Project Number: NE2001

Project Title: Harnessing Chemical Ecology to address agricultural pest and pollinator priorities

Period Covered: November 2022-November 2023

Date of this Report: 01/08/2024

Annual Meeting Date: October 27, 2023

The purpose of this multistate project is to provide a framework and opportunity for collaboration for diverse land grant researchers to work together to solve pressing problems in pest and pollinator management. The project aims to bring people together around a set of general goals. This broad umbrella allows us to coalesce a dynamic group of researchers from different locations and funding situations. The multistate meets annually to discuss directions, spawn new collaborations, share findings, develop tools, draft new proposals and write collaborative review papers.

Participants:

In-Person Members: Cesar Rodriguez-Saona (Rutgers), Rupesh Kariyat (U of Arkansas), Anurag Agrawal (Cornell), Chase Stratton (Delaware), Katja Poveda (Cornell), Jennifer Thaler (Cornell), Monica Kersch-Becker (Penn State), Keyan Zhu Salzman (Texas A&M), Seung-Joon Ahn (Mississippi State), Zain Syed (Kentucky)

In-Person Students and post-docs: Jack Collins, Beth Yoshimura Ferguson, Jae Kerstetter, Yahel Ben-Zvi, Haotian Liu, Amanda Quadrel

Virtual Members and Postdoc: Yolanda Chen (Univ. of Vermont), Andre Kessler (Cornell), Blair Siegfried (Penn State), Hany Dweck (Ag station, Connecticut), Kelli Hoover (Penn State), Leela Uppala (Univ. of Mass Amherst), Andrei Alyokhin (Maine), Swayamjit Ray (Cornell), Binita Shrestha (Cornell), Greg Loeb (Cornell), Sarah Hind (Univ. of Illinois), Flor Acevedo (Penn State), Anjel Helms (Texas A&M), Erica Kistner Thomas (NIFA national program leader), Todd Ugine (Cornell)

Brief summary of minutes of annual meeting:

The meeting had two primary objectives. The first was to introduce the group with new members and gain insights into ongoing research. The second was to formulate specific plans for collaborative group projects. Since the beginning of our multistate project, our aim has been to leverage our geographic diversity, a variety of approaches, and shared goals to collectively impact pest and pollinator management positively. During the previous annual meeting, we

identified broad areas for potential group projects where participants believed we could successfully translate our fundamental understanding of chemical communication into practical applications for pest and pollinator management. This year, a key focus was to update the members on these projects and explore new projects with applied potential that we could collaboratively pursue.

To that end, the objectives of this meeting were to:

1. Provide updates on the multistate Hatch project and NIFA funding sources.
2. Discuss new research developments over the past year, in particular introducing new members.
3. Discuss four project ideas and measure the group's interest in pursuing. Identify ways of collaborating to meet those goals.

On October 27, 2023, the group met to discuss research developments over the past year with individual presentations by 12 participants. These presentations are discussed in the Accomplishments section below. In the afternoon, we provided updates of ongoing Group projects and discussed ideas for new projects. The Group project ideas are also discussed in the Accomplishment section below.

At the meeting, the group had an update on the multistate Hatch project by our administrative advisor Dr. Blair Siegfried and had an update and discussion with Erica Kistner-Thomas, National Program Leader from NIFA. We then discussed four Group projects.

Accomplishments

Short term outcomes: Building Opportunities for Collaboration:

Building on the impact areas discussed during the previous multistate meeting, several group members have identified promising areas with significant applied potential over the next 3-5 years. These proposed projects were presented to the group and sparked extensive discussion during the meeting. Recognizing a critical opportunity for collaboration, the group aims to leverage past successes and evaluate their applicability across diverse systems. Given the variety of systems in which we conduct research, we are uniquely positioned to perform similar assays across different environmental and cropping systems, allowing us to gain a comprehensive understanding of how and why certain approaches consistently yield positive results.

Four Group Projects

1. Opinion paper—the group discussed writing an opinion paper on the challenges facing the registration of semiochemicals for pest control. For this, the group invited Dr. Agenor Mafra-Neto, CEO of ISCA technologies. During the discussion, Dr. Mafra-Neto highlighted the current pathways for registering semiochemicals and shed light on the difficulties his

company encounters, particularly when registering products containing blends of compounds that lack tolerance exemptions. The primary goal of the opinion paper is to educate the public, academia, and government agencies on semiochemicals, their applications, the hurdles in the registration process, and suggest potential solutions.

2. Predalure—a Group project was initiated in 2022 and continued in 2023 to evaluate the potential for using herbivore-induced plant volatiles to attract the natural enemies of herbivores. Methyl salicylate has been found to be attractive to natural enemies in many systems and is marketed under the tradename PredaLure (winter green oil—methyl salicylate). However, it is not known how different groups of natural enemies will respond to methyl salicylate in different crops and different locations. Cesar Rodriguez-Saona and his postdoc Patricia Prade (Rutgers) led this project to test PredaLure in multiple crops and multiple states (New Jersey, New York, Pennsylvania, Virginia). This project provided an opportunity to train students across states in chemical ecology by involving them in field research and group project meetings.

3. Meta-analysis on HIPVs—this group project led by Cesar Rodriguez-Saona and Sara Hermann will analyze data from peer-reviewed papers on the response of natural enemies of herbivores to synthetic herbivore-induced plant volatiles (HIPVs) in the field. While HIPVs have been employed for decades to attract natural enemies, their response may vary across different crops. Utilizing data from published papers, this project seeks to investigate and understand the diverse responses of natural enemies to HIPVs in the field. The ultimate goal is to predict how natural enemies react to HIPVs and identify key areas for future research.

4. Context of management strategies—Jennifer Thaler led discussions on the impact of various environmental conditions, such as soil composition, on management strategies like host-plant resistance.

Outputs:

Work and accomplishments over the past year include:

- Agrawal's group have been studying striped cucumber beetle and squash bugs to examine joint management possibilities via chemical ecology and breeding. In particular, they have been studying their pheromones as well as plant resistance in the descendants of the two domestication events of *Cucurbita pepo*. Squash bugs exploit the pheromone of striped cucumber beetle for host choice and this has implications for management: while there are trade-offs in varietal preference based on the two domesticates, synergistic trapping of both pests may be possible (via shared use of pheromone cues).
- Kessler's lab demonstrated in a maize intercropping system that chemical signals from neighboring plants as well as plant chemistry-mediated plant-soil feedbacks affect plant

secondary metabolism and thus resistance to herbivores and biomass accumulation. Most importantly, plant-soil feedback affects plant secondary metabolism in fundamentally different ways than chemical signals from neighboring plants. In consequence, rotation cropping and intercropping of maize with legumes can have fundamentally different effects on plant metabolism and performance. Moreover, chemical elicitation effects differ with intercrop species.

- Syed's lab is working on chemosensory basis of host/mate finding and avoidance/repellence. They just submitted a review of the concepts of attraction and repulsion in ticks. The lab continues to focus on researching spotted-wing drosophila (SWD) oviposition.
- Dweck's lab is deciphering how spotted lanternfly (SLF), an invasive polyphagous planthopper in North America, engages with its environment is a pressing issue with fundamental biological significance and economic importance. This interaction primarily depends on olfaction. However, the cellular basis of olfaction in SLF remains elusive. The lab is identifying new odorants that may be useful for managing this serious pest.
- Karban's lab continues to examine the mechanisms and consequences of volatile communication leading to induced resistance in Artemisia. They also conducted experiments examining the potential role of trichomes in communication in tomato and examined petal shading as a response to heat stress.
- Hoover's lab is investigating whether sequestration of toxin from tree of heaven by the SLF affects predator feeding preference.
- Thaler's lab is studying the non-consumptive effects of predators on herbivores and their potential use in agriculture. They are using the aggregation pheromone of stinkbug predator to reduce number of Colorado potato beetles and their damage and to increase tuber yield.
- Rodriguez-Saona's lab is studying the effects of domestication on plant guttation and tri-trophic interactions. They are also studying the repellent effects of volatiles from anthracnose-infected fruits on SWD.

- McArt's lab found that wax in NYS honey bee colonies contains 17 pesticides, on average, and some of these pesticides are known to synergize with each other. They also assessed how bees are exposed to pesticides in orchards and in this process found that most species of wild bees spill over from adjacent forest habitats to conduct crop pollination. When they placed experimental bumble bee colonies in orchards, they also found that they can function as ecological traps for wild nest-searching queens. This publication prompted rapid industry change in queen excluder practices for all outdoor hives sold in the USA.
- Loeb's lab continued research on discovery and development of repellents for SWD including large scale field testing of 2-pentylfuran (2pf) in fall raspberries, including impacts on beneficial arthropods. Also conducted lab bioassays on two other candidate repellents and began lab bioassays on specific mechanisms underlying repellency of 2pf. Conducted lab assessments of response of larval parasitoids of SWD to infested and uninfested fruit odors.

- Casteel's lab identified the 16 most common soil management practices across 80+ organic farms in NY. Two of the most common practices were cover cropping and composting. Using lab and field experiments we found cereal rye and canola cover crops reduced pest damage and enhanced plant resistance through changes in the soil microbiome. We used this data to obtain funding from NIFA ORG on the impact of seed origin on resilience enhancing soil microbiomes.
- Vannette's lab continued to examine how nectar chemistry influences microbial communities and attraction to pollinators. We conducted experiments comparing nectar chemistry and antimicrobial potential of 30+ plant species. We examined responses of 3 pollinator species to microbial colonization of nectar. We examined the role of hydrogen peroxide in antimicrobial defense of nectar.
- Losey's lab collected volatiles from the flowers and foliage of several species of carrot plants (Queen Anne's lace, poison hemlock, and wild parsnip). They have separated out the volatiles using GC-MS and characterized their emissions using principal component analyses. They found that the flowers of the three plants have several compounds in common that are candidate attractants for predators. They are now testing these compounds singly and in combination for their attractiveness to lady beetles. Additionally, we have identified and annotated all of the chemoreceptors (ionotropic, gustatory, olfactory, etc.) from the genomes of several lady beetle species for downstream functional characterizations in attraction.
- The focus of Dr. Ahn's lab is on insect-plant interactions using biochemical and molecular tools not only to understand host plant adaptation strategies of arthropod herbivores, but also to develop novel strategies for integrated pest management. They have established a CRISPR/Cas9 technique to edit the genomes of lepidopteran species, including soybean looper and corn earworm. A visual phenotypic marker gene was successfully knocked out to prove the concept of the technique. They are currently applying to edit detoxification genes to understand the molecular mechanism of host-plant adaptation.
- Keyan-Zhu's lab is studying the genetic and molecular bases of insect-plant-environment interactions, using electron beam to control storage insect pests and insect-vectored diseases, uncovering the mechanism of insect tolerance to hypoxia, and exploiting the metabolic constraint in insects and manipulate plant sterol profiles to control herbivore insects.
- Stout's group found that rice plants deficient in their ability to take up silicon from the soil were more susceptible to fall armyworm in greenhouse trials and to brown spot in field trials. Levels of some secondary metabolites were affected in mutants but the ability of mutant plants to respond to herbivory was not compromised. Two methods of coating rice seeds with solutions containing methyl jasmonate were evaluated in field trials but neither was as effective as seed soaking. Treatment of cotton seeds with methyl jasmonate imparted resistance in seedlings to thrips. They also characterized the spatial extent of induction of ipomeamarone (furnaoterpenoid) by sweetpotato weevil.
- Stratton's lab contributed preliminary work on an electroantennography study testing whether SWD habituates to natural repellents. They were also able to establish plants at our field station. One of the species, *Silphium integrifolium*, has insecticidal compounds

they are interested in testing. They also established the Cheminformatics/Bioinformatics Data Processing Unit where they are filling out chemical function dictionaries for high-throughput functional screening of plant chemicals.

- Alyokhin's lab continued work on using RNAi for managing Colorado potato beetles. The first sprayable active ingredient based on dsRNA, ledprona, has been issued an experimental use permit for the 2023 growing season. They tested the effects of ledprona on olfactory responses of Colorado potato beetles.
- Kariyat's lab is studying the chemical ecology of soybean- soybean looper interactions and rice-fall armyworm interactions.
- Chen's lab optimized the protocols for histone extractions and quantification. We have generated helpful preliminary data on the relationship between insecticide dosage and histone modifications.
- Poveda's lab performed growth chamber and field experiments to test the attraction of seedcorn maggot to different soil amendments. They found that soil amendments such as manure and decomposing organic matter are very attractive for seedcorn maggot.
- Duplais' lab is starting a project to evaluate the effectiveness of pheromone traps for monitoring insect pests. They aged corn earworm and codling moth lures from different suppliers and quantified the amount of pheromone emitted and remaining in the dispenser after aging the lures from 1 to 4 weeks in the field. They establish a correlation between the amount of pheromone emitted and the number of catch. They are also studying the detoxification of tomato steroidal alkaloid in the cabbage lopper. They have identified the detoxification product, the quantity uptaken, and the time required to excrete it from the caterpillar's body. They showed the variation between a wild-type strain and a Bt-resistant strain.
- Adler's lab is studying how sunflowers affect bee communities, parasite resistance and health in agroecosystems, and also intersections between abiotic conditions (drought), pesticide exposure and pathogen dynamics in the common eastern bumble bee.
- Helms' lab is evaluating the impacts of introducing beneficial insect-killing nematodes for biological control and enhanced plant resistance to improve pest management in cucurbit crops. We are also characterizing chemically mediated interactions among plants and herbivores in a squash agroecosystem to better understand plant resistance and impacts on the herbivore community.
- Kersh-Becker's lab focused on two key areas: (1) the impact of climate change on tritrophic interactions and (2) the effects of plant defenses on biological control. Their findings revealed that while drought can decrease pest numbers, it reduces the efficacy of biological control. Additionally, they found that salicylate defenses of plants enhance the biological control of aphids.
- Members of the UMass Cranberry Station (Sandler, Uppala, Mupambi) evaluated several coppers and biologicals products in 2022 and 2023 growing seasons SOLO and as part of fungicide regimes with a goal to develop an integrated cranberry fruit rot management program, identified fungicide regimes with coppers and biologicals that worked efficiently in reducing fruit rot, studied the fruit and soil microbiome of cranberry from wild and managed (conventional and organic) ecosystems through 16 S and ITS

sequencing, and characterized the most prevalent cranberry fruit rot fungi from Massachusetts cranberry bogs using Multiplex PCR.

Milestones

As a group, we met a major milestone by establishing four large group projects. Individual projects met their own milestones.

Impact Statement:

The outcomes of this project have been extensively shared through the publications listed below, as well as presentations at both national and international meetings by project members. The impact extends beyond disseminating technical approaches to chemical ecology; numerous post-docs, graduate, and undergraduate students have received training in posing and addressing impactful questions and have undergone significant professional development. We are pleased to note that the group continues to attract new investigators from various institutions.

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