Soybean entomology in the North Central region: Management and outreach for new and existing pests

Final Report (October 2015 through December 2018)

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Project Objectives

I. Extension and Outreach

II. Insect Monitoring and Management
1. Stink bug monitoring and management
2. Pollinator diversity and soybean yield
3. Soybean aphid insecticide resistance
4. Monitoring for aphids, thrips, and soybean vein necrosis
5. Technology development

III. Resistant Varieties and Biotypes
1. Breeding for resistant varieties
2. Aphid virulence genotyping and mapping
3. Aphid virulence management for resistant varieties
4. Economic returns on resistant varieties

IV. Biological Control

Summary

This report covers a 3-year project on management and outreach of soybean insects in the North Central region, involving 21 researchers in 10 states. The report contains four sections (1) a non-technical summary; (2) a detailed technical summary; (3) project deliverables; (4) performance metrics as of the third/final year of the project. During the 3-year reporting period we published 55 scientific journal papers, gave 105 presentations at scientific meetings, and organized 6 scientific symposia on soybean pest management. We gave 191 extension presentations containing NCSRP results to farmers and other crop professionals. We wrote 82 extension articles and published 73 extension publications and other outreach products utlizing NCSRP results. We trained 32 students or postdocs on this project, who are the researchers of the future.

During the reporting period we earned $5.27 million in additional leveraged funding related to our NCSRP-generated research (over a 350% return on NCSRP's investment), showing the power of NCSRP funding to leverage additional resources for soybean research. Finally, members of our group received 13 awards for NCSRP-related work during the reporting period. In two noteworthy honors, we received the International IPM Award of Excellence for an IPM team and the ESA Plant-Insect Ecosystems IPM Team Award to members of the group led by Bob Koch. Two members of our team (Kelley Tilmon and Erin Hodgson) have receive the Entomological Society of American NCB Distinguished Achievement Award in Extension.

Some highlights of our results include the following:

- We performed the first comprehensive survey of the stink bug species of the North Central Region.
- We determined a new sampling plan for stink bug sampling in soybean that's specific to the North Central Region.
- We documented an amazing diversity of pollinator species found in flowering soybeans, with 108 species of bees and 11 species of pollinating syrphid flies. This is a landmark study on pollinator diversity in the region.
- We developed three new tools to monitor for soybean aphid resistance to the insecticide thiamethoxam.
- We established a baseline susceptibility to thiamethoxam which can be used in future insecticide resistance studies, and documented the first reduced susceptibility to this insecticide.
- We have made the 13 year regional sampling data from the aphid suction trap network publicly available online through the Center for Invasive Species and Ecosystem Health.
- We have documented season trends and species composition of thrips which are the vector for soybean vein necrosis virus.
- We have developed experimental soybean lines containing all possible combinations of five resistance genes (32 combinations) in both a MG I and MG II background for further work on aphid-resistant soybeans.
- Soybean lines with the resistance genes Rag1, Rag2, and a pyramid of both have been released.
- We sequenced the soybean aphid genome.
- We have maintained research colonies of the four known soybean aphid biotypes.
- We have performed evaluations of soybean aphid virulence and screenings for new sources of resistance.
- We have determined that a refuge-in-a-bag approach with a 25% susceptible blend can protect soybean yield while serving as a suitable refuge to delay the development of aphid biotypes.
- We used field studies to ground-truth the economic viability and in many cases superiority of growing aphid-resistant varieties.
- We have documented the spread of the effective aphid biological control agent Aphelinus certus through much of the North Central Region.

Results: Non-Technical Summary

Program Area I. Extension and Outreach

We gave 105 extension presentations to farmers and other crop professionals containing NCSRP research. We wrote 82 extension articles and published 73 extension publications and other outreach products such as fact sheets, videos, website, and webinars. A highlight of these publications is the field guide, *Stink Bugs of the North Central Region*, a farmer-friendly pocket-sized booklet on stink bug identification, biology and management. 9000 free hard copies of this field guide have been distributed through universities and state checkoff organizations, and made available as a free download on SRII and other websites. Another noteworthy extension publication based on past results, *The Effectiveness of Neonicotinoid Seed Treatments in Soybean*, is a joint factsheet publication of North Central Land Grant Universities. This regional factsheet informs farmers about the relative costs and benefits of seed treatments for pest control in soybean, to help them with their input decisions. Another regional publication, distributed to producers through the 12 North Central Land Grant universities and through the SRII website, is *Management of Insecticide-Resistant Soybean Aphids*, the first extension publication to alert producers to the rise of insecticide resistance in soybean aphids in the Dakotas, Minnesota, and Iowa. We have published a new, updated 2nd edition of the popular *Soybean Aphid Field Guide*, a farmer reference for soybean aphid management in the North Central Region. Finally, NCSRP research on pollinators in soybean was used to inform a joint publication of the USDA, USB and the Honey bee Health Coalition on Best Management Practices (BMPs) for conserving pollinators that use soybeans as forage, and members of our team served on the technical committee which drafted this document. Additional extension deliverables are detailed in the Deliverables section below. All of these deliverables help to make the knowledge gained through NCSRP research available to farmers in a form they can use.

Program Area II. Insect Monitoring and Management

Project 1. Stink bug monitoring and management. Participants: Robert Koch* (University of Minnesota)*, Chris DiFonzo (Michigan State University); Thomas Hunt and Robert Wright (University of Nebraska), Andrew Michel (Ohio State University), Christian Krupke (Purdue University), Janet Knodel (North Dakota State University), Deborah Finke (University of Missouri), Adam Varenhorst (South Dakota State University) *Project leader

Stink bug monitoring and management: The goals were to (1) determine the range and abundance of different stink bug species throughout the region to document the extent of the problem, and (2) devise sampling plans for stink bug that are specific to the North Central Region. This work was conducted in a coordinated protocol across 3 years in 9 states, sampling and identifying stink bug species in multiple soybean fields per state. Brown stink bugs (comprised of a few species) were more abundant in the northwestern part of the region, whereas the green stink bug was more abundant in the southeast. The invasive brown marmorated stink bug was most abundant in the eastern part of the region and was detected in soybean in Minnesota for the first time. The second objective developed research-based scouting recommendations (i.e., a sampling plan) for estimating stink bug numbers in soybean, which can then be related to an economic threshold for pest management decision making. We have found that an average of 40 sample units per field are necessary to achieve acceptable precision across the region, though smaller sample sizes (5–10 units) are sufficient for states in the southeastern part of our region where stink bug densities are higher. Our findings are useful for farmers because they provide research-based recommendations on how to effectively sampling these emerging pests of soybean to make management decisions. These results will be shared with scientific and stakeholder audiences through various presentations and publications.

Project 2. Pollinator diversity and soybean yield. Participants: Matt O'Neal* (Iowa State University), Janet Knodel* (North Dakota State University), Kelley Tilmon (Ohio State University), Robert Wright (University of Nebraska), Bruce Potter (University of Minnesota), Christian Krupke (Purdue University), Deborah Finke (University of Missouri), Adam Varenhorst (South Dakota State University); collaborators at Mississippi State *Project leader

Pollinator diversity and soybean yield: The goals of this study were to (1) document the diversity of pollinators present in soybean fields, and (2) assess the time of day when bees are most active in soybean to aid with spray decisions. Pollinators may enhance soybean yield even though soybeans are self-pollinating, and soybean may serve as an important reservoir for pollinator biodiversity. It is relevant for farmers to understand what pollinators occur in their fields. Participants in ND, SD, IA, OH, MN, NE, IN, MO, WI collected pollinators weekly in flowering soybeans during two project-years. We found a surprising abundance and diversity of pollinator species. A total of 10,822 bees have been identified comprising 108 species in 27 genera and 5 families, and 1,190 syrphid flies have been identified comprising 11 species in six genera. The most abundant bee genera collected were Lasioglossum (44 spp.) constituting 66.4% of bee specimens, Agapostemon (3 spp.) 11.4%, Melissodes (11 spp.) 12.8%, and Halictus (4 spp.) 4%. Syrphid flies were dominated by Toxomerus marginatus, which made up 93.8% of all syrphid specimens. Many of the species within this community of pollinators are generalists that visit multiple plants. Pest management practices in soybeans is important for conserving these beneficial species and the services they provide especially pollination and biological pest control.

Based on the insecticide labels, farmers are required to limit their application of insecticide to periods when bees are not on flowering plants. For soybeans, this can be challenging as insect pest outbreaks can occur when soybeans are flowering. This flowering period can last several weeks with the amount of flowers changing over time. We asked if the abundance of bees in soybeans varied during this flowering period. Furthermore, honey bees and other wild bees typically fly only during periods of daylight, which limits application to dusk. Some commercial applicators have questioned whether honey bees are active throughout the day. They have asked if honey bees limit their foraging to optimal periods of activity, when temperatures are not at their highest. Empirical evidence is lacking on the activity on diurnal activity of honey bees in soybean fields. In this study, we collected honey bees and wild bees on a timed basis throughout a day for soybean fields grown in a variety of environments along a nationwide transect, from Mississippi to South Dakota and as far east as Ohio. Data are currently being combined and analyzed. These data will help provide concise information about how bees use soybean fields in the North Central region. This information can be valuable to improve management strategies for the application of insecticides to soybeans while also conserving pollinators within those fields.

Project 3. Soybean aphid insecticide resistance. Participants: Tom Hunt* (University of Nebraska), with cooperation from other entomology team members *Project leader

Soybean aphid insecticide resistance: The goals of this objective are to monitor for soybean aphid resistance to the insecticide thiamethoxam in the North Central Region, and to develop assay protocols to test aphids for resistance to thiamethoxam insecticide. This is important for farmers because when aphids develop insecticide resistance farmers lose management options and must adjust accordingly. Three bioassay techniques were developed/optimized to test soybean aphids for susceptibility to thiamethoxam insecticide. 1. Glass vial – A quick contact bioassay method for monitoring insecticide susceptibility. 2. Detached-leaf – A systemic bioassay method for monitoring insecticide susceptibility and for conducting resistance research. 3. Whole-plant – a systemic bioassay method for in-depth study of insecticide resistance and plant response research. Regional monitoring of soybean aphid populations for thiamethoxam susceptibility indicated a small decrease of susceptibility and the presence of sublethal effects. As a result of this study we now have bioassays for monitoring both bean leaf beetle and soybean aphid susceptibility to thiamethoxam. We have the first indication that soybean aphid susceptibility to thiamethoxam, is decreasing, and a baseline susceptibility data set for monitoring changes in soybean aphid resistance to thiamethoxam in the future.

Project 4. Monitoring for aphids, thrips, and soybean vein necrosis virus. Participants: Punya Nachappa* (Purdue University); Glen Hartman*, Doris Lagos-Kutz* and Nick Seiter (ARS/ University of Illinois), with cooperation from other entomology team members *Project leaders

The Midwestern USA aphid suction trap network (STN) was begun in 2005 as a way to monitor soybean aphid populations and other pests, and has been in continuous seasonal operation since then. It covers a broad geographic area: between 2016 and 2018 the network operated in 9 states with a total of 31 locations with cooperative funding from NCSRP and state, local, and business collaborators. In collaboration with Joseph LaForest (Department of Entomology, Center for Invasive Species and Ecosystem Health, University of Georgia; Southern IPM Center) in kind support, a voluminous collection of records of sample identifications and observations from the STN are now publicly available at https://suctiontrapnetwork.org/ and https://www.eddmaps.org. These data allows for studies on distribution of known species and new or non-identified species captured by the suction traps. The information gleaned from the suction trap network is important for the growers and researchers interested in insect pests and their occurrences and distribution over time and geographic space. The compiled information provides the basis for potential management, long-term dispersion studies, and an early warning for insect pest outbreaks including those caused by exotic introductions. A more complete summary of STN results is available in the full technical report.

Monitoring for aphids, thrips, and soybean vein necrosis: Soybean vein necrosis virus (SVNV) is transmitted by thrips. Our goal was to monitor thrips abundance and activity as an indicator of where SVNV risk is highest in the North Central Region. We sampled thrips and identified species from suction traps in 6 states across two years, with samples obtained from the suction trap network supported by this project. Overall, thrips counts were similar in 2016 and 2017 across the states that we sampled. The populations start to build as early as May which coincides with early vegetative stages of soybean in some Midwestern states. Thrips activity peaked in July-August in most states and begins a decline in September. The most common thrips species in the samples were eastern flower thrips followed by soybean thrips, both of which can transmit SVNV, although soybean thrips is the more efficient vector. We are in the process of completing counting and identification for 2018 samples, but preliminary data suggests similar trends as the previous years.

Project 5. Technology development. Participants: Brian McCornack* (Kansas State University), with cooperation from other entomology team members. *Project leader

Technology development: This objective includes work towards developing an aphid-counting app; the development of an electronic resource myFields.info which is designed to house integrated Extension information that is dynamic in nature with (see http://myfields.info/schematic), with interactive tools and resources that link agricultural information from different sources together; and digitizing the soybean aphid Speed Scouting sampling method to provide real-time decisions for managing aphids. These tools are described in greater detail in the Technical Report. The development of technical tools is important to give farmers new and more efficient avenues for pest management decision making and execution.

Program Area III. Resistant Varieties and Biotypes

Project 1. Breeding for resistant varieties. Participant: Brian Diers (University of Illinois); Louis Hesler (USDA-ARS)

Breeding for resistant varieties: The Diers program is developing and releasing soybean germplasm and varieties with aphid resistance. Aphid-resistant varieties are important to give farmers new, effective, convenient tools for aphid management (especially in light of insecticide resistance in soybeans aphids, which has now been documented). The breeding activities of this project have focused on developing soybean experimental lines that are useful for researchers and new aphid resistance varieties for farmers. The experimental lines being developed for researchers have different combinations of five aphid resistance genes in both a MG I and a MG II background. There will be 32 different lines developed in each background with each line having a different combination of the genes that range from having all five resistance genes to having no genes. These lines will be very useful to researchers who are testing the yield effect of these genes and are determining what combinations of genes best protects soybean from aphids. This usefulness was demonstrated by research that was done using lines that we previously developed with different combinations of three aphid resistance genes. Final selection of plants that will be used to develop these lines will be completed this spring in a greenhouse and the selected lines will be increased in the field this summer.

There has been limited availability to farmers of varieties that have resistance to soybean aphid. Through the project, we have been developing varieties that have the resistance genes *Rag1*, *Rag2* and the combination of the two genes (*Rag1*+*Rag2*). Varieties with these genes have been released for commercial production and a seed producer in Illinois is currently producing seed of a variety with *Rag1+Rag2*, a second with *Rag1*, and a third with *Rag2*.

Project 2. Aphid virulence genotyping and mapping. Participants: Andy Michel* (Ohio State University)*, Glen Hartman and Doris Lagos-Kutz (USDA-ARS at University of Illinois) *Project leader

Aphid virulence genotyping and mapping: Our goal is to genetically map aphid virulence. Soybean aphid virulence is when aphids are able to overcome our resistant varieties, and important issue for farmers who may wish to grow them. Our goal of understanding soybean aphid virulence involved several objectives. We sequencing the entire soybean aphid genome. Freely available at AphidBase, the soybean aphid genome represented the 4th aphid genome, as well as the smallest genome to date (302 mega basepairs). This genome will serve as a genetic foundation to investigate virulence as well as facilitate future objectives such as insecticide resistance (funded on the current NCSRP project). We also compared genes that the aphid biotypes differentially expressed, and found several effector genes with lower expression in the virulent aphid. Aphids use effectors to control or evade plant defenses, therefore the virulent soybean aphid may not express effector(s) that the soybean plant uses to recognize aphid attack. Third, we used mapping approaches to determine that soybean aphid biotypes may not mate randomly, which made identifying markers or the gene for virulence complicated. Nonetheless, our data suggest that virulence may not have a genetic basis, but yet be caused by epigenetic processes (i.e. differences in gene expression).

Aphid biotypes: Colonies of four known soybean aphid biotypes maintained at the USDA-ARS laboratory located the National Soybean Research Center at the University of Illinois are often used to compare field collections so that unknown clones can be classified or typed. Between 2016 and 2018 these clones have been shared with multiple researchers as part of this project.

Evaluation of soybean aphid virulence*:* We completed a study to evaluate the virulence of field collected soybean aphid clones on soybean genotypes with known soybean aphid resistance genes. Fourteen aphid clones collected on soybean and buckthorn (*Rhamnus cathartica* L.) plants in 2015 and 2017, along with four known aphid biotypes (from stock cultures) were evaluated. We found that the field collected clones were not of all the same biotype. None of the biotypes and field clones from Illinois, Indiana and South Dakota overcame the resistance of soybean PI437696.

Evaluation of soybean resistance: This information is useful to soybean growers since soybean breeders will use these soybean lines to develop more resistant soybean cultivars. Soybean resistance expressed in five plant introductions (PIs) to four soybean aphid biotypes was characterized to determine the mode of resistance inheritance, and identify markers associated with genes controlling resistance in these accessions. Five soybean PIs, from an initial set of 3000 PIs, were tested for resistance against soybean aphid biotypes 1, 2, 3, and 4 in choice and no-choice tests. Of these five PIs, PI 587663, PI 587677, and PI 587685 expressed antibiosis against all four biotypes, while PI 587972 and PI 594592 expressed antibiosis against biotypes 1, 2, and 3. The five soybean plant introductions expressed antibiosis resistance to multiple soybean aphid biotypes with two introductions having resistance genes located in the *Rag1*, *Rag2*, and

Rag3 regions, two introductions having resistance genes located in the *Rag1* and *Rag2* regions, and one introduction having a resistance gene located in the *Rag2* region.

Project 3. Aphid virulence management for resistant varieties. Participants: Matt O'Neal* and Jessica Hohenstein* (Iowa State University), Andy Michel* and Kelley Tilmon (Ohio State University), Deirdre Prischmann (North Dakota State University), Bruce Potter (University of Minnesota), Louis Hesler (USDA-ARS), Adam Varenhorst (South Dakota State University) *Project leaders

Aphid virulence management for resistant varieties: The purpose of this study is to find ways to maximize the longevity of aphid resistant varieties (delaying the development of biotypes that are virulent on them) through the use of a blended refuge of resistant and susceptible varieties – while at the same time minimizing yield loss. We performed a 3 year field study study in three states (Iowa, South Dakota, and Ohio) in quarter-acre, replicated plots to measure the impact of a Refuge-in-a-Bag approach, testing different percentage blends of susceptible seed. Overall, our data suggests that aphid-resistant soybeans blended with a minimum of 25% aphid-susceptible plants could serve as a refuge while still being effective for suppressing aphids in the field. Plots with interspersed refuge may produce a higher proportion of late-season avirulent individuals which is consistent with refuge requirements. Thus, inclusion of an interspersed refuge could be a viable resistance management strategy for soybean aphid. In short, the addition of susceptible seeds does not alter the ability of Rag to provide season-long aphid and yield protection; refuge fields produce a higher proportion of avirulent individuals than all-resistant fields; going forward, adherence to refuge inclusion could be a viable insect resistance management strategy for the sustainable use of Rag traits

Project 4. Economic returns on resistant varieties. Participants: Erin Hodgson* and Matt O'Neal (Iowa State University) *Project leader

Economic returns on resistant varieties: This was a year study designed to assess the economic returns on herbicide tolerant and aphid resistant traits. The goal was to determine the optimal economic approach to pest management for soybean production. This project was conducted in two parts: a field research component and a computer-based modeling economic analysis. The economic analysis is on-going and currently being refined, but the field research spanned two growing seasons and was completed in 2017. We compared four varieties that varied by aphid-resistance and herbicide-tolerance. Our findings indicate that if farmers in aphid-prone areas adopt resistant varieties they can maintain or improve profitability. This may be even more true in areas where aphids have developed resistance to commonly used insecticides. Soybean aphid-resistant varieties cost the same as similar susceptible varieties and do not cause yield loss, all while protecting plants from soybean aphids and eliminating insecticide applications, another input cost. Our preliminary results from the economic analysis show increased profitability for soybean farmers when they use resistant varieties.

Program Area IV. Biological Control (Coordinator: George Heimpel, University of Minnesota)

Project 1. Biological control of soybean aphid using Asian parasitoids. Participants: George Heimpel* (University of Minnesota) and Keith Hopper (USDA-ARS) *Project leader

Asian parasitoids of soybean aphid have the potential to provide biological control of soybean aphid, reducing the need for applications of foliar insecticides. If we can understand the conditions required for the overwintering survival of these parasitoids, we will be better able to predict where and when these parasitoids will be most successful at reducing soybean aphid pressure below the economic threshold, reducing the need to apply insecticides. We studied the overwintering biology of *Aphelinus* parasitoids to better understand if the winters in the Northern US might limit the success of these parasitoids as biological control agents. We used field studies to determine the usefulness of various habitats for successful overwintering and lab studies to determine the minimum temperatures that these insects can withstand. We found that survival of overwintering parasitoids was much higher when they were placed on the ground in the fall and subsequently covered by snow than when they were placed on buckthorn branches, the overwintering host plant of soybean aphid. The snow seems to act as a blanket. We found that these insects freeze and are killed at temperatures of approximately -28°C (-18°F), and temperatures under snow are unlikely to drop this low. Finally, we conducted field surveys to determine where on the landscape these parasitoids are attempting to spend the winter. We surveyed both soy fields and buckthorn in Minnesota in the fall of 2018 and while we found diapausing parasitoids in both habitats, we found many more in soy fields and almost exclusively unparasitized aphids on buckthorn plants.

We also conducted a sampling program to establish the range of the very effective soybean aphid parasitoid Aphelinus certus. Our surveys showed that Aphelinus certus is present throughout the North Central region. More details are available in the Technical Report.

Results: Technical Report

Program Area I. Extension and Outreach

We gave 105 extension presentations to farmers and other crop professionals containing NCSRP research. We wrote 82 extension articles and published 73 extension publications and other outreach products such as videos, website, and webinars. A highlight of these publications is the field guide, *Stink Bugs of the North Central Region*, a farmer-friendly pocket-sized booklet on stink bug identification, biology and management. 9000 free hard copies of this field guide have been distributed through universities and state checkoff organizations, and made available as a free download on SRII and other websites. Another noteworthy extension publication on our results, *The Effectiveness of Neonicotinoid Seed Treatments in Soybean*, is a joint factsheet publication of North Central Land Grant Universities. This regional factsheet informs farmers about the relative costs and benefits of seed treatments for pest control in soybean, to help them with their input decisions. Another regional publication, distributed to producers through the 12 North Central Land Grant universities and through the SRII website, is *Management of Insecticide-Resistant Soybean Aphids*, the first extension publication to alert producers to the rise of insecticide resistance in soybean aphids in the Dakotas, Minnesota, and Iowa. We have published a new, updated 2nd edition of the popular *Soybean Aphid Field Guide*, a farmer reference for soybean aphid management in the North Central Region. Finally, NCSRP research on pollinators in soybean was used to inform a joint publication of the USDA, USB and the Honey bee Health Coalition on Best Management Practices (BMPs) for conserving pollinators that use soybeans as forage, and members of our team served on the technical committee which drafted this document. Additional extension deliverables are detailed in the Deliverables section below. All of these deliverables help to make the knowledge gained through NCSRP research available to farmers in a form they can use.

Program Area II. Insect Monitoring and Management

Project 1. Stink bug monitoring and management. Participants: Robert Koch* (University of Minnesota)*, Chris DiFonzo (Michigan State University); Thomas Hunt and Robert Wright (University of Nebraska), Andrew Michel (Ohio State University), Christian Krupke (Purdue University), Janet Knodel (North Dakota State University), Deborah Finke (University of Missouri), Adam Varenhorst (South Dakota State University) *Project leader

This three-year project was focused on stink bugs of soybean and aimed to improve the understanding of this group of pests and develop a foundation for management programs. In particular, project goals were to: 1.) determine which species occur, at what abundance, and seasonal timing of infestation in North Central soybean fields; and 2.) develop a research-based sampling plan for stink bugs in soybeans. The research efforts spanned up to 9 states per year. A detailed protocol was developed with input from collaborators. Prior to each field season, the protocol was sent to all collaborators, along with sampling supplies. In each state, collaborators identified study fields, with generally two locations and four fields per location, resulting in eight fields per state. In 2016, 59 soybean fields from 8 states (Minnesota, North Dakota, South Dakota, Nebraska, Kansas, Missouri, Indiana and Ohio) were sampled. In 2017, 62 soybean fields from 9 states (the previously mentioned states plus Michigan) were sampled. In 2018, Wisconsin was added to the list of collaborating states. For each field, GPS coordinates, field history and other variables were recorded. In 2016-2017, fields were sampled weekly using sweep-net sampling through the soybean reproductive growth stages. In each field, sampling effort generally comprised 4 sample units (1 sample unit=25 sweeps) collected from the field edge and 8 sample units from the interior, resulting in a sample size of 12 sample units per field. In 2018, the sampling methodology was modified to compare different sample unit sizes, with sets of 10 sweeps and sets of 25 sweeps collected from each field. After collection of samples, stink bugs were stored in freezer and later identified to species for adults and genus for nymphs.

From 2016-2017, we characterized the relative abundance, richness and diversity of taxa in this community, and assessed seasonal differences in abundance of herbivorous and predatory stink bugs. Overall, the stink bug community was dominated by *Euschistus spp.* and *Chinavia hilaris*. *Euschistus variolarius*, *C. hilaris* and *Halyomorpha halys* were more abundant in the northwest, southeast and east, respectively. Economically significant infestations of herbivorous species occurred in fields in southern states. Species richness differed across states, while diversity was the same across the region. Herbivorous and predatory species were more abundant at later soybean growth stages. Our results represent the first regional characterization of the stink bug community in soybean fields and will be fundamental for development of state- and region-specific management programs for these pests in the North Central Region of the U.S.

The samples from 2016-2017 were also used characterize the spatial pattern of stink bugs in soybean fields and developed sampling plans. Taylor's power law was used to assess the spatial patterns of stink bugs and determine the effects of species (i.e., *C. hilaris* and *Euschistus* spp.), life stages (i.e., nymphs and adults) and locations in the field (i.e., edge and interior). Results showed that stink bugs were aggregated, but extent of aggregation varied by species, life stage and location. Sequential sampling plans were developed for each combination of species, life stage and location. A more practical combined sequential sampling plan was developed to be used for management purposes. Validation of the combined sampling plan showed that an average of 40 sample units (i.e., sets of 25 sweeps) would be necessary to achieve a precision of 0.25 for stink bug densities encountered across the region. However, based on the gradient of stink bug densities found across the region, smaller sample sizes (5–10 sample units) may be sufficient in states in the southeastern part of the region where stink bug densities were higher, whereas impractical sample sizes (>100 sample units) may be required in the northwestern part of the region where densities were lower. Our findings provide research-based recommendations sampling these emerging pests of soybean.

Additional analyses are underway based on the stink bug samples from 2016-2017. First, the samples are being used to assess the influence of landscape factors and within-field factors on the abundance of stink bug pests. The CropScape and Cropland data layers in ArcGIS are being used to characterize and quantify habitats surrounding soybean fields. Principal component Analysis (PCA) will be performed to reduce the complexity of the landscape data and linear regression models to test the effect of tillage, seed treatment, latitude, longitude and PCA results on stink bug density. Preliminary results suggest that certain landscape factors may be associated with stink bug abundance in soybean fields and could potentially be used in prioritization of fields for scouting. Second, the individual stink bugs are being carefully inspected for the presence of eggs from parasitic flies (Tachinidae). These parasitic flies are known biological control agents of stink bugs, but their prevalence and abundance on stink bugs in the North Central Region has been poorly studied. Results of this effort will improve our understanding of natural controls of stink bug pests.

Finally, samples collected from 2018 continue to be processed. This third year of data collection was designed to test sample unit size (i.e., how many sweeps per set of sweeps) provides the most efficient and precise estimate of stink bug abundance. Analyses of these data will continue on funding leveraged from the state of Minnesota to support a new Master's student working on stink bugs.

Results of the above mentioned research have been disseminated to scientific audiences at professional meetings and two scientific papers have been written and are in review with the Journal of Economic Entomology. Additional scientific papers from this work will be written of the next year. Results of this research have also been translated and disseminated to growers and agricultural professionals through presentations and publications. As more analyses are finalized, further extension materials will be produced.

Project 2. Pollinator diversity and soybean yield. Participants: Matt O'Neal* (Iowa State University), Janet Knodel* (North Dakota State University), Kelley Tilmon (Ohio State University), Robert Wright (University of Nebraska), Bruce Potter (University of Minnesota), Christian Krupke (Purdue University), Deborah Finke (University of Missouri), Adam Varenhorst (South Dakota State University); collaborators at Mississippi State *Project leader

<u>Pollinator Diversity</u>

Objectives

A growing body of scientific literature demonstrates the importance of pollinators in agricultural crops. The main objectives of this project were: 1) to survey the diversity of bee and syrphid fly fauna across a broad geographic soybean production area in the Midwestern United States; 2) to raise awareness of potential pollinators in soybean fields and promote IPM practices that foster pollinator conservation; and 3) to establish baseline pollinator species data to assess the feasibility of more rigorous future studies examining the effects of landscape and agricultural practices on soybean pollinator communities.

Materials & Methods

Six states (IA, IN, MN, ND, SD, WI) participated and surveyed nine field in 2014, and nine states (IA, IN, MN, MO, ND, NE, OH, SD, WI) surveyed 23 fields in 2016. This is a map (Figure 1) showing the locations for both years. Some locations were the same or very close for both years, hence some points appear on top of one another (ND, SD, IA, WI).

Two fields per state were sampled when soybean [*Glycine max* (L.) Merr.] was in flower (R1 through R4 growth stages). Pollinators were collected using yellow bee bowls placed at intervals of 0, 5, 10, 25, 50, 100, 250 and 500 m away from field edges in a single transect in each field. This will determine what pollinator species were present and how far from field edges pollinators would travel. Soapy water was used in the 'bee bowls' (5 ml Dawn blue dish detergent per 3.8 liters of distilled water). Samples were collected biweekly during flowering. Collected specimens were placed in vials containing 80% ethanol and labeled with field site, date, crop stage and bowl position. Bowls were maintained at canopy height using adjustable stakes. Soybean flowering generally occurred from mid-July through mid-August depending on latitude, planting date and maturity group. The 250 m and especially the 500 m bowl positions were not possible at several sites due to fields not being large enough.

Samples were sent to Patrick Beauzay at NDSU for processing and species identification. Sample processing entailed a gentle wash in soapy water, a water rinse, and resoaking in 80% and then 95% ethanol. Samples were dried in a food dehydrator at 45^{0}C for 10 minutes to evaporate alcohol. Special care was taken with hairy bees (e.g. *Bombus, Melissodes*) to ensure the hair did not become matted. A Leica M125 microscope with digital camera and software for making measurements was used for species identification.

Results

Bees.

A total of 10,822 individuals representing 108 species in 27 genera and five families was recorded across all states from the 2014 and 2016 surveys. The breakdown by bee family is shown in Table 1. A total of 1,314 individuals of 57 species in 20 genera were found in 2014, and 9,508 individuals of 96 species in 24 genera were found in 2016. The addition of 3 new states and 14 new fields in those states in 2016 resulted in a large increase in the number of bee species and individuals collected.

Table 1 Bee Count Summary for 2014 and 2016.

Family	No. of Genera	No. of Species	No. of Individuals	Percent
Andrenidae	4	7	13	0.1
Megachilidae	2	8	19	0.2
Colletidae	2	5	29	0.3
Apidae	11	31	998	9.2
Halictidae	8	57	9,763	90.2
Total	**27**	**108**	**10,822**	**100**

Andrenidae: This is a very large family. A total of 13 individuals of 7 species in 4 genera were identified in our survey. This family comprised only 0.1% of the total number of specimens, so it was poorly represented in our survey.

Megachilidae (leaf-cutter bees): A total of 19 individuals of 8 species in 2 genera were identified in our survey. This family also was poorly represented in our survey, comprising 0.2% of all specimens.

Colletidae - Cellophane (*Colletes*) and yellow-faced (*Hylaeus*) bees: A total of 29 individuals of 5 species in 2 genera were identified in our survey. Colletids comprised only 0.3% of all specimens. *Hylaeus* species are very difficult to identify. There were a few specimens that share characters between two species and could not be positively identified to species.

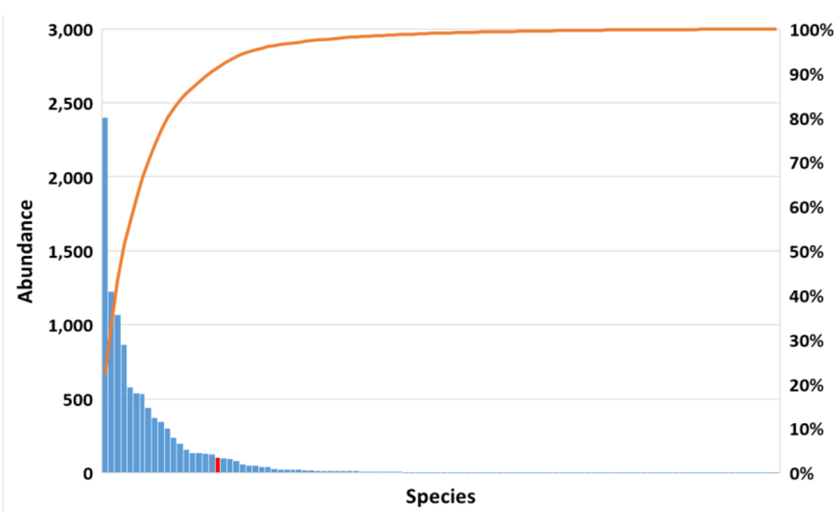
Apidae - Subfamily Apinae: Tribes Apini, Bombini: A total of 998 individuals of 31 species in 11 genera were identified in our survey. Apidae as a whole comprised 9.2% of all specimens. Perhaps the most notable find of the survey was the detection of two *Bombus pensylvanicus* from Indiana. This species is apparently in serious decline in the northern part of its range. *Bombus fervidus*, the most numerous bumblebee in our survey, also appears to be in decline. Bumble bees are rather difficult to identify due to variation in hair color patterns and physical morphology, among and within species and castes. *Apis mellifera,* European honey bee, was recorded from all states, but was poorly represented in the survey and accounted for only 0.9% of all bee individuals (n = 93).The 93 individuals collected represents 0.8% of all specimens. This species is not native to North America.

In the Subfamily Apinae, Tribes Anthophorini, Eucerini contain digger bees and long-horned bees. *Melissodes bimaculata* was the most abundant apid collected, especially in Nebraska, and was detected in all surveyed states. *Melissodes trinodis* was abundant in North Dakota, likely due to the close proximity to blooming sunflower at both locations in 2014 and 2016. Other species were much less common. *Melissodes* species and Anthophorines in general are particularly difficult to identify.

Subfamily Nomadinae: Tribes Ammobatoidini, Nomadini, Epeolini: Subfamily Xylocopinae: The subfamily Nomadinae contains the cuckoo bees, which are cleptoparasites. The subfamily Xylocopinae was represented in our survey by one species, *Xylocopa virginica*, the eastern carpenter bee, which was found only in Missouri and Ohio.

Halictidae – Sweat bees. Subfamily Nomiinae and Subfamily Halictinae: Tribes Augochlorini, Halictini: A total of 9,763 individuals of 57 species in 8 genera were identified in our survey. This was the dominant family in our survey, comprising 90.2% of all specimens. As a whole, *Lasioglossum* was the most abundant genus in the survey, representing 44 species and 6,922 individuals (41% of all species and 64% of all individuals). *Lasioglossum pruinosum* was the most abundant species (n = 2,403), representing 22.2% of all bee individuals collected, and was recorded from all states except Missouri. *Lasioglossum hitchensi* was the second most abundant species (n = 1,226), representing 11.3% of all bee individuals. *Agapostemon angelicus / texanus* was the third most abundant taxon (n = 1,069), representing 9.9% of all bee individuals. *Agapostemon virescens, Halictus confusus* and *H. ligatus* were collected in all surveyed states. Identification to species is important in terms of measuring diversity. We obtain much more information from 6,922 individuals across 44 species compared to 6,922 individuals in 1 genus. In the bee species histogram (Table 2), the left axis is species count and the right axis is percent accumulation which corresponds with the orange curved line. Species to the left of the red bar are represented by 100 or more individuals. The majority of bee species are represented by fewer than 100 individuals, and on this scale, many individual species bars are indistinguishable from the x-axis. In fact, 67 species are represented by fewer than 10 individuals, and 27 species are represented by only 1 individual.

Table 2. Bee Species Histogram



In Table 3, the bee species diversity including species richness, evenness and abundance indicates high values considering the monoculture environment of soybeans.

Table 3. Bee Species Diversity

	IA	IN	MN	MO	ND	NE	OH	SD	WI	Total
No. of Species (Richness)	37	39	38	27	36	37	49	22	36	108
No. of Individuals (Abundance)	629	1,660	1,643	490	338	2,346	2,681	458	577	10,822
Shannon-Wiener Index (H)	2.39	2.02	1.87	2.29	2.43	2.14	2.23	2.18	2.01	2.92
Evenness ($E = H/H_{max}$)	0.66	0.55	0.51	0.69	0.68	0.59	0.57	0.70	0.56	0.62
Simpson's Diversity (1-D)	0.87	0.75	0.73	0.87	0.84	0.80	0.82	0.83	0.73	0.91

Syrphid Flies.
A total of 1,190 individuals representing 11 syrphid fly species in six genera were recorded in 2014 (Table 4). Syrphid flies collected in 2016 are not added to this table yet. *Toxomerus marginatus* was the most abundant syrphid fly species (n = 1,116) and comprised 93.8% of all syrphid flies sampled. The presence of syrphid species with aphidophagous larvae (*Allograpta obliqua*, *Eupodes americanus*, *E. volucris*, *Sphaerophoria contigua*, *Toxomerus geminatus* and *T. marginatus*) was likely a function of soybean aphid population density, though this correlation was not specifically tested. The Harwood, ND field had approximately 100 aphids per plant at the start of sampling, and had reached or exceeded the economic threshold of 250 aphids per plant at the end of sampling. The Indiana fields had almost no soybean aphids. Adults of the non-aphidophagous species (*Eristalis arbustorum*, *E. stipator*, *E. tenax*, *Helophilus fasciatus* and *H. latifrons*) may have been present to utilize soybean flowers, or may have been foraging near the fields and were attracted by the bee bowls.

Table 4. Syrphid fly species identified and number of individuals by state.

Species	IA	IN	MN	ND	SD	WI	Total
Toxomerus marginatus	205	5	117	541	127	121	**1,116**
Toxomerus geminatus	6		2		7	9	**24**
Sphaerophoria contigua	1		10	5	2		**18**
Eristalis stipator			1	7		3	**11**
Eristalis arbustorum						4	**4**
Eupeodes americanus	1			3			**4**
Eupeodes volucris				4			**4**
Allograpta obliqua			1	2			**3**
Helophilus fasciatus				3			**3**
Helophilus latifrons				2			**2**
Eristalis tenax						1	**1**
Total	**213**	**5**	**131**	**567**	**136**	**138**	**1,190**

Diversity indices are quite low (Table 5); however, it's useful in comparing syrphid diversity and bee diversity from the same states. Overall, syrphids have a dual beneficial purpose in soybean fields: 1) adults are nectar feeders and can act as pollinators, and 2) the larvae of many species are aphid predators.

Table 5 Diversity indices for Syrphid flies.

	IA	IN	MN	ND	SD	WI	Total
No. of Species (Richness)	4	1	5	8	3	5	**11**
No. of Individuals (Abundance)	213	5	131	567	136	138	**1,190**
Shannon-Wiener Index (H)	0.19	0.00	0.44	0.27	0.28	0.51	**0.35**
Evenness ($E = H/H_{max}$)	0.04	0.00	0.09	0.04	0.06	0.10	**0.05**
Simpson's Diversity (1-D)	0.07	1.00	0.20	0.09	0.13	0.23	**0.12**

Conclusions:

In summary, we concluded the following:

- We were positively surprised by the overall species richness and abundance of bees and syrphid flies from the pollinator survey in soybeans.
- Syrphid flies and especially bees can be relatively abundant and diverse in soybean fields, given the monoculture environment.
- Our results provide important baseline data on the bee and syrphid fly fauna associated with flowering soybean in the Midwest.
- This survey provides justification for future studies examining the effects of landscape and agricultural practices on syrphid flies and bees, and to assess the value of the ecological services they provide to soybean production.
- We encourage soybean producers to implement and practice IPM strategies to maintain the pollinator fauna in soybean fields, and to develop practices that foster and conserve pollinator habitat.

Time of Pollinator Foraging

In order to gain a better understanding of how to improve management strategies of soybeans while conserving pollinator species in the area it is vital to understand how and when pollinators use soybean fields. Studies in some states, like Iowa, have indicated that there is a community of bees, including honey bee, present in soybean fields. How these communities differ within a field and throughout the North Central Soybean region is unclear. Furthermore, EPA requires farmers to limit their application of insecticide to periods when bees are not on flowers. Honey bees and other wild bees typically fly only during periods of daylight, which limits application to dusk. It is unclear if there is an optimal period of activity for bees in soybeans and if this varies between bee species and throughout the North Central region. In order to gain a better understanding of how bees use soybeans we aimed to answer three questions: 1) How does the bee community throughout the NCSR change? 2) Does the bee community within a soybean field change with distance from the field margin? 3) Does the diurnal activity of bees within soybeans change? In order to answer these questions we passively sampled for wild bees in soybeans throughout the North Central region and in Mississippi using modified pan traps called bee-bowls. In 2014 and 2016 we sampled bees in fields at varying depths from the field margin. In 2017 and 2018 we sampled diurnal activity of bees within soybeans 10m from the field edge. In 2018 we also directly observed honey bee activity in soybean fields. All bees captured were identified to species. Data are currently being combined for all states and analyzed for this project.

Project 3. Soybean aphid insecticide resistance. Participants: Tom Hunt* (University of Nebraska), with cooperation from other entomology team members *Project leader

Three bioassay techniques were developed/optimized for thiamethoxam.
1. Glass vial – A quick contact bioassay method for monitoring insecticide susceptibility

2. Detached-leaf – A systemic bioassay method for monitoring insecticide susceptibility and for conducting resistance research.
3. Whole-plant – a systemic bioassay method for in-depth study of insecticide resistance and plant response research

Regional monitoring of soybean aphid populations for thiamethoxam susceptibility indicated a small decrease of susceptibility and the presence of sublethal effects. Soybean aphid mortality and other parameters differ among age groups, but mixed-age bioassays are more practical than age-synchronized bioassays. When soybean aphid resistance to thiamethoxam evolved, it was non-stable, indicating a fitness-cost. Decreased soybean aphid survivorship and population growth inhibition was observed in the resistant population.

Key outcomes

- Bioassays are now available for monitoring bean leaf beetle and soybean aphid susceptibility to thiamethoxam.

- We have a better understanding of region-wide variability of soybean aphid susceptibility to thiamethoxam.

- A baseline susceptibility data set is now available for monitoring of soybean aphid resistance to thiamethoxam.

- Although thiamethoxam is still highly efficacious against soybean aphid, there were changes in susceptibility over time.

- Fitness costs indicate soybean aphid resistance to thiamethoxam (and possibly other neonicotinoids) could subside when selection pressure is reduced.

Glass Vial Bioassay Development.

Optimization for type of vial cap, number of replications, number of aphids per vial, kit storage temperature, and kit shipment time (Figures 1-4.) and materials acquired for kit production.

Figure 1.

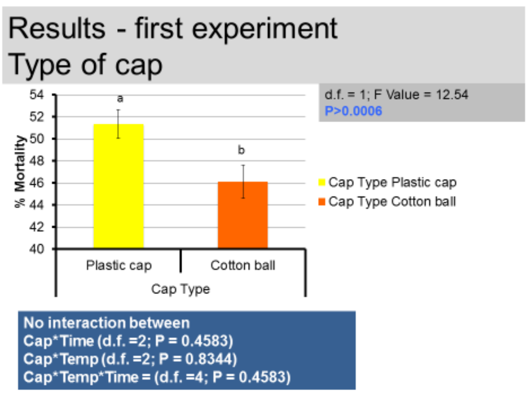


Figure 2.

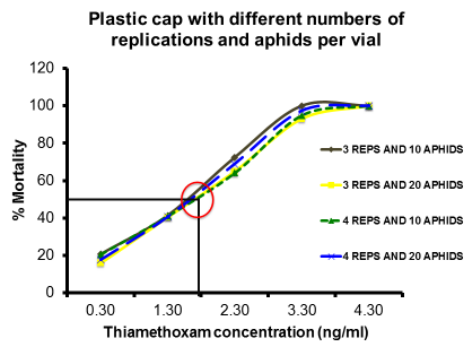


Figure 3.

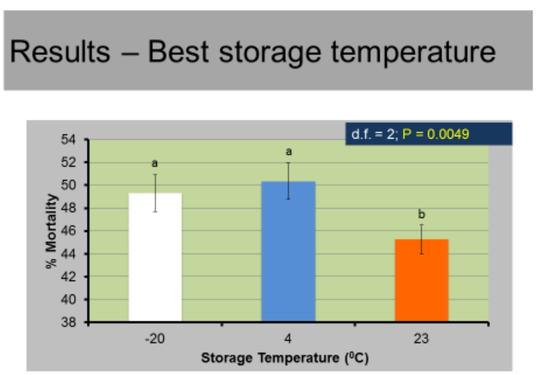
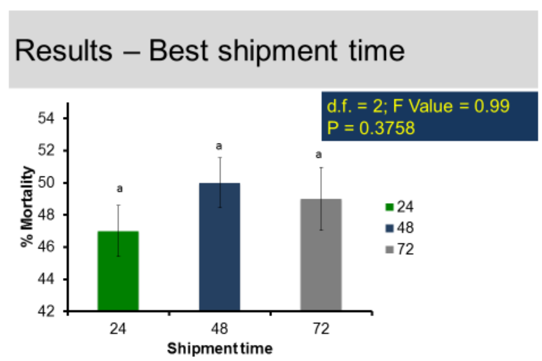
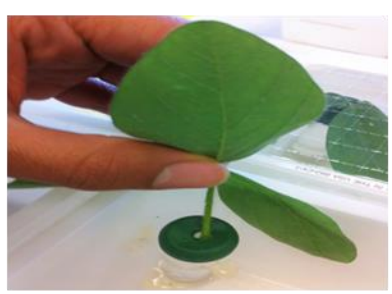


Figure 4.



Three Bioassay Techniques:

Glass vial



Detached-leaf

Whole-plant

Project 4. Monitoring for aphids, thrips, and soybean vein necrosis virus. Participants: Punya Nachappa* (Purdue University); Glen Hartman*, Doris Lagos-Kutz* and Nick Seiter (ARS/ University of Illinois), with cooperation from other entomology team members *Project leaders

Suction Trap Network to Monitor Soybean Aphids and other Pests

The Midwestern USA aphid suction trap network (STN) is broad in geographic area and has been in continuous operation since 2005. Between 2016 and 2018 the network operated in 9 states with a total of 31 locations (Table 1). The operation of the STN was made possible through NCSRP funding and through the devoted collaboration of farmers, extension and research personnel. In collaboration with Joseph LaForest (Department of Entomology, Center for Invasive Species and Ecosystem Health, University of Georgia; Southern IPM Center) in kind support, a voluminous collection of records of sample identifications and observations from the STN are now available at https://suctiontrapnetwork.org/ and https://www.eddmaps.org. This data allows for studies on distribution of known species and new or non-identified species captured by the suction traps. A total of 158 aphid species have been identified from the suction trap network (Table 2). The most diverse genera identified in suction trap samples were *Aphis* and *Uroleucon*. The most abundant aphid genera, besides the soybean aphid, were the cereal aphids (*Melanaphis sacchari*, *Rhopalosiphum padi*, *R. maidis* [abundant between 2005 and 2010], *R. rufiabdominale*, *S. avenae*, and *S. graminum*). Specimens and data collected to date have been used for multiple research studies, not only on aphids, but other insects such as thrips and mosquitoes. Stored samples from the traps are also available to the research community for further studies. As more data becomes available, the Southern IPM Center will continue to provide a long-term system to record data, generate visualizations for basic data exploration, and make the data available for other research and modelling efforts.

Population dynamics of the soybean aphids. In 2016, the summer migration peak was in mid-August in Minnesota and Iowa. The peak of fall migration in Iowa occurred in mid- September, and for Illinois and Indiana in the third week of September until first week of October. In 2017, the population was low, and peaks were not recorded in the summer, but did occur in the fall in Indiana and Iowa. In 2018, Minnesota and Wisconsin showed high counts in the summer, and there were no peak counts for any states in the fall (Fig. 1). The peaks of summer and fall migration through the years seem to be the same: from late July to about mid-August, and then from the mid-September through October, respectively, for the summer and fall migrations (Schmidt et al. 2012). The population dynamics of the soybean aphid in the Midwest seems to be changing as either fall (2017) or summer migrations (2018) occurred but not both at least in Illinois, Indiana, Iowa, Minnesota, and Wisconsin. Between 2016 and 2018, the suction traps located in Louisiana and Missouri did not capture any soybean aphids, and very few were captured in the one located in Kansas. Along with the soybean aphid, there have been other aphids captured and identified as well.

Cereal aphids. Other aphid species of agricultural interest include the cereal aphids including the bird cherry-oat aphid, *Rhopalosiphum padi*, which is widely distributed in the Midwest. Between 2016 and 2018, the summer migration peaks were more abundant than the spring migrations. In 2016 and 2017, the peak counts were highest for Iowa. In 2018, Illinois and Iowa had the highest counts (Fig. 2). The rice root aphid, *R. rufiabdominale*, was also widely distributed in the

Midwest and higher counts occurred in Kansas, Louisiana and Missouri (Fig. 3). The greenbug aphid, *Schizaphis graminum*, was also widely distributed in the Midwest, but less abundant than the bird cherry-oat aphid. In 2016, spring peaks occurred in Illinois, Iowa and Illinois, with summer peaks around mid-August to the first week of September. In 2017, only Indiana had a peak in the fall migration, and in 2018, the summer peaks were in Illinois Iowa, Minnesota, and Wisconsin (Fig. 4). The English grain aphid, *Sitobion avenae*, was abundant as the greenbug aphid with some similar seasonal population dynamics (Fig. 5). Interestingly, the spring migration peak in 2016 was in Kansas, and the summer peak fluctuated between mid-August and the first week of September mainly in Illinois, Indiana, Iowa, Kansas, Minnesota and Missouri. In 2018, the summer migration peak was only in August. The sugar cane aphid, *Melanaphis sacchari*, an invasive species, was widely distributed in Kansas, Missouri and Louisiana, although a few specimens were captured in Illinois, Indiana, Michigan, and Wisconsin (Fig. 6). In 2016, Kansas had a seasonal peak abundance of this species from 23 September through mid-October. The suction trap located in Louisiana captured sugarcane aphids from mid-May through 22 July and late September through 4 November. There were two distinct peaks at this location. One peak occurred at the end of July and first week of August and the other peak from the middle of August until the middle of September. The suction trap located in Columbia (Missouri) caught sugarcane aphids from the end of August until the end of the season (i.e., 21 October). This location had a small peak on 16 and 23 September 2016 compared with the locations above. The suction trap located in Portageville (Missouri) collected sugarcane aphids from the end of August until 23 September when samples collection ceased. In 2017, the suction trap located in Chase contained sugarcane aphids from 7 April until 20 October, with peak collections occurring in mid-August. The suction trap located in Kansas caught sugarcane aphids from 8 September until 13 October. Seasonal abundance was lower at this location compared with previous years. In 2018, only Louisiana showed multiple abundance peaks from the mid-July until the end of September, and very few specimens were captured in other states.

Other soybean insect pests. In 2018, we specifically noted other non-aphid soybean insect pests. We obtained the following records: *Acalymma vittatum* (striped cucumber beetle) in Morris, IL on 8/18/18 (1 individual), Urbana-Champaign, IL on 5/25/18 (2 individuals), and in Manhattan, KS on 8/24/18 (1 individual); few specimens of *Empoasca fabae* (potato leafhopper) were found in most of states, but the highest counts were from Urbana-Champaign, IL; few individuals of *Cerotoma trifurcate* (Bean leaf beetle) were found in Urbana-Champaign, IL; Wanatah, IN; Manhattan, KS and Columbia, MO. Few individuals of *Popilia japonica* (Japanese beetle) were counted in most of states and none from Kansas and Louisiana; none of *Chaetocnema pulicaria* (corn flea beetle), *Halyomorpha halys* (brown marmorated stink bug) and *Piezodorus guildinii* (redbanded stink bug) were captured in the suction traps. Few individuals of *Colaspis* spp. were captured in Urbana-Champaign, IL and Chase, LA. Records of soybean thrips, *Neohyadatothrips varabilis*, showed that Illinois and Iowa had the highest number of thrips in mid-August compared to other locations in the network. The only migration peak was mid-August (Fig. 7).

Table 1. Midwest Suction Trap Network locations, collector, geographic coordinates and years of operation.

State/city	Location name	Collector	Coordinates	Year
Illinois				
Freeport	Keith Hinrichs Farm	K. Hinrichs, P. Alberti	42.280°N 89.700°W	2001–2009 2018

Monmouth	Northwestern Illinois Agriculture Research and Demonstration Center, UI	M. Johnson	40.934°N 90.723°W	2001–2018
Morris	Russ Higgins Farm	R. Higgins	41.335°N 88.384°W	2007–2018
Orr	Orr Agricultural Research and Demonstration Center, UI	M. Vose	39.806°N 90.824°W	2001–2017
Urbana-Champaign-II	Crop Sciences Research and Education Center, UI	C. Montes, J. McGrath, D. Lagos-Kutz	40.042°N 88.232°W	2007–2018
Iowa				
Ames	Bio Century Farm, Iowa State University (ISU)	E. Hodgson	42.018°N 93.778°W	2005–2018
Kanawha	Northern Research Farm, ISU	M. Schnabel	42.018°N 93.778°W	2016–2018
Nashua	NE Research and Demonstration Farm, ISU	K. Penckiosky	42.932°N 92.574°W	2005–2018
Sutherland	NW Research and Demonstration Farm, ISU	D. Haden, J. Sievers, T. Tuttle	42.926°N 95.539°W	2005–2018
Indiana				
Butlerville	Southeast Purdue Agriculture Center, Purdue University	J. Wahlman	39.035°N 85.529°W	2005–2018
Columbia City	Northeast Purdue Agriculture Center, Purdue University	P. Walker	41.105°N 85.399°W	2005–2018
Farmland	Davis Purdue Agriculture Center, Purdue University	J. Boyer	40.254°N 85.150°W	2005–2018
Lafayette	Throckmorton Purdue Agriculture Center, Purdue University	P. Illingworth	40.175°N 96.594°W	2013–2018
Wanatah	Pinny Purdue Agriculture Center, Purdue University	J. Leuck	41.444°N 86.930°W	2005–2018
Kansas				
Manhattan	North Agronomy Farm, Kansas State University	B. McCornack	39.208°N 96.594°W	2005-2009 2011-2018
Louisiana				
Chase	Sweet Potato Research Station, Louisiana State University Agricultural Center	J. Ronsonet	32.101°N 91.703°W	2016–2018
Michigan				
East Lansing	South Campus Field Research Facilities	C. Malstrom, C. DiFonzo	42.691°N 84.498°W	2005–2018
Kalkaska	Ioot’s Potato Seeds Farm	S. D. Ioot	44.659°N 85.080°W	2016–2018
Hickory Corners	W. K. Kellogg Biological Station, Michigan State University (MSU)	C. Bahlai, J. Perrone, E. D’Auria	42.410°N 85.373°W	2005–2018
Mason	MSU Extension Center	B. Werling	43.836 N 86.368°W	Sept 2018
Monroe	MSU Extension Center	N. Birkey	41.927°N 83.466°W	2006–2018
Minnesota				
Crookston	Northwest Research and Outreach Center	I. MacRae, J. Dillon	47.798°N 96.621°W	2006–2018
Lamberton	Southwest Research and Outreach Center	B. Potter	44.240°N 95.315°W	2005–2018
Morris	West Central Research and Outreach Center	C. Reese	44.706°N 95.869°W	2005–2018
Rosemount	Rosemount Research and Outreach Center	J. Dregni	44.706°N 93.101°W	2005–2018

Missouri				
Columbia	Campus, University of Missouri	D. Finke	38.907°N 92.281°W	2006–2013 2016–2018
Portageville	Delta Research Center, University of Missouri	M. Jones	36.402°N 89.615°W	2007–2011 2016
Wisconsin				
Antigo	Andy Merry private farm	A. Merry, K. Gallenberg	45.178°N 89.209°W	2006–2018
Arlington	Arlington Agriculture Research Station	E. Cullen, J. Breuer, S. Chapman	43.317°N 89.328°W	2005–2015 2017-2018
Eau Claire	Pioneer Hi-Bred International	S. Spranger	44.754°N 91.589°W	2005–2013 2018
Hancock	Hancock Agriculture Research Station	S. Chapman, A. Gotch	44.118°N 89.534°W	2005–2018
Lancaster	Lancaster Agriculture Research Station	D. Wiedenbeck	42.831°N 90.789°W	2005–2018
Langlade	Langlade County Airport	K. Gallenberg	45.161°N 89.114°W	Sept 2018
Seymour	Dennis Lawkowski Farm	D. Lawkowski	44.553°N 88.309°W	2006–2010 2013–2018

Table 2. Preliminary list of the aphids identified so far from the suction trap network from 2001 to 2018.

No. of species	Genus species
1	*Acuticauda solidaginifoliae* (Williams, 1911)
5	*Acyrthosiphon caraganae* (Cholodkovsky, 1907) *A. kondoi* Shinji, 1938; *A. lactucae* (Passerini, 1860); *A. malvae* (Mosley, 1841); *A. pisum* Harris, 1776
4	*Anoecia corni* (Fabricius, 1775); *A. cornicola* (Walsh, 1863); *A. oenotherae* Wilson, 1911; *A. setariae* Gillette & Palmer, 1924
23	*Aphis asclepiadis* Fitch, 1851; *A. cephalanthi* Thomas, 1878; *A. coreopsidis* (Thomas, 1878); *A. craccivora* Koch, 1854; *A. decepta* Hottes & Frison, 1931; *A. fabae* Scopoli, 1763; *A. folsomii* Davis, 1908; *A. glycines* Matsumura, 1917; *A. gossypii* Glover, 1877; *A. illinoisensis* Shimer, 1866; *A. impatientis* Thomas, 1878; *A. maculatae* Oestlund, 1887; *A. monardae* Oestlund, 1887; *A. nasturtii* Kaltenbach, 1843; *A. nerii* Boyer de Fonscolombe, 1841; *A. polygonata* Nevsky, 1929; *A. pulchella* Hottes & Frison, 1931; *A. rubicola* Oestlund, 1887; *A. rumicis* Linneus, 1758; *A. sambuci* Linneus, 1758; *A. saniculae* Williams, 1911; *A. spiraecola* Patch, 1914; *A. (Toxoptera) aurantii aurantii* Boyer de Fonscolombe, 1841
1	*Aspidaphis adjuvans* (Walker, 1848)
2	*Aulacorthum solani* (Kaltenbach, 1843); *A. circumflexum* (Buckton, 1876)
2	*Brachycaudus cardui* (Linneus, 1758); *B. helichrysi* (Kaltenbach, 1843)
1	*Brevicoryne brassicae* (Linnaeus, 1758)
2	*Calaphis betulella* Walsh, (1862) 1863; *C. coloradensis* Granovsky, 1939
2	*Capitophorus elaeagni* (Del Guercio, 1894); *C. hippophaes* (Walker, 1852)
1	*Cavariella aegopodii* (Scopoli, 1763)
2	*Chaitophorus populicola* Thomas, 1878; *C. populifolii* Essig, 1912
1	*Cinara pilicornis* (Hartig, 1841)
2	*Colopha graminis* (Monell, 1882); *C. ulmicola* (Fitch, 1859)
2	*Cryptomyzus galeopsidis* (Kaltenbach, 1843); *C. ribis* (Linnaeus, 1758)
1	*Diuraphis noxia* (Mordvilko ex Kurdjumov, 1913)
2	*Drepanaphis acerifoliae* (Thomas, 1878); *D. keshenae* Granovsky ex Hottes & Frison, 1931
1	*Dysaphis plantaginea* (Passerini, 1860)
1	*Eucallipterus tiliae* (Linnaeus, 1758)
1	*Eulachnus rileyi* (Williams, 1911)
1	*Forda marginata* Koch, 1857
1	*Geoica utricularia* (Passerini, 1856)
1	*Hamamelistes spinosus* Shime, 1867
1	*Hayhurstia atriplicis* (Linnaeus, 1761)
2	*Hyadaphis foeniculi* (Passerini, 1860); *H. tataricae* (Aizenberg, 1935)
1	*Hyalopterus pruni* (Geoffroy, 1762)
2	*Hyperomyzus lactucae* (Linnaeus, 1758); *H. pallidus* Hille Ris Lambers, 1935
1	*Hysteroneura setariae* (Thomas, 1878)
1	*Illinoia pepperi* (MacGillivray, 1958)
1	*Iziphya flabella* Sanborn, 1904
1	*Kaltenbachiella ulmifusa* (Waslh & Riley, 1869)
1	*Lipaphis pseudobrassicae* Davis, 1914
2	*Macrosiphoniella abrotani abrotani* (Walker, 1852); *M. tapuskae* (Hottes & Frison, 1931)
2	*Macrosiphum euphorbiae* (Thomas, 1878); *M. venafuskae* Davis, 1914
1	*Melanaphis sacchari* (Zehntner, 1897)
1	*Metopolophium dirhodum* (Walker, 1849)
2	*Microparsus desmodiorum* Smith & Tuatay, 1960; *M. variabilis* Patch, 1909
1	*Monellia caryella* (Fitch, 1855)
2	*Monelliopsis caryae* Monell in Riley & Monell, 1879; *M. nigropunctata* Granovsky, 1931
1	*Mordwilkoja vagabunda* (Walsh, 1863)
4	*Myzocallis granovsky* Bondreaux &Tissot, 1962; *M. asclepiadis* (Monell, 1879); *M. punctatus* (Monell in Riley & Monell, 1879); *M. walshii* (Monell in Riley & Monell, 1879)
3	*Myzus certus* (Walker, 1849); *M. persicae* (Sulzer, 1776); *M. lythri* Schrank, 1801
2	*Nearctaphis bakeri* Cowen ex Gillette & Baker, 1895; *N. crataegifoliae* Fitch, 1851
1	*Neoprociphilus aceris* (Monell, 1882)
1	*Pachypappa pseudobyrsa* (Waslh, 1863)
1	*Paducia antennata* (Patch, 1913)
2	*Pemphigus monophagus* Maxson, 1934; *P. populitransversus* Riley in Riley & Monell, 1879
2	*Phorodon cannabis* Passerini, 1860; *P. humuli* (Schrank, 1801)
6	*Prociphilus americanus* (Walker, 1852); *P. caryae* (Fitch, 1856); *P. erigeronensis* (Thomas, 1879); *P. fraxini* (Fabricius, 1777); *P. longianus* Smith, 1974; *P. pergandei* Smith, 1974
3	*Protaphis debilicornis* Gillette & Palmer, 1929; *P. knowltoni* Hottes & Frison, 1931; *P. middletonii* Thomas, 1879
2	*Protopterocallis fumipenellus* Fitch, 1855; *P. pergandei* Bisell, 1978
1	*Pterocallis alnifoliae* (Fitch, 1851)
1	*Pterocomma smithiae* (Monell, 1879)
2	*Rhopalomyzus lonicerae* (Siebold, 1839); *R. poae* (Gillette, 1908)
2	*Rhopalosiphoninus staphyleae* (Koch, 1854); *R. latysiphon* (Davidson, 191
6	*Rhopalosiphum cerasifoliae* Fitch, 1855; *R. insertum* Walker, 1849; *R. maidis* (Fitch, 1856); *R. nymphaeae* (Linnaeus, 1761); *R. padi* Linnaeus, 1758; *R. rufiabdominale* Sasaki, 1899
2	*Schizaphis graminum* (Rondani, 1852); *S. minuta* (van der Goot, 1917)
2	*Schizolachnus curvispinosus* Hottes, Essig and Knowlton, 1954; *S. piniradiatae* (Davidson, 1909)
1	*Shivaphis celti* Das, 1918
2	*Sipha elegans* Del Guercio, 1905; *S. flava* (Forbes 1884)
1	*Sitobion avenae* (Fabricius, 1775)
2	*Tetraneura ulmi* (Linnaeus, 1758); *T. nigriabdominalis* (Sasaki, 1899)
2	*Therioaphis trifolii* (Monell, 1882); *T. riehmi* (Börner, 1949)
2	*Tinocallis saltans* (Nevsky, 1929); *T. ulmifolii* (Monell in Riley & Monell, 1879)
1	*Trama rara* Mordvilko, 1908
1	*Tuberculatus annulatus* (Hartig, 1841)
1	*Tuberolachnus salignus* (Gmelin, 1790)
13	*Uroleucon erigeronense* (Thomas, 1878); *U. gravicorne* Patch, 1919; *U. luteolum* Williams, 1911; *U. ambrosiae* Thomas, 1878; *U. leonardi* Olive, 1965; *U. nigrotuberculatum* Olive, 1963; *U. pieloui* Richards, 1972; *U. pseudoambrossiae* Olive, 1963; *U. sonchellum* Monell in Riley & Monell, 1879; *U. sonchi* Linneus, 1767; *U. helianthicola* Olive, 1963; *U. illini* Hottes & Frison, 1931; *U. taraxaci* (Kaltenbach, 1843)

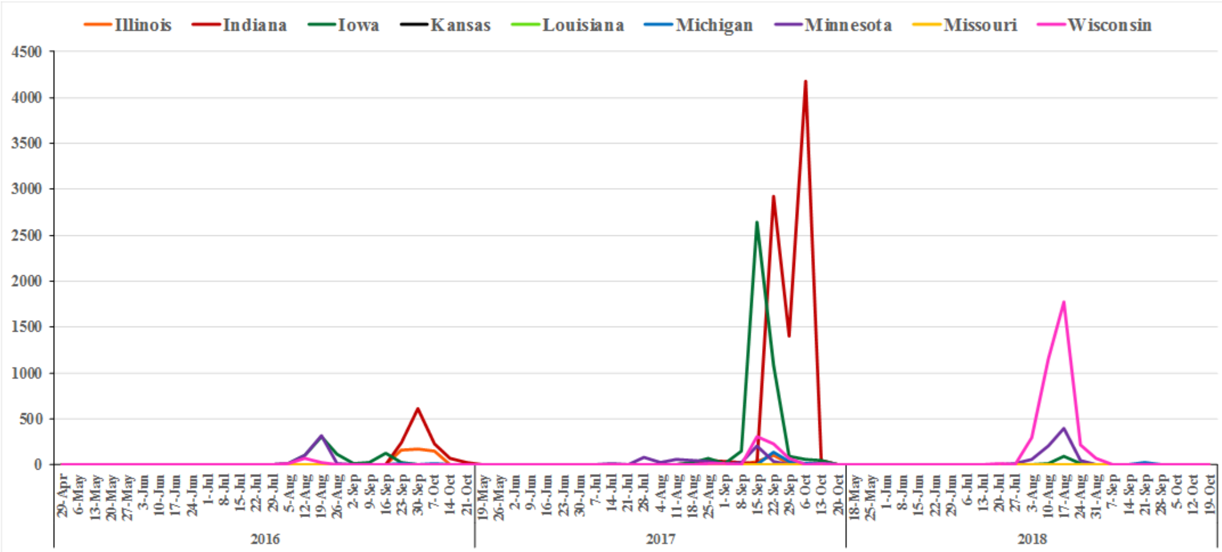


Fig. 1. Seasonal population dynamics of soybean aphids, *Aphis glycines*, captured in the suction trap network between 2016 and 2018. The Y axis corresponds to the number of soybean aphids per state.

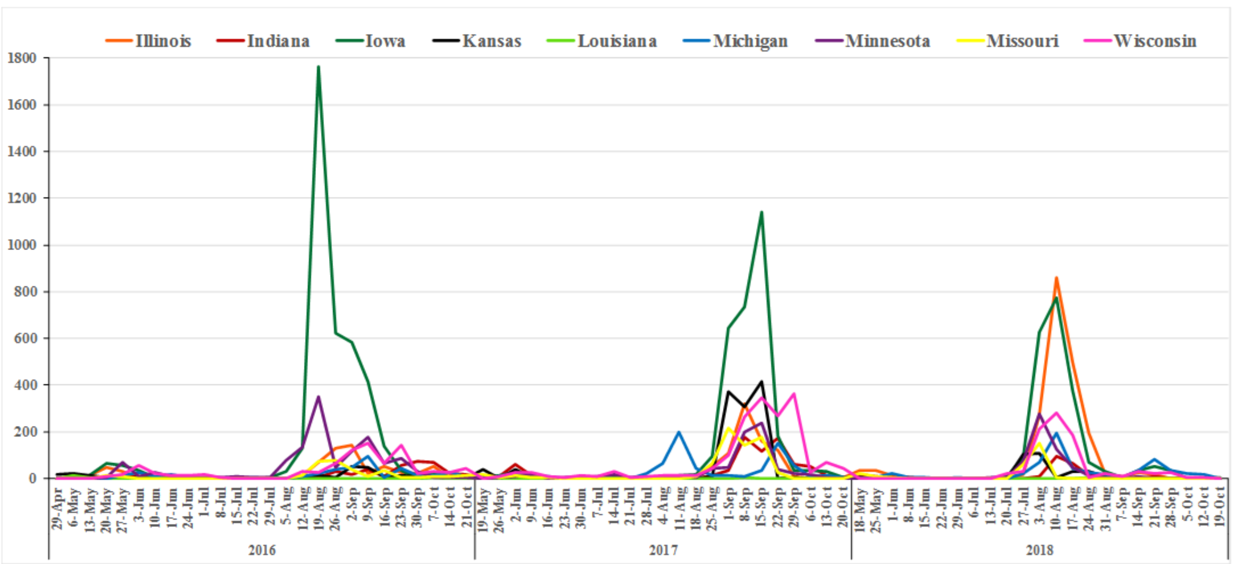


Fig. 2. Seasonal population dynamics of bird cherry-oat aphid, *Rhopalosiphum padi*, captured in the suction trap network between 2016 and 2018. The Y axis corresponds to the number of bird cherry-oat aphids per state.

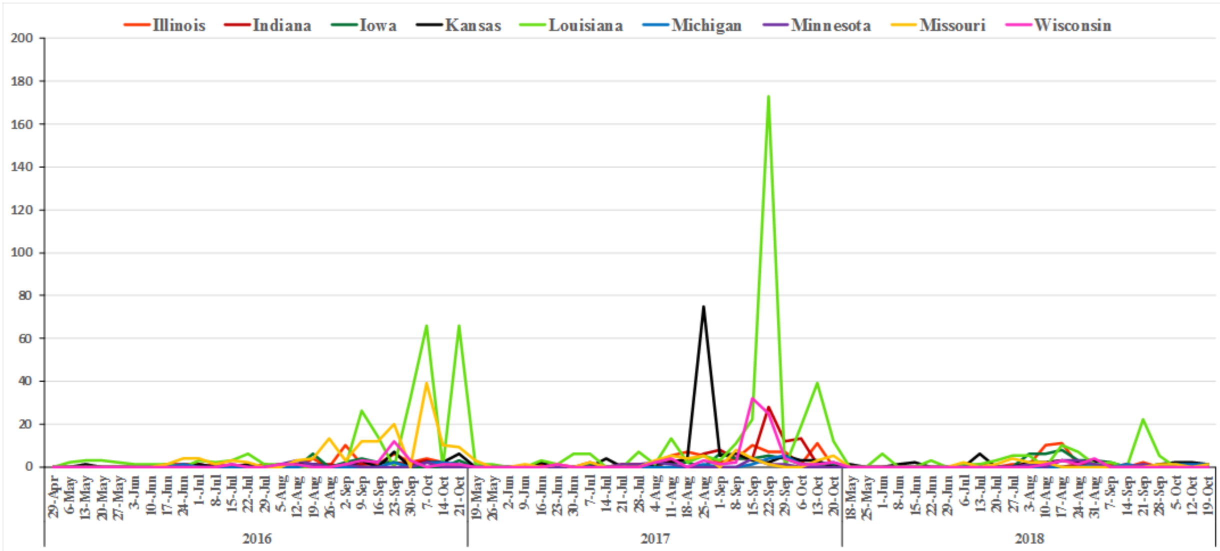


Fig. 3. Seasonal population dynamics of rice root aphid, *Rhopalosiphum rufiabdominale*, captured in the suction trap network in 2018. The Y axis corresponds to the number of rice root aphids per state.

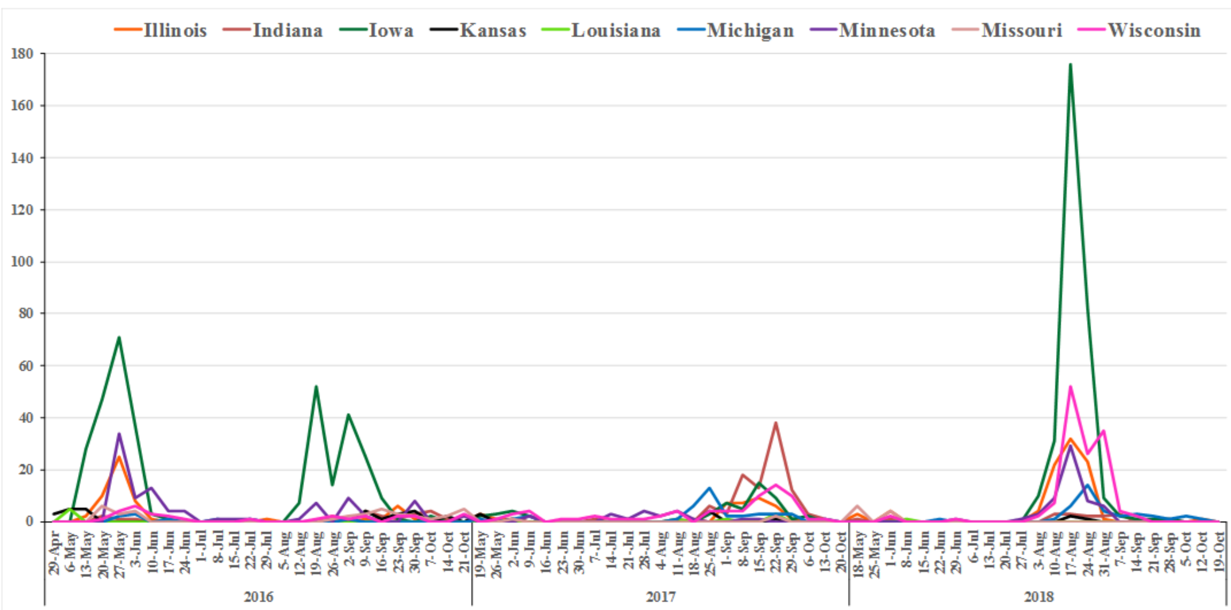


Fig. 4. Seasonal population dynamics of greenbug aphid, *Schizaphis graminum*, captured in the suction trap network between 2016 and 2018. The Y axis corresponds to the number of greenbug aphids per state.

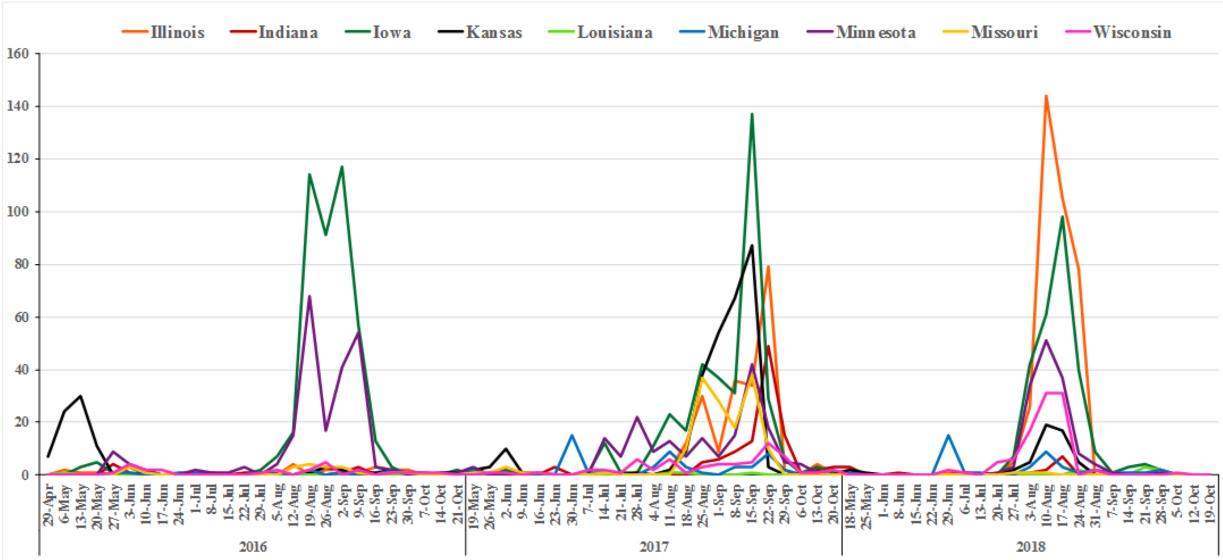


Fig. 5. Seasonal population dynamics of English grain aphid, *Sitobion avenae*, captured in the suction trap network between 2016 and 2018. The Y axis corresponds to the number of English grain aphids per state.

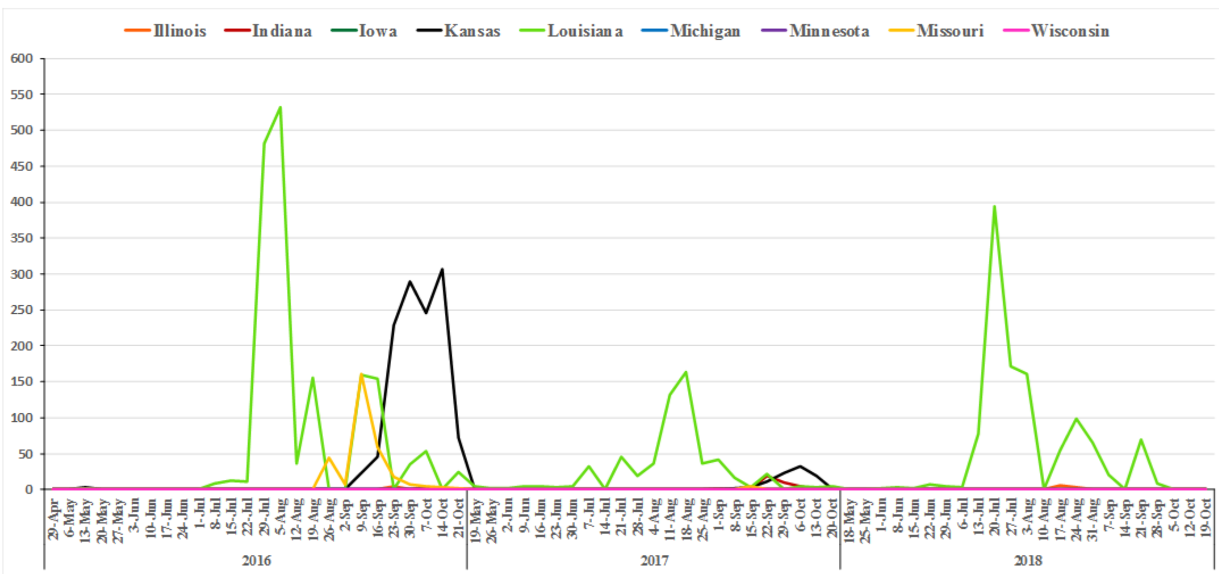


Fig. 6. Seasonal population dynamics of sugarcane aphid, *Melanaphis sacchari*, captured in the suction trap network between 2016 and 2018. The Y axis corresponds to the number of sugarcane aphids per state.

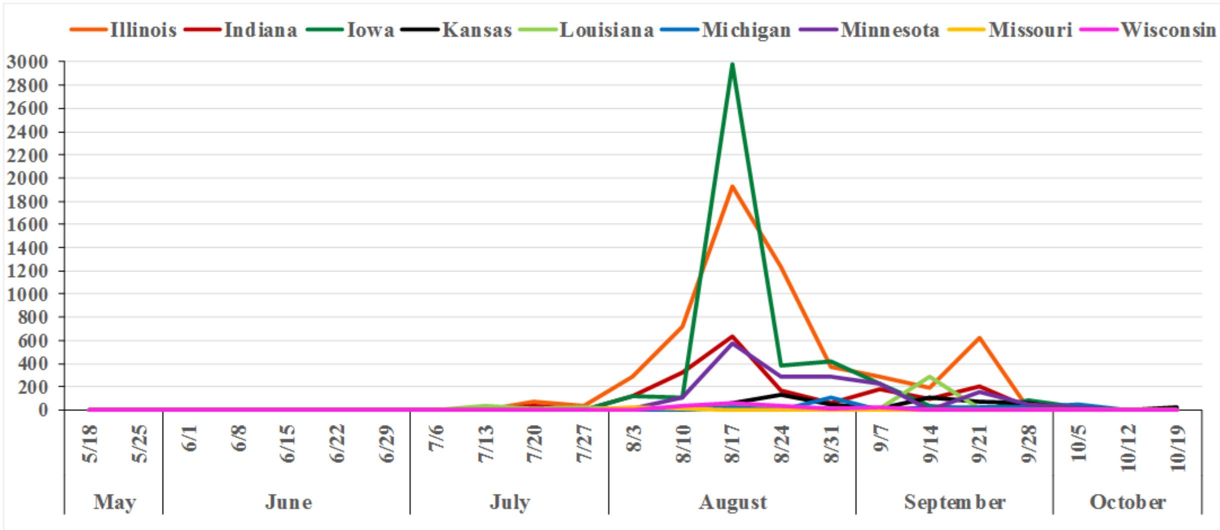


Fig. 7. Seasonal population dynamics of soybean thrips, *Neohyadatothrips variabilis*, captured in the suction trap network in 2018. The Y axis corresponds to the number of soybean thrips per state.

Thrips Monitoring (a Vector of Soybean Vein Necrosis Virus)

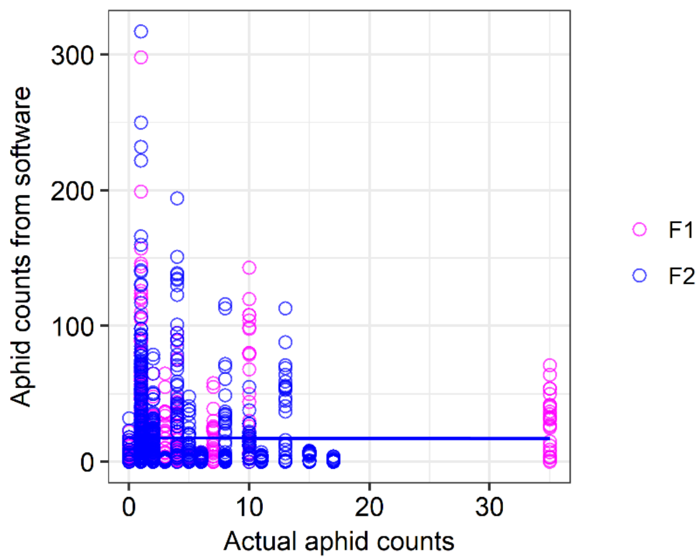
Season-long surveys were conducted using suction traps to determine timing and intensity of thrips vectors of Soybean vein necrosis virus (SVNV) across the mid-western states in 2016, 2017 and 2018. The samples were obtained from the North Central Regional Soybean Aphid Suction Trap Network and shipped to our laboratory from University of Illinois, Urbana-Champaign. Suction trap contents were filtered, and adult thrips were sorted under a dissection microscope. Identification of thrips species was performed using published keys based on morphological characteristics. The states that were included in our analyses are: Illinois, Indiana, Iowa, Michigan, Minnesota and Wisconsin. In 2016 and 2017, Illinois, Indiana, and Iowa had the highest thrips population in all three years, with thrips being detected as early as May in these states. Peak activity was usually observed in August and the populations start to decline in September. We are in the process of completing counting and identification for 2018 samples, but preliminary data suggests similar trends as the previous years. All three thrips vectors of SVNV were identified including soybean thrips, flower thrips and tobacco thrips. The most abundant species was flower thrips followed by soybean thrips. While both can transmit the virus, soybean thrips is the primary vector. We did not monitor SVNV incidence in any of the states because no samples were received, except for Indiana. In Indiana, SVNV was observed during late-reproductive growth stages (R5-R6), which coincided with peak activity for the vectors. Results from this study provides new information about thrips activity in the North Central states and can help inform SVNV epidemiology in the region.

Project 5. Technology development. Participants: Brian McCornack* (Kansas State University), with cooperation from other entomology team members. *Project leader

Performance indicators for smartphone-based estimation alogorithm included a refinement of the original sampling algorithm, collection of additional images (approx. 6400) from different device types (3 total). All aphid pictures captured during this project were manually counted, processed and statistically analyzed. The following factors were compared within and across four fields in two states (Iowa and Minnesota): leaflet position (newly expanded node, and mid- and low-canopy leaflets), sensor type, sensor distance from leaflet (8 to 12 cm), and background color (white, black, and green). Both sensor type and sensor distance varied slightly within fields, but responses were inconsistent between states; aphid density was low in Iowa and higher in Minnesota. In general, our algorithm grossly underestimates aphid counts when under high densities (>50 per leaflet) but overestimates when aphid density is low (<10 aphids per leaflet), which also varied by leaflet position (Fig. 1). There was a very weak relationship between manual aphid counts and aphids counted by our algorithm in sites one and two (Fig. 2). Following the output of over and underestimated aphid numbers on leaflets by our algorithm, we tested the effect of aphid density on accuracy in aphid density estimates. There was a significant but very weak linear relationship between manual aphid counts and aphids counted by our algorithm in sites three and four (Fig. 3). These data show that the current alogrithm overestimates when actual aphid numbers are low (Fig. 2) and underestimates aphids on leaflets when actual aphid numbers are much higher (Fig. 3). Overall, background color and distance of the sensor from the leaflet did not influence accuracy of estimations. Future experiments should include testing the affect of aphid density on accuracy and revising the detection algorithm to adjust counts based on low or high aphid estimates using unsupervised machine learning techniques and other open-source software used for quantitive analysis of biological images.

myFields.info is designed to house integrated Extension information that is dynamic in nature (see http://myfields.info/schematic), where we've included interactive tools and resources that link information from different departments together (see http://myfields.info/features for a current list of features). Key tools include *Diagnostic Guides, Herbicide Selection, Pest Scouting*, among others. In addition, the site allows the user to create a free account in order to customize their experience in terms of the types of crop information they are most interested in. Soybean herbicide and insecticide options were updated annually to reflect current performance ratings and application recommendations. This feature allows the a farmer or consultant to view pesticide performance ratings (where available), recommendations, specimen labels, and crop tolerance ratings filtered by selections of crop type, application type, and pest type. The insecticide option for soybean was updated to reflect the recommendations provided by 2018 KSU Entomology Insect Management Guides. This feature allows the site visitor to see recommended insecticides and rates filtered by selections of crop type and arthropod pest. In addition, a new feature of the tool is the display of mode of action (MOA) alongside all insecticides, so that the site visitor can see all available MOAs within that insecticide recommendation. Associated wording explains the importance of rotating MOA to maintain efficacy of products and avoiding resistance events.

We also digitized the Speed Scouting sampling method to provide real-time decisions for managing soybean aphid in soybean; note, a user must be registered to view and use this tool, but is free for all current users. A binomial sequential sampling plan called "Speed Scouting" was developed for soybean aphid (Hodgson et al. 2004) and we incorporated this decision tool into the digital Pest Sampler on myFields to help farmers make treatment decisions in the field. Key sampling steps for soybean aphid in the Pest Sampler include: A) a description of the sample method, B) user input on how many plants are infested with soybean aphid, and C) a final report showing the treatment recommendation and a record of inputs during the sample event (Fig. 4). Future iterations could populate a soybean aphid distribution map through existing webservice from myFields to EDDSMapS.org; which aggregates verified data from multiple sources for a robust distribution map on a national scale. By integrating the sampling method into the site, we can now direct site vistors to management information (i.e., Insecticide Selector) if populations require intervention.



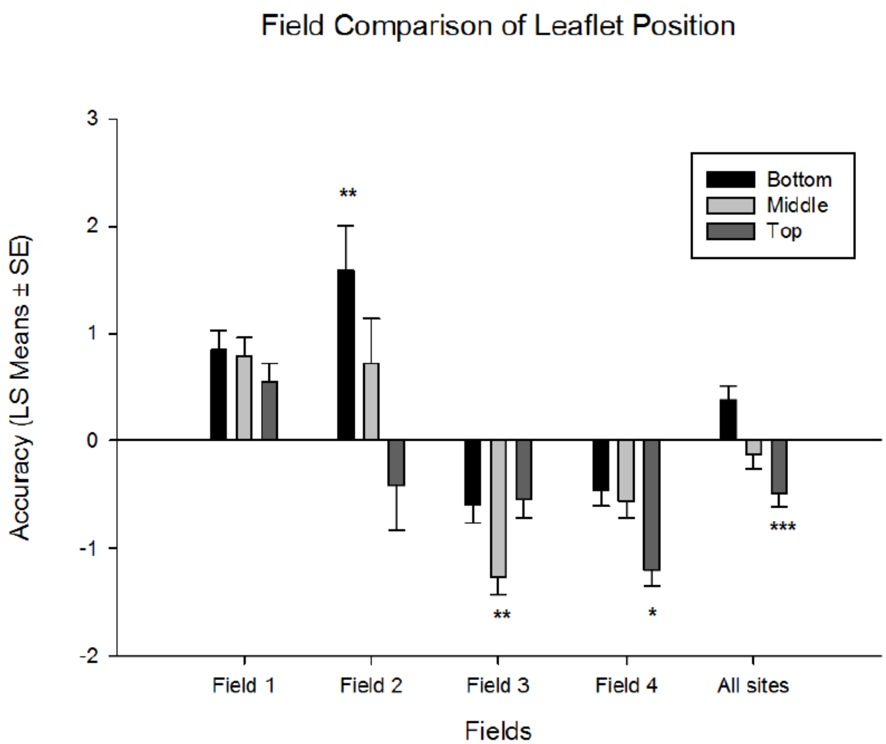


Figure 1. Field comparison of leaflet position. An accuracy of "0" equates to the algorithm estimate equaling the actual number of aphids counted manually an image. All statistical comparisons are within a given field. P-values represented by stars are for comparisons made within field. No star means not significant, * <0.05, ** <0.01, *** <0.001. Statistical model run using R statistical program is m1 <- lmer (accuracy.LRR ~ field * sensor * background * distance * leaf + (1|plant.id/leaf.id), data, REML = TRUE).

Figure 2. Relationship between manual and software counted aphids in fields 1 & 2

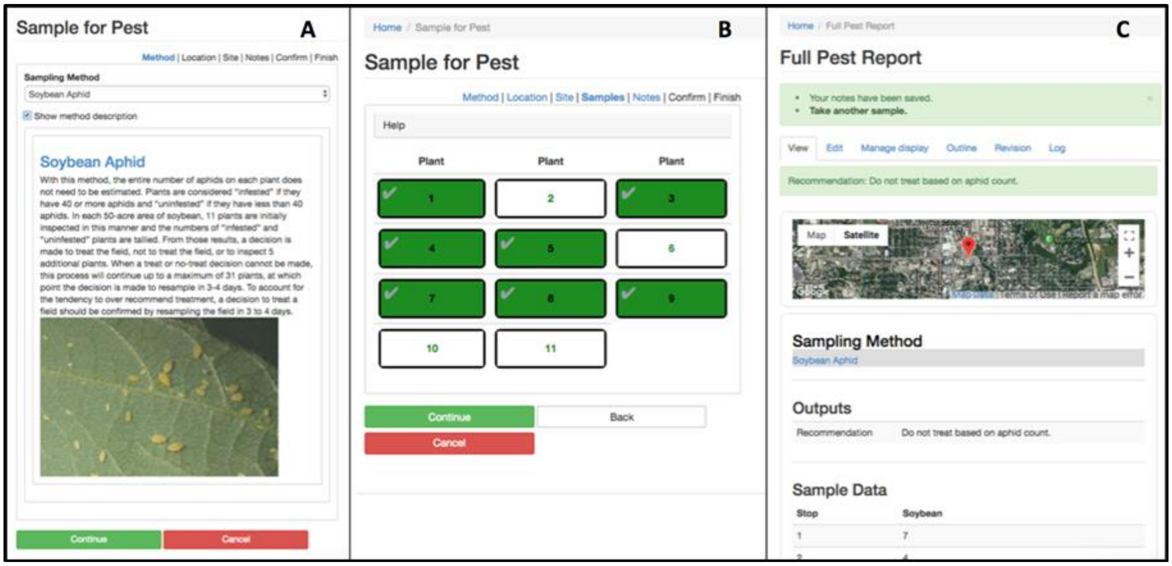
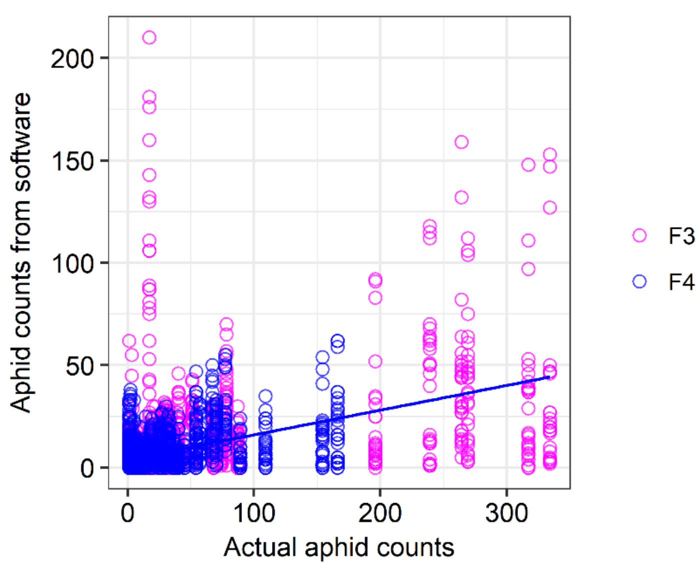


Figure 4. Key sampling steps for soybean aphid in the myFields.info Pest Sampler include: A) a description of the sample method, B) user input on how many plants are infested with soybean aphid, and C) a final report showing the treatment recommendation and a record of inputs during the sample event

Figure 3. Relationship between manual and software counted aphids in fields 3 & 4



Program Area III. Resistant Varieties and Biotypes

Project 1. Breeding for resistant varieties. Participant: Brian Diers (University of Illinois)

During the period of the grant, breeding activities focused on the objectives of developing backcross lines that carry combinations of five aphid resistance genes and developing high yielding varieties that are aphid resistant. In the development of backcross lines, we are combining the aphid resistance genes *Rag1, Rag2, Rag3, Rag4* and *Rag6* into two different genetic backgrounds and then developing isolines that have all combinations of these genes. These lines will be useful for studying the effectiveness of different combinations of these resistance genes for protecting plants from aphid infestations in both field and greenhouse studies.

The development of the isolines was initiated with previous NCSRP funding. With that funding, the genes *Rag1*, *Rag2* and *Rag3* were backcrossed into the backgrounds of the MG I variety Titan and the MG II variety LD02-4485. During the recently completed three-year project, we backcrossed both *Rag4* and *Rag6* into the two backgrounds. In each background, four backcrosses were completed, the genes *Rag4* and *Rag6* were combined through crossing and selection, and then crossed with backcross lines that carry *Rag1*, *Rag2* and *Rag3*. We are now growing in the greenhouse plants that were selected for different combinations of the five genes. These plants are still not homozygous for all five genes and we will plan to grow plants during the spring in the greenhouse that will be selected to be homozygous for all five genes. During the summer, the homozygous selected lines will be grown in the field. Developing lines with all combinations of the genes is difficult because there are 32 combinations of the five genes that need to identified and selected.

Progress has been made to develop high yielding varieties that carry *Rag1*, *Rag2* and the pyramid of the two genes (*Rag1+Rag2*). There have been releases of varieties that have each gene alone or the two-gene combination. A company that sells varieties from the University of Illinois is currently producing seed of one variety with *Rag1+Rag2*, a second with *Rag1*, and a third with *Rag2*.

Project 2. Aphid virulence genotyping and mapping. Participants: Andy Michel* (Ohio State University)*, Glen Hartman and Doris Lagos-Kutz (USDA-ARS at University of Illinois) *Project leader

Virulence Mapping. Our goal of understanding soybean aphid virulence involved several objectives. First, we sequencing the entire soybean aphid genome. The availability of genomic resources is important to establish effective and sustainable pest control and will provide for a genetic foundation for future studies (i.e. insecticide resistance). Using a hybrid-platform sequencing approach, we sequencing 302.9 Mbp, which represented 95.5% of the predicted genome size of 317.1 Mbp based on flow cytometry. The genome is mostly complete, with 19,182 predicted genes, 92% of known Ap. glycines transcripts mapping to contigs, and substantial continuity with a scaffold N50 of 174,505 bp. At the time of publication, the soybean aphid genome was the 4th aphid genome published, and the smallest known aphid genome. The genome is publically available at AphidBase (https://bipaa.genouest.org/is/aphidbase/).

Second, we compared gene expression among virulent and avirulent biotypes using RNA-Sequencing. We identified several effector proteins with decreased expression in the virulent aphids. Aphids use effector proteins to block or evade plant defenses. In this case, the virulent aphid may not express or include a certain effector in their saliva which a soybean plant uses to recognize aphid attack. Further work is ongoing to identify which effector is likely involved in virulence adaptation. Additionally, we determined that the virulent aphid expresses more transposable elements (TEs). TEs are genes that move and re-insert themselves across genomes, and have been known to be both disruptive as well as facilitate non-genetic adaptation (e.g. epigentically based).

Third, we crossed avirulent and virulent soybean aphids to determine heritability and to map the virulence trait. Unexpectedly, we observed segregation distortion in which both the trait and the molecular markers we used did not follow Mendelian segregation. Our data suggests that perhaps other or additional mechanisms (e.g. epigenetics) may be involved in soybean aphid virulence.

Aphid biotypes. Colonies of four known soybean aphid biotypes are maintained at the USDA-ARS laboratory located the National Soybean Research Center at the University of Illinois. Soybean aphid biotype 1 and biotype 2 are from Illinois and Ohio, respectively. Soybean aphid biotype 3 is from Indiana and soybean aphid biotype 4 is from Wisconsin. All biotypes are reared in square BugDorm-44545 insect cages that are: 47.5x47.5x47.5 cm (MegaView Science Co., Taichung, Taiwan) in isolated plant tissue-culture chambers (Percival, TC-2) set at 23°C constant temperature, and a photoperiod of 16 h per day. Each biotype was reared as follows: biotype 1 on Williams 82, biotype 2 on LD10-5903a (*Rag1*), biotype 3 on LD08-12435a (*Rag2*) and biotype 4 on LD12-12734a (*Rag1/Rag2*) (Table 1). Between 2016 and 2018 these clones have been shared with multiple researchers. For example, in 2018 a colony of biotype 2 was sent to Jonathan LaMantia, USDA-ARS and The Ohio State University, and the four soybean aphid biotypes were sent to Brad Coates, USDA-ARS and Iowa State University.

Evaluation of soybean aphid virulence. The objective was to evaluate the virulence of field collected soybean aphid clones on soybean genotypes with known *Rag* genes. Fourteen aphid clones collected on soybean and buckthorn (*Rhamnus cathartica* L.) plants in 2015 and 2017, along with four known aphid biotypes (from stock cultures) were evaluated in no-choice assays (Table 2). Aphid virulence was determined by quantifying the number of aphids on soybean genotypes with *Rag* genes and the susceptible cultivar Williams 82. No-choice assays were conducted using detached leaves (experiments 1 and 2) and whole plants (experiments 3 and 4). Statistical analyses were performed in JMP Pro 13 (SAS Institute, Cary, NC). Expected interaction between soybean genotypes and known aphid biotypes was found in the whole plant assays (Fig. 1) but not in the detached leaf assays (Fig. 2). None of the biotypes and field clones from Illinois, Indiana and South Dakota overcame the resistance of soybean PI437696 (Fig. 3). A soybean aphid clone from Wooster, Ohio was identified as a variant of biotype 4 without the virulence on LD14-8008 soybean with *Rag2/3*.

Evaluation of soybean resistance. The objectives were to characterize the resistance expressed in five soybean plant introductions (PIs) to four soybean aphid biotypes, determine the mode of resistance inheritance, and identify markers associated with genes controlling resistance in these accessions. Five soybean PIs, from an initial set of 3000 PIs, were tested for resistance against soybean aphid biotypes 1, 2, 3, and 4 in choice and no-choice tests. Of these five PIs, PI 587663, PI 587677, and PI 587685 expressed antibiosis against all four biotypes, while PI 587972 and PI 594592 expressed antibiosis against biotypes 1, 2, and 3. F2 populations derived from PI 587663 and PI 587972 were evaluated for resistance against soybean aphid biotype 1, and populations derived from PIs 587677, 587685, and 594592 were tested against biotype 3. In addition, F2:3

plants were tested against biotypes 2 and 3. Genomic DNA from F2 plants was screened with markers linked to *Rag1*, *Rag2*, *Rag3*, and *rag4* soybean aphid resistance genes. Results indicated that PI 587663 and PI 594592 had three resistance genes located in the *Rag1*, *Rag2*, and *Rag3* regions, PI 587677 and PI 587685 had two resistance genes located in the *Rag1* and *Rag2* regions, and PI 587972 had one resistance gene located in the *Rag2* region. The multi-biotype aphid resistance and information on resistance gene markers will be useful to improve soybean aphid resistance in soybean.

Project 3. Aphid virulence management for resistant varieties. Participants: Matt O'Neal* and Jessica Hohenstein (Iowa State University), Andy Michel* and Kelley Tilmon (Ohio State University), Deirdre Prischmann (North Dakota State University), Bruce Potter (University of Minnesota), Louis Hesler (USDA-ARS), Adam Varenhorst (South Dakota State University) *Project leaders

Aim: **Determine if fields with "refuge-in-a-bag" protect yield while producing a higher proportion of avirulent aphids than all-resistant fields.**

Materials and Methods

Design

With funding from the North Central Soybean Research Program, we conducted a multi-state evaluation of the "refuge-in-a-bag" strategy for inclusion of a susceptible refuge in 2017 and 2018. We compared two refuge proportions (10% and 25% susceptible, "S") with 100% S and 100% resistant (*Rag1/Rag2*) fields (hereafter called 0% S) in their ability to protect yield and produce avirulent aphids. The experiment was planted as a randomized complete block design at a total of eight location-years: Iowa (ISU), Ohio (OSU), and South Dakota (SDSU) in 2017 and 2018 and modified designs were planted in Minnesota (MN; smaller plot size) and North Dakota (NDSU; reduced number of replicate blocks) in 2018. Some location-years included a split-plot insecticide treatment to estimate yield loss from aphids and the effect of genetic differences on seed yield in an aphid-free environment. Aphids were scouted weekly from June to September.

Determination of late-season aphid virulence profiles

To determine if fields with interspersed refuge plots produced a higher proportion of late-season avirulent aphids compared with all-resistant fields, 10 leaves with aphids were collected from each of the ISU-2018 and OSU-2018 "No Insecticide" plots of each refuge treatment at the R5 growth stage. A single aphid was isolated from each field-collected leaf and the aphid was infested onto a *Rag1/Rag2* variety. Seven days after infestation, survival of the aphid's lineage and number of aphids on each plant (reproduction) were quantified.

Results and Discussion

Cumulative aphid days

The economic injury level (EIL; ~5,500 CAD) was not reached at any of the eight location-years except ISU-2017 (Figure 1). OSU-2017 CAD was not calculated due to extremely low aphid populations. Despite generally low aphid populations, there were significant differences among the refuge mixes at the seven location-years that experienced measurable aphid pressure (IA-2017: $F_{3,24}$=39.02; P<0.0001; SD-2017: $F_{3,12}$=39.19; P<.0001; IA-2018: $F_{3,24}$=24.74; P<0.0001; SD-2018: $F_{3,12}$=38.7; P<0.0001; OH-2018: $F_{3,24}$=82.49; P<0.0001; MN-2018: $F_{3,12}$=43.38; P<0.0001; ND-2018: $F_{3,16}$=20.79; P<0.0001). Aphid populations varied with the proportion of susceptible seed. For each location-year, the 100% S treatment experienced the highest aphid exposure and CAD generally decreased as the amount of susceptible seeds in the mixture decreased. The 100% S treatment experienced significantly higher aphid exposure than the 0% S treatment at all location-years. While plots of 10% S blended refuge experienced significantly higher aphid pressure than 0% S at three of the seven location-years (SD-2017, SD-2018, OH-2018, and MN-2018), plots of the 25% S refuge mix consistently experienced higher CAD across all location-years. Our results indicate that a minimum of 25% susceptible: 75% resistant blend will consistently yield larger pest populations, consistent with refuge requirements.

Yield

There was no effect of refuge seed mixture, insecticide, or their interaction on seed yield for seven of the eight location-years (Figure 2). NDSU-2018 seed yield was not estimated because plants did not reach physiological maturity before freezing. We saw a significant yield difference among the refuge seed mixtures at SDSU-2018 ($F_{3,12}$=4.26; P=0.0288). However, the low aphid populations at SDSU-2018 were not expected to cause yield losses; the yield pattern was consistent with neither aphid populations nor a yield drag from the *Rag1* or *Rag2* genes. Moreover, when insecticide-treated (aphid-free) plots were compared, we did not detect a yield drag from the pyramided *Rag* genes at any of the location-years that included the insecticide treatment. This suggests that factors other than *Rag* genes or aphid pressure caused yield differences among refuge mixes at SDSU-2018. We also failed to detect yield loss from aphids at any of the location-years, likely due to low aphid populations or in the case of Iowa-2017, the timing of aphid outbreak which occurred at full seed set (R6). In Iowa, insecticide treatments are not recommended for controlling soybean aphids past mid-seed set (R5.5) as there is little evidence that foliar insecticides provide yield protection from aphids past this growth stage.

Determination of late-season aphid virulence profiles

Aphids collected from “No Insecticide” plots from Iowa exhibited survival and reproduction similar to an avirulent (biotype 1) aphid population (Figure 3). Refuge had a significant effect on survival ($F_{3,12}$=3.92, p=0.0365) but not reproduction ($F_{3,12}$=1.66, p=0.2289) of Iowa-collected aphids. Aphids from Ohio exhibited survival and reproduction similar to a virulent (biotype 4) population. Refuge had a significant effect on reproduction ($F_{3,12}$=3.51, p=0.0491) but only a marginally significant effect on survival ($F_{3,12}$=3.19, p=0.0627) of Ohio-collected aphids. However, survival and reproduction of Ohio-collected aphids generally increased as the proportion of susceptible seed mix decreased. Our data suggests that plots with susceptible seeds may produce a higher proportion of avirulent individuals than all-resistant fields. Thus, for locations experiencing virulent soybean aphid populations, inclusion of an interspersed refuge may be a viable resistance management strategy.

Conclusion

Overall, our data suggests that aphid-resistant soybeans blended with a minimum of 25% aphid-susceptible plants could serve as a refuge while still being effective for suppressing aphids in the field. Plots with interspersed refuge may produce a higher proportion of late-season avirulent individuals which is consistent with refuge requirements. Thus, inclusion of an interspersed refuge could be a viable resistance management strategy for soybean aphid.

What does this mean for farmers?

- Addition of susceptible seeds does not alter the ability of *Rag* to provide season-long aphid and yield protection

- Refuge fields produce a higher proportion of avirulent individuals than all-resistant fields
- Going forward, adherence to refuge inclusion could be a viable insect resistance management strategy for the sustainable use of *Rag* traits

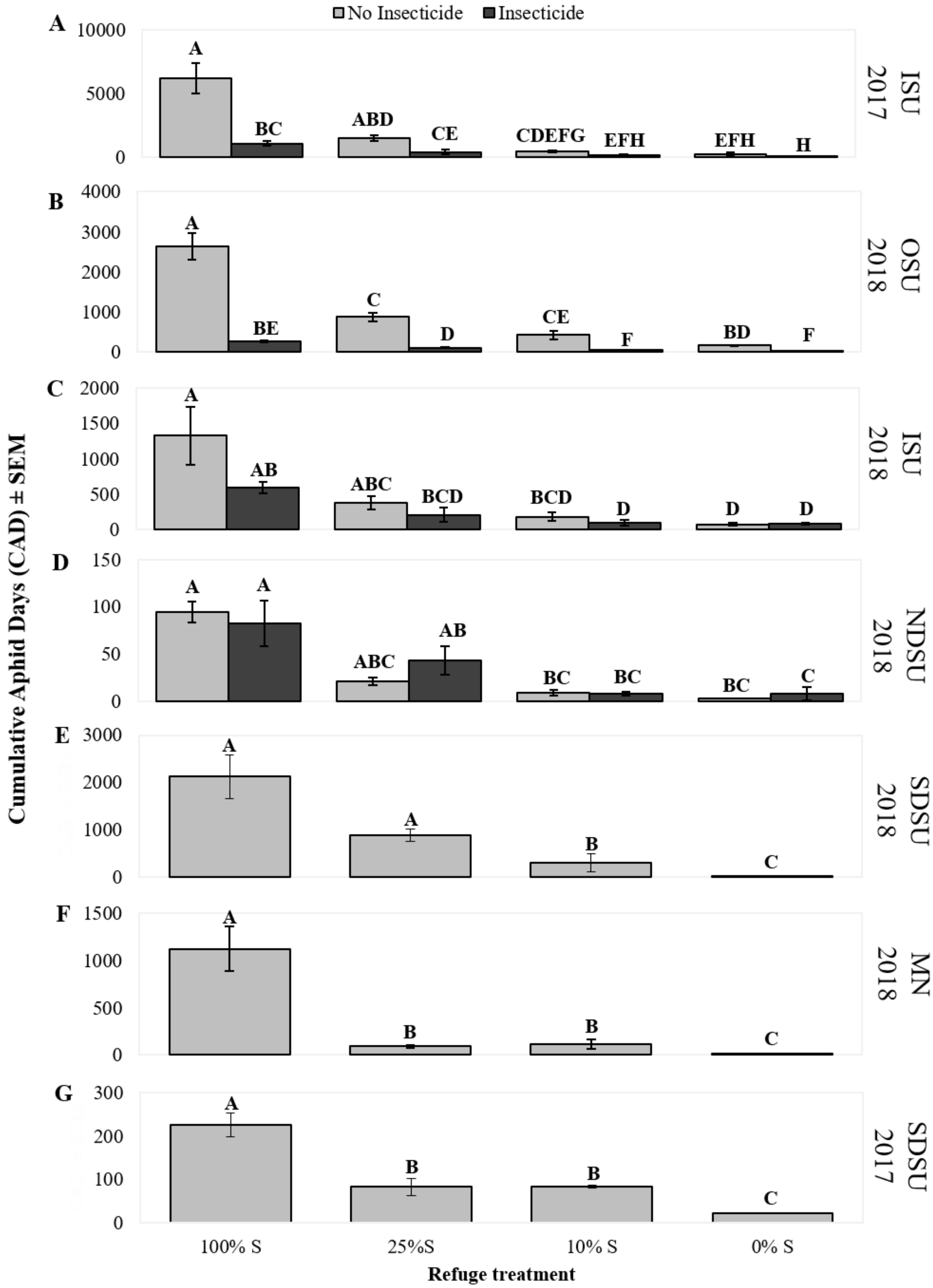


Figure 1. Season-long exposure of plants to soybean aphids for each of four seed mixes based on amount of aphid-susceptible soybean (i.e. refuge) in the mix. Locations including the insecticide treatment split plot (A-D) and those without the split plot (E-G). Different letters indicate significant difference P<0.05 within a location-year. Refuge seed mixture had a significant effect on CAD at all location years that experienced measurable aphid pressure.

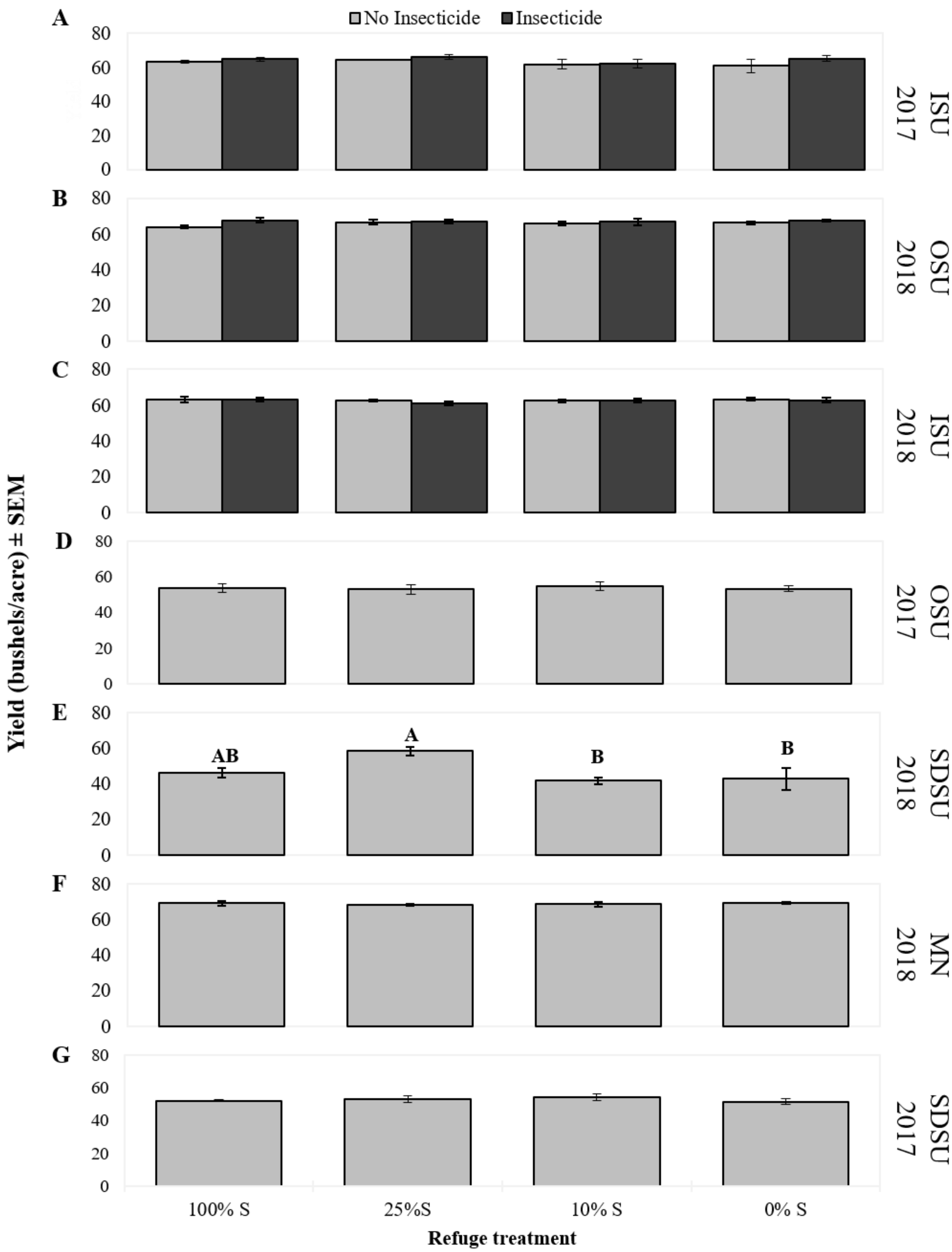


Figure 2. Seed yield for each of four seed mixes based on amount of aphid-susceptible soybean (i.e. refuge) in the mix. Locations including the insecticide treatment split plot (A-C) and those without the split plot (D-G). Different letters indicate significant difference P<0.05 within a location-year. There was no effect of refuge seed mixture, insecticide, or their interaction on seed yield for most location-years except SDSU-2018.

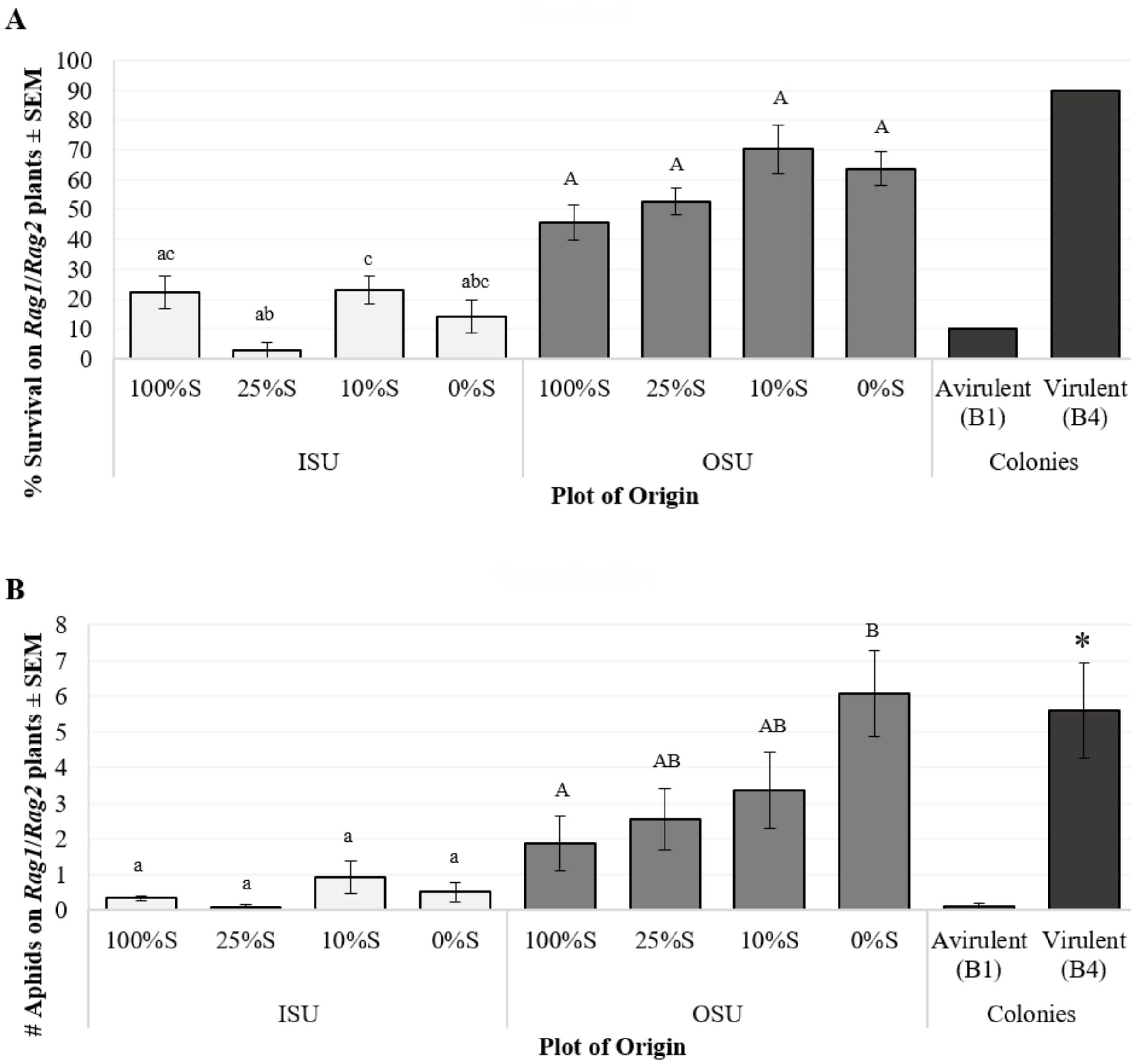


Figure 3. Determination of field-collected and colony aphid virulence. (A) Average survival (%) of infested aphid lineage (B) Aphid population (reproduction) on *Rag1/Rag2* plants 7 days after initial infestation. Different letters indicate significant differences within a location (lowercase-within ISU-2018, uppercase-within Ohio-2018). Only 10 aphids per laboratory colony were assayed and thus there was no repetition for calculating standard errors for survival. Asterisk indicates virulent (B4) colony aphids had significantly higher reproduction than avirulent (B1) colony aphids. Refuge had a significant effect on ISU-2018 aphid survival and OSU-2018 aphid reproduction.

Project 4. Economic returns on resistant varieties. Participants: Erin Hodgson* and Matt O'Neal (Iowa State University) *Project leader

This project is being completed in two parts: a field research component and a computer-based modeling economic analysis. The economic analysis is on-going and currently being refined, but the field research spanned two growing seasons and was completed in 2017.

Field research:
The field research component aimed to compare soybean aphid susceptible and resistant varieties across two locations (one with high aphid populations and one with low aphid populations) and two artificial yield environments (high and low). We measured aphid populations and yield for all varieties, and applied insecticides if populations reached the economic threshold to ensure that yield was protected. With our methods, we were also able to compare resistant varieties and insecticide applications (two management tactics for soybean aphid) at one location. The main conclusions from this research are:

1. No yield differences are expected between susceptible and resistant varieties.
2. Resistant varieties protect soybean plants from soybean aphid colonization, which supports all previous literature.
3. Resistant varieties provide yield protection equal to insecticides in most cases, and sometimes even resulted in higher yields than varieties that received insecticides.

These findings all contributed to enhancing our economic analysis component and building a model that soybean farmers might find useful.

Economic analysis:
The economic analysis component is in progress, but we have been able to make advancements based on price surveys and research. One major finding is that all available soybean aphid resistant varieties for Iowa are either conventional (no herbicide-tolerant traits) or USDA certified organic and do not come with a price increase in comparison to similar susceptible varieties. Since this is the case, our economic analysis focus is to evaluate different scenarios regarding inputs (i.e. management decisions) and issues farmers face throughout the growing season related to the varieties they choose to plant (e.g. scouting for pests, insecticide use, insecticide-resistant soybean aphids, etc.) to aid decision-making for better profitability. We will be computing the probability of profitability for each scenario over a range of soybean prices and yields, performing sensitivity analyses for different inputs, and creating a tool that farmers can use to decide what is best for their farming operation.

Program Area IV. Biological Control (Coordinator: George Heimpel, University of Minnesota)

Project 1. Biological control of soybean aphid using Asian parasitoids. Participants: George Heimpel* (University of Minnesota) and Keith Hopper (USDA-ARS) *Project leader

1. <u>Overwintering of *Aphelinus* parasitoids</u>

To assess the conditions necessary for the successful overwintering of *Aphelinus* parasitoids, we outplanted diapausing mummies of all species in various microhabitats and climatic conditions and measured their survival to adulthood in the spring. During the winter of 2016-17, we placed mummies along a north-south transect in woodlots adjacent to soy fields, either into leaf litter or suspended on buckthorn plants, the overwintering host of soybean aphid. Survival decreased with increasing latitude, and at all sites, survival was higher in the leaf litter than the foliage (Figure 1). During the winter of 2017-18, we placed mummies and temperature loggers at the University of Minnesota Agriculture Experiment Station both into soy fields in the leaf litter and into woodlots in the leaf litter and suspended on buckthorn plants. Again, those mummies placed in the leaf litter survived at much higher rates than those suspended above the snowpack. Of those placed in the leaf litter, mummies in woodlots fared much better than mummies in soy fields (74% *vs* 37%, respectively). In both years, those placed in the leaf litter were subsequently covered by snow. Temperature loggers revealed that mummies under the snow experienced, on average, 3.7°C higher and less variable temperatures than those suspended on branches. Between species, *A. rhamni* had the lowest survival, while *A. certus* and *A. glycinis* were approximately equal. Given that *A. certus* has established in much of the Northern US and Canada, temperature requirements alone cannot explain the apparent failure of *A. glycinis* to establish following multiple releases in Minnesota and Iowa in recent years.

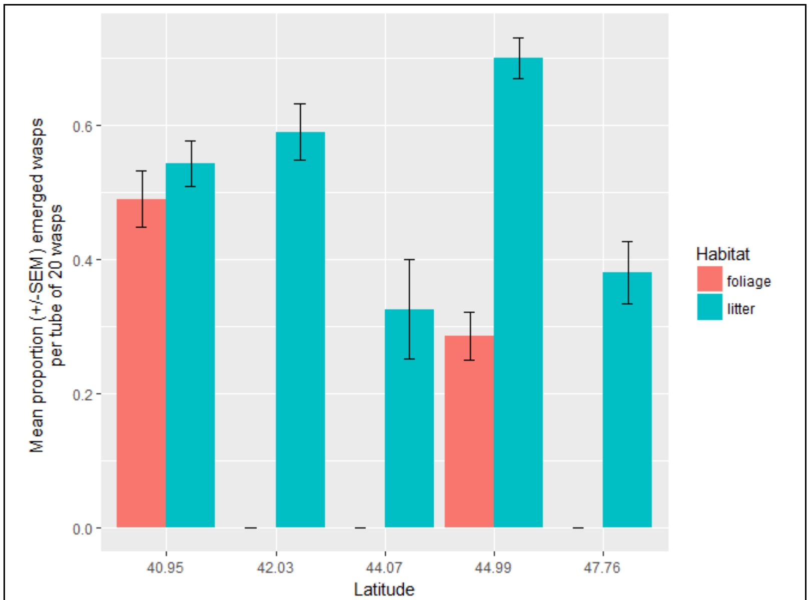


Figure 1. Mean overwintering survival to adulthood of *A. certus* mummies placed in leaf litter and foliage of woodlots adjacent to soy fields along a north-south transect.

To begin to understand the effects of temperature on diapausing *Aphelinus* mummies, we used thermocouple thermometry to measure supercooling points and assess survival after brief exposures to cold temperatures in a laboratory setting. We determined that the supercooling point (freezing point) of *A. certus*, at -28.1°C, is slightly lower than that of *A. glycinis*, at -27.1°C. Survival of parasitoids after cold treatment temperature exposures ranging from -20°C to -30°C was assessed by dissecting a subset one week after cold-exposure and monitoring mummies parasitoid emergence after being placed into spring conditions. By both measures, *A. certus* mummies that froze were much less likely to survive to adulthood, indicating that this species are likely to be freeze-intolerant (Figure 2).

Finally, we have used field surveys to begin to assess whether diapausing *A. certus* remain in soy fields in the fall or follow soybean aphids into buckthorn plots, either inside of winged aphids or independently. Extensive and repeated searches of buckthorn and soy fields in Rosemount and St. Paul, MN during the fall of 2018 revealed a much higher proportion of diapausing mummies in soy fields than on buckthorn plants, suggesting that a significant proportion of *A. certus* wasps attempt to overwinter in soy fields.

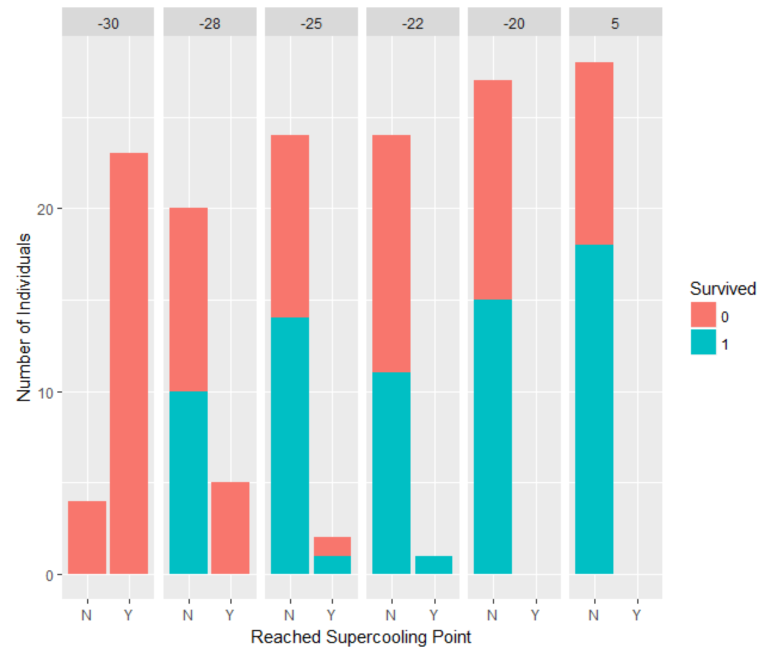


Figure 2. Survival to adulthood of *A. certus* mummies after instantaneous exposure to randomly assigned cold temperatures. Those that reached their supercooling point of approximately -28°C froze, and were much less likely to survive to adulthood, suggesting that this species is freeze-intolerant.

2. Regional survey of parasitoids

We worked with researchers from 12 states in the NCSRP network, and each scouted three times over the summers of 2017 and 2018. They provided information on soybean aphid pressure and the per-plant density of black (*Aphelinus*) parasitoid mummies in each state, and sent samples of black mummies to the Heimpel laboratory at the University of Minnesota for identification. A. certus was found in N. Dakota, Minnesota, Iowa, Illinois, Indiana and Michigan in 2017 and N. Dakota, S. Dakota, Minnesota, Wisconsin, Michigan and Ohio in 2018. Aphid and parasitism levels are shown in Fig. 3. All *Aphelinus* parasitoids were *A. certus*; despite releases in previous years no *A. glycinis* were recovered. However, the native parasitoid *Lysiphlebus testaceipes* was found in Iowa, Indiana, Michigan, and Minnesota during 2017.

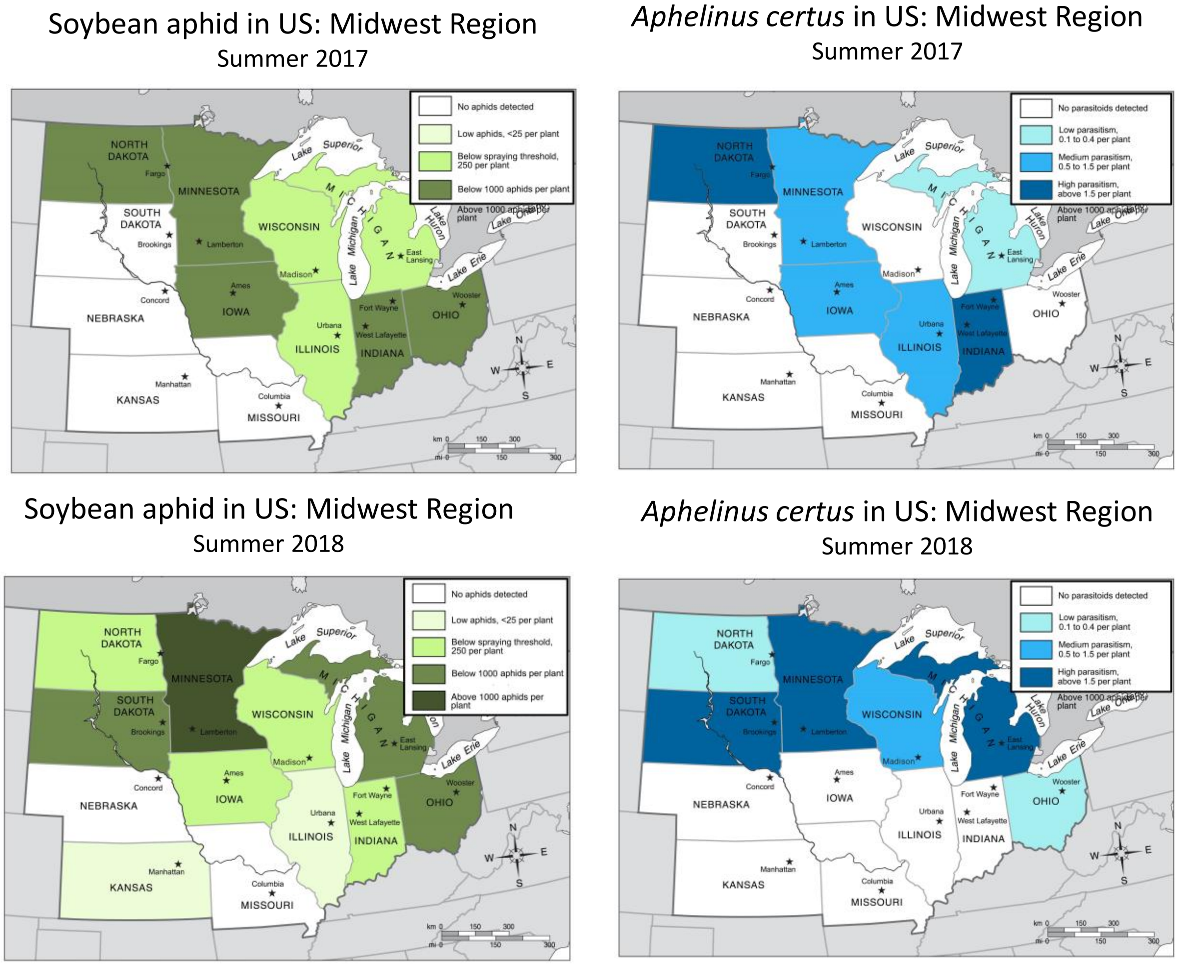


Figure 3. Levels of soybean aphid pressure (left panels) and Aphelinus certus density (right panels) in the North Central Region during 2017 (upper panels) and 2018 (lower panels).

The level of hyperparasitism was relatively high for *Aphelinus* at 17% and included species in the genera *Alloxysta* (Hymenoptera: Figitidae), *Dendrocerus* (Hymenoptera: Megaspilidae), *Asaphes* (Hymenoptera: Pteromalidae), and *Syrphophagus* (Hymenoptera: Encyrtidae) but dropped to 4% in 2018. The genus Alloxysta was the most abundant and included one species (*A. brevis*) that was found to be unisexual (i.e. only females are produced). Hyperparasitoids were found in all states that had *A. glycines*.

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Ribeiro, M.G.P. , T.E. Hunt, B.D. Siegfried, B. Tenhumberg. (*in revision*). Age-specific susceptibility of soybean aphid to thiamethoxam using a detached-leaf bioassay method. Journal of Insect Science.

Tena, A., M. Senft, N. Desneux, J. Dregni & G.E. Heimpel. 2018. The influence of aphid-produced honeydew on parasitoid fitness and nutritional state: a comparative study. Basic and Applied Ecology 29: 55-68.

Tietjen, C.L., T.E. Hunt, D.D. Snow, D. Cassada, and B.D. Siegfried. 2017. Method development for monitoring bean leaf beetle susceptibility to thiamethoxam seed treatments on soybean. Journal of Agricultural and Urban Entomology, 33: 32-43.DOI: 10.3954/1523-5475-33.1.32

Varenhorst AJ, Pritchard SR, O'Neal ME, Hodgson EW, Singh AK. 2017. Determining the Effectiveness of Three-Gene Pyramids Against Aphis glycines (Hemiptera: Aphididae) Biotypes. Journal of Economic Entomology 110 (6), 2428-2435 https://doi.org/10.1093/jee/tox230

Ward, R.A., K.S. Kim, and B.W. Diers. 2017. Yield drag associated with the soybean aphid resistance gene *Rag2* from PI 200538. Crop Sci. 57:3035-3042.

Wheelock, M.J., K.P Rey, and M.E. O'Neal. 2016. Defining the insect pollinator community found in Iowa corn and soybean fields: implications for pollinator conservation. Environmental Entomology. http://dx.doi.org/10.1093/ee/nvw087.

Wenger JA, Cassone B, Cassone BJ, Legeai F, Johnston JS, Bansal R, Yates AD, Coates BS, Pavinato VAC, Michel A. 2017. Whole genome sequence of the soybean aphid, Aphis glycines. Insect Biochemistry and Molecular Biology. doi: 10.1016/j.ibmb.2017.01.005.

Yates AD, Michel AP. 2018. Mechanisms of aphid adaptation to host plant resistance. Current Opinion in Insect Science. Accepted.

Scientific Presentations

Illinois Contributions

Constantinou, S., C. Larson, I. Osei-Bonsu, B. Van Deynze, C. R. Zirbel, D. Lagos-Kutz, and C. A. Bahlai. August 2107. Environmental variation influences aphid community structure over large spatial and temporal scales. Annual meeting of the Ecological Society of America. Portland, Oregon.

Constantinou, S., C. Larson, I. Osei-Bonsu, B. Van Deynze, C. R. Zirbel, D. Lagos-Kutz, and C. A. Bahlai. May 2017. Environmental variation influences aphid community structure over large spatial and temporal scales. Michigan State University's Ecology, Evolutionary Biology, and Behavior Program. First Annual Research Symposium. East Lansing, Michigan.

Diers, B.W. 2018. Effectiveness of Rag gene pyramids in controlling soybean aphid biotypes and can linkage drag between Rag2 and lower yield be broken? Soybean Breeders' Workshop, St. Louis, Mo.

Guidolin, A., V. Pavinato, D. Lagos-Kutz, G. Hartman, and A. P. Michel. November 2017. Association mapping of virulence in soybean aphid (Aphis glycines). Annual Meeting of Entomological Society of America. Denver, Colorado.

Lagos-Kutz, D.M., Halbert, S., Voegtlin, D., Hartman, G.L. September 2016. Revision of the taxonomic status of Aphis floridanae Tissot (Hemiptera: Aphididae). International Congress of Entomology. Orlando, Florida.

Lagos-Kutz, D., D. Voegtlin and G. L. Hartman. June 2016. Monitoring Regional Aphid Movement Patterns in the Midwest. Cleveland, Ohio.

Lagos-Kutz, D., and G. Hartman. February 2018. Midwest Suction Trap Network/Evaluation of soybean aphids to soybean genotypes that contain Rag genes and PI 437696. Soybean Breeders Workshop. St. Louis, Missouri.

Lagos-Kutz, D., R. Bowen, J. Haudenshield, L. Domier, J. Han, M. Pawlowski, and G. Hartman. November 2018. Evaluation of soybean for resistance to soybean thrips, Neohyadatothrips variabilis, infected and non-infected with soybean vein necrosis virus. Vancouver, Canada.

Pavinato, V. A. C., D. Lagos-Kutz, G. Hartman, C. Hill, A. Chirumamilla, and A. P. Michel. September 2016. Characterization of quantitative trait loci associated with soybean aphid adaptation to resistant plants. International Congress of Entomology. Orlando, Florida.

Indiana Contributions

Danielson, J., Loeffler, T., Keough, S., Marshall, J., and Nachappa, P. 2017. Factors Affecting the Population Dynamics of Thrips Vectors of Soybean Vein Necrosis Virus in Indiana. Indiana Academy of Science Annual Meeting. Indianapolis, IN. March 28th.

Danielson, J., Loeffler, T., Keough, S., Marshall, J., and Nachappa, P. 2017. Factors Affecting the Population Dynamics of Thrips Vectors of Soybean Vein Necrosis Virus in Indiana. Indiana University-Purdue University Research and Creative Endeavor Symposium. March 29th.

Nachappa, P., Keough, S., Han, J. 2018. Ecological and molecular mechanisms underlying Soybean vein necrosis virus-thrips interaction. North Central Branch Entomological Society of America Meeting. Madison, WI.

Nachappa, P., Keough, S., Han, J., Lagos, D., and Voegtlin, D. 2016. Factors affecting population dynamics of thrips vectors of Soybean vein necrosis virus in soybean. Research Update from the North Central Soybean Research Program (NCSRP) Symposium. North Central Branch Entomological Society of America Meeting. Cleveland, OH.

Iowa Contributions

Hodgson, E. W., and B. P. McCornack. See the nerd and then be the nerd with a Share Fair. In Symposium: Communicating effectively in extension: addressing new expectations in the learning experience. 66th Annual Entomological Society of America Meeting, Vancouver, BC, Canada, 14 November 2018.

Menger, J., R. Koch, I. MacRae, J. Knodel, B. Potter, P. Glogoza, E. Hodgson, A. Varenhorst, A. Chirumamilla, and J. Gavloski. A diagnostic-concentration, glass-vial bioassay for the rapid monitoring of soybean aphid (Aphis glycines) susceptibility to pyrethroid insecticides. Undergraduate P-IE Student Competition. 66th Annual Entomological Society of America Meeting, Vancouver, BC, Canada, 12 November 2018.

Rodbell, E., E. W. Hodgson, M. Liebman, and M. E. O'Neal. Effect of crop rotation on the population growth rate of soybean aphid. PI-E Student Paper Competition. 65th Annual Entomological Society of America Meeting, Denver, CO, 5 November 2017.

Dean, A., S. Pritchard, M. O'Neal, and E. Hodgson. Optimizing yield environments and soybean genetics for soybean aphid management. PI-E Student Poster Competition. 65th Annual Entomological Society of America Meeting, Denver, CO, 6 November 2017.

Dean, A., S. Pritchard, E. W. Hodgson, and M. E. O'Neal. Optimizing yield environments and soybean genetics for soybean aphid (Hemiptera: Aphididae) management. M.S. P-IE Student Competition. 73rd Annual North Central Branch Entomological Society of America Meeting, Madison, WI, 19 March 2018. *Second place award

Dean, A., S. Pritchard, E. Hodgson, and M. O'Neal. Using soybean genetics to evaluate the value of soybean aphid management tactics. American Society of Agronomy, the Crop Science Society of America, and the Canadian Society of Agronomy Annual Meeting, Baltimore, MD, 6 November 2018. *Third place award

Hohenstein, J., M, Kaiser, K.Tilmon, A.Varenhorst, E. Hodgson, and M.O'Neal. "Refuge in a bag" approach for sustainable management of virulent soybean aphids in the field. 73rd North Central Branch Entomological Society of America Meeting, Madison, WI, 21 March 2018.

O'Neal, M.E., and A. Dolezal. 2018. , Implementing best practices for conserving pollinators in soybeans: what will it help?. South Eastern Branch of the Entomological Society of America. Orlando, FL. 4-7 March, 2018.

O'Neal, M.E., A. Toth, E. Hodgson, H.P. Hendriksma, A. St Clair, G. Zhang, and A. Dolezal. 2018. Can we grow soybeans and protect pollinators while managing invasive pests? (A: maybe). North Central Branch of the Entomological Society of America. Madison, WI.

O'Neal, M.E., A. Toth, A. Dolezal, A. St. Clair, and G. Zhang. Pollinators in Soybean Fields: What are they good for? 71st North Central Branch Meeting, June 5-8, Cleveland, OH.

O'Neal, M.E. Is there a place (and a value) for pollinator conservation in landscapes dominated by annual crops?" Bi-University Guest Seminar Series (BUGSS) at University of Idaho/Washington State University. April 14, Moscow, ID.

Rodbell, E., E. W. Hodgson, M. Liebman, and M. E. O'Neal. Effect of crop rotation on the population growth rate of soybean aphid. M.S. Student Competition. 72nd Annual North Central Branch Entomological Society of America Meeting, Indianapolis, IN, 5 June 2017.

Kansas Contributions

Losey, S. M. and B. P. McCornack. 2016. *Using pictures to estimate soybean aphid densities in soybeans*. Research and the State: K-State Graduate Research, Arts, and Discovery (GRAD) Forum.

McCornack, B. P. Tracking and counting aphids using web-based applications and mobile technologies. Program Symposium: An Integrated Regional Response to an Invasive Aphid Pest of Sorghum. Entomological Society of America, South West Branch Meeting, Tulsa, OK.

McCornack, B P. Insect and ecosystem services—building resistance, resilience and recovery into the farm. In, 2017 Agriculture's Innovative Minds (AIM) Symposium. No-Till on the Plains, Salina, KS.

Minnesota Contributions

Dregni, J. & G.E. Heimpel. Susceptibility of Aphelinus parasitoids to neonicotinoid seed treatments in Minnesota soybean fields. Annual Meeting of the North Central Branch of the Entomological Society of America, Madison, WI, USA. 3/2018

Dregni, J., J.A. Peterson, K. Welch, N. Padowski & G.E. Heimpel. Promoting sustainable biological control of the soybean aphid: the effect of biodiversity, predation, and overwintering on Aphelinus parasitoids in North America. SARE Conference, St. Louis, MO, USA. 4/2018

Dregni, J.S., K. Welch, G.E. Heimpel, J.M. Kaser & P. Glogoza. Biological control of soybean aphid: impacts of neonicitinoid seed-treatments and aphid-resistant soybeans. Upper Midwest Invasive Species Conference. Rochester, MN. Poster presentation. 10/2018

Dregni, J., K. Welch, M. Ferrer-Suay & G.E. Heimpel. Parasitoids in North American soybean fields: The effect of neonicotinoid seed treatments and hyperparasitism on soybean aphid biological control. Poster presentation at the Annual meeting of the Entomological Society of America, Vancouver, Canada. 11/2018

Heimpel, G.. Causes and consequences of fecundity stimulation in aphids as a response parasitism. Keynote address. Ecology of Aphidophaga Conference, Freising, Germany, 8/2016.

Heimpel, G.. Biological control of the soybean aphid. Symposium presentation. Workshop on linkages between soybean aphids and endangered prairie butterflies. Institute on the Environment, St. Paul MN, USA, 11/2016

Heimpel, G. E., K.R. Hopper, J. Kaser, J. Miksanek, M. Bulgarella, I. Ramirez & R.A. Boulton. Parasitoid host ranges: comparing studies from the laboratory and field. Symposium presentation: 5th International Conference on Biological control of Arthropods, Malaysia. 9/2017

Heimpel, G.. Update on biological control of soybean aphid. Crop Pest Management Short Course. Minneapolis, MN, 12/2017

Hopper, K., K. Kuhn, A. Johnson, L. Qiyun, R. Wisser, S. Polson, S. Oppenheim, J. Woolley, J.M. Heraty, V. Gokhman, G.E. Heimpel, D. Voegtlin, K. Lanier, J. Rhoades, R. Kondos, D. Coutinot, G. Mercadier, M. Roche & R. Ramualde. Genetics and evolution of host specificity in aphid parasitoids. Symposium presentation at the Annual meeting of the Entomological Society of America, Vancouver, Canada. 11/2018.

Kaiser, M. & G.E. Heimpel. Transgenerational fecundity compensation in the aphid Aphis craccivora in response to parasitism by two competing parasitoids. International Congress of Entomology, Orlando, FL, USA, 10/2016.

Kaser, J. & G.E. Heimpel. Parasitoid host range, establishment success, and biological control efficacy. Symposium presentation. International Congress of Entomology, Orlando, FL, USA, 10/2016.

Kaser, J., G.E. Heimpel. Evaluating classical biological control benefits and non-target risk: from models to the field. Symposium presentation. Entomological Society of America, North Central Branch meeting, Cleveland, OH, 6/2016.

Kaser, J. J. Dregni, N. Padowski, R. Koch, G.E. Heimpel. Biological control ecology: lessons from introduced soybean aphid parasitoids. Symposium presentation. Entomological Society of America, North Central Branch meeting, Cleveland, OH, 6/2016.

Kaser, J., J. Miksanek & G.E. Heimpel. Cessation of enemy release or continuation of invasion meltdown? The case of soybean aphid and its natural enemies. Symposium presentation at the Annual meeting of the Entomological Society of America, Vancouver, Canada. 11/2018.

Koch, R., J. Menger, I. MacRae, J. Knodel, B. Potter, P. Glogoza, E. Hodgson, A. Varenhorst, A. Chirumamilla, and J. Gavloski. Insecticide resistance in soybean aphid: an emerging challenge in soybean production. 73rd North Central Branch Entomological Society of America Meeting, Madison, WI, 20 March 2018.

Marek-Spartz, M., G.E. Heimpel, R. Becker & K. Marek-Spartz. Generations: Understanding weed-herbivore interactions using Python. Upper Midwest Invasive Species Conference. Rochester, MN. Poster presentation. 10/2018

Miksanek, J. & G.E. Heimpel. Parasitism rate and percent parasitism in stage-classified matrix models: an example of soybean aphid and Aphelinus certus (Hymenoptera: Aphelinidae). Annual Meeting of the North Central Branch of the Entomological Society of America, Indianapolis, IN, USA, 6/2017

Miksanek J.R. & G.E. Heimpel. Evaluating the risks and benefits of Aphelinus certus, an introduced enemy of soybean aphid, in North America: Integrating ecosystem-level effects into the decision-making process. IOBC-WPRS Working Group Meeting [Benefits and risks of exotic BCA]. Ponta Delgada, Açores, Portugal. 9/2018

Miksanek J.R. & G.E. Heimpel. Understanding the theoretical and ecological influence of the parasitoid Aphelinus certus on soybean aphid. Upper Midwest Invasive Species Conference. Rochester, MN. 10/2018

Miksanek J.R., G.E. Heimpel & J. Kaser. Infiltration of native prairie habitat by the Asian parasitoid Aphelinus certus (Hymenoptera: Aphelinidae). Upper Midwest Invasive Species Conference. Rochester, MN. Poster presentation. 10/2018

Pezzini, D.T., D. Finke, T. Hunt, J. Knodel, C.H. Krupke, B. McCornack, A. Michel, C. Philips, A. Varenhorst, R. Wright and R.L. Koch. 2017, November. Influence of field and landscape factors on stink bug (Hemiptera: Pentatomidae) community in North Central soybean. Student competition 10-minute presentation. Meeting of the Entomological Society of America. Denver, CO.

Pezzini, D.T., D. Finke, T Hunt, J. Knodel, C. Krupke, B. McCornack, A. Michel, C.R. Philips, A. Varenhorst, R. Wright, and R.L. Koch. 2017, June. Spatial pattern and sequential sampling plan for stink bugs (Hemiptera: Pentatomidae) for soybean in the north central U.S. Student competition 10-minute paper. Meeting of the North Central Branch of the Entomological Society of America. Indianapolis, IN.

Pezzini, D. and R.L. Koch. 2016, June. Preliminary assessment of a sampling plan for stink bugs in Minnesota soybean. Student competition poster. Meeting of the North Central Branch of the Entomological Society of America. Cleveland, OH.

Pezzini, D.T. and R.L. Koch. 2018, March. Stink bugs in soybean in the North Central Region: Characterization of this emerging pest complex and detection of the invasive, Halyomorpha halys. Symposium talk. Meeting of the North Central Branch of the Entomological Society of America. Madison, WI.

Stenoien C, Christianson, L., Welch K, Hopper, K.R., & Heimpel G.E. The overwintering biology of Aphelinus certus, an adventive parasitoid of soybean aphid. Upper Midwest Invasive Species Conference. Rochester, MN. 10/2018

Stenoien, C., L. Christianson, K. Welch, K. Hopper & G.E. Heimpel. The overwintering biology of Aphelinus certus, an adventive parasitoid of soybean aphid. Oral presentation at the Annual meeting of the Entomological Society of America, Vancouver, Canada. 11/2018

Welch, K. G.E. Heimpel, K.R. Hopper, M.C. Kaiser, M.E. O'Neal. Can aphid-resistant soybean enhance early-season suppression of soybean aphids by Aphelinus wasps? Symposium at the North Central Branch meeting of the Entomological Society of America, Indianapolis, IN, USA, 6/2017.

Nebraska Contributions

Carmargo, C., Siegfried, B., Hunt, T., Giesler, L. J., Hein, G. L. 2015. Residues of thiamethoxam/mefenoxam in soybean plants and potential effects non-target insects. November 16, 2015. Annual Meeting of the Entomological Society of America, Minneapolis, MN.

Marchi-Werle, L., Fischer, H., Hunt, T., Heng-Moss, T., Graef, G. 2015. Integrating plant tolerance into breeding programs for soybean aphid, Aphis glycines Matsumura, management. November 16. Annual Meeting of the Entomological Society of America, Minneapolis, MN.

Ribeiro, M., Siegfried, B., Hunt, T. 2015. Selection for resistance of soybean aphid to the neonicotinoid insecticide thiamethoxam. November 16, 2015. Annual Meeting of the Entomological Society of America, Minneapolis, MN.

Ribeiro, M., Blair Siegfried, Thomas Hunt. 2016. Monitoring for Neonicotinoid Resistance in Soybean Aphid. March 14, 2016. Annual Meeting of the Southeastern Branch of the Entomological Society of America, Raleigh, NC.

Ribeiro, Matheus, Thomas Hunt, Blair Siegfried. 2016. Effects of systemic thiamethoxam exposure on the population dynamics of soybean aphids. September 27, 2016. XXV International Congress of Entomology, Orlando, FL, USA, Sept 25-30. doi: 10.1603/ICE.2016.115302

Baldin, Edson, Mitchell Stamm, José P. G. F. Silva, Kyle G. Koch, Tiffany Heng-Moss, Thomas Hunt. 2016. Feeding behavior of *Aphis glycines* (Hemiptera: Aphididae) on soybeans exhibiting antibiosis and tolerance. September 29, 2016. XXV International Congress of Entomology, Orlando, FL, USA, Sept 25-30. doi: 10.1603/ICE.2016.115154

Hunt, Thomas, Erin Hodgson, and Kelley Tilmon. 2017. Soybean IPM in the Midwest? 2017 Entomological Society of America Southeastern Branch Meeting, Invited, Memphis, TN, March 12 - 15, 2017.

Ribeiro, Matheus, Blair Siegfried and Thomas Hunt. 2017. Age-Specific Susceptibility of Soybean Aphid to Thiamethoxam Using a Detached-Leaf Bioassay Method. Entomological Society of America North Central Branch Meeting, Indianapolis, Indiana, June 04, 2017.

Fanela, T. L. M. (Presenter & Author), Baldin, E. L. L., Luhr, N., Hunt, T. E., 2017. Characterization of larval movement of Spodoptera eridania (Lepidoptera: Noctuidae) in non-Bt soybean. Entomological Society of America Annual Meeting, Denver, CO, November 7, 2017.

North Dakota Contributions

Beauzay, P., J. Knodel, C. Krupke, B. Dennis, D. Finke, D. Hogg, B. Jensen, M. O'Neal, B. Potter, A. Raudenbush, A. St. Clair, K. Tilmon, A. Varenhorst and R. Wright. 2018. Survey of Bees and Syrphid Flies Associated with Flowering Soybean in the Midwestern United States. 9th International IPM Symposium, Baltimore, MD, March 2018.

Beauzay, P., J. Knodel, C. Krupke, B. Dennis, D. Finke, D. Hogg, B. Jensen, M. O'Neal, B. Potter, A. Raudenbush, A. St. Clair, K. Tilmon, A. Varenhorst and R. Wright. 2018. Survey of Bees and Syrphid Flies Associated with Flowering Soybean in the Midwestern United States. SE Branch ESA meeting, Orlando, FL, March 2018.

Knodel, J., and P. Beauzay. 2016. Field Demonstration of Different Insecticide Strategies for Management of Soybean Aphids. XXV International Congress of Entomology, 25-30 September 2016, Orlando, FL.

Menger, J., R. Koch, I. MacRae, J. Knodel, B. Potter, P. Glogoza, E. Hodgson, A. Varenhorst, A. Chirumamilla and J. Gavloski. 2018. A diagnostic-concentration, glass-vial bioassay for the rapid monitoring of soybean aphid (Aphis glycines) susceptibility to pyrethroid insecticides. 2018 ESA, ESC and ESBC Joint Annual Meeting, Vancouver, B.C., Canada, Nov. 11-14, 2018.

Prasifka, P., D. Ruen, R. Koch, B. Potter, E. Hodgson, J. Knodel, and D. Prischmann-Voldseth. 2017. Isoclast™ Active for Management of Soybean Aphid: Application timing, efficacy and yield. 2017 Annual Meeting of the Entomological Society of America. Nov. 4-18, 2017. Denver, CO.

Prochaska, T.J., J. Knodel, P. Beauzay, L. Lubenow, A. Chirumamilla and S. Lahman. 2018. Extending Knowledge, Changing Lives: Insecticide Resistance to Soybean Aphid in North Dakota. 2018 ESA, ESC and ESBC Joint Annual Meeting, Vancouver, B.C., Canada, Nov. 11-14, 2018.

Ohio Contributions

Guidolin A, Lagos-Kutz D, Pavinato VAC, Hartman G, Michel AP. 2017. Association mapping of virulence in soybean aphid (Aphis glycines). Entomological Society of America Annual Meeting, Denver, CO Nov 2017

Michel, A.P. 2016. Microbiomes of Hemipteran Plant Pests. Foundation for Food and Agriculture Research. Tampa Bay, FL

Michel, A.P., Wenger, J., Legeai, F., Bansal, R. et al. (2016). Genome assembly of the soybean aphid (Aphis glycines) via hybrid approach. International Congress of Entomology.

Michel, A.P., Wenger, J.A., Cassone, B.J., Yates, A.D. et al. 2016. From farms to genomes: NCSRP and the soybean aphid genome. Entomological Society North Central Branch Annual Meeting. Cleveland, OH.

Michel, A.P. 2016. Soybean Aphid Adaptation to Aphid-Resistant Soybean. Bowling Green State University. Dept. of Biological Sciences, Seminar Series. Bowling Green, OH

Michel A. Soybean Aphid Adaptation to Aphid-Resistant Soybean. Dept. of Entomology, Iowa State University. Ames, IA. Oct 2017

Michel A. Soybean Aphid Adaptation to Aphid-Resistant Soybean. Dept. of Entomology, University of Nebraska-Lincoln. Lincoln, NE. Nov 2016

Pavinato, V. D Lagos-Kutz, G Hartman, C Hill, A Chirumamilla, AP Michel. September 2016. Characterization of quantitative trait loci associated with soybean aphid adaptation to resistant plants. International Congress of Entomology. Orlando, Florida.

Purandare, S. R. and K. J. Tilmon. 2016. Investigating Rag virulence among soybean aphid biotypes in South Dakota. Symposium: Research update from the North Central Soybean Research Program. Entomological Society of American North Central Branch Meeting. Cleveland, OH.

Tilmon, K. J. 2016. Late(er) season insect pests in soybean. Plant Management Network Focus on Soybean Webinar Series. http://www.plantmanagementnetwork.org/edcenter/seminars/soybean/LaterSeasonInsectPest/

Tilmon, K. J. and D. R. Kandel. 2016. Density-dependent response of natural enemies to soybean aphid. 13th International Symposium on Ecology of Aphidophaga. Freising, Germany.

Tilmon, K. J. 2016. Soybean entomology in the North Central region: Insect pest update. Board Meeting of the North Central Soybean Research Program at the Commodity Classic. New Orleans, LA.

Tilmon, K. J. 2016. An overview of checkoff-funded entomology research and outreach with the North Central Soybean Research Program. Symposium: Research update from the North Central Soybean Research Program. Entomological Society of American North Central Branch Meeting. Cleveland, OH.

Tilmon, K. J. 2017. Human behavior flows from three main sources: What Plato can teach us about grower pesticide choice. Symposium: Value, integration, and regional specificities of insecticide use in soybean production systems. Entomological Society of America Southeastern Branch Meeting. Memphis, TN.

Tilmon, K. J. 2017. Status of western bean cutworm resistance to Cry1F. Symposium: Insecticide/trait resistance of agronomic crop pests in the North Central Region. Entomological Society of American North Central Branch Meeting. Indianapolis, IN.

Tilmon, K. J. and C. Welty. 2017. Testing baited sticky cards as a sampling method for brown marmorated stink bug in soybean. Entomological Society of America Annual Meeting. Denver, CO.

Tilmon, K. J. 2017. The role of host plant resistance and biological control in regulating soybean aphid. Department of Biology Seminar Series, College of Wooster. Wooster, OH.

Tilmon, K. J. 2018. Plenary speaker: Integrating pest management research and extension in the Midwestern U.S. Entomological Society of America International Branch Meeting. Virtual conference.

Tilmon, K. J. 2018. Accomplishments of the North Central soybean entomology working group. 9th International IPM Symposium. Baltimore, MD, USA.

Wenger JA, Michel AP, Legeai F, Bansal R, Johnston JS, Pavinato V, Yates A, Cassone B. 2016. Genome assembly of the soybean aphid (Aphis glycines) via hybrid approach. International Congress of Entomology Meeting, Orlando, FL Sep 2016

Yates AD, Bansal R, Pavinato VAC, Michel AP. 2016. Identifying changes in gene expression that may promote virulence in the soybean aphid, Aphis glycines. International Congress of Entomology Meeting, Orlando, FL Sep 2016

South Dakota Contributions

Conzemius, S., L. Hesler, A. Varenhorst and K. Tilmon. 2017. Mind your elders: Wild soybean's contribution to soybean aphid resistance. Talk: Entomological Society of America Annual Meeting. Denver, Co. Novermber 6.

Conzemius, S., L. Hesler, A. Varenhorst, and K. Tilmon. 2017. Mind your elders: Wild soybean's contribution to soybean aphid resistance. 65th Annual Meeting of the Entomological Society of America. 6 November 2017. Denver, CO.

Conzemius, S., L. Hesler, A. Varenhorst, and K. Tilmon. 2017. No-Choice but to find plant resistance to soybean aphid biotype 4. 72nd Annual Meeting of the North Central Branch of the Entomological Society of America. 6/5/2017

Conzemius, S., L. Hesler, A. Varenhorst, and K. Tilmon. 2018. Eat, drink and be varied: Soybean aphid intrabiotypic variants on soybean ascensions. 73rd Annual Meeting of the North Central Branch of the Entomological Society of America. 19 March 2018. Madison, WI.

Hesler, L. and K. Tilmon. 2017. Identification and confirmation of resistance against soybean aphid (Aphis glycines) in eight wild soybean lines. Poster: Entomological Society of America Annual Meeting. Denver, Co. Novermber 7.

Hesler Lab. "Cool Beans! Soybean Accessions That Limit Aphid Biotype 4 Cool Beans!" Gamma Sigma Delta Honor Society of Agriculture Poster Contest, College of Agriculture and Biological Sciences, South Dakota State University, April 3, 2017

Hesler Lab. "Newly Identified Resistance to Soybean Aphid (Aphis glycines) in Soybean Plant Introduction Lines," North Central Branch Meeting, Entomological Society of America, Indianapolis, IN. June 6, 2017

Varenhorst, A. and M. O'Neal. 2017. Interspersed refuges: How do they impact soybean aphid natural enemies? 72nd Annual Meeting of the North Central Branch of the Entomological Society of America. 6/7/2017.

Varenhorst, A., S. Pritchard, M. O'Neal, E. Hodgson, and A. Singh. Managing biotype-4 soybean aphids using a Rag1+Rag2+Rag4 pyramid.73rd Annual North Central Branch Entomological Society of America Meeting, Madison, WI, 20 March 2018.

Pezzini, D. 2018. Community Characterization and Development of a Sampling Plan for Stink Bugs (Hemiptera: Pentatomidae) in Soybean in the North Central Region of the U.S. Master's Thesis, University of Minnesota.

Ribeiro, Matheus Geraldo Pires de Mello. 2017. Baseline Susceptibility, Resistance Detection and Selection for Resistance in *Aphis glycines* (Hemiptera: Aphididae) to the Neonicotinoid Insecticide, Thiamethoxam. ETD collection for University of Nebraska - Lincoln. AAI10271836.

Russell Ward, Ph.D. dissertation, 2017. Genetic improvement of aphid resistance, protein, and elemental composition in soybean. (Brian Diers Lab)

Joseph Kaser, University of Minnesota 2016: Risk and efficacy in biological control: an evaluation of the parasitoid Aphelinus certus in North America

Scientific Symposia Organized

Hodgson Lab. Co-Organizer, World Soybean Research Conference Symposium: Insect and Weed Resistance in Soybean, September 2017 [canceled due to Hurricane Irma]

Hodgson Lab. Co-Organizer and Moderator, NCB-ESA Symposium: Resistance management, June 2017

Hodgson Lab. Co-Organizer and Moderator, NCB-ESA Extension Entomology Share Fair, March 2018

Hodgson Lab. Co-Organizer and Moderator, ESA Extension Entomology Share Fair, November 2018

Hodgson Lab. Co-Organizer and Moderator, NCB-ESA Symposium: Emerging crop pests in the NCB, March 2019

O'Neal, M.E. and G. Lorenz. 2108. Program Symposium: "Soybean and Pollinators" Annual meeting of the South Eastern Branch of the Entomological Society of America. Orlando, FL. 4-7 March, 2018.

Extension Presentations

Indiana Contributions

Krupke Lab. Brooke Dennis, MS student presented "The role of insect pollinators in enhancing Indiana soybean yields" at Indiana Soybean Summit meeting in May 2017

Iowa Contributions

Anderson, M., and E. Hodgson. IPM 101 Quiz. Wyffels Field Day, Field Extension Education Laboratory, Iowa State University, Ames, IA. [5 sessions; 60 people] 1 August 2018

Hodgson, E. W., M. Dunbar, M. O'Neal, and A. Gassmann. Managing cover crop pests for corn and soybean production.2016 Iowa State University Extension and Outreach Crop Advantage Series Workshops. Atlantic, IA. [110 people] 19 January 2016 and Waterloo, IA. [40 people] 21 January 2016

Hodgson, E. W. Introduction to insect diagnostics. Iowa State University Extension and Outreach Crop Scout School, Ames, IA. [97 people] 27 February 2016

Hodgson, E. W. Introduction to insect diagnostics. Iowa State University Northeast Research Farm Outreach Crop Scout School, Nashua, IA. [22 people] 1 April 2016

Hodgson, E., and M. Rice. Early-season corn and soybean pest management. Early-season clinic, Field Extension Education Laboratory, Iowa State University, Ames, IA. [3 sessions; 68 people] 17 May 2016

Hodgson, E. Early-season corn and soybean pest management. United Field Day, Field Extension Education Laboratory, Iowa State University, Ames, IA. [22 people] 18 May 2016

Hodgson, E. Field crop pest management basics. Women's Agronomy Group, Northcentral Research Farm, Iowa State University, Kanawha, IA. [4 people] 5 June 2016

Hodgson, E. Field crop pest management basics. Women's Agronomy Group, Smeltzer Research Farm, Iowa State University, Otho, IA. [12 people] 12 June 2016

Hodgson, E. Early-season insect activity update. AgriGold Field Day, Field Extension Education Laboratory, Iowa State University, Ames, IA. [40 people] 21 June 2016

Hodgson, E. Field crop pest management basics. Women's Agronomy Group, Southeastern Research Farm, Iowa State University, Crawfordsville, IA. [13 people] 25 June 2016

Hodgson, E. Soybean aphid management update. Crop Management Clinic, Iowa State University Field Extension Education Laboratory, Ames, IA. [2 sessions; 45 people] 14 July 2016

Hodgson, E. Soybean aphid management update. BASF Field Day, Iowa State University Northeast Research Farm, Nashua, IA. [25 people] 17 August 2016

Hodgson, E., and M. O'Neal. Soybean aphid management update. Iowa Soybean Association Field Day, Iowa State University Field Extension Education Laboratory, Ames, IA. [35 people] 9 September 2016

Hodgson, E. W. Resistance management plan for soybean aphid. Iowa State University Field Agronomist Professional Development Workshop, Ames, IA. [22 people] 29 November 2016

Hodgson, E. W. Resistance management plan for soybean aphid. Iowa State University Extension and Outreach Integrated Crop Management Annual Conference, Ames, IA. [2 sessions; 150 people] 1 December 2016

Hodgson, E. W. Resistance management update for soybean aphid and corn rootworm. Iowa State University Extension and Outreach Crop Clinic.

- Mason City, IA. [85 people] 9 December 2016
- Northwood, IA. [115 people] 9 December 2016

Hodgson, E. W. Resistance management update for soybean aphid and corn rootworm. Iowa State University Extension and Outreach Ag Chem Dealer Update.

- Iowa City, IA. [115 people] 22 November 2016
- Ames, IA. [80 people] 7 December 2016

Hodgson, E. W. Resistance management plans for soybean aphid. 2017 Iowa State University Extension and Outreach Crop Advantage Series Workshops.

- Sheldon, IA. [38 people] 4 January 2017
- Okoboji, IA. [22 people] 5 January 2017
- Storm Lake, IA. [6 people] 10 January 2017
- Mason City, IA. [2 sessions; 75 people] 13 January 2017
- Fort Dodge, IA. [2 sessions; 85 people] 18 January 2017
- Le Mars, IA. [6 people] 24 January 2017
- Denison, IA. [8 people] 26 January 2017

Hodgson, E. W. Resistance management for two key field crop pests. Iowa Soybean Association Research Conference, Des Moines, IA. [15 people] 8 February 2017

Hodgson, E. W. Introduction to insect diagnostics. Iowa State University Extension and Outreach Crop Scout School, Ames, IA. [45 people] 25 March 2017

Hodgson, E. W. Introduction to insect diagnostics. Syngenta Annual Spring Training, Ames, IA. [25 people] 5 April 2017

Hodgson, E. Seed and seedling pest management in corn and soybean. Early-Season Clinic, Field Extension Education Laboratory, Iowa State University, Ames, IA. [4 sessions; 75 people] 16 May 2017

Hodgson, E. Soybean aphid and corn rootworm management update. Northcentral Research Farm, Iowa State University, Kanawha, IA. [55 people] 22 June 2017

Hodgson, E. Soybean aphid resistance management. Northwestern Research Farm, Iowa State University, Sutherland, IA. [3 sessions; 95 people] 12 July 2017

Hodgson, E. Soybean aphid management update. Crop Management Clinic, Iowa State University Field Extension Education Laboratory, Ames, IA. [2 sessions; 22 people] 13 July 2017

Hodgson, E. Corn and soybean pest management. Pioneer Field Day, Iowa State University Field Extension Education Laboratory, Ames, IA. [4 sessions; 110 people] 18 July 2017

Hodgson, E. Field crop pest management basics. Women’s Agronomy Group, Iowa State University Field Extension Education Laboratory, Ames, IA. [9 people] 1 August 2017

Hodgson, E. Soybean aphid management update. Northcentral Research Farm, Iowa State University, Kanawha, IA. [2 sessions; 40 people] 7 September 2017

Lewis, D., E. W. Hodgson, and L. Jesse. Introduction to field crop insects and management in the U.S. Iowa State University Extension and Outreach, India Study Abroad Course. Ames, IA. [20 people] 7 October 2016.

Hodgson, E. W. IPM and economic thresholds for insects. Iowa State University Extension and Outreach Ag Chem Dealer Update, Iowa City. 21 November 2017

Hodgson, E. W. Resistance management plan for soybean aphid. Iowa State University Field Agronomist Professional Development Workshop, Ames, IA. [22 people] 29 November 2016

Hodgson, E. W. Soybean aphid bites back: update on pyrethroid resistance. Iowa State University Extension and Outreach Integrated Crop Management Annual Conference, Ames, IA. [2 sessions; 155 people] 29 November 2017

Hodgson, E. W. Setting your defoliation eye for threshold-based spraying in field crops. The Illinois, Indiana, Ohio (Tri-State) Certified Crops Advisers Annual Conference, Indianapolis, IN [2 sessions; 95 people] 12 December 2017

Hodgson, E. W. IPM and economic thresholds for insects. Iowa State University Extension and Outreach Ag Chem Dealer Update, Ames, IA 13 December 2017

Hodgson, E. W. Soybean IPM: using thresholds to manage defoliators. University of Missouri Crop Management Conference, Columbia, MO [2 sessions; 150 people] 14 December 2017

Hodgson, E. W. #IPM: how do we build resilient, sustainable pest management crop systems? University of Minnesota Extension Crop Pest Management Short Course, Minneapolis, MN [325 people] 12 December 2018

Hodgson, E. W., E. Zaworski, and R. Baker. IPM 101 Game Show. Iowa State University Extension and Outreach Integrated Crop Management Annual Conference, Ames, IA. [2 sessions; 130 people] 27 November 2018

Hodgson, E. W. and J. McMechan. A fly in the ointment: soybean gall midge is a new pest. Iowa State University Extension and Outreach Integrated Crop Management Annual Conference, Ames, IA. [2 sessions; 230 people] 28 November 2018

Hodgson, E. W. Soybean gall midge is a new soybean pest. Iowa State University Extension and Outreach Ag Chem Dealer Update. Iowa City, IA. [85 people] 11 December 2018 and Ames, IA. [63 people] 12 December 2018

Hodgson, E. W. Field crop mashup for 2018.Iowa State University Extension and Outreach Crop Clinic for Worth and Cerro Gordo counties, Manly, IA. [60 people] 14 December 2018

Hodgson, E. W. Resistance management plans for soybean aphid.2018 Iowa State University Extension and Outreach Crop Advantage Series Workshops.
- Okoboji, IA.[45 people] 4 January 2018
- Burlington, IA.[7 people] 5 January 2018
- Storm Lake, IA.[18 people] 9 January 2018
- Atlantic, IA.[32 people] 16 January 2018
- Waterloo, IA.[2 sessions; 110 people] 18 January 2018
- Iowa City, IA.[40 people] 24 January 2018
- Davenport, IL.[2 sessions; 35 people] 26 January 2018

Hodgson, E. W. Introduction to insect diagnostics. Iowa State University Extension and Outreach Crop Scout School, Ames, IA. [3 sessions; 65 people] 24 March 2018

Hodgson, E. Seed and seedling pest management in field crops. Early-Season Clinic, Field Extension Education Laboratory, Iowa State University, Ames, IA. [2 sessions; 25 people] 10 May 2018
Richardson, J., and E. Hodgson. Insect identification and scouting in field crops. Corteva New Agronomists Field Day, Field Extension Education Laboratory, Iowa State University, Ames, IA. [3 sessions; 35 people] 25 July 2018

Anderson, M., and E. Hodgson. IPM 101 Quiz. Wyffels Field Day, Field Extension Education Laboratory, Iowa State University, Ames, IA. [5 sessions; 60 people] 1 August 2018

Hodgson, E. Soybean aphid life cycle, biology and dynamics. SCN and Soybean aphid Workshop, Field Extension Education Laboratory, Iowa State University, Ames, IA. [20 people] 17 August 2017

Hodgson, E. Insect updates. Monsanto Field Day, Field Extension Education Laboratory, Iowa State University, Ames, IA. [45 people] 21 August 2018

Hodgson, E. Soybean aphid efficacy evaluation using Sefina. Corteva Field Day, Northwest Research Farm, Iowa State University, Sutherland, IA. [8 people] 22 August 2018

Hodgson, E. Insect updates. Stine Field Day, Field Extension Education Laboratory, Iowa State University, Ames, IA. [2 sessions; 50 people] 23 August 2018

Hodgson, E., and A. Saeugling. A new emerging pest: soybean gall midge. Armstrong Farm, Iowa State University, Lewis, IA. [50 people] 5 September 2018

Hodgson, E., and E. Rodbell. Host plant resistance for soybean aphid. Practical Farmers of Iowa Field Day, Marble Rock, IA. [22 people] 6 September 2018

Hodgson, E. Seed and seedling pest management in field crops. Early-Season Clinic, Field Extension Education Laboratory, Iowa State University, Ames, IA. [2 sessions; 25 people] 10 May 2018

Hodgson, E. Soybean aphid life cycle, biology and dynamics. SCN and Soybean aphid Workshop, Field Extension Education Laboratory, Iowa State University, Ames, IA. [20 people] 17 August 2017

Hodgson, E. Insect updates. Monsanto Field Day, Field Extension Education Laboratory, Iowa State University, Ames, IA. [45 people] 21 August 2018

Hodgson, E. Soybean aphid efficacy evaluation using Sefina. Corteva Field Day, Northwest Research Farm, Iowa State University, Sutherland, IA. [8 people] 22 August 2018

Hodgson, E. Insect updates. Stine Field Day, Field Extension Education Laboratory, Iowa State University, Ames, IA. [2 sessions; 50 people] 23 August 2018

O'Neal, M.E. Can Honey bees thrive in IowaIowa Honey Producers Association Annual Meeting, Oskaloosa IA, November 11, 2017.

O'Neal, M.E. Conservation is Beautiful: the art of saving insects. Exhibition Lecture, University of Iowa Museum of Art, October 26, 2017.

O'Neal, M.E. Combing crop production and conservation for improved bee health: what can be learned from Iowa?", Western Illinois Organic Field Day, Roseville, IL, August 11, 2017.

O'Neal, M.E. Finding Diversity in a Green Desert: How to conserve the pollinators that use crop fields. South Dakota Pollinator Workshop, hosted by South Dakota State University Extension, Pierre Regional Extension Center, July 15, 2016.

O'Neal, M.E. Hidden diversity in farm fields: conserving pollinators in a landscape dominated by agriculture. Pollinator Session of the Delaware Department of Agriculture's Agriculture Week, January 13, State Fair Grounds, Harrington, DE.

Richardson, J., and E. Hodgson. Insect identification and scouting in field crops. Corteva New Agronomists Field Day, Field Extension Education Laboratory, Iowa State University, Ames, IA. [3 sessions; 35 people] 25 July 2018

Kansas Contributions

McCornack, B. 2017. Insect and ecosystem services—building resistance, resilience and recovery into the farm. In, 2017 Agriculture's Innovative Minds (AIM) Symposium. No-Till on the Plains, Salina, KS; bio: http://www.notill.org/brian-mccornack). (Symposium)

McCornack, B. 2017. Blending ecology and technology to manage pests and beneficial organisms. Department of Entomology and Plant Pathology Seminar Series, Oklahoma State University, Stillwater, OK. (Seminar)

McCornack, B. 2018. myFields.info—field crop information when and where you need it! Ohio AgriBusiness Association Industry Conference, Dublin, OH. (Presenter)

McCornack, B., and C.M. Smith. 2018. An integrated approach to managing Dectes stem borer in Kansas. Kansas Soybean Expo, sponsored by the Kansas Soybean Association, Topeka, KS. (K-State Research and Extension update)

Minnesota Contributions

Koch, R.L. 2016, December. Invasive pests and pesticide regulation: Implications for soybean insect pest management. Crop Pest Management Short Course. Minnesota Crop Production Retailers and University of Minnesota Extension. Minneapolis, MN (two 50-minute talks with 298 and 54 attendees).

Koch, R.L. 2016, June. Insect concerns for soybean: insecticide resistance and invasive species. Agronomy Tour. Southern Research and Outreach Center, Waseca, MN. (25-minute presentation with 71 attendees).

Koch, R.L., K. Ostlie and Erica Nystrom. 2017, July. Identification of insects and the injury they cause in field crops. Field School for Agricultural Professionals. Institute for Agricultural Professionals, University of Minnesota Extension. St. Paul, MN (four 90-minute presentations with 25, 26, 26, and 24 attendees).

Koch, R.L. 2017, February. Emerging challenges for insect pest management in soybean. Rice and Steele Counties Crops Day, University of Minnesota Extension. Owatonna, MN (50-minute talk with 26 attendees).

Koch, R.L. 2017, February. New challenges to soybean pest management. Tri State Aerial Applicators Conference. St. Cloud, MN (50-minute talk with 300 attendees).

Koch, R.L. 2017, January. Crop insects management. Field Crop Pest Management Recertification, University of Minnesota Extension. (40-minute talk; St. Cloud: 80 attendees; Faribault: 160 attendees).

Koch, R.L. 2017, January. Managing insect pests of soybean: Insecticide-resistant aphids and other challenges. Research Updates for Agricultural Professionals. Institute for Agricultural Professionals, University of Minnesota Extension. (30-minute talk; Waseca: 60 attendees; Kasson: 76 attendees; Lamberton: 56 attendees; Morris: 55 attendees; Crookston: 65; Willmar: 60 attendees).

Koch, R.L. 2018, January. Stink bugs as an emerging threat to crop production: Overview of their biology, impacts and management. Wisconsin Agri-Business Classic. Madison, WI (30-minute talk with 100 attendees)

Koch, R.L. 2018, March. Emerging soybean pest issues. Integrated Pest Management & Crop Update Workshop for Crop Producers. Pine City, MN (60-minute talk with 30 attendees).

Potter, Bruce. 2016. 26 meetings and more than 1100 attendees primarily in SC, SW and WC MN

Potter, Bruce. 2017. 26 meetings and more than 1100 attendees primarily in SC, SW and WC MN

Potter, Bruce. 2018. 19 meetings and more than 1000 attendees primarily in SC, SW and WC MN

Nebraka Contributions

Crop Production Clinics – approximately 1300 farmers and Ag business people attend each year

Soybean Production Clinic – approximately 80 farmers and Ag business people attend each year

Soybean Management Field Days – approximately 400 farmers and Ag business people attend each year

North Dakota Contributions

(All of the below by Janet Knodel)

Insecticide Update for 2017, NDSU / UM Commercial Pesticide Applicator Training, Fargo – Nov. 30, 2016. Total audience = 275 people.

Management of Soybean Aphids and Interaction with Soybean Cyst Nematode, North Dakota Soybean Council Research meeting, Fargo, ND, Nov. 15, 2016. Total audience = 22

Insect Pest Problems of Soybeans in ND, NDTO Big Iron International Visitors Ag Educational Session Program, Casselton, ND, Sept. 15, 2016. Total audience = 15

Soybean Insects. Remington Seeds, LLC, Mapleton, ND, July 26, 2016. Total audience = 65

Field Scouting for Insect Pests of Field Crops, Field tour at NDSU campus, ND State College of Science and Bismarck State College, Fargo, ND – July 22, 2016. Total audience = 82 people.

Pest Diagnostic Clinics – Insects & Insect Updates, NDSU NCREC Annual Field Day, Minot, ND - July 20, 2016. Total audience = 120.

Update on Soybean Aphid and Other Crop Pests, NDSU Agronomy Seed Farm Field Tour, Casselton, ND - July 18, 2016. Total audience = 100.

Insect Management Update, Crop Management Field School, Carrington, ND, June 16, 2016. Total audience = 57.

IPM Scout Training – Review of Scouting Protocols, NDSU IPM Survey Scout Training, Carrington, ND – May 25, 2016. Total audience = 20.

Insect Pest & Insecticide Updates, Centrol Roundtable, Fargo, ND, March 24, 2016. Total audience = 70.

Hands-on Laboratories: Insects of Wheat, Corn, Soybeans, Dry Beans, Sunflower and Canola (3 talks); 2016 Western Crop & Pest Management School, Minot, ND – March 1-2, 2016. Total audience = 125 people.

Hands-on Laboratories: Insects of Wheat, Corn, Soybeans, Dry Beans, Sunflower and Canola (3 talks); 2016 Eastern Crop & Pest Management School, Fargo, ND - Feb. 23--24, 2016. Total audience = 114 people.

Management of Insects: Biology and Insect Management Strategies, CCA exam, Fargo, ND – Jan. 7-8, 2016. Total audience = 26 people.

Insecticides and Resistant Issues with Soybean Aphids, NDSU / UM Commercial Pesticide Applicator Training, Nov. 29, 2017. Total audience = 315 people.

Field Scouting for Insect Pests of Field Crops, Field tour at NDSU campus, ND State College of Science and Bismarck State College, Fargo, ND – July 21, 2017. Total audience = 75 people.

Update on Soybean Aphid and Other Crop Pests, NDSU Agronomy Seed Farm Field Tour, Casselton, ND - July 17, 2017. Total audience = 60.

IPM Scout Training – Review of Scouting Protocols, NDSU IPM Survey Scout Training, Carrington, ND – May 24, 2017. Total audience = 20.

Insect Pest & Insecticide Updates, Centrol Roundtable, Fargo, ND, March 28, 2017. Total audience = 85.

Hands-on Laboratories: Insects of Wheat, Corn, Soybeans, Dry Beans, Sunflower and Canola (3 talks); 2017 Eastern Crop & Pest Management School, Fargo, ND – Feb. 21-22, 2017. Total audience = 130 people.

2017 Getting It Right Soybeans Production meeting with NDSC.

Soybean aphids & spider mites
Napoleon. January 27, 2017. Total audience = 30.
Washburn. January 26, 2017. Total audience = 30.
Bottineau. January 25, 2017. Total audience = 60.
Cando. January 24, 2017. Total audience = 24.

Management of Insects: Biology and Insect Management Strategies, CCA exam, Fargo, ND – Jan. 8, 2017. Total audience = 15 people.

Insecticides Updates for 2019; and Soybean Aphid Control and Pyrethroid Resistance, NDSU / UM Commercial Pesticide Applicator Training, Nov. 28, 2018. Total audience = 353 people.

Field Scouting for Insect Pests of Field Crops, Field tour at NDSU campus, ND State College of Science and Bismarck State College, Fargo, ND – July 20, 2018. Total audience = 80 people.

Update on Soybean Aphid and Other Crop Pests, NDSU Agronomy Seed Farm Field Tour, Casselton, ND - July 16, 2018. Total audience = 75.

IPM Scout Training – Review of Scouting Protocols, NDSU IPM Survey Scout Training, Carrington, ND – May 23, 2018. Total audience = 24.

Hands-on Laboratories: Insects of Wheat, Corn, Soybeans, Dry Beans, Sunflower and Canola (3 talks); 2018 Eastern Crop & Pest Management School, Minot, ND – Feb. 27-28, 2018. Total audience = 125 people.

The International Crops Expo, February 21-22, 2018, Grand Forks, ND. Total audience = 175 people.

Northern Corn & Soybean Expo, Soybean and Corn Insect Pest Management, Fargo, ND – Feb. 13, 2018. Total audience = 86.

Best of the Best in Soybean Productions, Soybean aphids – Pyrethroid Resistance, Moorhead, MN – Feb. 1, 2018. Total audience = 165.

Best of the Best in Soybean Productions, Soybean aphids – Pyrethroid Resistance,Grand Forks – Jan. 31, 2018. Total audience = 195.

2018 Getting It Right Soybeans Production meeting with NDSC.

Soybean aphids – Pyrethroid Resistance
Fessenden. January 23, 2018. Total audience = 62.
Kenmare. January 24, 2018. Total audience = 68.

Rugby. January 25, 2018. Total audience = 76.
Langdon. January 26, 2018. Total audience = 72.

Ohio Contributions

Michel, A. Insect Update for 2016/2017. Pesticide Applicators Training (PAT) Recertification Field Crop Conference. Akron, OH. Feb 15

Michel, A. Agronomic Crop Insect Management for 2016/2017. 2017 Agronomy Workshop Delaware County. Waldo, OH. Feb 23.

Michel, A. Insect Update for 2016/2017. Pesticide Applicators Training (PAT) Recertification Field Crop Conference. Dayton, OH. Feb 10.

Tilmon, K. J. 2016. Managing insects and slugs in no-till. Ohio No-Till Council Winter Conference. Attendance: 70

Tilmon, K. J. 2016. What's going on in corn and soybean this summer. Farm Science Review Field Day. Attendance: 30

Tilmon, K. J. 2016. Soybean entomology research for 2017. Ohio Soybean Council Board Meeting. Attendance: 15

Tilmon, K. J. 2016. Stink bugs in soybean. Japanese Visiting Dignitaries Tour.

Tilmon, K. J. 2016. What's going on in corn and soybean this summer. Western Research Farm Field Day. Attendance: 80

Tilmon, K. J. 2016. Sampling for pollinators in soybean. ACRE Intern Training Workshop
.

Tilmon, K. J. 2016. Field crop insect problems in Ohio. OARDC Advisory Meeting.

Tilmon, K. J. 2016. Insecticidal seed treatments in soybean. Ohio Commercial Pesticide Applicator Recertification Conference – Columbus. Attendance: 105.

Tilmon, K. J. 2016. Field crop insect update. Ohio Commercial Pesticide Applicator Recertification Conference – Columbus. Attendance: 90

Tilmon, K. J. 2016. Insecticidal seed treatments in soybean. Extension Educator Inservice Workshop. Attendance: 40

Tilmon, K. J. 2016. Insecticidal seed treatments in soybean. 2016 Ohio Agribusiness Association Industry Conference. Attendance: 100

Tilmon, K. J. 2016. Soybean insect management – late season pests and seed treatments. Intensive Soybean Management Workshop. Attendance: 30

Tilmon, K. J. 2016. Soybean insect seed treatment demonstration. 2016 OARDC Agronomy Workshop – Field crops management. Attendance: 00

Tilmon, K. J. 2016. Soybean insect seed treatment demonstration. 2016 OARDC Agronomy Workshop – Field crops management day 2. Attendance: 30

Tilmon, K. J. 2016. Insecticidal seed treatments in soybean. Ohio Commercial Pesticide Applicator Recertification Conference – Akron. Attendance: 18

Tilmon, K. J. 2016. Field crop insect update. Ohio Commercial Pesticide Applicator Recertification Conference – Dayton. Attendance: 120

Tilmon, K. J. 2016. Corn and soybean update. 2016 Tri-County Agronomy Day. Attendance: 100

Tilmon, K. J. 2016. Insecticidal seed treatment in soybean. 2016 Northeast Ohio Agronomy Schoo. Attendance: 80

Tilmon, K. J. 2016. Soybean insect management – late season pests and seed treatment. Intensive Soybean Management Workshop. Attendance: 30

Tilmon, K. J. 2016. Soybean insect management – late season pests and seed treatments. Intensive Soybean Management Workshop day 2. Attendance: 30

Tilmon, K. J. 2016. Insecticidal seed treatments in soybean. Ohio Seed Improvement Association 81nd Annual Ohio Professional Seed Grower's School. Attendance: 60

Tilmon, K. J. 2017. Field crop insect update. Ohio Extension Educator In-Service. Attendance: 56

Tilmon, K. J. 2017. Biology and management of slugs in field crops. TMK Bakersville Field Day. Attendance: 20

Tilmon, K. J. 2017. What to watch for in corn and soybean this summer. Ashland Field Day. Attendance: 20

Tilmon, K. J. 2017. Soybean entomology research update. Ohio Soybean Council Field Day. Attendance: 15

Tilmon, K. J. 2017. What to watch for in corn and soybean this summer. Northwest Ohio Field Day. Attendance: 60

Tilmon, K. J. 2017. How to estimate defoliation in soybean. Champaign Co. Field Day.

Tilmon, K. J. 2017. Slug management recommendations in no-till and cover crop systems. Ohio Conservation Tillage Conference. Attendance: 150

Tilmon, K. J. 2017. Soybean insect management. Ohio Intensive Soybean Management Workshop. Attendance: 30

Tilmon, K. J. 2017. Insect Trends from 2016: Western bean cutworm and stink bugs. Corn, Soybean and Wheat Connection Webinars.

Tilmon, K. J. 2017. Soybean slugs and other agronomy pests. Northern Ohio Crops Day. Attendance: 90

Tilmon, K. J. 2017. Insect pressure on today's genetics and future control. 2017 Soybean College. Attendance: 30

Tilmon, K. J. 2017. Insect Trends from 2016: Western Bean Cutworm and Stink Bugs. 2017 Ohio Commercial Pesticide Applicator Recertification Conference – Columbus. Attendance: 97

Tilmon, K. J. 2017. Insecticidal seed treatments in soybean. 2017 Ohio Commercial Pesticide Applicator Recertification Conference – Columbus. Attendance: 81

Tilmon, K. J. 2017. What's new in soybean insect management. McFarland County Extension Meeting. Attendance: 40

Tilmon, K. J. 2017. Field crop insect update. Western Ohio Agronomy Day. Attendance: 60

Tilmon, K. J. 2017. Aphid resistant soybean hands-on demonstration. Ohio Seed Improvement Association 82nd Annual Ohio Professional Seed Grower's School. Attendance: 100

Tilmon, K. J. 2017. 2017 Insect trends from 2016: Western bean cutworm and stink bugs. 2017 Ohio Commercial Pesticide Applicator Recertification Conference – Sandusky. Attendance: 175

Tilmon, K. J. 2017. Insecticidal seed treatments in soybean. 2017 Ohio Commercial Pesticide Applicator Recertification Conference – Sandusky. Attendance: 155

Tilmon, K. J. 2017. Soybean damage from stink bugs and other pests this past growing season. 2017 Putnam County Agronomy Night. Attendance: 40

Tilmon, K. J. 2017. Soybean insect management. Ohio Intensive Soybean Management Workshop. Attendance: 30

Tilmon, K. J. 2017. Estimating defoliation in soybean hands-on demonstration. Ohio Seed Improvement Association 82nd Annual Ohio Professional Seed Grower's School. Attendance: 20

Tilmon, K. J. 2017. Corn and soybean insect update. West Ohio Agronomy Day. Attendance: 73.

Tilmon, K. J. 2018. Identifying strategies for fighting slugs, protecting your no-tilled crop. National No-Tillage Conference. Attendance: 500

Tilmon, K. J. 2017. What's eating these soybeans? University of Minnesota Crop Pest Management Short Course. Attendance: 500

Tilmon, K. J. 2018. What's eating these soybeans? Southwest Ohio Agronomy Day. Attendance: 60

Tilmon, K. J. 2018. What's eating these soybeans? Northwest Ohio Crops Day. Attendance: 70

Tilmon, K. J. 2018. Field crop insect update: soybean defoliators and stink bugs. 2018 Ohio Commercial Pesticide Applicator Recertification Conference – Columbus. Attenance: 100

Tilmon, K. J. 2018. Estimating defoliation in soybean hands-on demonstration. Ohio Seed Improvement Association 82nd Annual Ohio Professional Seed Grower's School. Attenance: 30

Tilmon, K. J. 2018. Wheat and soybean updates. Ohio Seed Improvement Association Annual Meeting. Attendance: 80

Tilmon, K. J. 2018. Field crop insect update: soybean defoliators and stink bugs. 2018 Ohio Commercial Pesticide Applicator Recertification Conference – Akron. Attendance: 100

South Dakota Contributions

Hesler Lab. "Plant Resistance: A Crucial Link in Harvesting Soybeans' Full Potential," Eastern South Dakota Soil & Water Research Farm—Field Day, Eric Beckendorf, USDA-ARS, Brookings SD & Sophi Conzemius, SDSU, Brookings SD

Varenhorst, A. 2016 Integrated Pest Management Field School: topics covered included soybean aphid pyrethroid resistance, host plant resistance, defoliating insect pests. SDSU Volga Research Farm.

Varenhorst, A. 2017 Integrated Pest Management Field School: topics covered included soybean aphid pyrethroid resistance, host plant resistance, defoliating insect pests. SDSU Southeast Research Farm.

Varenhorst, A. 2018 Integrated Pest Management Field School: topics covered included soybean aphid pyrethroid resistance, host plant resistance, defoliating insect pests. SDSU Volga Research Farm.

Extension Publications

Illinois Contributions

Lagos-Kutz, D. and D. Voegtlin. 2016. Midwest Aphid Suction Trap Network. Farm Progress Reports: Vol. 2015 (1), Article 66. http://lib.dr.iastate.edu/farmprogressreports/vol2015/iss1/66

Lagos-Kutz, D. and D. Voegtlin. 2016. Midwest Aphid Suction Trap Network. Farm Progress Reports: Vol. 2015 (1), Article 66. http://lib.dr.iastate.edu/farmprogressreports/vol2015/iss1/66

Iowa Contributions

Dean AN, Hodgson EW, and O’Neal ME. 2017. Evaluation of soybean aphid management tactics. 2017 Northwest Research Farm Progress Report. https://lib.dr.iastate.edu/farmprogressreports/

Hodgson, E. W. Resistance management for soybean aphid, pp. 97-99. In Proceedings: 28th Annual Iowa State University Integrated Crop Management Conference, Ames, IA, 30 November - 1 December 2016.

Hodgson, E. W., and G. VanNostrand. 2016. 2016 Yellow Book Report of insecticide evaluation for soybean pests, 22 pp. Department of Entomology, Iowa State University, Publication 300-16.

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Raudenbush, A., A. Douridas, P. Beauzay and K. Tilmon. 2018. Pollinator Survey in Soybean Update, Logan County, OH.

Raudenbush, A., J. Barker, S. Custer, A. Douridas, M. Estadt, D. Marrison, E., P. Beauzay and K. Tilmon. 2018. Pollinator Survey in Soybean Update Ohio Summary.

Raudenbush, A., M. Estadt, P. Beauzay and K. Tilmon. 2018. Pollinator in Soybean Update, Pickaway County, OH.

Tilmon, K. J. and A. Raudenbush. 2018. Scouting for bean leaf beetle. The Ohio State University IPM Program.

Tilmon, K. J. and A. Raudenbush. 2017. YouTube training video: Common soybean defoliators. The Ohio State University IPM Program. https://www.youtube.com/watch?v=IjHe6YKVFcU

Tilmon, K. J. and A. Raudenbush. 2017. YouTube training video: Stink bugs in soybeans. The Ohio State University IPM Program. https://www.youtube.com/watch?v=hDFThnypmko

Tilmon, K. J. and A. Raudenbush. 2017. YouTube training video: Spider mites and management in soybeans. The Ohio State University IPM Program. https://www.youtube.com/watch?v=3ocPUH8EMvU

Tilmon, K. J. and A. Raudenbush. 2017. OSU Agronomic Crop Insects Website. OSU College of Food, Agriculture, and Environmental Science. https://aginsects.osu.edu/

Tilmon, K. J. 2017. External reviewer for the Soybean Research and Information Initiative website. http://www.soybeanresearchinfo.com/

University of Nebraska. Crop Production Clinics

University of Nebraska. Soybean Production Clinic

University of Nebraska. Soybean Management Field Days

Hodgson, E. W. Video: Threshold-based management for soybean defoliators. PSEP Program, Iowa State University. January - December 2018.

Hodgson, E. W. Video: Japanese beetle management. PSEP Program, Iowa State University. January - December 2017.

Hodgson, E. W. Video: Soybean aphid resistance management. PSEP Program, Iowa State University. January - December 2017.

Hodgson, E. W. et al. ISU Field Crop Entomology website: https://www.ent.iastate.edu/soybeanresearch/content/extension

Hodgson, E. W. Video: Soybean gall midge. Nationwide Insurance Pesticide Applicator Training Program. January - December 2018.

Hodgson, E. W. Video: Soybean gall midge. PSEP Program, Iowa State University. January - December 2018.

Hodgson, E. W. Video: Threshold-based management for soybean defoliators. PSEP Program, Iowa State University. January - December 2018.

Leveraged Grants

Fakhoury et al. 10/18-01/19. Developing a comprehensive management program for foliar diseases of soybean. United Soybean Board. $373,041.

Tilmon, K. J. and A. Michel. 2017-2018. Monitoring, research, and management of soybean insect pests FY18. The Ohio Soybean Council. $60,723.

Tilmon, K. J. and A. Michel. 2018-2019. Monitoring, research, and management of soybean insect pests FY19. The Ohio Soybean Council. $60,000.

Tilmon, K. J., A. Michel and J. LaMantia. 2016-2017. Monitoring and management of soybean insects FY17. The Ohio Soybean Council. $60,000.

Jasinsky, J., K. Tilmon, A. Dorrance, L. Lindsey, A. Michel and P. Paul. 2017-2019. Extension Implementation Program Area USDA-NIFA. $140,776.

Hartman, G. K. Tilmon, A. Michel and D. Wang. 2014-2016. Genetics of multi-soybean aphid biotype resistance and soybean aphid virulence on Rag genes. United Soybean Board. $159,798.

Heimpel, G. 2016-2018. University of Minnesota Agricultural Response Fund. The role of insecticidal seed treatments in limiting biological control of soybean aphid. Amount awarded: $170,800.

Heimpel, G. 2017-2021. Minnesota Invasive Terrestrial Plants and Pests Center. Biological control of the soybean aphid by Aphelinus certus. Amount awarded: $600,000.

Heimpel, G. 2017 – 2018. Minnesota Soybean Research and Promotion Council. Soybean aphid management – insecticide resistance and biological control. Amount awarded: $90,090.

Hodgson, E., M. O'Neal, J. Coats and B. Coates. Extension and research to combat insecticide-resistant soybean aphids," Iowa Soybean Association, 2017 – 2020 ($291,103)

Hodgson, E. H. Evaluating Soybean Aphid Management with an Expanded Toolbox,Iowa Soybean Association, 2017-2018 ($41,268)

Hunt, T., Wright, R. "Soybean Entomology in the North Central Region: Management and Outreach for New and Existing Pests", North Central Soybean Research Program, $105,000 (NE funding for multi-yr, multi-state project), 2015 – 2018.

Knodel, J.J. 2018. Identification of Pyrethroid Resistant Soybean Aphids and Use of Drones for Insect Scouting, North Dakota Soybean Council. $40,000.

Knodel, J.J. and S. Markell. 2017. Management of Soybean Aphids and Interaction with Soybean Cyst Nematode, North Dakota Soybean Council. $40,667.

Knodel, J.J. and S. Markell. 2016. Management of Soybean Aphids and Interaction with Soybean Cyst Nematode, North Dakota Soybean Council and North Dakota Soybean SBARE. $27,751.

Koch 2018. "Developing a spatially explicit bio-economic dispersal model to aid with the management of Halyomorpha halys." (2018-2022)Co-PIs: Senait Senay and T. Hurley. Minnesota Invasive Terrestrial Plants and Pests Center. $598,271

McCornack, B. P. ($30,000) Kansas Soybean Commission. Agricultural Research Experiences for Teachers (RET)—Using Soybean as a Model System in Kansas. The entomology lessons during the institute focus on soybean aphid and research findings from NCSRP.

Michel, A. 01/2018-02/2019: Identifying the Epigenetic Mechanism of Soybean Aphid Virulence. The Center for Applied Plant Science, Ohio State University. ($75,000).

Sharda, A., D. Flippo, R. Wang, and B. McCornack. 2018. ($1.2M total; multi-year) An autonomous insect Sense, Identify, and Manage PLatform (SIMPL) to advance crop protection strategies. NSF/USDA-NIFA National Robotics Initiative.

Smith, C.M., B. P. McCornack and R. J. Whitworth ($107K). Development of Genetic, Chemical and Population-Based Tactics to Manage Key Kansas Soybean Insect Pests.

Toth, A. L, M. E. O'Neal, E.W. Hodgson, and A.G. Dolezal. 2017-2019USDA-AFRI, Combining Crop Production and Conservation for Improved Bee Health. $999,317

Postdocs Trained

Matthew C. Kaiser, Iowa State

Jessica D. Hohenstein, Iowa State

Kelton Welch, University of Minnesota

Car Stenoien, University of Minnesota

Hilary Edgington, Ohio State University

Aline Sartori Guidolin, Ohio State University

Swapna Priya Rajarapu, Ohio State University

Swapna Purandare, Ohio State University

Graduate Students Trained

Carlos Esquivel (Ohio State University, PhD in training)

Ashley Yates, (Ohio State University, PhD in training)

Jacob Wenger, PhD. (Ohio State University, graduated, currently Assistant Professor, Fresno State University)

Russell Ward. Completed his Ph.D. degree May, 2017. (Brian Diers Lab). Currently a corn breeder for Syngenta in South Dakota.

Jaeyeong Han. Crop Sciences. University of Illinois at U-C. Trained in aphid taxonomy.

Ben Daniels. Natural Resources Environmental and Sciences. University of Illinois at U-C. Training on aphid taxonomy.

Sophia Conzemius, South Dakotat State University

Ezra Auerbach, South Dakota State University

Hodgson Lab, Iowa State University. Ashley Dean, master's degree

Jonathan Danielson, Nachappa Lab, Purdue Univeristy

Blessing Ademokoya PhD. University of Nebraska.

Thiago Fanela, PhD Sandwich student from Brazil. University of Nebraska.

Tamíris Araújo, PhD Sandwich student from Brazil. University of Nebraska.

Daniela Pezzini, MS student (U of MN, Entomology, Koch lab)

Brooke Dennis, graduation date of 05/2018 (Purdue University)

Ashley N. Dean –MS student, Iowa State

Ashley St. Clair, Iowa State

Joseph Kaser, University of Minnesota

Jonathan Dregni, University of Minnesota

James Miksanek, University of Minnesota

Stepen Losey, PhD, Kansas State University

Ashley Hough, MS, Kansas State University

Jeremy Hackley, MNRM (Masters of Natural Resource Management, Professional Degree), graduated Fall 2018

Savannah Fritz, MS, NRM (Masters of Science in Natural Resource Management), graduated Summer 2017

Undergraduates Trained

Missouri: 5

Illinois: 1

Iowa:2

Ohio: 6

North Dakota: 3

Awards

International IPM Award of Excellence, awarded to the North Central Soybean Entomology Research and Extension Team. 9th International IPM Symposium, Baltimore MD, March 2018

ESA Plant-Insect Ecosystems IPM Team Award, November 2018 (Koch, Hodgson, Potter, MacRae, Glogoza, Knodel, Varenhorst, Gavloski, Siebert, Jorgenson, and Ellers-Kirk)

Kelley Tilmon, Distinguished Achievement Award in Extension, Entomological Society of Americal North Central Branch. 2017. Based on extension programming related to NCSRP research.

Daniela Pezzini (MS student, Koch lab): 2nd Place, Student 10-minute Paper Competition, Meeting of the Entomological Society of America, Denver, CO. (2017)

Daniela Pezzini (MS student, Koch lab): Master's Student Achievement in Entomology Award, Plant-Insect Ecosystems (P-IE) Section, Entomological Society of America. (2017)

Daniela Pezzini (MS student, Koch lab): 2nd Place, M.S. Student 10-minute Paper Competition, Meeting of the North Central Branch of the Entomological Society of America, Indianapolis, IN. (2017)

Daniela Pezzini: Larry Larson Graduate Student Award for Leadership in Applied Entomology. Entomological Society of America. (2018)

Daniela Pezzini: Lugger-Radcliffe Fellowship, Department of Entomology, University of Minnesota. (2018)

Daniela Pezzini: 1st Place, Student Poster Competition, Meeting of the North Central Branch of the Entomological Society of America, Madison, WI. (2018)

Brooke Dennis won Indiana Seed Trade Association scholarship for her work with native pollinators in Indiana soybeans. (Purdue University)

Erin Hodgson. NCB-ESA Distinguished Achievement Award in Extension, March 2018

Brooke Dennis, Indiana Corn and Soybean Marketing Council, Graduate Student Award

Ashley Yates, USDA-AFRI Pre-Doctoral Research Fellowship

Project Metrics for Final Year

I. Extension and Outreach.

- Goal: Produce at least three extension deliverables.
    - Outcome: Goal met, with four project-wide extension deliverables and a cumulative extension output for the project of 346 deliverables all informed by current or past NCSRP research
- Goal: Capstone extension event
    - Outcome: Funds for the capstone event were re-directed to producing 8,000 hard copies of the new 2nd edition of the Soybean Aphid Field Guide and distributing them throughout the region.

II. Insect Monitoring and Management

1. Stink bug monitoring and management
    - Goals: Third year of data collection; continued sample processing; data analysis; begin dissemination of results
        - Outcomes: all goals met
2. Pollinator diversity and foraging
    - Goal: Species identification and data analysis; present sampling results; contribute to extension deliverables
        - Outcomes: all the goals were met except the final one, which is planned for early spring of 2019
    - Goal: collect a second year of data on the time of day when pollinators are active in soybean; begin analysis of data (yield assessment has been deferred to the new project)
        - Outcomes: Data has been collected and data analysis begun, to be continued in 2019

3. Soybean aphid insecticide resistance

- Goals: Complete constructing protocol for chlorpyrifos and L-cyalothrin bioassay; Preliminary monitoring program; begin disseminating results.
    - Outcomes: early in the project the goal was shifted to developing resistance bioassays for thiamethoxam. This goal was met, with the develop of three types of bioassays which can be used for different purposes. We also met the goal of first-state resistance monitoring and dissemination of results.

4. Monitoring for aphids, thrips, and soybean vein necrosis

- Goal: Weekly trap monitoring in summer; Communicate trap data to collaborators for extension and research
    - Outcomes: all goals met
- Goal: Thrips sampling; Thrips sample processing begins; Prepare final reports for broader communication of results
    - Outcomes: year 3 summer sampling was completed; with the relocation of the PI to Colorado State there has been a delay in processing the sampling and the preparation of final reports, though this work will be completed past the end of the project.

5. Technology development

- Goals: Field validate tool; Communicate results; Release of Android app; Adapt Android code
    - Outcomes: The first goal was met; the goal to release an app was unmet.

III. Resistant Varieties and Biotypes

1. Breeding for resistant varieties

- Goals: Analyze data from year 2; Test segregating populations; Yield tests Analyze data; Preliminary communication of results; Release at least one new variety
    - Outcomes: all goals met

2. Aphid virulence genotyping and mapping

- Goals: Determine inheritance of virulence;

- Outcomes: goals have not been fully met but progress has been made and work on them continues

3. Aphid virulence management for resistant varieties

    - Goals: Conduct multistate experiment; Develop field tested RIB recommendation; Promote use of aphid resistant soybeans

        - Outcomes: all goals have been met; promoting aphid resistant varieties will be ongoing

4. Economic returns on resistant varieties

- Goals: Field experiment, year 3; Data analysis; Communicate results

    - Outcomes: the field experiment was performed; work on the economic model continues; preliminary communication of results at scientific meetings has begun

IV. Biological Control

- Goals: Evaluate success of previous year releases; Communicate results on geographic spread of parasitoids

    - Outcomes: all goals met