S1070 Regional Research Project Agenda
Saturday, November 16, 2019

Project/Activity Number: S1070
Project/Activity Title: The Working Group on Improving Microbial Control of Arthropod Pests
Period Covered: December 2018-December 2019
Date of This Report: June 27 2020
Annual Meeting Date(s): November 16, 2019

Robert Behle, Chair
Jimmy Klick, Vice-chair
Anamika Sharma, Secretary
Stefan Jaronski, Member-at-large
Rogers Leonard, Administrative Advisor

Agenda and location 2019 meeting

Marriott St. Louis Hotel, Landmark Ballroom 5

8:00 AM	REGISTRATION (Coffee, Juice, Bagels, Fruit) Registration = $20.00
8:30 AM	PRELIMINARY BUSINESS MEETING 1. Local arrangements report 2. Introductions 3. Minutes of 2018 (Anamika) 4. Sub-project Leads
9:00 AM	Funding Opportunities from NIFA, Robert Nowierski
10:00 AM	Break
10:30 AM	NEW PROJECT REVIEW AND PLANNING-Large acreage crops Annual Crops [Gadi V.P. Reddy and Anamika Sharma]
11:30 AM	NEW PROJECT REVIEW AND PLANNING-Orchard Systems [Ed Lewis]
12:30 PM	LUNCH (on your own)
2:00 PM	NEW PROJECT REVIEW AND PLANNING-Small Fruits and Vegetables [Surendra Dara]
3:00 PM	NEW PROJECT REVIEW AND PLANNING-Urban and Natural Landscapes, Rangelands, and Nurseries [David Oi]
4:00 PM	BREAK
4:15 PM	DISCUSSIONS 1. Theme for 2020 (ESA 15-18 November 2020, Orlando, FL) 2. Discussion of collaborative projects

a. Publication projects (Dara)

3. New business, Elections, Officers

5:30 PM ADJOURN

Participants 2019

Name	Affiliation	Email
1. Robert Behle	USDA-ARS, Peoria	robert.behle@ars.usda.gov
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15. Shaohui Wu	University of Georgia	shaohui.wu@uga.edu
16. Juan Luis Jurat-Fuentes	University of Tennessee	jurat@utk.edu
17. José Carlos Verle Rodrigues	University of Puerto Rico	jose_carlos@mac.com

BUSINESS MEETING

1. *Local arrangements report:* (Robert Behle)

2. *Introductions:* Robert Behle (2019 chair): Welcomed all and began with introductions (17 participants). Attendees introduced themselves including a short introduction about their affiliation and work.

4. *Minutes of 2018* (prepared by Anamika Sharma): A copy of the 2018 minutes was circulated electronically prior to the meeting and a hardcopy was available at the meeting. A motion to approve the 2018 minutes was made by Stefan and was seconded by Pasco and passed unanimously. Minutes of the 2019 meeting are required to be posted within 60 days.

6. *NIFA administrators report* (Rogers Leonard):

The participation in this group changed over time and both industry and public partnership is important for this group. USDA-NIFA move from Washington changes several things in terms of timeline and responses. Due to the change, several members especially research leaders have moved to Kansas and are still moving. New positions will be opening and filling up with USDA in the near future. A tremendous amount of opportunities are available with USDA now. However, due to the change and movement, more time will be taken in decision making and decisions will be slower. The survey of stakeholders regarding projects is also on going. Response to the grants will be delayed significantly, not sure how much time it will take. Not everyone is moving to Kansas but several of them are.
On the personal front, I have been serving this group since 2012 and will be moving in 2020 from LSU (after 41 years). I will be starting private consulting and a new email will be available soon. I will be happy to post the minutes of this 2019 meeting in the next 60 days.

Robert Behle presented details about Funding Opportunities in Plant Protection from NIFA as supplied by Robert M. Nowierski, (National Program Leader, Bio-Based Pest Management, USDA-NIFA, Washington, DC). Details are specified below:

- 2009 - NRI and IFAFS (Initiative for Future Agriculture and Food Systems) combined into a "premier" program called the Agriculture and Food Research Initiative (AFRI). 60% fundamental, 40% applied research (up to 30% can be integrated [res., ed., and ext.]). Indirect Cost cap is currently up to 30%.
- Education and Workforce Development - $24 million.
- Foundational and Applied Science Programs (basic research) - $193 million.
    - Coord. Ag. Projects (CAP) and Standard Grants
    - Critical Ag. Research and Extension
      This is a great source of funding specially for combination of research and extension work
- Sustainable Agricultural Systems (more applied research and often integrated – Research, Education, Extension) - $90 million.
- Foundational Program - Education and Workforce Development Program
    - Pre- and Post-Docs
    - Secondary School teachers

- Research/Extension Experiential Learning

- Foundational Program – Critical Agricultural Research and Extension Program- - $300,000
- AFRI (Foundational and Applied Science Programs: $193 million)
  - Plant Health and Production and Plant Products
    Foundational Knowledge of Ag Production Systems
    Pests and Beneficial Species in Ag Production Systems
    Physiology of Agricultural Plants
    Plant Breeding for Ag Production
    Pollinator Health: Research and Application
  - Animal Health and Production and Animal Products
  - Food Safety, Nutrition and Health
  - Renewable Energy, Nat. Resources, and the Environment
  - Ag. Systems and Technology
  - Ag. Economics and Rural Communities
- AFRI (Sustainable Agricultural Systems: Program Area Priorities):
  - Increasing profitability in agriculture through reducing input costs, increasing productivity, and reducing losses due to environmental and biological stresses, including pests and diseases;
    - Fostering economic development and prosperity in rural America by catalyzing production of high-value bio-based chemicals and other products using agricultural feedstocks; and/or — incredible source of money and will run for couple of years.
- Enhancing rural prosperity and health by ensuring access to affordable, safe and nutritious food to sustain healthy lifestyles.
- Pest Management Programs:
  - CPPM - Crop Protection and Pest Management Program
  - ARDP – Applied Research and Development Program (Applied Research, Research-led, Extension-led)- ARDP is best for pest management-provide funding at every stage of project
  - EIP – Extension Implementation Program- (amount: three hundred thousand and agricultural centers needs to be registered).
  - RCP – Regional Coordination Program- good for seed money
  - MBT – Methyl Bromide Transitions Program- working on alternatives for methyl bromide- success 40-50%
  - OTP – Organic Transitions Program
- Other PM Opportunities
  - IR- 4 – Minor Crop Pest Management Program
  - SARE – Sustainable Ag. Res. and Education Program
  - OREI – Organic Ag. Res. and Extension Initiative ($19 mil.)
  - SCRI – Specialty Crop Research Initiative ($50 mil.) + $25 mil citrus res.

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

Dr. Nowierski also answered questions raised by the members and spoke about the present status and success rates of the grants.
For the Sustainable Agriculture Systems grant, multiple laboratory initiatives are also accepted.

Most of the programs have a 9-12% success rate.
Contractors need to speed up because everything is being delayed. Funds are going to be way delayed. There is no budget for the AFRI program at present so need to be patient.
AFRI programs can be slide to another fiscal year, and no-cost extension can be applied.
For NIFA 2020, the funding level could be the same as in previous years.

We completed all efforts on FY2019, crop protection and pest management area
Forty-five continuous words to crop protection and presentation program for NIFA-USDA.
Some of the states did not have a proposal and missed out on the opportunity. Sixteen new programs applied development program area. For most of grants, review panel will be conducted virtually. Most of the programs will be prior to grant responsibility. Different programs are administered by different heads. Twenty-five percent of the staff have already moved to Kansas. We are not sure how quickly we will be able to fill the empty positions but it should take some time. There is an open announcement for program leaders. PI's meeting is also postponed.

7. *New business*: David Shapiro proposed the development of a proposal for AFRI grant. He suggested the development of a collaborative applied program on various aspects of enhancing formulations and incorporating IPM systems.
Juan: There is a great interest in microbial entomopathogens and a program can be developed to support the insect population so that we can create a bigger avenue to attract people from other streams. Such as pollinators, hence the inclusion of microbial on sustainable environment and making microbials as conservation biocontrol agents and incorporating more ecological aspects is a good idea. Measuring beneficial insects can also be included.
Robert: we should be thinking about crops, should be a single crop or multi-crop program in different geographical areas so that various institutes can be involved.
Rogers: target one pest and collect more data on that model insect pest, diversity, and geography, diversity in the program will be good.
David: it is hard to involve non-unified program which can put off funding agency; can develop something on the fruit fly. Stefan also suggested fruit fly.
Jimmy: chili thrips could also be a possible insect pest.
Stefan: hemp is a good crop, has a lot of insect pests. Pasco and Rogers agreed.
Anamika: sap-sucking hemipteroids could be possible insect pests from different regions.
Robert: Metarhizium is being used for hemp. Stefan and Julie mentioned the reason being the issue of pesticide residue and EPFs are used to avoid restriction from authorities and get clarification.
David: a list of names who will be interested to join the project can be made.
Surendra: insect decline is a controversial concern so, in this project, pollinator decline might not be a genuine concern, growers do not usually consider the decline in pollinators a real issue. Using these microbials will be beneficial for overall ecology.
Juan: we need to make beneficial insects specific.
Jimmy showed interest if fruit fly and chilli thrips is included.
Juan mentioned if molecular aspect is needed he can be involved.
Julie mentioned that she can provide products.
Stefan is happy to participate as a consultant. Robert and Pasco also expressed their interest.
David will send an email to the entire group and maybe a rough outline of the proposal.

Large acreage crops

Anamika Sharma:

Alfalfa: On Alfalfa weevil, in 2017 Bioinsecticide-BeetleGone® (*Bacillus thuringiensis galleriae strain SDS-502*) provided 50-60% control of alfalfa weevil (*Hyperapostica*). It had no negative impact on parasitoid populations (*Bathyplectes curculionis* and *Oomyzus incertus*). In 2019, two formulations of BeetleGone were tested at two sites.

In 2019, two formulations of BeetleGone were tested. The product was provided by PhyllomBio Products Corporation, Oakland, California, USA. The product was applied at two rates 4 and 8 oz per gallon. Following conventional practice, the product was applied two times, first time in June and second time in July (after 1st harvesting) with five replications with each plot of 5x5meter. New formulation left less residue on leaves while applying and at a higher rate, it reduced the larval population of alfalfa weevil. The parasitoid population was found to be improved at the site with a greater population of alfalfa. At the site with less alfalfa weevil population also the second formulation performed well; however, improved population of parasitoids was associated with a low rate of the product.

Canola: For canola pests, in 2016 at two locations biopesticides were tested for flea beetle (*Phyllotretacruciferae*) and cabbage seedpod weevil (*Ceutorhynchusobstrictus*). The biopesticides Entrust, Steinernema-System (Steinernemafeltiae) + Barricade polymer gel 1%, Aza-Direct (azadirachtin), Pyganic1.4 EC (pyrethrins extracted from chrysanthemum), Grandevo SC (*Chromobacterium subtsugae*), and VenerateXC (Heat killed *Burkholderia* sp. strain A396) were tested as seed treatments and foliar sprays. Control (water) and Gaucho were tested for comparison. Entrust and *Steinernema*-System generated significantly positive results (significant lower feeding injury) compared to the control and was equally efficient as Gaucho treatment. In 2018, biopesticides were tested at two locations against the flea beetles. The selected biopesticides were Entrust (spinosad), Aza-Direct, and Mycotrol (*Beauveria bassiana*). Conventional pesticides, Gaucho and Zeta-cypermethrin (Mustang Maxx) were tested as comparison standards. At the high flea beetle population site (Conrad), Entrust provided maximum yield followed by Gaucho and Mycotrol. At the Cut Bank site with low flea beetle population but more thrips population Entrust provided maximum control and yield followed by Mustang and Mycotrol. In 2019, following biopesticides were compared with conventional pesticides, by direct and indirect interaction: Entrust, BoteGHA (*Beauveria bassiana@11.3%)*, Xpectro (*B.bassiana* +pyrethrum), BeetleGone (*B. thuringiensis*), Aza-Direct, Mustang maxx. All the products were tested at two rates (low and high as per label). The sets of experiments were established where products were sprayed on the canola leaves and then flea beetles were released. In another set of experiments, a direct spray of the products was done. In indirect application, in five days Entrust high, Bote GHA high, and xpectro low and high showed the maximum mortality and on 8 days the maximum mortality was shown by BoteGHA low and high> Entrust low>BoteGHA high>Aza high>Entrust high. In direct application, the results were similar to indirect application, expect BeetleGone @ high caused maximum mortality and Aza @ low rate caused minimum mortality.

Wheat

Wheat stem sawfly (On behalf of **Dr. GVP Reddy**): For the wheat stem sawfly (WSS) study in 2017, study of adult settling preference behavior on wheat plants with both synthetic plant defense elicitors [Actigard (Acibenzolar-S-meth) and cis-jasmone] and a botanical insecticide (Azadirachtin) showed that two times applications of Actigard had significantly lowered WSS

infested stem damage, significantly increased diapausing larval mortality percentages and lowered stem lodging. Based on this result, in 2018 bioinsecticides were tested at high, and low doses: Actigard (1.50 g/L and 0.75 g/L), neem (5.76 ml/L and 2.88 ml/L) and Xpectro (5.0 ml/L and 2.5 ml/L). Results showed that, In general, WSS adult populations were found higher at the Knees location followed by the Choteau, Conrad, and Devon locations. Regardless of location, treatments did not have a significant impact on WSS adult population, at any sampling time. Except, at the Knees location, the wheat plots treated with a lower dose of Xpectro had significantly lower WSS adult population compared with the untreated control plots at 10 days after treatment application. In Knees and Conrad locations, wheat plots treated with Actigard lower dose inflicted noticeably higher percentage of mortality compared to plots treated with Xpectro, Neem, and control, while with higher Actigard dose application at the Devon location. However, no significant differences were found between treatments either of these locations. At Conrad location, a significantly lower mean stem lodging (± SE) occurred when wheat plots were treated with Actigard lower dose (2.78 ± 0.79), and Neem low (2.89 ± 0.20) and high (2.82 ± 0.36) doses compared with untreated control plots (4.33 ± 0.33). At both Choteau and Conrad locations, wheat plots treated with higher dose of Actigard had significantly or numerically lower grain yield compared with other treatments including water. Similar patterns were also observed at the Knees and Devon locations. The same experiment is established in 2019, results are being analyzed.

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

Ramandeep Kaur Sandhi: PhD student using entomopathogenic nematodes (EPNs) for wireworm management in wheat.
Non-native commercially available EPNs: Ten EPN strains; Steinernema carpocapsae (Sc) (all strains and Cxrd strain), Steinernema feltiae (Sf) (SN strain), Heterorhabditis bacteriophora (Hb) (HP88 strain, VS strain), Steinernema riobrave (Sr) (355 strain, 7-12 strain), Heterorhabditis floridensis (Hf) (K22 strain), Heterorhabditis georgiana (Hg) (Kesha strain), and Steinernema rarum (Sr) (17 c + e strain) were received from Dr. David Shapiro-Ilan. In laboratory bioassays, these strains were tested against wireworms *Limonius californicus* at four doses (700, 1400, 2800, 5600 IJs/larva) and mortality was observed weekly. Strains ScAll, ScCxrd, Sr 7-12, Sr 355, HbVS, and Sr 17c+e were found to be more effective than the others. After 2 weeks, mortality remained at 30% in almost all the strains except Sr 355 and Sr 7-12 which was 40-60%. After 2 weeks, it

increased and reached 50-70% in the promising strains. In addition, shade house experiments were conducted using 2 doses, 80000 IJs (8000 IJs/larva) and 10000 IJs (100 IJs/larva). Almost the same mortality was observed at both doses; no significant differences were found. EPN strains (ScAll, ScCxrd, Sr 355, and Sr 7-12) caused almost 30-50% mortality after 4 weeks. Only 10% mortality was observed in the control. There was no significant difference in plant damage caused by L. californicus when exposed to the different treatments. In 2019, field trials were conducted at two locations using insect cadavers as treatments with Sc All, Sc Cxrd, Sr 355, and Sr 7-12 strains. No significant differences were observed in respect to number of wireworms, plant damage, and post-harvest parameters (yield, test weight, protein, and moisture).

Montana native EPNs present in wireworms: 30 fields were surveyed in 2018 and found two isolates of S. feltiae and one isolate of H. bacteriophora were discovered. In the laboratory, 50% L. californicus mortality was caused by S. feltiae after 4 weeks as compared to only 20-25% mortality by H. bacteriophora. In shade house experiments, two isolates of S. feltiae were tested against *L. californicus*; however, mortality did not increase by 25%. No significant differences were observed between plant damage caused by *L. californicus* in the presence of EPN species.

Stefan Jaronski:
Wheat stem sawfly: Endophytic *Beauveria bassiana* demonstrated infection in the larvae. To work with diapausing larvae, pupation and entire life cycle and stem elongation is a cumbersome experiment due to the scheduling. A method of scraping the plants and fungus infestation after? 3 weeks was employed. In the Republic of Georgia Beauveria bassiana reduced fusarium head blight. An enzyme assay to induce systemic resistance, and exposure of a certain variety of wheat to *Beauveria bassiana* increases the resistance. Georgian scientists also looked at the fumigant effects of *Beauveria bassiana* and *Metarhizium pemphigi*, and *Beauveria* was found to be more effective. There is a volatile effect that inhibits the growth of *Fusarium* (we understand this happens at least in-vitro). ARS has filed a patent registration.

Stefan mentioned the work done by Dr. Ann Hajek and her team members. Her team is looking at BoteGHA (Certis) for the management of lanternflies. 50% reduction is reported in larvae by the spray of Beauveria. Ann and her postdoc are bio assaying impact of fungi on all life stages. With lanternfly, natural epizootic was recorded and there could be a diverse population.

At Virginia Tech, work on Hemp is going on and testing out the biopesticides, BT and BoteGHA against European corn borer, stink bugs, and thrips.
We are also testing native baculovirus from Australia, granular fungus on wireworms (*Limonius* sp.) on the potato crop. Also working with AgBio with Gates foundation in Africa on sweet potato against sweet potato weevil adults.

Orchard System

José Carlos Verle Rodrigues (Puerto Rico): Exploring and isolating, EPNs in different classes and types of soil for managing coffee borer. New species of Oscheius was found in soil. Further laboratory evaluation is being conducted to establish the pathogenicity of the species. A large dataset was built on the population of Oscheius in soils. We are also checking Metarhizium in soil with coffee plants to manage coffee borer. Isolating thousands of strains of this fungus and

establishing the experiment in the field. We are looking for symbionts that can have a role in the Oscheius establishment and pathogenicity.

Stefan Jaronski: From the past two years working with APHIS and screening commercial fungi for managing Asian citrus psyllid. They have 6 Potter towers to do several bioassays. We have a large Asian citrus psyllid (ACP) and *Tamarixia radiata* colony. Good replications of all the isolate are established. *Isaria* (NoFly) is marketed by two companies in the USA. Both blastospores and conidia are produced. Brazil has commercialized *Isaria* for Asian citrus psyllid, but is not available in the US. *Isaria* PFR 97 is reported to be best in the US. Conidia are better than blastospores (1:1 ratio are better). Auto dissemination can be also used for managing psyllids. Pasco mentioned that nymphs will be more susceptible due to less mobility.

Pasco Avery: For managing Asian citrus psyllid, we have some tolerant varieties, otherwise the citrus industry is declining in Florida. We are testing ultra-low volume versus air blast spraying techniques to manage psyllid with *Isaria fumosorosea* (Ifr). Adults may become repelled from *Isaria* (due to volatiles) from lying on the plant surface and hence they do not settle on the leaf surfaces; however, this hypothesis is being tested under laboratory and greenhouse conditions. Therefore, the experiment is ambiguous due to the lack of contact between insect and residue. In field, we are not sure if and how the psyllids are coming in contact with the fungus. We are trying a new surfactant, Ampersand® which is also rainproof. This product may keep the spores on the surface of the leaf, and possibly improve the overall efficacy by increasing the chances of contact by the psyllid. Auto dissemination can also work with color and phago-stimulant attractant.

Also working with lebbeck mealybug, which is a citrus insect pest. We are exploring *Beauveria* and *Isaria*. We cover the plant with a netted bag that should create a microclimate and enable fungal sporulation. However because the nymphal stages keep moulting and keep shedding the fungus deposited on the exuviae, only the adult stage should die after the moulting process stops.

About citrus psyllid, Stefan said that we should get out of the psychology of control, rather we should concentrate on the interference of pathogen transmission. Orange jasmine tree is a big reservoir for citrus psyllid, which makes the management tough. Also for the successful establishment of EPF, higher humidity is required under field conditions.

Camila Hofman: Working with Peach tree borer. We are applying *Steinernema carpocapsae* on the base of the tree and this method is working very well. We are applying Barricade polymer gel (2%) immediately after applying *S. carpocapsae*. Also checking weevil population and plant-parasitic nematodes, in lab and green house experiments. The first application at the base of the tree is in water and then the full percentage of Barricade gel can be applied. 2% gel can be applied along with EPNs. Both curative and preventative reasons are there.
In another project, we are exploring the impact of pheromones on the movement of *S. carpocapsae* and *S. feltiae*. Pheromones can cause greater mobility; this work is getting ready to publish. For citrus root weevil, *Steinernema riobrave* and *S. carpocapsae* are being tested against this.
David mentioned that pheromones are the boosters and stimulants to excite the nematodes. The company is focusing on producing pheromones.

Robert Behle: Walnut borer is an annual pest and they feed on the nuts and overwinter in the soil. During the overwintering stage, they can be treated with EPF. We are trying *Isaria* and *Metarhizium*, in the soil and still do not have any significant results.

David Shapiro-ilan: We are focusing on walnut borer pupae. In pecan, for pecan weevil, also we are testing *Beauveria*. We are focusing on the endophytic fungus. Pecan can be hedged and this can reduce insect infestation. The impact of hedging on the efficacy of EPF is being studied. We are also trying to invest in the production of EPNs to make it a self-sufficient process for growers. Also working on fungus formulations, establishing the fungus by nano-solution. We are also considering adding fungus to GF Protein.
International Space Station (ISS) National Lab is planning to incorporate microbials in their program. ISS is sending EPNs to the space station to investigate if they can move and infect the insect in microgravity. I am involved as a co-project director and will be exploring pheromone production and infectivity.

Rogelio Trabanino: Working with the fungus inoculant to manage coffee borer in Honduras. We are also encountering and worried about the problem of *Fusarium* on the banana crop. We are trying to improve soil health to manage *Fusarium* in the banana crop.

Surendra: Trying to work with leaf-footed bugs. This pest is the problem in pomegranate and future problem for almonds. I was thinking of *Isaria* but due to the disappearance of pest, no work could have been conducted at present.

Juan Luis Jurat-Fuentes: In Sri Lanka, we have isolated XenTari (BT) like isolate against armyworm. Toxins are different from XenTari. Might work against other lepidopteran pests. We are testing this isolate against early instars of armyworms.

<u>Small fruits and vegetables</u>

Jimmy Klick: The focus of our work is on blueberries and strawberries. During a recent visit to China, we explored *Metarhizium* and *Beauveria* for blueberry and strawberry insect pests. Collaborating with Nemat Keyhani. He has worked in China, where growers are regularly using *Metarhizium* strains. Growers used this product in pots. Chili thrips in China is a huge issue. We tried the drench method and compared the results with control. The combination of *Metarhizium* drench and predatory mites worked well. Looking forward to work with EPNs against white grubs.

Also working with *Lygus* sp. problem in strawberries, we did not find any EPNs in strawberry soil but found *S. feltiae* in soil with the alfalfa insectary. For blueberries, Mycotrol and AzaDirect worked better for whiteflies and aphids. A combination of both products also performed well.
David, Robert, and Surendra mentioned that there could be additive or synergistic relation could be there but hard to prove and depends on the amount of both the products.
Stefan mentioned that sometime fecundity can be reduced by combing products such as neem and fungus for cotton aphids on cotton crop.
Julie mentioned that we recommend to the growers for managing aphids to use half-rate of Aza and half rate of Mycotrol or rotation of full rate of Aza and *Beauveria bassiana*.

Shaohui Wu: We found new strain for *Isaria* against whitefly. This is even better than *Beauveria bassiana* GHA. The temperature has a greater impact on fungus growth. At moderate temperature (10-35º C) and low temperature, no fungus growth was observed on *Galleria*.

David Shapiro: Screening EPNs and EPFs against thrips on vegetable crops. Working on a new project on sweet potato weevil in South Africa.

Surendra: In a 2019 strawberry field study, unformulated California isolates of *Beauveria bassiana* and *Metarhizium anisopliae* s.l. were used in a rotation program to control gray mold (*Botrytis cinereal*). Rotating entomopathogenic fungi with fungicides Merivon and Pristine resulted in a significant reduction in disease severity. Efficacy was comparable to some of the chemical or non-chemical treatments evaluated in the study. https://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=30729

Urban and natural landscapes, rangelands, and nurseries

David Shapiro: Working on the control of ticks by using nematodes. Could be potentially sprayed from the chute. At feeding stations, animals get shot of EPNs (study is published).

Robert Behle: Working on the management of white grub research in the golf course for golf association.

Shaohui Wu: Imidacloprid and EPNs have an additive affect. Microsclerotia are more tolerant than conidia.

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

David Oi (ARS-Gainesville, FL): Nine new viruses were discovered in fire ants from South America. Two of the viruses exhibit unique genome structures which suggest that they may be a new category of viruses. The nine viruses have not been detected in the U.S. and potentially could be released into the U.S. fire ant population as biological control agents. A project to examine the stinging, invasive ant, *Wasmannia auropunctata* or little fire ant, for pathogens to be used as biocontrol agents has been initiated. Initial samples will be ants be from Florida, Hawaii, Argentina, and Australia. Following methods developed for imported fire ants, metatranscriptomics and next generation sequencing will be used to accelerate prospecting for viral pathogens.

Chromobacterium Csp_P extract suspended in the sucrose solution was provided to red imported fire ant workers to determine potential utility as an ant bait toxicant. Preliminary results have been inconsistent. Further testing is in progress.

Stefan: Company is producing *Beauveria bassiana* GHA for bed bug control. The product is adopted by the pest control industry. It is a barrier spray. Special oil formation and bed bugs pick it up on their field. The product needs to be sprayed around the mattress at the base of the wall.

A.M. **Koppenhofer** (Rutgers University):
Project 1: A field experiment targeting the externally feeding mid-size larvae of the annual bluegrass weevil (ABW), Listronotus maculicollis, were conducted in spring of 2019 at four golf courses. Treatment timing was centered around the presumed optimal timing for M. brunneum F52 conidia to infect ABW larvae, when about 50% of the larval population had reached the fourth to fifth instar. At this time, treatments were applied that were able to immediately affect the ABW larvae (i.e., conidial formulation and imidacloprid). A microsclerotial formulation of F52 was applied 3 weeks earlier to give the microsclerotia time to produce conidia.
Treatments were the microsclerotial granular formulation of F52 (50 kg ha-1), two rates of the conidia-based liquid formulation of F52 (9.55 kg ha-1 and 19.1 kg ha-1 equivalent to 5 and 10 × 1013 CFU ha-1), the neonicotinoid imidacloprid (336 g ai ha-1), and the combination of each F52 treatment with imidacloprid. Treatments were watered in with 5 mm overhead irrigation. Treatments were evaluated 12 to 16 days after the last application by taking eight cores per plot and determining the number of live ABW individuals in them.
For all sites combined, the density of ABW developmental stages was significantly affected by treatment and site; treatment and site did not interact significantly. All treatments except for the microsclerotia (18%) significantly reduced ABW densities with 29% and 51% for the low and high rate, respectively, of the conidial formulation, 40% for imidacloprid, 51% for the microsclerotia-imidacloprid combination, and 55% and 70% for the combination of low and high rate, respectively, of the conidial formulation. In all combination treatments, fungus and imidacloprid did not interact resulting in additive mortality.
The efficacy of the microsclerotial and the conidial formulations was likely somewhat limited by relatively low temperatures. However, applications against the larvae in summer with more conducive temperature would be constrained by the regular fungicide use on golf courses. The M. brunneum-imidacloprid combinations all provided consistent significant control across all four experimental sites, but only the combination with the high conidia rate provided control high enough to be considered satisfactory golf course managers.

<u>Discussions and Outcomes</u>

1. The theme for symposium at ESA 2020.
   Team members discussed the status of microbials as natural enemies and their contribution to eco-systems services. We can attract the audience by including bio-control people. David, Stefan, Pasco, Robert suggested the possible names for next year's symposium.
   Title: Stefan: importance of entomopathogens as natural enemies
   BOB: entomopathogens-the important natural enemies
   David: hidden heroes: entompathogens as natural enemies
   <u>All agreed- Hidden Heroes: Entomopathogens as Natural Enemies</u>

   Suggested tentative names are: Ann Hajek (Cornell), Diane Carter (Florida), Bruce Webb (Kentucky), Jennifer Cory (Canada), Dr. Larry Duncan (Florida).
   Stefan: Speakers on nematodes, fungus, virus, bacteria as natural enemies can be involved.

Surendra: combine entomo- vectoring as well.
Tentative speakers on various natural enemies:
Viruses- Jennifer Cory, Wayne Hunter, Kelli Hoover, Trevor Williams,
Nematodes- Ivan Hiltpold, Mary Barbercheck
Fungus- Ann Hajek
Bacteria: Trevor Jackson, Colin Berry
Ecological modelling: Bret Elderd
Motion moved by Pasco, seconded by Stefan and approved unanimously.

2. Robert Behle: We should target the AFRI large grant as multi-institutional. David will lead the proposal and Co-PIs can be found as we progress.
3. Surendra: Frontiers (special issue) will be coming out on 'Entomopathogens for sustainable food production (Frontiers in sustainable food systems). Research and Review articles are invited (tentative deadline April 2020; research or review article are accepted; charges $700-900; impact factor: 2.8).
4. New business: Roger will resign and we need to find a replacement. Robert mentioned about increasing the membership and present members should spread the word. University people have to sign in and application will go in, there is a link so please all go through and sign in.
5. Need to conduct the election to identify member-at-large.
   Jimmy will be chair and Stefan will be vice-chair, Julie Graesch will be Member-at-large.
   Motion passed by Robert, seconded by José Carlos, motion unanimously passed.
6. José mentioned that the Southeastern branch meeting in 2021 will happen in Puerto Rico and this group can present there.

4:40 PM meeting adjourned.

Microbial related publication from group members (2018-2019):

Arthurs, S. and S. K. Dara. 2018. Microbial biopesticides for invertebrate pests and their markets in the United States. J. Ivertebr. Pathol. https://doi.org/10.1016/j.jip.2018.01.008

Aristizábal, L. F., Avery, P. B., Caldwell, J., McKenzie, C. L., and L. S. Osborne. 2018. Mitigating trans-boundary movement of *Bemisia tabaci* (Hemiptera: Aleyrodidae) on Mentha sp. by pre-shipping treatments of biopesticides. Crop Protection 107: 71-78.

Avery, P. B., Bojorque, V., Gámez, C., Duncan, R. E, Carrillo, D., and R. D. Cave. 2018. Spore acquisition and survival of ambrosia beetles associated with the laurel wilt pathogen in avocados after exposure to entomopathogenic fungi. Insects. 9 (2), 49; doi:10.3390/insects9020049

Avery, P. B., Kumar, V., Skvarch, E. A., Mannion, C. M., Powell, C. A., McKenzie, C. L. and L. S. Osborne. 2019. An ecological assessment of *Isaria fumosorosea* applications

compared to a neonicotinoid treatment for regulating invasive ficus whitefly. Journal of Fungi 5, 36. doi:10.3390/jof5020036

Brown, K., Olendraite, I., Valles, S.M., Firth, A., Chen, Y., Guerin, D., Hashimoto, Y., Herrero, S., De Miranda, J., Ryabov, E. 2019. ICTV virus taxonomy profile: Polycipiviridae. Journal of General Virology. 100:554-555.

Brown, K., Olendraite, I., Valles, S.M., Firth, A., Chen, Y., Guerin, D., Hashimoto, Y., Herrero, S., De Miranda, J., Ryabov, E. 2019. ICTV Virus Taxonomy Profile: Solinviviridae. Journal of General Virology. 100:736-737.

Chow, A., Dunlap, C. A., Jackson, M. A., Avery, P. B., Patt, J. M., and M. Sétamou. 2018. Field efficacy of autodissemination and foliar sprays of an entomopathogenic fungus, *Isaria fumosorosea* (Hypocreales: Cordycipitaceae), for control of Asian citrus psyllid, *Diaphorina citri* (Hemiptera: Liviidae), on residential citrus. Journal of Economic Entomology (submitted Apr 2018; accepted 2 July 2018). doi: 10.1093/jee/toy216

Dara, S.K. Non-Entomopathogenic Roles of Entomopathogenic Fungi in Promoting Plant Health and Growth. Insects 2019, 10, 277.

Dara, S.K.; Montalva, C.; Barta, M. Microbial Control of Invasive Forest Pests with Entomopathogenic Fungi: A Review of the Current Situation. Insects 2019, 10, 341.

Dara, S. K. and R. A. Humber. Entomophthoroid fungi. *In* Beneficial microbes in agro-ecology: volume 2: fungi. Eds. N. Amaresan, K. M. Senthil, K. Annapurna, K. Kumar, and A. Sankaranarayanan. Elsevier. Submitted. (Book chapter)

Dara, S. K. Entomopathogens and their interactions with other pest management options. *In* Microbes and metabolites for sustainable insect pest management. Eds. M. A. Khan and W. Ahmad, Springer, pp. 299-316. (Book chapter)

Dara, S. K. Implementation of integrated pest and disease management in greenhouses: strawberries and other berries. *In* Pest and disease management in greenhouse crops. Eds. Gullino, M. L., A. Albajes, P. Nicot, and J. C. van Lenteren. Springer. In Press (Book chapter)

Dara, S. S., S.S.R. Dara, S. K. Dara, and S. T. Jaronski. 2019. Entomopathogenic fungi antagonizing *Macrophomina phaseolina* in strawberry. Progressive Crop Consultant 4(6): 20-24.

Dara, S. K., S. S. Dara, and S. Jaronski. 2019. Controlling the western grapeleaf skeletonizer with biorational products and California isolates of entomopathogenic fungi. CAPCA Adviser, 22(2): 46-48.

Dara, S. K. 2018. Entomopathogenic fungi as key players in crop protection and production. Progressive Crop Consultant 3(5): 4-7.

Dara, S. K., D. Peck, and D. Murray. 2018. Chemical and non-chemical solutions for managing two spotted spider mite, western tarnished plant bug, and other arthropod pests in strawberries. Insects 9: 156. https://doi.org/10.3390/insects9040156

Eivazian Kary N., Sanatipour Z., Mohammadi D., Koppenhofer A.M. 2018. Developmental stage affects the interaction of *Steinernema carpocapsae* and Abamectin for the control of *Phthorimaea operculella* (Lepidoptera, Gelechidae). Biol. Control. 122, 18-23.

Kamali S., Karimi J., Koppenhofer A.M., Anaraki F.T. 2018. New insight into the management of the tomato leaf miner, *Tuta absoluta* (Lepidoptera: Gelechiidae) with entomopathogenic nematodes under greenhouse condition. J. Econ. Entomol. 111, 112-119.

Karimi, J., S. K. Dara, and S. Arthurs. 2018. Microbial insecticides in Iran: history, current status, challenges and future prospects. J. Ivertebr. Pathol. https://doi.org/10.1016/j.jip.2018.02.016

Kumar, V., Francis, A., Avery, P. B., McKenzie, C. L., and L. S. Osborne. 2018. Assessing compatibility of *Isaria fumosorosea* and buprofezin for mitigation of *Aleurodicus rugioperculatus* (Hemiptera: Aleyrodidae): an invasive pest in the Florida landscape. Economic Entomology 111: 1069-1079. doi: 10.1093/jee/toy056

Kumar, K. K., J. Sridhar, R. K. Murali-Baskaran, S. Senthil-Nathan, P. Kaushal, S. K. Dara, and S. Arthurs. 2018. Microbial biopesticides for insect pest management in India: current status and future prospects. J. Invertebr. Pathol. https://doi.org/10.1016/j.jip.2018.10.008

Pick, D. A., Avery, P. B., Quershi, J. A., Arthurs, S. P. and C. A. Powell. Field persistence and pathogenicity of *Isaria fumosorosea* for management of *Diaphorina citri*. Biocontrol Science and Technology (submitted 14 Nov 2019, being revised)

Rhodes, E. M., Avery, P. B., and O. E. Liburd. 2018. Efficacy of entomopathogenic fungal products for biocontrol of spotted wing drosophila assessed under laboratory conditions. Florida Entomologist 101: 526-528.

Sánchez Barahona, C.F., Threlkeld, B. S., Avery, P. B., Francis, A. W. and R. D. Cave. 2018. Compatibility and efficacy of the ladybird beetle *Thalassa montezumae* and the entomopathogenic fungus *Isaria fumosorosea* for biological control of the green croton scale: laboratory and greenhouse investigations. Arthropod-Plant Interactions 12: 715-723. doi: 10.1007/s11829-018-9618-9

Sharma A, Jaronski S, Reddy GVP. 2019. Impact of the granular carriers to improve the efficacy of entomopathogenic fungus against wireworms in spring wheat. Journal of Pest Science. DOI: 10.1007/s10340-019-01161-1.

Valles, S.M., Rivers, A.R. 2019. Nine new RNA viruses associated with the fire ant *Solenopsis invicta* from its native range. Virus Genes. https://doi.org/10.1007/s11262-019-01652-4.

Valles, S.M., Porter, S.D. 2019. Influence of temperature on the pathogenicity of *Solenopsis invicta* virus 3. Journal of Invertebrate Pathology. https://doi.org/10.1016/j.jip.2019.107217.

Zhou Y., Avery, P. B, Carrillo, D., Duncan, R. H., Lukowsky, A., Cave, R. D. and N. O. Keyhani. 2018. Identification of the Achilles heels of the laurel wilt pathogen and its beetle vector. Applied Microbiology and Biotechnology 102: 5673-5684. doi:org/10.1007/s00253-018-9037-y.

Outreach Articles:

Multiple extension presentations emphasizing the importance of biologicals including entomopathogens (Surendra Dara).

Organized the 3rd Ag Innovations Conference: Biologicals in March, 2019 in Santa Maria and some of the topics included microbial control.

Spotted lanternfly presentation and video with information about microbial control. https://www.youtube.com/watch?v=45103-PFI4M (Surendra Dara).

Sharma A, Jaronski S, Reddy GVP. 2019. Efficacy of entomopathogenic fungus for managing wireworms on spring wheat in Golden Triangle region of Montana. Traders Dispatch, May 2019, Conrad, Montana.

Sandhi RK, Sharma A, and Reddy GVP. 2019. A potential tool to manage wireworms in wheat and barley. Traders Dispatch, August 2019, Conrad, Montana.

Activities 2018-2019

In 2019, at the annual meeting of the Entomological Society of America (ESA) (Entomology 2019: Advocate Entomology) a member symposium was organized on November 19, 2019 (09:00 AM - 11:15 AM).
"Member Symposium: Advocating Entomopathogens for Sustainable Agriculture". Five presentations were included.
Organizers: Robert W. Behle (USDA – ARS); Moderators: Jimmy Klick (Driscoll's) and Anamika Sharma (Montana State University)

Frontiers (special issue) will be coming out on 'Entomopathogens for sustainable food production (Frontiers in Sustainable Food Systems). Research and review articles are invited (tentative deadline April 2020). More information can be found here: https://www.frontiersin.org/research-topics/11865

Microbials related publications generated by members of S1070 in 2018-2019 are cited at the end of the report.