United States Department of Agriculture

Progress Report

Title:	**Ecology and Integrated Management of Ambrosia Beetles in Eastern US Orchard and Ornamental Tree Crops**

Sponsoring Agency	NIFA	**Project Status**	ACTIVE
Funding Source	Non Formula	**Reporting Frequency**	Annual
Accession No.	1027493	**Grants.gov No.**	GRANT13367754
		Award No.	2021-51181-35863
Project No.		**Proposal No.**	2021-07812
Project Start Date	09/01/2021	**Project End Date**	08/31/2025
Reporting Period Start Date	09/01/2022	**Reporting Period End Date**	08/31/2023
Submitted By	Christopher Ranger	**Date Submitted to NIFA**	11/28/2023

Program Code: SCRI **Program Name:** Specialty Crop Research Initiative

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Recipient Organization

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Entomology
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{NO DATA ENTERED}
Agricultural and Applied Economics

Non-Technical Summary

Exotic ambrosia beetles established in the U.S. are emerging as highly destructive pests in apple and pecan orchards and continue to be damaging insects of trees in ornamental nurseries. Infestations are a major source of revenue losses in these three commodity groups. Substantial losses have been reported throughout the eastern U.S. Ambrosia beetles are consistently ranked among the most concerning insect pests of horticultural tree crops in the eastern U.S. Rapid branch dieback and tree death on alarming scales are commonly observed following infestations due to their wood-boring behavior and association with symbiotic and secondary microorganisms. A multi-disciplinary team has been assembled to conduct field and laboratory research to maximize tree health and reduce tree vulnerability, optimize monitoring tactics, identify chemical and biological alternatives to broad-spectrum insecticides, determine the economic impacts of ambrosia beetles, and transfer new knowledge via outreach and extension to end-users. The expected accomplishments of this research include: (1) improving the understanding of stakeholders across the three commodity groups about ambrosia beetle monitoring and management; (2) implementing pest management tactics for ambrosia beetles beyond solely relying on preventive applications of broad-spectrum insecticides; (3) establishing and disseminating knowledge about the economic impact and cost:benefit ratio of managing ambrosia beetles; and (4) determining effective outreach avenues and expanding IPM tactics to reduce the risk of ambrosia beetle attacks.

The collaborative nature of this project will facilitate cooperation among researchers, extension, and stakeholders resulting in productive outcomes to solving an emerging agricultural issue. Economic benefits will be realized by decreasing the negative economic impacts of ambrosia beetle through prevention of tree loss, increasing marketability of nursery trees, sustained orchard production, reduced management inputs by growers, and improved profitability. Social benefits from this project include improved knowledge and research-driven decision making for growers in their respective production systems. Furthermore, reducing applications of broad-spectrum insecticides, particularly during spring months, will reduce impacts on pollinating

insects and end-users and enhance environmental stewardship within communities. Addressing these pest management issues can help enhance grower and farmworker health and quality of life by reducing exposures to harmful chemicals.

Accomplishments

Major goals of the project

Exotic ambrosia beetles established in the U.S. are emerging as highly destructive pests in apple and pecan orchards and continue to be damaging insects of trees in ornamental nurseries. Ambrosia beetle nfestations are a major source of revenue losses in these three commodity groups (i.e., apples, pecans, ornamentals). Infestations result in perforated stems, oozing sap, bark staining, branch dieback, and rapid tree death. Ambrosia beetles can render trees unmarketable, decrease integrity of surviving trees, and make trees vulnerable to infection. This project will address the needs of stakeholders in the Eastern U.S., but will have applications to stakeholders across the U.S. where ambrosia beetles and horticultural tree crops overlap. Stakeholder needs were identified through the Ambrosia Beetle Working Group supported by the Southern IPM Center using a comprehensive stakeholder survey and in-person and virtual meetings attended by researchers, extension specialists, agents, and growers affiliated with eastern and southeastern US states. The goal of the proposed research and outreach activities align with the priorities of stakeholders to develop sustainable management practices for ambrosia beetles that maximize tree health and reduce tree vulnerability, optimize monitoring tactics, and identify chemical and biological alternatives to broad-spectrum insecticides. A systems approach will be used to achieve our overall goal of developing sustainable ambrosia beetle management strategies in our three commodity groups by integrating expertise on plant physiology, horticultural science, chemical ecology, plant pathology, insect-microbe interactions, engineering, applied insect ecology, biocontrol, economics, and social science.

A multi-disciplinary team of experts has been assembled to address the following objectives:

Objective 1) Predict the risk of infestations in orchard and nursery crop systems through improved understanding of ambrosia beetle biology and ecology. The following sub-objectives will be addressed: 1a) Characterize abiotic stressors that induce ethanol production and ambrosia beetle attacks, 1b) Characterize biotic plant stress-related factors that influence ambrosia beetle attacks, 1c) Assess the pathogenicity and virulence of auxiliary and symbiotic fungi associated with ambrosia beetles to elucidate the basis for branch die-back and tree death, and 1d) Determine ambrosia beetle dispersal and attack patterns within agro-ecosystems and relate to landscape level factors.

Objective 2) Develop novel tools to enhance the accuracy and precision of ambrosia beetle infestation and monitoring tactics. The following sub-objectives will be addressed: 2a) Evaluate trapping tactics and lure release rates for species-specific monitoring of ambrosia beetles and correlating trap captures with attacks, and 2b) Develop and compare existing and portable technologies to monitor tree ethanol production in orchard and nursery crop systems.

Objective 3) Implement comprehensive management strategies. The following sub-objectives will be addressed: 3a) Compare new and current insecticidal active ingredients at different timings and frequencies to reduce ambrosia beetle attacks, 3b) Test and integrate repellents and attractants into a push-pull strategy, 3c) Evaluate plant defense elicitors for promoting tree health and inhibiting ambrosia beetle attacks and/or colonization, and 3d) Assess antagonistic fungi and entomopathogenic nematodes against ambrosia beetles and their symbiotic fungi.

Objective 4) Determine the economics of ambrosia beetle damage and control interventions on orchard and ornamental tree crop stakeholders. The following sub-objectives will be addressed: 4a) Quantify the commodity-specific economic impact of ambrosia beetles, 4b) Determine the risk adjusted cost-benefit framework and feasibility of alternative management tactics for ambrosia beetles, and 4c) Identify social barriers for technology adoption and facilitators to enhance grower acceptance of improved strategies.

Objective 5) Transfer research-based information to stakeholders. The following sub-objectives will be addressed: 5a) Developing a publicly accessible centralized website and project specific social media, 5b) Promote existing land grant Extension programs, 5c) Evaluating stakeholder reaction and utilization to Extension efforts, and 5d) Coordinate with other Regional IPM Centers to increase promotion of project outputs and calls for participation.

What was accomplished under these goals?

Objective 1) Predict the risk of infestations in orchard and nursery crop systems through improved understanding of ambrosia beetle biology and ecology.

- Co-PIs at NCSU determined the effect of the interaction between apple rootstocks and water stress on soil and plant

water status, leaf gas exchange, and ambrosia beetle (AB) colonization. 'G-41' trees tended to have higher transpiration, stomatal conductance, and assimilation rate than 'B-9' and 'EMLA-7' trees. Co-PIs at NCSU, USDA-ARS (OH), and TSU conducted a series of studies to determine main effects and interactions of water stress on plant stress, ethanol production, and AB attack. In short, flood stress, but not drought stress, lead to mass attacks by ABs.

• Co-PIs at NCSU and Cornell isolated auxiliary and symbiotic fungi from ABs. Fusarium and Trichoderma spp. were commonly recovered from beetles and galleries. Phytopathogens of apple were rare. Fusarium spp., but not AB symbionts, exhibited pathogenicity to apple shoots.

• Fire blight (shoot blight) experiments were deployed in OH, NY, PA, and NC to evaluate the potential of fire blight infection of apple to attract ABs and produce ethanol in potted apple trees. In PA, OH, and NC, fire blight infection resulted in fewer AB attacks than flood stress.

• Co-PIs with the USDA-ARS (Wooster, OH) demonstrated that ethanol and acetic acid in host tree tissues increases the attraction of ABs, burrowing, and offspring production.

• A study was initiated to learn more about habitat suitability and beetle distribution based on landscape factors such as elevation, species composition of woodlots adjacent to tree fruit production areas, and flood risk. Results indicate that AB species respond differently to the observed landscape factors.

Objective 2) Develop novel tools to enhance the accuracy and precision of ambrosia beetle infestation and monitoring tactics.

• Co-PIs at Cornell Univ. compared trap types for ABs. After two years of our trap comparison study, clear sticky traps with ethanol bait captures more beetles than the other trap types tested.

• Co-PIs at UGA, USDA-ARS (OH and GA), NCSU, and VT deployed expansive grids of traps within cooperating commercial nurseries, apple orchards, and pecan groves to characterize dispersal patterns of ABs. ABs disperse from woodlots into neighboring nurseries and will fly at least 100 m into the interior of nurseries.

• Co-PIs at TSU, UGA, and USDA-ARS (Wooster, OH) conducted experiments to evaluate portable devices for detecting the emission of ethanol from stressed trees. A 3-D printed sensor mounting device for housing a commercially available sensor has been developed. The sensor mounting device is moderately successful.

• Co-PIs compared low vs high release rates for ethanol using baited traps and cored bolts filled with ethanol. Higher release rates from lures generally captured more beetles than lower release rates. Similarly, cored bolts filled with 90% ethanol are generally more attractive to ABs than 10% ethanol.

• 263 reports from 10 reporters were added to the online AB monitoring system shown on StopAB.org through EDDMapS. Total data set now includes 2,099 records of AB activity from 20 reporters.

• Co-PIs at UGA initiated a study to determine the risk of AB emergence patterns from pine-dominated and mixed pine-hard wood woodlots in Georgia.

Objective 3) Implement comprehensive management strategies.

• Insecticide efficacy trials were conducted by co-PIs at multiple locations. Permethrin and bifenthrin were consistently the only active ingredients that reduced AB attacks. Surfactants were not effective at enhancing insecticide activity.

• Co-PIs at the UGA also evaluated the residual longevity of bifenthrin and found that 0- and 7-day bifenthrin treated bolts had significantly lower attacks compared to control, 28-, 21-, and 14-day bolts.

• Steinernema riobrave was the most effective strain against the granulate AB (X. crassiusculus), while S. carpocapsae was the most effective strain against the black stem borer (X. germanus).

• Co-PIs at multiple locations evaluated integrating repellents and attractants into a push-pull strategy for protecting vulnerable trees. The "push-pull" strategy testing verbenone + methyl salicylate (push) and ethanol-baited traps (pull) significantly reduced attacks on flood stressed dogwood trees deployed in ornamental nurseries in Ohio and other locations. Yet, results were inconsistent at other locations and the push-pull strategy continues to be elusive.

• Co-PIs at TSU tested a stress reducer treatment. Dogwoods were pre-treated with foliar sprays 7 days prior to flooding with three reported stress mitigating products: Regalia (biofungicide extract of Reynoutria sachalinensis), Reliant (fungicide/fertilizer phosphorous acid) and Axiom (harpin protein). None of the products reduced attacks to acceptable levels and in at least one trial, Axiom had more attacks than the flooded control.

• Co-PIs at the UF conducted a first screening of their assembled Trichoderma collection. Twenty-three strains were included in the metabolite in vitro assay to test their antagonistic effect against the laurel wilt pathogen (the ambrosia fungus Harringtonia lauricola). Six Trichoderma strains produced metabolites that inhibit the growth (>75%) of the laurel wilt pathogen. A protocol for inoculating avocado seeds with potential antagonistic and endophytic Trichoderma was also developed.

• Co-PIs at the USDA-ARS (Ithaca, NY) challenged three species of AB with three commercially available insect-killing fungi. All three fungi could kill all three beetle species at the highest dose, but at lower doses, beetle survival differed.

• Co-PIs with the USDA-ARS (Byron, GA) evaluated the efficacy of nematodes. Steinernema carpocapsae was the most

effective strain of nematodes against the AB Xylosandrus germanus; S. riobrave was most effective against X. crassiusculus.

Objective 4) Determine the economics of ambrosia beetle damage and control interventions on orchard and ornamental tree crop stakeholders.

• Agricultural economists with the UGA, Auburn Univ., and UTenn have developed producer and consumer surveys. The grower survey has been developed and will identify the economic impact of AB on production. The end customer survey to identify end consumer familiarity with and response to ABs has been developed and IRB approval obtained with a target launch in early 2024. In the next reporting period the bulk of objective 4 will be completed. During the next reporting period, the economics team will launch the survey using a panel of green industry stakeholders to assess the perceived current and potential economic impact of ABs on their operations and the industry.

Objective 5) Transfer research-based information to stakeholders.

• A total of 58 presentations were given to stakeholders representing growers, producers, and the scientific community.
• Publications in peer-reviewed journals, trade articles, and theses/dissertations are listed under Products and Other Products.
• The website https://stopab.org/ (established in 2022) provides the first level of outreach efforts. The site targets academics working with ABs, growers working in pecan, nursery, or tree fruit, and individuals wanting to know more about the project activities and impacts.
• AB monitoring and management tactics have been established in all three cropping systems. AB flight seasonal activity is available in near real time through the website to provide growers and extension agents with activity.
• Pages on how ABs are managed in apple and about AB fungi have been released (https://stopab.org/management/apple/ and https://stopab.org/about/about-ambrosia-fungi/). Overall, www.stopab.org has received 1,130 page views from 417 users. Two stakeholder advisory panel meeting videos, three research manuscripts, an extension fact sheet, and a popular press article were also published on the site.

What opportunities for training and professional development has the project provided?

• Graduate (1) and undergraduate (3) students were trained by VT staff on insect identification, scouting techniques and experimental design.
• Growers, Extension agents, crop consultants, and agrichemical industry representatives attended "Apple Field Day" at the NCSU Mountain Horticultural Crops Research and Extension Center to learn about the impact and interactions of ambrosia beetles, associated auxiliary fungi, and water stress in apple trees
• USDA-ARS researchers in Wooster, Ohio are supervising two postdoctoral researchers being paid by the SCRI funding. Three undergraduate interns were supervised in spring/summer 2023, one of which formally participated in the Ohio Research Internship Program through The Ohio State University. The ORIP intern conducted research to compare the impact of drought stress and flood stress on ambrosia beetle host selection and colonization, along with the induction of stress-induced ethanol production.
• A USDA-ARS (Wooster, OH) lab technician provided training in (1) rearing ambrosia beetles to a PhD student from a Co-PIs lab at Cornell (October 24-25, 2023), (2) volatile sampling and analysis by SPME-GC-MS was provided to two postdocs and one PhD student visiting from a Co-PIs lab at NCSU (March 14-15, 2023), (3) ambrosia beetle rearing and identification to a technician from a co-PIs lab at Penn State Univ. (March 20-23, 2023), and (4) ambrosia beetle identification, setting up nematode field and lab efficacy bioassays (June 20-22, 2023).
• UGA staff participated in the 2023 Georgia Pecan Annual Conference at Georgia National Fairgrounds, Perry, GA, on March 28, 2023.
• Co-PI Apurba Barman attended 2-day Bark Beetle Academy help at University of Florida, Gainesville, FL from October 20-21, 2022 to learn about identification of different ambrosia beetle and related species.
• Co-PIs at TSU trained a summer intern and postdoctoral scientist in beetle behavior, identification, and management of ambrosia beetles. One PhD and two Master's students at TSU were trained in experimental design, data collection, analysis and scientific writing and presentations.
• A postdoc from USDA-ARS (Wooster, OH) was hosted by a co-PI at Virginia Tech to learn about light reflectance collection and imagery processing. The ARS postdoc in turn provided training to the VT staff about ambrosia beetle identification.
• An intern at UF was trained in plant husbandry, including the development and implementation of IPM management for greenhouse grown plants. The intern also attended and presented in the Florida Phytopathological Society meeting, May 17-19, Immokalee, FL, USA.
• UF postdoc attended and presented in the Florida Phytopathological Society meeting, May 17-19, Immokalee, FL, USA. The postdoc also attended the Laurel Wilt and Phytophthora root rot grower workshop, June 08, 2023, Homestead, FL, USA. The UF postdoc interacted with industry representatives through two visits to a co-PIs UF lab. One by Bioworks and one by

IQ-Biotech, both companies produce Trichoderma-based products among other biopesticides.

- UF Intern attended the Laurel Wilt and Phytophthora root rot grower workshop, June 08, 2023, Homestead, FL, USA.
- UF co-PI presented at the Laurel Wilt and Phytophthora root rot grower workshop, June 08, 2023, Homestead, FL, USA; attended and presented at the Entomological Society of America Invasive Species Tour, September 13, 2023, Orlando, FL, USA; and attended and presented at the International Congress of Plant Pathology, August 21-25, 2023, Lyon, France.
- Members of a co-PIs UF lab hosted a co-PIs postdoc from the USDA-ARS (Byron, GA) for five days (10-15 July 2023) to learn about beneficial nematodes and their use as biological control agents of bark and ambrosia beetles. The UF staff learned how to propagate nematodes, isolate their symbiotic bacteria, and apply nematode-based products to bolts and rate the efficacy of the treatments.
- A technician at Clemson Univ. received training on processing samples, field collection and ambrosia beetle identification.
- Co-PIs with the USDA-ARS in Ithaca, NY hired and are co-mentoring a postdoctoral researcher in ambrosia beetle biology, mycology, molecular genetics, and insect pathology. This includes different laboratory rearing methods of the beetle, culturing a variety of fungi (symbiotic, entomopathogenic, mycoparasitic, and other species commonly associated with beetle cultures), molecular identification of isolates, and conducting bioassays with insect-killing fungi. The post-doc is investigating the efficacy of entomopathogenic and mycoparasitic fungal products against multiple ambrosia beetle species.
- Co-PIs at UGA trained a temporary hourly employee (a research assistant) to help with sorting ambrosia beetle trap contents.
- At PSU, two program technicians and three summer student assistants were actively involved in the project. During the winter 2022/2023 project entomology technician participated in hands-on training on ambrosia beetle identification intensive training provided by the project personnel from USDA lab in Wooster, OH.
- A postdoc with the USDA-ARS (Byron, GA) trained other individuals in ambrosia beetle identification and rearing techniques including technicians and undergraduate interns.

How have the results been disseminated to communities of interest?

- 58 presentations given on ambrosia beetles to scientific and/or stakeholder audiences. (Full list under "Other Products")
- Co-PIs at NCSU Local apple growers and the general public were invited to the Mountain Horticultural Crop Research and Extension Center (MHCREC) to learn more about apple production, disease control, and insect control. Results from research being conducted at the MHCREC regarding habitat suitability and risk management were also shared via oral presentation and posters at the Field Day activities NCSU Apple Field Day, August 10, 2023.
- An ambrosia beetle management page specific to apple production was added to the StopAB.org website.
- VT co-PI Guided a tour of 20 Certified Arborists at the Hampton Road AREC and presented information on ambrosia beetle research projects. July 25, 2023. Virginia Beach, VA.
- VT co-PI led a class for 30 community college students from TCC. The class included a presentation on ambrosia beetle biology and management, as well as showing insect displays and a hands-on workshop on insect collection. September 6, 2023. Virginia Beach, VA.
- Communication with project team and stakeholders at Stakeholder advisory meeting. Website is delivering information to academics working on ambrosia beetles, growers working in pecan, nursery, and tree fruit, and individuals wanting to better understand the outputs and impacts of this project.
- Co-PI at Clemson Univ. disseminated information via the biweekly newsletter and made available via GrowerTalks (Ball Publishing). Current subscription to the newsletter is more than 27,800.
- Grower Field Day: 100 North Carolina nursery growers educated on 8 Sept. 2023; 80 nursery growers were educated on 23 Feb. 2023.
- Grower Information Shared: Pest alerts including ambrosia beetle recommendations were shared with Phillip Haar (East Tenn. Nursery Specialist) for an upcoming grower newsletter. 12 Apr. 2023.
- Youth Outreach: Warren County Third Grader Entomology Event: >200 students, 26 Sept. 2023; >700 students, 21 Sept. 2023; >60 students, 28 June 202; >150, 20 June 2023.
- Nursery pest information shared with NCSU Specialized Agent, Ornamental Nursery and Greenhouse Crops NC State Extension-Western Region, North Carolina State University) on management and trapping of camphor shot borer (a pest causing issues in NC nurseries) via a journal article and 1-hour zoom conference. 12 May 2023.
- Nursery Industry Ambrosia Beetle Alerts: Ambrosia beetle alerts were issued on 24 Mar. and 8 Apr. 2023 based on trap collections via Dr. Amy Fulcher (Univ. Tenn. Extension Specialist and Professor for Sustainable Ornamental Plant Production and Landscape) and Tennessee nursery associations.
- Consultation: Information was shared with a North Carolina peach tree grower pertaining to Xylosandrus ambrosia beetle tree attacks. 3 Mar. 2023.
- Nursery Association Newsletter: A short section on ambrosia beetles and the need to scout for early detection of damage was prepared for Tennessee Department of Agriculture Plant Inspector Gary Clendenon's Middle Tennessee

Nursery Association Newsletter article. 9 Feb. 2023.

• Guided a tour of 20 Certified Arborists at the Hampton Road AREC and presented information on ambrosia beetle research projects. July 25, 2023. Virginia Beach, VA.

• Led a class for 30 community college students from TCC. The class included a presentation on ambrosia beetle biology and management, as well as showing insect displays and a hands-on workshop on insect collection. September 6, 2023. Virginia Beach, VA.

• Stakeholder meeting: Highlight of research being conducted by USDA-ARS-Application Technology Research Unit scientists. Hosted by The Ohio State University Extension's--Next Generation Nursery and Greenhouse Research Workshop.

• Co-PIs with the USDA-ARS (Ithaca, NY) provided informal training of extension agent to identify relevant ambrosia beetles in upstate New York. Informal training was also provided to NY apple growers on ambrosia beetles and their potential management using microbial products during site selection visits to four orchards.

• Co-PIs with the USDA-ARS (Byron, GA) published a report in a trade journal that reaches pecan growers across the U.S. (Pecan South) concerning ambrosia beetles and pecan. Additionally, pecan producers were reached during the Georgia Pecan Growers Field Day (about 250-300 attendees) where ambrosia beetles and pecan were discussed.

• Co-PI efforts at Cornell were made apparent at the LOF summer apple fruit tour in August 2023, Albion NY. There were 256 growers in attendance.

• Ambrosia beetles and research efforts have been presented by Co-PIs at Cornell on the scaffolds podcast https://podcasters.spotify.com/pod/show/scaffolds?%24web_only=true&_branch_match_id=1243604277815335201&utm_source=web&utm_campaign=web-share&utm_medium=sharing&_branch_referrer=H4sIAAAAAAAAA8soKSkottLXLy7IL8lMq0zMS87IL9ItT03SSywo0MvJzMvWT9UPMDMxsixMrAytTAIA6xqX6jAAAAA%3D

• Co-PIs with the USDA-ARS (Byron, GA) shared in-person presentations at the Entomological Society of America, Entomological Society of Canada, and Entomological Society of British Columbia Joint Annual Meeting (Vancouver, Canada), Southeastern Pecan Growers Conference (Gulf Shores, AL, Feb. 2023), Entomological Society of America Southeastern Branch Meeting (Little Rock, AR, March 2023), Georgia Pecan Growers Association Annual Conference and Trade Show (Perry, GA, March 2023, Georgia Entomological Society (Helen, GA, April 2023), Society for Invertebrate Pathology (College Park, MD, Aug. 2023), and Georgia Pecan Growers Association Fall Field Day (Byron, GA, Sept. 2023), Western Pecan Growers conference (Las Cruces, NM, March 2023), Oklahoma Pecan Growers meeting (Tulsa, OK, June 2023).

What do you plan to do during the next reporting period to accomplish the goals?

{Nothing to report}

Participants

Actual FTE's for this Reporting Period

Role	Non-Students or faculty	Students with Staffing Roles			Computed Total by Role
		Undergraduate	Graduate	Post-Doctorate	
Scientist	4.2	4.8	7.5	8.3	24.8
Professional	0	0	0	0	0
Technical	6.1	0	0	0	6.1
Administrative	0	0	0	0	0
Other	0	0	0	0	0
Computed Total	10.3	4.8	7.5	8.3	30.9

Student Count by Classification of Instructional Programs (CIP) Code

Undergraduate	Graduate	Post-Doctorate	CIP Code
0	1	0	01.01 Agricultural Business and Management.
1	2	3	26.03 Botany/Plant Biology.

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Undergraduate	Graduate	Post-Doctorate	CIP Code
8	7	7	26.07 Zoology/Animal Biology.

Target Audience

The primary audience for this research is any grower who works with an agricultural commodity (e.g., nut trees, fruit trees, ornamentals) that are used as hosts for ambrosia beetle. Currently, insecticides are the primary method of ambrosia beetle management. The primary methods for sharing this research will be done through extension and outreach including grower meetings and publications that target these audiences (e.g., The Pecan Grower magazine). Target audiences reached by our efforts to improve the management of exotic ambrosia beetles include commercial and homeowner growers/producers of apple, crop consultants, peach and pecan crops in the Eastern, mid-Atlantic, and Southeastern U.S.; ornamental tree and shrub producers in the Eastern, mid-Atlantic, and Southeastern U.S.; avocado growers in the Southern U.S.; retail nurseries and garden centers; arborists, ground managers, and landscape care professionals; county and regional extension agents; pest management specialists; master gardeners; agrichemical industry representatives; and the scientific community, including entomologists, plant pathologists, biologists, economists, engineers, undergraduate students, graduate students, and postdoctoral researchers. Growers and the public were provided with information on ambrosia beetles. For example, Tennessee and other southeastern regional plant inspectors were trained in identification and management for ambrosia beetles. Scientists were presented with recent research findings. Our results reached a wider audience through extension activities such as the Tennessee State University Extension Publications and Tennessee Greentimes publications. The apple grower stakeholders of NY collectively represent more than 600 farm business and 50,000 acres of commercial apples in six growing regions. Target audiences include over 1,500 fruit growers in PA and equivalent numbers in the adjacent mid-Atlantic fruit growing regions of MD, VA, WV, NY, NJ, and NC. The website is targeted at academics working on ambrosia beetles, growers working in pecan, nursery, and tree fruit, and individuals wanting to better understand the outputs and impacts of this project.

Products

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Published	2022	NO

Citation

Dzurenko, M., Galko, J., Kulfan, J., Vá?ka, J., Holec, J., Saniga, M., Zúbrik, M., Vakula, J., Ranger, C.M., Skuhrovec, J., Jauschová, T., Zach, P. 2022. Can the invasive ambrosia beetle Xylosandrus germanus withstand an unusually cold winter in the West Carpathian forest in Central Europe? Folia Oecologica. 49: 1-8.

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Published	2023	NO

Citation

Gugliuzzo, A., Kreuzwieser, J., Ranger, C.M., Tropea Garzia, G., Biondi, A., Biedermann, P.H.W. 2023. Volatiles of fungal cultivars act as cues for host-selection in the fungus-farming ambrosia beetle Xylosandrus germanus. Frontiers in Microbiology. 14: 1151078

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2023	NO

Citation

Halliday, P., A. Monterrosa, A. Acebes-Doria, J. Oliver, and C. Ranger. 2023. Field guide to ambrosia beetles of agricultural importance in the eastern and southern United States. (https://extension.uga.edu/publications/detail.html?number=C1239). Univ. of Georgia Extension Circular 1239. (Aug.

Accession No. 1027493 **Project No.**

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Published	2023	YES

Citation

Parajuli, M., C. Oksel, K. Neupane, C.M. Ranger, J.B. Oliver, K.M. Addesso, and F. Baysal-Gurel. 2023. Acibenzolar-S-methyl induces resistance against ambrosia beetle attacks in dogwoods exposed to simulated flood stress. Journal of Insect Science. 23(4): 12; 1-8.

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2023	NO

Citation

Poudel, A., A. Gautam, K. Addesso, J. Oliver, and G. Roper. 2023. Ambrosia beetles important to Tennessee nurseries. Tenn. State Univ. Cooperative Extension Publ. ANR-ENT-02-2023 (TSU-23-148(B)-15c-13515). 31 Jan. 2023.

Type	Status	Year Published	NIFA Support Acknowledged
Theses/Dissertations	Published	2023	NO

Citation

Poudel, A. 2023. Ecology and Integrated Management of Ambrosia Beetles in Ornamental Nursery Trees. Masters Thesis. Tennessee State University, Nashville, TN.

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Published	2023	YES

Citation

Ranger, C.M., Parajuli, M., Gresham, S., Barnett, J., Villani, S., Walgenbach, J., Baysal-Gurel, F., Owen, J., and M. E. Reding. 2023. Type and duration of water stress influences host selection and colonization by exotic ambrosia beetles (Coleoptera: Curculionidae). Frontiers in Insect Science. doi.org/10.3389/finsc.2023.1219951

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Published	2023	NO

Citation

Sutherland, R., Meurisse, N., Pugh, A.R., Ranger, C.M., Reding, M.E., Kerr, J.L., Russell, J., Withers, T.M. 2023. Phenological observations and trapping tactics for the granulate ambrosia beetle Xylosandrus crassiusculus (Coleoptera: Curculionidae, Scolytinae) in New Zealand. Agricultural and Forest Entomology. doi: 10.1111/afe.12558

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Published	2023	YES

Citation

Williamson, Z. V., Blaauw, B. R., & Joseph, S. V. (2023). Effects of permethrin on ambrosia beetles (Coleoptera: Curculionidae: Scolytinae) in ornamental nurseries. Journal of Insect Science, 23(4), 4.

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2023	NO

Citation

Barman, A. and A. Sawyer. 2023. Tiny insect, but big impact: should we be concerned with ambrosia beetles? The Pecan Grower. Vol. 35(1): 46-51.

Accession No. 1027493 **Project No.**

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2023	NO

Citation

Barman, A. and A. Sawyer. 2023. 2023 Ambrosia beetle update. UGA Pecan Extension (A website from UGA Cooperative Extension). https://site.extension.uga.edu/pecan/2023/02/2023-ambrosia-beetle-update/

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2023	NO

Citation

Cottrell, T., Barman, A., and W. Hudson. 2023. Keeping up with ambrosia beetles. Pecan South Magazine. Vol. 56 (2): 6-13. https://www.pecansouthmagazine.com/magazine/article/keeping-up-with-ambrosia-beetles/

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2023	NO

Citation

Parajuli, M., C. Oksel, J. B. Oliver, K. M. Addesso, and F. Baysal-Gurel1. 2023. Integration of control strategies for management of Phytophthora root rot and ambrosia beetles in nursery trees. Tennessee Greentimes (Mar. 2023) https://issuu.com/leadingedgepubs/docs/tn-greentimes-2023-spring/s/21599813

Type	Status	Year Published	NIFA Support Acknowledged
Other	Published	2023	NO

Citation

Slusher, E.K. and D. Shapiro-Ilan (2023) Use of entomopathogenic nematodes as a management tactic for weevil pests in Pecan. Pecan South Magazine. May 2023 (56:3): 30-37.

Type	Status	Year Published	NIFA Support Acknowledged
Theses/Dissertations	Published	2023	NO

Citation

Gresham, S. 2023. Association of Xyleborine ambrosia beetles and phytopathogens with declining apple trees in North Carolina. Disseration submitted to the Department of Entomology and Plant Pathology, North Carolina State University, Raleigh, NC.

Other Products

Product Type

Audio or Video

Description

Interview:
UGA Pecan Update – February 2023 (Interview with Dr. Apurba Barman)
https://soundcloud.com/andrewsawyer-2/uga-pecan-update-february-2023?utm_source=clipboard&utm_medium=text&utm_campaign=social_sharing

Product Type

Other

Description

Website, including Monitoring Network:
The www.stopAB.org was launched in FY22 and is active. It includes a database of ambrosia beetle flight activity in participating regions of the U.S.

Ambrosia Beetle Activity Monitoring Network. (2023). Trap Catch Data. [Site based trap catch data]. Accessed on 8/31/2023 from www.eddmaps.org. 263 records from 10 reporters.

Product Type

Physical Collections

Description

Researchers with the University of Florida assembled an ambrosia fungi collection (~100 strains, several genera), from locally collected beetles associated to tropical fruit trees and landscape ornamentals (palms/woody ornamentals in the landscape). They also assembled a Trichoderma strain collection (25 strains from different sources). These strains have been barcoded (ITS/LSU marker). These, together with the ones that will be isolated from commercially available formulations, will be used in the in vitro pathogenicity assays. Selected strains, based on their antagonistic performance, will be used in the in-planta assays. We will screen these strains under the framework “no fungi, no beetles” since the objective is to prevent the growth of the nutritional symbiont so the beetle is unable to survive

Product Type

Instruments or Equipment

Description

A prototype volatile sampling chamber 3-D printed by engineers at the University of Georgia is being evaluated to detect the emission of stress-induced volatiles (i.e., ethanol) released by trees that attract ambrosia beetles.

Product Type

Databases

Description

A USDA Box folder continued to be maintained that stores documents, presentations, photos, etc. supporting the USDA-NIFA-SCRI project. All program staff have access to the folder and sub-folders. The folder includes presentations of monthly meetings (Nov. 2021 – present) organized and led by PD Ranger with all levels of program staff to discuss administrative topics pertaining to the SCRI ambrosia beetle grant. The folder also includes virtual presentations organized and held in 2022 and 2023 to update the Stakeholder Advisory Panel on administrative and research activities. PD Ranger, Objective Leaders (Villani, Joseph, Chong, Campbell, and LaForest), and postdocs/students gave presentations.

Product Type

Other

Description

58 scientific and/or extension outreach paper or poster presentations were given during the rating period.

Altland. Impacts of water stress on tree susceptibility to exotic ambrosia beetles. Ohio Research Internship Program. Ohio State University. 7/23.
Addesso. Wood boring beetles and Japanese maple scale in nurseries. Horticultural Inspection Society - Southern Chapter Meeting. Tennessee State University. 9/19/2023. McMinnville, TN 9/23.
Baniszewski. Seasonal patterns of ambrosia beetle (Coleoptera: Scolytidae) species in Ohio. Entomological Society of America. 11/22. Vancouver, British Columbia, Canada.

Barman. Ambrosia beetle infestations in pecan and citrus crops. Georgia Entomological Society. 4/23.
Del-Pozo. Improving the Management of Ambrosia Beetles as Pests of Ornamental Trees. ESA annual meeting. 11/22. Vancouver, Canada.
Del-Pozo. Managing ornamental pests. Virginia Cooperative Extension. 12/22. Henrico, VA; Virginia Turf Council. 1/23, 2/23, Richmond, VA. 2/23 Glen Allen, VA.
Del-Pozo. Management of arthropods. Atlantic City, NJ. 3/23. Smithfield, VA. 3/23. Goochland, VA. 3/23.
Del-Pozo. Improving Monitoring Efforts for Ambrosia Beetles in Virginia. ESA Eastern Branch. Providence, RI. 4/23
Del-Pozo. Research Update on Relevant Pests for Virginia Nurseries. ESA Eastern Branch. 3/23. Providence, RI.
Del-Pozo. From red-headed flea beetle to box tree moth: an update on emerging and invasive pests in ornamentals. Blacksburg, VA. 3/23, Raleigh, NC. 8/23, Virtual 9/23.
Gazis. Laurel Wilt Disease Management: Current Strategies and Ongoing Lines of Research. International Plant Pathology Congress. Lyon, France. [poster] 8/23)
Gresham. Cryptic Erwinia amylovora infections induce attack by exotic ambrosia beetles. 2023 APS Meeting, Denver, CO.
Gresham. Phytopathogen Infection Increases Attractiveness of Apple Trees to Ambrosia Beetles. 2022 ESA, Vancouver Canada.
Gresham. Rapid Apple Decline Update: Stress, Beetles, and Opportunistic Fungi. Ornamental Workshop on Insects and Diseases, Raleigh, NC. 10/22
Gresham. Competition between Ambrosia Beetle Nutritional Symbionts and Common Filamentous Fungi on Ethanol-Enriched Media. Ornamental Workshop on Insects and Diseases, Raleigh, NC, 10/22
Hayter. Updates on RAD: Ambrosia Beetles, Physiological Indicators, and Disease. Mountain Horticultural Field Day, 11/23
Joseph. Biology and management of invasive and emerging pests in landscapes. Atlanta, GA. 2023; Griffin, GA. 2023; Cairo, GA. 2023; Atlanta, GA. 2023; Hartwell, GA. 2023; virtual 2023.
Joseph, S. 2023. UGA Extension Event: Biology and management of ornamental pests: Zoom session to 12 educators. 2022.
Krawczyk. Seasonal orchard fruit IPM updates conducted at 8 grower's orchards located in main PA fruit growing regions: Lancaster, PA, Ortanna, PA, Chambersburg, PA, Kempton, PA, Paxinos, PA, New Paris, PA, New Wilmington, PA, North East, PA. 2023.
Navia-Urrutia. Re-evaluating the use of propiconazole in controlling laurel wilt in avocado orchards in south Florida. Florida Phytopathological Society. 5/23
Oliver. An overview of ambrosia beetles and control options for nursery production. Nursery Field Day. Lenoir, NC. 8 Sept. 2023; Middle Tennessee Nursery Association Monthly Meeting. 23 Feb. 2023.
Oliver. Field evaluation of Beetle Guard semiochemical for reducing ambrosia beetle attacks on ethanol-infused bolts or captures in ethanol-baited traps. Southeastern Branch ESA. 3/23. Little Rock, AR.
Parajuli. Effect of plant defense elicitor in preventing ambrosia beetle attacks in flowering dogwoods exposed to simulated flood stress condition. TSU Wide Research Symp. 3/23 Nashville, TN.
Parajuli. Plant defense elicitor reduces ambrosia beetle attacks in flowering dogwoods exposed to simulated flood stress condition. 132nd Meeting of the Tennessee Academy of Science. 18 Nov. 2022. Nashville, TN. (Oral Presentation and Abstract).
Parajuli. Effect of plant defense elicitor in preventing ambrosia beetle attacks in flowering dogwoods exposed to simulated flood stress condition. Prairie View A&M University, TX. 3/23
Parajuli. Research updates on ambrosia beetles and their management. Horticultural Inspection Society. TSU McMinnville, TN 9/23.
Patwa. Transcriptomic analysis of the mycangium from the ambrosia beetle Xylosandrus germanus. Entomological Society of America Vancouver, British Columbia. 11/22.
Poudel. Identification and evaluation of repellent compounds for the management of ambrosia beetles. 132nd Meeting of the Tennessee Academy of Science. Nashville, TN. 11/22.
Poudel. Evaluation of low-cost ethanol detectors for assessing flood stress in dogwood to facilitate field detection of ambrosia beetle susceptible trees. Southeastern Branch of Entomological Society of America Meeting. Little Rock, AR. 3/23.
Poudel. Assessment of the effectiveness of low-cost ethanol detectors in determining flood stress in dogwood (Cornus florida L.) to facilitate on-site detection of trees vulnerable to ambrosia beetles. Annual Tenn. State University-Wide Research Sympos. Nashville, TN. 3/23
Poudel. Assessment of ambrosia beetle attack using repellents in ethanol infused bolts to facilitate its

effective management. Chemical Ecology Student Paper Competition. Joint Entomological Society of America, Vancouver, BC. 11/22
Poudel. Assessment of ambrosia beetle attack using repellents in ethanol infused bolts to facilitate its effective management. Annual Conf. of the Tenn. Entomological Society. Knoxville, TN. 10/22.
Ranger. Acetic acid stimulates burrowing and colonization success of the ambrosia beetle, Xylosandrus germanus. Entomological Society of America, Vancouver, BC. 11/22.
Ranger. USDA-NIFA-SCRI: Ecology and Integrated Management of Ambrosia Beetles in Eastern US Orchard and Ornamental Tree Crops. Entomological Society of America, Vancouver, BC. 11/22.
Ranger. Biology, Ecology, and Management of Ambrosia Beetles Infesting Ornamental Tree Crops. Ohio State University Extension's--Next Generation Nursery and Greenhouse Research Workshop. Painesville, OH. 12/22.
Ranger. 2023. Ecology and integrated management of ambrosia beetles in Eastern US orchard and ornamental tree crops. 2nd Annual Meeting with the USDA-NIFA-SCRI Stakeholder Advisory Panel. (virtual). (January 26, 2023.)
Ranger. Type and duration of water stress influence host selection and colonization by exotic ambrosia beetles. IUFRO - Global challenges and innovative management of bark and wood borers in planted forests. Bordeaux, France. 8/23.
Ranger. Ecology of Anisandrus maiche, a newly established ambrosia beetle in North America. IUFRO - Global challenges and innovative management of bark and wood borers in planted forests. Bordeaux, France. 8/23.
Reding. Influence of pH and Ethanol on Colonization of Wood Bolts by Ambrosia Beetles. ESA. virtual. 11/22.
Reding. Managing Ambrosia Beetles in Ornamental Nurseries. Ohio State University Extension's--Next Generation Nursery and Greenhouse Research Workshop. 12/22.
Salcedo-Sarmiento. Antagonistic and biocontrol potential of Trichoderma spp. against the avocado laurel wilt pathogen Harringtonia lauricola. Florida Phytopathological Society. 5/23.
Vail. A non-ALBOW infesting seasoned wood. Entomological Society of America. Vancouver, BC. 11/22.
Williamson. Effects of permethrin on ambrosia beetles in ornamental nurseries. Southeastern Branch Meeting. Little Rock, AK. 3/23.
Williamson. Effects of permethrin on ambrosia beetles in ornamental nurseries. Georgia Entomological Society Meeting. Helen, GA. 4/23.

Product Type

Audio or Video

Description

Ambrosia beetles and research efforts have been presented by Co-PIs at Cornell on the scaffolds podcast https://podcasters.spotify.com/pod/show/scaffolds?%24web_only=true&_branch_match_id=1243604277815335201&utm_source=web&utm_campaign=web-share&utm_medium=sharing&_branch_referrer=H4sIAAAAAAAAA8soKSkottLXLy7IL8lMq0zMS87IL9ItT03SSywo0MvJzMvWT9UPMDMxsixMrAytTAIA6xqX6jAAAAA%3D

Changes/Problems

{Nothing to report}