Whole-farm Organic Management of BMSB and Endemic Pentatomids through Behavior-Based Habitat Manipulation

2012-2013 PROJECT UPDATE

A multi-state project funded by the

Organic Research and Extension Initiative

USDA United States Department of Agriculture
National Institute of Food and Agriculture

WHOLE-FARM ORGANIC MANAGEMENT OF BMSB AND ENDEMIC PENTATOMIDS THROUGH BEHAVIOR-BASED HABITAT MANIPULATION

USDA-NIFA Organic Agriculture Research and Extension Initiative Project

The Brown Marmorated Stink Bug (BMSB) has become a significant threat to US agriculture since its introduction, causing severe losses for organic farmers. Little to no information is available on organic management of this important invasive pest. Our goal is to develop BMSB management techniques based around a better understanding of BMSB dispersal and whole-farm movement and the application of core organic pest management principles including: enhancing natural enemy activity, habitat manipulation and crop barriers. USDA-NIFA OREI # 2012-51300-20097 *http://eorganic.info/brown-marmorated-stink-bug-organic*

Project Investigators

Rutgers University
Dr. Anne L. Nielsen
Dr. George C. Hamilton
Michigan State University
Dr. Matthew Grieshop
North Carolina State University
Dr. Jim Walgenbach
Redbud Farms
Clarissa Mathews
The Ohio State University
Dr. Celeste Welty
University of Florida
Dr. Russell Mizell
University of Kentucky
Dr. Ricardo Bessin
University of Tennessee
Dr. Mary Rogers
University of Maryland
Dr. Cerruti R. Hooks
Dr. Galen Dively
USDA-ARS
Dr. Kim Hoelmer
Dr. Tracy Leskey
Virginia Tech
Dr. Doug Pfeiffer
West Virginia University
Dr. Jim Kotcon
Dr. Yong-Lak Park
Rodale Institute
Dr. Gladis Zinati
Jeff Moyer
***e*Organic**
Alexandra Stone

Objectives

The programs developed in our project are based on BMSB dispersal and whole-farm movement integrated with core organic pest management strategies —*i.e.* conservation biological control, habitat manipulation and the use of trap crops and crop barriers. Our specific objectives are:

1. *Develop habitat manipulation tactics based upon how host plant phenology impacts BMSB preference and dispersal.*
2. *Determine biotic and abiotic factors affecting adult and juvenile BMSB whole-farm movement.*
3. *Determine the identity and importance of extant natural enemies of stink bugs and their impact on BMSB populations.*
4. *Evaluate integrated management plans for BMSB and endemic stink bugs specific to organic production systems.*
5. *Develop and deliver extension materials for organic growers.*

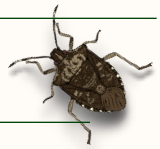
HABITAT MANIPULATION
PG. 4

WHOLE-FARM MOVEMENT
PG. 5

IMPACT OF NATURAL ENEMIES
PG. 7

ROW COVER MANAGEMENT
PG. 9

Introduction to the Project



Organic famers in the mid-Atlantic states and now in some central and southern states are experiencing significant crop loss due to the Brown Marmorated Stink Bug (BMSB). Much of the research has focused on management, primarily with insecticides, on conventional farms. However, after input from organic farmers, we identified key organic management tactics that show promise for stink bug management. Established BMSB population are significantly higher than native stink bugs and are not naturally regulated by predators. The primary goal of this large, multi-state research project is to rapidly identify management tactics that will integrate a whole-farm approach for BMSB management while conserving the main ideals of organic farming; including conservation of natural enemies and biodiversity.

This project unifies 13 institutions across 12 states with expertise in entomology, horticulture, and organic management. We have conducted work in direct collaboration with organic growers and will seek further input from them during the following two years of this project. To date, the project has recruited 8 graduate students and 5 post-docs. Our primary outputs for the first year were to establish relationships with the organic growing community and collect data on management tactics and behavior. Many researchers in our team have focused on

grower education and natural enemy surveys. We made significant accomplishments on the development of trap crops and natural enemy services, as well as filling knowledge gaps regarding dispersal behavior. In January 2013 researchers and cooperating growers met to discuss research updates and refine field trials for Year 1. We have continued to meet monthly through web-conferencing hosted by *e*Organic while developing and evaluating systems-based integrated pest management programs to control BMSB and endemic stink bugs in organically grown cropping systems.

Training and Professional Development

Several post-doctoral research associates, graduate and undergraduate students (including students whose PhD dissertations or masters theses will result from this work), and growers were instrumental in accomplishing this research. In order for these participants to skillfully their portions of the work, they were initially trained by the investigators at their corresponding institutions. Training consisted of brown marmorated stink bug (BMSB) identification, introduction to the overall OREI project, and education on performing and completing appropriate portions of the project.

During the first year of this OREI funded project, for example, at Rutgers University a post-doctoral research associate, Brett Blaauw, a PhD student, John Pote, and two research assistants were trained to work on the OREI project. The USDA-ARS in West Virginia trained one post-doctoral research associate, Doo-Hyung Lee, a masters student from Virgina Tech, Torri Hancock, and an undergraduate research assistant. In Delaware, the USDA-ARS trained Christine Diekhoff, a post-doctoral research associate, and a research assistant was trained at the University of Delaware to work on the OREI funded project. Additionally, the University of Maryland trained three graduate students, a post-doctoral research fellow, two research associates, two grade school teachers, and several student research assistants. Jenny Moore, a post-doctoral research associate and one student research assistant were trained at the University of Tennessee. The University of Florida had one student research assistant, North Carolina State University trained a research associate, and two undergraduate research assistants, and the Rodale Institute trained a research associate and a research assistant. Furthermore, two grower collaborators, Haroun Hallack of Redbud Farms and Warren Landis of Strawberry Creek Farms were also trained in BMSB identification and execution of research projects at their respective farms.

The training these individuals received was essential for the completion of the first year objectives from this OREI project. The education and experience everyone received while participating during this first year is also important for their advancement in their career and/or development as future scientists.

Summary Results from the First Year Projects

Objective 1 - Habitat manipulation

Develop habitat manipulation tactics based upon how host plant phenology impacts BMSB preference and dispersal

Trap crops are a core tactic for managing insects by attracting and retaining the pest in a non-crop plant. Due to the broad feeding habits and mobile behaviors of BMSB we hypothesized this would be a suitable tactic for managing BMSB. We tested four potential organic trap crops (millet, okra, sunflower, and sorghum) in four states for their effectiveness at attracting and retaining stink bugs. Results varied across the states (Fig. 1), but sorghum was generally the most attractive trap crop tested (MD P=0.046; NJ P=0.020; PA P = 0.075; WV P=0.001). For example, in West Virginia relative attractiveness of each trap crop to BMSB was 0.52, 0.31, 0.04, and 0.012 for sorghum, sunflower, millet, and okra, respectively. Across states, sunflower and millet had the highest number of BMSB eggs and native stink bugs. In year 2 we will evaluate a polyculture of the top trap crops. Pfeiffer (VT) and Kotcon (WVU) separately evaluated sunflower and/or sweet corn as trap crops. These appeared effective at attracting BMSB but injury was still reported on the tomato cash crop. PD Nielsen's lab began testing BMSB management strategies within the trap crop and found that flaming to be the most effective organic management tactic evaluated.

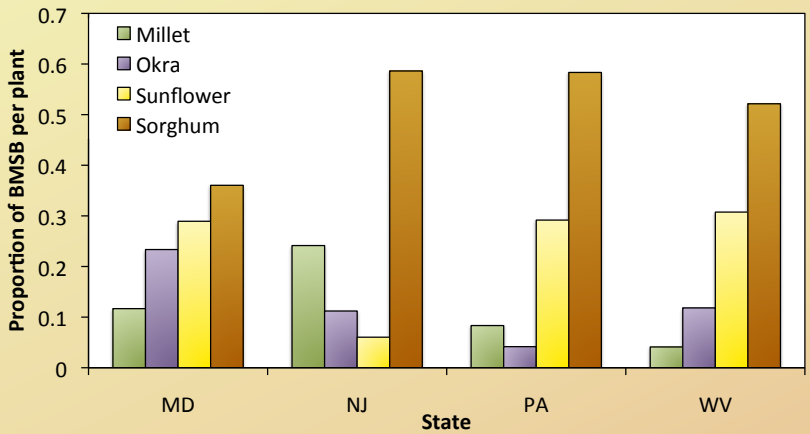


Figure 1. Proportion of adult BMSB observed on the four potential trap crops tested in four different states; Maryland, New Jersey, Pennsylvania, and West Virginia.

Tested four potential trap crops for BMSB


Millet


Okra


Sunflower


Sorghum


BMSB on Sorghum

Summary of outputs from Objective 1: *Trials across 4 states identified sorghum as the most attractive trap crop for BMSB with sunflower a close second and attractive to many native stink bugs. Sunflower also attracts many natural enemies which may enhance natural enemy services.*

Objective 2 - Dispersal

Determine biotic and abiotic factors affecting adult and juvenile BMSB whole-farm movement

We evaluated BMSB on-farm movement throughout the year at different spatial scales. At the field level we identified that nymphs are making feeding choices and will readily disperse to a more suitable crop depending on plant phenology. PD Nielsen, PI Hamilton, and post-doc Blaauw (Rutgers) compared four organic crops; Swiss chard, bell pepper, sweet corn, and soybean. As seedlings, BMSB nymphs were more attracted to Swiss chard (P=0.005). As ears of corn were forming, more nymphs dispersed to sweet corn than to any other host plant (P=0.0008). Similarly, at the end of August, nymphs dispersed to soybean as pods were forming (P=0.0001). By plotting the attractiveness of each of the crops against the progressive stages of the host plants' phenologies, we found that corn and soybean plants became more attractive to nymphs as the stages progressed, whereas the attractive of pepper remained relatively the same throughout and Swiss chard never progressed beyond the vegetative stage (Fig. 2).

Similarly, PI Leskey and post-doc Lee completed trials establishing flight dispersal capacity from wild BMSB populations. Additionally they also began quantifying the capacity and rate of nymph dispersal. Under lab conditions Leskey found that nymphs have a high capacity for horizontal and vertical walking, with distances even greater than that of the adults (Fig. 3). In field conditions, 5th instars were capable of dispersing 2m/hr with speed increasing under higher temperatures.

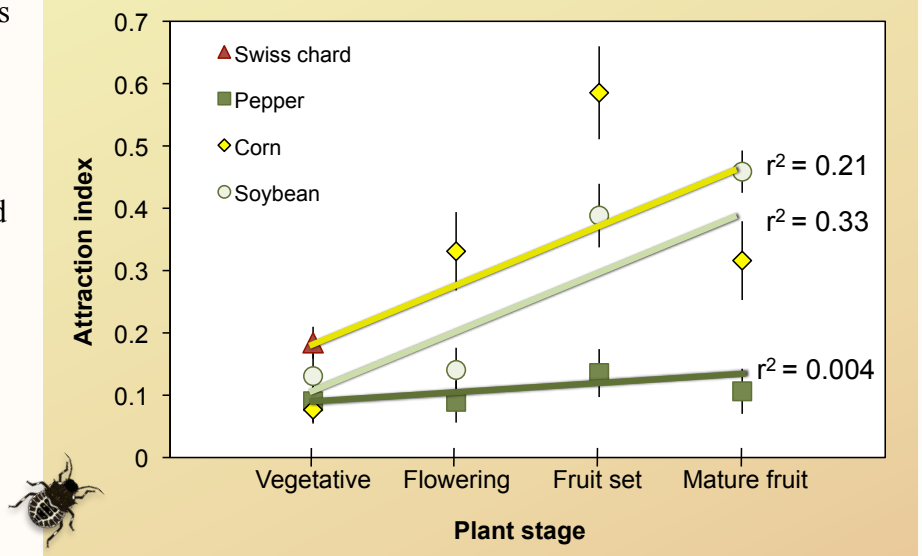


Figure 2. Regression of BMSB nymphal attraction to progressive phenological stages of host plants. Only corn and soybean plants became more attractive as their phenology progressed.

Whole-farm movement was evaluated at 3 organic farms. PI Park characterized movement as aggregation within sheds moved to

wooded areas and blackberry hosts. At one farm BMSB populations were then found in cherry and pear before moving to grape and then soybean. Final movement prior to overwintering was to corn and black locust.

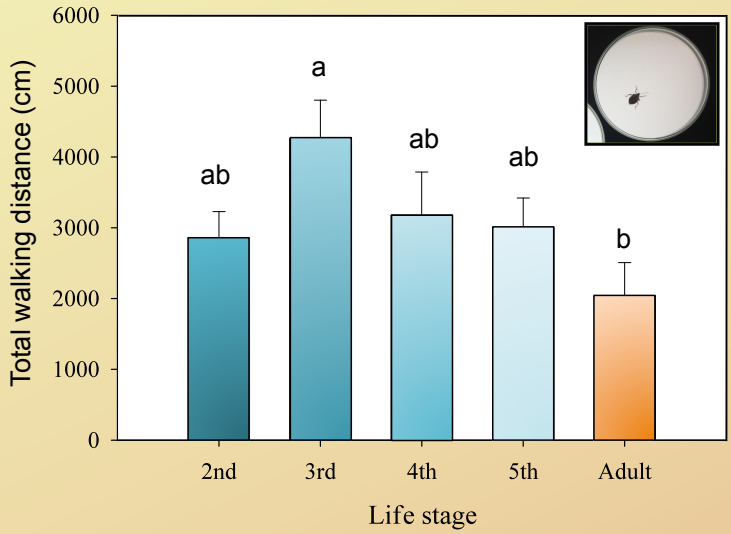


Figure 3. Horizontal walking capacity of BMSB nymphs compared to adults under laboratory conditions.

At the landscape level, year-long dispersal to/from overwintering sites was evaluated on-farm. It proved difficult to use pheromone traps to trap BMSB as they dispersed from shelters in the spring. We developed a simple 'overwintering trap' to capture and remove BMSB in the fall as they disperse to overwintering sites. The use of shelters filled with materials such as floating row cover did not work as well as those filled with cardboard. These shelters resemble 'bat boxes,' are made of plywood and are inexpensive to construct. Identification of an overwintering trap will permit non-chemical removal of BMSB during their hibernation stage and reduce the population density the following spring. PI Leskey also initiated a Citizen Science project aimed at identifying cues used by BMSB to select overwintering sites with 200+ volunteers. Together these projects will permit removal of source populations to reduce the following year's population.

Summary of outputs from Objective 2: *Nymphs on the move! We discovered that BMSB nymphs move quickly through the landscape and will move to a host plant as it produces fruiting structures. Additionally, over 200 volunteers in the DC metro area participated in the "Great Stink Bug Count" in 2013. This outreach project will identify characteristics of houses attractive to BMSB and lead to future management tactics such as overwintering traps.*

Objective 3 - Natural enemies

Determine the identity and importance of extant natural enemies of stink bugs and their impact on BMSB populations

There are two main types of insect natural enemies: predators and parasitoids. Predators, like lady beetles and big-eyed bugs, eat many prey in a lifetime, generally feeding as juveniles and as adults. Parasitoids, which are generally small wasps or flies, are specialized insects that develop as a juvenile in one host, eventually killing it. Thus there is a potential for BMSB to be managed by natural enemies.

Ten states covering Eastern, Central, and Southern regions participated in this objective. Sentinel BMSB egg masses were deployed throughout the growing season to measure the impact of natural enemies in pepper, tomato, apple, soybean, corn, and numerous other crops. As an invasive species, BMSB has no specific predators or parasitoids. However, there are generalist predators and stink bug parasitoids that naturally control BMSB eggs, with 31% of eggs attacked by natural enemies in New Jersey (Fig. 4).

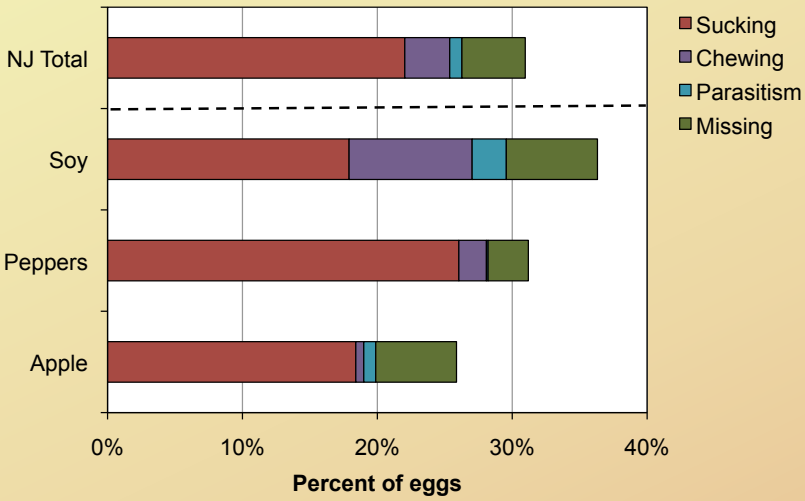
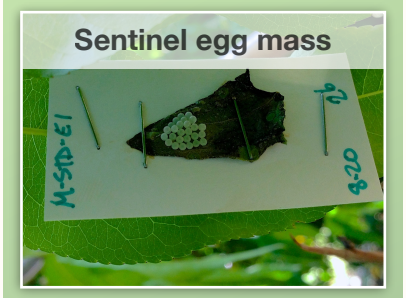


Figure 4. Comparison of natural enemy impact on sentinel BMSB eggs in New Jersey and then by individual crop type.

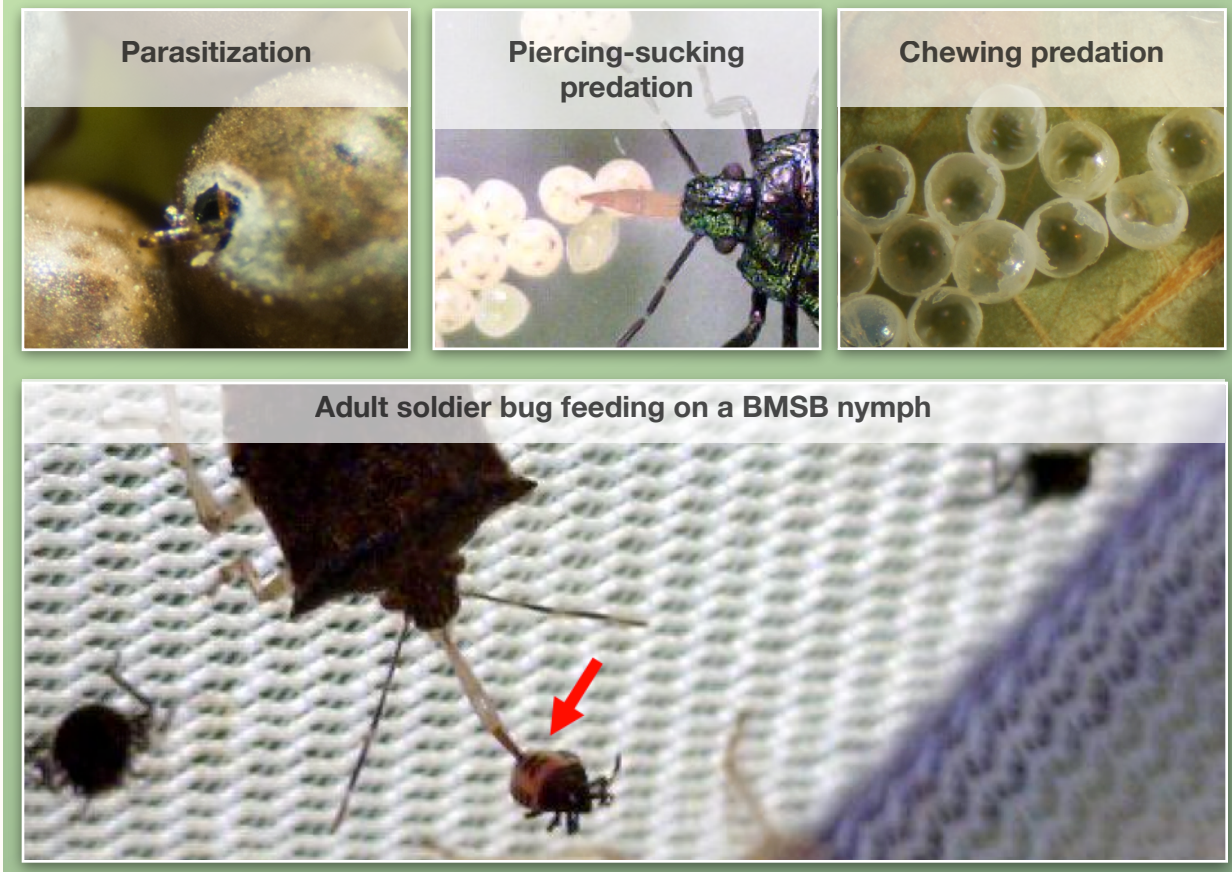


A portion of the predator activity in NJ and MI was recorded with video cameras. In NJ we made the first observation of katydids consuming BMSB egg masses. Video has shown that BMSB eggs have additionally been attacked by natural enemies, such as spiders, parasitoid wasps, lady beetles, sucking predators, and ants. Examples of the different types of feeding damage can be seen in the images below.

Endemic stink bug species in MD field crops had a 5% hatch rate due to natural enemy activity whereas BMSB had a 55% hatch rate. BMSB egg masses had 38% parasitism while native species had 70%. Despite high predator activity, it is clear that the natural enemy community does not 'prefer' BMSB eggs. To enhance natural enemy

activity on BMSB eggs, conservation of parasitoids was investigated by PI Hooks (UMD) to identify insectary plants. Hook's data suggests that partridge pea has desirable characteristics of a good insectary plant and will be evaluated further.

Examples of the different types of natural enemy feeding damage done to BMSB eggs and nymphs.



Summary of outputs from Objective 3: *Low levels of parasitism were found in all states but surprisingly high levels of predation by generalist natural enemies were discovered. Field crops hosted the highest levels of predation and a new stink bug predator - katydids - was discovered through video surveillance!*

Objective 4 - Row covers

Evaluate integrated management plans for BMSB and endemic stink bugs specific to organic production systems

In Year 1 PI's Rogers (UTK) and Bessin (UK) and farmer Landis (Strawberry Creek Farm) investigated the use of barrier fabrics to prevent stink bug injury in vegetables. These row covers are able to reduce damage by BMSB and native stink bugs (Fig. 5), with fine mesh fabrics providing more protection from insects and sunscald. However, fine netting reduced fruit production and natural enemy colonization. Exclusion may be a viable approach, but only under high levels of stink bug activity.

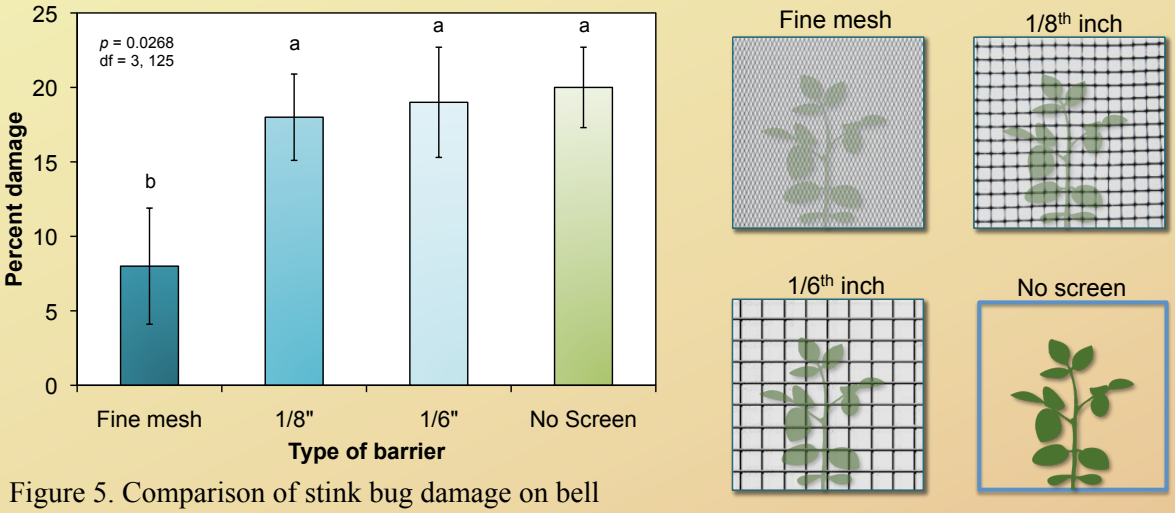


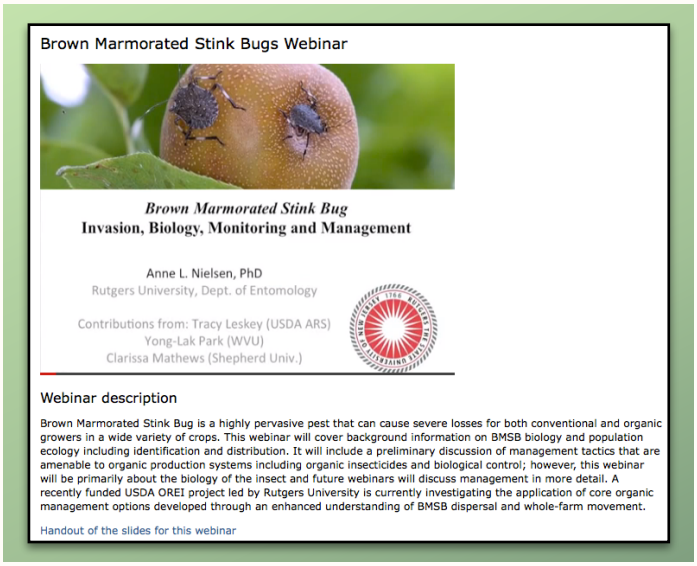
Figure 5. Comparison of stink bug damage on bell peppers under four different row cover treatments: fine mesh, 1/8", 1/6", and a no screen control.

Summary of outputs from Objective 4: *Fine mesh row covers successfully prevented stink bugs from feeding on bell peppers but high costs and a reduction in natural enemies may reduce adoption of this tactic.*

Objective 5 - Extension and outreach

Provide a diverse set of educational opportunities that increase grower understanding of BMSB behavior and ecology

One important aspect accomplished from our extension objective has been our work with the cooperating growers on this project. Many of these experiments were conducted on organic farms, including Muth Family Farm (NJ), Terhune Orchards (NJ), Rodale Institute (PA), Redbud Farm (WV), Strawberry Creek Farm (VA), Gladheart Farms (NC), Thatchmore Farms (NC), Brickel Creek Organic Farm (OH), Northridge Organic Farm (OH), Stratford Ecological Center (OH), and Three Brothers Orchards (MI), where we were able to communicate results directly to the stakeholders. Ohio State University PI Welty also presented about stink bug management at 6 field days over the summer of 2013. Three states conducted research trials on university run student organic farms at West Virginia University, University of Tennessee, and Michigan State University. Collaborating with the student groups allows us to reach a much larger group of students who are learning the ins and outs of organic farming practices and will be able to incorporate such tactics into their own farms during internships and when they run their own farm in the future.



Additionally, Year 1 results and BMSB identification information have been distributed to target audiences, primarily organic farmers, through an online webinar and farm field days. Specifically, extension activities include:

Online resources

- A webinar was presented by PD Nielsen and hosted through eOrganic (posted at http://eorganic.info/brown-marmorated-stink-bug-organic), which discussed a background of BMSB biology and how the project aims to investigate management in organic systems in February 2012. During the webinar there were 135 participants and the You-Tube video has received 326 views since it's posting.

- Investigators at The Rodale Institute have developed a website dedicated to this project (http://rodaleinstitute.org/our-work/pest-management/pest-management-current-projects/).

Field Days and Twilight Meetings

- 2013 Rodale Annual Field Day. July 19, 2013. Featured dozens of research and demonstration projects at their research farm, including work done by Dr. Gladis Zinati on pyramid traps and trap crops as part of the OREI project for organic stink bug management. This information was shared with over 80 people that attended the annual field day.

- University of Maryland (UMD) held a field day at the Clarksville, MD experiment station with 4,000 attendees. There, PI's Hooks and Dively had two posters – one on habitat manipulation to increase natural enemies of stink bugs and the other on how to use flowering borders to enhance biological control of stink bugs in organic field corn.

- UMD also held an organic farming field day on August 15, 2013 at the Central Maryland Research and Education Center in Upper Marlboro. This field day focused on organic stink bug management and identification, beneficial insects, weed management, and tillage. Over 30 farmers attended the field day, including about a dozen of new growers who interested in growing crops organically.

- Additionally, UMD participated in two twilight meetings where similar research on conservation biological control was presented to 65, 45, and 30 attendees on August 2, 9, and 28th respectively.

- West Virginia University hosted a field day at the student organic farm where PI's Park and Kotcon showed 30 attendees how to identify and control BMSB along with explaining about multistate OREI project in general.

- West Virginia University additionally organized a field day on August 9, 2013, which was attended by approximately 120 growers and Extension personnel. This field day included a brown marmorated stink bug workshop entitled "Brown Marmorated Stink Bug: Monitoring and Management" presented by PI's Park and Kotcon. Participants were also introduced to the OREI project through a field demonstration and wagon tour of our ongoing trap crop experiment.

- University of Tennessee, which is on the edge of BMSB distribution, participated in an organic crops field tour where PI Rogers discussed damaged and organic management options for BMSB and native stink bugs in April. Dr. Rogers also gave a workshop on BMSB at the University of Tennessee organic and sustainable crop production series in September.

- The Ohio State University held six field days over the course of the 2013 growing season. These field days were used to inform growers and other members of the community on organic stink bug management.

Identification Workshop

- PI Hoelmer from the USDA co-led an endemic parasitoid identification workshop sponsored by the Northeast IPM Center. Several members of our project participated to learn the identification of BMSB parasitoids. Held June 10, 2013 at the Rutgers Agricultural Research and Extension Center in Bridgeton, NJ.

Summary of outputs from Objective 5: *Field days were hosted in many states reaching over 4,000+ people. Team members were interviewed, presented data, gave webinars and provided hands-on identification instructions to growers.*

Project Additions

Major additions to the project include a Citizen Science project called "The Great Stink Bug Count" initiated by researchers at the USDA in Kearneysville, WV. Volunteers are trained to count BMSB on the outsides of their homes from Sept 15-Oct 15, during the peak dispersal period. The color, material and ordinal direction will be recorded to help identify key characteristics involved in identifying overwintering sites. In the projects first year over 200 volunteers in WV, VA, MD, DE, DC and PA participated. The information gathered here will permit management of BMSB in their overwintering sites to reduce the emerging population in the spring that will damage the crops and produce the next generation.

Another new project includes expansion of research by teams at Rutgers and USDA investigated nymphal dispersal behaviors. We found that nymphs can and readily disperse, even making host plant choices themselves. These results are leading to additional studies investigating what cues are used to initiate dispersal and host plant selection.

Based on the encouraging data from multiple states on natural enemy services, Rutgers will join researchers from Ohio and Maryland to investigate insectary plantings for the support of natural enemies for the enhancement of BMSB control. Rutgers will be expanding the continuing work from Ohio and Maryland to focus on native floral resources and their support of predaceous natural enemies and their services for enhancing the organic control of BMSB.

Outputs from the First Year Projects

In addition to the extension outputs from the work from our first year of this project, two journal articles are in the process of being published in peer-reviewed journals, and investigators associated with this OREI funded project have been featured in numerous news articles. Furthermore, initial results from the first year of this project have helped team members at West Virginia University and The Ohio State University leverage funding to obtain additional funding for BMSB research. The following is a detailed list of these outputs:

Journal articles

- Baek, S., Y. Son, and Y.-L. Park. 2014. Temperature-Dependent Development and Survival of *Podisus maculiventris* (Hemiptera: Pentatomidae): Implications for Mass Rearing and Biological Control. J. Pest Sci. (In Revision)

- Gawaly, S. and Y.-L. Park. 2014. Feeding Potential and Prey Acceptance of *Podisus maculiventris* (Hemiptera: Pentatomidae): Implications for Biological Pest Control. J. Plant Biol. Soil Heal. (Accepted for Publication)

Press coverage

- "Organic management of brown marmorated stink bugs?" AG Professional. Nov 20, 2012. Features Dr. Mary Rogers of the University of Tennessee.

- "UT Institute of Agriculture to research organic management of brown marmorated stink bug." MidAmerica Farmer Grower. Issue 48, Nov 30, 2012. Features Dr. Mary Rogers of the University of Tennessee.

- Deb Martin. "Stopping stink bugs: How to keep stink bugs from destroying your garden". Organic Gardening. January 2013. Features Dr. Anne Nielsen from Rutgers University.

- Rebecca D. Williams. "Stinky bugs, big eaters" Knoxville News Sentinel. July 18, 2013. Features Dr. Mary Rogers of the University of Tennessee.

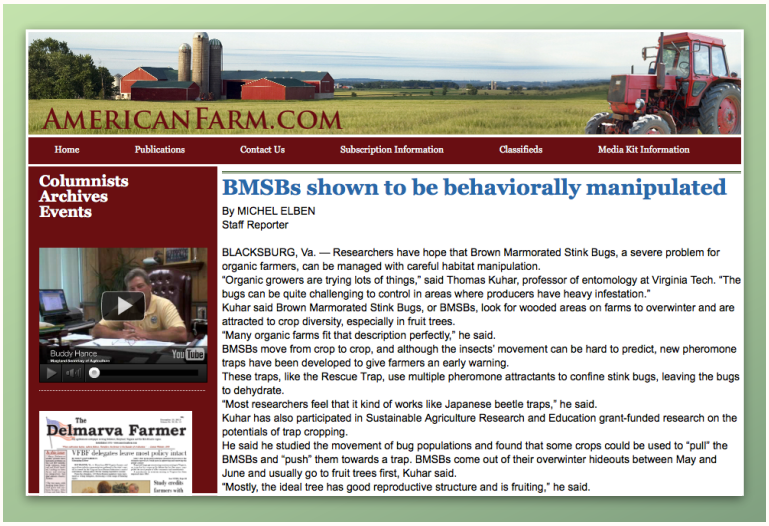
- Antonia Cekada. “Dreaded stink bugs set to make reappearance shortly.” The Exponent Telegram. August 5, 2013. Features Dr. Y.-L. Park of West Virginia University.

- Greg Bowen. "The Organic Vegetable Twilight Tour focused on weed management, tillage, beneficials, etc." Southern Maryland Agricultural Development Commission. August 22, 2013. Featured organic field day activity and work from Lauren Hunt, a graduate student from the University of Maryland.

- Paul Bedard. “Feds build citizen army to attract and annihilate stink bugs: 100,000 found in a shed.” Washington Examiner. August 24, 2013. Features Dr. Tracy Leskey from USDA-ARS.

- Cecelia Mason. “Study Aims to Determine Why Stink Bugs Choose Some Homes and Not Others.” NBC4 Washington Local News. August 27, 2013. Features Dr. Tracy Leskey from USDA-ARS.

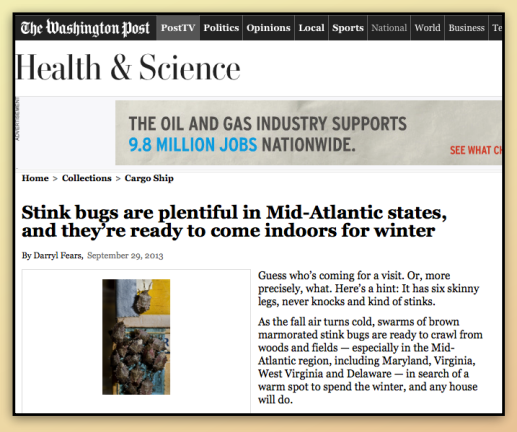
- Michel Elben. “BMSBs shown to be behaviorally manipulated.” Delmarva Farmer (www.americanfarm.com/ publications/the-delmarva-farmer/ events/2182-bmsbs-shown-to-be-behaviorally-manipulated). August 31, 2013. Featured work from Lauren Hunt, a graduate student from the University of Maryland.



- Cecelia Mason. “Residents sought to help in stink bug study.” West Virginia Public Broadcasting. September 2, 2013. Features Dr. Tracy Leskey from USDA-ARS.

- Frank Kracher. “North Carolina researchers are concerned about the growing number of invasive stink bugs.” WLOS television station (ABC affilate) in Asheville, NC. http://wlos.com/ shared/news/features/top-stories/ stories/ wlos_stink-bug-invasion-13148.shtml. September 10, 2013. Featured work from North Carolina State University.

- Darryl Fears. “Stink bugs are plentiful in Mid-Atlantic states, and they’re ready to come indoors for winter.” Washington Post. September 29, 2013. Features Dr. Tracy Leskey from USDA-ARS.


The Washington Post PostTV Politics Opinions Local Sports National World Business Te

Health & Science

THE OIL AND GAS INDUSTRY SUPPORTS 9.8 MILLION JOBS NATIONWIDE. SEE WHAT C

Home > Collections > Cargo Ship

Stink bugs are plentiful in Mid-Atlantic states, and they’re ready to come indoors for winter

By Darryl Fears, September 29, 2013

Guess who’s coming for a visit. Or, more precisely, what. Here’s a hint: It has six skinny legs, never knocks and kind of stinks.

As the fall air turns cold, swarms of brown marmorated stink bugs are ready to crawl from woods and fields — especially in the Mid-Atlantic region, including Maryland, Virginia, West Virginia and Delaware — in search of a warm spot to spend the winter, and any house will do.

Leveraged Funding

- Dr. Y.-L. Park of West Virginia University used his experience and work on this OREI project to develop behaviorally-based methods to organically manage stink bugs, to help obtain funding for international stink bug research. Dr. Park and his collaborators were funded by the rural Development Administration, South Korea ($150,000/3 years) to evaluate the spatial ecology of stink bugs (including BMSB), search for natural enemies for BMSB in South Korea, and work on the population genetics of stink bugs (including BMSB).

- At The Ohio State University, Dr. Celeste Welty used her expertise of stink bug research to receive funding from Ohio growers to help enhance her work on stink bug monitoring and management at locations throughout the state of Ohio.

Priorities for the Second Year of this Project

As the first year of our project finishes we are preparing for second year of exciting research. In addition to the continuation of current research, in the second year we will:

- We plan to increase our emphasis on our extension and outreach priorities:
  - Disseminate our results to organic growers and the general public through printed and online extension materials, grower meetings, and various research presentations.
  - Activities from our resources with *e*Organic, such as informational videos, webinars, and fact sheets on trap cropping and crop barriers, which will be posted on our project website (http://eorganic.info/brown-marmorated-stink-bug-organic).
  - Grower meetings will consist of field days with on-farm demonstrations to show research in action and to illustrate management techniques for BMSB.

- Strengthen partnerships with state or regional organic organizations like NOFA, MOFFA, MOSES, Virginia Institute for Biological Farming, and TOGA.
- Utilize our contacts at Rodale Institute, Redbud Farm, and student-run University farms to reach a broader audience on BMSB education and stink bug injury.
- Furthermore, research presentations to reach our extended science community will be given at various meetings across the country, such as the Entomological Society of America's Annual Meeting.

- Establish an on farm study to investigate the effectiveness of trap crops for stink bug management:
  - A large, multi-state project to determine BMSB spatial and temporal utilization patterns of trap and cash crops.
  - A smaller-scaled project to determine the source-sink dynamics of the trap crop within the whole farm.
  - Additionally, investigating management techniques for BMSB within trap crops.

- Determine the identity and importance of natural enemies of stink bugs:
  - Also as a continuation from our previous year, a project to investigate the potential of insectary plants to enhance BMSB and native pentatomid predation/parasitism will be conducted by researchers at the University of Maryland and The Ohio State University.
  - Assess the impacts of various trap crops on supporting natural enemies of BMSB and native stink bugs.
  - Determine natural enemy mortality due to organic insecticides that are currently used for stink bug management.

This project was funded in 2012 by the Organic Research and Extension Initiative grant, part of the USDA National Institute of Food and Agriculture. Grant number 2012-51300-20097.

United States Department of Agriculture
National Institute of Food and Agriculture

This document was created by Anne L. Nielsen and Brett R. Blaauw. December 2013.