Our long-term goals for this project are to develop economically and environmentally sustainable pest management practices for the brown marmorated stink bug (BMSB), *Halyomorpha halys* (Stål), in specialty crops and to implement a coordinated, rapid delivery system to disseminate critical information generated from this project to specialty crop end-users. USDA-NIFA SCRI # 2011-51181-30937

**OBJECTIVES**

**Objective 1.** Establish biology and phenology of BMSB in specialty crops.

**Objective 2.** Develop monitoring and management tools for BMSB.

**Objective 3.** Establish effective management programs for BMSB in specialty crops.

**Objective 4.** Integrate stakeholder input and research findings

**PROJECT DIRECTORS**

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- Classical biological control  Pg. 7
- Pheromone-Based Tools  Pg. 11
- Future Outreach Efforts  Pg. 16
- Project Outputs  Pg. 18
Rapid transcriptome sequencing of an invasive pest, the brown marmorated stink bug, *Halyomorpha halys* by Leslie Pick and Julie Dunning-Hotopp

Understanding the biology of the brown marmorated stink bug requires investigations at all levels, from population and behavioral measures to dissection of the genetic and genomic information that provides instructions for all developmental and physiological processes of the organism. In a study published this summer in *BMC Genomics*, investigators at the Institute for Genome Sciences at the University of Maryland School of Medicine and the University of Maryland Department of Entomology used state-of-the-art next generation sequencing methods to identify the sequences of all of the genes active in BMSB, the so-called transcriptome of BMSB. These researchers utilized new strategies to rapidly sequence the full transcriptome that allowed them to skip the time-consuming first step of breeding genetically identical individual animals in the laboratory, which is normally a first step in analysis of new genomes. Instead, the researchers were able to sequence and analyze all of the genetic variants that arose in their population of stink bugs, and to do so at all points in the insects’ life cycle, from the egg stage through late adulthood, including animals in diapause. This type of rapid sequencing provides a wealth of information about the biology of BMSB that is now available to the entire research community. In addition, it sets a precedent for an approach to sequencing that can provide a rapid response to other pest invasions similar to that already described for human disease epidemiology.

The genome of each organism, present in each and every cell, is the information center that harbors the code for virtually every process carried out by the organism over its entire life cycle. This code is in the form of genes - DNA sequences with unique combinations of 4 different bases (A,T,C,G) in unique orders and of unique length. To be active, genes must be copied by cellular machinery into RNA that can then act on its own to execute cellular functions, or which, more often, is translated into proteins that function as enzymes, structural molecules, hormones, etc., responsible for everything from fertility, to embryonic development to homeostasis and aging. The differential expression of genes at different times during development and in different cells of the animal is the key step in making cells and processes different from one another. For example, cells destined to become wing cells express a particular set of genes while cells destined to become parts of the brain express a different and unique complement of genes. Thus,
the key step required for a gene to be active in a cell or organism is the copying or transcription into RNA. Identifying all of the different RNA molecules in an organism tells us which genes are active in that organism.

The goal of the study published in BMS Genomics was to - in one fell swoop - identify as many genes as possible that are transcribed by BMSB at any stage of the life cycle of BMSB. This approach would provide an overview of virtually all the genes that are active in this species. To achieve this, RNA was extracted from BMSB eggs, 1st instar nymphs, 2nd instar nymphs, 3rd instar nymphs, 4th instar nymphs, 5th instar nymphs, an active adult male, an active adult female, an adult male in diapause, and an adult female in diapause (Figure 1). The RNA was divided into two pools: pre-adult stages and adult stages in order to get a first glimpse at the differential expression of genes between developing animals and adults. From this RNA, strand-specific libraries were constructed and Illumina HiSeq was used to gather the sequences of these transcripts. Bioinformatic analysis, using the program Trinity, as well as a novel method that analyzed the strand-specificity of the data, led to the identification of 53,071 putative transcripts from 18,573 components (Figure 2). By integrating other data, such as comparison to known genes from other insects, this number was further narrowed to 13,211 representative transcripts (Table 1). For comparison, *Drosophila melanogaster*, the insect best-studied at the molecular level, is estimated to express ~14,000 genes (http://www.nature.com/scitable/topicpage/eukaryotic-genome-complexity-437), suggesting that this single sequencing approach likely identified the majority of the genes active in BMSB.

To begin to determine the different functions carried out by the transcripts identified, their sequences were compared to genes from other insects and the transcripts were assigned to putative functional categories based upon the types of proteins they likely encode (Figure 3). Approximately 5,000 of the sequenced
transcripts could be assigned to functions based on this sequence comparison. They fall into the following major categories: information storage and processing, cellular processes and signaling, and metabolism. The top five sub-categories were general function prediction only (22.2%); DNA replication, recombination and repair (8.2%); posttranslational modification, protein turnover, and chaperones (7.9%); transcription (7.5%); and amino acid transport and metabolism (7.1%). Overall, this is very similar to the distribution of gene categories in other transcriptomes of eukaryotes, including insects. However, now that the BMSB-specific sequences are available for these genes, they can be used for monitoring and tracking pest populations and for designer gene targeting using approaches such as RNA interference (RNAi).

Table 1. Summary of Assembly and Annotation

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Before filtering</th>
<th>After filtering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of reads (both pools)</td>
<td>366,689,206</td>
<td>N/A</td>
</tr>
<tr>
<td>Number of putative transcripts (both pools)</td>
<td>194,729</td>
<td>13,211</td>
</tr>
<tr>
<td>Average length (bp)</td>
<td>1,005</td>
<td>2,026</td>
</tr>
<tr>
<td>Standard deviation (bp)</td>
<td>1,474</td>
<td>1,592</td>
</tr>
<tr>
<td>Median length (bp)</td>
<td>439</td>
<td>1,649</td>
</tr>
<tr>
<td>Maximum length (bp)</td>
<td>27,655</td>
<td>24,046</td>
</tr>
<tr>
<td>Length &gt;1000 bp</td>
<td>50,599</td>
<td>9,657</td>
</tr>
<tr>
<td>With a Uniref100 hit (e-value &lt; 1e-10)</td>
<td>80,536</td>
<td>11,513</td>
</tr>
<tr>
<td>Matching unique Uniref100 proteins</td>
<td>37,160</td>
<td>9,993</td>
</tr>
<tr>
<td>With a NR hit (e-value &lt; 1e-10)</td>
<td>80,262</td>
<td>11,497</td>
</tr>
<tr>
<td>Matching unique NR proteins</td>
<td>37,346</td>
<td>10,007</td>
</tr>
<tr>
<td>Number of Trinity components</td>
<td>123,175</td>
<td>13,211</td>
</tr>
<tr>
<td>Number of ORFs</td>
<td>89,684</td>
<td>13,210</td>
</tr>
<tr>
<td>&gt;450 bp</td>
<td>61,569</td>
<td>11,141</td>
</tr>
<tr>
<td>With a function assigned</td>
<td>57,197</td>
<td>9,811</td>
</tr>
</tbody>
</table>

The mass-sequence information obtained is publically available and accessible to the scientific community for use by researchers in many different ways, dependent upon their individual research programs. Here we suggest several immediate applications that the transcriptome data will support: (1) Population tracking. The assembled transcriptome sequences will have heterogeneity that reflects some of the genetic heterogeneity of the US BMSB population. Such heterogeneity at the sequence level was identified in 11,462 different putative transcripts, 86.8% of the total number of putative transcripts identified. These polymorphisms can be used to examine the future spread of BMSB in the US, as well as for a retrospective tracking of current populations from the original invasion in Allentown. (2) Monitoring of insecticide resistance. Transcripts with functions related to pesticide detoxification were identified.
in both the juvenile and adult RNA pools. Interestingly, there were 25 genes encoding proteins related to cytochrome P450 and glutathione S-transferase that were more abundant in adults. There were nine such proteins that were more abundant in the pre-adult RNA pool. Differential expression of these and other detoxification genes under field conditions may occur, providing an early warning signal for the emergence of pesticide-resistance in a population. (3) Monitoring Symbionts and lateral gene transfers. A recent report by others members of the USDA-SCRI group suggests that, like many other insects, BMSB is dependent upon symbionts that are likely necessary to supplement dietary needs (Taylor et al, PLoS One.2014;9:e90312). The BMC Genomics paper reported that, in addition to gut symbionts, evidence was found for lateral gene transfer between bacteria and BMSB. This suggests that, as in other animals, direct transfer of DNA into the genome of BMSB has occurred and been maintained in insect lineages, likely because of the benefits conferred to the insect from these bacterial genes. Transcriptome sequencing identified putative lateral gene transfers between bacteria and BMSB of genes encoding ankyrin-repeat related proteins, lysozyme, and mannanase. Some of these appear to have occurred in hemipteran stem groups while other may be BMSB-specific. While further research at the genomic level is necessary to verify lateral gene transfer, these Hemiptera- and BMSB-specific transfers provide novel targets for the development of genome based methods to control them. (4) Development of gene-specific pest control strategies. The advent of RNAi technology has opened up the possibility of generating gene

![Figure 3. Transcript functional categories.](image)

The NCBI Cluster of Orthologous Groups (COG) database was used to classify the predicted proteins in the 13,211 representative transcripts. Assignment of COG categories showed that a large number of ORFs belonged to categories of proteins whose functions are poorly characterized, namely those that have general function prediction only and those with unknown function.
specific agents that will abolish the expression of a gene of choice, thereby impacting
the viability or fertility of the treated animals. Preliminary data suggests that RNAi is
effective in BMSB (Lu and Pick, unpublished). The transcriptome sequence makes
available to the research community numerous potential targets for these types of
gene-based pest control.

In sum, the complete transcriptome of BMSB was assembled using novel
methods that are likely to be useful for rapid genomic analysis of invasive species.
The sequence information is publically available and will provide resources for
researchers throughout the world interested in BMSB. The overall complement of
BMSB genes appears to be similar to other related insects, as expected. However,
specific BMSB gene sequences identified will be broadly useful for understanding the
fundamental biology of BMSB, for monitoring pest populations and insecticide
resistance, and for gene-based targeting techniques to control BMSB populations.
Classical biological control of brown marmorated stink bug, *Halyomorpha halys*  
by Christine Dieckhoff and Kim Hoelmer

Scientists at the USDA-ARS Beneficial Insects Introduction Research Unit in Newark, DE, continue to work towards a classical biological control solution for brown marmorated stink bug. A classical (importation) biological control program became warranted when our initial surveys showed that the impact of native stink bug parasitoids on BMSB in the Mid-Atlantic states was very low and not sufficient to significantly suppress BMSB populations. We’ve continued these surveys but there is no indication that native parasitoids are adapting to BMSB (figs. 1a and 1b). In contrast, egg masses of BMSB are routinely parasitized in Asia at much higher rates of 60-90%.

![Figure 1](image)

**Figure 1. Impact of indigenous parasitoids on BMSB in the Delmarva area.** a) proportion of adult BMSB containing egg deposited by tachinid flies (Diptera: Tachinidae), 2005-2013; b) proportion of parasitized sentinel egg masses placed around Newark, DE, 2007-2013. Egg mass columns indicate those clusters of eggs with at least one or more eggs attacked. Usually only a few of the available eggs in the cluster were attacked. Numbers above columns indicate the respective sample sizes (BMSB egg masses typically contain 28 individual eggs).

Foreign exploration in Asia was begun in 2005, focusing on the native range of BMSB in China, Japan, and South Korea. These exploratory trips identified several species in the genus *Trissolcus* (Hymenoptera: Scelionidae) that frequently attack and kill BMSB eggs. *Trissolcus* are tiny parasitic wasps, 1-2 mm in length as adults, that attack eggs of various species of stink bugs, and members of this genus have been used as biological agents of other stink bug pests (Orr 1988, Corrêa-Ferreira & Moscardi 1996). Several *Trissolcus* species from different Asian locations have been recovered over the course of the explorations and a total of 32 populations comprising 4 species is currently maintained in the Newark, DE quarantine facility. The most abundant and widespread of these species in Asia are *T. japonicus* (originally described as *T. halyomorphae* by Yang et al. 2009, and synonymized as *T. japonicus* by Talamas et al. 2013) and *T. cultratus*. Other species occur less frequently (Fig. 2). The identities of the Asian parasitoids have been confirmed with the cooperation of ARS scientists at the Systematic Entomology Laboratory (Matt Buffington and Elijah Talamas) and the European Biological Control Laboratory (Marie-Claude Bon).

This research project supports Objective 2. Develop monitoring and management tools for BMSB
To fast-track the host range evaluations needed to assess the safety and suitability of Asian *Trissolcus* for field release, the Newark ARS laboratory is coordinating regional tests by state and university cooperators in other parts of the U.S. (Florida Dept. Food & Consumer Services; Michigan State Univ.; Oregon Dept. Agric.; Univ. California (Riverside); and California Dept. Food & Agriculture) with supplemental funding from APHIS Farm Bill funds. Currently the focus of these host range evaluations is on a Chinese populations of *Trissolcus japonicus* collected in the Beijing area (fig. 3). In addition, evaluations of a second species, *T. cultratus*, were initiated during 2014 in cooperation with FDACS to support the research with this species already begun in Newark, DE.

To date, sixty-two species and/or geographic populations of non-target stink bug species have been tested within the framework of host range tests using standardized protocols for no-choice (only the non-target species offered to the parasitoid) and choice (BMSB and non-target offered simultaneously) tests. Testing of the *Trissolcus japonicus* (Beijing) population is nearing completion. Tests conducted so far have shown an inability to develop in twenty of these species. No-choice testing of 18 additional species is currently underway or planned. Thirty-two species of non-targets
were attacked to some degree in no-choice tests (ranging from minor to significant levels); these species have been subjected to choice testing. Fourteen of the non-targets exhibited varying levels of attack in choice tests and tests of other species are still pending. In many cases, parasitoids that attack some non-target species in no-choice tests show a preference for the BMSB target when a choice is presented. Because no-choice and choice tests are deliberately designed to give every possible opportunity to attack a non-target, they are very conservative tests and often overestimate the impact on non-target species under actual field conditions. Non-target species which are attacked under choice test conditions are therefore being studied further to determine the influence the laboratory conditions of exposure and how these may change under more natural conditions. Particular emphasis is given in these additional studies to the spined soldier bug, *Podisus maculiventris* (figure 4), which is a predator of other pest insects in natural and agricultural settings.

**Figure 3. Female *Trissolcus japonicus* parasitizing BMSB eggs in the ARS Newark, DE quarantine facility. (photo credit: Christine Dieckhoff)**

This research project supports Objective 2. Develop monitoring and management tools for BMSB
Additional tests with both BMSB and *P. maculiventris* egg masses have been started or are planned to test the influence of the test arena size, length of time exposure, order of egg mass exposure, and plant structure on attack rates under choice condition to better understand how these factors may change the behavior of *Trissolcus* under actual field conditions. If these studies show that the impact on non-target species is likely to be insignificant in nature, we will then be able to submit a petition for field release.

**References**


Working Toward Commercialization and Application of Pheromone-Based Tools by Tracy C. Leskey

As reported last year, the BMSB pheromone has been identified as a two-component mixture of \((3S,6S,7R,10S)-10,11\text{-epoxy-1-bisabol-3-ol and} (3R,6S,7R,10S)-10,11\text{-epoxy-1-bisabol-3-ol} \) (Khrimian et al. 2014). In addition, this pheromone is synergized when deployed in combination with \((E,E,Z)\text{-2,4,6-decatrienoate (MDT), the pheromone of another Asian stink bug species, Plautia stali} \) (Weber et al. 2014). In combination (Fig. 1), these stimuli can be used as a sensitive lure for deployment in traps for season-long monitoring of presence, abundance and activity of BMSB.

**Commercialization.** However, there still is much work needed to ultimately commercialize pheromone-based products. Therefore, a series of coordinated multi-state trials were conducted throughout the season to provide commercial companies with information regarding overall lure performance. Lures evaluated included those from AgBio/ChemTica, Rescue/Sterling, Alpha Scents, Scentry and Trece. Standard black pyramid traps (Fig. 2) were baited with treatments provided by commercial companies and compared with traps baited with our experimental standard of 10mg lures of the BMSB aggregation pheromone + 66mg MDT (AgBio) and an unbaited control. Trials were conducted throughout the season. Thus, population pressure was variable. However, because we included our experimental standard during each interval, we can make some baseline inferences. Trials were conducted in, DE, MD, NC, NY, PA, NJ, OR, VA, WA, and WV and from May – November 2014.
Trial one was conducted throughout May 2014 and compared our experimental standard with: 1) #10 mg BMSB pheromone + 2X AgBio MDT; 2) standard Rescue/Sterling combination lure and 3) an unbaited control. This early season trial clearly demonstrated that BMSB adults were responding to baited traps. However, there were no significant differences among our experimental standard, #10+ 2X AgBio MDT or the Sterling/Rescue lure (Fig. 3). Very few nymphs were present in the field at this time.

Our second trial was conducted in June 2014. Treatments included: 1) experimental standard; 2) Scentry #1; 3) Scentry #2; and 4) an unbaited control. For adults and for nymphs, significantly greater numbers were captured in traps baited with our experimental standard and both Scentry treatments compared with the unbaited control (Fig. 4).

In July, Trece provided us with two experimental formulations. We evaluated four treatments: 1) experimental standard; 2) Trece 1126; 3) Trece 1127; and 4) an unbaited control. At this point in the season, nymphal populations were higher than adults. However, for both adults and for nymphs, both Trece treatments yield captures significantly greater than our experimental standard and control (Fig. 5).

In late July-early August, we evaluated three treatments from AlphaScents. These included the following treatments: 1) 80/11; 2) 80/13; and 3) 80/31. These

*This research project supports Objective 3. Establish effective management programs for BMSB in specialty crops.*
treatments were compared with our experimental standard and with an unbaited trap as a control. Adult and nymphal captures were significantly higher in traps baited with our experimental standard and with AlphaScents treatments compared with the unbaited control (Fig. 6).

Finally, in the late-season, we compared captures in traps baited with our experimental standard and with three commercial treatments; Trece 1126, AgBio, and Rescue and with an unbaited control. Among all treatments, only Trece 1126 performed as well as experimental standard with significantly greater adult captures compared with AgBio, Rescue and the unbaited control. Captures of nymphs, however, were low but were significantly greater in baited traps compared with the unbaited control (Fig. 7).

**Application.** Based on our results, it appears that commercial companies have products that can be used to detect the presence, abundance, and seasonal activity of BMSB in specialty crops. To further determine if we can utilize the biological
information generated by baited traps to guide BMSB management, we conducted a two-year study aimed at determining if pre-set trap-based treatment thresholds could be used to successfully manage BMSB in apple. In this study, apple blocks were monitored with two traps baited with the pheromone and synergist; one in the center of the block and one in the perimeter row. When captures in either trap reached one of our pre-set thresholds, the block was treated with an insecticide considered to be effective against BMSB using an alternate-row-middle (ARM) spray pattern. The block was treated again seven days later and the threshold was then reset. Trap-based threshold evaluated in this study were: 1) 1 adult/trap; 2) 10 adults/trap; and 3) 20 adults/per trap. Blocks under these management regimes were compared with blocks treated weekly and those that were never treated. In both years of the study, our moderate threshold of 10 adults/trap reduced spray applications by ~40% from 21 to ~12 applications (Fig. 8) whereas blocks managed using 1 adult / trap saw reductions of only ~10%. More importantly, blocks managed using our moderate threshold of 10 adults/trap to trigger sprays resulted in statistically identical levels of injury compared with blocks treated weekly during both years of the study (Fig. 9). Blocks managed using a higher threshold of 20 adults/trap resulted in overall spray reduction of about 50% compared with blocks treated weekly. However, it appears that some key sprays were missed as injury was significantly higher.
Our results indicate that the biological information generated by baited pheromone traps can be used to guide management of BMSB in apple orchards. It seems likely that this same approach could be useful in other specialty crops such as peaches (Fig. 10) as well. In 2014, five commercial growers evaluated this provisional threshold for guiding BMSB management in an apple block on their farms. Although we are still in the process of receiving and evaluating spray records, we found that there was no statistical difference in the amount of injury in apple blocks managed using this provisional threshold and under standard management tactics used by each grower. Although these results are promising, we likely will need to continue to recalibrate these threshold-based management tactics as commercial companies refine and tweak their pheromone-based products. Furthermore, trap styles and deployment strategies may also be improved. However, we now have the ability to reliably monitor BMSB season-long and develop more sustainable approaches for their management.

References


BMSB Stakeholder Survey Yields Directions for Future Outreach Efforts by Keoki Hansen and Tracy C. Leskey

Led by The Northeastern IPM Center and Eric Day at Virginia Tech, the stakeholder community has been surveyed since the inception of the BMSB SCRI CAP. The goal of this survey effort was to first quantify baseline knowledge of BMSB biology and management tactics, level of specialty crop damage being inflicted, and outreach needs.

The survey efforts were extremely successful with 776 individuals completing in-person, paper surveys at grower-oriented meetings and 360 individual completing an online version based on Qualtrics.

Over 60% of all participants characterized themselves as growers (Fig. 1). Data were generated from participants from a total of 35 states (9 using the in-person, paper surveys).

A key issue identified by this survey was the need for simple identification tools for BMSB and other stink bugs. In the online survey we asked respondents if they knew how to scout for BMSB; only 24% responded yes, while 37% responded maybe. However, 64% reported scouting for BMSB on their farm. In response to this need, the Northeastern IPM Center has led an effort to update the Field Guide to Stink Bugs put together by researchers from Virginia Tech and Clemson and funded by the Virginia Agricultural Council and Southern Center (Fig. 2). The newly updated guide has been expanded by Ames Herbert and Tom Kuhar at Virginia Tech. to provide a national scope for both pest and beneficial stink bugs. 

This research project supports Objective 4: Integrate stakeholder input and research findings to form and deliver practical outcomes.
Center has also developed BMSB ID tools using small bottles of clear hand sanitizer, which allows full view of the stink bug.

Another revealing question from the online survey asked respondents to identify which natural enemy of BMSB eggs have shown promise. Most respondents identified parasitic wasps as being a promising biological control agent. However, the correct answer was all of the above as generalist predators such as big-eyed bugs, *Geocoris* spp. (Fig. 3), have also been identified as consuming BMSB eggs.

Among respondents who grew specialty crops, tree fruit was the most frequently damaged with nearly 60% reporting damage in 2012 and 2013. Damage to peppers and tomatoes for both years was reported by 40% of the survey participants (Fig. 4).

Among respondents, 45% of growers reported losses from BMSB and 79% of growers said they thought it was likely or very likely they would be threatened by this invasive pest. The majority of the growers participating in the survey practiced IPM but those dealing with BMSB did make changes in their management practices. For those taking the online survey, 57% reported increases in the use of insecticides though 56% also reported an increase in scouting.

In addition to questions regarding identification, damage and management tactics, we asked participants what types of BMSB information would be most helpful. They indicated that scouting, sprays, trapping and BMSB biology and behavior were the most important. In-person delivery of information was still considered very important by our participants, though Extension publications, websites and email were also favored. All of this information can be used by our BMSB SCRI CAP team to further refine outreach efforts.
Project Outputs

Research Talks


Bergmann, E., H. Martinson, and P. Shrewsbury, 2014. Patterns of host use by


Fleischer 2014 Developing a phenological model for the invasive brown marmorated stink bug in peaches IOBC WPRS. Vienna, Austria.


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Leskey, T.C. 2014. Developing monitoring and management tools for the invasive brown marmorated stink bug. Plant and Food Research Center, Auckland, NZ.


Morrison, III W.R., Z. Szendrei and T. Leskey. 2014. Steps leading to the identification


Nielsen A.L. 2014 Deciphering the population ecology and behavior for the invasive BMSB in fruit. MSU Departmental Seminar. East Lansing, MI.


Research Posters


Research Workshops/Meetings/Symposia

Hoelmer, K., C. Dieckhoff, and M. Buffington. 2014. Parasitoids of the brown marmorated stink bug: A specialized training workshop, June 17-18 in conjunction with the BMSB IPM working group meeting. Georgetown, DE. June 16-18.

Research-Oriented Websites and Digital Products


Hudson Valley Research Laboratory, Use of pheromone trapping data to determine the presence of BMSB in NYS agricultural production systems. Provide historical urban tracking of BMSB throughout NYS. [http://www.eddmaps.org/bmsbny/](http://www.eddmaps.org/bmsbny/)


New York Invasive Species Public Map. Use of Citizen Science-based data to track BMSB throughout NYS.  http://imapinvasives.org/nyimi/map/


**Research Publications**


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**Extension Talks and Meetings**

2013 CCE Suffolk Annual Meeting: The Entomology Program at CCE: 20 November. 70 attended.
2013 IPM Working Group Meeting. December.
2013 Monitoring the BMSB in Urban and Agricultural Environments in New York State. Agricultural Invasive Species session. Annual CCE Agriculture and Food System In-service, Ithaca, NY, November 13. 20 attended.
2013 Port Jeff. High School Environmental Science class: Entomology at Cornell on Long Island: November. 26 attended.
2013 Stakeholder Advisory Panel Meeting, December.
2014 Insect Management in Sweet Corn, including BMSB. NJ Ag Convention and Trade Show. February 5.
2014 Mid-Atlantic Fruit and Vegetable Meetings, Hershey, PA Over 300 attended.
2014 BMSB control in organic vegetable systems. MOFFA Meeting. February.
2014 BMSB in vegetable high tunnel production systems. Delaware Ag Week. Harrington, DE. January.
2014 New pests and some old ones to watch for in 2014. Central MD Fruit and Vegetable
2014 Biological Control Approaches. Advanced Landscape IPM Shortcourse.
2014 Summary Report Year 3

Department of Entomology, University of Maryland. College Park, MD. January.


2014 CCE Master Gardener training; Pests in the Home Garden and Landscape. April 29. 29 attended.


2014 Cornell Gardeners: The Entomology Program at LIHREC. April 4. 24 attended.


2014 Ecological Entomology. St. Mary’s Master Gardeners. Leonardtown, MD. February 27.


2014 Gloucester/Cumberland/Salem County Twilight Meeting. April 2. 26 attended.

2014 Gloucester/Cumberland/Salem County Twilight Meeting. May 8. 25 attended.


2014 Hunterdon, Mercer, Morris, Warren, Monmouth County Twilight Meeting. Insect
Control Update with a Focus on Early Season Pests. April 8. 41 attended.


2014 IPM Working Group Meeting, June.


2014 Managing Sweet Corn Insects and Resistance with New Insecticides. Northern Commercial Vegetable Growers' School, Plattsburgh City Recreation Department, Plattsburgh, NY. February 25.


2014 Organic Pesticide Applicator Training for Fruit and Vegetable Growers; 'IPM in Organic Pest Management Programs' Cornell Cooperative Extension, Hudson Valley Laboratory, Highland, NY. April 3-4. 29 attended.


2014 Whole Season Tree Fruit Insecticide Programs in Light of BMSB. February 13. 28 attended.


2014. Insect Management in Sweet Corn, including BMSB. Mid-Atlantic Fruit and Vegetable Meeting. January 30.


Butler, Sr., B.R. 2014. Brown marmorated stink bug on tree fruit. Western Maryland
Fruit Meeting, Queenstown, MD. 46 attended.


Krawczyk, G. 2014. Revisiting IPM in the world of BMSB and SWD. President Day Fruit Growers Educational Meeting, Biglerville, PA, February 17. 220 attended.


Krawczyk, G. 2014. BMSB and seasonal orchard IPM updates. Adams County Twilight IPM meeting. Aspers, PA, May 7. 65 attended.


Krawczyk, G. 2014. BMSB and seasonal orchard IPM updates. Erie County Tree fruit IPM meeting. North East, PA, May 15. 30 attended.

Krawczyk, G. 2014. BMSB and seasonal orchard IPM updates. Franklin County Twilight IPM meeting. Chambersburg, PA, May 8. 35 attended.


Krawczyk, G. 2014. BMSB and seasonal orchard IPM updates. Western PA Twilight IPM meeting. Wexford, PA, May 14. 35 attended.


Krawczyk, G. 2014. Integrated fruit production update for the new season. Regional IPM meeting, Biglerville, PA, April 10. 55 attended.


Krawczyk, G. 2014. Revisiting IPM in the world of BMSB and SWD. Franklin County Fruit Growers Educational Meeting, Waynesboro, PA. February 19. 35 attended.

Krawczyk, G. 2014. Revisiting IPM in the world of BMSB and SWD. Lancaster County Fruit Growers Educational Meeting, Lancaster, PA. May 6. 45 participants

Krawczyk, G. 2014. Revisiting IPM in the world of BMSB and SWD. Northeast PA Tree Fruit Meeting. Avoca, PA, February 27. 50 attended.

Krawczyk, G. 2014. Revisiting IPM in the world of BMSB and SWD. Western PA Tree Fruit Growers Meeting. Wexford, PA, March 5. 45 attended.


Kuhar T. 2013. Emerging row crop pests - stink bugs, kudzu bugs, and others, Private
Applicators Recertification Category 91. Madison, VA. December.


The 46th annual Meeting of the NC Tomato Growers Association and Winter Vegetable Conference and Trade Show, February 19-20. Asheville, NC.


Extension Workshops

Gill S., B. Kunkel, E. Day, P. Shrewsbury, M. Raupp, J. Brust, B. Butler, and S. Klick. 2013 A day-long workshop Brown marmorated stink bug research and practical use that combined lecture with hands-examination of the BMSB and the predators and parasites that are helping reduce populations of this bug. Landscape and grounds maintenance professionals, 51 people from green industry and Master Gardener program registered. Westminster, MD.

Extension Oriented Websites and Digital Products


Brown Marmorated Stink Bug Control: Keeping Stink Bugs Out of Your House. [https://www.youtube.com/watch?v=9jIgJ4WjryY](https://www.youtube.com/watch?v=9jIgJ4WjryY)


Brust, G. Maryland Vegetables. [http://extension.umd.edu/mdvegetables](http://extension.umd.edu/mdvegetables)


Jentsch P. J. 2013. NYS Insecticide Materials and Efficacy to Manage the Asian Invasive Brown Marmorated Stink Bug ([http://hudsonvf.cce.cornell.edu/bmsb1.html](http://hudsonvf.cce.cornell.edu/bmsb1.html)).


Maryland Vegetables([http://extension.umd.edu/mdvegetables](http://extension.umd.edu/mdvegetables)) - articles on BMSB posted.


**Extension and Outreach Publications**
2014 Fruit and Vegetable Newsletter article, Brown Marmorated Stink Bug (BMSB) Update, April 3.
2014 Fruit and Vegetable Newsletter article, Brown Marmorated Stink Bug (BMSB) Update, June 5.
2014 Fruit and Vegetable Newsletter article, Brown Marmorated Stink Bug (BMSB) Update, September 25.
2014 Weekly Crop Update - Seasonal Occurrence Posted to our website and reported weekly throughout the summer of 2014.
Best-Hope-for-Stink-Bug-Control-
Gill, S. and B. Kunkel. Refereed reviewed Factsheet - Joint between University of Maryland and Delaware University Extension - Brown Marmorated On Annuals and Herbaceous Perennials. Factsheet 2014 03-09


New Leveraged/Complementary Resources

Cornell. Jentsch, P. 03/01/13 to 11/30/13 Field Insecticide Trials to Manage the BMSB on Apple, Agricultural Company Gifts/Grants (Dow Agrochemical). $1,600


Cornell. Jentsch, P. and T. Lampasona. 04/01/14 to 3/31/15, Monitoring and Management Strategies for the Invasive Brown Marmorated Stink Bug in the Hudson Valley of NY. NYS Ag & Mkts / CCE Columbia County. $32,429

OSU. Determining economic impact and orchard distribution patterns of Brown Marmorated Stink Bug in Hazelnut. Oregon Hazelnut Commission. $16,500

PSU. Determining economic impact and vineyard distribution patterns of Brown Marmorated Stink Bug in Oregon. Oregon Wine Research Institute, Fermentation Funds Initiative. $15,000


PSU. Krawczyk, G. Re-introducing of IPM principles into management programs for brown marmorated stink bug and other fruit pests. State Horticultural Association of Pennsylvania. $25,243

PSU. Stoy, G. and D.A. Sunday. Tracking brown marmorated stink bug dispersal among multiple crop systems. Program Support for Fruit Production Research, PSU, University Park, PA. $4,216


Rutgers. Blaauw, B., A. Nielsen and D. Polk. 4/01/14-03/31/15, Bringing IPM and natural enemies back to the orchard post BMSB. USDA SARE NE Partnership Grants Program. $15,000

Rutgers. Nielsen, A. 2014 Developing a reduced risk early season management program for BMSB in peach IR-4 Biopesticide Program. $11,184

Rutgers. Polk, D. 02/01/13-12/31/14 Monitoring and Management of the Brown Marmorated Stink Bug., New Jersey State Horticultural Society. $3,500

Rutgers. Polk, D. and A. Nielsen. 04/01/13-03/31/14, Mating Disruption and Reduced Risk Methods to Control Peach Pests and Brown Marmorated Stink Bug. USDA SARE NE Partnership Grants Program. $14,833

UMD. Hooks, C.R.R. and G. Chen. 2013-2014. Designing a more sustainable weed and insect pest management system for vegetable producers. Maryland Agriculture Experiment Station Competitive Grants Program. $30,000

UMD. Hooks, C.R.R., G. Chen and Buchanan, A. 2013-2014. Developing economic and ecological sustainable pest management practices for growers of
leguminous and solanaceous crops. USDA-NIFA Northeastern IPM Competitive Grants Program. $83,058


UMD. Maryland State Horticulture Society Travel Grant. $1,000


USDA-ARS. SCRI natural enemy host-range evaluations in collaboration with the USDA ARS Beneficial Insect Introduction Research laboratory in Newark, DE, have been facilitated with APHIS FY14 Farm Bill funds to a consortium of researchers in Delaware, Florida, Michigan, California, and Oregon under the direction of the ARS BIIR laboratory in Newark. $620,700

VT. Bergh, JC. 2014. Monitoring the seasonal abundance and host-use patterns of brown marmorated stink bug nymphs at the orchard/woodland interface. Virginia Dept of Agriculture and Consumer Services. $33,759

VT. Herbert, D.A., and T.P. Kuhar. 2014. Continued effort to monitor the spread and to develop predictive and management strategies for the brown marmorated stink bug (BMSB) in agricultural row crops in Virginia. Virginia Agricultural Council. $17,113

Selected Media Contacts and Press Coverage

Print


**Broadcast**


PRWeb - September 19, 2013. Katie Dubow. Think the Stink Bug Has Vanished This Year; Think Again.  http://www.prweb.com/releases/2013/9/prweb11136169.htm/


WVTF. May 1, 2014. Robbie Harris. The perfect stink bug trap is all natural!.  http://wvtf.org/post/perfect-stink-bug-trap-all-natural


**Ag Commodities**


Project Investigators

**USDA/ARS**
- Tracy Leskey
- Ashot Khrimian
- Aijun Zhang
- Kim Hoelmer
- Jana Lee
- Peter Landolt
- Doo-Hung Lee
- William R. Morrison III

**University of Maryland**
- Cerretti R.R. Hooks
- William Lamp
- Karen Rane
- Gerald Brust
- Paula Shrewsbury
- Michael Raupp
- Raymond St. Leger
- Galen Dively
- Bryan Butler
- Jian Wang
- Holly Martinson
- Pedro Barbosa
- Mariam Lekveishvili
- Jon Traunfeld
- Stanton Gill
- Leslie Pick
- Amanda Buchanan
- Guihua Chen
- Dennis vanEngelsdorp
- Dilip Venugopal

**Rutgers University**
- George Hamilton
- Dean Polk
- Cesar Rodriguez-Saona
- Anne Nielsen

**Pennsylvania State Univ**
- Greg Krawczyk
- David Biddinger
- Gary Felton
- Shelby J. Fleischer
- Jayson K. Harper
- Steven Jacobs
- John Tooker
- Michael Saunders
- Shi Chen

**University of Delaware**
- Joanne Whalen
- Brian Kunkel

**Northeastern IPM Center**
- Carrie Koplinka-Loehr
- Stephen Young
- Christopher Gonzales
- Kevin Judd
- Koeki Hansen
- James Monahan

**Cornell University**
- Art Agnello
- Peter Jentsch
- Deborah Breth
- Charles Bornt
- Amy Ivy
- Faruque Zaman
- Teresa Rusinek
- Maire Ulrich
- Laura McDermott
- Crystal Stewart
- Michael Fargione
- Daniel Gilrein
- Anna Wallis
- Daniel Donahue
- Elizabeth Tee

**Virginia Tech**
- Chris Bergh
- Tom Kuhar
- Doug Pfeiffer
- Ames Herbert
- Eric Day

**Oregon State University**
- Peter Shearer
- Vaughn Walton
- Silvia Rondon
- Jeff Miller
- Yan Wang
- Nik Wiman
- Elizabeth Tomasino
- Steve Castagnoli

**Washington State Univ**
- Jay Brunner
- Elizabeth Beers

**North Carolina State Univ**
- James F. Walgenbach
- Mark Abney
- George G. Kennedy
Stakeholder Advisory Panel

More than 30 independent growers, association directors, and business leaders from across the United States are working in our Stakeholder Advisory Panel. This group reviews project accomplishments, provides feedback on research plans, and guides the execution of objectives.

Member Name, Affiliations, and State

Current Members

George Behling, Tree Fruit Grower and Owner, Nob Hill Orchards, WV
Robert Black, Fruit and Vegetable Grower, Catoctin Mt. Orchards, MD
Steve Black, Nursery Owner, Raemelton Farm, MD
Susan Futrell, Director of Marketing, Red Tomato, MA
Tom Green, President, IPM Institute of North America, WI
Ken Gauen, Lima Bean Processor, Pictsweet, DE/MD
Tom Haas, Tree Fruit Grower and Owner, Cherry Hill Orchards, PA
Brad Hollabaugh, Tree Fruit Grower, General Manager and Co-Owner, Hollabaugh Bros., Inc., PA
Doug Inkley, Senior Scientist, National Wildlife Federation, MD/DC
Edith Lurvey, Northeast Region Field Coordinator, IR-4 Project, Cornell University, NY
Santo John Maccherone, Fruit Grower, Circle M Farms; Chair, NJ Peach Promotion Council, NJ
Clarissa Mathews, Redbud Organic Farm; Professor of Environ. Studies, Shepherd University, WV
Nathan Milburn, Fruit and Vegetable Grower, Milburn Orchards, MD
Guy Moore, Fruit and Vegetable Grower, Larriland Farms, MD
Mark Orr, Fruit, Vegetable, and Ornamental Grower; Orr’s Farm Market & Orchard, WV
Kay Rentzel, Managing Director, National Peach Council, PA
Mark Seetin, Director, Regulatory and Industry Affairs, US Apple, VA
Rob Shenot, Fruit and Vegetable Grower, Shenot Farms, PA
H. Lee Showalter, Grower Services and Food Safety Manager, Rice Fruit Co., PA
Chad Vargas, Vineyard Manager, Adelsheim Vineyards, OR
John Wise, Associate Professor, Michigan State University, MI

New Members

Sam Doane, Production Horticulturist, J.S. Schmidt, OR
Bill MacKintosh, Consultant and Owner, Mackintosh Fruit Farm, VA
Jennie Schmidt, Vineyard Manager & Jane of all trades, Schmidt Farms, MD
Michael Rozyne, Executive Director, Red Tomato, MA
David & Jeannine Beck, Owners, Crawford Beck Vineyard, LLC, OR
Polly Owen, Executive Director, Oregon Hazelnut Commission, OR
Rebecca Sisco, Regional Field Coordinator, Western Region IR-4 Center, CA
Scott Hoffman, Field Representative, Furmano Foods, PA
Gene Klimstra, Crop Consultant, Agricon Consulting, NC
Wayne Marston, Owner, Adam’s Apple Farm, VA
Tom Peerbolt, Senior Consultant, Peerbolt Crop Management, OR
Michael Seagraves, Entomology Lead, Driscoll Strawberry Associates, Inc., CA

Outgoing Members

Bunky Dulin, Sweet Corn Processor, S.E.W. Friel, DE/MD
Dan Flick, Tree Fruit Grower; Business Development manager, Wilbur Ellis, WA
Art Galleta, Executive Chair, US Highbush Blueberry Council, NJ
Rick Hood, Organic Grower, Summer Creek Farm, MD
Tom Kelly, Vineyard Manager, Rappahannock Cellars, VA
Christian Krupke, Associate Professor of Entomology, Purdue University, IN
Phil Neary, Director of Operations and Grower Relations, Sunny Valley International, NJ
Rob Neenan, Vice President, California League of Food Processors, CA
John Saunders, Fruit and Vegetable Grower, Silver Creek Orchards, VA
Tyler Wegmeyer, Director of Congressional Relations, American Farm Bureau Federation, WV/DC