**S1070: The Working Group on Improving Microbial Control of Arthropod Pests**

S1070 Regional Research Project Agenda

**November 9, 2024 | 9:30 AM MST**

In-person location: Sheraton Phoenix Downtown, Alhamabra

Phoenix Convention Center, North Building (PCC), Phoenix, Arizona

and virtually

Anamika Sharma, Chair

Shaohui Wu, Vice-chair

Pasco Avery and Eric Clifton, Member-at-large

Lorenzo Rossi, Secretary

Paula Agudelo, Administrative Advisor

Christopher Phillips and Erica KistnerThomas, NIFA Reps

**9:30 AM REGISTRATION**

**10:00 AM PRELIMINARY BUSINESS MEETING**

1. Local arrangements report

2. Introductions

3. Minutes of 2023 (Lorenzo Rossi)

4. Sub-project Leads

**10:30 AM Funding Opportunities from NIFA** (Christopher Phillips)

**11:00 AM NEW PROJECT REVIEW AND PLANNING**

Large acreage crops Annual Crops (Shaohui Wu)

**11:45 AM NEW PROJECT REVIEW AND PLANNING**

Orchard Systems (Colin Wong and David Shapiro-Ilan)

**12:30 PM LUNCH** (on your own)

**1:45 PM NEW PROJECT REVIEW AND PLANNING**

Small Fruits and Vegetables (Jimmy Klick)

**2:30 PM NEW PROJECT REVIEW AND PLANNING**

Urban and Natural Landscapes, Rangelands, and Nurseries (David Oi)

**3:15 PM DISCUSSIONS**

1. Theme for 2025

2. Discussion of collaborative projects

3. New business

**4:00 PM** **ADJOURN**

**Attendees 2024**

**Name Affiliation Email**

1. Lorenzo Rossi University of Florida [l.rossi@ufl.edu](mailto:l.rossi@ufl.edu)
2. Christopher Philips USDA-NIFA [christopher.philips@usda.gov](mailto:christopher.philips@usda.gov)
3. Stephanie Haines BASF [stephanie.haines@basf.com](mailto:stephanie.haines@basf.com)
4. Josephine Antwi Oregon State University [josephine.antwi@oregonstate.edu](mailto:josephine.antwi@oregonstate.edu)
5. Pasco Avery University of Florida [pbavery@ufl.edu](mailto:pbavery@ufl.edu)
6. Anamika Sharma Florida A&M University [anamika.sharma@famu.edu](mailto:anamika.sharma@famu.edu)
7. Jimmy Klick Driscoll’s, California [jimmy.klick@driscolls.com](mailto:jimmy.klick@driscolls.com)
8. Dylan Tussay USDA-APHIS [dylan.tussay@usda.gov](mailto:dylan.tussay@usda.gov)
9. Eric Clifton BioWorks, Inc. [eclifton@bioworksinc.com](mailto:eclifton@bioworksinc.com)
10. Maryam Nouri-Aiim University of Vermont [maryam.nourii-aiim@uvm.edu](mailto:maryam.nourii-aiim@uvm.edu)
11. M. Eric Benbow Michigan State University [benbow@msu.edu](mailto:benbow@msu.edu)
12. Kyle Slusher Texas A&M University [eddie.slusher@ag.tamu.edu](mailto:eddie.slusher@ag.tamu.edu)
13. Julien Levy Texas A&M University [julienlevy@tamu.edu](mailto:julienlevy@tamu.edu)
14. David Shapiro-Ilan USDA-ARS [david.shapiro@usda.gov](mailto:david.shapiro@usda.gov)
15. Edwin Lewis University of Idaho [eelewis@uidaho.edu](mailto:eelewis@uidaho.edu)
16. Stefan Jeronski Consultant [thebugdoc01@gmail.com](mailto:thebugdoc01@gmail.com)
17. Jermaine Perier University of Georgia [jermaine.perier@usda.gov](mailto:jermaine.perier@usda.gov)
18. Ryan Kennedy Driscoll’s, California [ryan.kenneduy@driscoll.com](mailto:ryan.kenneduy@driscoll.com)
19. Liliana Cano University of Florida [lmcano@ufl.edu](mailto:lmcano@ufl.edu)
20. Shaohui Wu The Ohio State University [wu.6229@osu.edu](mailto:wu.6229@osu.edu)
21. Surendra Dara Oregon State University [surendra.dara@oregonstate.edu](mailto:surendra.dara@oregonstate.edu)

**BUSINESS MEETING**

**1. *Introductions:*** Eric Clifton (2024 Member-at-large): Welcomed all and began with introductions. Attendees introduced themselves including a short introduction about their affiliation and work.

**2. *Minutes of 2024***(prepared by Lorenzo Rossi and Shaohui Wu): A copy of the 2023 minutes was circulated electronically prior to the meeting. A motion to approve the 2023 minutes was made by Lorenzo Rossi. Minutes of the 2024 meeting are required to be posted within 60 days.

**3. *NIFA administrators report* (**[**Dr.**](https://www.nimss.org/users/461) **Christopher Philips):**

Dr. Philips provided link for NIFA-funded projects search

<https://www.nifa.usda.gov/data/data-gateway>

<https://www.nifa.usda.gov/data/cris-current-research-information-system>

Additional useful links can be found here:

Signing up for NIFA Updates

<https://public.govdelivery.com/accounts/USDANIFA/subscriber/new?qsp=USDANIFA_2>

Searching for Funding Opportunities

<https://www.nifa.usda.gov/grants/funding-opportunities>

List of NIFA’s Competitive RFAs

<https://www.nifa.usda.gov/grants/request-for-application-list-rfa>

Upcoming NIFA RFA Calendar

<https://www.nifa.usda.gov/grants/upcoming-request-applications-calendar>

[Dr.](https://www.nimss.org/users/461) Philips also mentioned that NIFA always looks for qualified reviewers. If anyone is interested in serving as a volunteer as a NIFA panelist, the information can be found via:

<https://prs.nifa.usda.gov/prs/preLogin.do?page=welcome>

**Large-Acreage Crops**

**David Shapiro-Ilan (USDA-ARS):**

We are testing if entomopathogenic nematodes (EPNs) and their pheromones booster the control efficacy against whiteflies with promising success. Thus far, the work has only been conducted in the laboratory and greenhouse.

**Orchard Systems**

**Shaohui Wu (The Ohio State University):**

For a collaborative project funded by AFRI, we performed preliminary field studies on the efficacy of bacteria symbiotic to entomopathogenic nematodes in suppressing pecan pests. Previously, under laboratory conditions the bacterial cultures of *Photorhabdus luminescens* and *Xenorhabdus bovienii* caused significant mortality of pecan aphids. In the field study, adults of the black pecan aphid *Melanocallis caryaefoliae* were caged onto pecan twigs to produce nymphs that were treated with bacterial broths. The average number of aphids in the untreated control (55 ±26) was more than twice of that observed in *P. luminescens* (23 ±12), with 46 ±14 in *X. bovienii*, which followed a similar trend as to the laboratory observation. However, no significant treatment effects were detected, probably because of large variations among small replicates (only four trees per treatment), or the lack of adequate efficacy. We plan to repeat the field test with more replicates, improved methods (without cages) and higher bacterial concentrations to be compared with a standard insecticide.

We also tested the potential systemic effects of bacterial compounds in pecan trees by spraying one side of the tree with a bacterial species and the other side with water, compared to a tree without the bacterial treatment. There was no difference between the bacterial treatment and control, suggesting either a potential systemic effect or the treatment effect was not potent enough. However, we also observed interactions between pecan cultivars and treatments with fewer aphids in both bacterial treatments in the cultivar Desirable than in Stuart, which should be considered in future studies.

In addition, we carried out a field test targeting *phylloxera* on pecan trees. No live phylloxerawere found at the result evaluation after dissecting 300 galls across all treatments. However, we found approximately 10% galls were parasitized, likely by syrphid larvae. In future studies, we will target the active stages such as adults and crawlers instead of galls to assess the treatment effects. (Collaborator David Shapiro-Ilan, USDA-ARS).

**David Shapiro-Ilan (USDA-ARS):**

Some highlights:

* Reported that a capsule formulation for *Steinernema feltiae* from Biobee/E-Nema allowed for substantial persistence of the entomopathogenic nematodes (EPNs) in a pecan orchard (Perier et al., 2024a). (Collaborators: Steve Arthurs, Biobee; Mike Toews UGA).
* Discovered that EPN pheromones enhanced field efficacy of *S. feltiae* in controlling pecan weevil under field conditions (Perier et al. 2024b). (Collaborators: Fatman Kaplan, Pheronym, Inc.; Ed Lewis, University of Idaho; Mike Toews, UGA).
* Continuing work on novel gel formulations to protect EPNs from UV and desiccation, seeking alternatives to Barricade gel (e.g., Ha et al., 2024). Primary targets in the US are wood borers (Collaborators: David Mota-Sanchez, Michigan State University; Brett Blaauw, UGA, et al.).
* Discovered that EPNs can potentially provide multi-season control of pecan weevil even when applied at low rates (Collaborator: Kyle Slusher, Texas A & M).
* Continuing work on endophytic entomopathogenic fungi in pecan. (Collaborator: Kyle Slusher, Texas A & M).

**Josephine Antwi (Oregon State University):**

We conducted a compatibility study on the commercial entomopathogenic fungal (EPF) products, *Beauveria bassiana* (BoteGHA ES) and *Cordyceps javanica* (PFR97 20% WDG) with the fungicide, Bravo Weather stik (chlorothalonil, group M5) on green peach aphid (*Myzus perscicae*) on potato. In a bioassay, aphids were placed on potato leaflets (petioles in Falcon tubes filled with water to keep leaflets alive) and caged in deli cups. Each leaflet was sprayed with the fungicide followed by spraying with either BoteGHA or PFR97 at different time points. This is our first year initiating this project.

Five DAT, we counted the number of aphids on each leaflet and found numerical differences in aphid numbers, especially when both the fungicide and BoteGHA or the fungicide and PFR97 were sprayed on the same day. However, these differences were not statistically significant. In the PFR97 treatment, however, the number of aphids were less than those in the BoteGHA treatments. Aphid numbers in all cases increased over time, irrespective of treatment. As a check, we tested the efficacy of the fungicide in controlling *Alternaria sp.*, the pathogen that causes early blight in potato. The incidence of early blight was low, especially, when the fungicide was sprayed on the same day as *Alternaria sp*. As per Pasco Avery’s (Univ. of FL) suggestion, in the future, we plan to conduct in-vitro compatibility studies with other fungicide chemistries and other species and strains of EPF, then repeat our potato bioassay experiment with those fungi that are compatible in the in-vitro study.

The long-term goal of this project is to develop an IPM program in potato insect management that integrates EPF. We are in eastern Oregon in the Columbia Basin where summers are hot and dry. The main challenge of implementing an IPM program based on EPF in these conditions is timing for the best environmental conditions for EPF growth. Potatoes are grown under center pivot irrigation in this region. During the potato growing season, humidity rises following plant row-closure. We expect this timeframe to be ideal to implement our EPF-based IPM program. In the future, we hope to expand our study to the field to test efficacy on aphids and other potato insect pests.

**Lorenzo Rossi and Pasco Avery (University of Florida):**

Entomopathogenic fungi offer an alternative strategy for citrus growers seeking environmentally friendly pest management solutions. Our studies aimed to assess the ability of two commercially available strains of the fungus *Beauveria bassiana* to become endophytic in citrus plants after a single foliar application. A completely randomized block design, consisting of ‘Valencia’ sweet orange trees (*Citrus × sinensis*) grafted on ‘US-942’ (*Citrus reticulata × Poncirus trifoliata*) rootstock, was established under greenhouse conditions. Treatments comprised 6 replications of treated plants in two separate greenhouses (*n* = 16 per greenhouse), along with one control (water only). Treated plants were foliar sprayed asynchronously with the fungus at the beginning of each experimental trial per treatment. To assess endophytism over time, a series of cohorts were destructively sampled every two months. Detached leaves collected post-spray were imprinted on potato dextrose agar (PDA), amended with dodine and bactericides, to determine fungal coverage of the leaf surface by counting colony forming units. To assess endophytism, sterile samples of plant organs (i.e., leaves, stems, and roots) were placed onto PDA-dodine plates to allow detection of phenotypic mycelia. Results from the first cohorts indicated successful application of the fungi on the citrus leaves, and endophytism was assessed in new leaves, stems and roots after two months. Additionally, no statistically significant changes were recorded in terms of plant height, root, stem, and leaf biomass, as well as stem girth. This project contributed to a clearer understanding of the long-term endophytic persistence of commercially available entomopathogenic fungi and their effect on plant growth in citrus trees. The trial will continue in the field for additional screening.

**Stefan Jaronski (Jaronski Mycological Consulting LLC):**

USDA APHIS (Mission TX), UTRGV (Edinburg TX), and Jaronski Mycological Consulting LLC (Blacksburg VA) have continued field evaluations of *Beauveria bassiana* ANT03, the previously determined lead from among the commercial mycoinsecticides, against the Asian citrus psyllid (ACP) (*Diaphorina citri*). In 2024 we evaluated the impact of UV radiation, low-humidity driven desiccation, and windborne physical displacement of conidia, as well as potentially inhibitory temperatures, on the persistence after application of two commercial formulations of this strain, a wettable powder (WP) and an emulsifiable concentrate (EC), to orange jasmine citrus. Conidial viability of conidia as the EC remained above 50% after 7 days indoors versus dropping to 30% outdoors, while the WP showed considerably lower, even < 0.1% viability in either setting. Thus, the EC may have greater efficacy. In addition, we have evidence that conidia in the WP dislodge from leaf surface over time significantly lowering the concentration, and thus numbers of conidia encountered by an immigrating psyllid. Under cooler conditions (14-19⁰C), both formulations performed similarly. At higher temperatures (26-35⁰C), the EC formulation achieved an average mycosis rate of 61%, while the WP formulation averaged at 18%. These findings suggest that temperature significantly influences the effectiveness of *B. bassiana* formulations, providing valuable insights for ACP management in the Lower Rio Grande Valley, TX. The effect of the *Beauveria* on *Tamarixia radiata*, an important biocontrol agent of ACP, was investigated in laboratory bioassays. We observed antagonism between *T. radiata* and *B. bassiana* when the fungus was applied during *T. radiata* egg development with ACP, with a dose response relationship. While *Tamarixia* emergence from control ACP was ~70%, parallel emergence from *Beauveria* treatments was reduced to 20-50% depending on the fungus dose, but even at the high dose was not completely eliminated. Likewise, 5th instar ACP nymph mortality had a dose response to the application, also contributing to lower emergence of *T. radiata*. ACP adult survivorship after emergence suffered from *B. bassiana* application, implying that the *Beauveria* was still able to colonize the insect after molting, killing all eclosed ACP within 7 days.

**Ann Hajek (Cornell University):**

*Sirex noctilio*

We evaluated population level interactions between an invasive woodwasp, an invasive nematode and a community of native parasitoids using data from 204 pine trees sampled in 2011-2019. This nematode, *Deladenus siricidicola*, sterilizes this invasive woodwasp that kills pine trees. Nematode parasitism was positively associated with *S. noctilio* density, and negatively associated with the density of rhyssine parasitoids. There appeared to be no competition between the nematode and parasitoids.

Spotted lanternflies

Studies of fungal pathogens of spotted lanternflies (SLF) demonstrated naturally-occurring widespread infection by *Beauveria bassiana* in Pennsylvania, While this was the only species of *Beauveria* found to infect this invasive planthopper 20 different strains within this species, grouped into two clades were scattered in the area infested by SLF.

Studies with the poorly known entomophthoralean fungus causing epizootics in SLF in 2018, *Batkoa major*, investigated diurnal patterns and conidial dynamics using *Galleria mellonella* larvae as hosts. Death of *G. mellonella* followed a diurnal cycle with most larvae dying within 4 h before or after the end of photophase. Time for initiation of rhizoid emergence also followed a diurnal rhythm and, on average occurred 3.6 h after host death. While *B. major* sometimes began producing rhizoids to attach cadavers to substrates while *G. mellonella* were alive (but moribund), often hosts were dead before rhizoids began emerging. On average, conidial discharge began 18.6 h after host death and was greater 4–8 h before the end of photophase, compared with 4–8 h after scotophase began. At 20 ◦C under high humidity, initiation of conidial discharge was 95% complete within 24 h after host death. To evaluate *B. major* activity by temperature, we tested percent conidial germination over 24 h from 5 to 35 ◦C. When showered onto water agar, all primary conidia produced secondary conidia. At 20 and 25 ◦C, at 3 h ≥89% of primary conidia had produced and discharged secondaries and from 10 to 30 ◦C, secondaries were produced by over 75% of primary conidia within 12 h. When cover slips were placed over primary conidia to force production of germ tubes, germination was much slower, with *>*85% germination from 20 to 30 ◦C only by 24 h.

Nymphal- and adult-stage lanternflies in Pennsylvania and New York were surveyed for entomopathogenic fungal infections from October 2021 to November 2023, and assays were conducted to confirm the pathogenicity of species that were potentially pathogenic. *Beauveria bassiana* was the most abundant pathogen, but we report an additional 15 previously unreported species of entomopathogenic fungi infecting spotted lanternflies, all in the order Hypocreales (Ascomycota) (previously four species were known; three in the Hypocreales and one in the Entomophthorales). The next most common pathogens were *Fusarium fujikuroi* and *Sarocladium strictum.* While infection prevalence by species was often low, probably impacted to some extent by the summer drought in 2022 when most sampling occurred, together these pathogens caused a total of 6.7% mortality. A significant trend was evident over time within a season, with low levels of infection among nymphs and higher infection levels in midand late-stage adults, the stages when mating and oviposition occur.

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

**David Shapiro-Ilan (USDA-ARS)**:

* Initiated a new project on goat grazing in pecan orchards. Measured virulence of various entomopathogenic nematode species to goat lice – several species are shown to be highly virulent in the lab. (Collaborators: Sehrish Gulzar, USDA-ARS; Tom Terrill Fort Valley State University).

**Ann Hajek (Cornell University):**

We sampled populations of brown marmorated stink bugs (BMSB) before, during, and after overwintering. These invasives overwinter as adults, often in aggregations. We found high levels of infections by *Colletotrichum fioriniae* and *Nosema maddoxi* (sometimes co-infecting) in the many BMSB that died while overwintering. *Colletotrichum fioriniae* had never previously been reported as a pathogen of BMSB. Increasing levels of *N. maddoxi* infection caused epizootics among *H. halys* after overwintering. Models were used to evaluate the potential for biological control provided by *T. japonicus* and *N. maddoxi* across the US. Modelling showed that this parasitoid and microsporidian could be key for managing *H. halys* given their overlapping niches. Mod­els can aid in delineating areas where biocontrol may be most effective.

**Albrecht M. Koppenhofer (Rutgers University):**

We are conducting research to elucidate the combined effects of silicon supplementation and entomopathogenic nematodes (EPNs) on controlling three major turfgrass insects: black cutworm (Agrotis ipsilon), white grubs (larvae of scarab beetles such as Japanese beetle, oriental beetle, and masked chafers), and annual bluegrass weevil (Listronotus maculicollis). Silicon, a beneficial nutrient for plants, can provide multiple benefits to turfgrasses, including resistance to biotic and abiotic stresses. Grasses are high accumulators of silicon which makes tissues abrasive and tougher and difficult for insects to consume and digest. We conducted a series of laboratory and greenhouse experiments to investigate the effects of silicon supply to different turfgrasses (i.e., annual bluegrass, creeping bentgrass, perennial ryegrass) in combination with the application of entomopathogenic nematodes (S. carpocapsae or H. bacteriophora) on controlling the three insect pests.

Our observations to date suggest that silicon fertilization could support plant resistance against these insects, particularly against cutworms, and could enhance insect susceptibility to entomopathogenic nematodes. In greenhouse experiments, silicon fertilization reduced weight gain in black cutworm larvae by around 36%. Silicon also accelerated mortality by S. carpocapsae and increased mortality by up around 45%. However, due to reduced larval growth silicon exposure also reduced reproduction of S. carpocapsae in infected larvae by 43%. In greenhouse experiments with white grubs (oriental beetle), silicon fertilization reduced larval weight gain but did not affect susceptibility to H. bacteriophora. Fertilization with silicon reduced populations of annual bluegrass weevil larvae in greenhouse experiments by around 60% but did not affect their susceptibility to S. carpocapsae. In the field, silicon fertilization decreased adult weevil numbers pre nematode application by around 76% and larval populations post application by around 50%.

**Discussion:**

Anamika Sharma formally notified the working group of her intent to relinquish her position as chair, nominating Shaohui Wu, the current vice-chair, as her successor. The working group unanimously endorsed this transition. All other officers shall retain their respective positions until the next scheduled meeting in November 2025, at which time elections for new officers will be conducted. Topics for the next symposium were discussed but not finalized.

**Microbial related publications (research and outreach) from group members (2023-2024):**

* + - 1. Alwaneen, W.S., Wakil, W., Kavallieratos, N.G., Qayyum, M.A., Tahir, M., Rasool, K.G., Husain, M., Aldawood, A.S., **Shapiro-Ilan, D**. 2024. Efficacy and persistence of entomopathogenic fungi against *Rhynchophorus ferrugineus* on date palm: host to host transmission. Agronomy 14, 642. <https://doi.org/10.3390/agronomy14040642>
      2. Alwaneen, W., Tahir, S., M., **Avery, P. B.**, Wakil, W., Kavallieratos, N. G., Eleftheriadou, N., Boukouvala, M. C., Rasool, K. G., Husain, M., and A. S. Aldawood. 2024. Initial evaluation of the entomopathogenic fungi *Beauveria bassiana* and *Metarhizium robertsii*, and the entomopathogenic nematode *Heterorhabditis bacteriophora*, individually and in combination against the noxious *Helicoverpa armigera* (Lepidoptera: Noctuidae). Agronomy **14** (7), 1395. DOI: 10.3390/agronomy14071395.
      3. Barrett, J. E., B. J. Adams, P. T. Doran, H. A. Dugan, K. F. Myers, M. R. Salvatore, S. N. Power, M. D. Snyder, A. T. Wright, and M. N. Gooseff. 2024. Response of a Terrestrial Polar Ecosystem to the March 2022 Antarctic Weather Anomaly. Earth's Future **12**:e2023EF004306.
      4. Canini, F., B. J. Adams, L. P. D'Acqui, F. D'Alò, and L. Zucconi. 2024. Antarctic rock and soil microbiomes: Shared taxa, selective pressures, and extracellular DNA effects. Geoderma **446**:116918.
      5. **Clifton, E.H**., Castrillo, L.A., **Jaronski, S.T**., **Hajek, A.E**. 2023. Cryptic diversity and virulence of *Beauveria bassiana* recovered from *Lycorma delicatula* (spotted lanternfly) in eastern Pennsylvania. Frontiers in Insect Science: Focus on Spotted Lanternfly 3: 1127682.
      6. **Dara, S. K.**2024. 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, pp. 229-235. CABI, Oxfordshire, UK. [https://doi.org/10.1079/9781800620322.0013](https://nam10.safelinks.protection.outlook.com/?url=https%3A%2F%2Fdoi.org%2F10.1079%2F9781800620322.0013&data=05%7C02%7Cl.rossi%40ufl.edu%7C25310e0a17bf4517f4b108dd1bc4f797%7C0d4da0f84a314d76ace60a62331e1b84%7C0%7C0%7C638697255038517158%7CUnknown%7CTWFpbGZsb3d8eyJFbXB0eU1hcGkiOnRydWUsIlYiOiIwLjAuMDAwMCIsIlAiOiJXaW4zMiIsIkFOIjoiTWFpbCIsIldUIjoyfQ%3D%3D%7C0%7C%7C%7C&sdata=YdF%2FokkECy3aKjqWVFFumsto8aEGkNC5nnkGL5gVdeo%3D&reserved=0)
      7. Gonzalez, J.B., Lambert, C.A., Foley, A.M., **Hajek, A.E.** 2023. First report of *Colletotrichum fioriniae* infections in brown marmorated stink bugs, *Halyomorpha halys*. J. Invertebr. Pathol. 199: 107939. <https://doi.org/10.1016/j.jip.2023.107939>
      8. Gryganskyi, A.P., **Hajek, A.E.,** Voloshchu, N., Idnurm, A., Eilenberg, J., Manfrino, R.G., Bushley, K.E., Kava, L., Kutovenko, .B., Anike, F., Nie, Y. 2024. Potential for use of species in the subfamily *Erynioideae* for biological control and biotechnology. Microorganisms 12: 168. <https://doi.org/10.3390/microorganisms12010168>
      9. Ha, B., Wei, X., Lu, P. , Qing, H., Guo, J., Zhang, R., Lei, C., Li, X., Hu, B., Wang, S., Xu, Y., Fu, Z., **Shapiro Ilan, D**., Ruan, W. Natural UV protectants and humectants to improve the efficiency of *Steinernema carpocapsae* in controlling foliar pests. Pest Management Science. In Press, Accepted 11/20/2024.
      10. **Hajek, A.E.**, Brandt, S.N., Gonzalez, J.B., Bergh, J.C. 2023. Entomopathogens infecting brown marmorated stink bugs before, during, and after overwintering. J. Insect Science 23(3): 8; 1-8. DOI: [10.1093/jisesa/iead033](https://doi.org/10.1093/jisesa/iead033)
      11. **Hajek, A.E.,** Everest, T.A., **Clifton, E.H.** 2023. Accumulation of fungal pathogens infecting the invasive spotted lanternfly, *Lycorma delicatula*. Insects 14: 912. <https://doi.org/10.3390/insects14120912>
      12. **Hajek, A.E.**, Harris, C.H. 2023. Diurnal patterns and conidial dynamics of *Batkoa**major*, a generalist entomophthoralean pathogen. Fungal Ecology 65: 101278. <https://doi.org/10.1016/j.funeco.2023.101278>
      13. Intasin J. 2024. Determining Epichloë infection status across commercial perennial ryegrass cultivars and evaluating Epichloë-mediated resistance against *Noctua pronuba* in cool-season turfgrass. MS Thesis submitted to the Oregon State University. 85 pages.
      14. Jorna, J., **B. J. Adams**, Z. T. Aanderud, P. B. Frandsen, C. Takacs-Vesbach, and S. Kéfi. 2024. The underground network: facilitation in soil bacteria. Oikos **2024**:e10299.
      15. **Kaur, N.,** Rivedal, H. M., Intasin, J., Verhoeven, E. C., Di, Y., Anderson, N. P., ... & Duringer, J. M. (2024). Response of sod webworm *Chrysoteuchia topiaria* Zeller (Lepidoptera: Crambidae) to endophyte infection and mycotoxin profiles of cool‐season turfgrass species grown for seed in Oregon. *Crop, Forage & Turfgrass Management*, *10*(2), e20291.
      16. **Koppenhöfer A.M.,** Sousa A.L. 2024. Long-term suppression of turfgrass insect pests with native persistent entomopathogenic nematodes. J. Invertebr. Pathol. 204, 108123. doi.org/10.1016/j.jip.2024.108123
      17. **Koppenhöfer A.M.,** Sousa A.L. 2024. Turfgrass and Pasture Applications. In: Entomopa-thogenic Nematodes as Biological Control Agents (D.I. Shapiro-Ilan, E.E. Lewis), pp. 370–391. CABI Publish., Wallingford, UK. doi.org/10.1079/9781800620322.0021
      18. **Koppenhöfer A.M.,** Foye S. 2024. Interactions with Agrochemicals and Biological Control Agents. In: Entomopathogenic Nematodes as Biological Control Agents (D.I. Shapiro-Ilan, E.E. Lewis), pp. 494–518. CABI Publ., Wallingford, UK. doi.org/10.1079/9781800620322.0027
      19. Leite, L.G., Chacon-Orozcoa, J.G., **Shapiro-Ilan, D.I**., Baldo, F.B., Cardoso, J.M. 2023. Effects of temperature for optimizing production and storage of *Steinernema rarum* in a novel biphasic process, and efficacy of the nematode against *Sphenophorus levis*. Biological Control 187, 105381. <https://doi.org/10.1016/j.biocontrol.2023.105381>
      20. Li, Y., Mbata, G.N., Simmons, A.M., **Shapiro-Ilan, D.I., Wu, S.** 2024. Management of *Bemisia tabaci* on vegetables Crops using entomopathogens. Crop Protection. 180, 106638. <https://doi.org/10.1016/j.cropro.2024.106638>
      21. Li, X., S**hapiro-Ilan, D**., Tarasco, E., Zeng, S., Liu, Q., Yang, W., Yi, J., Chen, C. and Fu, H. 2024. Thiourea as a polyphenol oxidase inhibitor enhances host infection by the entomopathogenic nematode, *Heterorhabditis beicherriana*. Biological Control 191, 105474. <https://doi.org/10.1016/j.biocontrol.2024.105474>

1. Li, J., Wei, X., Pei, Z, Suna J., Xi, J., Li, X., **Shapiro-Ilan, D**., and Ruan, W. 2024. Volatile organic compounds released from entomopathogenic nematode-infected insect cadavers for the biocontrol of *Meloidogyne incognita*. Pest Management Science DOI 10.1002/ps.8268
2. Machado, R.A.R.,Muller, A.,Hiltmann, A., Bhat, A.H., Puza, V., Malan, A.P., Alvarez, C., San-Blas, E., Duncan, L.W., **Shapiro-Ilan, D.I**., Karimi, J., Lalramlian, Lalramnghaki, H.C., Baimey, H. 2025. Genome-wide analyses provide insights into genetic variation, phylo- and co-phylogenetic relationships, and biogeography of the entomopathogenic nematode genus *Heterorhabditis*. Molecular Phylogenetics and Evolution. In Press (Accepted 1/5/2025).
3. **Perier, J.D.**, Wu, S., Arthurs, S.P., Toews, M.D., **Shapiro-Ilan, D.I**. 2024a. Persistence of the entomopathogenic nematode Steinernema feltiae in a novel capsule formulation. Biological Control. In Press (accepted 12/20/24). <https://doi.org/10.1016/j.biocontrol.2024.105684>
4. **Perier, J.D., Kaplan, F., Lewis, E.E**., Alborn, H., Schliekelman, P. Toews, M.T., and **Shapiro-Ilan, D**. 2024b. Enhancing entomopathogenic nematode efficacy with pheromones: A field study Targeting the pecan weevil. Journal of Invertebrate Pathology. 203, 108070. <https://doi.org/10.1016/j.jip.2024.108070>
5. Power, S. N., M. R. Salvatore, E. R. Sokol, L. F. Stanish, S. R. Borges, **B. J. Adams**, and J. E. Barrett. 2024. Remotely characterizing photosynthetic biocrust in snowpack-fed microhabitats of Taylor Valley, Antarctica. Science of Remote Sensing **9**:100120.
6. Rodriguez-Saona, C. and **S. K. Dara.**2024. Entomopathogenic nematodes in berry crops. *In*Entomopathogenic nematodes as biological control agents. Eds. D. I. Shapiro-Ilan and E. E. Lewis, pp. 312-332. CABI, Oxfordshire, UK. [https://doi.org/10.1079/9781800620322.0018](https://nam10.safelinks.protection.outlook.com/?url=https%3A%2F%2Fdoi.org%2F10.1079%2F9781800620322.0018&data=05%7C02%7Cl.rossi%40ufl.edu%7C25310e0a17bf4517f4b108dd1bc4f797%7C0d4da0f84a314d76ace60a62331e1b84%7C0%7C0%7C638697255038548394%7CUnknown%7CTWFpbGZsb3d8eyJFbXB0eU1hcGkiOnRydWUsIlYiOiIwLjAuMDAwMCIsIlAiOiJXaW4zMiIsIkFOIjoiTWFpbCIsIldUIjoyfQ%3D%3D%7C0%7C%7C%7C&sdata=IQ2AFBUhmVOnSIaNpgPZXJZUGQ4uZo22eMngF%2Bh1pO4%3D&reserved=0)
7. **Shapiro-Ilan, D.I.** and **Lewis, E.E** (Eds.). 2024. Entomopathogenic Nematodes as Biocontrol Agents. CABI Publishing. Wallingford, UK. 554 pp. DOI: 10.1079/9781800620322.0000.
8. **Slusher, E.K., Lewis, E., Stevens, G., Shapiro-Ilan, D**. 2024. Movers and shakers: Do nematodes that move more invade more? Journal of Invertebrate Pathology 203, 108060. <https://doi.org/10.1016/j.jip.2024.108060>
9. **Stevens, G.,** Usman, M. Gulzar, S., Stevens, C., Pimentel, E. Erdogan, H. Schliekelman, P., **Kaplan, F**., Alborn, H., Wakil, W., **Shapiro-Ilan, D., and Lewis, E.E**. Group movement in entomopathogenic nematodes: Aggregation levels vary based on context. Journal of Nematology, 56, e2024-1. DOI: <https://doi.org/10.2478/jofnem-2024-0002>
10. Stone, M. S., S. P. Devlin, I. Hawes, K. A. Welch, M. N. Gooseff, C. Takacs-Vesbach, R. Morgan-Kiss, **B. J. Adams**, J. E. Barrett, J. C. Priscu, and P. T. Doran. 2024. McMurdo Dry Valley lake edge ‘moats’: the ecological intersection between terrestrial and aquatic polar desert habitats. Antarctic Science **36**:189-205.
11. Toledo, P.F.S. Phillips, K., Schmidt, J.M., Bock, C.H., Wong, C., Hudson, W.G., **Shapiro-Ilan, D**., Wells, L., Acebes-Doria, A.L. 2023. Canopy hedge pruning in pecan production differentially affects groups of arthropod pests and associated natural enemies. Crop Protection 176, 106521. <https://doi.org/10.1016/j.cropro.2023.106521>
12. van Nouhuys, S., Harris, D.C., **Hajek, A.E**. 2023. Population level interactions between an invasive woodwasp, an invasive nematode and a community of native parasitoids. Neobiota 82: 67-88. doi: 10.3897/neobiota.82.96599
13. Varliero, G., P. H. Lebre, **B. Adams**, S. L. Chown, P. Convey, P. G. Dennis, D. Fan, B. Ferrari, B. Frey, I. D. Hogg, D. W. Hopkins, W. Kong, T. Makhalanyane, G. Matcher, K. K. Newsham, M. I. Stevens, K. V. Weigh, and D. A. Cowan. 2024. Biogeographic survey of soil bacterial communities across Antarctica. Microbiome **12**:9.
14. Wakil, W., Boukouvala, M.C., Kavallieratos, N. G., Riasat, T., Ghazanfar, M. U., and **P. B. Avery**. Acaricidal activity of abamectin is enhanced against *Tetranychus urticae* populations when combined with entomopathogenic fungi. Horticulturae **10**, 1019. DOI: 10.3390/horticulturae10101019.
15. Wakil, W., Boukouvala, M. C., Kavallieratos, N. G., Filintas, C. S., Eleftheriadou, N., Yasin, M., Qayyum, M. A., and **P. B. Avery**. Current status of biology - biotechnic and biological control of *Rhynchophorus ferrugineus*: a review. Insects **15**, 955. DOI: 10.3390/insects15120955
16. Xue, X., A. R. Thompson, and **B. J. Adams**. 2024. An Antarctic worm and its soil ecosystem: A review of an emerging research program in ecological genomics. Applied Soil Ecology **193**:105110.
17. Yasin, M., Wakil, W., Kavallieratos, N.G., Naeem, A. Qayyum, M.A., Asrar, M., Alhewairini, S.S., and **Shapiro-Ilan, D**. 2024. Dual-strategy approach for *Rhynchophorus ferrugineus* control: endophytic *Beauveria bassiana* and *Bacillus thuringiensis* topical application. Crop Protection 106954. <https://doi.org/10.1016/j.cropro.2024.106954>
18. Zhu, G, Illan JG, **Hajek AE**, Nielsen AL, Leskey TC, Walgenbach JF, Beers EH, Crowder DW. 2024. Assessing geographic dimensions of biological control for *Halyomorpha halys* in the United States. Entomologia Generalis 44(4): 895-904. DOI: 10.1127/entomologia/2024/2528
19. Zhang, M., Spaulding, N. Reddy, G.V.P, **Shapiro-Ilan, D.I**. The efficacy of entomopathogenic nematodes plus an adjuvant against *Helicoverpa zea* and *Chrysodeixis includens* in aboveground applications. Journal of Nematology 56: e2024-1: 1-14. [https://doi.org/10.2478/jofnem-2024-0018](https://gcc02.safelinks.protection.outlook.com/?url=https%3A%2F%2Fdoi.org%2F10.2478%2Fjofnem-2024-0018&data=05%7C02%7Cdavid.shapiro%40usda.gov%7C839c096dce7141267f4a08dc7135442b%7Ced5b36e701ee4ebc867ee03cfa0d4697%7C1%7C0%7C638509721464137958%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C0%7C%7C%7C&sdata=7Vl%2BQ7uYHE2b%2BrC0Dr%2F%2F95j%2F9XUEdGNi%2FpVJ%2BKkyn3A%3D&reserved=0)