BBG Boxwood Blight Insight Group

Newsletter

Volume 6, Issue 2 (May 2025)
Specialty Crop Research Initiative Project #: 2020-51181-32135

USDA United States Department of Agriculture
National Institute of Food and Agriculture

FEATURED NEWS

CONTENTS

Scouting for boxwood blight in nurseries: Insights from six years in the field by Jerry Weiland, USDA-ARS Horticultural Crops Disease and Pest Management Research Unit, Corvallis, OR

Over the past 6 years, I've scouted nearly 9 million boxwood plants across dozens of nurseries to better understand how boxwood blight develops and spreads. Along the way, I've picked up several strategies that can help you detect this disease early and accurately.

Know your symptoms

During wet weather between 50-80°F, look for typical boxwood blight symptoms: leaf spots (**Fig. 1A**) or leaf blight (**Fig. 1B**), bare branches (**Fig. 1C**), and stem lesions (**Fig. 1D**). However, if the weather has been dry or if you don't irrigate very often, leaf symptoms become harder to find. In those cases, concentrate on searching for bare branches with stem lesions (**Figs. 1C to 1E**) and for any fallen, infected leaves lying on top of the soil (**Fig. 1E**). These will often have old leaf spots on them (**Fig. 1F**) that will sporulate if they get wet.

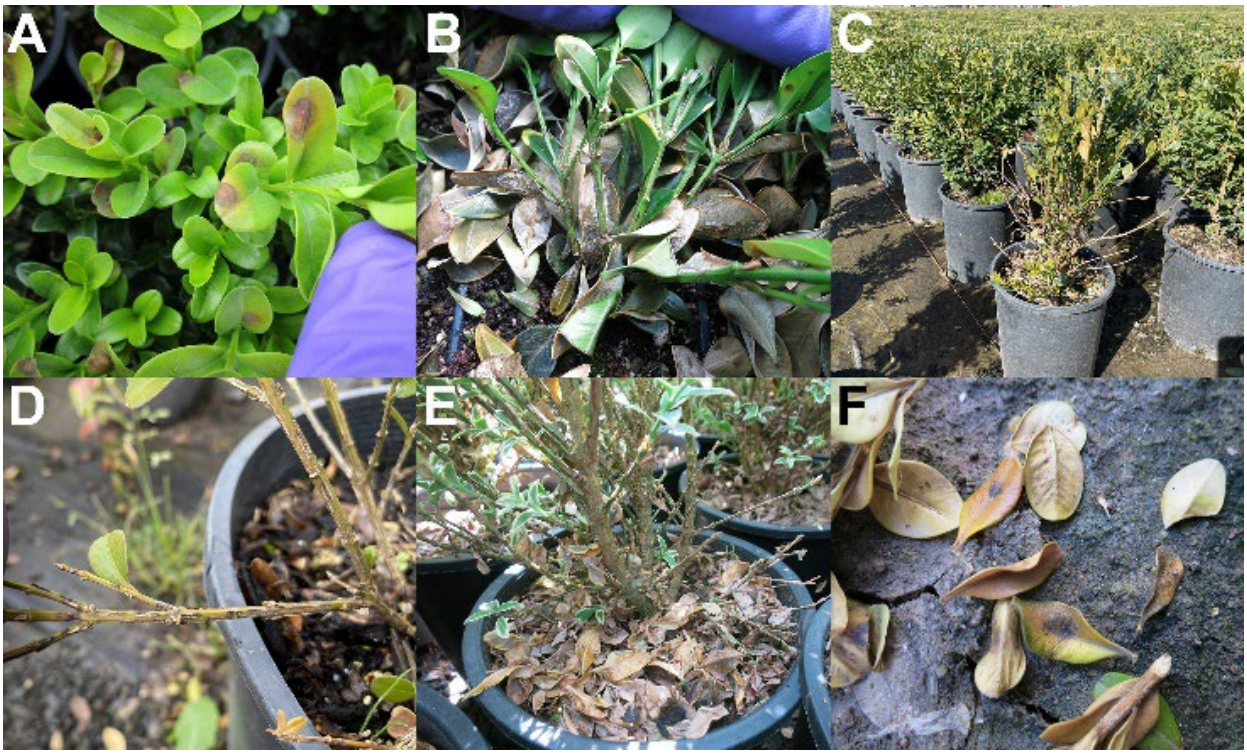

Figure 1. Symptoms of boxwood blight. A, Leaf spots. B, Leaf blight (when the entire leaf turns gray), defoliation, and stem lesions. C, Bare stems caused by boxwood blight. D, Stem lesions on a bare branch. E, Bare stems and fallen leaves. F, Old leaf spots are often visible on fallen debris.

DELIVERABLES
(Mar 01, 2025 to May 31, 2025)

Research

1 Refereed journal article

Extension & Outreach

1 Webinar program
3 Extension presentations
15 Samples diagnosed
36 Email/phone inquiries answered
2,230 People reached with articles/news

Education

2 Postdoctoral associates
1 Intern

Of course, it is also important to know which symptoms are not boxwood blight. Diseases commonly confused with boxwood blight include Phytophthora root rot (**Fig. 2A**) and Volutella blight (**Fig. 2B**). In both cases, the leaves tend to remain firmly attached to the plant and do not pull off easily. Volutella and boxwood blight often go hand-in-hand, as the characteristic salmon pink spores of Volutella blight almost always develop on any dead boxwood leaves regardless of what killed them. Chemical burn is also a common problem that gets mistaken for boxwood blight, especially if contact herbicides for controlling weeds accidentally splash onto the lower canopy (**Fig. 2C**). Chemical spotting may also occur if droplets sit on the young leaves in hot sun. In this case, the spots remain small and have an almost transparent white or light tan center (**Fig. 2D**). Be careful though! Sometimes chemical damage occurs on plants that also have boxwood blight, making it difficult to tell whether the disease is present or not. Drought can cause boxwood leaves to suddenly fall off, leaving the branches bare (**Fig. 2E**). However, the dead leaves are usually almost completely tan without any of the spotting associated with boxwood blight and there are no black stem lesions. Lastly, winter burn is occasionally confused for boxwood blight. This happens when new growth hasn't properly hardened off before cold temperatures arrive. Cold damaged leaves and stem tips will suddenly go limp and shrivel up or turn shades of gold, bronze, brown, or black (**Fig. 2F**). But again, the entire leaf remains firmly attached to the plant and there are no stem lesions.

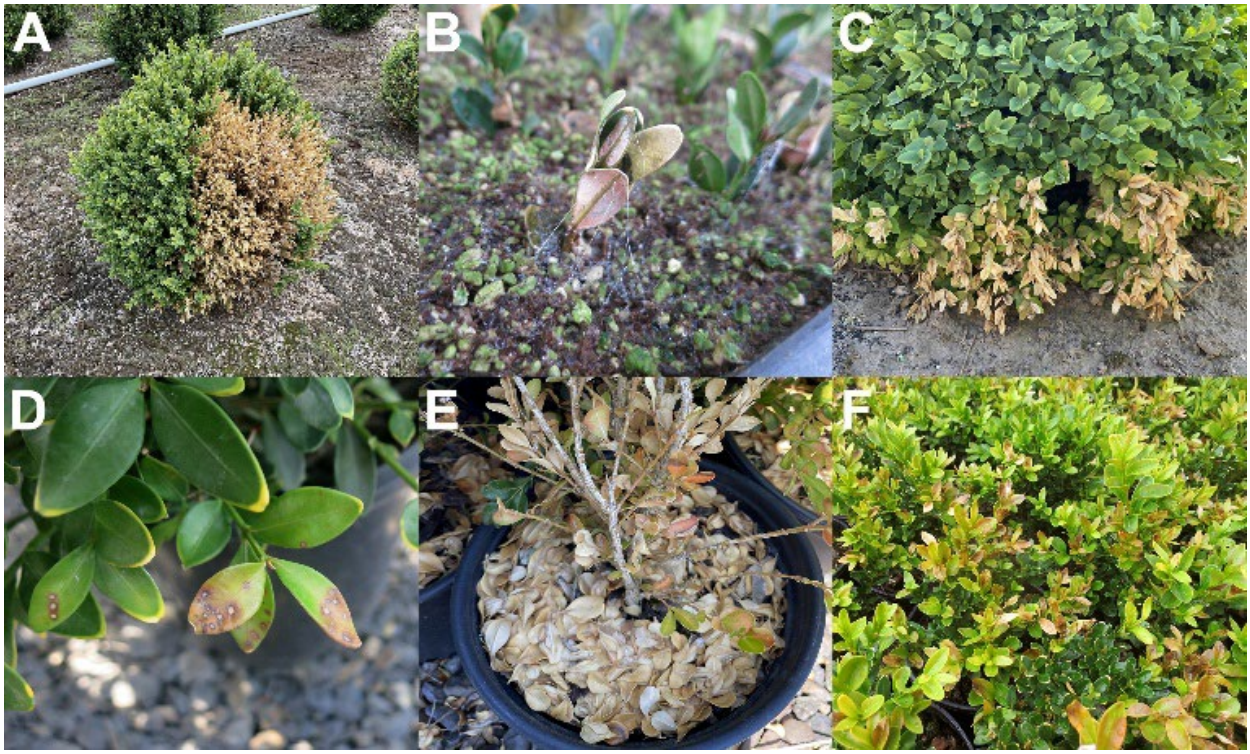

Figure 2. Symptoms that are often confused with those of boxwood blight: A, Phytophthora root rot. B, Volutella blight on a young cutting. C, Chemical burn. D, Chemical spotting. E, Leaf drop due to drought. F, Winter burn on young boxwood foliage.

Choose a good time for scouting

The best conditions for scouting are overcast, dry days. Bright sunlight creates harsh shadows that hide symptoms. Variegated boxwood is difficult to scout for a similar reason - the contrast between the green and

cream variegated parts of the leaf makes symptoms difficult to spot. In these cases, scout earlier or later in the day to reduce some of the harsh contrast and make finding the disease easier. If the plants are still wet from rain, dew, or irrigation, it's better to wait until the foliage has dried out so you don't accidentally contaminate your clothes and move the pathogen to someplace new. In general, scout more often and intensively when recent weather has been conducive for disease (moist, with temperatures between 50-80°F). Boxwood blight can be explosive, seeming to appear overnight following warm, wet weather. Use the boxwood blight forecasting app at https://uspest.org to help determine when there is an increased risk for an outbreak. The risks are lower when the weather is above 80°F and dry or when temperatures are below 50°F.

General scouting strategy

Wear disposable gloves, changing to new ones between blocks and carry a spray bottle of rubbing alcohol to periodically disinfest your boots and tools. I recommend that you scout in your propagation houses first because this is where the symptoms are usually the most obvious. New boxwood cuttings and young plants are watered much more frequently than those in container and field production areas so that they don't dry out. Unfortunately, propagation conditions are also ideal for boxwood blight because the pathogen requires wet foliage and high humidity to infect and thrive. In addition, young boxwood plants are almost always packed tightly together, which allows the disease to spread undetected underneath an apparently healthy upper canopy (**Fig. 3)**.

After the propagation houses, scout your container production areas next. Because these plants are larger and

Figure 3. Underneath the canopy of this apparently pristine bed of Green Velvet, boxwood blight lurks.

have a bigger pot volume, they tend to be watered less frequently than those in the propagation houses. Container boxwood plants are often spread farther apart too (**Fig. 4**). As a result, there are fewer opportunities for infection to occur and for the disease to spread, which leads to fewer and milder symptoms. Scout your field production areas last. Field-grown plants are larger and spread out over much more area within the nursery (**Fig. 4**), and they are usually watered the least often compared to propagation and container plants. This means that boxwood blight symptoms in the field are often very mild and very difficult to find, especially in Oregon where summers are warm and dry. Our survey results bear this out. On average, 40% of the boxwood plants in propagation houses were infected compared to 30% in container production and 16% in the field. This is why it is important for all workers who handle boxwood to be familiar with the symptoms – more eyes means better chances of catching an outbreak early.

In each area, move systematically through each block, scanning for obvious leaf spots, fallen leaves, bare branches with lesions, and for changes in leaf color. Pause periodically to dig into the canopy and investigate the lower branches and leaves for disease. It's not enough to scout from the sidelines while walking by – get close. Otherwise, you can be fooled into thinking a block is healthy when there is actually disease hiding down below (**Fig. 3**). Because of this, my #1 recommendation for boxwood blight management is to space your plants far enough apart so that their canopies don't touch (**Fig. 4**). This limits the ability for the disease to spread and makes it much easier to find symptoms if they are there. Pay special attention to the north side of plants, as well as any

under dripping irrigation lines or that are shaded by larger plants. These areas dry out slowly and are often first to develop severe disease.

Figure. 4. Plants in container and field production areas are often spaced further apart. This helps the plants dry out faster and slows the spread of boxwood blight throughout a production block. It makes scouting easier too!

An Ounce of prevention

As the old saying goes, an ounce of prevention is worth a pound of cure. For those of you fortunate enough to not have boxwood blight, my #1 recommendation is to be very careful if you must bring in boxwood from an outside source. Purchase only from nurseries participating in a boxwood cleanliness program and thoroughly inspect new plants for disease. Again, pay particular attention to the lower and interior canopy, keeping an eye out for mild infections (bare branches with lesions). Keep new plants quarantined from your main boxwood production areas for as long as possible and consider placing new arrivals in a humid location to coax out any new symptoms.

I hope these tips help you stay ahead of boxwood blight. Feel free to reach out if you have questions or need assistance.

FEATURED RESEARCH

Research and Innovation Highlights from the 2025 BBIG Annual Virtual Meeting May 14-15 by Doug Luster, USDA ARS Foreign Disease-Weed Science Research Unit, Ft Detrick, MD

On May 14 -15 2025, BBIG scientists attended the final virtual BBIG Annual Meeting in a Zoom format to present their findings from all previous years of grant funding to the BBIG Advisory Panel and USDA National Program Leaders. The meeting was organized around the foundational objectives and sub-objectives in the original NIFA SCRI grant, effectively demonstrating the accomplishments over the life of the project.

Highlights included:

Doug Luster, **USDA ARS Ft Detrick, MD** provided an update on the development of assays for detection and diagnosis of boxwood blight. Both antibody- and nucleic acid- based assays are being developed in high throughput and point of care formats. **Postdoc John Dobbs** in the Crouch lab at Ft. Detrick is currently testing a nucleic-acid isothermal Recombinase-Polymerase Amplification (RPA) assay in high throughput fluorescent format. The assay detects both *Calonectria pseudonaviculata* (*Cps*) and *C. henricotiae* (*Che*) with high sensitivity and specificity using isolated DNA (analytical sensitivity) and crude extracts of leaves harvested from 'Justin Brouwer' plants inoculated with *Cps* or *Che* (diagnostic sensitivity). The RPA assay will be translated to field use with commercially available lateral flow devices, and a Statement of Work is being prepared for contracting the manufacturing of antibody-based lateral flow devices. Both assays will be tested in the field once the devices are ready.

Jo Anne Crouch**, USDA ARS Ft Detrick, MD** is investigating whether there is a correlation between the boxwood blight pathogen genotypes and disease phenotypes, given that there is little genetic diversity in the blight pathogen in the US and globally. The Crouch lab is currently characterizing the genetic diversity of Oregon nursery isolates of *Cps* provided by Jerry Weiland, now using a more precise genotyping by sequencing approach on samples collected from nurseries across six counties in Oregon. They identified nine SSR multilocus genotypes including five new ones that had never been seen before, which evolved from a central genotype. When they contrasted the multilocus genotypes against the county in which they were collected as well as the production type (propagation**,** container or field nursery) they found that population structure was significant for all three based on those parameters.

They also conducted a temperature study based upon Jerry Weiland's results showing that some Oregon isolates had much lower temperature optima. They used a subset of representative isolates for *in vitro* growth studies and confirmed the lower optimal growth temperatures for most Oregon isolates. When they evaluated temperature optima by genotype there was a very small but significant effect of genotype relative to their temperature optima.

Post Doc John Dobbs (Crouch Lab) has been studying the genetic factors underlying differences in pathogenesis between *Cps* and *Che,* identifying gene differences between the two species. The objective is to identify the genes responsible for the higher virulence exhibited by *Che* in boxwood. In a comparative genomic approach, he identified putative pathogenicity-related genes in the two species and noted significantly higher numbers of these genes in *Che* vs. *Cps*. The second approach applied transcriptomics to identify the genes that are expressed during infection of boxwood. Using leaves harvested from Justin Brouwers plants inoculated with *Cps* and *Che* at different time points, he identified significantly higher numbers of putative pathogenicity genes upregulated in *Che* vs. *Cps*. *Che* transcripts represented more upregulated genes overall, including putative effectors and other pathogenicity-related genes. These results illustrate how different the two species are and provide an understanding of the differences in disease phenotype. Plans are in place to conduct metabolomics studies on the inoculated leaf extracts.

Nina Shishkoff, **USDA ARS Ft Detrick, MD** reported on experiments designed to determine the effect of relative humidity on lesion expansion and sporulation. Nina devised a clever experimental system to study relative humidity using both *Cps* and *Che*, and four cultivars of boxwood (*Buxus sempervirens* 'Suffruticosa', *B.sempervirens* 'Justin Brouwers', *B.* x 'Green Velvet', and *B. microphylla* 'Little Missy'). Shortly before each experiment, branch tips were cut from plants. The cut end of each branch was inserted through the cap of a water-filled floral tube and sprayed with water (control) or with a spore suspension of *Cps* or *Che*. The cuttings were placed in a dew chamber set at 20 C for 24 hours. Then two cuttings from each treatment were placed in a relative humidity chamber assembled from air-tight plastic boxes. Each box contained 100 mL of a solution of water and glycerol adjusted to give different relative humidity levels of 40, 60, 80 or 100% in the airspace above. One box with inoculated leaves and one box of controls at each temperature was fitted with a humidity sensor. The chambers were then placed in a growth chamber set at 24 C with a 12-hr photoperiod for seven days. Branches were rated for incidence and percent lesion area per leaf and infected leaves placed into centrifuge tubes with 10 mL water and agitated to release spores. Spore counts were conducted using a hemocytometer. Although there was no effect of different relative humidities on incidence or severity of leaf lesions, sporulation was only observed at 80 and 100% relative humidities. This is useful information to add to predictive disease models.

Figure 5. BBIG Annual Meeting; slide used to illustrate an example of going above and beyond the Proposed Project Objectives. (Chuan Hong)

Chuan Hong**, HRAREC - Virginia Tech** reported on epidemiological studies with multiyear data from boxwood cultivar and fungicide evaluation trials in northern

Germany from 2006 to 2020, and mulching trials in western North Carolina and Virginia from 2014 to 2017. These collaborative studies demonstrated the pathogen population buildup is critical to boxwood blight outbreaks. The studies consistently showed boxwood blight is highly weather dependent while identifying several important new blight-driving weather variables - rainfall, wind speed and high humidity. Although boxwood blight could occur any time of year when weather conditions are favorable, it was most prevalent in the fall season in northern Germany and in the Mid-Atlantic region of the United States. These findings highlight the importance of slowing the pathogen population buildup by using more resistant cultivars, mulching, and practicing strict sanitation. They also provide new leads for calibrating a boxwood blight infection risk model.

Fulya Baysal-Gurel**, Tennessee State University** updated the group on survey responses to questions aimed at critical boxwood blight control points in nursery practices that affect disease spread and mitigation. The survey, which was directed to boxwood propagators, growers or nursery owners, had a 62% response rate from 9 states, providing answers to questions on market channels, diagnosis of disease, cultural practices, disease management, and perceptions of practices that can limit or prevent disease. Boxwood transplants, cutting tools, potting media/soil/irrigation water, plant debris, human factors and worker hygiene were identified to be critical sources for entry and spread of boxwood pathogens, including *Cps*. Survey respondents were familiar with and believed to have adopted the processes and programs of boxwood disease management (Best Management Practices - scouting and employee training, boxwood blight cleanliness program etc.). Critical practices to lower the risk of boxwood disease spread were identified as avoiding introduction, sanitation, cultural practices in boxwood production and Fulya noted that there is still a need for full adoption of those practices. There was a gap between awareness and adoption of management practices, e.g. sanitation (sanitizing cutting tools) and use of certified plant materials or small blocks for production. Likewise, adoption of some prevention methods, including several sanitation practices was less than a calculated consensus limit of 70% that is yet to be addressed in future extension programming.

Fulya also reported that her former PhD student – Bhawana Ghimire's (now with Bartlett) studies on UV-C sensitivity of *Cps* using LED diodes, and experiments testing plasma activated water on bacterial pathogens were both published in Plant Disease.

Jerry Weiland, **USDA ARS Corvallis, OR** reported on two research components: 1) a boxwood blight nursery survey to determine which nursery practices lead to outbreaks, and 2) epidemiological studies to determine whether there is latent infection and to show how the disease spreads in nursery settings. For the nursery survey, they discovered that intensive disease management practices (frequent scouting for and immediate removal of infected plants, fungicide program) reduced the incidence of disease by 80% compared to nurseries that didn't follow best management practices as closely. Boxwood blight was more frequently detected in propagation facilities, less frequently in container blocks, and least frequently in field blocks. This is because plants in propagation houses are watered more frequently and crowded closer together while plants in the field are spaced the furthest apart and watered the least frequently. Disease was also worse in the center of production beds, where the plants did not dry out as quickly. Last, they showed that there wasn't much difference in how often a disease was detected by cultivar. Instead, disease tended to be more severe on susceptible cultivars like Suffruticosa and Green Velvet and milder on resistant cultivars like Winter Gem and Green Beauty.

For the epidemiological studies, they showed that boxwood blight is likely not latent in infected plants: the boxwood blight pathogen was always detected from leaves and stems with disease symptoms but rarely detected from asymptomatic tissues at all taken from the same infected plants. What this means is that it is more likely that mild boxwood blight symptoms are being accidentally overlooked, and that has been the primary reason why boxwood blight has moved to new locations via plant trade. Their studies also showed that the pathogen tends to move more readily towards neighboring plants that had overlapping foliage and never spread to plants that were spaced so that their canopies didn't touch. Boxwood blight also spread faster within crops that were watered more frequently. What this means is that growers should space their plants further apart and water less frequently to avoid having frequent boxwood blight outbreaks and to minimize the number of plants that become infected.

The findings from the survey and the epidemiological studies have been used to train growers and nursery inspectors on how to effectively scout for boxwood blight, to update the boxwood blight forecasting and mapping apps, and are being used to update boxwood blight best management practices.

Chuan Hong**, HRAREC - Virginia Tech** reported on two other research components: 1) further developing biological control agents (BCAs), and 2) evaluating and adapting antidesiccants for blight mitigation. For the biocontrol component, five BCAs were selected and evaluated on two farms in western North Carolina for 2

years. *Burkholderia* sp. SSG applied at monthly intervals protected American and Vardar Valley boxwood crops as effectively as the fungicide standard – Concert II applied at 3-week intervals. Two other BCAs also provided the similar level of protection of American boxwood but at a slightly lower level for Vardar Valley than Concert II. We are looking for a company to make these BCAs into biocontrol products for field application. cDNA transcriptome revealed that SSG triggers plant defense priming, including 120 differentially expressed genes encoding biotic and abiotic stimuli and stresses. Additionally, a new potent BCA and biofertilizer – *Pseudomonas* sp. 1021Bp was identified.

Figure 6. BBIG Annual Meeting; slide used to summarize major research and innovation accomplishments achieved during the project performance, 2020-present. (Chuan Hong)

For the antidesiccant component, six products were evaluated using containerized Justin Brouwers boxwood plants under controlled environments, and three – TransFilm, Vapor Gard, and Wilt-Pruf – consistently provided excellent control of boxwood blight at both the infection and sporulation steps of the disease cycle. However, when these three products were applied to field-grown American and Vardar Valley boxwood crops at monthly, bimonthly, and quarterly intervals, the maximum blight reduction was only 47%. Phytotoxicity was observed on both boxwood cultivars when Vapor Gard was applied at monthly intervals.

In addition to proposed the above research objectives, Chuan and Ping Kong**, HRAREC - Virginia Tech** also surveyed and collected boxwood plantings in southern Europe for *Calonectria henricotiae* (*Che*) and reported its first observation in Italy, Spain and Switzerland. These discoveries help prevent this more aggressive, heat-tolerant and fungicide-resistant pathogen from entering US and other countries where it is not present now.

Nina Shishkoff, **USDA ARS Ft Detrick, MD** generated a presentation including photographs of symptoms of boxwood blight on a variety of cultivars, demonstrating that some cultivars display atypical symptoms that might not be recognized as boxwood blight. Although the future control of boxwood blight will include the use of tolerant cultivars, there has always been the risk that adding a tolerant cultivar to a landscape already planted with susceptible cultivars might bring in the pathogen as a passenger in a "Trojan Horse". These include *Buxus harlandii*, with very small, dark spots, and variegated cultivars such as 'Golden Gem', where symptoms are difficult to see. Photographs were also taken of symptoms on various cultivars at 24, 48, 72 and 96 hr after inoculation, illustrating that very early symptoms are not easy to see or identify. Photographs will be used to develop extension/outreach material to help with identification of diseased plants. Following the presentation, **Tim Widmer with the USDA ARS Office of National Programs** noted that the differences seen in symptoms might lend themselves to an AI detection phone app.

Margery Daughtrey**, Cornell LIHREC** introduced the concept of SAR inducers and selective fertilization for enhancing boxwood self-defense, which are the subjects of ongoing studies. **Fred Gouker, USDA ARS in Geneva NY** followed up with studies on application of orthosilicic acid which inhibits pathogen colonization, in detached leaf experiments, and saw that *Cps* lesion size in Little Missy and Suffruticosa cultivars was significantly reduced. He reported on effective doses of UV-C treatment in suppression of *Cps* and *Che* in fungal colony growth, detached leaf, and whole plant assays. He observed no phytotoxic effects on leaves in Wintergreen and Suffruticosa and noted that UV-C can be a powerful sanitation tool for blight mitigation, with an effective lethal dose of 1000-2500 J/m^2. The waxy cuticle of boxwood may provide a sufficient protective barrier against UV-C light allowing UV-C doses without phytotoxicity. The treatment can be improved by optimizing the positioning of lamps/or using reflective surfaces to irradiate abaxial sides. **Doug Luster, USDA ARS Ft Detrick, MD** asked whether the treatment required dark conditions; **Tim Widmer with the USDA ARS Office of**

National Programs noted that the USDA ARS AFRL in Kearneysville WV has developed a robotic UV-C system for night irradiation of strawberry plants in the field, effectively suppressing fungal disease.

Jim LaMondia**, CAES, CT** summarized his long-term studies on integrating key technologies, including fungicides, plant resistance, cultural controls, sanitation/exclusion, epidemiology, and interactions of these technologies. He noted that conidia don't become airborne indicating that infection spread requires airborne splash or spread by mechanical means such as pruning equipment, even when plants are dry, likely due to longevity of conidial masses. Work with Nina Shishkoff identified alcohols as a rapidly effective sterilant, providing a valuable practice for reducing disease during propagation activities.

Fred Gouker, **USDA USNA, DC (now with USDA ARS in Geneva NY)** reported on developing breeding populations, genomic and biotechnology resources for breeders. He screened the US National Arboretum boxwood collection including 276 accessions representing 112 cultivars using detached leaf inoculation assays to identify a set of breeding parents exhibiting resistance to boxwood blight. These efforts resulted in 1,100 inter-specific hybrids, from which 15 F1 hybrids were evaluated in the field in collaboration with Saunders Genetics. An advisory panel with industry stakeholders has facilitated field evaluations of hybrids to assess horticultural traits and resistance levels. Early data from field trials show promising resistance in selected hybrids compared to traditional cultivars, suggesting potential for commercial production, but will require several more years of additional evaluation for blight resistance and other key horticultural traits.

Fred also updated progress on the reference genome assembly that has been developed for *Buxus sempervirens* 'Suffruticosa' which will aid in accelerating resistance breeding and genetic improvements. Additionally, there are ongoing RNA sequencing studies now being conducted by Laura Brindisi, who has replaced Fred at **USNA**, that are examining gene expression changes in boxwood cultivars in response to blight infection, indicating how susceptible and tolerant cultivars react differently and may provide key insights for the genetic basis of blight resistance. A protocol for isolating protoplasts from boxwood leaves has been established **by postdoc Feliz Gurel**, which is of great importance for initiating *in vitro* regeneration and genome editing in boxwood, as well as enabling functional genomics and multi-omics studies and efforts to develop boxwood tissue culture and transformation technologies.

Ping Kong, **Virginia Tech's HRAREC** reported the major discoveries from their boxwood microbiome research. First, extensive mycorrhizal genera and other beneficial microbes were identified from five boxwood cultivars, providing microbiome evidence supporting boxwood as a low maintenance crop and landscape plant. Second, agrochemicals were demonstrated to have profound impacts on boxwood phyllosphere fungal and bacterial community composition and structure. Specifically, Pseudonectria and Colletotrichum populations rose on boxwood plants cover sprayed with agrochemicals, helping understand the recent rise of both Volutella blight and boxwood dieback, and highlighting nonchemical approaches as preferable where possible. Likewise, a variety of fungal genera were shown to have reduced sensitivity to chlorothalonil after being repeatedly exposed to this chemistry, providing the first evidence that fungi are developing resistance to a multi-site chemistry. More importantly, this research underlines that understanding the boxwood microbiome and its response to agrochemicals and other cultural practices is foundational for developing a systems approach to crop health and production.

In the economic update, Charlie Hall**, Texas A&M University** walked the group through the production-level analyses that have been conducted regarding the impacts of boxwood-blight-mitigating Best Management Practices on the cost structure of 3-gallon boxwood within the nursery. Charlie also provided an overview of the journal article under development that addresses objectives 4.5 and 3.3 regarding the economic return of long-term investment in blight mitigation, resistant cultivars, and consumer acceptance of more resistant cultivars. The economic analysis begins by quantifying how full best-management-practice (BMP) adoption—funded through the federal mitigation grant—raises variable costs by $1.85–2.13 per #3 container plant (23–28 %) yet yields positive margins and double-digit returns on investment whenever baseline disease losses exceed 20% or the market pays even a 10% disease-free premium. It contextualizes those results within a decade of green-industry sales data—highlighting pandemic demand shocks—and traces production's geographic drift from early-blight states toward lower-risk regions, illustrating the strategic value of mitigation. A survey of growers details labor-heavy sanitation, scouting and fungicide regimens already in use, while partial-budget sensitivity tests show that preventive BMPs insulate nurseries from wage inflation, tariff-driven input spikes and costly crop restarts. Parallel analyses of shrink trends and the Index of Prices Paid confirm that unmitigated outbreaks magnify existing cost pressures. Demand-side sections add further economic justification: willingness-to-pay and

likelihood-to-purchase studies reveal 10–30 % consumer premiums for disease-resistant ornamentals, and risk-communication research pinpoints trust factors that shape acceptance of biotech solutions. A meta-analysis of cultivar trials ranks low-susceptibility genotypes, and a BBIG case study documents a US $50 million annual market shift toward these cultivars, underscoring the grant's impact. Collectively, every section of the economic analysis converges on the conclusion that rigorous, grant-supported blight mitigation is not a discretionary expense but a resilience-building capital investment that secures profitability, sustains supply-chain confidence and preserves the cultural value of boxwood in American landscapes.

Impacts:

Charlie and Chuan provided an overview of the summary analysis underway of the overall BBIG project impacts. Charlie has developed a summary already based on each of the annual reports and is in the midst of further delineating and categorizing those impacts by objective using the refereed journal articles developed under each objective, as well as the efforts that have been highlighted in the quarterly newsletters. Altogether these studies have resulted in over 62 refereed journal articles with numerous major advancements. The upcoming Focus issue of PhytoFrontiers is anticipated to add a significant number of new publications to this body of work.

The analysis of the project's economic contributions traces how the USDA-funded Boxwood Blight Insight Group (BBIG) has converted threat into opportunity by embedding rigorous economics into every technical milestone: it opens by framing boxwood blight as a crisis menacing a wholesale crop valued at $400 million—and a green-industry supply chain exceeding $348 billion—then details how 100-plus studies on resistant cultivars, precision sanitation, weather-driven spray models, biocontrols and microbial soil amendments collectively safeguard sales, trim inputs and unlock new markets. Section-by-section analyses quantify avoided crop culls, lower fungicide and labor bills, earlier cash realization and reduced regulatory burden, showing that even conservative adoption curves yield a net-present value of about $1.2 billion in direct producer gains over ten years and up to $2.1 billion once environmental, public-health and consumer welfare spill-overs are added; the project thus posts a benefit-cost ratio near 21:1. The synthesis demonstrates that there are ancillary dividends including thousands of jobs retained, 13,000 lbs of pesticide abated, 48,000 tons of CO_2-e abated, historic landscapes preserved, and a pipeline of cross-trained pathologists and economists—demonstrating that BBIG's transdisciplinary approach generates durable economic, environmental and societal returns that far outlive the grant itself.

EXTENSION HIGHLIGHTS

Extension Accomplishments by Margery Daughtery, Cornell University, Riverhead, NY

During the BBIG Annual Meeting, held May 14 & 15, project scientists presented extension and outreach accomplishments to the BBIG Advisory Panel and USDA National Program Leaders. Over the life of this project, there have been wonderful extension accomplishments: a number of our program directors are in close touch with green industry stakeholders and have well-established extension programs—and some of the researchers have joined in with considerable outreach. Throughout the years, BBIG has been reaching out to both the production and landscape industries with programs conducted at local, regional and national levels. We have benefited from information shared with us from the global boxwood community via the International Webinars and have actively

Figure 7. BBIG Annual Meeting; slide used to summarize major extension/outreach accomplishments achieved during the project performance period, 2020-present. (C. Hong)

disseminated this knowledge as well as that developed by our own research partners within BBIG.

The following are some highlights from those presentations, including some beyond what was proposed.

1) Introduction – Fulya Baysal-Gurel (TSU, TN) and Luisa Santamaria (OSU, OR)

Field Demonstrations. ***These have covered critical control points (CCPs), antidesiccant use, biocontrols, resistance, tech integration, new cultivars, detection kits, pictorial keys, and scouting. For a complete listing of presentations, see the archived BBIG Newsletters at boxwoodhealth.org***

Luisa Santamaria **(OSU, OR)** has focused on scouting, providing extra value by offering bilingual programs, and helping frontline workers to learn how to identify boxwood blight. She has seized any opportunity to meet workers in propagation, production, or delivery areas, wherever - to teach them to reduce the spread of the disease. She conducted workshops even during the pandemic; using a hybrid approach to meetings allowed her to do programs out of state as well as in Oregon. Luisa has made presentations at Cultivate and the FarWest show, and her website also has information on boxwood blight.

Fulya Baysal-Gurel **(TSU, TN)** teamed up with **Luisa Santamaria** to do programs in TN, including partly virtual scouting workshops. For a pilot study in Warren Co., TN in March 2022, Luisa did zoom training in Spanish and Fulya then took the workers into the fields to practice scouting. The Tennessee Nursery and Landscape Assn requested a similar program: they had Luisa do zoom training in Spanish and then hands-on learning was conducted outdoors, having workers inspect plants and come up with answers. Bilingual educational resources have been developed in Oregon by Luisa to use for such courses. Likewise, she organized and moderated a symposium – Ornamental Production Challenges and Perspectives: A Case Study of Boxwood Blight at the 99th annual meeting of the APS Southern Division in Chattanooga, TN from March 7 to 10, 2022.

Jerry Weiland **(USDA ARS, OR)** also teamed up with **Luisa Santamaria** at **Jay Pscheidt's (OSU, OR)** suggestion to develop a video on scouting; many nurseries use this video as a tool to train workers. A poster on boxwood blight was developed by Luisa some years ago and a new improved version has just been created. Different kinds of media are needed by different nurseries: many want videos, some want graphics.

Many programs and zoom events have been given across the country to educate various audiences on boxwood blight. **Fulya Baysal-Gurel** described one great program – an all-day event – that was held at Dixon Gallery and Gardens in Memphis, TN in 2022. There were >150 attendees (landscapers, gardeners, extension agents). Advisory Panel members **Lynn Batdorf** and **Bennett Saunders** participated as instructors along with **Fulya Baysal-Gurel.**

Chuan Hong **(VT, VA)** has worked with nurseries and historic gardens (e.g. Saunders Brothers, Colonial Williamsburg, Longwood Gardens) to improve boxwood blight risk mitigation and management—and with the Virginia Boxwood Blight Task Force to develop BMPs. **Margery Daughtrey** mentioned a recent new kind of audience from the New York Botanic Garden's landscape design program alumni, who were interested in boxwood blight and how it can be managed today with the advantage of resistant varieties of *Buxus*.

2) Alliance with the Hort Research Institute – Chuan Hong and Jennifer Gray (HRI, OH/DC)

Horticultural Research Institute, part of AmericanHort, has been an invaluable partner for extension effectiveness—this gave BBIG a collaborative connection to HRI's impressive stakeholder network. HRI helped us run two highly successful webinar series, invited BBIG speakers to update the audience at Cultivate, and provided us with an online knowledge center at boxwoodhealth.org to fill with boxwood information.

Jennifer Gray and staff (particularly **Nick Leas** and **Amanda Holton**) have helped us to run the International Boxwood Seminar and the BBIG Boxwood Seminar series, both of which were intended to move research from lab to field. Our international series included **Lynn Batdorf** and **Len Coop** as speakers, as well as international scientist collaborators who helped us to collect and share European and Australasian knowledge of boxwood blight. The HRI team publicized, hosted, recorded, and posted webinars, and also provided metrics afterwards. 24 countries on 5 continents and 46 states of the US were reached. Most attendees (94%) were from the US, with the vast majority being 'multipliers' [e.g. industry leaders, supervisors, or educators], which increased the impact of the webinars. In the BBIG Seminar series begun in 2023**, Jim LaMondia (UConn), Fred Gouker (USDA ARS), Fulya Baysal-Gurel, Xiao Ping Li (VT), Nina Shishkoff (USDA ARS**) and **Ping Kong (VT)** have provided seminars on their research. Jennifer and **Charlie Hall (TAMU, TX)** have surveyed attendees and collected data on improvements in knowledge accomplished by the webinars. They also asked about the potential financial impact. **Fred Gouker's** 1-hr seminar was valued at $2.9 mill by the industry, and all of the seminars have been considered to have a return of at least $1 mill!

Also, HRI organizes the educational program for the trade show Cultivate, and has provided BBIG with two On-Demand sessions in 2021 and 2022 as well as speaking opportunities in 2023 and 2024. The 2021 On-Demand session speakers included **Jim LaMondia (CAES, CT), Fred Gouker, Chuan Hong**, plus one collaborator **Len Coop (OSU, OR).** Likewise, the 2022 session speakers were **Fulya Baysal-Gurel, Jay Pscheidt, Luisa Santamaria, and Jerry Weiland.** Individual research updates were provided by **Fulya Baysal-Gurel** and **Nina Shishkoff** in 2023 and 2024. The key, lasting, aspect of the relationship with HRI has been the development of a website that will continue to be maintained, so that the information generated by our project will remain retrievable.

Jennifer Gray proclaimed that the BBIG website has been a model of effective industry-research collaboration – a very productive, high-impact partnership…helping to mitigate the impact of boxwood blight. HRI has been excited to be part of BBIG. The webinar series has had attendance in the hundreds, and cumulatively 1000s, of people across 5 continents. The information from BBIG can be implemented by the industry, giving a strong return of investment (ROI) for the growers. One stellar outcome is the website: an important conduit for info. All the visual resources provide critical assistance for diagnosis. The continued maintenance of the web site means that new diagnosticians can be trained into the future. The knowledge transfer has been excellent. The website has newsletters, journal articles, webinars, a deep knowledge base, so that it is an industry go-to resource on all things about boxwood and boxwood blight. Finalized BMPs will be there shortly. This website shows the power of connecting research & education to the industry.

Chuan Hong gave a brief tour of the website [boxwoodhealth.org]. There are several tabs: The **Boxwood Gardening tab** is for the general public—it was established in response to the upswelling of interest in the topic after a New York Times article on June 1, 2022. The **Research Updates tab** has 5 items: BBIG monthly, BBIG quarterly newsletters, BBIG annual report, and a listing of all of the researchers' publications [In future we will have links to all the literature we have generated for direct access, as part of fulfilling our promise to USDA NIFA as our funding source]. Also, a new section under the Research Updates tab is now being developed (a special project with APS PRESS that will showcase our research in the journal *PhytoFrontiers*).

The **Knowledge Center tab** has seven sections: the diagnostic aids and management strategies section covers symptoms on boxwood, pachysandra and sweet box as well as a lot of other practical information. Other sections include both of the seminar series and Cultivate presentations for all boxwood enthusiasts as well as outreach to different stakeholder groups. Here you can also find information on the disease boxwood anthracnose and Jerry's information on scouting. Lists of resistant cultivars and the latest global boxwood blight map are included.

Next is the **Box Tree Moth tab**: AP members requested the latest info on that new pest. The **Event Calendar tab** keeps us straight on meeting times; material about the team and its objectives is available under the **About BBIG tab**. We'll be adding a **Spanish Language tab**, coming very soon. The Knowledge Center tab will have the BMPs that **Jerry Weiland** is now developing. **Fulya Baysal-Gurel** let us know that HRI has engaged a Spanish curriculum developer, and Fulya will be doing a program on June 26 on sanitation, which Alejandra Feliciano Rivera will be translating.

3) Partnership with other stakeholders – Karen Snover-Clift (Cornell University).

a. Karen described some of our partnerships with other organizations and professional societies. With the **American Phytopathological Society (**APS), we have done Symposia and Idea Cafes and numerous posters and presentations at regional and national levels. The **American Public Gardens Assn** (APGA) has also been a partner—they were helpful initially by suggesting AP member **Casey Sclar**, and they have connected BBIG to citizen science projects at Longwood Gardens.

BBIG has worked closely with a number of federal and state groups. We have provided program material to the **National Plant Board**, who are regulatory inspectors (largely SPROs, who are state plant regulatory officials who work closely with federal SPHDs, state plant health directors). **USDA APHIS** (Animal Plant Health Inspection Service) has supported us in outreach events and helped with permitting. **USDA ARS** has given grant support as well as supplemental financial support and, importantly, provided many of our project directors! Additional assistance has come from IR-4 (**Inter-regional Research Project 4** (created to provide data to support registration of pesticides for specialty crops). NPDN (**National Plant Diagnostic Network**) has been one of our audiences that has been especially hungry for info. At a national meeting in Portland, ME last August we had a poster to help them find our website and be aware of BBIG. [Two of the BBIG post-docs have found jobs as Clemson and Oregon Diagnosticians in part due to their experience working on BBIG grant studies]. BBIG did a

special symposium for NPDN in Jan 2024, a 3-hr session of key investigators sharing what they had found. This was attended by 147 people, including diagnosticians, extension educators, state Dept. of Ag staff, Plant Board members, foresters, nurserymen and USDA employees. Of those returning the survey, 55/56 said it was helpful; about half had been unaware of BBIG before. Awareness of our diagnostic guides was improved—more than half were unaware of them before the webinar. This audience wants to learn more about test methods; they were very thankful for the webinar. The **Great Plains Diagnostic Network** (a subset of the NPDN) invited us to do a BBIG webinar in 2022, and **Doug Luster (USDA ARS, MD)** and **Margery Daughtrey** gave presentations aimed at diagnosticians. The national data repository of NPDN is accessible through diagnostician channels. There have been 2.7 million total uploads in the repository, some with more than one diagnosis. From Sept 2019 to May 15, 28,000 entries have been associated with boxwood – from 46 states. Of these, 15,727 were pathogen-related, while some 6,000 were related to arthropods. 3700 of these were boxwood blight related: 1306 were confirmed as boxwood blight positives, 156 'suspected boxwood blight', and 10 'undetermined'.

b. **Jerry Weiland (USDA ARS HCRL, OR)** covered the Oregon workshops for nursery inspectors and other OR activities. He lauded the boxwood education team in OR, which has **Luisa Santamaria**, **Jay Pscheidt** and himself collaborating, with help from a number of colleagues. They've created scouting videos, conducted field days and trained inspectors (at the ODA Nursery Inspectors' Field Day, e.g.); they've developed training materials in two languages and delivered onsite trainings and grower workshops. At a stakeholder meeting they started out by getting feedback from growers in the Oregon Assn of Nurserymen (OAN) on what the industry needed from research. Then they gave updates of research results in 2020, 2022, 2023. They have done 30+ nursery consults to assist with boxwood blight management. One result has been increased rigor for ODA's boxwood blight cleanliness program—now they have an audit checklist. There is also an improved nursery compliance agreement. They have contributed a boxwood blight poster, mapping apps, and are updating the BMPs. Their successes in Oregon are important for the entire national picture, as Oregon is an important source of boxwood for the nation. They would like to do more to reach out to landscapers and tree care professionals in their region as well.

c. Communications to other plant pathologists – Chuan Hong (VT, VA). These included publications in scientific journals and presentations at annual meetings of APS and regional meetings of plant pathologists as Karen described above; research and extension publications are all recorded in the BBIG Monthlys and BBIG Newsletters archived under the Research Updates tab at boxwoodhealth.org. We have prepared an article on the International Boxwood Seminars for a journal which has already been accepted and has been revised for publication. We want to offer our methodology for a successful program based on partnerships to others in the scientific community.

4) Luisa Santamaria spoke on her Spanish Communication Initiative in which she aims to explain how to fight boxwood blight to nursery workers, 60-80% of whom are Spanish speakers. We often don't realize how important the role that workers play in disease management. Educating the workforce can improve disease control. She has thoughtfully considered how to most effectively present the information, and consequently always aims to do hands-on education. Key topics are disease ID, sanitation, disinfection of tools---live, hands-on presentations result in active participation and questions. She lectures first, then brings in the boxwood. She presents annually at the FarWest Show of OAN where she made presentations on boxwood in Aug 2022 and 2024. For educating non-readers, she is adding voice-over to short 15-min presentations and wants to develop

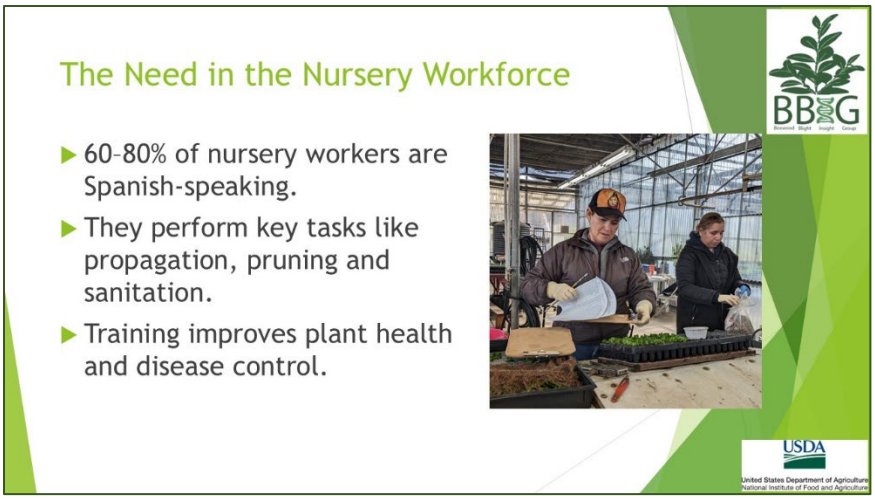

Figure 7. BBIG Annual Meeting; slide used to convey importance of workforce trainings available in Spanish. (Luisa Santamaria)

a short version of BMPs in Spanish as well. Luisa finds it necessary to explain the "why" of sanitation to workers. She has found that videos are a good format for presenting to nursery workers (**John Keller** agreed that this format was desirable), to empower them—and she is also interested in doing podcasts. Luisa's trainings are being incorporated into ODA's voluntary Boxwood Cleanliness program, and her materials are being gathered at the new Spanish language tab at **boxwoodhealth.org**.

5) New Best Management Practices (BMPs) Jerry Weiland, (USDA ARS)

Jerry is heading up the revision of the BMPs with the help of 8 volunteers who, together with him, have formed the BBIG editorial team: **Jay Pscheidt, Jennifer Gray, Fulya Baysal-Gurel, Luisa Santamaria, Margery Daughtrey, Nina Shishkoff, Jim LaMondia** and **Chuan Hong**. The draft of the new BMPs has been sent to HRI for comment. There have been major improvements as the result of BBIG research, including information on spacing and irrigation frequency and improved photos. In response to Jerry's request, **Mike Gaines** volunteered some additional photos of devastated boxwood in the landscape. So far there have been 499 revisions to the previous BMP document.

6) BBIG Magazines – Karen Snover-Clift, (CU)

Karen described the magazines produced by BBIG, starting with the **BBIG Monthly** that is released the first of every month, covering events and publications in a timely way. Karen is herself now spearheading the drafting and online publishing of both of our newsletters. News/research updates/extension programming/publications are all included in the Monthly. The more extensive **BBIG Newsletter** is produced quarterly, at the end of each 3rd month. Newsletters contain featured news, featured research, reports on Extension activities, reviews of project meetings, spotlights on advisory panel members and announcements, lists of publications and presentations from that time period, and the list of project directors and advisory panel members. The next issue will cover March, April and May 2025. Both the BBIG monthly and the BBIG newsletter are archived at **boxwoodhealth.org**, under the Research Updates tab.

PROJECT MAJOR DELIVERABLES

(2020-present)

62 Refereed journal articles in a broad array of journals
60 Presentations at scientific meetings (e.g. APS, ASHS, ICPP, IPPC and NPDN)
2 Boxwood seminar series – International with 8 webinars and BBIG with 6 webinars
2 On-Demand sessions (2021, 2022), plus two presentations at Cultivate
1 Outreach website
13 Workshops (some in Spanish) for growers, regulatory staff and diagnosticians
123 Extension presentations (some in Spanish) for a broad audience of boxwood enthusiasts
909 Boxwood disease samples diagnosed
1,405 Email/phone inquiries answered
64,692 Stakeholders reached via Google groups.

PROJECT MEETING BRIEF

The BBIG Leadership Team met with Advisory Panel (AP) members on March 07, 2025, to report the project progress and seek their feedback. **Dr. Ayse Filiz Gurel of USDA-ARS and the U.S. National Arboretum** was the invited speaker and presented "Development of a system to evaluate the effects of UV-C radiation on Boxwood blight pathogen, *Calonectria* spp.". Other topics of importance included: 1) Annual meeting planning, 2) Collaboration with the American Phytopathological Society on the BBIG focus issue of PhytoFrontiers, and 3) Development of a new Spanish tab for the BBIG Knowledge Center to support Spanish-speaking workforce in the horticulture industry, best management practices for the horticulture industry, etc.

The project Leadership Team held three monthly meetings on March 19, 2025, April 14, 2025, and May 07, 2025. Among the most important planning topics were 1) a project-wide annual meeting, and 2) a BBIG focus issue of PhytoFrontiers – Reclaiming Boxwood from the Blight.

The annual meeting planning was a frequent topic of discussion. Doug Luster led the planning efforts and site logistics. The meeting was to be held at the U.S. National Arboretum on May 14 & 15, 2025. In early May, the leadership learned that numerous project directors would be unable to travel; the advisory members were polled to ask if a switch to an all-virtual session made more sense. All agreed and the meeting was changed to all virtual. Doug Luster also developed the agenda for the meeting. The leadership team met several times to assist and provide input. The resulting agenda provided a comprehensive review of 5 years of accomplishments and examples of going above and beyond the objectives developed at the start of the project. The focus issue is to highlight the latest research and innovations as well as their economics and impacts, and this is to be done in collaboration with the American Phytopathological Society.

ANNOUNCEMENT

Barb Riker from Cornell University has joined the BBIG team and is assisting with the development of the two publications, the BBIG Monthly and the quarterly BBIG Newsletter. Please reach out to Barb at br347@cornell.edu if you have material for either publication. Welcome to the team Barb!

PUBLICATIONS

Refereed Journal Articles

1. Likins T., Davis B., Anderson P., Gillis B., and **Hong C. X.** 2025. Flutriafol drench provides season-long protection of boxwood plantings pre-infected by *Calonectria pseudonaviculata* in the Mid-Atlantic. Plant Disease. Abstract available at: https://doi.org/10.1094/PDIS-12-24-2731-SC.

RECENT PRESENTATIONS

Professional Conference Presentations, Seminars and Webinars

1. BBIG: Boxwood Health Webinar; Prospecting for Biocontrols. presented by Ping Kong, Virgina Tech University. March 11.

Extension/Outreach Programs and Presentations

1. Daughtrey, M. 2025. Streaking in the shrubbery. Long Island Horticulture Conference. Cornell Cooperative Extension of Suffolk Co. Brookhaven National Lab, Upton, NY. March 2.
2. Daughtrey, Margery. Battling for Boxwood Health. Landscape Design Student and Alumni Organization. New York Botanical Garden. Virtual, April 8.
3. Daughtrey, Margery. The 2025 Pests of the Landscape: Diseases. Urban Forestry Today. University of Massachusetts. Virtual, April 10.

PROJECT DIRECTORS

Chuan Hong (Project Leader), Virginia Tech, Virginia Beach, VA
Margery Daughtrey (Extension Leader), Cornell University, Riverhead, NY
Douglas Luster (Research Leader), USDA, ARS, Foreign Disease & Weed Science Research, Ft. Detrick, MD
Charles Hall, Texas A&M University, College Station, TX
Jerry Weiland, USDA, ARS, Horticultural Crops Disease and Pest Management Unit, Corvallis, OR
Fulya Baysal-Gurel, Tennessee State University, McMinnville, TN
Fred Gouker, USDA, ARS, Floral & Nursery Plants Research, Beltsville, MD
Ping Kong, Virginia Tech, Virginia Beach, VA
Jo Anne Crouch, USDA, ARS, Foreign Disease & Weed Science Research, Ft. Detrick, MD

James LaMondia, Connecticut Agricultural Experiment Station, Windsor, CT
Jay Pscheidt, Oregon State University, Corvallis, OR
Luisa Santamaria, Oregon State University, Aurora, OR
Nina Shishkoff, USDA, ARS, Foreign Disease & Weed Science Research, Ft. Detrick, MD
Karen Snover-Clift, Cornell University, Ithaca, NY

ADVISORY PANEL & LIAISON TO AMERICANHORT

Jill Calabro (Chair), Sr Product Development Manager, Valent USA Corporation, Walnut Creek, CA
Lynn Batdorf, Boxwood Cultivar Registration Authority, International Society for Horticultural Science
Frank Collier, Owner, Pleasant Cove Nursery, Rock Island, TN
Michael Gaines, President, CW Arborists, Ltd., Sagaponack, NY
Laura Gladwin, Plant Health Manager, Everde Growers, Forest Grove, OR
John Keller, Planning & Research Vice President, Monrovia – Grow Beautifully in CA, CT, GA, OR
Bennett Saunders, General Manager, Saunders Genetics, LLC., Piney River, VA
Richard Schnall, Vice President, Rosedale Nurseries, Inc., Hawthorne, NY
Casey Sclar, H.O. Smith Endowed Director, The Arboretum at Penn State, State College, PA
Mark Sellew, Owner, Prides Corner Farms, Lebanon, CT
Jennifer Gray (Liaison to AmericanHort), Administrator, Horticultural Research Institute, Washington, DC

DISCLAIMER