**S1070 Regional Research Project Agenda**

**November 8 and 9, 2021; 1:00 am – 4 pm (EST) (Virtual)**

Jimmy Klick, Chair

Stefan Jaronski, Vice-chair

Anamika Sharma, Secretary

Julie Graesch, Member-at-large

Paula Agudelo, Administrative Advisor

Vijay K. Nandula, NIFA representative

**November 08, 2021**

(EST)

1:00 PM PRELIMINARY BUSINESS MEETING

1. Introductions and general information
2. Minutes of 2020 (Anamika Sharma)
3. Sub-project Leads

1:30 PM Funding Opportunities from NIFA, Vijay K. Nandula

2:00 PM NEW PROJECT REVIEW AND PLANNING-Large acreage crops Annual Crops [Anamika Sharma]

2:45 PM NEW PROJECT REVIEW AND PLANNING-Orchard Systems [David Shapiro-Ilan]

3:30 PM NEW PROJECT REVIEW AND PLANNING-Small Fruits and Vegetables [Surendra Dara]

**November 09, 2021**

(EST)

1:00 PM NEW PROJECT REVIEW AND PLANNING-Urban and Natural Landscapes, Rangelands, and Nurseries [David Oi]

1:45 PM DISCUSSIONS

1. Theme for 2022
2. Discussion of collaborative projects
3. New business, Elections, Officers

4:00 PM ADJOURN

**Attendees 2021**

 **Name Affiliation Email**

1. Robert Behle USDA-ARS, Peoria robert.behle@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@usda.gov
7. Anamika Sharma Virginia Tech anamika@vt.edu
8. Pasco Avery University of Florida pbavery@ufl.edu
9. Julie Graesch BioWorks Inc. jgraesch@bioworksinc.com
10. Shaohui Wu University of Georgia shaohui.wu@uga.edu
11. Colin Wong USDA-ARS, Georgia cwong1@iastate.edu
12. Mika Pagani Virginia Tech mika396@vt.edu
13. Navneet Kaur Oregon State University navneet.kaur@oregonstate.edu
14. Nate Royalty BioWorks Inc. nroyalty@bioworksinc.com
15. Lina Weiler USDA-ARS, Peoria lina.weiler@usda.gov
16. Ashley Tessnow Texas A&M atessnow@tamu.edu
17. Vijay K. Nandula REE-NIFA vijay.nandula@usda.gov

Apologies from Byron Adams and Paula Agudelo were received.

BUSINESS MEETING

1. *Introductions:* Jimmy Klick (2021 chair): Welcomed all and began with introductions. Attendees introduced themselves including a short introduction about their affiliation and work.

2. *Minutes of 2020* (prepared by Anamika Sharma): A copy of the 2020 minutes was circulated electronically prior to the meeting. A motion to approve the 2020 minutes was made by Stefan Jaronski and was seconded by Robert Behle and passed unanimously. Minutes of the 2021 meeting are required to be posted within 60 days.

3. *NIFA administrators report* ([Dr.](https://www.nimss.org/users/461) Vijay K. Nandula):

**NIFA relocated from Washington, DC to Kansas City, MO (September 2019)**

**NIFA Current Hiring:**

1. Division Directors: Plant Production, Plant Protection
2. National Program Leaders (Biological Sciences): Agronomy, Horticulture, Plant Pathology, Entomology (2 or 3), Ag Economist
3. Program Specialists (Biological Sciences): Plant Protection

**Dr. Carrie Castille now serves as NIFA Director**

**NIFA Budget Update:**

1. Congress appropriated $1.95 Billion to NIFA programs for FY2021, including one-year COVID Response Funding
2. Enhanced Programs: $10M increase in AFRI funding; $3M increase in SARE funding
3. New Programs: $2M for 1890 Agribusiness Center of Excellence; $4M for a Farm of the Future

**USDA FY2021 Priorities:**

1. Addressing the impacts of climate change
2. Containing the pandemic and promoting economic recovery
3. Ensuring food and nutrition security
4. Rebuilding the rural economy
5. Ensuring racial justice and equity

**Crop Protection and Pest Management (CPPM)**

1. Team members: Vijay Nandula as National Program Leader

 Kathryn Kimble-Day and Carina Teri Allen as Program Specialists

1. CPPM history introduction
2. Purpose, Goals and Objective of CPPM
3. Program Areas:

Applied Research and Development Program Area (ARDP): Funds applied IPM research and extension projects – annual competition

Extension Implementation Program Area (EIP): Funds Extension projects for IPM Coordinators across the states and US Territories - competition every 3 years

Regional Coordination Program Area (RCP): Funds the IPM Centers in the Western, North Central, Northeastern and Southern Regions in the US - competition every 4 yrs

1. Number of Proposals and Awards

ARDP: 20 out of 75 proposals were awarded (FY 2021)

RCP: 4 awards (FY 2022)

EIP: 53 new Continuations (FY 2021)

1. FY 2022 CPPM (ARDP & RCP) RFA closes on February 13, 2022

**Critical Agricultural Research and Extension (CARE)**

1. 2021 CARE Team members: Jim Dobrowolski, Susan Muhidin, Vijay Nandula, Cierrah Kassetas, Andres Cibils
2. CARE Background:

Established in 2013

Originally only production oriented, expanded to all Farm Bill priorities

Program budget increased from $3M to $7M in 2019, 2020 and reduced back to $5M in 2021, increased to $7M in 2022.

1. Priorities for CARE (Any of the six Farm Bill priorities):

Plant health and production and plant products

Animal health and production and animal products

Food safety, nutrition, and health

Bioenergy, natural resources, and environment

Agriculture systems and technology

Agriculture economics and rural communities

1. CARE Cross-cutting:

Program Area Priority Code: A1701

Proposed Budget Requests: $300,000 total per project for project periods of 1-3 years Project Types: Integrated (research and extension) Projects only

Grant Types: Standard and FASE (Strengthening Standard and New Investigator) Grants only

Application Deadline: September 15, 2022 (5:00 pm ET)

Contact: James Dobrowolski, james.dobrowolski@usda.gov Vijay Nandula, vijay.nandula@usda.gov

 Andres Cibils, Andres.Cibils@usda.gov

 Susan Muhidin, Susan.Muhidin@usda.gov Cierrah Kassetas, Cierrah.Kassetas@usda.gov

1. Purpose of the CARE Program
2. From 2014 to 2020, 391 total proposals were received, 130 projects funded, with a total funding amount of $33,554,579.00

**Agriculture and Food Research Initiative (AFRI)**

1. AFRI: Pests and Beneficial Species in Agricultural Production Systems (Plant Health and Production & Plant Products Program Area)

Program Area Priority Code: A1112

Proposed Budget Requests:  Not to exceed $750,000 per project (3-5 years)

Project Types:  Research-only and Integrated Projects (Research and Extension) only Grant Types:  Standard, Conference, and FASE (Strengthening Standard, New Investigator, Strengthening Conference, Seed, Equipment, and Sabbatical) Grants Only Application Deadline:  August 25, 2022 (5:00pm ET)

Contacts:  Erica Kistner-Thomas, erica.kistnerthomas@usda.gov

 Logan Appenfeller, logan.appenfeller@usda.gov

1. Goals: Advance knowledge of invasive plant pests and associated beneficial species Development of innovative biologically-based strategies to manage pests

Subject Matter: Invertebrates, plant pathogens, slugs, nematodes, weeds, parasitoids

History: Pests and Beneficial Species programming began 2017

 Funded 92 projects with 81 currently active

 Total funding 2017-2020: $35.8 million

 FY20: 114 applications, Funded 16 projects for 14% funding rate at $6.8 million

 FY21: 116 applications plus 22 postdoc applications

1. AFRI: Pollinator Health: Research and Application (Plant Health and Production & Plant Products Program Area)

Program Area Priority Code:  A1113

Application Deadline:  August 25, 2022 (5:00pm ET)

Contacts:  Erica Kistner-Thomas, erica.kistnerthomas@usda.gov

**Minor Crop Pest Management Program Interregional Research Project #4 (IR-4)**

 Contact: Thomas Bewick, tbewick@usda.gov

**Organic Agriculture Research and Extension Initiative**

https://nifa.usda.gov/funding-opportunity/organic-agriculture-research-and-extension-initiative

 RFA for FY2022 closes on January 23, 2022

**Organic Transitions**

https://nifa.usda.gov/funding-opportunity/organic-transitions-org

 RFA for FY2022 closes on March 22, 2022

**More information about NIFA**

Organizational Chart: https://nifa.usda.gov/resource/nifa-organizational-chart Institutes/Divisions/National Program Leaders: https://nifa.usda.gov/institutes

National Program Leaders/Non-AFRI: https://nifa.usda.gov/national-program-leaders

AFRI New Investigator Webinars: https://nifa.usda.gov/2021-afri-ni-webinar-series

Volunteer to Serve on a NIFA Peer-Review Panel: https://nifa.usda.gov/panelist-information

**Large acreage crops**

**Anamika Sharma (Virginia Tech)***:* Currently working with USAID, IPM innovation lab, at Virginia Tech. In Tanzania, currently using *Metarhizium* and *Beauveria* against stem borers, *Trichoderma*,and *Bacillus* sp. against rice blasts. Real IPM (private sector) in supplying all the microbial agents. In the future they also plan to use *Trichoderma* as foliar application for rice. For managing fall armyworm, planning to use entomopathogenic fungi (EPF) along with egg and larval parasitoids.

**Robert Behle (USDA-ARS):** In cooperation with scientists from the University of Georgia and ARS (Byron, GA), Crop Bioprotection (CBP) scientist (Robert Behle -ARS, Peoria, IL) studied methods for liquid culture production of the Wf GA 17 strain of *Cordyceps javanica* blastospores along with processing using a spray dryer to create a wettable powder formulation using skim milk powder. Media with greater nitrogen concentrations produced more spores although media costs increased. Production of Wf GA 17 was less than that of the commercial Apopka-97 strain of *C. javanica* (formerly *C. fumosorosea*) when produced under identical culture conditions. In addition, CBP scientist Patrick Dowd continues to study the impact of host plant resistance genes in corn that target plant fungal pathogens for their direct impact on insect pests and EPF used to control these same insect pests in an evert to understand interactions among pest control strategies and pest damage.

**Shaohui Wu (University of Georgia)**: Last year unformulated *C. javanica* blastospores were not very effective in the control of whiteflies in cotton fields. They found that it was partially because most of the spores were distributed on the upper leaf surface while whiteflies were mostly active on the lower leaf surface; also, without a formulation the spores lost viability quickly in the field. Thus, in collaboration with Dr. Robert Behle, this year they have been testing different formulations to improve the persistence and efficacy of the fungus. They tried to compare the fungus to a commercial product PFR-97 in the field test, but because of the poor quality of the product the treatment was removed.

Robert Behle did a follow-up comment on the commercial product PFR-97 and agreed that the product was ineffective for low spore viability. Behle also mentioned the production of *C. javanica* blastospores with skim milk powder in various formulations in his lab. Stefan Jaronski followed up the comment with his experience on NO-FLY (another fungal product based on *C. javanica*) having variable spore viability and the product quality varying from batch to batch, and he emphasized the need to verify conidial viability in commercially sourced mycoinsecticides before use.

Pasco Avery commented that the species of PFR-97 and NO-FLY have been re-identified to be *C. javanica* instead of *C. fumosorosea* by Christopher Dunlap from USDA-ARS, Peoria, IL. The identification results will be published soon, added with more comments in the following sections. Jaronski added that a paper published in Mexico reported the species of primarily *C. fumosorosea* was also found to be *C. javanica*, and two very recent papers from Texas on the *Cordyceps* strain also changed to *C. javanica*. Avery added that the low efficacy of fungal spores could be potentially caused by the presence of gossypol, an allelochemical found in cotton to be antagonistic to the growth of EPF, and suggest testing the effect *in vitro* against *C. javanica*.

Jimmy Klick asked about a protocol for checking the viability of fungal products like PFR-97, and Jaronski responded and added that germination of blastospores is much faster than conidia, 12-14 h instead 16-18 h for *Beauveria* and *Metarhizium*. Behle followed up on the discrepancy of conidia and blastospores. Jaronski mentioned that it can be difficult to separate individual spores for colony forming unit (CFU) determinations and so CFU counts can underestimate the actual spore viability; Behle agreed and added that included mycelium fragments can also result in CFU growth as well from non-clean preparation. Jaronski also mentioned that PFR-97 is being switched from blastospores to conidia, and the same also seems to be the case with NO-FLY® WP.

**Orchard Systems**

**Robert Behle (USDA-ARS):** Evaluated two fall applications of *Metarhizium* Strain F52 microsclerotia granules for control of walnut husk maggot (*Rhagoletis sauvis*), targeting maggots as they enter the soil prior to pupation. Unfortunately, treatments did not reduce fly densities as measured by subsequent adult emergence the following season.

**Pasco Avery (University of Florida)**: Continuing their study on minimizing washing-off of spores with rain fast products, they are quantifying the persistence of products containing *C. javanica* strains over time by using a rain simulator under semi-controlled greenhouse conditions. The EPF products include PFR-97, Ancora (same strain as PFR-97) and NO-FLY. They tested their compatibility *in vitro* with two rain fast products, Ampersand® and Powerblox®. Each rain fast product at labeled rate was mixed in 50-ml centrifuge tubes with EPF based products containing spores (10^4 spores / ml) of *C. javanica* strains. An aliquot of 100 µl was spread on PDA plates after 1 h and 6 h exposure of spores to the rain fast product. Plates were sealed with Parafilm and transferred to a growth chamber set at 25 °C and 14 h photophase for 7 days to allow time for CFUs to form. CFU counts were used to evaluate compatibility of rain fast products with fungi. The results show that they are compatible after 1 h and 6 h exposure, with equal or higher CFU counts in rain fast incorporated products than EPF products alone, and radial growth on PDA was assessed over time. The next step is to assess how well they last after spraying in the small citrus plants in different rain regiments; they will do leaf print and CFU counts for assessment.

Previously, BotaniGard ES, BotaniGard MAXX, BoteGHA ES, and PFR-97 provided higher mortality than the untreated control against spherical mealybug. Field trials were conducted and the manuscript titled “Suitability of formulated entomopathogenic fungi against spherical mealybug, *Nipaecoccus viridis* (Hemiptera: Pseudococcidae), deployed within mesh covers intended to protect citrus from huanglongbing” has been submitted. Survival of spherical mealybug *N. viridis*(Newstead)nymphs exposed to all *Beauveria bassiana*-based products was reduced as compared to controls (water only) under laboratory conditions. Under field conditions in mesh exclusion bags, mortality of *N. viridis* nymphs on leaves sprayed with each fungal formulation was significantly greater than on control treatments up to four weeks post application. Formulated *B. bassiana*-based products applied alone or combined with an insect growth regulator are effective tools for managing *N. viridis*populations on young citrus trees protected with mesh exclusion bags.

Fungi alone were not very effective against mealybugs because they frequently molt, shedding the cuticle attached with fungal conidia, until they reached the adult stage.

**Stefan Jaronski (USDA-ARS, Retired; Virginia Tech):** Collaborating with APHIS for control of Asian citrus psyllids, a pest problem in South Texas, with EPF. They did spray type bioassays using all the U.S. commercial strains of fungi plus several noncommercial strains, as conidia and, where appropriate, as blastospores. The NO-FLY *Cordyceps* and *B. bassiana* strain ANT-03 (BioCeres® WP) were far superior to PFR-97. The manuscript has been accepted recently. The work was conducted by the staff of Dr. Dan Flores at the APHIS Mission TX lab.

The best fungus against psyllids was actually a Brazilian *Metarhizum* strain (not available in the U.S.), far superior to NO-FLY and PFR-97 at 2×1012 spores/acre, in sprays on Jasmine shrubs with artificial infestation. Jaronski’s advice was to check the viability of commercial products before use; he can provide protocols to anyone on request.

The BioCeres® *Beauveria* worked better than other commercial strains against psyllids in outdoor mesocosm tests. At 2×1012 spores/acre, they achieved about 50% reduction in psyllid numbers by the *Beauveria* in one week, NO-FLY and PFR-97 (conidia produced by himself) had only 10% reduction, while the control population increased 30%.

In addition, a survey of adult psyllids in the Lower Rio Grande Valley of Texas uncovered 10 infected psyllids among 5000+ insects collected. *Beauveria bassiana* was the predominant fungus (7 isolates) with three *Cordyceps* sp. (presumably *javanica* or *fumosorosea*. This survey consisted of collecting live psyllids and incubating them in the lab for several days, further incubating surface sterilized cadavers at 100% humidity for 2-3 days and isolating any fungi emerging from the cadavers.

Pasco Avery mentioned that Dr. Xavier Martini is controlling the psyllids in Northern Florida. A Master’s student gave a presentation entitled “Entomopathogenic fungus emits volatiles that attract its hosts, the Asian citrus psyllid, to infected con-specific cadavers”. If psyllids come in close contact with leaves sprayed with *C. javanica*, the psyllid adults would be repelled, but adults that get infected with the fungus become an attractant of the adult psyllids. The best strategy is to focus on the eggs and nymphs as adults are highly mobile. Jaronski commented fungus-killed grasshopper cadavers show the same repellant behavior.

David Shapiro-Ilan mentioned that nematodes behave similarly, being attractive at the beginning of the infection process but then repellent to other nematodes in the late phase when host resources are lower; Interspecific competition may vary with species, depending on how competitive the species are, like *Steinernema glaseri* generally outcompetes other species.

**David Shapiro-Ilan (USDA-ARS):** They’ve been working on fungal endophytes in pecan, looking at different cultivars and inoculation methods, impact on aphids and also plant growth. They also looked at Grandevo biopesticide against pecan weevil in pecan. As Jaronski mentioned how long you can go, because the price is kind of high, they looked at a lower rate, which was 2 lb (quarts)/acre of Grandevo, and found that worked very well and gave two year in a row >90% control. They also found that Grandevo does not impact the natural enemies, the lady beetles, lacewings, which might be expected from chemical control, and this is another benefit. They’re also looking at the nematode pheromones, and the idea is to expose the entomopathogenic nematodes (EPNs) to pheromones they produced before application, directing their behavior and telling the nematodes it is time to go to infect the host or time to disperse. They’ve seen that a number of times in the lab and also in cold temperatures the pheromones stimulate the nematodes to move, which is a benefit late in the season. Ed Lewis recently published a paper in the journal Frontiers that the nematodes will follow each other in a trail, and it’s already known from their prior research that nematodes travel in packs instead of randomly in aggregated movement.

Jimmy Klick asked about what fungus was the endophyte and methods of inoculation in pecan endophyte. Shapiro-Ilan answered it was *Beauveria* and *Metarhizium*, both can be successfully inoculated, haven’t had good luck into large trees, mostly seedlings, but had success in pest control, a little bit with disease control with the fungal endophyte. The methods of inoculation included foliar spray, rolling seeds in fungal spore power and drenching seedling roots; all of these methods worked. Shaohui Wu did some endophyte work too.

They have a paper published this year testing pH effect on EPNs and found that *S. carpocapsae* and *S. riobrave* tend to be the best in tolerating a broad range of pH levels (paper published in Journal of Nematology) with the South Africa group and they also looked at the native strains to see which one was the best. They are also starting a project with Texas A&M with Anjel Helms and Fatma Kaplan looking at acquired resistance; so if putting nematodes there, the plant reacts and provides protection, and they will explore this scenario further; Helms has done a fair bit of work on that. For the nematodes in space, the paper has been published. Lastly, they’ve done some work on fruit flies; two Ph.D. students from Pakistan conducted bioassays on different nematodes against fruit flies and a combination of fungi with nematodes and found only additive effect by adding *Beauveria/Metarhizium* but the best nematode was *S. riobrave* and *S. feltiae* for control of the fruit flies in the soil.

Stefan Jaronski commented that for endophytism and plant-mediated effects against herbivores, he suggests use heat-killed *Beauveria/Metarhizum* spores to see if they have the same effect to induce systemic resistance of plants. In his previous study in 2000 using *Bacillus mycoides* strain BacJ (now LifeGuard® produced by Certis) in sugar beets, the heat-killed bacteria induced remarkable systemic resistance to the major fungal pathogens of sugar beets. Also, a growing number of literature has supported the microbe-associated resistance patterns that plants can sense these patterns on the cuticles and respond. In *Beauveria* endophytic literature, there was major effects on leaf miners while the rate of endophytism was less than 10%. Shapiro-Ilan agreed and added that for inducing plant resistance his work will be mainly on nematodes and bacterial metabolites.

Shaohui Wu added that in a survey of the natural presence of fungal endophytes in pecan orchards in different varieties, five out of 45 mature trees were found to have *Beauveria*.

Julie Graesch mentioned about the collaborative *Ambrosia* beetle project. Shapiro-Ilan described the project will be directed to the management of *Ambrosia* beetles, pests in many different crops, and the work in his lab will focus on using endophytes and different formulations of nematodes against ambrosia beetles in pecan orchards next year; a new postdoc will be involved in the project.

Stefan Jaronski mentioned there are increasing concerns from regulators in Europe about the safety of endophytes, and he was contacted by EPA last spring about if increased safety testing is required for the presence of fungal endophytes (especially *Beauveria*) in plants and the metabolites they produce.

**Small Fruits and Vegetables**

**Stefan Jaronski (USDA-ARS, Retired; Virginia Tech):** Spotted Lanternfly has been spread to many locations including Virginia. He has a graduate student, Jason Bielski, working on management of Lanternflies at Virginia Tech, while Eric Clifton at Cornell has been looking at various native *Beauveria* for Lanternfly management. Clifton screened the virulence of different commercial fungi and presented the work in ESA 2020. His bioassays targeted 1st through 4th instars, and adults, and found differential results varying with stages. For 1st instar, Velifer (*B. bassiana* strain from BASF) was more effective than the BioCeres *Beauveria* strain (ANT-03), *Beauveria* GHA strain, *Beauveria* ATCC74040 (Naturalis®) or *C. javanica* Apopka 97 (PFR-97®). Against 2nd to 4th instars, many of the differences among fungi disappeared; overall, Apopka97 was inferior to all *Beauveria* strains. AT the ESA 2021 meeting, Clifton gave a presentation on bioassays of several non-commercialized *Beauveria* strains isolated from the insect, using conidia produced by Jaronski. These strains seemed more efficacious than GHA, the main strain currently used against Lanternfly nymphs and adults. Hajek is looking at natural epizootics of *Batkoa major*, an Entomophthorales fungus against Lanternfly. Bielski, at Virginia Tech, is evaluating *Beauveria* in treating the egg masses in fall, early or late spring, comparing the GHA strain WP formulation with the ES formulation. The fall treatment was not effective, and the more promising option being spring treatment, with 30-40% infection of neonates. A high control mortality, however, needs to be addressed, as well as the real infection rate. these tests will be repeated in 2022.

Stefan Jaronski (Virginia Tech) compared *B. bassiana* ATCC74040 (in Naturalis L®) with the GHA strain (BotaniGard® and BoteGHA® products), to determine if ATCC74040 was considerably more infectious / virulent than strain GHA, as a way of explaining the purported efficacy of Naturalis when the Naturalis L *Beauveria* concentration is 1/200th the concentration of spores in the GHA products. The fungi used were isolated from the respective formulation, conidia for the bioassays produced on solid substrate fermentation, and applied as aqueous sprays to larval *Tenebrio molitor* and adult *Anasa tristis* (squash bug). With *Tenebrio molitor*, there was no difference between GHA and ATCC74040 in terms of median survival time, when the conidia were applied at the equivalent of \_x1013/acre.

ATCC74040, applied at 3 or 5x1013 conidia/acre, 40-60% infection of adults.

Similarly, with *A. tristis adults* there were also no significant differences in median survival times between the two strains. The conidia were applied at the equivalent of 3x1013 or 5x1013 conidia/acre in 20 gallons/acre, which rates resulted in final mean mortality of 60-73% or 100% after 14 days at the two respective rates.

ANT-03 having 70%, suggesting adults are not very susceptible, being consistent with literature on the stink bugs.

As part of the dissertation researchof Mika Pagani (Virginia Tech), Jaronski tried to duplicate some published work on producing *Beauveria* microsclerotia in liquid fermentation, using New Zealand’s recipe and methodology as well as the Brazilian methodology, but could not verify their data despite repeated attempts. No microsclerotia were produced. A lesson to learn: the need to replicate some of the published work in our field.

**Pasco Avery (University of Florida)**: They isolated an EPF from whitefly; it could be *Cordyceps.* They have sent the samples to USDA-ARS in Peoria, IL to get them identified. They will evaluate if this can be used to manage whiteflies. *Bemisia tabaci* has been a pest of vegetables in Quincy, Florida. A fungal epizootic was found among *B. tabaci* and the isolate was identified as *C. javanica*. Same species was identified on *B. tabaci* from an epizootic in Gainesville, Florida. Earlier it was also found in Georgia (Shaohui Wu). They are trying to identify if the strain is the same. Dr. Martini is putting together a grant to work on this.

Stefan Jaronski commented that horticultural oils can cause repellency. Orthoptera shows strong repellency for EPFs.

**Mika Pagani (Virginia Tech):** Under mentorship of Dr. Stefan Jaronski, she is a Ph.D. student at Virginia Tech, working with EPF for managing the wireworm *Melanotus communis*, for 2 and half years. They conducted extensive soil incorporation bioassays and immersion exposure tests, with commercially available strains of *Beauveria* and *Metarhizium*. They found ANT-03 strain of *B. bassiana* worked the best, PPRI5339 second best, although the wireworms were quite resistant to infection at doses of 2×105 conidia/ cc soil or 1×108 conidia /ml (immersion bioassay). In semi-controlled outdoor mesocosm experiments, they evaluated several types of granular carriers for the ANT-03 strain. Tests were conducted for 3 weeks to allow full time for efficacy to occur. There was 40-50% infection by *Beauveria*; they also discovered considerable amounts of *Beauveria and Metarhizium* indigenous in the soil used.

Julie Graesch commented that she read a paper that *Beauveria* and *Metarhizium* did not provide high mortality of wireworms but found a reduction in fecundity of those that were not killed, suggest Pagani can follow that direction. Pagani replied and added that wireworms were deterred by EPF, probably volatiles.

**Surendra Dara (University of California):**

**Research:**

* Tried to pursue releasing the granulovirus for the western grapeleaf skeletonizer in Paso Robles in collaboration with Brian Federici. There wasn’t a clear direction due to regulatory issues and I could not release the virus.
* Collaborative work with Japanese and Indonesian researchers on using EPF against *Meloidogyne incognita* and *Fusarium oxysporum* in ginger.

**Outreach:**

* Put together IPM guidelines for managing western flower thrips management in lettuce with multiple microbial control options.
* Gave multiple talks on pest management in organic vegetables with microbial control options.
* Used various outreach opportunities such as individual consultations, podcasts, social media, and extension presentations to promote microbial control as a part of IPM.
* Gave extension presentations on using biostimulants (including EPF) as a part of IPM.

**Adam Chun-Nin Wong** **(University of Florida):** Continuing their basic research on the symbiotic gut microbiome associated with *Drosophila suzukii* and Mediterranean fruit fly (with colleagues from Israel). A new automated video tracking system has been established in my lab to study microbial impacts on insect foraging behavior. They discovered that the microbiome influences *D. suzukii* foraging activity in a sex-specific manner, due to differences between male and female reproduction response to microbiome manipulation. They also developed a hybrid genome assembly method integrating short-read (Illumina) and long-read (nanopore) sequencing to resolve the complete genome of fly gut symbionts.

**David Shapiro-Ilan (USDA-ARS):** Involved in PEER project in South Africa and Benin, on sweet potato weevils with EPNs in various formulations. It’s knows that nematodes may lose virulence and other beneficial traits after several passages, and there are some work on inbred lines in South Africa. In conjunction with Shaohui Wu’s work on whitefly management in cotton, they are also doing the test with vegetables. Also, he is involved in the whitefly project in collaboration with Dr. George Mbata at Fort Valley State University and his postdoc Yinping Li for using EPNs against whiteflies and screening for the best strains. They also did a screening test on EPNs and EPF and their combinations against tobacco thrips, conducted by the Ph.D. visiting students from Pakistan, and saw some positive results.

**Albrecht M**. **Koppenhofer (Rutgers University):** They continued a study on the use of EPNs for the control of plum curculio (PC), *Conotrachelus nenuphar*, in highbush blueberries. Laboratory and field studies were conducted to determine the persistence of *S. riobrave*, *S. carpocapsae*, *S. feltiae*, and *Heterorhabditis bacteriophora* in acidic blueberry soil; compare the virulence of these EPNs to PC larvae and pupae; and compare the efficacy of these EPN species to control this pest in blueberry fields. The greatest persistence in blueberry soil was exhibited by *S. riobrave* followed by *S. carpocapsae*. Superior virulence was observed in *S. riobrave* against PC larvae and pupae. In the field, *S. riobrave* provided significantly higher levels of PC suppression (90%) than the others EPNs (all at 50 IJs per cm2 = 1.67 billion IJs per ha total blueberry hectarage). In 2021, the field efficacy of *S. riobrave* against PC at low (25 IJs per cm2) and high rate (50 IJs per cm2) was confirmed. *S. riobrave* has the potential to become an important component in the management of PC in highbush blueberry

**Anamika Sharma (Virginia Tech):** In Kenya, using *Trichoderma harzianum, T. asperellum* (Real *Trichoderma*), and *T. harzianum* + *T. asperellum* to manage root knot nematodes and bacterial wilt in cauliflower, kale and tomato crops. Farmers have found that use of *T. asperellum* was able to reduce the root knot nematodes populations by 75%. For cauliflower, the seedlings were raised in an insect-proof nursery. The IPM package including rice straw mulching, application of biological controls *Trichoderma viride*, *B. bassiana, Pseudomonas fluorescens*, neem oil, yellow sticky traps, and sweet bait made from cabbage and molasses to trap moths were found to be highly successful.

**Urban and natural landscapes, rangelands, and nurseries**

**Stefan Jaronski (USDA-ARS, Retired; Virginia Tech):** For grasshopper microbial control, a program at APHIS in Phoenix, Arizona, with whom he collaborates, is still in progress, continuing research Jaronski accomplished while in ARS. The work focus in the past few years has been to develop a bait carrier for fungus for control of grasshoppers. The trials were conducted in New Mexico. The whole concept is to develop rates and methodologies for a bait delivery of fungus, especially, eventually, *Metarhizium acridum*, as regular *Metarhizium* and *Beauveria* strains cannot tolerate the behavioral fever (elevated body temperatures when infected by a pathogen) as *M. acridum*, which has been commercialized in Africa, Australia, Asia for locust control, and there are two commercial strains available. But *M. acridum* has not been isolated in the U.S., so the species is not indigenous. He has been working with two companies to get either of two commercial strains of the fungus registered in the U.S. An efficient method to deliver fungus spores to grasshoppers is through bait versus broadcast sprays, and he found that a rate of 1/10th and 1/20th of the amount of spores/acre achieved good efficacy in 2020. The test was repeated this year and there was good efficacy at 2 lbs of bait/acre, which is the same used for carbaryl insecticide application.

Jaronski has been working on tick biocontrol since Met 52 disappeared from the marketplace at the end of 2020. He conducted a preliminary screening bioassay spraying fungus spores at the equivalent of 2\*10^13 conidia/acre using the strains GHA (CertisBio), PPRI 5339 (BASF), ANT-03 (Anatis Bioprotection), the Naturalis L strain (Lallemand), and Apopka-97 (CertisBio) against adults of two of the tick species present in Virginia. *Haemaphysalis longicornis* tick suffered zero mortality after 3-week incubation; Ixodes scapularis was somewhat more susceptible. According to Dana Ment (Volcani Institute, Israel), who worked with tick control using EPF in Israel, tick adults can be quite resistant to infection while larvae are not necessarily more susceptible than adults. The bioassay will be repeated next summer, encompassing additional tick species and perhaps small scale field trials.

Jaronski reported collaborative work with EMBRAPA in Brazil, whereby microsclerotial granules of *Metarhizium robertsii* could serve as a biocontrol tool of the cattle tick, *Rhipicephalus microplus,* under semi-field conditions. Granules applied to the soil surface at 25 or 50 kg/ha prior to introduction of engorged tick females reduced the subsequent larval tick population by 65%. Persistence of infectious fungal inocula was observed for 336 days, spanning two seasons.

**Robert** **Behle (USDA-ARS):** In cooperation with USDA-APHIS personnel, CBP scientist (Robert Behle – ARS, Peoria, IL) assisted with studies on *Ovavesicula popilliae*, a host-specific microsporidia for control of Japanese beetle. Beetles trapped around Peoria will be evaluated for the presence of this organism using specific PCR primers. CBP Post-Doc (Kristin Duffield – ARS, Peoria, IL) is administrating and participating in the Insect Meal Grand Challenge, a project exploring the use of insect cultures as livestock to provide a new source of feed and food. Her research focus is on identifying and understanding the impact of insect pathogens on these cultures and has recently published results of initial studies on viruses infecting cricket colonies. CBP scientist (Jose Ramirez – ARS, Peoria, IL) is evaluating entomopathogenic microbes for control of mosquitoes and the impact of pathogenic and endemic microbes on the vector competence of mosquitoes.

**Navneet** **Kaur (Oregon State University):** Working on using grass endophytes to manage insect pests, with a study focus described below:

The larvae of cranberry girdler or subterranean sod webworm *Chrysoteuchia topiaria* Zeller (Lepidoptera: Crambidae) inflict damage to the plant roots leading to poor fall regrowth and ultimately reduced yields in cool-season grass seed production systems. As soil-dwelling insect species, larvae are continuously exposed to a wide range of subterranean pathogenic organisms; identifying these organisms and determining their impact would contribute to the development of biological control. The main aim of this study was to survey and determine what native EPN species occur in grass seed fields and test if they can offer effective control against sod webworms. Soil samples were collected during a field survey at biweekly intervals during March-May 2021 in 22 commercial grass seed fields in western Oregon. Isolation of EPNs was performed using insect baiting techniques using commercially available waxworm larvae, *Galleria mellonella* Linnaeus (Lepidoptera: Pyralidae). Out of 88 composite samples (440 single point samples); nematodes were recovered from 22 samples. Three different EPN isolates were identified using molecular tools. BLASTn analyses indicated that the most predominated Oregon EPN isolate (Oregon\_WV-3) were conspecific to an unidentified EPN isolate N6734 from Nebraska Cornfields (GenBank accession: MK754228) with up to 100% identity of the partial sequence of the cytochrome oxidase subunit 1 (cox1) gene and other two isolates being conspecific to *Steinernema* and *Oschieus sp*. Laboratory infectivity tests using native strains identified in this study are in progress. Dr. David Shapiro-Ilan is willing to provide some commercial strains to compare the virulence. The pilot studies were funded by the Western IPM center and Oregon seed council. Funds from other sources will be solicited to conduct future bioassays soon.

Stefan Jaronski commented that Ag Research in New Zealand has been doing lots of work on endophytes and has one that eliminated the animal toxic alkaloid; the endophytes have moved to the U.S. grass market. Navneet Kaur mentioned that her research has been mostly on turfgrass.

**Albrecht M. Koppenhofer (Rutgers University):** They are testing whether inoculative applications of native EPN strains adapted to persist in the local conditions can effectively suppress turfgrass pest populations for several years. They surveyed fairways and roughs at two golf courses in central New Jersey for such EPNs. The majority of EPNs collected were *H. bacteriophora* and *S. carpocapsae*. Mixes of isolates of each species were used to inoculate the field plots at two courses in early June 2020. These plots (20 m by 10 m) were half in the fairway, half in the rough with two plots per treatment per golf course. Treatments were *H. bacteriophora*, *S. carpocapsae*, a 1:1 mixture of both species, all applied at a total of 1.25 billion infective juveniles (IJs) per ha. Control plots were left untreated. Samples of each kind were taken in each plot from a central 4 m by 4 m area in the rough and one in the fairway (subplots).

EPN populations were determined 1 week before application and again 1, 4, 6, 13, and 16 months after application. Forty soil cores (2.5 cm diam, 7.5 cm depth) were taken per subplot, mixed thoroughly, and 4 subsamples baited with 5 waxworms for 3 consecutive 3-day baiting rounds. EPN-infected waxworms were incubated to determine EPN species by the color of the cadavers and size and behavior of emerging IJs. Higher EPN numbers were detected in the rough vs. the fairway. EPN numbers also tended to be higher in the treated plots than the untreated plots for the species the plots were treated with. A third species, likely *S. cubanum*, was also found regularly in many plots.

Annual Bluegrass Weevil (ABW) populations were determined in mid-June 2020 and 2021 in 32 turf/soil cores (5.4 cm diam, 3 cm depth) taken from each subplot. In both years, numbers in the fairway were significantly lower in the plots treated with both EPN species (47% in 2020, 89% in 2021) than in the untreated plots and the ones treated with *S. carpocapsae* only. The only other insects found in significant numbers during the ABW sampling were larvae of the black turfgrass ataenius (BTA), numbers of which were not significantly affected by EPN treatments.

Surface-active insect populations were determined in July and early September of 2020. Soap extraction revealed many insects but only adults of ABW and especially BTA were found in number high enough for meaningful analysis. ABW numbers in the fairway were lower in the plots treated with *S. carpocapsae* and the species combination than in the untreated plots. BTA numbers in the fairway were lower in all EPN treatments than in the untreated plots.

White grub populations were determined in late September 2020 and 2021 in 16 turf/soil cores (10.5 cm diameter, 7.5 cm depth) taken per subplot. In the rough, densities were significantly lower in the plots treated with *H. bacteriophora* than in the untreated plots. BTA larvae were not affected by EPN treatments.

**David Oi (USDA, ARS-Gainesville, FL)** (From Steven Valles and David Oi): A search for viral pathogens for the biocontrol of the little fire ant, *Wasmannia auropunctata,* an invasive, stinging ant is continuing. Transcriptome sequencing of little fire ant samples from Florida, Hawaii, and Argentina collected in 2020 revealed six sequences that appear to be of viral origin across several families. Some of the virus sequences were only found in the Argentine samples. Samples collected in 2021 from Florida, Hawaii, and Australia confirmed this result. These represent the first viruses from the little fire ant.

Surveys to track the spread of *Solenopsis invicta* virus 3 (SINV-3) in fire ants at an inoculation site located in the Coachella Valley of California (Palm Springs area) in 2021 were postponed to 2022 due to COVID-19. Inoculations were initially conducted in 2014 resulting in very localized spread.

**Pasco Avery (University of Florida)**: Quantifying the effect of plant extracts from croton on the viability of EPF. Excised leaves used in the experiment were categorized as either young (newly formed leaves at the bottom of the plants, with purple and green coloring only, ~65 days old) or mature (variegated colors, ~105 days old). After 15 days, extracts from the young and the mature croton leaves incorporated in the agar had a significant stimulatory effect on the fungal hyphal growth of *C. javanica* Apopka strain and *B. bassiana* GHA strain *in vitro* compared to the control with no extract added. For both fungi, there was no significant difference in the stimulatory effect on *in vitro* fungal hyphal growth between leaf extracts of young or mature croton leaves incorporated into the agar. Identification of biochemicals by using gas chromatography-mass spectrophotometry analysis is still in progress.

**David Shapiro-Ilan (USDA-ARS):** Cattle fever tick is a big problem in Texas. In a collaboration project with John Goolsby, they have used EPNs to control ticks in rangeland. The application was made by smart spraying when the animals come to feed. It was found that EPNs were viable on the grass ground in the spraying application, and the cattle or antelope can pick up the nematodes. In lab and outdoor tests, Barricade® gel improved nematode survival on cow hide, but the Barricade test has not been conducted on the animals yet.

A screening test on EPN efficacy for control of the small hive beetle, a serious pest of bee hives, was conducted by targeting the pupal stage under the ground, and *S. carpocapsae* was most effective. They have a new project in collaboration with Fort Valley State University, and a Master student has worked on screening the nematodes for their persistence in soil for prolonged control of the small hive beetle using different formulations.

Julie Graesch commented that an ESA presentation described a new strain of *S. feltiae* in New York that persist longer in the soil than commercial strains.

**Discussions**

1. The theme for the symposium at ESA 2022.

Stefan Jaronski suggested, we could pursue the same title, and include students as well.

Navneet Kaur mentioned, extensions agents case studies can be included. Anamika Sharma indicated, inviting users and international speakers from developing countries could be an issue.

Robert Behle indicated that the theme should match the next year’s ESA theme ‘*Entomology as Inspiration: Insects through Art, Science, and Culture*’.

Stefan Jaronski suggested: Incorporating microbials agents into the culture of IPM

“Incorporating microbials into IPM culture”

All agreed to the title.

We can collaborate with IOBC.

Julie Graesch could suggest some names.

Speakers are yet to be identified.

2. Collaborative projects:

Last year, Robert Behle, David Shapiro-Ilan, and Stefan Jaronski 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.

This could be pursued further. We need to find a platform, which can be used without getting into legal problems and need to get together to put together a grant. An extension-heavy member could do that.

3. New businesses, selections, and officers:

Next year ESA meeting will be Vancouver, since nothing is certain at the moment, so not sure how USDA people will be able to travel. In future we can prefer virtual meeting. Next year we could following Monday after the ESA virtually and members could share if they are attending ESA meeting, and could decide on a stipulated time and meet. In-person attending people, could decide to meet on a stipulated time and meet personally.

Stefan Jaronski mentioned that we could invite a speaker for the group.

Elections: Stefan Jaronski will be chair, Julie Graesch will be vice-chair. David Shapiro-Ilan nominated Shaohui Wu as secretary, Stefan Jaronski seconded, and all in favor. Shaohui Wu accepted.

David Shapiro-Ilan nominated Navneet Kaur as Member-at-Large. Robert Behle nominated Anamika Sharma as Member-at-Large. After discussion, Julie Graesch seconded and all agreed for Anamika Sharma, Anamika Sharma accepted.

3:30 PM meeting adjourned.

**Microbial related publications (research and outreach) from group members (2020-2021):**

**Scientific publications**

***Book chapters and an editorial***

1. Dara, S. K. Role of marketing and outreach for the success of entomopathogenic nematodes. *In* Entomopathogenic nematodes as biological control agents. Eds. D. I. Shapiro-Ilan and E. E. Lewis, CABI. Submitted. (Book chapter)
2. Dara, S. K. Role of entomopathogenic microorganisms in IPM. *In* Advances in integrated pest management technology: Innovative and applied aspects. Ed. A. S. Tanda, Springer. In print. (Book chapter)
3. Dara, S. K. Advances in biostimulants as an integrated pest management tool in horticulture. *In* Improving integrated pest management in horticulture. Ed. R. Collier, Burleigh Dodds Science Publishing Limited. <https://tinyurl.com/BiostimulantsinIPM> (Book chapter)
4. Dara, S. K. 2021. The principles of the application of biopesticides in organic farming. *In* Biopesticides in organic farming: recent advances. Ed. L. P. Awasthi, Taylor and Francis, pp. 11-13. (Book chapter)
5. Dara, S. K. 2021. Integrated insect pest management in economically important crops. *In* Biopesticides in organic farming: recent advances. Ed. L. P. Awasthi, Taylor and Francis, pp. 295-303. (Book chapter)
6. Dara, S. K. 2021. 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, pp. 349-353. (Book chapter)
7. Dara, S. K. 2021. Microbial metabolites as pesticides. *In* Microbial metabolites for sustainable insect pest management. Eds. M. A. Khan and W. Ahmad, Springer, pp 75-88. <https://doi.org/10.1007/978-3-030-67231-7_4> (Book chapter)
8. Dara, S.K., Behle, R.W. and Arthurs, S.P., 2021. Entomopathogens for sustainable food production. Frontiers in Sustainable Food Systems special issue <https://www.frontiersin.org/research-topics/11865/entomopathogens-for-sustainable-food-production> (Journal Special Issue)
9. Dara, S.K., Behle, R.W. and Arthurs, S.P., 2021. Editorial: Entomopathogens for sustainable food production. Frontiers in Sustainable Food Systems special issue <https://doi.org/10.3389/fsufs.2021.672404>
10. Rodriguez-Saona, C. and Dara, S.K. Entomopathogenic nematodes in berry crops. *In* Entomopathogenic nematodes as biological control agents. Eds. D. I. Shapiro-Ilan and E. E. Lewis, CABI. Submitted. (Book chapter)

***Refereed journal articles***

1. Avery, P.B., Duren, E.B., Qureshi, J.A.,Adair Jr., R.C., Adair, M.M.and Cave, R.D., 2021. Field efficacy of *Cordyceps javanica*, white oil and spinetoramfor management of the Asian citrus psyllid, *Diaphorina citri*. Insects12, 824. doi.org/10.3390/insects12090824
2. Behle, R.W., 2021. Emergence of walnut husk maggot adults in central Illinois and potential for control with *Metarhizium brunneum*. Journal of Insect Science, 20(6) doi:10.1093/jisesa/ieaa134
3. Cerritos-Garcia, D.G., Avery, P.B., Martini, X.., Candian, V., Cano, L.M.and Cave, R.D., 2021. *In vitro* effects of leaf extracts from *Brassica rapa* on the growth of two entomopathogenic fungi. Journal of Fungi7, 779. doi.org/10.3390/jof7090779
4. Cimen, H., Touray, M., Hazal Gulsen, S., Erincik, O., Wenski, S.L., Bode, H.B., Shapiro-Ilan, D. and Hazir, S., 2021. Antifungal activity of different *Xenorhabdus* and *Photorhabdus* species against various fungal phytopathogens and identification of the antifungal compounds from *X. szentirmaii.* Applied Microbiology and Biotechnology (In Press, Accepted June 16, 2021).
5. Cisneros, J., Wendel, J., Jaronski, S., Vitek, C, Ciomperlik, M. and Flores, D., 2021. Assessment of two novel host-derived *Beauveria bassiana* (Hypocreales: Cordycipitaceae) isolates against the citrus pest, *Diaphorina citri* (Hemiptera: Liviidae). Journal of Economic Entomology, XX(XX), 2022, 1–9. [Publication](https://gcc02.safelinks.protection.outlook.com/?url=https%3A%2F%2Facademic.oup.com%2Fjee%2Fadvance-article%2Fdoi%2F10.1093%2Fjee%2Ftoab229%2F6455511%3FguestAccessKey%3D3e6e7499-9928-4a30-9b9b-e2cb85c7c3ad&data=04%7C01%7C%7C6d4bf52c6c18400f981b08d9cede82af%7Ced5b36e701ee4ebc867ee03cfa0d4697%7C0%7C0%7C637768277332818037%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C3000&sdata=29gND22hgwiLiRTdZIoPSuZ4HB8SOG0nR4Hn3AdFfno%3D&reserved=0)
6. Diepenbrock, L.M., Olabiyi, D.O. and Avery, P.B., 2021. Laboratory screening of selected entomopathogenic fungi, bioinsecticide, and insect growth regulator against hibiscus mealybug, *Nipaecoccus viridis* (Newstead). Arthropod Management Tests 46, 1-2. doi: 10.1093/amt/tsaa121
7. Doherty, E.M., Avery, P.B., Duren, E.B., Cano, L.M. and Rossi, L., 2021. *In planta* localization of endophytic *Cordyceps fumosorosea* in Carrizo citrus. Microorganisms 9, 219. doi.org/10.3390/microorganisms9020219

Eads, D.A., Jaronski, S.T., Biggins, D.E. and Wimsatt, J., 2021. Insect pathogenic fungi for biocontrol of plague vector fleas: A review. Journal of Integrated Pest Management, 12(1), p.30.

1. Erdogan, H., Cruzado-Gutierrez, K., Stevens, G., Shapiro-Ilan, D., Kaplan, F., Alborn, H. and Lewis, E., 2021. Nematodes follow a leader. Frontiers in Ecology and Evolution (In Press, Accepted October 15, 2021).
2. Dragone, N.B., Diaz, M.A., Hogg, I.D., Lyons, W.B., Jackson, W.A., Wall, D.H., Adams, B.J. and Fierer, N., 2021. Exploring the boundaries of microbial habitability in soil. Journal of Geophysical Research: Biogeosciences126 (6). <https://doi.org/10.1029/2020jg006052>
3. Fu, Y., Wang, W., Chen, C., Shan, S., Wei, X., Liu, Y., Shapiro-Ilan, D., Gu, X., Hu, B., Yoshiga, T. and Ruan, W., 2021. Chemotaxis behavior of *Steinernema carpocapsae* in response to *Galleria mellonella* (L.) larvae infected by con- or hetero-specific entomopathogenic nematodes. Biocontrol Science and Technology 31: 299-313. <https://doi.org/10.1080/09583157.2020.1853049>
4. Goettel, M.S., Douglas Inglis, G., Duke, G.M., Lord, J.C. and Jaronski, S.T., 2021. Measurement of internal *Beauveria bassiana* to ascertain non-target impacts on arthropods in field environments. Biocontrol Science and Technology, pp.1-16.
5. Gulzar, S., Wakil, W. and Shapiro-Ilan, D.I., 2021. Combined effect of entomopathogens against *Thrips tabaci* Lindeman (Thysanoptera: Thripidae): laboratory, greenhouse and field trials. Insects. 12, 456. <https://doi.org/10.3390/insects12050456>
6. Gulzar, S., Waqas, W. and Shapiro-Ilan, D.I., 2021. Potential use of entomopathogenic nematodes against the soil dwelling stages of onion thrips, *Thrips tabaci* Lindeman: laboratory, greenhouse and field trials.  Biological Control. In Press (Accepted May 22, 2021).
7. Gulzar, S., Usman, M., Wakil, W., Wu, S., Oliveira\_Hofman, C., Srinvasan, R., Toews, M. and Shapiro-Ilan, D. 2021. Virulence of entomopathogenic nematodes to pupae of *Frankliniella fusca* (Thysanoptera; thripidae). Journal of Economic Entomology (In Press, Accepted June 10, 2021).
8. Hay, W.T., Behle, R.W., Berhow, M.A., Miller, A.C. and Selling, G.W., 2020. Biopesticide synergy when combining plant flavonoids and entomopathogenic baculovirus. Scientific Reports, 10(1) doi:10.1038/s41598-020-63746-6
9. Jagdale, G.B., Brenneman, T.B., Severns, P.M. and Shapiro-Ilan, D.I., 2021. Differences in distribution and community structure of plant-parasitic nematodes in pecan orchards between two ecoregions of Georgia. Journal of Nematology (In Press, Accepted July 28, 2021).
10. Khathwayo, Z., Ramakuwela, T., Hatting, J., Shapiro-Ilan, D.I. and Cochrane, N., 2021. Quantification of pH tolerance levels among entomopathogenic nematodes. Journal of Nematology. 53, e2021-62. DOI: 10.21307/jofnem-2021-062.
11. Kiran Kumar, K. and Dara, S. K., 2021. Fungal and bacterial endophytes as microbial control agents for plant-parasitic nematodes. International Journal of**Environmental Research**and**Public Health** 18: 4269. <https://doi.org/10.3390/ijerph18084269>
12. Li, Y., Mbata, G.N., Punnuri, S., Simmons, A.M. and Shapiro-Ilan, D.I., 2021. *Bemisia tabaci* on vegetables in the Southern United States: Incidence, impact, and management. Insects. In Press.
13. Li, Y., Mbata, G.N. and Shapiro-Ilan, D.I., 2021. Laboratory virulence of entomopathogenic nematodes to the sweetpotato whitefly, *Bemisia tabaci*. Journal of Nematology 53, 96. DOI: 10.21307/jofnem-2021-096.

Marciano, A.F., Mascarin, G.M., Franco, R.F.F., Golo, P.S., Jaronski, S.T., Fernandes, É.K.K. and Bittencourt, V.R.E.P., 2021. Innovative granular formulation of *Metarhizium robertsii* microsclerotia and blastospores for cattle tick control. Scientific reports, 11(1), pp.1-11.

1. Nalinci, E., Karagoz, B., Ulug, D., Hazal Gulsen, S., Cimen, H., Touray, M., Shapiro-Ilan, D. and Hazir, S., 2021. The effect of chemical insecticides on the scavenging performance of *Steinernema carpocapsae*: direct effects and exposure to insects killed by chemical insecticides. Journal of Invertebrate Pathology. 184, 107641.  <https://doi.org/10.1016/j.jip.2021.107641>
2. Oliveira-Hofman, C., Cottrell, T.E., Bock, C., Mizell, R.F, Wells, L. and Shapiro-Ilan, D.I., 2021. Impact of a biorational pesticide on the pecan aphid complex and its natural enemies. Biological Control 161, 104709. <https://doi.org/10.1016/j.biocontrol.2021.104709>
3. Oliveira Silva, M.S., Maringoli Cardoso, J.F., Pacheco Ferreira, M.E., Baldo, F.B., Silva, R.S.A., Chacon-Orozco, J.G., Shapiro-Ilan, D.I., Hazir, S., Júnior Bueno, C. and Garrigós Leite, L., 2021. An assessment of *Steinernema rarum* as a biocontrol agent in sugarcane with focus on *Sphenophorus levis*, host-finding ability, compatibility with vinasse and field efficacy. Agriculture. 11, 500. <https://doi.org/10.3390/agriculture11060500>
4. Pick, D.A., Avery, P.B., Qureshi, J.A., Arthurs, S.P. and Powell, C. A., 2021. Field persistence and pathogenicity of *Isaria fumosorosea* for management of *Diaphorina citri*. Biocontrol Science and Technology doi.org/10.1080/09583157.2021.1976727
5. Pileggi, M G, Chase, J U, Shu, R G, Teng, L g, Jeong, KC, Kaufman, P and Wong, ACN., 2021. Prevalence of field-collected house flies and stable flies with bacteria displaying cefotaxime and multidrug resistance. Journal of Medical Entomology, 58 (2), 921–928. Doi: 10.1093/jme/tjaa241
6. Sanchez, W., Shapiro-Ilan, D., Williams, G. and Lawrence, K., 2021. Entomopathogenic nematode management of small hive beetles (*Aethina tumida*) in three native Alabama soils under low moisture conditions. Journal of Nematology (In Press, Accepted June 14, 2021).
7. Shapiro-Ilan, D.I. and Wells, L. 2021. Control of *Curculio caryae* (Coleoptera: Curculionidae) with reduced rates of a microbial biopesticide. Journal of Entomological Science (In Press, Accepted October 6, 2021).
8. Shapiro-Ilan, D.I. and Goolsby, J.A., 2021. Evaluation of Barricade® to enhance survival entomopathogenic nematodes on cowhide. Journal of Invertebrate Pathology, 184, 107592. <https://doi.org/10.1016/j.jip.2021.107592>
9. Shu, R. and Wong, A.C.N., 2021. Hybrid Nanopore-Illumina Genome assembly of a *Drosophila suzukii* gut bacterial symbiont, *Gluconobacter cerinus* FLW-1. *Microbiology Resource Announcements*, 10 (16). Doi: 10.1128/MRA.00190-21.
10. Shu, R., Hahn, D., Jurkevitch, E., Liburd, O., Yuval, B. and Wong, A.C.N., 2021. Sex-dependent effects of the microbiome on foraging and locomotion in *Drosophila suzukii*. *Frontiers in Microbiology*, 12, 1094. Doi: 10.3389/fmicb.2021.656406.
11. Sivakala, K., Jose, P., Shamir, M., Wong, A.C.N., Jurkevitch, E. and Yuval, B., 2022. Foraging behaviour of medfly larvae is affected by maternally transmitted and environmental bacteria. Animal Behaviour, 183, 169-176. Doi: /10.1016/j.anbehav.2021.10.014.
12. Srygley, R.B. and Jaronski, S.T., 2021. Increasing temperature reduces cuticular melanism and immunity to fungal infection in a migratory insect. Ecological Entomology.
13. Stevens, G., Erdogan, H., Stevens, A., Shapiro-Ilan, D., Kaplan, F., Alborn, H. and Lewis, E.E., 2021. Infected host responses across entomopathogenic nematode phylogeny. The Journal of Nematology (In Press, Accepted November 23, 2021).
14. Thompson, A.R., Roth-Monzón, A.J., Aanderud, Z.T. and Adams, B.J., 2021. Phagotrophic protists and their associates: Evidence for preferential grazing in an abiotically driven soil ecosystem. Microorganisms9 (8), 1555.
15. Touray, M., Cimen, H., Gulsen, S.H., Ulug, D., Erdogus, D., Shapiro-Ilan, D. and Hazir, S., 2021. The impact of chemical nematicides on entomopathogenic nematode survival and infectivity. Journal of Nematology 53: 49.  DOI: 10.21307/jofnem-2021-049
16. Usman, M., Wakil, W., Sufyan, M. and Shapiro-Ilan, D. 2021. Entomopathogenic nematodes as biological control agent against *Bactrocera zonata* and *Bactrocera dorsalis* (Diptera: Tephritidae). Biological Control (In Press, Accepted July 6, 2021).
17. Usman, M., Wakil, W., Gulzar, S., Pinero, J.C., Wu, S., Toews, M.D. and Shapiro-Ilan, D.I., 2021. Evaluation of locally isolated entomopathogenic fungi against multiple life stages of *Bactrocera zonata* and *Bactrocera dorsalis* (Diptera: Tephritidae): laboratory and field study. Microorganisms. 9, 1791. <https://doi.org/10.3390/microorganisms9081791>
18. Wendel, J., Cisneros, J., Jaronski, S., Vitek, C., Ciomperlik, M., and Flores, D., 2021. Screening commercial entomopathogenic fungi for the management of *Diaphorina citri* populations in the Lower Rio Grande Valley, Texas, USA.BioControl, In Press.
19. Wu, S., Blackburn, M.B., Mizell, R.F. III, Duncan, L.W., Toews, M.D., Sparks, M.E., El-Borai, F., Bock, C.H. and Shapiro-Ilan, D.I., 2021. Novel associations in antibiosis stemming from an insect pupal cell. Journal of Invertebrate Pathology 184, 107655.  <https://doi.org/10.1016/j.jip.2021.107655>
20. Wu, S., Toews, M.D., Castrillo, L.A., Barman, A.K., Cottrell, T.E. and Shapiro-Ilan, D.I., 2021. Identification and virulence of *Cordyceps javanica* strain wf GA17 isolated from a natural fungal population in sweetpotato whiteflies, *Bemisia tabaci* (Hemiptera: Aleyrodidae). Environmental Entomology. 50(5): 1127-1136.
21. Yanagawa, A., Krishanti, N.P.R.A., Sugiyma, A., Chrysanti, E., Ragamustari, S. K., Kubo, M., Furumizu, C., Sawa, S., Dara, S.K. and Kobayashi, M., 2021. Evaluating the non-entomopathogenic interactions of *Beauveria bassiana* and *Cordyceps fumosorosea* with *Fusarium oxysporum*, *Meloidogyne incognita*, and *Zingiber officinale*. Journal of Natural Medicines <https://doi.org/10.1007/s11418-021-01572-4>
22. Zhang, Y., Cai, T., Ren, Z., Liu, Y., Yuan, M., Cai, Y., Yu, C., Shu, R., He, S., Li, J., Wong, A.C.N. and Wan, H., 2021. Decline in symbiont-dependent host detoxification metabolism contributes to increased insecticide susceptibility of insects under high temperature. *The ISME Journal*, 15(12), 3693-3703. Doi: 10.1038/s41396-021-01046-1.

***Outreach materials***

1. AgNet West podcast about nonentomopathogenic role of entomopathogenic fungi, 16 February 2021. (<https://agnetwest.com/msob-beneficial-fungi-showing-more-benefits-than-pest-control/>)
2. Good to Grow podcast with Jake Turner on the potential of biologicals for crop protection, 10 May 2021. (<https://fmcgoodtogrow.com/episodes/the-potential-of-biologicals-the-next-layer-of-crop-protection/>)
3. Trade journal news article about suppressing western flower thrips. Progressive Crop Consultant, 10 May 2021. (<https://progressivecrop.com/2021/05/tactics-to-suppress-western-flower-thrips/>)
4. AgNet West podcast about biologicals options for western flower thrips management, 17 May 2021. (<https://agnetwest.com/msob-biological-options-for-western-flower-thrips/>)
5. AgNet West podcast about beevectoring, 4 June 2021. (<https://agnetwest.com/msob-delivering-biological-materials-through-bee-vectoring/>)
6. AgNet West podcast about biologicals for arthropod pest management in organic vegetables, 22 October 2021. (<https://agnetwest.com/msob-biological-materials-for-arthropod-management-in-organic-vegetables/>)
7. AgNet West podcast about biostimulants in IPM, 2 November 2021. (<https://agnetwest.com/msob-the-role-of-biostimulants-in-ipm-systems/>)

***Extension articles***

1. Dara, S.K., 2021. Biopesticides: categories and use strategies for IPM and IRM. eJournal of Entomology and Biologicals, 18 March 2021. (<https://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=46134>)
2. Dara, S.K., 2021. Managing western flower thrips in lettuce. Vegetables West 25(6): 8-9.
3. Dara, S.K, 2021. Biopesticides and their role in integrated pest management. CAPCA Adviser 24(2): 46-48.
4. Sharma, A. and Muniappan, R., 2021. IPM for Tropical Crops: Lentil. Invited article. CAB Reviews 2021, 16, No. 052. <https://www.cabi.org/CABREVIEWS/review/20210419168>
5. Sharma et al., 2020. IPM package for lentil. <https://ipmil.cired.vt.edu/wp-content/uploads/2020/10/Lentils-Package-2.pdf>
6. Sharma et al., 2021. IPM package for chickpea. <https://ipmil.cired.vt.edu/wp-content/uploads/2021/09/Chickpea-IPM-Package.pdf>
7. Sharma et al., 2021. IPM package for longan. <https://ipmil.cired.vt.edu/wp-content/uploads/2021/09/Longan-IPM-Package.pdf>
8. Sharma et al., 2021 IPM package for rice. <https://ipmil.cired.vt.edu/wp-content/uploads/2021/03/Rice-IPM-Package.pdf>
9. Sharma et al., 2021. IPM package for maize. <https://ipmil.cired.vt.edu/wp-content/uploads/2021/06/Maize-Package.pdf>
10. Sharma et al., 2021. IPM package for pearl millet. <https://ipmil.cired.vt.edu/wp-content/uploads/2021/08/Pearl-Millet-IPM-Package-4.pdf>
11. Sharma, A., 2021 (22 July 2021). IPM Packages Streamline Crop-Pest Solutions in Developing Countries. Entomology Today (Entomological Society of America). <https://entomologytoday.org/2021/07/22/integrated-pest-management-packages-solutions-developing-countries/>
12. Sharma, A., 2021 (25 October 2021). Why Augmentative Biological Control Holds Promise for Advancing Agriculture in Developing Countries. Entomology Today (Entomological Society of America). <https://entomologytoday.org/2021/10/25/augmentative-biological-control-advancing-agriculture-developing-countries/>