S1073: Biological Control of Arthropod Pests and Weeds

Meeting Agenda

March 28, 2022
5-6pm AST (4-5pm EST)

I. Welcome and call to order

II. 2022 Symposium notice:

Climate Change and Biological Control : S1073 Project Highlights
Session Date: Tuesday, March 29, 2022
Session Time: 2:00 PM – 5:00 PM AST
Location: Sheraton Puerto Rico Hotel & Casino, Bahia 2

III. New member introductions

IV. State reports- highlights and discussion

V. Words from our Administrative Advisor: Dr. Saied Mostaghimi

VI. Impact Statements

a) Form committee 2-3 ppl

VII. Spring meetings and reports for group going forward

a) Meeting 2023 SEB Meeting (March 12-15, Little Rock, AR)

b) State reports (accomplishments 2022, plans for 2023)- due late February 2023

VIII. Nominations: New secretary 2023

IX. Other business

Upcoming project re-write

X. Adjournment

S1073 Meeting Notes

March 28, 2022 5-6pm AST (4-5pm EST)

Welcome and call to order.

New member introductions:
None

State reports:
State reports were collected by email by Kris Giles and Steve Frank. The complied reports were sent via email to all members prior to the meeting for review and discussion.

Members were encouraged during the meeting to send any updates asap. Final version is due in 30 days and will be prepared by Steven Frank, NCSU, the incoming president.

Admin Perspective:
Notes from our administrator, Dr. Saied Mostaghimi, were provided to Kris Giles by email and relayed to participants during the meeting. Key points include:

1. New project required. Steve Frank and committee to conduct rewrite.
2. Impact statement needs to be written. Perhaps also by committee.
3. Consider interdisciplinary proposals.
4. Final report to be submitted in 30 days.

Kris Giles requests ideas for potential projects, especially interdisciplinary projects in response to Dr. Mostaghimi's suggestions:

JC Chong (Clemson) suggested proposals related to invasive species since there is no unifying commodity among group members. Group members work on biological control broadly in many different crop and landscape systems.

Norm Lepla encouraged members to make reports as detailed as possible to help people find areas for collaborations.

2023 Meeting:
2023 meeting will most likely be held at the ESA SE Branch in Little Rock, Arkansas based on participant feedback. This will conserve travel resources and time by not planning a separate meeting.

We will plan a symposium around unifying themes among members and their research. Participants encouraged general themes for the symposium topic to encourage new members and to encourage people to think outside the box and conceptualize their work in new ways and

in line with new trends. Topics suggested include: Climate change, urbanization, Invasive species.

Elections. Adam Dale (UF) nominated and elected unanimously as secretary.

Other business.
Money from an old SE biocontrol working group was discovered in a desk drawer and needs to be spent. $3200. Jerome Grant brought this topic to our attention and asked for suggestions on how to use it.

S1073 – BIOLOGICAL CONTROL OF ARTHROPOD PESTS AND WEEDS ANNUAL REPORT 2021-2022

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OTHER PARTICIPANTS: Adam Dale, Carey Minteer, James Cuda, Lance Osborne, Muhammad Ahmed, Norm Leppla, Pasco Avery, Phil Hahn, Sryanka Lahiri.

ACCOMPLISHMENTS

- To discover, assess, and release new biological control agents

Earleaf acacia. *Acacia auriculiformis*, is a fast-growing, evergreen tree from Australia that was purposefully introduced into the United States as an ornamental plant at the turn of the 20th century. It is now listed as a Category I plant on the Florida Exotic Pest Plant Council's 2019 List of Invasive Species. Currently, 89 arthropod species that feed on earleaf acacia in its native range have been found. Several of those arthropods have the potential to be host specific and damaging to the weed. Two of those species, *Calomela intemerata* (Coleoptera: Chrysomelidae) and *Trichilogaster* sp. nov. (Hymenoptera: Pteromalidae), has been introduced into containment labs in Florida for study. So far, *C. intemerata* has been tested on over 40 species of native plants and remains host specific to *A. auriculiformis. Trichilogaster* sp. nov. colonies have been established in containment labs in Florida. Host range testing will begin as soon as colonies are large enough to facilitate testing.

- To characterized and evaluate the impact of native and introduced biocontrol agents

Strawberries. Commercially available biological control agents such as entomopathogenic nematodes (EPNs) and fungi (EPFs), as well as predatory mites were evaluated for chilli thrips, *Scirtothrips dorsalis* management in organic strawberry in field study. Specifically, EPNs *Steinernema feltiae* and *Heterorhabditis bacteriophora*, EPF *Beauveria bassiana* and *Isaria fumosoroseus* Apopka strain 97, and predatory mites, *Amblyseius swirskii* and *Neoseiulus cucumeris* were compared to spinosad insecticide. Results indicated that EPNs and EPFs are needed to apply twice at least within a 7-day interval to achieve both adult and larval suppression comparable to efficacy of spinosad. Predatory mites were effective in suppressing larval chilli thrips only. Results were presented at field days with strawberry growers and a second year of field study is being planned. A manuscript is under preparation currently to be submitted as a peer reviewed research article.

Air potato. Biocontrol herbivores often fail to kill their host plants and their effectiveness can vary from site-to-site. This creates difficulties for managing invasive plant infestations using

classical biological control. We conducted field surveys of 12 air potato populations across Florida and measured cover of air potato, abundance of air potato beetle, and herbivory damage to the plants. We found that herbivory levels decrease at the highly invaded sites by air potato compared to the sites with lower air potato infestation.

Brazilian peppertree. The stem thrips, *Pseudophilothrips ichini* (Thysanoptera: Phlaeothripidae), and the yellow Brazilian peppertree leaf galler, *Calophya latiforceps* (Hemiptera: Calophyidae), are currently under study at the University of Florida Institute of Food and Agricultural Sciences (UF/IFAS) Biological Control Research and Containment Laboratory for use as biological control agents for the invasive Brazilian peppertree. Release permits for *C. latiforceps* and *P. ichini* were issued in June 2019. Since release permits were issued for *P. ichini*, UF, Florida Department of Agriculture and Consumer Services, and federal collaborators (USDA-ARS) have released over 2,500,000 *P. ichini* at sites throughout Florida. Recently *C. latiforceps* were collected in Brazil and colonies are being established inside containment labs in Florida. Releases of *C. latiforceps* will begin after colonies have been cleared of potential parasitoids and pathogens.

- To develop integrated pest management programs that have a biological control component

Strawberries. Chemical control and biological control techniques were compared in a greenhouse study using potted strawberry plants for chilli thrips management. The findings of this study indicate that biological control agent, *Amblyseius swirskii* is as effective as spinetoram for 21 days after treatment in suppression of larval chilli thrips but not effective in adult thrips suppression. The findings of this study were published in Florida Entomologist.

Urban landscapes. Ongoing research is investigating the role of turfgrass genetic diversity as an IPM tactic for conserving natural enemies and reducing pest pressure. Thus far, evidence indicates that mixing intra-specific turfgrass cultivars reduces non-turfgrass weed invasion, severity of disease spread, and fall armyworm herbivory and fitness. Current experiments are expanding this work to investigate if cultivar blends increase the abundance or diversity of ground-dwelling predatory arthropods, and if that helps regulate insect pest populations.

- To develop augmentation and conservation biological control tactics, especially to improve the quality of agricultural habitats for pollinators

XI.

XII. *Strawberries.* Field experiment in conventional strawberry planted next to strips of five banker plants (cowpea, buckwheat, sunn hemp, sweet alyssum, and ornamental pepper) is underway to assess the diversity of predatory insects and augmentatively released predatory mites, *Amblyseius swirskii* for thrips management. Also, field studies were conducted to assess efficacy of drone-released versus hand-released predatory mites for chilli thrips and twospotted spite mite management in organic strawberry. Results showed that irrespective of release method, *A.*

swirskii was more mobile and able to colonize plants that only received *Phytoseiulus persimilis*. This study has been discontinued currently due to lack of funds.

XIII.

- Short-term Outcomes: 5-6 strawberry growers have started released predatory mites and EPFs for chilli thrips management in strawberry in Florida as communicated to me in person.

Air potato. We explored the different strategies to exploit plant defense mechanisms to improve the biocontrol efficacy of the air potato beetle (*Lilioceris cheni*) as a biocontrol agent of the invasive plant air potato *(Dioscorea bulbifera*), using exogenous applications of Methyl jasmonate (MeJA), salicylic acid (SA) and water as control. We used a greenhouse experiment with plants randomly subjected to four treatments: MeJA, SA, water with no herbivory and water with herbivory damage and then reared air potato beetles on treated plants. We found that MeJA treated plants suffered significantly greater damage than the SA treated plants. However, our control plants showed huge variation and were not statistically different than MeJA treated plants. It is plausible that the specialist beetle is exploiting plant defenses as a counter mechanism.

Sweet potato. Grower recommendations were developed for managing wireworms in Florida sweet potato. Sweet potato, *Ipomoea batatas* L., production in Florida and cultural practices, primarily soil tillage and crop rotation, can suppress populations of these root pests but adequate management currently requires the use of insecticides. Due to a tenuous dependence on chlorpyrifos, research was conducted on managing wireworms with alternative methods, including biological control with commercially-available nematodes.

- Short-term Outcomes: Small-scale farmers in North Florida adopted crop rotation and soil tillage guidelines to significantly reduce the number of wireworms in a field prior to planting sweet potatoes. Sweet potato crops grown after corn or sorghum typically have higher populations of wireworms.
- Outputs: Alternative biological control methods for managing wireworms in sweet potato were evaluated and described in a management guide. The best sampling methods, e.g., intensity and frequency for defining the distribution and abundance of wireworms, were determined. General thresholds were established and IPM tactics recommended for sweet potato in the region.
- Activities: Entomopathogenic nematodes were applied to reduce the number of harmful wireworms, resulting in increased plant vigor and health. The nematodes were easy to handle and applied in a liquid using standard pesticide spraying equipment. Success or failure of entomopathogenic nematodes depended primarily on their host specificity and handling during transportation, storage, and application.
- Milestones: Entomopathogenic nematodes were evaluated because chlorpyrifos may no longer be available for controlling wireworms.

Urban landscapes. Turfgrass monoculture lawns provide relatively little value for predatory arthropods and insect pollinators compared to diverse flowering plants. There is growing

interest in planting turfgrass alternatives to enhance floral resources in lawns. However, this is expensive, labor intensive, and there are few commercially available plant species options. Fortunately, most lawns are already a mix of turf and forbs, which may be providing conservation value without the additional monetary and time inputs of replacing a lawn. Ongoing research is investigating the role of naturally occurring lawn plant diversity and cover in supporting insect pollinators and arthropod natural enemies. Preliminary evidence indicates that lawn forb diversity peaks in spring and fall, with relatively few floral resources widely available in mid-summer months. It is also clear that many lawn weeds need to be mown less frequently than conventional turfgrass if they are to flower and have real conservation value.

IMPACTS

Air potato- The biocontrol beetle holds great promise for controlling infestations of air potato, although its potential is often not realized. Improving air potato biocontrol efficiency therefore requires understanding the environmental conditions that facilitate control as well as consideration of strategies that co-opt plant defenses to increase their susceptibility.

Sweet potato. Sweet potato growers in Suwannee County, Madison County, and adjacent counties directly benefited from the project, including Townsend Brother Farms and Coggins Farms in Florida, and Danny Herring and Lake Park in Georgia. The project was funded by a Southern IPM Center Enhancement Seed Grant, "Pest Risk Assessment and IPM Tactics to Monitor and Control Wireworms for North Florida Sweet Potato Growers" and partially supported by USDA, NIFA, CPPM, EIP funds. Field technical work was accomplished by Bob Hochmuth plus a student at Live Oak, Florida. Norm Leppla conducted a survey to detect and characterize (scouting, diagnostics) the key pests of sweet potato in North Florida. Dak Seal evaluated the IPM tactics.

- Milestones: The project directly affected both Florida and Georgia because the same root and tuber crops are grown extensively across the region. The preliminary survey conducted at four North Florida sweet potato farms resulted in identification of two main wireworm pest species, *Conoderus rudis* and *C. scissus*.
- Indicators: Florida growers recently planted more than 10,000 acres of sweet potatoes. In our preliminary assessments, sweet potato damage due to wireworms was extensive and costly in several fields, ranging from 6.5% to 75%. The cooperating growers reportedly experienced 30-50% damage in past years. The project decreased damage to sweet potato significantly, thereby increasing profitability of these crops. A savings will accrue from reductions in overall pesticide use accomplished by preventing outbreaks and targeting infested sites.

PUBLICATIONS (2021-2022)

Research:

Khadka, A., Hodges, A. C., Leppla, N. C., and Tillman, P. G. 2001. *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae) nymph survival and adult feeding preferences for crop plants in Florida. Florida Entomologist. 104:136-139.

Lahiri, S., and A. Yambisa. 2021. Efficacy of a biopesticide and predatory mite to manage chilli thrips, *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae) in strawberry. Florida Entomologist. 104: 322-324.

Lake, E.C., David, A.S., Spencer, T.M., Wilhelm Jr, V.L., Barnett, T.W., Abdel-Kader, A.A., Cortes, A.C., Acuna1, A., Mattison, E.D., and C.R. Minteer. 2021. First drone releases of the biological control agent *Neomusotima conspurcatalis* on Old World climbing fern. Biocontrol Science and Technology 31: 97-106. DOI: 10.1080/09583157.2020.1828280.

Leppla, N. C. 2021. Concepts and Methods of Quality Assurance for Mass-Reared Parasitoids and Predators, Chapter 9. *In* Juan Morales Ramos, David Shapiro and Guadalupe Rojas (Eds), *Mass Production of Beneficial Organisms: Invertebrates and Entomopathogens*, 2nd Edition.

Leppla, N. C., Morales-Ramos, J. A., Shapiro-Ilan, D. I., and Rojas, M. G. 2021. Introduction, Chapter 1. *In* Juan Morales Ramos, David Shapiro and Guadalupe Rojas (Eds), *Mass Production of Beneficial Organisms: Invertebrates and Entomopathogens*, 2nd Edition.

Goode, A.B.C., Tipping, P.W., Minteer, C.R., Pokorny, E.N., Knowles, B.K., Foley, J.R., and R. J. Valmonte. 2021. *Megamelus scutellaris* (Berg) (Hemiptera: Delphacidae) biology and population dynamics in the highly variable landscape of southern Florida. Biological Control 160, 104679. DOI: 10.1016/j.biocontrol.2021.104679.

Nighswander GP, Sinclair JS, Dale AG, Qiu J, Iannone III BV. 2021. Importance of plant diversity and structure for urban garden pest resistance. *Landscape and Urban Planning*. 215, 104211. https://doi.org/10.1016/j.landurbplan.2021.104211

Pearson, DE, Clark TJ, Hahn PG. 2022. Evaluating unintended consequences of intentional species introductions and eradications for improved conservation management. *Conservation Biology* 36(1): e13734. https://doi.org/10.1111/cobi.13734

Penca, C., Hodges, A. C., Leppla, N. C., & Cottrel, T. E. 2021. Analysis of the spatial distribution and development of sequential sampling plans for heteropteran-associated fruit injury in Florida peaches. Journal of Economic Entomology. 114: 1823-1833.

Prade, P., Minteer, C.R., Gezan, S.A, Arguijo, V.C., Bowers, K., Cuda, J.P, and W.A. Overholt. 2021. Host specificity and non-target longevity of *Calophya lutea* and *Calophya terebinthifolii*, two potential biological control agents of Brazilian peppertree in Florida, USA. BioControl. DOI: 0.1007/s10526-020-10058-3

Prade, P., Cuda, J., and C.R. Minteer. *In press.* Investigating the potential for plant-mediated interactions between biological control agents for Brazilian peppertree. Biocontrol Science and Technology.

Rafter, M.A., Moore, K. and C.R. Minteer. 2021. No-choice risk assessment of *Gratiana boliviana*, a potential biological control agent of *Solanum viarum* in Australia. Biocontrol Science and Technology. DOI: 10.1080/09583157.2021.1944606.

Extension:

Hochmuth, R. C., D. Seal, N. C. Leppla, D. Fenneman, R. Broughton, and A. Baniya. 2021. Managing Wireworms in Florida Sweet Potatoes. UF/IFAS EDIS.

LeBeck, L. M. and N. C. Leppla. 2021. Guidelines for Purchasing and Using Commercial Natural Enemies and Biopesticides in North America. UF, IFAS EDIS.

Minteer, C. R., Kariuki, E.M. and J. P. Cuda. 2021. Biological control of weeds: Is it safe? UF/IFAS Electronic Data Information Source. https://edis.ifas.ufl.edu/publication/IN1342 (peer reviewed)

Nestle RP, Cope GC, Benda ND, Dale AG. 2021. Creating wildflower habitats in golf course out-of-play areas. UF/IFAS EDIS. #ENY-2059. https://edis.ifas.ufl.edu/publication/in1316

S-1073 ANNUAL REPORT FOR 2022 AND PLANS FOR 2023

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ACCOMPLISHMENTS

1. To discover, assess, and release new biological control agents

   Giant salvinia: Efforts continued to bring a population of the salvinia weevil, *Cyrtobagous salviniae*, from Argentina and Uruguay. Covid was a major setback due lack of flights and opportunities for collection of weevils. As March 2022, we are working on the procurement of an export permit from Uruguay. If successful, a colony will be established in the quarantine facility at LSU.

2. To characterize and evaluate the impact of native and introduced biocontrol agents

   Giant salvinia: During 2021-2022, the salvinia weevil mass rearing program had several harvests where state agencies and private citizens received weevils. Salvinia weevils were sent to South Carolina for establishment at an electrical dam. Technical assistance about the establishment of mass rearing facilities and monitoring of biological control was provided to

South Carolina and Puerto Rico. In cooperation with Dr. Jerrod Penn, a survey about the economic impact of giant salvinia and biological control was developed. The survey was delivered from January to March 2022.

Air potato: Dr. Veronica Manrique from Southern University in Baton Rouge is leading the mass rearing and monitoring of air potato beetles, *Lilioceris cheni*, in Louisiana. Dr. Manrique hired a new masters student, Abigail Yeboah, who will study the thermal ecology of the air potato beetle. We continued the cooperation with Dr. Emily Kraus from FDACS (Gainesville) to study the ecology of the Chinese and Nepalese populations of the air potato beetle.

Roseau cane scale: In cooperation with scientists from Taiwan, the LSU Entomology laboratory conducted a caged study to understand the impacts of local parasitoids of the roseau cane scale, *Nipponaclerda biwakoensis*. Results from the studies were presented at the ESA National Meeting in 2021.

Water lettuce: In cooperation with scientists from the University of Puerto Rico, we visited the Carraizo dam and determined the extent of the water lettuce (*Pistia stratiotes*). Due to the extent of the problem, a proposal was submitted to USDA-APHIS and PRASA (local agency) to conduct surveys and determine the presence of the water lettuce weevil. If funded, we will measure the coverage of water lettuce, several water quality parameters, and densities of weevils.

3. To develop integrated pest management programs that have a biological control component

The LSU AgCenter website on Invasive Species was updated with new species. The website contains biological control options for the management of several invasive weeds and insects common in Louisiana. https://www.lsuagcenter.com/invasivespecies

Social Media: To inform the public about the biological control programs in Louisiana, the LSU and Southern University programs used social media including Facebook and Instagram. Please follow us at: https://www.instagram.com/lsubiocontrol/; and https://www.instagram.com/su_entomology_lab/

4. To develop augmentation and conservation biological control tactics, especially to improve the quality of agricultural habitats for pollinators

None.

UTILITY OF FINDINGS

- Giant salvinia weevils were mass reared and distributed in Louisiana in 2021.
- Air potato beetles were mass reared and distributed in Louisiana and Texas. Field surveys demonstrated that severe cold fronts and reduce the populations of beetles in regions north of the I-10 corridor. Based on citizen scientist reports and public comments, the air potato beetle is already established in several regions of Louisiana.

XIV.

- During this reporting period, target audiences reached varied based on the invasive species.

XV.

  - Roseau cane die-off: The project reached state biologists and land managers involved with coastal issues in Louisiana.
  - Giant salvinia: The project reached biologists from state and federal agencies working on aquatic weed management, and private landowners from Louisiana, Mississippi, Florida, South Carolina and Puerto Rico.
  - Air potato: The project reached land managers, park rangers, extension agents and private citizens.

WORK PLANNED FOR NEXT YEAR (2022-2023)

Giant Salvinia: The LSU AgCenter leads the mass rearing efforts of salvinia weevils. In addition, the impact of the weevil is monitored in several regions in Louisiana. A cooperative agreements will continue to supply weevils to Lake Ossa in Cameroon, and Las Curias in

Puerto Rico. During 2022, we expect to finish the survey of the economic impact of giant salvinia and the salvinia weevil.

Roseau cane die-off: During the next reporting period, we will continue the coordination of the multidisciplinary program. There are 15 principal investigators including experts on plant pathology, entomology, remote sensing, wetland ecology, and biological control. Monitoring of the population dynamics of the roseau cane scale and plant health conditions will continue in 2022 and 2023. The impact of biological control of the roseau cane scale will be studied in laboratory and the field. Surveys of a native scale, *Aclerda holci*, will be conducted in coastal Louisiana.

Water lettuce: During 2022 and 2023, a graduate student from Puerto Rico will lead the biological control program of water lettuce in the Carraizo Dam. On April 1, 2022, baseline data will be collected at the dam, including plant biomass, dissolved oxygen, and conductivity. In addition, the presence of the water lettuce weevil will be determined using visual observations and extractions using Berlese funnels.

Chinese tallowtree: Dr. Veronica Manrique will be working with the USDA Forest Service on the impact of the tallow invasion on pollinators and native plants.

PUBLICATIONS (2021-2022)

Kang, I., M Sharkey, and R. Diaz. 2021. Revision of the genus *Schoenlandella* (Hymenoptera, Braconidae, Cardiochilinae) in the New World, with a potential biological control agent for a lepidopteran pest of bitter gourd (*Momordica charantia* L.). Journal of Hymenoptera Research 86(16). DOI: 10.3897/jhr.86.72690

Project/Activity Number: S1073

Project/Activity Title: Biological Control of Arthropod Pests and Weeds

Period Covered:

Date of This Report: 3/23/2022

Annual Meeting Date(s):

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Other Participants: in this work, I have been interacting with Jason Schmidt of University of Georgia and J. Chong of Clemson University.

Accomplishments:

My work has impact on two goals of S1073:

2. To characterize and evaluate the impact of native and introduced biocontrol agents, and

3. To develop integrated pest management programs that have a biological control component

However, the biological control component is a new characteristic transferred to tomato: the acylsugar-mediated insect resistance found in several wild *Solanum* species; the original source of this trait for my program was the wild tomato *Solanum pennellii.*

I am cooperating with Drs. Schmidt and Chong in planning of their experiments for their locations and produced and provided seed of the tomato lines possessing acylsugar mediated insect resistance to them. Schmidt and Chong are using these lines to determine their impacts on Bemisia whitefly, on TYLCV transmission, and on insect that could be used as predators or parasites of the whitefly. My laboratory also processes leaf samples from their experiments using the acylsugar assay developed in my lab to provide them with acylsugar readings from their experiments.

Development and release of new lines for research: Most of the work to date was performed using the acylsugar benchmark line CU071026, and additional lines developed in the CU071026 background, but differing from it in either the level or the type of acylsugar produced due to the addition of one to three additional acylsugar QTL that resulted in the change in acylsugars produced. The ability to produce acylsugars was transferred to tomato, to create CU071026 from the wild tomato *Solanum pennellii* in the form of 5 introgressions that comprised 11% of the CU071026 genome, and the additional QTL modifying acylsugar production were obtained by transferring 1 to 3 additional small introgressions. This set of CU071026 derived lines supported lab and field research on the impact of acylsugar level or acylsugar type on insects, insect transmitted virus, or on predators/parasites of those insects. However, those lines suffered from poor fruit set, seed set, and reduced germination, limiting the number of researchers who could use them. To remedy those deficiencies, the new benchmark line, CU17NBL, was bred that

produces the same acylsugar level and type as CU071026 but has normal fruit set, seed set, and germination. In 2022 my program completed the development of the full set of lines in the CU17NBL background, by adding the same additional QTL (introgressions) that had been added to CU071026 to create the prior set of lines. Like the lines in the CU071026 background, the new set of lines in CU17NBL produce acylsugars of different types and/or different levels than their background line, CU17NBL. Since these CU17NBL lines have normal fruit set, seed set, and germination, the improved set of lines will facilitate their use in lab and field research on the impacts of acylsugar level or acylsugar type on insects, insect transmitted virus, or on predators/parasites of those insects, and allow expansion of this work. This is an important advance, since the information from such studies would guide the use of acylsugar-producing commercial hybrids, when seed companies transfer this trait to their proprietary lines and new commercial hybrids. The full set of acylsugar producing lines in the CU17NBL background will be submitted in Spring of 2022 to the USDA germplasm bank to make these lines available to interested researchers. A publication detailing the development and full characterization of these lines is being prepared for submission later in 2022.

Continued development of lines with acceptable horticultural quality for use by seed companies to deploy acylsugar mediated insect resistance and virus control. Work is nearly completed on a final, smaller set of tomato lines that produce acylsugars of different levels and types, but which have significantly reduced sizes of *S. pennellii* introgressions. The reduction in introgression size reduced the amount of *S. pennellii* DNA in their genomes from 11% as in CU17NBL to ca 2.0%. This reduction also removed QTL that caused negative plant and fruit traits of CU071026 and CU17NBL derived lines, such as excessive branching and very small fruit. The newest lines are remarkably similar in plant and fruit type to the normal tomato line used in their development and are of the quality needed for seed companies to use for transfer of the acylsugar-mediated insect resistance to commercial tomato hybrids. The new lines should be released to seed companies by the end of 2022. The creation and sale of such tomato hybrids with the acylsugar trait, and their use by growers in a well developed IPM program, would significantly reduced loss of crop and crop quality due to insect and insect transmitted virus, while reducing the need for, and use of, pesticides that also kill beneficial insects and pollinators in the agricultural setting.

PUBLICATIONS (2020-2021)

1. Mutschler, MA. 2021. Breeding for Acylsugar Mediated Control of Insects and Insect Transmitted Virus in Tomato. IN: Plant Breeding Review vol 45. Goldman I ed. https://doi.org/10.1002/9781119828235.ch9

XVI.

2. Marchant WG, S Legarrea, JR Smeda, MA Mutschler and R Srinivasan 2020 Evaluating Acylsugars-Mediated Resistance in Tomato against Bemisia tabaci and Transmission of Tomato Yellow Leaf Curl Virus Insects, 11(12), 842; https://doi.org/10.3390/insects11120842 28 Nov 2020

S-1073 ANNUAL REPORT FOR 2021 AND PLANS FOR 2022

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OTHER PARTICIPANTS: None

ACCOMPLISHMENTS

Objective 1. To develop integrated pest management programs that have a biological component

As part of a collaboration among members of this group (Chong, Mutschler-Chu and Schmidt), Chong and a PhD student (Matthew Brown) had investigated the foraging behavior and efficacy of three predatory mite species (*Phytoseiulus persimilis*, *Neosieulus californicus* and *Amblyseius andersoni*) and a predatory beetle (*Stethorus puntillumi*) on a commercial tomato cultivar (Amelia) and an acylsugar-producing experimental tomato line (CU07). Results suggested that *S. punctillum* foraged on both tomato lines equally, whereas the predatory mites foraged on CU07 at a much lower frequency than on Amelia. Consumption of spider mite eggs by the predatory mites were also significantly lower on CU07.

In another study, Chong and Brown also investigated the potential for bifenthrin medium incorporation to impact predatory mite efficacy. As part of the red imported fire ant quarantine requirements, ornamental plant nurseries in the quarantined areas are required to treat the artificial medium used to grow the plants with selected insecticides (bifenthrin being the most commonly used). The team released *P. persimilis* on medium treated with bifenthrin at different times (thus different residual ages) and documented the numbers of predatory mites and the numbers of surviving spider mite eggs on lima bean plants where the predatory mites moved to after crawling across the treated medium. Results suggested that even bifenthrin residue of 7 days had not observable impacts on the survival of the predatory mites and their consumption of spider mite eggs.

Objective 2. To characterize and evaluate the impact of native and introduced biocontrol agents

XVII.

XVIII. A study to document natural enemy diversity of the muhly grass mealybug, *Stemmatomerinx acircula*, in urban landscape of South Carolina is on-going. The invasive mealybug species was first detected in 2018 and is now known in the coastal counties throughout the southeastern US and other states further in-land. An egg predatory wasp in the family Pteromalidae have been collected in 2020 but its identity has not been confirmed. Common lady beetle species, such as *Harmonia axyridis* and *Coleomegilla* maculate, do not appear to be attracted to the mealybugs.

XIX.

UTILITY OF FINDINGS

Muhly grass is prized as an ornamental plant, as well as having cultural and economic significance as the raw materials for African Americans' sweetgrass baskets. Understanding the natural enemy complex of the muhly grass mealybug will allow researchers to develop integrated management plan for the invasive mealybug species in order to protect the valuable muhly grass from this new pest. The study on the foraging behavior of predatory mites and predatory beetles on commercial and experimental tomato line suggested that the acylsugar deposits on the experimental line may be impeding biological control of twospotted spider mites by predatory mites. Additional management tactics may be necessary to make up for the shortfall in biological control on the experimental line. Results from the survival of predatory mite on bifenthrin-treated medium suggested that growers can release the predatory mites in

their operation and do not have to worry about bifenthrin used for fire ant quarantine treatment impacting the survival and efficacy of the predatory mites.

WORK PLANNED FOR NEXT YEAR (2022)

Efforts will continue to collect and identify, as well as document the impacts of natural enemies of muhly grass mealybug (Objective 1). Observations of the selection behaviors of predatory mites and beetles between the commercial and acylsugar-producing tomato lines will be validated in whole plant study in a greenhouse in South Carolina. The study on the impact of bifenthrin medium incorporation on the survival and efficacy of *P. persimilis* will be replicated to generate more data for manuscript preparation.

PUBLICATIONS

Peer-reviewed extension bulletins:

Jeffers, A. H., and J. H. Chong. 2021. Biological control strategies in integrated pest management (IPM) programs. LGP 1111. Land-Grant Press by Clemson Cooperative Extension, Clemson, SC. https://lgpress.clemson.edu/publication/biological-control-strategies-in-integrated-pest-management-ipm-programs/

Jeffers, A. H., and J. H. Chong. 2021. Integrated pest management strategies for fungus gnats in ornamental plant propagation. LGP 1131. Land-Grant Press by Clemson Cooperative Extension, Clemson, SC. https://lgpress.clemson.edu/publication/integrated-pest-management-strategies-for-fungus-gnats-in-ornamental-plant-propagation/

Trade journal articles:

Chong, J. H. 2021. Kill those whiteflies and viruses! PestTalks 25 May 2021.

Chong, J. H. 2021. Marengo and Fortress crop safety, SLF egg hatch predictor, and morbid insects. PestTalks 7 May 2021.

IMPACT STATEMENT:

Vegetables and ornamental plants grown in fields, greenhouses and nurseries, as well as ornamental plants and grasses maintained in urban landscapes, are highly valuable to the economy and wellbeing of our citizens. But, these valuable plants are often attacked by a myriad of insect and mite pests. These endemic and invasive pests have traditionally been managed through the frequent applications of insecticides, which resulted in reduced efficacy, pesticide resistance, and human and environmental risks. By integrating biological control within the larger framework of vegetable and ornamental plant management, we will be able to reduce pesticide application and the associated environmental, pest management and socioeconomic consequences. Research and extension activities conducted under this project result directly in achieving pest management goals while alleviating the associated problems. The multi-state survey of natural enemies of thrips, whiteflies and spider mites will inform organic vegetable growers in the southern US on the diversity of natural enemies occurring in their fields, as well as the impacts of these natural enemies. Muhly grass is prized as an ornamental plant, as well as of cultural and economic significance as the raw materials for sweetgrass baskets. Understanding the natural enemy complex of the muhly grass mealybug will allow researchers to develop integrated management plan for the invasive mealybug species in order to protect the valuable muhly grass from this new pest. The study on the compatibility of Group 9 insecticides will allow growers to better develop an effective pest management plan that integrates chemical and biological control. Understanding the foraging behavior of predators and parasitoids on pest resistant crop varieties or their compatibility with pest quarantine treatments are also important in determining the potential of integrating biological control and host plant resistance. Through better understanding of the ecological relationship between pests and their natural enemies, and better utility of compatible insecticides and pest resistant varieties, we will be able to develop integrated pest management programs that reduce pest damage, improve economic returns, and alleviate negative consequences of pest management activities.

S-1073 ANNUAL REPORT FOR 2021 AND PLANS FOR 2022

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ACCOMPLISHMENTS

5. To discover, assess, and release new biological control agents

6. To characterize and evaluate the impact of native and introduced biocontrol agents

XX.

We have initiated work to understand biological control of the exotic pest European pepper moth using entomopathogens, nematodes, and native generalist predators. We continue to study the ecology of native biological control organisms including predators and parasitoids of gloomy scale, lecanium scale, crape myrtle aphids, brown scale, whiteflies, and others. We measured effects of nitrogen and drought on natural enemies and pests associated with maples. We measured predation of crape myrtle aphids and scales as related to landscape variables such as impervious surface cover and canopy cover and as related to local variables such as plant diversity within 10m of the tree. We also have studied the differences between native and exotic trees in the natural enemy communities they support.

7. To develop integrated pest management programs that have a biological control component

   Our newest project will focus on biological control of European pepper moth in nurseries and greenhouses. Our goal is to develop a comprehensive program that may include conventional insecticides, biological insecticides, and other biological control organisms. We are also working to develop conservation biological control solutions for urban landscapes. We continue working on IPM programs including planting recommendations for urban trees that will maximize natural enemy abundance and efficacy by planting trees in the correct location for them to thrive and by increasing habitat complexity. Location characteristics include impervious surface, tree diversity, and tree density. In addition, our work will help identify tree species that support the most natural enemies and fewest pests so these can be planted in locations that are especially pest prone or stressful.

8. To develop augmentation and conservation biological control tactics, especially to improve the quality of agricultural habitats for pollinators

Our conservation biological control program development focuses on natural enemies rather than pollinators this year. Our work focuses on urban landscapes and urban forest fragments.

UTILITY OF FINDINGS

Our research has shown that habitat complexity within 10m of trees like crape myrtles and red maples is a primary factor determining natural enemy abundance and efficacy. Landscape scale density of trees and tree species is also important. In addition, tree planting recommendations (locations and species) will help reduce pest pressure and increase natural enemies on those trees. This will improve IPM and reduce the need for insecticide applications.

WORK PLANNED FOR NEXT YEAR (2022)

We will develop our European pepper moth research program and begin experiments to understand it biology and management. We will continue studying how aspects of urbanization affect conservation biological control in urban landscapes. This will include more work on several scale insect species and possibly other pests like aphids.

PUBLICATIONS (2020-2021)

Backe, K.†, Rousselet, J., Bernard, A., Frank, S.D., and Roques, A. (2021). Human health risks of invasive caterpillars increase with urban warming. Landscape Ecology, https://doi.org/10.1007/s10980-021-01214-w.

\ Just, M.G., Dale, A.G., and Frank, S.D. (2020) Gloomy scale (Hemiptera: Diaspididae) ecology and management on landscape trees. Journal of Integrated Pest Management, 11(1): 24; 1-9. DOI: 10.1093/jipm/pmaa028.

Martinson, H.M., Raupp, M.J., and Frank, S.D. (2020) How urban forest composition shapes the structure and function of arthropod communities. In P. Barbosa (Ed.), Urban ecology: Its nature and challenges (pp.15-36). CAB International.

Frank, S.D. and Tooker, J.F. (2020) Opinion: Neonicotinoids pose undocumented threats to food webs. Proceedings of the National Academy of Sciences, DOI: 10.1073/pnas.2017221117. PDF.

Frank, S.D. (2020) Review of the direct and indirect effects of warming and drought on scale insect pests of forest systems. Forestry: An International Journal of Forest Research, https://doi.org/10.1093/forestry/cpaa033.

Frank, S.D. and Just, M.G. (2020) Can cities activate sleeper species and predict future forest pests? A case study of scale insects. Insects, 11(3): 142. https://doi.org/10.3390/insects11030142. PDF.

Long, L.C.† and Frank, S.D. (2020) Risk of bird predation and defoliating insect abundance are greater in urban forest fragments than street trees. Urban Ecosystems, https://doi.org/10.1007/s11252-020-00939-x.

Parsons, S.E.†, Kerner, L.M., and Frank, S.D. (2020) Effects of native and exotic congeners on diversity of invertebrate natural enemies, available spider biomass, and pest control services in residential landscapes. Biodiversity and Conservation, https://doi.org/10.1007/s10531-020-01932-8. PDF.

Just, M.G., and Frank, S.D. (2020) Thermal tolerance of gloomy scale (Hemiptera: Diaspididae) in the Eastern United States. Environmental Entomology, nvz154, https://doi.org/10.1093/ee/nvz154. PDF.

Lahr, E.C., Backe, K.M.†, and Frank, S.D. (2020) Intraspecifc variation in morphology, physiology, and ecology of wildtype relative to horticultural varieties of red maple (Acer rubrum). Trees – Structure and Function, https://doi.org/10.1007/s00468-019-01942-2. PDF.

IMPACT STATEMENT : https://www.enago.com/academy/writing-an-impact-statement-four-things-you-need-to-know/

The problem we address in our research program is that urban landscape plants often have more pests and require more insecticides than plants in rural or natural locations. To address this problem we study the effects of urban landscape factors such as impervious surface, tree cover, plant diversity, and temperature to determine how they affect pests and natural enemies and biological control. Our work benefits municipalities, landscape professionals, landscape designers, urban planners, and the millions of residents of the US who interact with ornamental landscapes each day. This is because preventing and reducing pest infestations reduces the economic costs associated with maintaining trees and other landscape plants and reduces the amount of insecticide applied to those plants. We conduct this work in collaboration with a diverse team of undergraduate and graduate students, post docs, technicians, and colleagues in the US and around the world. We also work with stakeholders and conduct extension activities to disseminate our findings to end users.

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ACCOMPLISHMENTS-S1073 Objective specific (see numbers)

9. To characterize and evaluate the impact of native and introduced biocontrol agents

Whiteflies: Based on lack of research on whitefly natural enemies in the landscape, we reviewed the literature on current understanding of whitefly predators in the United States and published this in a special feature article. We have now begun targeting gaps in knowledge identified in the review, and assembling a molecular gut content strategy to efficiently document both whitefly host use in the landscape and also predator feeding on whiteflies.

Peanut biological control communities: We know little about the dynamics of predators and pests in peanut systems. During 2019-2020 seasons we partnered with the GA Peanut Commission to initially fund work to sample peanut fields across GA. Samples are still being processed from both of these studies.

Pecan predators and parasitoids: Work began in pecan systems too. We funded two projects to document pecan natural enemy communities, and later to study effects of current cultural practices on biocontrol efficacy. We have just begun work on the predators and this will continue in 2021.

Tracking predators and parasitoids in onion systems: we are finalizing work on a NIFA funded project for characterizing the predators and parasitoids of thrips in onions. In the coming year our plan is to publish the current results and finalize field sampling for a second year of a two year project in onion landscapes.

Parasitoids in blueberry systems: Finished a study in blueberry systems on determining the different parasitoids in blueberry landscapes. No current plans for follow up work at this time.

3. To develop augmentation and conservation biological control tactics, especially to improve the quality of agricultural habitats for pollinators

On-going work in pollinator and conservation of habitat continued this year. We continued a project partnered with NREL and Solar America companies to sample our establishing wildflower habitat is solar arrays. Second, we began sampling blueberry landscapes to characterize the pollinator and natural enemy communities in these environments in partnership with the NRCS.

UTILITY OF FINDINGS

To fully utilize biodiversity for the ecosystem services provided, we must document diversity patterns and also the interactions under natural conditions. Our work attempts to document diversity at large scales and also the frequency of interactions between biocontrol agents and pests in agricultural landscapes.

WORK PLANNED FOR NEXT YEAR (2020-2021)

Plans for next year are to first finalize manuscripts on whiteflies, submit and plan our next course of action based on results. We are close to having results for multiple studies and are getting excited for publication phase. We are still processing peanut community samples and preparing them for molecular gut content analysis to understand these food webs. For 2021 plans, we will wrap up processing and work through publications to decide on next studies needed. Currently working on multiple pecan biocontrol projects which we will continue in 2021. Two manuscripts will are planned for next year.

PUBLICATIONS (2020-2021)

Bowers, C., Toews, M.D., Schmidt, J.M. Winter cover crops shape early-season predator communities and trophic interactions. Ecosphere 12:7 e03635 **https://doi.org/10.1002/ecs2.3635**

Kheirodin, A.; Simmons, A.M.; Legaspi, J.C.; Grabarczyk, E.E.; Toews, M.D.; Roberts, P.M.; Chong, J.-H.; Snyder, W.E.; Schmidt, J.M. 2021. Can Generalist Predators Control *Bemisia tabaci*? *Insects 11*, 823.

Slusher, E.K., Hudson, W.G., Halliday, P.L., Acebes-Doria, A.L. 2021. Multisite Seasonal Monitoring of Pecan Aphids and Their Parasitoid in Commercial Pecan Orchards. *Environmental Entomology*. https://doi.org/10.1093/ee/nvab069.

Slusher, E.K., Hudson, W.G., Acebes-Doria, A.L. 2021. Multisite Seasonal Monitoring of Pecan Aphids and Their Parasitoid in Commercial Pecan Orchards. *The Pecan Grower Magazine*. April 2021. 22-33.

Slusher, E.K., Cottrell, T., Acebes-Doria, A.L. 2021. Effects of Aphicides on Pecan Aphids and Their Parasitoids in Pecan Orchards. *Insects* 12.3: 241.

Schmidt, J.M., Whitehouse, T.S., Neupane, S., Miranda Rezende, S., Sial, A., Gariepy, T.D., 2021. Parasitoid Communities in the Variable Agricultural Environments of Blueberry Production in the Southeastern United States, *Journal of Economic Entomology*, 114: 4, 1480–1488.

Martins, E.F., Franzin, M.L., Perez, A.L., Schmidt, J.M., Venzon, M. 2021. Is *Ceraeochrysa cubana* a coffee leaf miner predator? Biological Control 160:104691.

LIST OF PRESENTATIONS (2020-2021)

Kaldor, A., Blaauw, B., Schmidt J.M. 2020. Peach tree arthropod community composition. Entomological Society of America. Virtual meeting. Oral presentation.

Kheirodin, A., Toews, M.D., Roberts, P.M., and Schmidt, J.M. 2020. Do generalist predators contribute meaningfully to silver whitefly, *Bemisia tabaci*, suppression in the United States? Evidence and implications. Entomological Society of America, Orlando, FL. Oral presentation.

Kheirodin, A., and Schmidt, J.M. 2021. Contribution of generalist predators to pest control services in Georgia cotton fields.

Pandey S, da Silva ALBR, Dutta B, Chong JC, Mutschler MA, & Schmidt JM. 2020. Exploring the efficacy of predatory mite (*Ambylseius swirskii)* as a potential biocontrol agent against whiteflies in different tomato plants). ESA (virtual). Oral presentation.

Pandey S, da Silva ALBR, Dutta B, Chong JC, Mutschler MA, & Schmidt JM. 2021. Efficacy of *Ambylseius swirskii* as biological control agent for the management of whitefly population in tomato plants. Southeastern Branch ESA (virtual). Oral presentation.

Pandey S, da Silva ALBR, Dutta B, Chong JC, Mutschler MA, & Schmidt JM. 2021. Efficacy of *Ambylseius swirskii* as biological control agent for the management of whitefly population in tomato plants. University of Georgia (organized by Lund Club). Oral presentation.

Pandey S, da Silva ALBR, Dutta B, Chong JC, Mutschler MA, & Schmidt JM. 2021. Managing whiteflies with hairy tomato plants. University of Georgia. Oral presentation.

Slusher, E.K., T. Cottrell, A.L. Acebes. 2021. Effects of Aphicide Application on Pecan Aphid and Aphid Parasitism in a Georgia Pecan Orchard. Entomological Society of America International Meeting. Virtual poser.

Slusher, E.K., W. Hudson, A.L. Acebes. 2021. Multi-site Seasonal Monitoring of Pecan Aphids and Their Parasitoids in Commercial Pecan Orchards. Entomological Society of America Southeastern Branch Meeting. March 29-31, Virtual poster.

Toledo PFS, Phillips K, Schmidt JM & Acebes-Doria AL. 2021. Effects of mechanical hedge-pruning on aphid-parasitoid interactions in southeastern US pecan orchards Southeastern Branch ESA. Oral presentation

S-1073 ANNUAL REPORT FOR 2021 AND PLANS FOR 2022

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ACCOMPLISHMENTS

I. I am participating in objectives 2, 3 and 4 as outlined in the multistate research project. **Objective 2. To characterize and evaluate the impact of native and introduced agents.** Research continues to focus on native agents that attack insect pests, and describing aphid parasitism in agricultural landscapes. In 2021, submitted for publication results of a multi-year studies to examine the role of aphid natural enemies in agricultural landscapes. Completed and published studies related to the dynamics of sugarcane aphid and parasitoids and provide the framework for current studies on parasitoid ecology and competition. Studies continued to describe the latitudinal ecology of aphid parasitoids in the Southern Plains with an emphasis on the role of symbionts, and how diapause may influence effective parasitism. **Key Outcomes:** The role of natural enemies attacking sugarcane aphid varies by geographic location in the great plains with parasitoids as key factors in more southern locations. **Objective 3: To develop augmentation and conservation biological control tactics, especially to improve the quality of agricultural habitats for pollinators.** Research is focusing primarily on conservation approaches. Studies describing pest suppression and conservation of natural enemies and pollinators in landscapes with winter canola were completed and have been submitted for publication. **Key Outcome:** Crop diversity in time and space in agricultural landscapes has a positive effect on aphid suppression by parasitoids and diversity and services provided by pollinators. **Objective 4. To develop integrated pest management programs that have a biological control component.** A study is being initiated to field validate natural enemy thresholds for sugarcane aphid in sorghum from southern Texas, through Oklahoma and into southern Kansas. This study will also investigate how natural enemy counts can be

integrated into SCA sampling plans. **Key Outcome.** Studies are just being initiated with the goal to incorporate expected aphid suppression into pest management programs.

WORK PLANNED FOR NEXT YEAR (2022):

*Continued studies related to objectives 2, 3, and 4.

*Studies describing spatial and temporal patterns of aphid parasitism and pollinators in agriculture landscapes of the Southern Plains will continue.

*Validation of natural enemy thresholds for SCA on sorghum, and integration of sampling approaches.

PUBLICATIONS/PRESENTATIONS (2020/2021)

Lindenmayer, J.C., M. Payton, K.L. Giles, N.C. Elliott, A.E. Knutson, R. Bowling, N. Seiter, B. McCornack, S. Brown and T. A. Royer. Evaluation of Two-Leaf Sampling Units to Estimate Sugarcane Aphid (Hemiptera: Aphididae) Economic Thresholds in Commercial Grain Sorghum. J. Econ. Entomol. 114: 481-485.

Giles, K.L., N.C. Elliott, H. E. Butler and K. A. Baum. 2021. Increase in Importance of *Aphelinus nigritus* (Howard) on Winter Crops in Oklahoma Coincides with Invasion of Sugarcane Aphid on Sorghum in Oklahoma. Southwestern

Entomol. 46: 59-68.

Elliott, N., K. Giles, M. Brewer, A. Szczepaniec, A. Knutson, JP Michaud, C. Jessie, A. Faris, B. Elkins, H. Waing, T. Koralewski and W. Grant. 2021. Recruitment of Natural Enemies of the Invasive Sugarcane Aphid Vary Spatially and Temporally in Sorghum Fields in the Southern Great Plains of the USA. Southwestern Entomol. 46: 357-372.

Elliott, N. C., K. L. Giles, K. A. Baum and S. D. Elzay. 2021.Quantitative assessment of aphid parasitoids and predators in central Oklahoma wheat fields during five growing seasons. Southwestern Entomol. 46: 833-842.

Cibils-Stewart, X., D. J. Klebenstein, B. Li, K. Giles, B. McCornack and J. Nechols. 2022. Aphid Species and Feeding Location on Canola Influences the Impact of Glucosinolates on a Native Lady Beetle Predator. Environ. Entomol. 51: 52-62.

Conference Papers & Presentations

Brewer, M., N. Elliott, I. Esquivel, A. Jacobson, A. Szczepaniec, A. Faris, K. Giles, B. Elkins and J. Gordy. 2021. Distribution, abundance, and diversity of natural enemies of sugarcane aphid following its invasion onto sorghum, with notes on agro-landscape and weather correlates. ESA-SEB Meeting: Virtual. S-1073 Symposium.

Giles, K., N. Elliott, M. Brewer, T. Koralewski and A. Szczepaniec. 2021. Plant resistance and biological control: Disruption of annual range expansion to reduce the likelihood of sugarcane aphid outbreaks in US sorghum. ESA-SEB Meeting: Virtual. S-1073 Symposium.

Giles, K., T Royer, N. Rudin, B. Arnall, N. Elliott, J. Lindenmayer, B. McCornack and M. Brewer. 2022. Advanced insect pest scouting applications for smart devices. 10th international IPM symposium. Denver, CO.

Impact Statement

46% of winter wheat in Oklahoma is deliberately sampled for pests AND beneficial insects each year since formal delivery of the Glance ‘N Go aphid/parasitoid sampling plan. Based on USDA NASS data, the most conservative estimates of savings associated with reducing pesticide use by utilizing the Glance ‘N Go aphid/parasitoid sampling plan are $8.9 million annually and $160 million cumulatively over 18 years.

Multistate Research Activity
Accomplishments Report

Project/Activity Number: VT-H02702MS
Multistate #: S1073
Project/Activity Title: The role of Ultraviolet-C mediated induced defense in ornamental plants to control western flower thrips
Period Covered: FY2021 (FY21 = October 1, 2020 – September 30, 2021)
Date of This Report: March 23, 2022
PIs: Bruce L Parker, Margaret Skinner
Other individuals: Cheryl Frank Sullivan (UVM)

Annual Meeting Date(s): NA

Participants: NA

Brief summary of minutes of annual meeting: NA

Non-Technical Summary:
Western flower thrips (WFT) is considered economically one of the most important pests world- wide. Growers report that WFT resistance to chemical pesticides is widespread and the public is concerned about environmental and human health hazards of chemical pesticides. Despite decades of research to devise biological and cultural control strategies, thrips remain a persistent pest in most ornamentals production systems. A novel approach to managing WFT is critically needed. The use of ultraviolet light as an innovative tool against WFT has been investigated by the PIs. A functional relationship between UV dose and WFT mortality was established. We found that specific levels of UV light have lethal effects on WFT. Though adults were less susceptible to UV than larvae and it took longer for adults to immediately die from UV, we believe that there are many aspects of the WFT biology that are influenced by UV light. We hypothesize that sublethal dosages of UV can affect the interaction between WFT and the host plant, mainly through UV-mediated induced defenses. This innovative approach could be a great addition to current thrips IPM if it is compatible with other existing tactics.

Accomplishments:
In year 1 we determined if the application of supplemental UV-C on ornamental plants changed the host plant feeding preference by WFT (Obj.1. Question 1). Bush bean, Phaseolus

vulgaris var. royal burgundy and French marigolds, Tagetes patula, var. superhero yellow were grown from seed using Metro-Mix360 potting mix in trays containing 36-cell inserts. Trays were held in a temperature-controlled glass greenhouse maintained at 25°C. When plants reached a height of ~ 15cm, the cells were cut to individualize plants for exposure to UV-C. Plants were subjected to one of four UV-C doses (0.08, 0.17, 0.34 and 0.68 J/cm2) once per day for 5 days in a UV chamber. Untreated plants were used as controls. Three plants were treated simultaneously for each dose and the entire experiment was repeated three times. Dual-choice, leaf bioassays were conducted to assess if WFT to feed on either UV-treated versus untreated leaves after one, three and five UV-C treatments. The second-third youngest leaves were cut from each plant treatment. Each UV treated leaf was paired with an untreated control, each from a different plant. Treated and untreated leaf pairs from each treatment were placed within tight-fit lid Petri dishes lined with filter paper that was moistened with sterile distilled water (SDW). Two, adult female WFT were added per dish with a fine-hair brush. Dishes held on a metal lab bench and held at ambient temperature (ca. 20–25 ºC) under 24hours daylight. After 1 week silvering damage on the leaf surface (characteristic symptoms of thrips feeding) was rated using the following rating scale: 0: no damage; 1: damage to <10% of the foliage, 2: damage to 11–25% of the foliage, 3: damage to 26–50% of the foliage, 4: damage to 51–75% of the foliage and 5: damage to >76% of the foliage. Data was analyzed using ANOVA and t-test procedures.

Results showed there were significant differences in WFT feeding preference on marigold and bean plant foliage treated with up to five exposures of UV-C at doses of 0.08, 0.17, 0.34 and 0.68 J/cm^2. There was also differences in plant foliage quality after treatment. Plant quality generally declined after three exposures of UV-C particularly at rates of 0.34 and 0.68 J/cm^2. Foliage damage to both beans and marigolds was minimal after one exposure from all rates with slight damage at 0.68 J/cm^2 (<10%). After three and five exposures, damage was minimal in 0.08 and 0.17 J/cm^2 treatments but more pronounced at 0.34 and 0.68 J/cm^2. Beans were more susceptible than marigolds to UV-C damage. After five exposures the damage rating range was 51-75% for beans treated at 0.34 and >76% at 0.68 whereas for marigolds it was 11-25% and 26-50% respectively.

The general trend for WFT feeding preference was there was greater feeding damage on the untreated leaves as opposed to the treated leaves and the difference was more pronounced after three and five exposures to UV-C and at the higher doses (0.34 and 0.68 J/cm^2) as opposed to the lower doses (0.08 and 0.17 J/cm^2). On beans, after one exposure, there was significantly less feeling damage by WFT when foliage was treated at (0.34 and 0.68 J/cm^2) as opposed to the lower doses (0.08 and 0.17, J/cm^2). Mean damage rating and associated estimated % on treated vs. untreated leaves, respectively per treatment rate are as follows: 0.08 J/cm^2 (3.33, 33.5%; 2.89, 23%); 0.17 J/cm^2 (2.11, 12.5%; 2.67, 20%); 0.34 J/cm^2 (0.78, <1%; 1.89, 9%) 0.68 J/cm^2 (0.33, <1%; 1.89, 9%) and untreated control (2.89, 23%; 2.56 18.5%). The difference between treated and untreated leaves was significant within the 0.34 and 0.68 J/cm^2 rate. After three exposures, the differences between feeding was significant within all rates and between the rate groups 0.08 and 0.17 J/cm^2 and 0.34 and 0.68 J/cm^2. The two higher rates had significantly less feeding compared with the untreated control. Mean feeding damage ratings ranged from 0.11 (< 1%) to 1.67 (7%) on UV treated foliage as opposed to 14% in the untreated control. On marigolds, after one exposure, there was significantly less feeling

damage by WFT when foliage was treated at (0.68 J/cm^2) as opposed to the other treatments. Within that rate mean feeding damage rating was 1.11 (2%) on the treated leaf and 2.67 (20%) on the untreated. After three exposures, the differences between feeding was significant within rates 0.08 and 0.17 J/cm^2 and 0.34 and 0.68 J/cm^2. There was no difference within or between rate 0.08 J/cm^2 and the untreated control. Mean damage rating and associated estimated % on treated vs. untreated leaves, respectively per treatment rate are as follows after three exposures: 0.08 J/cm^2 (2.00, 11%; 2.33, 15.5%); 0.17 J/cm^2 (1.11, 2%; 3.22, 31%); 0.34 J/cm^2 (1.11, 2%; 2.22, 14%) 0.68 J/cm^2 (1.00, 1%; 2.33, 15.5%) and untreated control (2.67, 20%; 2.56 18.5%). After five exposures, the differences between feeding was significant within all rates with rates 0.34 and 0.68 with significantly less feeding than the other treatments.

These results show application of supplemental UV-C on plants changes the host plant feeding preference by WFT. Damage to foliage quality likely affected WFT feeding at the higher rates as the number of exposures increased. Considering plant damage from UV treatments, on beans, one exposure at 0.34 and 0.68 J/cm^2 caused noticeable differences in the feeding preference of WFT on treated and untreated foliage and three exposures of 0.08 and 0.17 J/cm^2 would be sufficient to affect WFT foliar feeding with minimal adverse effects on plant quality. On marigolds, one exposure at 0.68 J/cm^2 caused noticeable differences in the feeding preference of WFT on treated and untreated foliage, three exposures of 0.17 and 0.34 J/cm^2 was sufficient to reduce feeding and five exposures of 0.08 and 0.17 to affect WFT feeding with minimal adverse effects on plant quality.

Nuclear magnetic resonance spectroscopy (NMR) analysis was performed on the third/fourth youngest leaf from the apex in control and UV-treated plants after each exposure to address Obj.1. research questions of what is the effect of UV-C on host plant leaf metabolome (chemical characteristics)? and is the UV-C induced defense in ornamental plants species specific? We are currently in the process of analyzing the results due to an equipment malfunction delay.

Outputs:

- Data generated on WFT feeding preferences on marigolds and beans treated at four UV-C doses (0.08, 0.17, 0.34 and 0.68 J/cm^2) and NMR spectra generated.

Milestones:

Completed Objective 1; Research Question 1

Impacts:

Two related presentations about using UV to manage WFT were given.

Davari, A., M. Skinner & B.L. Parker. 2021. Ultraviolet light for integrated pest management of western flower thrips, Frankliniella occidentalis (WFT) in Greenhouses. 22 Feb. 2021. Role of Plant Protection in Sustainable Agriculture Development. Plant Protection Institute, Cairo, Egypt.

Davari, A. B.L. Parker & M. Skinner. 2020. Ultraviolet light for integrated pest management of Western flower thrips, Frankliniella occidentalis (WFT). Seminar 13 Nov. 2020. Clemson Univ.

Publications:

None **Authorization**: NA

S-1073 ANNUAL REPORT FOR 2021 AND PLANS FOR 2022

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ACCOMPLISHMENTS (we are actively involved in Objectives 1-3; we plan to expand efforts in Objective 1, once the pandemic improves and international efforts are revitalized; we also plan to be involved with Objective 4).

1. To discover, assess, and release new biological control agents

Although collaboration had been established in a climate-matched area of China to search for natural enemies of crapemyrtle bark scale, suspension of this cooperative effort continued in 2021 due to Covid-19. Hopefully, this cooperative effort can be continued in the future.

Efforts to rear and release new biological control agents continued with targeting natural enemies of hemlock woolly adelgid: The Lindsay Young Beneficial Insects Laboratory (LYBIL) at the University of Tennessee currently rears two predators of the hemlock woolly adelgid (HWA): *Laricobius nigrinus* and *Laricobius osakensis*. *L.*

nigrinus has been reared at LYBIL since 2005. *L. osakensis* was reared at LYBIL in 2011, and from 2013 to the present. A third predator, *Sasajiscymnus tsugae,* was reared at LYBIL from 2003-2018, but production ceased in 2019 to better focus our time and resources on rearing and releasing *Laricobius*.

Late 2020 to early 2021

Laricobius nigrinus

Substantial mortality of beetles in storage and oviposition jars beginning in early November 2020 affected the number of beetles released, and also reduced the number of beetles available for rearing. Beetles began emerging from soil boxes on 8/28/20, with a total of 7690 emerging by 1/31/21. Releases, made from 10/13/20 to 12/7/20, were: Daniel Boone National Forest (KY) (2 releases, 1,024 adults), Frozen Head State Park (1 release, 445 adults), Great Smoky Mountains National Park (2 releases, 545 + 400 eggs), Hemlock Restoration Initiative (NC) (1 release, 502 adults), Meadow Creek Park (Monterey, TN) (2 releases, 1,012 adults), and Pickett State Park (2 releases, 927 adults)

Laricobius osakensis

As with *L. nigrinus*, the number of beetles available for release and for rearing was affected by substantial mortality in storage and oviposition jars. Resulting adults began emerging in the lab on 8/18/20. A total of 6030 had emerged by 2/23/21. Beetle releases, made from 10/29/20 to 12/14/20, were: Great Smoky Mountains National Park (2 releases, 1,047 adults) and Savage Gulf State Natural Area (2 releases, 1,109 adults).

Early 2021 to October 2021

Laricobius nigrinus

HWA infested hemlock foliage was exposed to beetles in oviposition jars from 1/26/21 to 6/14/21. (Exposed foliage containing ca. 400 *L. nigrinus* eggs were released in the GRSM in March.) 8211 mature larvae were harvested from 2/9/21 to 7/20/21. As of September 1, no beetles have emerged from soil containers.

Laricobius osakensis

Oviposition jars were initiated on 1/21/21 and run until 6/17/21. 13357 mature larvae were collected from 2/3/21 to 6/27/21. Beetles began emerging from soil containers in the lab on 7/23/21. As of 9/1/21, 73 have emerged.

2. ***To characterize and evaluate the impact of native and introduced biocontrol agents***

Hemlock Woolly Adelgid (Adelges tsugae): Scientists in Tennessee participated in a regional research project (with Virginia, North Carolina, New York, and others) to assess several introduced predators (from Japan and from the Pacific Northwest U.S.) that have been released throughout the eastern U.S. to help reduce populations of hemlock woolly adelgid. In fact, about one million of these predators have been released in Tennessee, mainly in the Great Smoky Mountains National Park. The main focus of the project is to assess establishment and impact of *Laricobius nigrinus* and *Leucopis* spp. on hemlock woolly adelgid in areas where they both have been released and recovered, as well as to assess success and survival of predators placed in sleeve cages adelgid-infested branches. Initial populations of both predators were obtained from collections on hemlock in the northwestern U.S. and introduced to the eastern and southern U.S. Several of these predator species have been recovered at numerous sites and are reducing populations of hemlock woolly adelgid in numerous areas. Data collected quantified predation of *L. nigrinus* and *Leucopis* spp. in a field setting across a wide geographical area. Data were shared with other cooperators. Results documented predation by *L. nigrinus* and provided additional support that this species can significantly impact HWA. Results also demonstrated that *Leucopis* spp. can survive, develop, and reproduce at least through one generation in this area. *Leucopis* spp. are compatible with *L. nigrinus* in a biological control program against hemlock woolly adelgid in this region. This regional multi-year cooperative research program provided definitive results of the benefit of several introduced predators on mortality of hemlock woolly adelgid. The program has been expanded to assess the role of these natural enemies in improving forest health across the eastern U.S.

Emerald Ash Borer (Agrilus planipennis): Research continues to assess establishment of three parasitoids of emerald ash borer. With the procedural and financial assistance of USDA APHIS, we introduced several species of parasitoids of emerald ash borer into the Tennessee ecosystem. In fact, more than 100,000 individuals were released at several locations in east and middle Tennessee over a five-year period. However, no releases were made in the last three years in order to effectively assess establishment and

effectiveness of these introduced natural enemies. These parasitoids were evaluated in 2020-2021. Our research documented the first recovery of two introduced parasitoids of emerald ash borer in the southern U.S. These recoveries strengthen biological control activity to protect ash from this invasive pest and will inform future UDSA APHIS management programs against emerald ash borer in the U.S.

Crapemyrtle Bark Scale Acanthococcus* (= *Eriococcus) lagerstroemiae: A two-year study continued to focus research efforts on the life history and biological control of crapemyrtle bark scale in Tennessee. This pest, first found in Shelby County in late 2013, has been documented in 16 counties (10 counties are in West TN, 4 in Middle TN, and 2 in East TN). It has now been found in four major metropolitan areas (Chattanooga, Knoxville, Memphis and Nashville), and extensive damage is apparent in many of these areas. We have identified the lifecycle of this invasive pest, which encompasses eggs, four nymphal instars, adult females (sessile), and winged males, with two or three overlapping generations per year. Overwintering populations of last-stage instar females, adult females, and pre-pupal/pupal males were found in mid-February. Populations of several species of lady beetles, *Harmonia axyridis*, *Chilocorus* spp. and *Hyperaspis bigeminata*, were found to reduce crapemyrtle bark scale densities at some locations. Two of these predators (*H. axyridis* and *H. bigeminata*) were found at all locations, but *H. bigeminata* occurred in the highest densities and appeared to have the greatest impact on crapemyrtle bark scale populations. This research will continue to assess the natural enemy complex of crapemyrtle bark scale to determine unoccupied niches as a target for biological control and to develop strategies to enhance the impact of those already established predatory species.

Kudzu Bug (Megacopta cribraria): A three-year research project was continued to determine temporal and seasonal presence of *Beavueria bassiana* in kudzu, in kudzu bug onkudzu, and in soil around kudzu. This fungal pathogen is an important mortality factor of kudzu bug, and little is known about ecological interactions among the host plant, the fungus, and the insect. This research has demonstrated that *B. bassiana*: 1) is present in kudzu bugs as early as June, 2) does not colonize kudzu until July, and 3) peaks in late summer, contributing as much as 75% mortality of kudzu bugs in some areas. A fungus, *Beauveria bassiana*, infecting ca. 90% of kudzu bugs in some areas, was discovered. In addition, a small parasitoid (a wasp) was found to parasitize 52% of kudzu bug eggs. This fungus and parasitoid are important mortality factors of kudzu bugs. Their presence will protect soybeans from damage by this invasive insect, enabling growers to maximize their profits. In east Tennessee, this pest caused little damage to soybean production in 2021 (due to these natural enemies). Research also has shown that *B. bassiana* is present

in stems (endophyte), on kuduz bugs, and in the soil, suggesting multiple pathways for pathogen dissemination onto kudzu bug immatures and adults. Further research will address the role of this fungus and parasitoid in maintaining kudzu bug populations below damaging levels, especially in west Tennessee where the majority of our soybean is grown.

3. To develop integrated pest management programs that have a biological control component

Hemp Production and Pest Management: A multi-year project is underway to better understand the pests associated with hemp, as well as the natural enemies associated with this new crop in Tennessee and the southeastern U.S. At least 15 natural enemies have been identified on hemp, and the impact of each of these natural enemies is under investigation to better understand their role in reducing pests on hemp. The major pest on hemp in Tennessee is the corn earworm, *Helicoverpa zea*, and management strategies are necessary to reduce the damage caused by this pest insect. Several natural enemies (primarily parasitoid species; two Dipertan species) have been identified to feed on larvae; research to investigate tritrophic interactions among larvae, parasitoids and hemp varieties is underway.

4. To develop augmentation and conservation biological control tactics, especially to improve the quality of agricultural habitats for pollinators

II. Not applicable this year.

III.

IV.

UTILITY OF FINDINGS

V.

***Ash*.** Emerald ash borer, an invasive species from Asia, has killed 90%+ of the ash in Tennessee (as well as throughout the native area of ash in the United States). This invasive insect has reduced the viability and profitability of the ash industry, and has been predicted to have potential to cause many ash species to become extinct. Activities from this project strengthen the ash industry, enhancing and improving lumber production and productivity, leading to the continued use of ash in furniture, baseball bats, etc. The broader public benefit from this project by the preservation and conservation of ecosystem services provided by ash in forest systems, providing a healthier forest for all individuals. They also benefit by

continuing to have ash available as a wood product for various purposes (furniture, home, baseball bats, etc.)

Hemlock. Hemlock woolly adelgid has killed hundreds of thousands of trees throughout the eastern U.S. The loss of this long-lived, foundation species in our forests has numerous ecological, environmental, social, and economical ramifications, as well as safety issues when dealing with so many dead trees in highly traveled and visited areas, such as the Great Smoky Mountains National Park. Thus, the management of this invasive insect species introduced from Japan is critical to forest health, aesthetics, safety, and the environmental sustainability of forest systems. The target audience is comprised of land managers, Park managers, and natural area personnel, as well as landowners with hemlock growing on their properties. These groups have benefited from this project by the development of management tools (incorporating biological control) that enhance survival of eastern hemlocks in our forests. As a foundational tree species, eastern hemlock is a vital compoent to forest health. These results are being used to inform and improve future management decisions to enhance forest health and reduce cost inputs for management decisions. The broader public benefits from this project's activities by the preservation and conservation of a foundational species in our forests (eastern hemlock), which is vital to so many other species (birds, other animals, plants, etc.) in the forest. This project enhances forest health and forest productivity, while providing the broader public a safe environment to hike (fewer dead trees falling in the forest and/or on hiking trails/campgrounds/etc.) and enjoy the natural beauty of the forest.

Crape myrtle Crapemyrtle bark scale, an invasive species from Asia, is a new pest of crape myrtles and has been found in several locations across the state. This insect affects the aesthetics and saleability of crape myrtles, and the appearance of infested trees in landscapes can lead homeowners to have the trees removed, imposing an economic hardship on families. This invasive insect will impact nursery producers who grow and sale this plant, as well as homeowners and landscapers. Because little is known about its state-wide distribution, lifecycle, biology, natural enemies, and impact on crape myrtles, a study was initiated to gain additional knowledge to mitigate crapemyrtle bark scale before it becomes an economic barrier for crape myrtle production and growth. The target audience of this project include nursery producers who grow and sell crape myrtle, wholesalers and garden stores that sell crape myrtle, and homeowners who plant and grow crape myrtle in their landscapes. Results of this study will enhance management of this invasive pest, improving/maintaining profitability for growers and enhancing plant survival and aesthetics for homeowners. The broader public benefits from this project by the maintenance of beautiful landscapes where crape myrtles grow, enhancing landscape aesthetics. They also benefit by fewer pesticides in the environment to control this invasive pest, and reducing the potential of pesticide pollution in the

environment due to reduced pesticide use. The project's activities provide healthier, more aesthetically pleasing landscapes, while minimizing threats to the environment.

Kudzu Bug Kudzu bug is a new pest of soybean in Tennessee and the southeastern U.S. In addition, this pest is a home invader and can cause health issues with homeowners. Its home invasive qualities and its economic impact on soybean cause great concern. We initiated a research program to assess the status, seasonality and natural enemies of kudzu bug to inform development of a management program to reduce numbers of kudzu bug. The target audience is soybean growers who will benefit greatly from reduced populations of kudzu bug. This reduction will protect soybean profits, and reduce the amount of management expenses (pesticides, application costs, etc.) necessary to control this pest. Thus, results of this research will inform management decisions for kudzu bug on soybean. Another target audience is homeowners who live close to kudzu or soybean fields, where kudzu bug may overwinter in their homes, outbuildings, etc. A reduction in kudzu bug populations will enhance their quality of life and reduce their efforts to control this invasive pest. The broader public benefits from reasonably-priced products made from soybean, due to reduced management costs. They also benefit by fewer pesticides in the environment to control this invasive pest, and reducing the potential of pesticide pollution in the environment due to reduced pesticide use. The project's activities provide healthier food, while minimizing threats to the environment.

WORK PLANNED FOR NEXT YEAR (2022):

Hemlock woolly adelgid – Efforts will continue to rear, release and evaluate biological control agents of hemlock woolly adelgid in forested systems; continue to assess establishment of introduced biological control agents; participate in multi-state project to assess impact of two introduced predators (*Laricobius nigrinus* and *Leucopis* sp.) on hemlock health as a result of reductions of hemlock woolly adelgid populations.

Emerald ash borer – Research will continue to assess establishment of introduced species of emerald ash borer using yellow pan trap sampling; an Emerald Ash Borer Aftermath Study will continue to determine if tree regrowth and reestablishment coincide with successful establishment of introduced parasitoids of emerald ash borer in the southern U.S.

Kudzu bug - Research will continue to evaluate the ecological interactions of kudzu, kudzu bug, soybean, and a fungal pathogen (*Beauveria bassiana*) to better understand disease epidemiology and to enhance management of kudzu bug.

Crapemyrtle bark scale - Research continues to assess the distribution of crapemyrtle bark scale and assess the role of biological control agents in reducing its populations; efforts will be made to identify niches that provide potential for introduction of non-native biological control agents.

Natural Enemies on Hemp – Efforts will continue to identify natural enemies impacting pest insects on hemp. Integrated pest management programs, incorporating biological control, will be evaluated and assessed.

Publication Plans – We plan to publish several journal articles and extension publications, as well as develop several promotional items/outreach materials to educate the general public and others about invasive species, biological control, and integrated pest management.

PUBLICATIONS (2020-21)

Britt, K. E., T. P. Kuhar, C. T. McCullough, B. R. Arends, D. Owens, H. Burrack, M. Pulkoski, B. J. Fritz, and J. F. Grant. 2021. Pest Management Needs and Limitations for Corn earworm (Lepidoptera: Noctuidae), An Emergent Key Pest of Hemp in the United States. Journal of Integrated Pest Management 12 (Issue 1): 34, https://doi.org/10.1093/jipm/pmab030

Cornish, A. 2021. Seasonality, Distribution, and Biological Control of Crapemyrtle Bark Scale,

A New Invasive Threat in Tennessee. M.S. Thesis, University of Tennessee, Knoxville.

Cosner, J. 2021. Feeding Behavior and Influence of Hemp Varieties and Fertilization Rates on Damage Caused by Corn Earworm, *Helicoverpa zea*. M.S. Thesis, University of Tennessee, Knoxville.

Hansen, Z., R. Akinrinlola, H. Kelly, V. Sykes, R. Guyer, M. Cartwright, J. Grant, and J. Cosner. 2021. Hemp Variety Trials in Tennessee 2020. University of Tennessee Institute of Agriculture, Publication No. W 1016.

S1073: Biological Control of Arthropod Pests and Weeds

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ACCOMPLISHMENTS:

- To characterize and evaluate the impact of native and introduced biocontrol agents

Pests of cucurbit crops. In 2021, we conducted research quantifying the impacts of introducing beneficial entomopathogenic nematodes for biological control and enhanced plant resistance to improve pest management in cucurbit crops. We partnered with a local vegetable farm to conduct biological control trials with entomopathogenic nematodes (EPNs) in summer squash, cucumbers, and watermelons. We applied 2 species of EPNs, *Steinernema riobrave* and *Heterorhabditis bacteriophora*, and quantified pest and beneficial arthropod species, pest damage, plant growth, and yield. We observed a marginal reduction in early season pest damage for summer squash and cucumbers and no effect in watermelons for plots treated with EPNs. We also observed higher yield in summer squash (~33% increase) and cucumber (~138% increase) and no difference in watermelon plots treated with EPNs compared to our control plots.

Striped cucumber beetle biological control. In 2020 and 2021, we conducted research evaluating the mechanisms and efficacy of managing striped cucumber beetle larvae using entomopathogenic nematodes (EPNs) for biological control. We documented evidence that EPNs are attracted to beetle-damaged cucumber roots and can provide effective control (~70% of larvae were killed in lab studies). However, beetle larvae ultimately suppress defenses in cucumber roots attenuating EPN attraction. We also evaluated cucumber beetle larvae responses to chemical cues from EPNs and found that larvae are repelled by cues from *Heterorhabditis bacteriophora* EPNs.

UTILITY OF FINDINGS:

Pests of cucurbit crops. Our findings revealed that on-farm application of EPNs can reduce pest damage and increase yield for some cucurbit crops like summer squash and cucumbers.

Striped cucumber beetle biological control. Beetle suppression of plant defense and EPN attraction highlight a potential challenge for biological control in this system. Beetle repellence from EPN chemical cues could present another challenge, if beetles avoid EPN infection and mortality. Alternatively, our results could represent an opportunity for repelling pests for increased plant protection.

WORK PLANNED FOR NEXT YEAR (2022)

We will continue our research to characterize and evaluate the impact of native and introduced biocontrol agents. In 2022, we will continue our on-farm research with entomopathogenic nematode (EPN) applications for biological control of cucurbit pests. We are also starting a new project to further explore the mechanisms of enhanced plant resistance following plant exposure to EPNs.

PUBLICATIONS (2020-2021)

Grunseich, J.M., Aguirre, N.M., Thompson, M.N., Ali, J.G., Helms A.M. (2021) Olfactory cues from entomopathogenic nematodes vary across species with different hunting strategies, triggering different behavioral responses in prey and competitors. Journal of Chemical Ecology. 47, 822–833 https://doi.org/10.1007/s10886-021-01304-8

Gale, C.C., Lesne, P., Wilson, C., Dickens, C.M., Helms A.M., Suh, C.P., Sword, G.A. (2021) Foliar herbivory increases sucrose concentration in bracteal extrafloral nectar of cotton. PlosOne. 16, e0258836 https://doi.org/10.1371/journal.pone.0258836

Lin, P.A., Chen, Y., Chaverra-Rodriguez, D., Heu, C.C., Bin Zainuddin, N., Singh Sidhu, J., Peiffer, M., Tan, C.W., Helms, A.M., Kim, D., Ali, J., Rasgon, J.L., Lynch, J., Anderson, C.T., Felton, G.W. (2021) Silencing the alarm: an insect salivary enzyme closes plant stomata and inhibits volatile release. New Phytologist. 230: 793-803 https://doi.org/10.1111/nph.17214

Grunseich, J.M., Thompson, M.N., Hay, A.A., Gorman, Z., Kolomiets, M.V., Eubanks, M.D., Helms A.M. (2020) Risky roots and careful herbivores: Sustained herbivory by a root-feeding herbivore attenuates indirect plant defences. Functional Ecology. 34,1779–1789 https://doi.org/10.1111/1365-2435.13627

Grunseich, J.M., Thompson, M.N., Aguirre, N.M., Helms A.M. (2020) The Role of Plant-Associated Microbes in Mediating Host-Plant Selection by Insect Herbivores. Plants. 9, 6 https://doi.org/10.3390/plants9010006

PRESENTATIONS (2020-2021)

Helms, A.M., Grunseich, J.M., Hay, A.A., Thompson, M.T. “Nobody Likes a Tattletale: A Belowground Herbivore Suppresses Indirect Plant Defenses.” Invited oral presentation in symposium “Molecular battle between plants and insects”. Entomological Society of America Annual Meeting. Denver, USA. October 2021.

Grunseich, J.M., Helms, A.M. “Olfactory Cues from Entomopathogenic Nematodes Vary Across Species with Different Foraging Strategies, Triggering Different Behavioral Responses in Prey and Competitors.” Oral Presentation. Entomological Society of America Meeting. November 2021.

Helms, A.M. “Chemical Cues Linked to Risk: How Organisms Navigate Conflict in a Chemical World.” Invited Seminar. University of Texas Rio Grande Valley. October 2021.

Helms, A.M. “Chemical Cues Linked to Risk: How Organisms Navigate Conflict in a Chemical World.” Invited Seminar. Cornell University. September 2021.

Grunseich, J.M., Helms, A.M. “A Root-Feeding Herbivore Suppresses Indirect Plant Defences to Avoid Elevated Predation Risk.” Poster Presentation. Symposium on Insect-Plant Interactions. July 2021.

Grunseich, J.M., Helms, A.M. “Olfactory Cues from Entomopathogenic Nematodes Vary Across Species with Different Foraging Strategies, Triggering Different Behavioral Responses in Prey and Competitors.” Oral presentation. Entomological Society of America Southwestern Branch Meeting. June 2021.

Manuel, E., Grunseich, J.M., Helms, A.M. “The Attenuation of Belowground Indirect Plant Defenses Following Sustained Herbivory by *Acalymma Vittatum*.” Oral presentation. Entomological Society of America Southwestern Branch Meeting June. 2021.

Manuel, E., Grunseich, J.M., Helms, A.M. “The Attenuation of Belowground Indirect Plant Defenses Following Sustained Herbivory by *Acalymma Vittatum*.” Oral presentation. Texas A&M Student Research Week. March. Texas A&M University. March 2021.

Grunseich, J.M., Helms, A.M. “A root-feeding herbivore suppresses indirect plant defenses to avoid elevated predation risk.” Poster presentation. Texas Plant Protection Association Annual Meeting. December 2020.

Helms, A.M., Grunseich, J.M., Hay, A.A., Thompson, M.T., Aguirre, N.M., Ali, Jared G. “Challenges and opportunities for enhancing biological control of cucumber beetles.” Invited oral presentation in IOBC-NRS symposium “Early career professionals promoting biological control in a changing world”. Entomological Society of America Annual Meeting. Virtual. November 2020.

Grunseich, J.M., Helms, A.M. “A root-feeding herbivore attenuates indirect plant defenses to avoid elevated predation risk.” Oral presentation. Entomological Society of America Virtual Meeting. November 2020.

Helms, A.M. “The smells of dinner, death, and danger: How organisms navigate multitrophic interactions in a chemical world.” Invited seminar. University of California Davis Department of Entomology. October 2020

Helms, A.M. “The smells of dinner, death, and danger: How organisms navigate multitrophic interactions in a chemical world.” Invited seminar. University of Nevada Reno Ecology, Evolution, and Conservation Biology Program. October 2020.

Helms, A.M. “The smells of dinner, death, and danger: How organisms navigate multitrophic interactions in a chemical world.” Invited seminar. Purdue University Department of Entomology. September 2020.

Helms, A.M. “The smells of dinner, death, and danger: How organisms navigate multitrophic interactions in a chemical world.” Invited seminar. Texas A&M University Department of Entomology. August 2020.

Grunseich, J.M., Helms, A.M. A root-feeding herbivore suppresses indirect plant defenses to avoid elevated predation risk. Oral presentation. Texas A&M Entomology Graduate Student Forum. Virtual. August 2020.

Grunseich, J.M., Thompson, M.N., Hay, A.A., Helms, A.M. “Temporal changes in olfactory cues from plant roots influence foraging by entomopathogenic nematodes.” Oral presentation. North-Central/Southwestern Branch Entomological Society of America Joint Meeting. Virtual. March 2020.