 or more times, and 55% used biological control one to three times.

Good record-keeping for tracing plants from initial to final stages of production is a popular practice in production nurseries (Lebude et al. 2012), so the growers were very familiar with it. Some important and common components of integrated plant disease management are scheduling applications of pesticides and scouting; hence the growers were familiar with pesticide application training, certification, scouting, and employee training (Khachatryan et al. 2020; Lebude et al. 2012). With numerous publications of extension articles related to boxwood blight management, the growers were very familiar with best management practices (BMPs) and boxwood blight cleanliness programs

Table 3. Perceptions of the panel composed of nursery growers regarding the knowledge of the items used in boxwood (*Buxus* sp.) production which could be sources of plant pathogens. The mean rating is based on a Likert scale from 1 to 5 (disagree to agree).

Source of plant pathogens	N	Mean	*SD*[i]
Boxwood transplants	18	4.9	0.2
Cutting tools	18	4.7	0.6
Nursery equipment	18	4.7	0.6
Nursery bench, floor, and sidewall surfaces	18	4.7	0.5
Plant debris or culled plants	18	4.6	0.7
Media or soil	18	4.6	0.5
Trays, pots, or containers	18	4.3	1.0
Irrigation water	18	4.3	1.1
Worker clothing and shoes	18	4.3	1.0
Visitors and nonemployees	18	4.2	1.2
Worker hygiene	18	3.8	1.3
Other crops	18	3.7	0.9
Animals (pets, rodents, livestock)	18	3.4	1.5
Composted manure	18	2.8	1.3
Pesticide applications	18	2.7	1.5
Insects and bumblebees	18	2.6	1.1
Weeds	18	2.4	1.1

[i] Standard deviation of the perception of source of plant pathogens.

Table 4. Perceptions of the panel composed of nursery growers regarding the practices that can limit or prevent plant disease during boxwood (*Buxus* sp.) production. The mean rating is based on a Likert scale from 1 to 5 (disagree to agree).

Practices	N	Mean	*SD*[i]	Growers currently following these practices (%)
Cultural control methods	15	5.0	0.0	72
Isolate or quarantine incoming plants	15	5.0	0.0	67
Inspect incoming plant material	15	5.0	0.0	72
Scout for diseases	15	5.0	0.0	78
Remove infected or damaged plants	14	5.0	0.0	83
Remove plant debris and dead plants	15	4.9	0.3	72
Eliminate weeds	16	4.2	1.4	67
Provide a crop-free period in nursery	18	4.2	1.1	17
Sanitize cutting tools	15	4.9	0.3	68
Sanitize surfaces	15	4.8	0.4	50
Sanitize carts and nursery equipment	17	4.8	0.4	33
Provide sanitary facilities	17	4.7	1.0	39
Sanitize containers	16	4.5	1.1	33
Provide employee sanitation training	17	4.5	1.3	56
Provide worker gloves and coat	17	3.6	1.5	17
Provide handwashing stations	18	4.1	1.3	44
Provide vehicle tire baths at entry	18	4.0	1.4	0
Provide foot baths at entry	18	4.3	1.3	17
Limit vehicle entry into the production areas	15	4.5	1.1	44
Exclude animals from production areas	17	3.5	1.6	22
Use clean water at all times	16	4.8	0.5	44
Avoid standing water in production area	16	4.8	0.5	61
Avoid runoff water from holding areas/cull piles to production areas	16	4.7	0.6	50
Treat irrigation water for pathogens	17	4.3	0.9	22
Monitor/test irrigation water for pathogens	18	4.4	0.9	17
Send samples to a diagnostic laboratory	15	4.9	0.3	67
Implement smaller-sized blocks	15	4.1	1.4	44
Use certified pathogen-free cuttings	16	4.7	0.7	11
Provide employee pesticide application training	15	4.7	0.7	67
Use chemical disease controls	15	4.7	0.6	67
Use biopesticides	18	4.0	0.9	0

[i] Standard deviation of the practice of boxwood production.

because a holistic approach has been recommended to manage boxwood blight (Daughtrey 2019; Lebude et al. 2012; Palmer and Shishkoff 2014). Although growers were familiar with the importance of irrigation water treatment to prevent disease spread, some factors such as lack of readily available treatment technologies or the higher cost of establishment might be a hinderance to adopting them (Hong 2014).

Management and economic impact of boxwood production. Growers mostly propagated cuttings in November, December, and January and transplanted rooted cuttings in March, May, June, and October. They grew boxwood in almost every month of the year and harvested boxwood (digging whole plants for commercial purposes) from February to June and August to November. They sold boxwood from February to November. Table 6 shows the percentage of boxwood loss during the propagation and finished stages during 2009 to 2019. The loss during the propagation stage increased from 3.6% to 3.8% from 2009 to 2019. The loss of boxwood in the finished stage increased from 2.9% to 4.3% from 2009 to 2019.The increase in loss of boxwood during propagation and the production stage from 2009 to 2019 is comparable to the decrease in the percentage loss of sales of broad-leaved evergreen shrubs, which included boxwood, from 2009 to 2019 (Rihn et al. 2021). These boxwood losses could be accounted for by several factors, such as occurrence of plant diseases caused by pathogens discussed earlier, insects and pests, and changes in soil conditions

Table 5. Perceptions of the nursery grower panel regarding the extent they are familiar with the processes and programs in boxwood (*Buxus* sp.) production. The mean rating is based on a Likert scale from 1 to 5 (not familiar to very familiar).

Processes/Programs	N	Mean	*SD*[i]	Growers currently following these practices (%)
Pesticide applicator training and certification	15	4.9	0.3	89
Standard operating procedures for sanitation	15	4.9	0.3	83
Scouting and employee training	14	4.9	0.4	94
Traceability, from final product to initial	15	4.7	0.5	68
Best management practices	14	4.6	0.5	83
Boxwood blight cleanliness program	14	4.6	1.1	83
Irrigation testing for plant pathogens	18	4.2	1.0	28

[i] Standard deviation of the process or program of boxwood production.

Table 6. Percentage of boxwood (*Buxus* sp.) production loss (e.g., shrink, scrap, dump) during the propagation stage and the finished stage.

	Boxwood production loss (%)		
Stage	2009	2014	2019
Propagation	3.6	3.8	3.8
Finished	2.9	3.5	4.3

(Dhakal et al. 2022; Wayne 1979). The increase in percentage of boxwood production losses is parallel to the trend of decrease in percentage of total US boxwood sales from 2009 to 2019 studied by Hall et al. (2021), where these losses were analyzed to evaluate the impact on US annual sales of boxwood after the introduction of boxwood blight in 2011 as described by Ivors et al. (2012).

Approximate annual yield (of all sized plants) was highest for propagation materials of boxwood of 84,455 followed by container production of 44,387 and field production of 4,408 plants. The approximate wholesale value was highest for container production of $1,853,077 followed by field production of $649,428 and nursery propagation of $284,231. Approximate retail value was highest for field production of $5,587,692 followed by container production of $2,879,231 and nursery propagation of $100,600. Sixty percent of growers sold boxwood using re-wholesalers/distributors, 56% sold using retail garden centers, 56% sold through landscape distributors, 16% through home centers, and 16% through direct sales to consumers.

In 2021, 39% of respondents earned annual income between $5.1 to $15 million, 17% between $15.1 to $25 million, 11% between $25.1 million to $50 million, 11% between $1 million to $5 million, and 11% less than a million by selling nursery products (Fig. 1). In addition, 6% of the respondents reported annual income between $50.1 million to $100 million, and only 6% reported more than $100 million (Fig. 1). A US green industry survey in 2018 by Khachatryan et al. (2020) reported that 82% of the respondents in the survey had less than $999,000 annual sales. They also reported that 14% had sales of $1 million to $4.9 million, 2% had between $5 million to $9.9 million, 1.6% had sales of $10 million to $50 million, and 0.4% had sales of $50 million or more. When comparing the percentages of income categories of our results with 2018 report, annual income was spread throughout more of the categories. It is important to note that the study by Khachatryan et al. (2020) comprised a large sample compared to our study, although the selected members in this study represent most of the states.

Panel members sold 39% of their boxwood products to retail garden centers and 38% of their boxwood products to mass merchandisers such as Walmart, Menards, Aldi, and other retailers on average. Moreover, 37% of the boxwood products of the panel members were sold to landscape re-wholesalers (distributors). Some growers sold 50% of their total annual boxwood product using

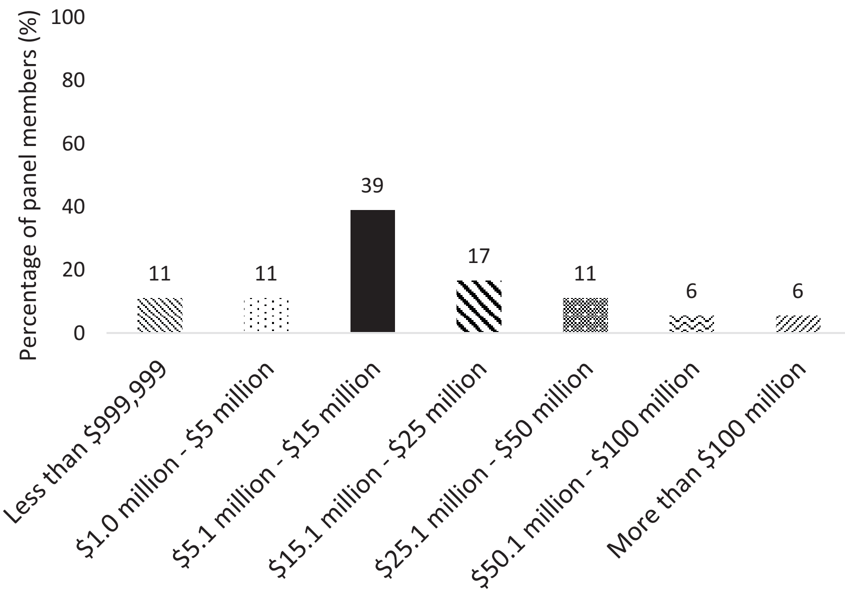

Fig. 1. Nursery's approximate total gross sales in 2021 ($US).

market channels other than those listed in the questions, such as their own retail centers or landscape department and wholesale growers (Table 7). In the study by Khachatryan et al. (2020), the most popular outlets for selling of nursery crops were re-wholesalers, landscapes firms and mass merchandisers which is similar to outlets of boxwood nursery products observed in this study.

Most of the growers agreed that they currently receive information about boxwood diseases via university extension services (100%), followed by the Internet (89%), and commodity or industry groups (78%) (Fig. 2). Additionally, 67% of growers obtained information from government entities, other producers and prints from industry, or mass media. Moreover, 61% obtained information from chemical/industry suppliers or distributors and 56% obtained information from printed references and books as well (Fig. 2). In this question, many growers indicated that they received information about boxwood via at least two or more options. The results of this study are similar to previous surveys regarding the most popular sources of information among the growers related to nursery production. Seminars and webinars from the university, university extension agents, and pest news on the Internet published by university extension system were the most followed source of information related to ornamental nursery productions in the United States because the growers exclusively used these channels to obtain information (Lebude et al. 2012). Among the different panel members, 94% of total respondents would like to get boxwood disease management information through direct e-mail and 78% via presentation or webinars (Fig. 3). In addition, 61% of the respondents preferred instructions via Internet information sites and 56% from workshops and training sessions (Fig. 3).

Among the panel members' nurseries, family members, domestic laborers, and migrant workers worked full time, and only domestic laborers and migrant workers worked part time in the boxwood production. On average, about three family members, 78 domestic workers, and 42 migrant workers worked full time in the nurseries. Also, six domestic laborers and nine migrant workers were involved in working part time in nurseries (Table 8). The number of family members and domestic and migrant workers who were working full time and part time were more dispersed with the varying size of the industry. According to the US green industry survey conducted in 2018, national average number of employees per firm was 20.8, including 11 full-time/permanent employees, 7.5 temporary/part-time/seasonal employees, and 1.9 foreign national employees who were working under the H2A visa program in the US ornamental plant industry (Khachatryan et al. 2020). All the panel members reported that some of their employees were speaking both English and Spanish in nurseries. In addition to this, some other languages were also spoken. The average percentage of workers who spoke English was ∼34% (33.8 ± 17.7), Spanish was ∼66% (66.0 ± 17.6), and 5% of workers spoke other languages.

Conclusions

On the basis of the responses to the questions related to boxwood industry, it is clear that the grower respondents were knowledgeable and experienced in boxwood production, hence the assumption of the Delphi method that the panel members are knowledgeable about the subject was met (Johnson and Schumacher 1989). Participants in this study represented most of the boxwood-producing nurseries throughout the United States. Boxwood represented a notable amount and value of the total nursery sales among US nurseries, and Asiatic boxwood was the most grown category followed by other boxwood hybrids. The majority of the boxwood nurseries were involved in propagation and container production compared with field production.

The growers currently exercise several best management practices that have the potential to directly influence the establishment and spread of boxwood blight in the nurseries. Such practices included planting of moderate to highly resistant categories such as other hybrids and Asiatic boxwood, not planting alternate hosts (pachysandra and sweet box) of the pathogen (*Cps*), routine cleaning and sanitation, crop rotation, sanitization of cutting tools, and sending suspected plant samples for disease diagnosis. However, they also exercised some practices that could accelerate boxwood blight spread, such as preparing propagation material and producing boxwood crops in the same area or in close proximity; not properly sanitizing the equipment, worker clothes, boots, and gloves; and overlooking worker hygiene. Growers need to be aware of the importance of distance or use of smaller blocks, hygiene (using clean equipment, gloves, and boots) while working in the farm to prevent the spread of disease in production system as has already been demonstrated by quantitative experimental studies (Bika et al. 2021; Dart et al. 2014; LaMondia 2015; Parke and Grünwald 2012).

Boxwood blight is perceived to be a present and future leading biotic constraint to boxwood production, and infected boxwood transplants are rated as the number one source of the pathogen before cutting tools and other sources. However, there seems to be a gap in the knowledge among growers about the importance of workers' hygiene, the presence of animals, and compost in spreading boxwood blight, although studies have been published on their potential to spread this disease (Bika 2021; Dart et al. 2014; Daughtrey 2019; Lamondia et al. 2023; May 2023). The highest rated practices to limit the pathogen activity in nurseries (which were already being done) included cultural controls, inspection, and quarantine of incoming plants, scouting for diseases, and removing of infected/damaged plants and others. Panel members were extremely familiar

Table 7. The mean percentage (%) of total annual product by volume sold by growers in different market channels.

Market channel	Mean	*SD*[i]
Other	50.0	28.3
Retail garden centers	38.5	24.2
Mass merchandiser (e.g., Walmart, Menards, Aldi, etc.)	38.3	53.9
Re-wholesaler/distributor	36.7	18.2
Landscape contractor	27.9	23.6
Home centers (home improvement, building supply, hardware, etc.)	25.3	35.2
Direct sales to consumers	2.33	1.53

[i] Standard deviation of the market channel.

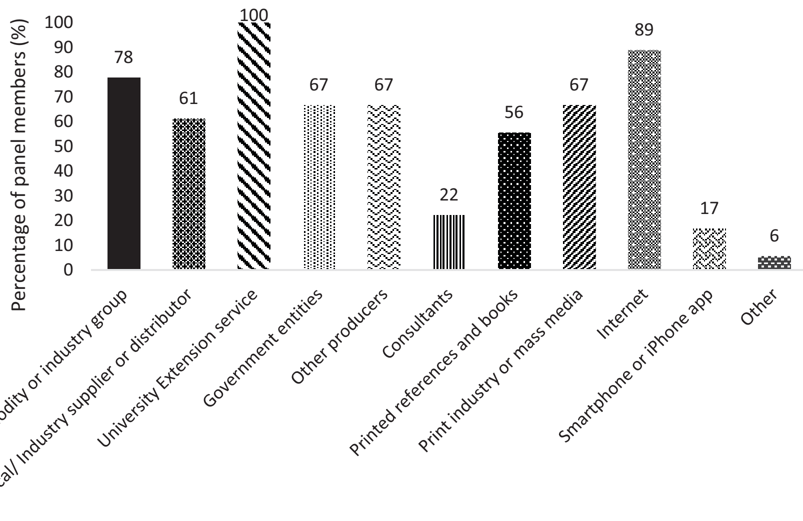

Fig. 2. Venues where growers receive information on boxwood disease management issues.

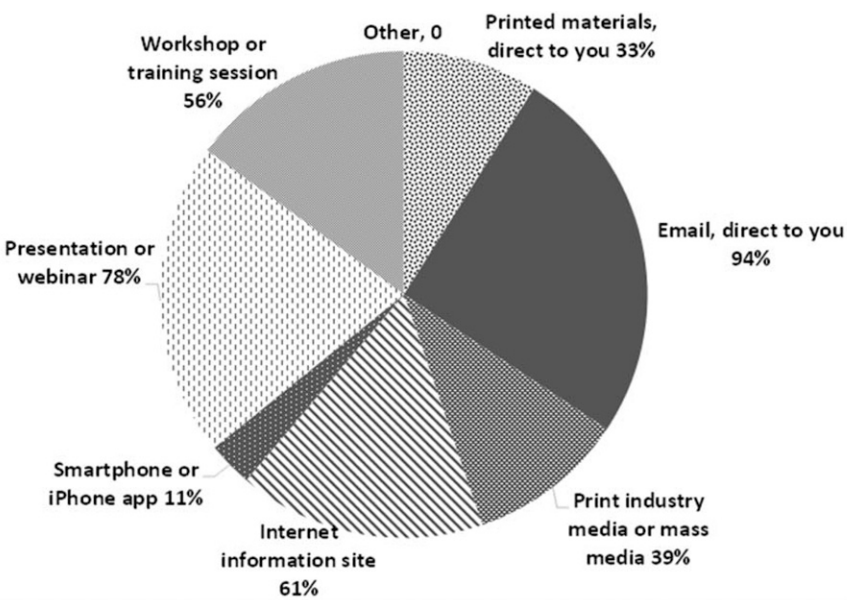

Fig. 3. Percentage of growers most like to receive boxwood disease management information.

Table 8. Employment status in nurseries in 2021.

	Full time		Part time	
Employment category	Mean	*SD*[i]	Mean	*SD*[i]
Family members	3.2	3.3	0.4	0.7
Domestic laborers	77.7	95.6	6.2	7.7
Migrant workers	42.3	32.2	9.3	13.5

[i] Standard deviation of the employment category.

with scouting and employee training, BMPs, and the boxwood blight cleanliness program, which is important for the success of future dissemination of research findings to alleviate boxwood blight. They sold their boxwood primarily at retail garden centers, mass merchandisers, and re-wholesalers/distributors. University extension services were the main media/channel from which the panel members received information about boxwood, followed by the Internet and industry groups. The majority of the panel members preferred to receive information about boxwood disease via direct e-mail, presentations, and seminars.

The perceptions and experiences of growers about certain practices, resources, and methods that could influence (or alleviate) the spread of boxwood blight in the US nurseries have been identified in this study. These findings can be used to aid in the establishment of critical control points of boxwood blight in production nurseries and could be confirmed by further sampling to minimize boxwood blight spread in the future.

References Cited

Ab Latif R, Mohamed R, Dahlan A, Mat Nor MZ. 2016. Using Delphi technique: Making sense of consensus in concept mapping structure and multiple choice questions (MCQ). Educ. Med. J. 8(3):89–98. https://doi.org/10.5959/eimj.v8i3.421.

Balehegn M, Duncan A, Tolera A, Ayantunde AA, Issa S, Karimou M, Zampaligré N, André K, Gnanda I, Varijakshapanicker P, Kebreab E, Dubeux J, Boote K, Minta M, Feyissa F, Adesogan AT. 2020. Improving adoption of technologies and interventions for increasing supply of quality livestock feed in low- and middle-income countries. Glob Food Secur. 26:100372. https://doi.org/10.1016/j.gfs.2020.100372.

Bartíková M, Holková L, Šafránková I. 2020. Occurrence of boxwood blight (*Calonectria pseudonaviculata* and *C. henricotiae*) in historical gardens in the Czech Republic. Eur J Plant Pathol. 158:135–142. https://doi.org/10.1007/s10658-020-02061-2.

Baysal-Gurel F. 2023. Boxwood blight. https://www.dixon.org/media-library/PDF-Files/Fulya-Basal-Gurel.pdf. [accessed 4 Apr 2023].

Baysal-Gurel F, Liyanapathiranage P. 2017. Boxwood blight https://digitalscholarship.tnstate.edu/cgi/viewcontent.cgi?article=1107&context=extension. [accessed 4 Apr 2023].

Bika R. 2021. Integration of sanitation practices and fungicide applications for assuring better postharvest shelf life of cut flowers and greenery. Tennessee State University, Nashville, TN, USA.

Bika R, Copes W, Baysal-Gurel F. 2021. Comparative performance of sanitizers in managing plant-to-plant transfer and postharvest infection of *Calonectria pseudonaviculata* and *Pseudonectria foliicola* on boxwood. Plant Dis. 105: 2809–2821. https://doi.org/10.1094/PDIS-03-21-0481-RE.

Boxwood Blight Insight Group. 2023. Horticultural Research Institute Boxwood Blight Insight Group. https://www.boxwoodhealth.org. [accessed 4 Apr 2023].

Bush EA, Hansen MA, Dart N, Hong C, Bordas A, Linkins TM. 2016. Best management practices for boxwood blight in the Virginia home landscape. https://plant-pest-advisory.rutgers.edu/wp-content/uploads/2015/06/Best-Management-Practices-for-Boxwood-Blight-in-the-Virginia-Home-Landscape.pdf. [accessed 4 Apr 2023].

Castroagudín VL, Yang X, Daughtrey ML, Luster DG, Pscheidt JW, Weiland JE, Crouch JA. 2020. Boxwood blight disease: A diagnostic guide. Plant Health Prog. 21:291–300. https://doi.org/10.1094/PHP-06-20-0053-DG.

Dart N, Hong C, Bordas A, Bush E, Hansen MA, Likins TM. 2014. Best management practices for boxwood blight in Virginia production nurseries with boxwood blight. https://www.pubs.ext.vt.edu/content/dam/pubs_ext_vt_edu/PPWS/PPWS-29/PPWS-29-pdf.pdf. [accessed 4 Apr 2023].

Daughtrey ML. 2019. Boxwood blight: Threat to ornamentals. Annu Rev Phytopathol. 57:189–209. https://doi.org/10.1146/annurev-phyto-082718-100156.

Dhakal K, Bika R, Ghimire B, Parajuli M, Neupane S, Neupane K, Addesso KM, Baysal-Gurel F. 2022. Arthropod and disease management in boxwood production. J Integr Pest Manag. 13:18. https://doi.org/10.1093/jipm/pmac013.

Dillman DA. 2011. Mail and internet surveys: The tailored design method—2007 update with new Internet, visual, and mixed-mode guide. John Wiley & Sons, Hoboken, NJ, USA.

Douglas SM. 2011. Boxwood blight—A new disease for Connecticut and the U.S. http://www.vgsltd.ca/files/boxwood%20blight.pdf. [accessed 4 Apr 2023].

Filho AB, Inoue-Nagata AK, Bassanezi RB, Belasque J, Amorim L, Macedo MA, Barbosa JC, Willocquet L, Savary S. 2016. The importance of primary inoculum and area-wide disease management to crop health and food security. Food Secur. 8:221–238. https://doi.org/10.1007/s12571-015-0544-8.

Fry WE. 2012. Diagnosis, p 13. In: Fry WE. Principles of plant disease management. Academic Press, Amsterdam, the Netherlands.

Ganci M, Benson DM, Ivors KL. 2013. Susceptibility of commercial boxwood taxa to *Cylindrocladium buxicola* (C). Proceedings of the International Plant Propagators Society. 2012: 369–370.

Ganci ML. 2014. Investigation of host resistance in buxus speceis to the fungal plant pathogen *Calonectria pseudonaviculata pseudonaviculata* (= *Cylindrocladium buxicola*), the causal agent of boxwood blight and determination of overwinter pathogen survival. (PhD Diss). North Carolina State University, Raleigh, NC, USA.

Gehesquière B. 2014. *Cylindrocladium buxicola* nom. cons. prop. (syn. *Calonectria pseudonaviculata*) on Buxus: Molecular characterization, epidemiology, host resistance and fungicide control (PhD Diss), Ghent University, Ghent, Belgium.

Hall CR, Hodges AW, Palma MA. 2011. Sales, trade flows and marketing practices within the U.S. nursery industry. J Environ Hortic. 29:14–24. https://doi.org/10.24266/0738-2898-29.1.14.

Hall CR, Hong C, Gouker FE, Daughtrey M. 2021. Analyzing the structural shifts in U.S. boxwood production due to boxwood blight. J Environ Hortic. 39:91–99. https://doi.org/10.24266/0738-2898-39.3.91.

Hansen J. 2020. Sanitation success. Greenhouse Management 2020. https://greenhousemag.com/article/cover-story-sanitation-success. [accessed 12 Apr 2023].

Hantsch L, Braun U, Scherer-Lorenzen M, Bruelheide H. 2013. Species richness and species identity effects on occurrence of foliar fungal pathogens in a tree diversity experiment. Ecosphere. 4. https://doi.org/10.1890/ES13-00103.1.

Harvey RJ, Davis DD, Shishkoff N, Pecchia J. 2019. Survival of lab grown *Calonectria pseudonaviculata* microsclerotia during small-scale composting. Compost Sci Util. 27:24–34. https://doi.org/10.1080/1065657X.2018.1536865.

Henricot B. 2006. Box blight rampages onwards: The latest news on the spread and control of a devastating disease. Plantsman London 5(3): 153–157.

Hodges AW, Khachatryan H, Palma MA, Hall CR. 2015. Production and marketing practices and trade flows in the United States green industry in 2013. J Environ Hortic. 33:125–136. https://doi.org/10.24266/0738-2898-33.3.125.

Hong C. 2014. Economic threshold of plant pathogens in irrigation water, p 175–183. In: C. Hong C, Moorman G, Wohanka WY, Büttner C (eds). Biology detection and management of plant pathogens in irrigation water. American Phytopathological Society, St. Paul, MN, USA.

Ivors KL, Lacey LW, Milks DC, Douglas SM, Inman MK, Marra RE, LaMondia JA. 2012. First report of boxwood blight caused by *Cylindrocladium pseudonaviculatum* in the United States. Plant Dis. 96:1070. https://doi.org/10.1094/PDIS-03-12-0247-PDN.

Johnson DM, Schumacher LG. 1989. Agricultural mechanics specialsists identfication and evaluation of agricultural mechanics laboratory management competencies: A modified delphi approach. J Agric Educ. 30:23–28.

Khachatryan H, Hodges AW, Hall C, Palma M. 2020. Production and marketing practices and trade flows in the United States green industry, 2018. South. Coop. Ser. Bull. 421:2020–2021.

Kodati S, Cowles RS, LaMondia JA. 2022. Survival of conidia of the boxwood blight pathogen Calonectria pseudonaviculata under different relative humidity conditions. Plant Heal Prog. 23(3):317–320. https://doi.org/10.1094/PHP-12-21-0142-RS 23:317–320.

Kong P, Likins TM, Hong CX. 2017. First report of blight of *Sarcococca hookeriana* var. *humilis* by *Calonectria pseudonaviculata* in Virginia. Plant Dis. 101:247. https://doi.org/10.1094/PDIS-05-16-0654-PDN.

Kong P, Hong C. 2019. Host responses and impact on the boxwood blight pathogen, *Calonectria pseudonaviculata.* Planta. 249:831–838. https://doi.org/10.1007/s00425-018-3041-4.

Kramer M, Guo Y, Pooler M. 2020. Ranking resistance of *Buxus* cultivars to boxwood blight—An integrated analysis. J Environ Hortic. 38:50–55. https://doi.org/10.24266/0738-2898-38.2.50.

Lamm K, Powell A, Lombardini L. 2021. Identifying critical issues in the horticulture industry: A Delphi analysis during the COVID-19 pandemic. Horticulturae. 7:416. https://doi.org/10.3390/horticulturae7110416.

LaMondia JA. 2015. Management of *Calonectria pseudonaviculata* in boxwood with fungicides and less susceptible host species and varieties. Plant Dis. 99:363–369. https://doi.org/10.1094/PDIS-02-14-0217-RE.

LaMondia JA, Douglas SM. 2015. *Calonectria pseudonaviculata* can cause leaf spot and stem blight of *Pachysandra terminalis* and *Pachysandra procumbens.* Acta Hortic. 1085:205–206. https://doi.org/10.17660/ActaHortic.2015.1085.34.

LaMondia JA, Maurer K. 2020. *Calonectria pseudonaviculata* conidia dispersal and implications for boxwood blight management. Plant Health Prog. 21:232–237. https://doi.org/10.1094/PHP-04-20-0024-RS.

LaMondia JA, Allan-Perkins S, Kodati S. 2021. Factors affecting boxwood blight spread under landscape conditions. J Environ Hortic. 39:100–107. https://doi.org/10.1094/PHP-04-20-0024-RS.

Lamondia J, Kodati S, Li Y, Douglas S. 2023. Best management practices for boxwood blight for Connecticut-production and retail nurseries-version 4.0. https://portal.ct.gov/-/media/CAES/DOCUMENTS/Publications/Fact_Sheets/Valley_Laboratory/CT-BMPs-for-Boxwood-Blight-Nurseries.pdf. [accessed 4 Apr 2023].

LeBlanc N, Salgado-Salazar C, Crouch JA. 2018. Boxwood blight: An ongoing threat to ornamental and native boxwood. Appl Microbiol Biotechnol. 102:4371–4380. https://doi.org/10.1007/s00253-018-8936-2.

Lebude AV, White SA, Fulcher AF, Frank S, Klingeman WE, Chong JH, Chappell MR, Windham A, Braman K, Hale F, Dunwell W, Williams-Woodward J, Ivors K, Adkins C, Neal J. 2012. Assessing the integrated pest management practices of southeastern US ornamental nursery operations. Pest Manag Sci. 68:1278–1288. https://doi.org/10.1002/ps.3295.

Likert R. 1932. A technique for the measurement of attitudes. Arch Psychol. 140:5–55.

Linstone HA, Turoff M. 1975. The Delphi method, p 3–12. In: Archives of Hellenic medicine. Addison-Wesley, Reading, MA, USA.

Linstone HA, Turoff M. 2002. The Delphi method: Techniques and applications: New Jersey institute of technology, Newark, NJ, USA. http//is.njit.edu/pubs/delphibook/index.html. [accessed 31 Jan 2023].

Malapi-Wight M, Demers JE, Veltri D, Marra RE, Crouch JA. 2016. LAMP detection assays for boxwood blight pathogens: A comparative genomics approach. Sci Rep. 6:26140. https://doi.org/10.1038/srep26140.

May S. 2023. Boxwood blight: Emerging threat to Pennsylvania's landscape. https://extension.psu.edu/boxwood-blight-emerging-threat-to-pennsylvanias-landscape. [accessed 4 Apr 2023].

McClellan M. 2019. Saunders Brothers introduces NewGen boxwood. https://www.google.com/search?q=McClellan+M.+2019.+Saunders+Brothers+introduces+NewGen+boxwood.+Nursery+Management%2C+Jan.+2.+https%3A%2F%2Fwww.nurserymag.com%2Farticle%2Fnew-gen-boxwood-announcement-saunders-brothers%2F&rlz=1C1CHBF_enUS996US996&oq=McClellan+M.+2019.+Saunders+Brothers+introduces+NewGen+boxwood.+Nursery+Management%2C+Jan.+2.+https%3A%2F%2Fwww.nurserymag.com%2Farticle%2Fnew-gen-boxwood-announcement-saunders-brothers%2F&aqs=chrome.69i57j69i60.463j0j4&sourceid=chrome&ie=UTF-8. [accessed 4 Apr 2023].

Mihajlovic M, Rekanovic E, Hrustic J, Grahovac M, Tanovic B. 2017. Methods for management of soilborne plant pathogens. Pestic Fitomed. 32:9–24.

Miller SA, Ivey MLL, Baysal-Gurel F, Xu X. 2015. A systems approach to tomato disease management. Acta Hortic. 1069:167–172. https://doi.org/10.17660/ActaHortic.2015.1069.23.

Miller ME, Norris RS, Cubeta MA. 2016. Evaluation of boxwood cultivars for resistance to boxwood blight, 2015. Plant Dis Manag Rep. 10:1037. https://doi.org/10.1094/PDMR10.

Mitchell CE, Tilman D, Groth JV. 2002. Effects of grassland plant species diversity, abundance, and composition on foliar fungal disease. Ecology. 83:1713–1726. https://doi.org/10.1890/0012-9658(2002)083.

Mitroff II, Turoff M. 2002. Philosophical and methodological foundations of Delphi, p 17–34. In: Linstone H, Turoff M (eds). The Delphi method: Techniques and applications. New Jersey Institute of Technology, Newark, NJ, USA.

Omolehin O, Keller J, Gouker FE, Daughtrey ML, Luster DG, Pscheidt JW, Hong C. 2022. Combating an invasive boxwood pathogen—*Calonectria pseudonaviculata*—in the United States by shifting production to less susceptible cultivars. Plant Dis. https://doi.org/10.1094/PDIS-09-22-2124-RE.

Palmer CL, Shishkoff N. 2014. Boxwood blight: A new scourge, a new paradigm for collaborative research. Outlooks Pest Manag. 25:230–236. https://doi.org/10.1564/v25_jun_10.

Parke JL, Grünwald NJ. 2012. A systems approach for management of pests and pathogens of nursery crops. Plant Dis. 96:1236–1244. https://doi.org/10.1094/PDIS-11-11-0986-FE.

Parke JL, Redekar NR, Eberhart JL, Funahashi F. 2019. Hazard analysis for *Phytophthora* species in container nurseries: Three case studies. HortTechnology. 29:745–755. https://doi.org/10.21273/HORTTECH04304-19.

Raudales RE, Irani TA, Hall CR, Fisher PR. 2014. Modified Delphi survey on key attributes for selection of water-treatment technologies for horticulture irrigation. HortTechnology. 24:355–368. https://doi.org/10.21273/HORTTECH.24.3.355.

Redekar NR, Eberhart JL, Parke JL. 2019. Diversity of *Phytophthora, Pythium*, and *Phytopythium* species in recycled irrigation water in a container nursery. Phytobiomes J. 3:31–45. https://doi.org/10.1094/PBIOMES-10-18-0043-R.

Rihn AL, Hall CR, Peterson BJ, Torres AP, Palma MA, Khachatryan H. 2021. Changes in production practices by green industry growers from 2009 to 2019. J Environ Hortic. 39:123–130. https://doi.org/10.24266/0738-2898-39.3.123.

Ristvey AG, Belayneh BE, Lea-Cox JD. 2019. A comparison of irrigation-water containment methods and management strategies between two ornamental production systems to minimize water security threats. Water. 11:2558. https://doi.org/10.3390/w11122558.

Senyolo MP, Long TB, Blok V, Omta O. 2018. How the characteristics of innovations impact their adoption: An exploration of climate-smart agricultural innovations in South Africa. J Clean Prod. 172:3825–3840. https://doi.org/10.1016/j.jclepro.2017.06.019.

Shishkoff N, Daughtrey M, Aker S, Olsen RT. 2015. Evaluating boxwood susceptibility to *Calonectria pseudonaviculata* using cuttings from the national boxwood collection. Plant Health Prog. 16:11–15. https://doi.org/10.1094/PHP-RS-14-0033.

The HC Companies, Inc. 2023. Greenhouse sanitation limits pests and pathogens problems with greenhouse sanitation. https://hc-companies.com/greenhouse-sanitation/. [accessed 12 Apr 2023].

US Department of Agriculture, National Agricultural Statistics Service. 2020. Census of Horticultural Specialties 2019. https://www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys/Census_of_Horticultural_Specialties/2019-US-census-of-hort.pdf. [accessed 4 Apr 2023].

von der Gracht HA. 2012. Consensus measurement in Delphi studies. Review and implications for future quality assurance. Technol Forecast Soc Change. 79:1525–1536. https://doi.org/10.1016/j.techfore.2012.04.013.

Wayne M. 1979. Growth and foliar accumulation of mineral nutrient elements by *Buxus sempervirens* l. as affected by hydroponic nutrient level, soil type, soil pH and source of nitrogen. (PhD Diss). University of Maryland, College Park, MD, USA.

Weeda SM, Dart NL. 2012. Histological evidence that microsclerotia play a significant role in disease cycle of the Boxwood blight pathogen in Southeastern United States and implications for disease mitigation. Plant Heal Prog. 13:45. https://doi.org/10.1094/PHP-2012-0403-01-BR.

Yoder KS, Dunn RA, Saunders JB, Mays TR, Yanny MD, Hong C, Scoggins HL. 2022. Field performance of *Buxus* cultivars and selections against boxwood leafminer and boxwood blight. J Environ Hortic. 40:129–142. https://doi.org/10.24266/2573-5586-40.4.129.