S1070 Regional Research Project Agenda
November 12 and 13, 2020; 8:00 am – 3 pm (EST) (Virtual)

Jimmy Klick, Chair
Stefan Jaronski, Vice-chair
Anamika Sharma, Secretary
Julie Graesch, Member-at-large
Paula Agudelo, Administrative Advisor
Robert M. Nowierski, NIFA Rep

November 12, 2020 (EST)

11:00 AM PRELIMINARY BUSINESS MEETING
1. Introductions and general information
2. Minutes of 2019 (Anamika Sharma)
3. Sub-project Leads

11:30 AM Funding Opportunities from NIFA, Robert Nowierski

12:00 PM NEW PROJECT REVIEW AND PLANNING-Large acreage crops Annual Crops [Gadi V.P. Reddy and Anamika Sharma]

12:45 PM NEW PROJECT REVIEW AND PLANNING-Orchard Systems [David Shapiro-Ilan]

1:30 PM NEW PROJECT REVIEW AND PLANNING-Small Fruits and Vegetables [Surendra Dara]

2:15 PM NEW PROJECT REVIEW AND PLANNING-Urban and Natural Landscapes, Rangelands, and Nurseries [David Oi]

November 13, 2020 (EST)

11:00 AM DISCUSSIONS

1. Theme for 2021
2. Discussion of collaborative projects
3. New business, Elections, Officers

3:00 PM ADJOURN

Outcomes 2019-2020

Frontiers (special issue) will be coming out on 'Entomopathogens for sustainable food production (Frontiers in Sustainable Food Systems). Research and review articles are invited (Topic Editors: Surendra Dara, Steven Arthurs, Robert Behle). More information can be found here: https://www.frontiersin.org/research-topics/11865.

Environmental Research and Public Health (special issue: Current Status, Challenges, and Prospects of Biopesticides). Research and review articles are invited (Deadline for manuscript submission, 15 April 2021; Guest Editors: Surendra Dara, Stefan T. Jaronski).

Microbials related publications generated by members of S1070 in 2019-2020 are cited at the end of the report.

Attendees 2019

Name	Affiliation	Email
1. Robert Behle	USDA-ARS, Peoria	robert.behle@ars.usda.gov
2. Stefan Jaronski	MycoSystems Consulting	thebugdoc01@gmail.com
3. Surendra Dara	UC Cooperative Extension	skdara@ucdavis.edu
4. Jimmy Klick	Driscoll's, California	jimmy.klick@driscolls.com
5. David Shapiro-Ilan	USDA-ARS, Georgia	david.shapiro@usda.gov
6. David Oi	USDA-ARS, Florida	david.oi@ars.usda.gov
7. Anamika Sharma	Virginia Tech	anamika@vt.edu
8. Pasco Avery	University of Florida	pbavery@ufl.edu
9. Ramandeep Sandhi	Montana State Univ.	Ramansandhi2010@gmail.com
10. Julie Graesch	BioWorks Inc.	jgraesch@bioworksinc.com
11. Shaohui Wu	University of Georgia	shaohui.wu@uga.edu
12. José Carlos Verle Rodrigues	University of Puerto Rico	jose_carlos@mac.com
13. Gadi VP Reddy	USDA-ARS, Mississippi	gadi.reddy@usda.gov
14. Patricia Stock	University of Arizona	spstock@email.arizona.edu
15. Govinda Shrestha	Oregon State University	shresthg@oregonstate.edu
16. Daniel Zommick	valentbiosciences	Daniel.Zommick@valentbiosciences.com
17. Hai Tran	Agbiome	htran@agbiome.com
18. Adam Chun	University of Florida	adamcnwong@ufl.edu
19. Rogelio Trabanino	Honduras	rtrabanino@zamorano.edu
20. Carlos E Bográn	OHP, Texas	cbogran@ohp.com
21. Robert M. Nowierski	USDA (NIFA)	robert.nowierski@usda.gov
22. Paula Agudelo	Clemson University	pagudel@clemson.edu

Apologies from Edwin Lewis and Olga Kostromytska were received.

BUSINESS MEETING

1. *Introductions:* Jimmy Klick (2020 chair): Welcomed all and began with introductions. Attendees introduced themselves including a short introduction about their affiliation and work.

2. *Minutes of 2019* (prepared by Anamika Sharma): A copy of the 2019 minutes was circulated electronically prior to the meeting. A motion to approve the 2019 minutes was made by David Shapiro and was seconded by Pasco Avery and passed unanimously. Minutes of the 2020 meeting are required to be posted within 60 days.

3. *NIFA administrators report* (Robert M. Nowierski):

Parag Chitnis (former Associate Director) is our new Interim Director for NIFA

RFAs and Grant Program Assignments

1. NIFA is making every attempt to release the RFAs as soon as feasibly possible.
2. RFAs have been developed for a number of grant programs that cover a two-year period.

3. Most of the grant review panels will be conducted virtually following the same panel review format as in the past.
4. Most of the NPLs will have additional grant program assignments until new NPL positions can be filled.

Grant Program Assignments for Nowierski (2020):

1. Small Business Innovation Research (SBIR) Program 8.2: Plant Production and Protection – Biology Phase I
2. SBIR Program 8.2: Plant Production and Protection – Biology Phase II
3. Crop Protection and Pest Management (CPPM) – Regional Coordination Program (RCP)
4. CPPM – Extension Implementation Program (EIP)
5. CPPM – Applied Research and Development Program (ARDP)
6. AFRI A1102: Foundational Knowledge of Agricultural Production Systems (Co-Directed with Mat Ngouajio)
7. AFRI A1112: Pests and Beneficial Species in Agricultural Production Systems (Co-Directed with Erica Kistner-Thomas)
8. AFRI A1113: Pollinator Health: Research and Application Program (Co-Directed with Erica Kistner-Thomas)
9. Specialty Crop Research Initiative - Emergency Citrus Research and Extension Program (Co-Directed with Ann Lichens-Park).
10. HUD-IPM in Affordable Housing Program

New Grant Program Assignments (2021):

1. CPPM (RCP, EIP)– Program Director - Vijay Nandula, NPL for Weed Science
2. CPPM (ARDP) – Program Director – Bob Nowierski
3. A1112 – Program Directors: Erica Kistner-Thomas (NPL for Entomology) and Bob Nowierski
4. A1113 – Program Directors: Erica Kistner-Thomas, Bob Nowierski, and Megan O'Rourke (NPL) will administer

Application Deadlines:

1. CPPM – ARDP – June 2021?
2. A1102 – Foundational Knowledge - June 17, 2021
3. A1112 – Pollinator Health - May 27, 2021
4. A1113 – Pests and Beneficial Species - May 27, 2021

Multistate Committees: NIFA rep to 15 multistate committees; secondary NIFA rep to 9 multistate committees.

Hatch Projects: Administer 400 Hatch Projects.

New Building Location for NIFA staff - 805 Pennsylvania Avenue, Kansas City, Missouri. Move date for NIFA staff, from Beacon Building to new location on Pennsylvania Avenue, anticipated to be late fall, 2020.

Interviews for new staff positions

1. NIFA continues to conduct interviews for new NPL, Program Specialist, Division Director, and Deputy Director positions.
2. Hopefully, positions will continue to be filled over the next few months!

Process Improvement – NIFA is in the process of improving all NIFA functions and processes relative to competitive grants, formula funds and customer service, based on feedback from NIFA staff and external stakeholders!

NIFA Staff Points of Contact

1. NIFA selected six National Science Liaisons from current NIFA National Program staff who are stationed in Washington, DC and did not move to the Kansas City Area.
2. The National Science Liaisons will focus on DC-centric interactions, and will lead the coordination of stakeholder and interagency relations.
3. Dr. Mathieu (Mat) Ngouajio is one of the National Science Liaisons who will cover plant production and plant protection aspects of NIFA's portfolio in this new role.

Points of Contact for plant protection and integrated pest management issues:

Bob Nowierski, National Program Leader for Bio-Based Pest Management
Erica Kistner-Thomas, National Program Leader for Entomology
Vijay Nandula, National Program Leader for Weed Science
Ann Lichens-Park, National Program Leader for Plant Pathology and Division Director – Plant Health
Kathy Kimble-Day, Program Specialist and Administrative Contact

Further details about funding can be assessed from http://www.NIFA.usda.gov/fo/funding.cfm

Large acreage crops

Anamika Sharma: Wireworms: In 2017, granular formulations of three EPFs, on polenta and millet spent substrate carriers, were applied in-furrow at planting, at two rates, against a water control and imidacloprid seed treatment in spring wheat in Montana, USA. The selected EPFs were *Beauveria bassiana* GHA, *Metarhizium robertsii* DWR356, *M. robertsii* DWR2009, applied as granular formulations at 11 kg ha−1 or 22 kg ha−1. In 2017, at Valier, DWR356, DWR2009 on millet carrier at 22.4 kg ha−1 provided greater yield, but all the treatments at the lower rates were still cost-effective. In 2018, *B. bassiana* GHA and *M. robertsii* DWR2009 were retested along with *B. bassiana* ERL836 and *M. brunneum* F52. Millet carrier alone, GHA and ERL836 on millet carrier obtained cost-effective results at irrigated and non-irrigated sites in 2018. However, these were less cost-effective than imidacloprid as a seed treatment. The overall cost-benefit ratio of using EPF granules was higher in both the years compared to control. Millet on which the fungi were grown worked better than the other carriers. In 2019, Couscous, Millet, BB couscous, BB Millet, ERL couscous, ERL Mille, 2009 couscous, 2009 millet were applied. Results are yet to be analyzed but raw data explains that at the site with higher wireworm pressure (Barley) 2009 millet is effective and at Choteau site (spring wheat) ERL couscous, ERL Millet, 2009 couscous, and 2009 Millet performed better than control.

In 2020, a bioassay was established. The viability of EPFs used in the field was tested. Two sets of experiments were established. In one set presence and efficacy of soil samples from the fields where EPFs were consecutively applied for 2 years were tested. In another set efficacy of EPFs were tested in soil obtained from Western Triangle Agriculture Research Center, Montana where EPFs were never applied. For both sets, the soil was oven-dried before maintaining standard moisture content. The mortality of wireworms was evaluated on basis of the development of EPFs on wireworms. In the first set where EPF was applied to the soil, *B. bassiana* ERL836 on millet and *M. robertsii* DWR2009 on millet produced the same mortality followed by *B. bassiana* ERL836 and *B. bassiana* GHA on couscous. In another set of experiments, maximum mortality was observed in *M. robertsii* DWR2009 on millet followed by *M. brunneum* F52 on millet, *M. robertsii* DWR2009 and *M. brunneum* F52 on couscous.
Stefan mentioned that there is a study going on which shows that microbes in wireworms could reduce the efficacy of EPFs on wireworms. The study is being conducted and more results will be forthcoming.

Stefan Jaronski: Wheat stem sawfly: USDA has patented certain strains of endophytic *Beauveria* and *Metarhizium* which demonstrated infection in the larvae. These strains are extracted from diapausing larvae of wheat stem sawfly. This has been licensed by Montana Bioagriculture Inc. and Microtech. We are assessing the practicability. We are also testing native baculovirus from Australia, and a granular fungus on wireworms (*Limonius* sp.) on the potato crop. Also working with AgBio with Gates foundation in Africa on sweet potato against sweet potato weevil adults.

A graduate student at Virginia Tech is looking for biobased IPM for CBD hemp. In a field-based work, she is looking for the efficacy of microbials such as commercial NPVs, BTs, *Beauveria* GHA, chromobacterium, against corn earworm, stink bugs, aphids, mites, thrips.

Robert Behle: Working with some companies to evaluate fungal seed coating to manage soil insects in cotton. Seed coating with microsclerotia, does not survive in field condition and the half-life of these can be less than a week. We are trying to reduce the moisture content to prevent the metabolism of fungus.

Shaohui Wu: Since 2017, high whitefly pressure has been recorded on cotton in Georgia. We are isolating a naturally occurring new strain of fungus, *Cordyceps javanica*. We established bioassays to test the efficacy of this fungus and have also established field experiments. At this point, we are comparing a new strain with *C. javanica* wf GA17 with *C. fumosorosea* Apopka97, *Metarhizium brunneum* F52, and *Beauveria bassiana* GHA. This new fungus strain showed greater efficacy; however, temperature plays a major role and higher temperature (over 100 F) could reduce the efficacy of all the strains. We are also trying to incorporate oil with the fungi to improve the efficacy.

Stefan mentioned that good dispersion is necessary and especially if nymphs are on the abaxial side of the leaf so that more than 80% of spray could reach the abaxial surface. Hence modification in the dispersal method is also necessary. For CFUs, checking in the microscope to see if the spores are stuck together and forming a colony, could be helpful. Also, measure leaf temperature to check

if the cotton plants are themselves managing the temperature on plant surfaces. Look for microclimate, not just macroclimate.

Orchard System

Robert Behle: Working on walnut husk maggot (Tephritidae). There are six species in the Americas. Instead of fruit flies, we used walnut husk maggots. I have established the work in the home yard. I have targeted maggots with microsclerotia fall application while they migrate to the soil to pupate. I have used a granular single application per year. The adult emergence was reduced by 35%. This year I have used three applications in September 2020. I have used traps to catch the emergence in October. We believe that this information could be applied to other flies such as cherry and blueberry maggots.

Pasco Avery: For managing Asian citrus psyllid (ACP), we have some tolerant tree varieties, otherwise, the citrus industry is declining in Florida. We are testing ultra-low volume versus air blast spraying techniques to manage ACP with *Cordyceps fumosorosea* (=*Isaria fumosorosea*) PFR-97. With air blast spraying both sides of leaves were covered whereas ultra-low volume method sprayed well at the topside of the leaves. Hence, we will continue with an air blast to promote better coverage. However, cost-wise (per acre) ultra-low volume spraying method is cheaper, but coverage on both sides of the leaf is not as good. We are removing leaves post spray and with a leaf bioassay exposing a single psyllid and finding 80% mortality with an air blast and 30% with ultra-low volume spraying. Rain also reduces efficacy. We are working on a new method to improve the rainfastness of spores on the leaf surface. We are trying a new surfactant, Ampersand® which is rainfast This product may keep the spores on the surface of the leaf, and possibly improve the overall efficacy by increasing the chances of contact by the psyllid. Stefan mentioned that a change in the concentration of oil helps with rain fastness. PFR 97 *Cordyceps fumosorosea* repels all the adult stage of ACP. Eggs and the newly emerged nymphal stage are the most susceptible stages since they are not/less mobile.

Persistence of PFR-97 with water and oil on small citrus trees in the field in the shade and open area is being accessed. We recorded good mortality of ACP after 7 days but after 14- and 21-days, efficacy was reduced due to rain removing the spores. Number of CFUs were higher on the underside of the leaf regardless of location but was higher for the trees in the shade. Overall, there was a higher efficacy against the ACP on trees located in the shade.

In the field, we are also trying EPFs against lebbeck mealybug. IPC (individual protection covers) for seedlings is very effective in keeping moisture inside and allowing mealybugs to come in contact with the leaf surface. For mealybugs, we are trying to spray on the leaf surface and then cover the surface to maintain a microclimate. BoteGHA ES, BotaniGard ES, BotaniGard MAXX, PFR-97 provided higher mortality than the control, and almost all provided 90-100% efficacy. Now we will try this in the field.

Tested *Beauveria*-based product, Velifer® ES which is as effective as BotaniGard ES against ambrosia beetles on avocado. Avocado bark plug bioassay was established (high humidity for long duration). Description of the bioassay is published in Zhou et al. 2018. Identification of the Achilles

heels of the laurel wilt pathogen and its beetle vector. Applied Microbiology and Biotechnology 102: 5673-5684.

Stefan: Certis is planning to reduce the rates of *Beauveria* in their products to increase their efficacy. Working with APHIS, our previous work on citrus using the spray tower bioassay, indicated that NoFly performed better than PFR-97 and Bb strain ANTO3 (BioCeres WP) against the ACP. We performed limited field trials with, BioCeres, PFR-97, and NoFly formulations. In Mission, Texas, there is a big ACP colony; hence, we developed bioassays using 40 gallon pots with citrus plants in 3x3x3 meter cages and released several hundred psyllids. BioCeres performed better than the other two products. More experiments are getting established in the orchard with hand sprayers and backpack sprayers. Individual trees are getting sprayed but after the hurricane, the work got disturbed. A master's student found a low amount of *Beauveria* and *Cordyceps* species from the natural psyllid population. Another student is working on evaluating fungus present in an orchard in the air. ACP shows repellency after exposure to NoFly formulations.

David Shapiro-Ilan: International Space Station (ISS) program for microbial control was successfully completed. EPNs sent to space were able to reproduce and kill insects indicating that they do not need electromagnetic signals to find the host and also the possibility of utilizing entomopathogens in space. However, nematodes born in space did not do well after they came back to earth. Work is in collaboration with Fatma Kaplan (Pheronym, Inc.).

We are working with nematode pheromones with Edwin Lewis and Fatma Kaplan. Pheromones help in invading the host and also in the dispersal of nematodes. We are patenting our study.
For peachtree borer, EPNs can be used both curatively and preventatively, whereas chlorpyrifos only worked preventatively because it does not penetrate deep enough and EPNs have provided better results compared to chlorpyrifos. EPNs also manage root weevils in peach trees along with peachtree borer. We are also working on plum curculio and apple maggot. Applying nematodes in cadavers has more advantages due to better dispersal and infectivity which is due to the pheromones. Environmental tolerance in EPNs from cadavers compared to the solution. Fungal endophytes (*Beauveria*, *Metarhizium*) in pecan trees. Aphid infestation was suppressed due to endophytic fungus.

José Carlos Verle Rodrigues (Puerto Rico): A student is working on the efficacy of EPNs on coffee berry borer in Puerto Rico. We surveyed about 32 farms and extracted EPNs (140 isolates). We have evaluated them with molecular techniques, and several soil parameters such as pH and moisture were also considered. Populations of *Oscheius* in soils were found in about 90% of fields. We have established the pathogenicity of these native EPNs on coffee berry borer.

Ann Hajek: We have been working with brown marmorated stink bugs and the microsporidian *Nosema maddoxi* to investigate how this pathogen overwinters, its distribution and host range, and infection levels in the field.

<u>Small fruits and vegetables</u>

Pasco Avery: We have isolated an EPF from whitefly, it could be *Cordyceps.* We have sent the samples to ARSEF at Cornell to get them identified. We will evaluate if this can be used to manage whiteflies.

Stefan: Stefan mentioned the work done by Lena Jankson. Field trials were established in 2019-2020 with *Beauveria* BoteGHA ES. She compared helicopter applications with ground applications and the ground application was more effective. Penn State could use *Beauveria* for Lantern Fly.
In Cornell (Dr. Ann Hajek's lab), Ann and her postdoc are using bioassays to determine the impact of fungi on all life stages. With lanternfly, a natural epizootic was recorded and there could be a diverse population. They are also looking for dispersal of native *Beauveria*.

Ann Hajek: Ann Hajek and Eric Clifton worked with Penn State to evaluate spraying the *B. bassiana* BoteGHA product against spotted lanternflies (invasive pests of vineyards and potentially other crops) in southeastern PA in 2019 and results from this study were published in 2020. During the 2020 season, Eric Clifton (postdoc) used bioassays to challenge spotted lanternflies with entomopathogenic fungi in a quarantine lab at Cornell because this invasive is not (yet) established in the Ithaca area. Bioassays with *Beauveria bassiana* included comparing commercialized *B. bassiana* products against all instars. Ann developed methods for conducting bioassays with the poorly known entomopathogenic fungus *Batkoa major* in the quarantine. Natural epizootics were caused by *both B.* bassiana *and B.* major were studied in fall 2020. We have also been evaluating the genetic diversity of each of these naturally occurring native pathogens.

Matthew Borden (intern with Driscoll's, California): Worked on the efficacy of EPFs and EPNs on spider mites. EPFs with oil showed repellency for spider mites.

Stefan: Horticultural oils can cause repellency. Orthoptera shows strong repellency for EPFs.

Surendra: A study was conducted in Brussels sprouts for controlling the diamondback moth where *Bacillus thuringiensis* was used as an IPM tool. A Bt product was sprayed in each of the 10 applications.

1. A grower in Paso Robles has been having western grape leaf skeletonizer infestations. I am working with Brian Federici to use his GV for its control. Sent him several hundred larvae, which he infected with GV, and building the inoculum for release next year.
2. Suggesting microbial control as an option for various pest problems (including spotted lanternfly control on the East Coast with EPF).
3. Several presentations, podcasts, trade journal articles, videos, and book chapters about biologicals including entomopathogens.

Jimmy Klick: Did a trial in Mexico on strawberries on white grubs which caused 40% plant dieback. We applied commercial EPNs (*Heterodontus bacteriophora* and *Steinernema feltiae* and a combination of two). We established pot and field experiments. *Steinernema feltiae* caused a 50% reduction in plant dieback. I am also working on *Metarhizium robertsii* for spotted wing drosophila adults as a lure and infect approach.

Shaohui Wu: Working on nanoparticle formulations of EPFs against various insect pests.

David Shapiro: Working on the control of ticks by using nematodes. Using EPNs (*Steinernema riobrave*) to manage ticks on Nilgai by spraying EPNs when animals are close to the EPN station. Evaluating the persistency of EPNs in this study. EPNs persistency is greater in tall grass. Barricade Fire Gel could improve the viability of EPNs in field conditions. Collaborator = John Goolsby (ARS-Texas).

A.M. **Koppenhofer** (Rutgers University):
We initiated a study on the use of entomopathogenic nematodes (EPN) for the control of plum curculio (PC), *Conotrachelus nenuphar*, in highbush blueberries. In the lab, we tested the ability of the EPN species *Steinernema carpocapsae*, *S. feltiae*, *S. riobrave*, and *Heterorhabditis bacteriophora* to persist in the typical highly acidic (pH 4) sandy blueberries soil in comparison to a typical sandy loam turfgrass soil. *S. scarabaei* was not included in this study as we knew from the previous experiment that it persists well in blueberry soil. Cups were filled with soil and inoculated with 200 infective juvenile nematodes (IJs) per cup. The persistence of the nematodes was determined by saturation baiting with wax moth larvae starting at 0 to 56 days after treatment. All *Steinernema* species persisted very well in blueberry soil at levels similar to their persistence in turfgrass sandy loam. *H. bacteriophora* persisted poorly particularly in blueberry soil. In lab virulence tests and in a field test, *S. riobrave* provided excellent control when applied just before PC larvae exit the fruit and enter the soil; *S. scarabaei*, *S. feltiae*, and *S. carpocapsae* did not provide significant control. Experiments will be repeated in 2021.

Urban and natural landscapes, rangelands, and nurseries

David Oi (ARS-Gainesville, FL): To search for viral pathogens that may be utilized as biocontrol agents of the stinging and invasive little fire ant, *Wasmannia auropunctata.* Samples of this ant were obtained from Florida, Hawaii, and Argentina and submitted for transcriptome sequencing. The libraries have yielded a large number of virus genome sequences from *Wasmannia*, with many being highly represented. This suggests that the ant serves as a host for these novel viruses (i.e., replication of the virus). The next steps are to screen field samples and verify the findings.

Solenopsis invicta virus 3 (SINV-3) is an RNA virus-specific for red imported fire ants that offers promise as a natural control agent. To determine the prevalence of SINV-3 in winged female fire ants to understand the possible natural spread of the virus through mating flights. Collections were made from five urban areas and five adjacent rural areas of north Florida. SINV-3 was detected in winged females in nests from 7 of the 10 collection locations. The average infection rate of 44% was similar in rural and urban areas. Winged females were sampled because they mate aerially and disperse, founding colonies in new areas. Infected winged females may be the mechanism of SINV-3 spread throughout the fire ant community providing additional sustained control of fire ants in the U.S. This was a collaborative project with Florida A & M University and ARS-Gainesville.

Stefan: Conidia Tech company is producing *Beauveria bassiana* GHA for bed bug control. The product is adopted by the pest control industry. It is a barrier spray. This is a special oil formation of *Beauveria bassiana* GHA and bed bugs pick it up in the field. The product needs to be sprayed around the mattress at the base of the wall. They are looking for the impact of environmental conditions such as humidity on the persistency of the product.

Julie: In Africa, there is a study going on to study different kinds and compatibility of Fire Gel. We are also working on using EPF solution (diluted fire gels) and dropping them on the ground by using airplanes to manage the locust population. We are also trying to focus on breeding grounds to target larval stages and using growth regulators to slow down the molting process and growth regulators are also synergistic with EPFs.

Daniel Zommick (Valent Biosciences): We have relaunched Certan (Bt treatment for beehives), again as B402.

Rogelio Trabanino (Zamorano University): Working on managing ticks by using EPFs and EPNs. We also maintain colonies of predatory mites. We produce EPFs and EPNs and evaluate different commercially available products as well and disseminate the information to the farmers. Also working on the use of bio-pesticides to manage agricultural pests such as thrips, mites, and whiteflies. We also evaluate cost-profit analysis. We supply EPFs to farmers as a wettable powder.

A.M. **Koppenhofer** (Rutgers University):
Studies in field crops indicated that inoculative applications of native EPN strains adapted to the local conditions and maintained to preserve their ability to persist in the environment can effectively suppress pest populations for several years. To obtain such a local adapted persistent EPN strain for turfgrass studies, during 2019 we surveyed one fairway each at two golf courses in central New Jersey for native EPNs. These fairways had received only limited insecticide applications for many years. Soil samples were taken from the fairway and the adjacent rough and baited with wax moth larvae. The vast majority of EPN isolates collected were either *H. bacteriophora* or *S. carpocapsae*. Isolates of each species were mixed to increase the genetic diversity of the populations to be used in inoculative applications. The EPNs were mass-reared in waxworms and used to inoculate the field plots in early June 2020.
Field plots (20 m × 10 m, half in the fairway, half in the rough) were treated with 1.25 × 109 IJs/ha. Treatments included *H. bacteriophora*, *S. carpocapsae*, a 1:1 mixture of both species, and untreated control. There were two replicates per treatment at each of the two golf courses.
EPN populations in the plots were determined.
Plots were also surveyed for EPNs (1 week before and 1 and 3 months after application), ABW (mid-June), surface-active insects (late July and early September), and white grubs (late September).
EPN detection showed a high level of variation. The number of EPN-infected waxworms had increased by 1 month after application at one site in fairway and rough but at the second site only in the fairway. At 3 months after application, EPN infections had increased at both sites. Not all of these increases matched with the treated plots, with nematode numbers increasing in untreated controls and *H. bacteriophora* recovered from plots not treated with that species.
ABW densities at 10 days after EPN application did not vary much between treatments. During the ABW survey, larvae of the black turfgrass ataenius (BTA) were recovered in similar numbers

as ABW, also without any clear trends among treatments. The very low densities of ABW and BTA in spring 2020 (around 10 per 0.1 m2) likely did not allow for significant effects of EPN applications and certainly not for significant EPN recycling in these small host species. BTA adults were the only consistently recovered insect in the soap flushes but did not show any significant trends among treatments. Very few white grubs were recovered in September and were outnumbered by a scattering of BTA larvae across all treatments.
Additional sampling late in 2020 for EPNs and continued sampling of EPNs and potential hosts in 2021 should help determine if the to date observed patterns are consistent and if the applied EPNs persist and have any long-term effects on insect pest densities.

Carlos E Bográn (OHP): We market microbiological products. At present focusing on the product Ancora (*Cordyceps* (=*Isaria*) *fumosorosea*).

Stefan Jaronski: For grasshopper's microbial control, the program at APHIS in Phoenix, Arizona is in progress. Developed a bait as a good carrier for BT and fungus. Bringing the *Metarhizium acridum* which is only infectious to Orthoptera. APHIS will sign an agreement to get the strains and start doing the molecular screening. Shelf life is empirical and hard to develop a pattern. Needs about 7-10% (water activity 0.3) to achieve a better shelf life.

Adam Chun Nin: My lab does basic research on *Drosophila suzukii*. We have discovered a few candidate bacteria that may serve as SWD attractants or repellents, just got some volatile data back. Hopefully, next year will have some exciting results to share.

Ann Hajek: My lab has been challenging Asian longhorned beetle adults with entomopathogenic fungi over numerous years. This year we published studies optimizing application rates of *Metarhizium brunneum* microsclerotia to tree trunks. We also published bioassays testing numerous commercially available entomopathogenic fungi against Asian longhorned beetle adults.

Discussions

1. The theme for the symposium at ESA 2021.
   Jimmy mentioned that Symposium (2020) was not accepted since they were asking for more information. The team discussed and decided to choose a new title for the symposium instead of using the earlier suggested title (Hidden Heroes: Entomopathogens as Natural Enemies). José and Surendra mentioned that all the details of speakers will be highly needed to get the symposium accepted. Robert mentioned that microelements of our symposium can also be mentioned in the application. José, Surendra and David mentioned that contacting the speakers beforehand is necessary and their agreement should also be mentioned in the application.
   David, Stefan, Pasco, Robert, Surendra suggested the possible names for next year's symposium. Stefan suggested the idea of the use of microbials against current invasive pests, (lessons being learned). We can focus on the USA or Americas. Motion moved by Jimmy, seconded by Pasco, and approved unanimously.

   'All agreed- entomopathogens for current invasive species' (symposium for 2021)

2. Suggested potential speakers are:
Pasco Avery: Asian citrus psyllid
Ann Hajek or Eric Clifton or Nina Jackson: Lantern Fly
Ann Hajek: Emerald ash borer or ambrosia beetle
Leah Bauer: longhorn beetle
Daniel Carrillo: microbial control of ambrosia beetle
We can try to include some international speakers as well.
We can include fruit flies, thrips, mites
We can incorporate urban, agriculture, and forestry arthropods where microbials are used or being used to manage.

3. Collaborative projects:
Robert, David, and Stefan mentioned that preparing/create short videos of the annual microbial course (a weeklong insect pathology short course lead by Ann Hajek at Cornell University), could be a good idea for outreach activity. Other members could also collaborate to create some educational videos to promote microbials. One of the members will contact Ann Hajek.
Stefan mentioned fetching funding for creating videos for educational purposes. Julie and Surendra mentioned that microbial industry people could also provide some funding. Daniel and Carlos endorsed the fact that industry funding will be easy, especially with BPIA (Biological Products Industry Alliance).
David mentioned that members and speakers of the symposium could be encouraged to write articles to submit to JIP. Surendra mentioned that members could submit articles to Frontiers and ERPH (more details are provided in outcomes of minutes).

4. New businesses, selections, and officers:
José mentioned that the ESA-Southeastern branch meeting in 2022 will happen in San Juan, Puerto Rico and this group can present there. The initial 2021 was postponed.
ICE got postponed to 2022 in Helsinki. An EPN symposium will be organized and David Shapiro and Selcuk Hazir are involved with that.
Robert moved the motion for the 2021 meeting earlier to the ESA meeting, seconded by Stefan and the motion passed unanimously.
Elections: Jimmy will be chair and Stefan will be vice-chair, Julie Graesch will be Member-at-large, Anamika will be the secretary. Motion moved by Jimmy, seconded by Stefan, motion unanimously passed.

1:00 PM meeting adjourned.

Microbial related publications (research and outreach) from group members (2019-2020):

1. AgNet West podcast about biologicals in IPM https://agnetwest.com/making-sense-of-biologicals-biologicals-not-just-for-an-organic-ipm-program/
2. AgNet West podcast about entomopathogenic fungi https://agnetwest.com/making-sense-of-biologicals-entomopathogenic-fungi-mythbusting/
3. Arnold, D.P., S.P. Balasubramani, S.M. Valles, and B.A. Hottel. 2020. Prevalence of

Solenopsis invicta virus 3 (Solinviviridae: Invictavirus) in *Solenopsis invicta* (Hymenoptera: Formicidae) alates collected in north Florida. *Florida Entomol.* (in press).

4. Avery, P. B., V. Kumar, A. Francis, C. L. McKenzie, and L. S. Osborne. 2020. Compatibility of the predatory beetle, *Delphastus catalinae* with an entomopathogenic fungus, *Cordyceps fumosorosea* for biocontrol of invasive pepper whitefly, *Aleurotrachelus trachoides.* Insects 11, 590. doi:10.3390/insects11090590.
5. Avery, P. B., V. Kumar, E. A. Skvarch, C. M. Mannion, C. A. Powell, C. L. McKenzie, and L. S. Osborne. 2019. An ecological assessment of *Isaria fumosorosea* applications compared to a neonicotinoid treatment for regulating invasive ficus whitefly. Journal of Fungi 5, 36. doi:10.3390/jof5020036.
6. Bock, C.H., Hotchkiss, M.W., Shapiro-Ilan, D.I., Brock, J.H., Brenneman, T.B., Wilkins, B., Wells, D.E., Wells, L., Mizell, R.F., 2019. A comparison of organic fungicides: alternatives for reducing scab on pecan. Organic Agriculture 9, 305-314.
7. Bock, C.H., Hotchkiss, M.W., Shapiro-Ilan, D.I., Wells, L., Brock, J., Brenneman, T., Mizell, R. 2019. Efficacy of Bordeaux mixture in reducing pecan scab in the southeastern U.S.A. Organic Agriculture 9, 189-198.
8. Chacón-Orozco, J.G., Bueno, C.J., Shapiro-Ilan, D., Hazir, S., Leite, L.G., and Harakava, R. 2020.Antifungal activity of *Xenorhabdus* spp. and *Photorhabdus* spp. against the soybean pathogenic *Sclerotinia sclerotiorum*. Scientific Reports, 10, Article number: 20649. https://doi.org/10.1038/s41598-020-77472-6
9. Chen, C., Ma, H., Ma, M., Li, J., Zheng, S., Song, Q., Gu, X., Hu, B., Shapiro-Ilan, D.I., Ruan, W. 2020. An innovative strategy for control of fungus gnats using entomopathogenic nematodes alone or in combination with waterlogging. Journal of Nematology, e2020-57. DOI: 10.21307/jofnem-2020-057.
10. Clifton, E., Hajek, A.E., Jenkins, N.E., Roush, R.T., Rost, J.P., Biddinger, D.J. 2020. Applications of Beauveria bassiana (Hypocreales: Cordycipitaceae) to control populations of spotted lanternfly, Lycorma delicatula (Hemiptera: Fulgoridae), in semi-natural landscapes and on grapevines. Environ. Entomol. 49: 854-864.
11. Clifton, E.H., Jaronski, S.T., Hajek, A.E. 2020. Virulence of commercialized fungal entomopathogens against Asian longhorned beetle, Anoplophora glabripennis. J. Ins. Sci. 20(2): 1: 1-6. doi: 10.1093/jisesa/ieaa006
12. Cottrell, T.E., Shapiro-Ilan, D.I., Horton, D.L., 2019. Laboratory assays against adult and larval sap beetles (Coleoptera: Nitidulidae) using entomopathogenic nematodes, microbial-based insecticides and synthetic insecticides. Journal of Entomological Science 54, 30-42.
13. Dara, S. K. 2020. Arthropod resistance to biopesticides. Organic Farmer 3(4): 16-19. http://organicfarmermag.com/2020/08/arthropod-resistance-to-biopesticides/ (Trade journal article)
14. Dara, S. K. 2020. Biological pesticides in nut crops: a look at use strategies and the risk of resistance development. September issue of West Coast Nut, pp. 48-50. (Trade journal article)
15. Dara, S. K. 2020. Mating disruption as an IPM tool in diamondback moth management. eJournal of Entomology and Biologicals, 12 November 2020. https://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=44160 (Extension article)

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17. Dara, S. K. Constraints and challenges in the popularization of biopesticides in organic farming. *In* Biopesticides in organic farming: recent advances. Ed. L. P. Awasthi, Taylor and Francis, In print. (Book chapter)
18. Dara, S. K. Integrated insect pest management in economically important crops. *In* Biopesticides in organic farming: recent advances. Ed. L. P. Awasthi, Taylor and Francis, In print. (Book chapter)
19. Dara, S. K. Microbial metabolites as pesticides. *In* Microbial metabolites for sustainable insect pest management. Eds. M. A. Khan and W. Ahmad, Springer, In print. (Book chapter)
20. Dara, S. K. The principles of the application of biopesticides in organic farming. *In* Biopesticides in organic farming: recent advances. Ed. L. P. Awasthi, Taylor and Francis, In print. (Book chapter)
21. Dara, S. K. 2019. Interactions of entomopathogens with other pest management options. *In* Microbes and mebolites for sustainable insect pest management. Eds. M. A. Khan and W. Ahmad, Springer, pp. 299-316. https://doi.org/10.1007/978-3-030-23045-6_11 (Book chapter)
22. Dara, S. K. 2020. Implementation of IPDM in strawberries and other berries. *In* Pest and disease management in greenhouse crops, Plant Pathology in the 21st Century. Eds. Gullino, M. L., A. Albajes, P. Nicot, and J. C. van Lenteren. Springer. pp. 597-624 https://doi.org/10.1007/978-3-030-22304-5_21 (Book chapter)
23. Dara, S. K. and R. A. Humber. 2020. Entomophthoran. *In* Beneficial microbes in agro-ecology: volume 2: bacteria and fungi. Eds. N. Amaresan, K. M. Senthil, K. Annapurna, K. Kumar, and A. Sankaranarayanan. Elsevier. pp 757-775. https://doi.org/10.1016/B978-0-12-823414-3.00039-3 (Book chapter)
24. Dara, S. K., S. S. Dara, and S.S.R. Dara. 2020. Managing *Fusarium oxysporum* f. sp. *vasinfectum* Race 4 with beneficial microorganisms including entomopathogenic fungi. Acta Horticulturae 1270: 111-116. https://doi.org/10.17660/ActaHortic.2020.1270.11 (Trade journal article)
25. Eric H. Clifton, Sana Gardescu, Robert W. Behle, and Ann E. Hajek. 2020. Optimizing application rates of Metarhizium brunneum microsclerotia for infecting the invasive Asian longhorned beetle (Coleoptera: Cerambycidae). J. Econ. Entomol. 113: 2650-2656.
26. Fu, Y., Wang, W., Chen, C., Shan, S., Wei, X., Liu, Y., Shapiro-Ilan, D., Gu, X., Hu, B., Yoshiga, T., and Ruan, W. 2020. Chemotaxis behavior of *Steinernema carpocapsae* in response to *Galleria mellonella* (L.) larvae infected by con- or hetero-specific entomopathogenic nematodes. Biocontrol Science and Technology. In Press. Accepted 11-14-2020.
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33. *Kaplan, F*., Shapiro-Ilan, D., Schiller, K.C. 2020. Dynamics of entomopathogenic nematode foraging and infectivity in microgravity. NPJ Microgravity6:20, https://doi.org/10.1038/s41526-020-00110-y
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46. Preston, C.E., Agnello, A.M., Hajek, A.E. 2020. Nosema maddoxi (Microsporidia: Nosematidae) in brown marmorated stink bug (Hemiptera: Pentatomidae) populations in the US. Biol. Control 144: 104213.
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58. Sharma A, Muniappan R. 2021. IPM for Tropical Crops: Lentil. Invited article submitted to CABI, under review.
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Cares, T. Caruso, L. de Brito Caixeta, X. Chen, S. R. Costa, R. Creamer, E. C. J. M. da Cunha, M. Dam, D. Djigal, M. Escuer, B. S. Griffiths, C. Gutierrez, K. Hohberg, D. Kalinkina, P. Kardol, A. Kergunteuil, G. Korthals, V. Krashevska, A. A. Kudrin, Q. Li, W. Liang, M. Magilton, M. Marais, J. A. R. Martin, E. Matveeva, E. H. Mayad, E. Mzough, C. Mulder, P. Mullin, R. Neilson, T. A. D. Nguyen, U. N. Nielsen, H. Okada, J. E. P. Rius, K. Pan, V. Peneva, L. Pellissier, J. C. P. da Silva, C. Pitteloud, T. O. Powers, K. Powers, C. W. Quist, S. Rasmann, S. S. Moreno, S. Scheu, H. Setala, A. Sushchuk, A. V. Tiunov, J. Trap, M. Vestergard, C. Villenave, L. Waeyenberge, R. A. Wilschut, D. G. Wright, A. M. Keith, J. I. Yang, O. Schmidt, R. Bouharroud, Z. Ferji, W. H. van der Putten, D. Routh, and T. W. Crowther. 2020. A global database of soil nematode abundance and functional group composition. Sci Data 7:103.

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Special issues of journals (Dr. Surendra Dara):

1. Published the Journal of Invertebrate Pathology special issue on “Regional status of microbial control programs and practices”. Editors: Steve Arthurs and Surendra Dara
2. Working on the special issue of the International Journal of Environmental Research and Public Health on “Current status, challenges, and prospects of biopesticides”. Editors: Surendra Dara and Stefan Jaronski.
3. Working on the special issue of Frontiers on “Entomopathogens for sustainable food production”. Editors: Surendra Dara, Steve Arthurs, and Bob Behle.
4. Special Issue: “Invasive Arthropod Species”, Journal Insects. Editors: Jose C Verle Rodrigues and Todd Gilligan.