S1073: Biological Control of Arthropod Pests and Weeds
Meeting Agenda

September 7, 2021

10 am EST

I. Welcome and call to order

II. 2021 Symposium: Potential for Multistate Collaborations in Biological Control: Moving Forward Together 2021 ESA Southeastern Branch Virtual Meeting (recording available)

III. New member introduction

IV. State reports- highlights

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

VI. Impact Statements

a) 1 page impact statement/ infographic for S1073

b) Form committee 2-3 ppl

VII. Return to usual schedule "post" pandemic

a) Meeting 2022 SEB Meeting (March 26-30, San Juan Puerto Rico)

b) State reports (accomplishments 2021, plans for 2022)- due late February

VIII. Nominations: New secretary 2022

IX. Other business

X. Adjournment

*****See page 2 for meeting minutes**

Minutes from Meeting: S1073: September 7, 2021.
Chair: Carey Minteer Secretary: Kristopher Giles

Participants meet online from 10-11:30am (Zoom) as an annual requirement of the multi-state working group and addressed each item on the agenda. Brief notes for each item are summarized below.

*Participants discussed the success of the 2021 S1073 symposium affiliated with the online ESA SEB meeting. Online participation exceeded 90 viewers at different stages of the symposium. The symposium Potential for Multistate Collaborations in Biological Control: Moving Forward Together was developed in an effort to stimulate ideas for future projects among participants. Participants agreed that future symposiums affiliated with the SEB, but also available online for other regions, remains an excellent opportunity to highlight project accomplishments.

*New participants were introduced, as well as non-formal participants.

*State reports were provided prior to the meeting and several participants discussed projects that could be highlighted for the group. The chair referred to the combined state reports (Attached) for any questions and encouraged follow up interactions.

*Administrative Advisor Dr. Saied Mostaghimi discussed the need for the group to develop impact statements, similar to other working groups, in an effort to highlight accomplishments. Example impact statements were discussed, and the incoming chair and newly elected secretary will establish a committee during 2022 to develop a document to highlight project impacts. Dr. Mostaghimi also suggested that the group develop priorities associated with potential future funding opportunities, particularly those associated with the potential infrastructure bill. Participants discussed several topics, and collectively identified the topic of climate change and biological control. This topic will be the focus of the S1073 2022 symposium. The symposium will be designed to highlight research on the topic and stimulate collaboration among participants.

*Participants agreed to return to meeting in person in 2022, but also provide online access to interested colleagues from outside the region. The official S1073 meeting and symposium will be held concurrently with the ESA-SEB meeting in San Juan Puerto Rico (March 26-30). State reports will be due in February 2022.

*Steve Frank was nominated as upcoming secretary, and unanimously elected among voting participants.

*No new business was discussed and the meeting was adjourned at 11:30 am.

S-1073 ANNUAL REPORT FOR 2020 AND PLANS FOR 2021
Impact statement: (to be added)

NAME OF REPRESENTATIVE: Adam Dale
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OTHER PARTICIPANTS: Jillian Rutkowski, Jillian Skairus, Janna Josafat, Ike Irvin, Gabrielle Cintron, Oscar E. Liburd, Lorena Lopez, Lance Osborne, Erich Schoeller, Daniel Carrillo, Liliana Maria Cano, Sriyanka Lahiri, Carey Minteer; Cindy McKenzie (USDA, ARS); Dan Gilrein,(Cornell); Nancy Rechcigl, (Syngenta); Katelyn Venner (BASF); Sheryl Wells (Bayer CropScience); Matthew Weaver (Intelligro); Mark Brotherton (SePRO); Purnama Hidayat, Izza Putri, Redani Dinata, Dedi Huteapea (Bogor Agricultural University); Jesusa C. Legapsi, R. Meagher (USDA, ARS-CMAVE); M. Haseeb, L. Kanga, A. Bolques, C. Okoroji, W. Diedrick, J. Perier (FAMU); P. Wu, R. Zhang (Univ. of Chinese Academy of Sciences, China); W. Tavares, A. de Castro, J. C. Zanuncio (Universidade Federal de Vicosa, Brazil); D. Amalin (De La Salle Univ., Philippines); X. Zhao, N. Dufault, Z. Gao, A. Hodges, K. Sattano, M. Swisher (Univ. of FL); J. Diaz -Perez, T. Coolong (Univ. of GA)

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

Brazilian peppertree. The stem thrips *Pseudophilothrips ichini* (Thysanoptera: Phlaeothripidae); *Calophya latiforceps*, *Calophya terebinthifolii*, and *Calophya lutea* (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. Host range testing of the other two other *Calophya* spp. is completed. Since release permits were issued for *P. ichini*, UF, Florida Department of Agriculture and Consumer Services Division of Plant Industry, and federal collaborators (USDA-ARS) have released over 1.7 million *P. ichini* at sites throughout Florida.

Continued maintenance of a colony of the stem-boring weevil *Apocnemidophorus pipitzi* in the EDCL. A manuscript describing the host range of the weevil *A. pipitzi* was published in *Biocontrol Science and Technology*.

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 2017 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. One of those species, *Calomela intemerata* (Coleoptera: Chrysomelidae), has been introduced into containment labs in Florida for study. So far, *C. intemerata* has been tested on 45 species of native plants and remains host specific to *A. auriculiformis*.

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

Brazilian peppertree. Brazilian peppertree (BP) thrips (*P. ichini*) releases have continued in Florida. No differences in growth between plants treated with thrips and plants protected by a systemic insecticide have been found as of yet, nor are they expected until thrips populations increase at each site and supply significant insect pressure on the plants. BP thrips establishment has been achieved at a majority of release sites.

Organic squash pests. A combination of tactics was used to suppress squash pests such as aphids, sweet potato whiteflies, and thrips, as well as maintaining a healthy community of beneficial arthropods. Non-crop flowering plants such as sweet alyssum, African marigold, or cowpea were introduced as alternative food and shelter for pollinators, predators, and parasitoids. The predatory mite *Amblyseius swirskii* was released for suppression of whiteflies and thrips. The research showed that refugia increased pollinators and naturally occurring predators and parasitoids around organic squash. *Amblyseius swirskii* suppressed whitefly populations; thus, reducing the need for frequent insecticide applications.

Urban landscapes. Ongoing research is evaluating the role of ground-dwelling predatory arthropods (e.g., spiders, ground beetles, rove beetles, ants) that inhabit urban lawns in regulating turfgrass insect pests. Specifically, we are investigating the role of plant diversity and non-turfgrass plant cover in supporting predatory arthropods and if having more non-turf plant species and/or cover influences the regulation of turfgrass pests. If we can identify a specific lawn plant community traits that promote pest regulation, we could develop IPM programs that reduce pesticide (herbicide and insecticide) inputs in lawns, where nearly everyone is exposed to the associated plant and pest management practices.

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

Sweet potato whitefly. Sweet potato whitefly, thrips and aphids are major insect pests of vegetable crops in north Florida. The use of "push-pull" technology is a cultural control method which may mitigate damage by insect pests. We continued the evaluation of "push-pull" strategies to control insect pests in organic vegetables in a screened structure. We used potted repellent plants of citronella, garlic society and lemon grass. Flowering plants such as marigold and basil were placed on the edge of the screenhouse paired with commercial "preda-lure" volatiles to complement the "push-pull" strategy. The use of "push-pull" technology complemented with use of flowering plants and commercial attractants of beneficial insects, may be part of an integrated pest management program to control major insect pests in vegetables.

Whitefly and thrips pests. (a) Whitefly biotyping services have continued for growers and researchers free of charge to help guide management programs to more effectively control whitefly pests based on biotype (MEAM1 vs. MED / B vs. Q
(b) Management plans for thrips (https://edis.ifas.ufl.edu/pdffiles/IN/IN114500.pdf) and

whiteflies http://edis.ifas.ufl.edu/pdffiles/IN/IN117100.pdf are continually updated/available online. (c) Non-neonicotinoid rotation greenhouse trials have continued and made progress generating new MED whitefly recommendations compatible with predatory mites.

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, recent 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 other key pests like the southern chinch bug and investigating if cultivar blends increase the abundance or diversity of ground-dwelling predatory arthropods, and if that helps regulating insect pest populations.

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

Chilli thrips. Assessed the potential of the generalist predatory mite, *Amblyseius swirskii* (Acari: Phytoseiidae) to control the invasive chilli thrips, *Scirtothrips dorsalis* (Thysanoptera: Thripidae) in greenhouse studies using potted strawberry plants. The *A. swirskii* treatment was compared with spinetoram and an OMRI certified capsicum oleoresin-based pesticide treatments. The control plants had ~2–4 times higher *S. dorsalis* nymph numbers compared to the plants treated with *A. swirskii* and spinetoram, respectively. Results indicate that *A. swirskii* is an effective candidate for augmentative biological control agent of *S. dorsalis*.

Urban landscapes. Turfgrass monocultures provide relatively little value for insect pollinators compared to diverse flowering plants. There is a growing interest in planting turfgrass alternatives like sunshine mimosa and perennial peanut to enhance floral resources in lawns. However, most lawns are already a mix of turf and flowering 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 flowering lawn plant diversity or cover in supporting insect pollinators or other arthropods that use nectar or pollen as a resource. Recent work has shown that flowering lawn weeds like white clover are excellent resources for insect pollinators. However, Florida lawns support many naturally occurring flowering lawn weeds, but we poorly understand their value for insect pollinators (bees and natural enemies). Preliminary evidence indicates that lawn weed floral 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.

UTILITY OF FINDINGS:

Brazilian peppertree. The introduction of multiple *Calophya* spp. that can establish across the different climatic zones in Florida can increase chances for establishment and target plant suppression. For example, *C. terebinthifolii* should be introduced in areas with cold climate like North Florida, *C. lutea* should be introduced in areas with mild winter, and *C. latiforceps* should be introduced in areas with high humidity and summer temperatures.

Sweet potato whitefly. This research will enhance cultural and conservation biocontrol methods such as "push-pull" strategies complemented with use of flowering plants to control insect pests in vegetables in an integrated pest management program.

Organic squash pests. Organic growers who have limited options to manage whiteflies can use *A. swirskii* as a management tactic. However, more research is needed to determine when releases should occur and the suitable conditions that are needed to allow *A. swirskii* to thrive.

Chilli thrips. Findings from these studies will provide information to support and improve the adoption of augmentation and conservation biological control agents for conventional and organic strawberry production.

Urban landscape pest management. Our work investigating the role of lawn plant diversity in regulating pest and beneficial arthropods has generated a large amount of interest among stakeholders (sod growers, landscape management professionals, Extension professionals, and homeowners) as well as a large amount of data. These data will fuel multiple new research and extension publications as well as upcoming grant proposals. Ultimately, the results of this work will increase the sustainability of turfgrass production and maintenance by increasing the resilience of lawns and their associated biodiversity, thereby reducing pesticide and natural resource inputs used to maintain them.

WORK PLANNED FOR NEXT YEAR (2022)

We plan to continue ongoing investigations into identifying, rearing, releasing, and evaluating classical biological control agents of invasive insect and plant pests throughout Florida. We will also continue ongoing efforts to develop and refine IPM tactics that leverage augmentative and conservation biological control strategies to reduce key arthropod pests while promoting biological control organisms and their services. These efforts include developing new research ideas and programs, the submission (and resubmission) of state and federal grant proposals, publishing peer-reviewed and industry articles on work related to biological control, and training undergraduates, graduate students, and post-docs in all aspects of biological control research and implementation.

PUBLICATIONS (2020-2021)

Cuda JP, Gillmore JL, Garcete-Barrett BR, Benda N, Sharma S. 2021. Is the stem boring weevil *Apocnemidophorus pipitzi* (Coleoptera: Curculionididae) host specific to *Schinus terebinthifolia* (Sapindales: Anacardiaceae)? *Biocontrol Science and Technology*. DOI: https://doi.org/10.1080/09583157.2021.1929071

Zhang B, Yuan Y, Shu L, Grosholz E, Guo Y, Hastings A, Cuda JP, Zhang J, Zhai L, Qiu J. 2021. Scaling up experimental stress responses of grass invasion to predictions of continental-level range suitability. *Ecology*. E03417.

Weeks ENI, Kroll KJ, Johnson TS, Colquhoun T, Cuda JP, Denslow ND, Stevens BR. 2021. Novel effective mosquito larvicide DL-methionine: Lack of toxicity to non-target aquatic

organisms. *Ecotoxicology and Environmental Safety*. 213, 112013.

Prade P, Minteer CR, Gezan SA, Arguijo VC, Bowers K, Cuda JP, Overholt WA. 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*. 66(2), 281-294.

Stachowiak C, Baniszewski J, Cuda JP, Mary CS, Weeks ENI. 2021. Influence of competition and predation on survival of the hydrilla tip mining midge and its success as a potential augmentative biological control agent of hydrilla. *Hydrobiologia*. 848(3), 581-591.

Olaniyi OG, Rhodes EM, Chase CA, Liburd OE. 2021. The effect of summer cover crops and strawberry cultivars on the twospotted spider mite, *Tetranychus urticae* (Acari: Tetranychidae) and the predatory mite, *Neoseiulus californicus* (Acari: Phytoseidae) in organic strawberry production systems in Florida. *Journal of Economic Entomology*. https://doi.org/10.1093/jee/toab131

Calvin W, Beuzelin JM, Liburd OE, Branham MA, Simon LJ. 2021. Effects of biological insecticides on the sugarcane aphid, *Melanaphis sacchari* (Zehntner) (Hemiptera: Aphididae), in sorghum. *Crop Protection*. 142, 105528.

Gogi MD, Syed AH, Atta B, Sufyan M, Arif MJ, Arshad M, Nawaz A, Khan MA, Mukhtar A, Liburd OE. 2021. Efficacy of biorational insecticides against *Bemisia tabaci* (Genn.) and their selectivity for its parasitoid *Encarsia formosa* Gahan on Bt cotton. *Scientific Reports*. 11(1), 1-12.

Akyazi R, Welbourn C, Liburd OE. 2021. Mite species (Acari) on blackberry cultivars in organic and conventional farms in Florida and Georgia, USA. Acarologia. 61(1), 31-45.

Doker I, Revynthi AM, Kazak C, Carrillo D. 2021. Interactions among exotic and native phytoseiids (Acari: Phytoseiidae) affect biocontrol of two-spotted spider mite on papaya. *Biological Control*. 104758.

Cruz LF, Cruz JC, Carrillo D, Mtz-Enriquez AI, Lamelas A, Ibarra-Juarez LA, Pariona N. 2021. In-vitro evaluation of copper nanoparticles as a potential control agent against the fungal symbionts of the invasive ambrosia beetle *Euwallacea fornicatus*. *Crop Protection*. 143, 105564.

Tillman G, Toews M, Blaauw B, Sial A, Cottrell T, Talamas E, Buntin D, Joseph S, Balusu R, Fadamiro H, Lahiri S, Patel D. 2020. Parasitism and predation of sentinel eggs of the invasive brown marmorated stink bug, *Halyomorpha halys* (Stal) (Hemiptera: Pentatomidae), in the southeastern US. *Biological Control*. 145, 104247.

Goode ABC, Tipping PW, Minteer CR, Pokorny EN, Knowles BK, Foley JR, Valmonte RJ. 2021. *Megamelus scutellaris* (Berg) (Hemiptera: Delphacidae) biology and population dynamics in the highly variable landscape of southern Florida. *Biological Control*. 160,

104679.

Rafter MA, Moore K, Minteer CR. 2021. No-choice risk assessment of *Gratiana boliviana*, a potential biological control agent of *Solanum viarum* in Australia. *Biocontrol Science and Technology*. 1-16.

Lake EC, David AS, Spencer TM, Wilhelm Jr VL, Barnett TW, Abdel-Kader AA, Cortes AC, Acuna A, Mattison ED, Minteer CR. 2021. First drone releases of the biological control agent *Neomusotima conspurcatalis* on Old World climbing fern. *Biocontrol Science and Technology*. 31(1), 97-106.

Minteer CR, Smith MC, Madeira P, Goosem C, Zonneveid R, Makinson J, Wheeler GS, Purcell M. 2020. Is biological control for earleaf acacia (*Acacia auriculiformis*) feasible in the United States? *Biocontrol Science and Technology*. 30(12), 1275-1299.

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.

S-1073 ANNUAL REPORT FOR 2020 AND PLANS FOR 2021

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ACCOMPLISHMENTS-S1073 Objective specific (see numbers)

1. 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

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. The major limitation of this project is the procurement of exports permits from the Province of Buenos Aires. 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, the salvinia weevil mass rearing program had three harvests where state agencies and private citizens received weevils. Due to the popularity of the program, salvinia weevils were also sent to South Carolina, South Africa and Cameroon. Technical assistance about the establishment of mass rearing facilities and monitoring of biological control was provided to several institutions. In cooperation with Dr. Jerrod Penn, a survey about the economic impact of giant salvinia and biological control was developed. We expect to deliver the survey in the Fall of 2021.

   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 directed the thesis of one doctoral student, Felicia Amenyo, who studied the thermal ecology of the air potato beetle. A cooperation was established with Dr. Emily Kraus from FDACS (Gainesville) to study the ecology of the Chinese and Nepalese populations of the air potato beetle.

   Conyza: In cooperation with CSIRO from Australia, a survey of the insect herbivores and pathogens was conducted in Louisiana, Mississippi, and Texas. We found that *Conyza bonariensis* lacks specialist herbivores in the sites sampled, suggesting that this region might not be considered its native range.

Roseau cane scale: An international team of scientists is working on the ecology of the roseau cane scale, *Nipponaclerda biwakoensis*. The goal of the team is to understand the population growth of the scale in its native, Asia, and adventive range, Louisiana. During 2021, a PhD student was recruited by Diaz to study the impact of local parasitoids in Louisiana. As August 2021, the population growth of the scale is being monitored using exclusion cages in Baton Rouge, LA, and in Taiwan.

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.

   https://www.lsuagcenter.com/invasivespecies

   A manual about how to use air potato beetles was developed. The goal of the manual is to share with the public practical tips about air potato and beetle recognition, phenology of organisms, and how to monitor biological control.

   https://www.suagcenter.com/assets/suag/Entomology_Content/AP-MANUAL_Final.pdf

   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

- 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 presented in several regions of Louisiana.

- Field surveys of *Conyza* herbivores revealed the lack of specialist herbivores at several sites in Louisiana, Texas, and Mississippi.

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

- Roseau cane die-off: The project reached state biologists 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.
- Chinese tallowtree: The project reached private citizens and wildlife biologists in Louisiana and Texas.
- Air potato: The project reached land managers, park rangers, extension agents and private citizens.

WORK PLANNED FOR NEXT YEAR (2022)

Giant Salvinia: Continue with mass rearing program of salvinia weevils, and monitoring of its impact in Louisiana. Cooperation will continue to monitor the impact of the weevils at Lake Ossa in Cameroon, Las Curias in Puerto Rico, and a private property in Jamaica. 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. 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. Preliminary studies demonstrate that this scale is the host of at least eight parasitoids, however, their biology and host range are unknown. Due its close proximity to the non-native scale, *Nipponaclerda biwakoensis*, the biology and ecology of the native scale will be studied.

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

PUBLICATIONS (2020-2021)

Neal, A., **Diaz, R**., Qureshi, J. and Cave R. D. 2021. Adult cold tolerance and potential North American distribution of *Myllocerus undecimpustulatus undatus* (Coleoptera: Curculionidae). Biological Invasions. In Press: https://link.springer.com/article/10.1007/s10530-021-02601-9

Harms, N., Knight, I., Pratt, P., **Diaz, R**. 2021. Climate Mismatch Between Introduced Biological Control Agents and Their Invasive Host Plants: Improving Biological Control of Tropical Weeds in Temperate Regions. Insects. In Press: https://www.mdpi.com/2075-4450/12/6/549

Wahl, C.F., **Diaz, R.**, and Kaller, M. 2021. Nutrients enhance the negative impact of an invasive floating plant on water quality and a submerged macrophyte. *Journal of Aquatic Plant Management*. In Press.

Wahl, C.F., **Diaz, R.**, and Kaller, M. Invasive floating fern limits aerial colonization and alters community structure of aquatic insects. *Wetlands*. In Press: https://link.springer.com/article/10.1007/s13157-021-01457-y

Wahl, C.F., Kaller, M, and **Diaz R.** 2021. Invasion of floating fern alters freshwater macroinvertebrate community structure with implications for bottom-up processes. *Hydrobiologia*. In Press: https://link.springer.com/article/10.1007/s10750-021-04571-4

Escalante, C., Galo, D., **Diaz, R**. and Valverde, R. 2021. First report of dasheen mosaic virus infecting taro (*Colocasia esculenta*) in Louisiana. Plant Disease. In Press: https://doi.org/10.1094/PDIS-04-21-0854-PDN

Cronin, J. Johnson, J. and **R. Diaz.** 2020. Multiple Potential Stressors and Dieback of Phragmites australis in the Mississippi River Delta, USA: Implications for Restoration. Wetlands. DOI: 10.1007/s13157-020-01356-8

Harms, N., J. Cronin, **Diaz, R.** and R. Winston. 2020. A review of the causes and consequences of geographical variability in weed biological control successes. Biological Control. DOI: 10.1016/j.biocontrol.2020.104398

Knight, I., J. Cronin, M. Gill, J. A. Nyman, B. Wilson, and **R. Diaz.** 2020. Investigating Plant Phenotype, Salinity, and Infestation by the Roseau Cane Scale as Factors in the Die-Back of Phragmites australis in the Mississippi River Delta, USA. Wetlands. DOI: 10.1007/s13157-020-01307-3

Wahl, C., **Diaz, R**. and J. Ortiz. 2020. Assessing *Salvinia molesta* impact on environmental conditions in an urban lake: case study of Lago Las Curias, Puerto Rico. Aquatic Invasions. Accepted Article https://www.reabic.net/aquaticinvasions/2020/accepted.aspx

Wahl, C. F. and **R. Diaz.** 2020. Winter and spring conditions determine the production of the salvinia weevil mass rearing programme. Biocontrol Science and Technology 30: 569-580.

Reid, M., Coetzee, J. A., Hill, M., **Diaz, R.**, Gettys, L., Cuda, J. P., and C. S. Reid. 2020. Insect Herbivores Associated with *Nymphaea mexicana* (Nymphaeaceae) in Southern United States: Potential Biological Control Agents for South Africa. Florida Entomologist 103: 54-63, https://doi.org/10.1653/024.103.0409

S-1073 ANNUAL REPORT FOR 2021 AND PLANS FOR 2022

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ACCOMPLISHMENTS

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.

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.

S-1073 ANNUAL REPORT FOR 2020 AND PLANS FOR 2021

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ACCOMPLISHMENTS

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

A study to document predators and parasitoids of the muhly grass mealybug, *Stemmatomerinx acircula*, and the impacts of these natural enemies on the new invasive mealybug species in urban landscape is on-going. The invasive mealybug species was first detected in 2018 and is now known in the coastal counties of SC and NC. To date, an egg predatory wasp in the family Pteromalidae have been collected but its identity has not been confirmed. There are few predators, with the common lady beetle species not apparently attractive to the mealybugs.

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

As part of collaboration between members of this group (Chong, Mutschler-Chu and Schmidt), Chong and his post-doctoral research fellow (Gunn Gill) had investigated the foraging behavior of whitefly predator, *Delphastus catalinae*, on several acylsugar-producing, pest-resistant tomato breeding lines and a commercial line. Study demonstrated that the predator was not deterred, and its foraging efficacy (i.e. consumption of whitefly eggs) was not reduced by the acylsugar droplets presented on the tomato trichomes.

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 *D. catalinae* demonstrated that the predator has the potential of being used to further reduce the density of whiteflies on pest-resistant tomato lines, and thus further reduce the need for pesticide application.

WORK PLANNED FOR NEXT YEAR (2021)

Efforts will continue to collect and identify, as well as document the impacts of natural enemies of muhly grass mealybug (Objective 1). Manuscripts reporting on the compatibility of Group 9 insecticides with minute pirate bugs and the compatibility of pest-resistant tomato lines with biological control agents (Objective 3) will be published. Additional studies will be conducted to determine the compatibility between pest-resistant tomato lines with additional biological control agents, such as the predatory mite *Phytoseiulus persimilis*, as well as compatibility of OMRI-listed insecticides with common biological control used in augmentation biological control programs in vegetable production (Objective 3 and 4).

PUBLICATIONS

Peer-reviewed article:

Kheirodin, A., A. M. Simmons, J. C. Legaspi, E. E. Grabarcyzk, M. D. Toews, P. M. Roberts, J.-H. Chong, W. E. Snyder, and J. M. Schmidt. 2020 Can generalist predators control *Bemisia tabaci*? Insects 11: 823. doi:10.3390/insects11110823.

Trade journal articles:

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/

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

Chong, J. H. 2021. Celebrating pesticide safety, IPM, and killing aphids and callery pears. PestTalks 8 February 2021.

Chong, J. H. 2020. Broad mite management and new biocontrol products. PestTalks 26 August 2020.

Chong, J. H. 2020. Mysterious seeds; BioCeres for root aphids; black root rot efficacy. PestTalks 11 August 2020.

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 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 2020 AND PLANS FOR 2021

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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 crape myrtle bark scale, this cooperative effort was suspended in 2020 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 rears two predators of hemlock woolly adelgid (HWA): *Laricobius nigrinus* (introduced from the Pacific Northwest) and *Laricobius osakensis* (introduced from Japan). *L. nigrinus* has been reared here since 2005. *L. osakensis* was reared here in 2011, and from 2013 to present. Substantial mortality of beetles in storage and oviposition jars earlier in 2019 affected ability to rear large numbers in 2019/2020. Beetles began emerging from soil boxes on August 12, 2019, with a total of 3,398 emerging by January 19, 2020. Releases, made from August 29, 2019 to December 18, 2020, are detailed below. As with *L. nigrinus*, the number of mature larvae produced earlier in 2019 was less than for previous years, due to substantial mortality in storage and oviposition jars. Resulting adults began emerging in the lab onAugust 27, 2019. A total of 3,337 had emerged by January 19, 2020. Beetle releases, made from September 26, 2019 to December 17, 2020, are detailed below.

Releases (location/numbers) of adult *L. nigrinus* in late 2019 and 2020 were: Great Smoky Mountains National Park, 535; Pickett State Forest, 53 (supplemental release); Hemlock Restoration Initiative lands (in NC), 883; Cumberland Gap National Historic Park, 587; and Catoosa Wildlife Management Area, 284 (supplemental releases). Releases (location/numbers) of adult *L. osakensis* were: Foothills Parkway, 128 (supplemental releases); Kentucky Division of Forestry lands, 948; Pickett State Forest, 363 (supplemental releases); and US Forest Service (NC), 831.

Purification of L. osakensis field-collected in Japan: In total, 143 *L. osakensis* were collected in northern Japan by Virginia Tech personnel and shipped to LYBIL on January

30, 2020 after held in quarantine in Blacksburg, VA for over 10 weeks. Beetles were separated into six lines and lines were reared separately to "purify" them of *L. naganoensis*, which is difficult to distinguish from *L. osakensis* morphologically. Oviposition jars were established on January 30, 2020. The last jar was broken down on June 12, 2020. From February 24, 2020 to July 7, 2020, a total of 3,616 mature larvae were collected for all six lines. Adults began emerging on August 18, 2020. As of October 11,955 had emerged. All beetles dying during the oviposition period were stored separately in 95% ethanol for molecular analysis. The few surviving beetles at the end of the oviposition period were "euthanized" separatelyin 95% ethanol. Dead beetles were shipped to Virginia Tech where molecular analysis has, thus far, not detected any *L. naganoensis*. Purified lines will be used for releases and rearing.

2. ***To characterize and evaluate the impact of native and introduced biocontrol agents Hemlock Woolly Adelgid (Adelges tsugae):*** A cooperative multi-state approach 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 was initiated in late 2019 and continued through 2020. 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. States involved are MA, NC, TN and VA. One site (Cosby Site) in TN was used in the 2019- 2020 study. 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 multi-year project will better define the mortality of hemlock woolly adelgid contributed by these introduced natural enemies.

Emerald Ash Borer (Agrilus planipennis): Research continues to assess establishment of three parasitoids of emerald ash borer. Extremely low numbers of two parasitoids have been recovered in Tennessee in past years, suggesting that their establishment in the southern U.S. may be difficult due to asynchrony of adult parasitoids with larvae of emerald ash borer. Pan trap collections yielded potential recoveries of two of these introduced parasitoids in 2020.Species confirmation will be determined by expert taxonomists. The released egg parasitoid has not been recovered. A grant was received from USDA APHIS to enable us to more thoroughly assess establishment and spread of these exotic parasitoids on emerald ash borer in Tennessee.

Crapemyrtle Bark Scale Acanthococcus* (= *Eriococcus) lagerstroemiae: A grant was received from USDA APHIS to focus research efforts on the life history and biological control of crapemyrtle bark scale in Tennessee. Covid-19 restricted and limited field research during 2020. Even though research was limited, 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*) was found at

all locations, but *H. bigeminata* occurred in the highest densities and appeared ot 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 two-year research project was initiated in late 2019 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.

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

Impact of Dual-Use Cover Cropping on Beneficial Insects: A two-year study examined impact of a dual-use cropping system on pest and beneficial insects to enable growers to better manage pests insoybean. Cover crop species, such as crimson clover and woollypod vetch, with more biomass tended to have more arthropods (pest and beneficial). Cover crop species impacted arthropod community composition prior to soybean planting. However, no significant differences in pest or beneficial arthropod densities were observed among cover crop species after soybean planting. Results suggest that dual cropping did not serve as a reservoir for pests to move into soybean, but it did tend to preserve beneficial insects. No significant differences in average number of pest or beneficial arthropods were found between cover crop management practices. Results will enable soybean growers to make more informed decisions when choosing cover crops and planting methods.

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.

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

Not applicable this year.

UTILITY OF FINDINGS

Ash. The emerald ash borer has devastated populations of numerous species of ash throughout the eastern U.S. About 95% of the ash in east and middle Tennessee are dead from emerald ash borer. However, cooperative efforts with scientists with USDA APHIS have enabled the release of thousands of introduced parasitoids into Tennessee. Efforts are underway to determine their establishment and effectiveness as part of a management program to enable ash to grow and thrive. Findings from these studies will provide information to enhance management of emerald ash borer and promote ash regeneration throughout the southeastern U.S.

Hemlock. Our multi-state, multi-region research efforts directed against the invasive hemlock woolly adelgid on eastern hemlock have advanced our knowledge, our understanding and our management of this invasive pest. The use of classical biological control has been an effective component of this management plant.

Crape myrtle is a prized ornamental plant in the landscape, and it is economically important to nursery growers throughout our state. The spread of the invasive insect crapemyrtle bark scale poses a threat to the nursery industry, to landscapes, and to homeowners. Understanding the natural enemy complex of the invasive crapemyrtle bark scale will enable researchers to develop an integrated pest management plan for this invasive species. The potential to discover and evaluate new natural enemies in China and other countries is promising for management of crapemyrtle bark scale.

Hemp is a new crop in Tennessee that has generated tremendous interest among growers, especially some of those who had previously grown tobacco. Hemp provides an alternative crop for these growers. Unfortunately, we know little about the insects that impact this crop, as well as how to effectively manage those pest species. Because pesticide choices are limited, biological control remains a viable option to reduce corn earworm and other pests on hemp.

WORK PLANNED FOR NEXT YEAR (2021):

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 has been established 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 assessthe distribution, seasonality, and lifecycle of crapemyrtle bark scale and assess the role of biologicalcontrol 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 developed and implemented.

Impact of Dual-Use Cover Cropping on Beneficial Insects - This research is completed; data will be thoroughly analyzed and research publications will be developed and submitted for publication.

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)

David Bechtel. Spring 2020. Impact of Insecticide on Pollinator Communities in a Forested System: A Model System Using Eastern Hemlock, *Tsuga canadensis*, Rosebay Rhododendron, *Rhododendron maximum*, and Imidacloprid. M.S. Thesis, Univ. Tennessee, Knoxville, 141 pp.

Cornish, A., J. Grant, F. Hale, D. Paulsen, and P. Lambdin. 2020. Crapemyrtle bark scale, Acanthococcus (= Eriococcus) lagerstroemiae (Kuwana), in Tennessee: distribution, life cycle, and natural enemies. The Firefly, Proceedings of the Tennessee Entomological Society Annual Meeting (Virtual) (October 9, 2020).

Cosner, J., Grant, Z. Hansen, and H. Kelly. 2020. Corn earworm (*Helicoverpa zea* Boddie) on hemp: The Unwanted Consumer. The Firefly, Proceedings of the Tennessee Entomological Society Annual Meeting (Virtual) (October 9, 2020).

Hollabaugh, K., J. Grant, A. Michael, and W. Liang. 2020. Natural enemy targets invasive kudzu bug: where does the enemy originate? The Firefly, Proceedings of the Tennessee Entomological Society Annual Meeting (Virtual), October 9, 2020).

Liang, W., M. Abidi, L. Carrasco, J. McNelis, L. Tran, Y. Li, and J. Grant. 2020. Mapping vegetation at species level with high-resolution multispectral and lidar data over a large spatial area: A case study with kudzu. Remote Sensing, 12(4), 609, https://doi.org/10.3390/rs12040609.

Liang, W., L. Tran, V. Srivastava, and J. Grant. 2020. Estimating invasion dynamics with geopolitical-unit level records: Selection of optimal method depends on irregularity and stochasticity of spread. Sustainability, 12, 8526; doi:10.3390/su12208526.

Jubb, C., A. R. Heminger, A. E. Mayfield III, J. S. Elkinton, G. J. Wiggins, J. F. Grant, J. A. Lombardo, T. J. McAvoy, R. S. Crandall, and S. M. Salom. 2020. Impact of the introduced

predator, *Laricobius nigrinus*, on ovisacs of the overwintering generation of hemlock woolly adelgid in the eastern United States. Biological Control 143, 104180, https://doi.org/10.1016/j.biocontrol.2019.104180.

Matthew Longmire. Summer 2020. Influence of Traditional and Dual-Use Cropping on Arthropods and Slugs in Soybean in Tennessee. M.S. Thesis, Univ. Tennessee, Knoxville, 107 pp.

Longmire, M., J. Grant, S. Stewart, and V. Sykes. 2020. The more crops the merrier: Impact of dual-use cover cropping on pest and beneficial arthropods in soybean in Tennessee. The Firefly, Proceedings of the Tennessee Entomological Society Annual Meeting (Virtual)(October 9, 2020).