

Brown Marmorated Stink Bug IPM Working Group Meeting



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Virginia Agriculture Experiment Station
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Table of Contents

Brown Marmorated Stink Bug Working Group Participants	3
<i>Executive Summary</i>	9
BMSB Presentations	10
Welcome/Opening Remarks/MAP	10
Northeast Pest Status Update	10
Southern Pest Status Update	11
North Central Pest Status Update	12
Western Pest Status Update	13
BMSB in California, Its Current Distribution and Potential for Biological Control	14
BMSB Expansion in Georgia	15
<i>Halyomorpha halys</i> – a new invader in Hungary.....	15
Engineering Computer Vision Tools for Entomology Research	16
Review of Outreach and Grower Survey	17
Home Invasion by the Brown Marmorated Stink Bug	22
Biological Control of BMSB	23
Update on host-specificity testing of <i>Trissolcus japonicus</i>	24
Attack and success of exotic and native parasitoids on BMSB	25
United Soybean Project	25
OREI Project	27
SCRI Project	30
Next Steps for National Projects	32

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Executive Summary

The brown marmorated stink bug (BMSB), *Halyomorpha halys* (Stål) continues to spread throughout the United States. BMSB has been detected in 42 states and 2 Canadian provinces, posing severe agricultural problems in 8 states and nuisance problems in 19 other states. Large populations are now established in DC, DE, MD, NC, NJ, PA, VA and WV; each state documented severe losses in crops and serious nuisance problems from BMSB since 2010. Agricultural and nuisance problems have been reported in CT, KY, IN, MI, NY, OH, OR, TN, and WA. Though crop losses have not yet been reported, they are considered a nuisance problem only in AL, CA, IL, GA, NH, MA, MO, RI, SC, UT, VT and Ontario. In addition, BMSB has been detected in AR, AZ, FL, HI, IA, ID, KS, ME, MN, MS, NE, NM, TX, WI and Quebec. The BMSB IPM Working Group updated the BMSB map that is published on the www.StopBMSB.org website.

The twelfth formal BMSB Working Group meeting was held at the Alson H. Smith, Jr. Agricultural Research and Extension Center in Winchester, Virginia, on December 2nd, 2015. Research and extension personnel from Rutgers University, USDA-ARS, Penn State University, Cornell University, University of Delaware, University of Maryland, Virginia Tech, Ontario Ministry of Agriculture, Food and Rural Affairs, IPM Institute, Cherry Hill Orchards, University of California, Hercon Environmental, North Carolina State University, Oregon State University and industry participants attended the meeting. In addition, participating through webinar were representatives from University of Connecticut, University of California Cooperative Extension, Michigan State University, Agriculture and Agri-Food Canada and industry members from DuPont Pioneer, AgBio, and Bedoukian Research. A special presentation was given by Dr. Gábor Vétek from Hungary regarding the invasion of *Halyomorpha halys*.

There were fifty-one participants in attendance along with ten participating by webinar. The meeting was opened with welcoming remarks, discussion of map nuisance survey results and Northeast, Southern, North Central and Western pest status updates. Specific discussions followed from California and Georgia with a guided imagery tool presentation for entomological research. A review of the outreach and grower survey was held in the afternoon session. Speakers also presented updates on their projects such as United Soybean, OREI and SCRI.

BMSB Presentations

Welcome/Opening Remarks/MAP

Presented by: Tracy Leskey¹ & George Hamilton²

USDA-ARS-AFRS¹ and Department of Entomology, Rutgers University²

Summary:

- Welcomed everyone to the 12th annual working group meeting
- Overview of day's schedule
- Updated Priorities/Lunch Discussion
 - Removed completed priorities
 - Added further priorities
- 2014-2016 BMSB IPM WG Objectives reviewed
- BMSB Nuisance Pest Survey was open for 6 weeks and over 550 responses were received from all over the country – survey was for homeowners and businesses

Northeast Pest Status Update

Presented by: George Hamilton

Rutgers University

Summary:

- Reviewed New England States – ME, VT, NH, MA, CT, RI
- New York, New Jersey, Pennsylvania, Delaware, Maryland, West Virginia
- Management
 - Management is almost entirely insecticide-based.
 - Some organic growers using hand removal, protective covering, or companion plants.
 - Many growers ask workers to alert them if BMSB observed in the trees during thinning, summer pruning, or harvesting.
 - Growers involved in research projects are using monitoring traps to help guide management decisions.
 - Some growers have curbed their use of pyrethroids to intentionally protect beneficial insects.
- Knowledge gaps
 - Finalized insecticide spray guide by crop
 - Decision support tools such as treatment thresholds for various crops
 - Trap deployment strategies for monitoring and management (i.e., number of traps per acre, where to put the trap)
 - Forecasting of pest densities

- Utility of alternative management strategies (e.g., trap cropping, attract-and-kill, border sprays with embedded attract and kill sites) and how can they be improved
- Cultural control – Host removal and managing wood lines.
- Identification of BMSB adults and nymphs for growers and scouts
- Spread and impact of *T. japonicus*
- Development of management programs in absence of neonics (regulatory changes)

Southern Pest Status Update

**Presented by: Jim Walgenbach
North Carolina State University**

Summary:

- Factors Limiting BMSB Distribution in Southeastern US.
 - Photoperiod
 - Overwintering Ecology
 - Summer temperatures
 - Host plant availability
- BMSB Research Activities in the Southeast
 - Kentucky (Bessin, Hardwood, Palli)
 - Exclusion netting for organic control
 - Stink bug communities in soybean
 - Impact of biological control, including gut content analysis
 - Development of BMSB RNAi tools.
 - Tennessee (Jenny Moore)
 - Exclusion netting for organic control
 - Impact of biological control agents
 - Virginia (C. Bergh, A. Herbert, T. Kuhar, D. Pfeiffer)
 - Monitoring tools and management strategies on tree fruit, vegetables, grapes and field crops
 - Seasonal movement patterns among habitats
 - Overwintering biology and ecology
 - Factors affecting colonization of new habitats
 - Development on different hosts
 - Impact on soybeans, corn and cotton
 - Organic management on vegetables
 - Structural and household pest control approaches
 - Development of climate models for predicting spread
 - North Carolina (J. Walgenbach, D. Reissig, G. Kennedy)
 - Management on fruits, vegetables and field crops

- Trap crops in organic systems
 - Impact of biologic control agents in managed and non-managed habitats
 - Overwintering biology and ecology
 - Biotic and abiotic factors affecting colonization of different regions
- Georgia (M. Toews, G. Tillman, T. Cottrell)
 - Distribution in southern cotton-corn-soybean systems
 - Bacterial and fungal pathogen load in BMSB (G. Medrano, USDA-ARS College Station)
 - Trapping and distribution studies
- Alabama (K. Flanders)
 - Distribution and spread of established populations throughout state.
 - Impact of southern climates on development and reproduction.
- BMSB has become firmly established in several areas of the southeast, principally in mountain and piedmont areas.
- BMSB population dynamics in southeast is likely to be much different than Mid-Atlantic States due to climatic.
- Establishment in coastal plain ecoregions appears to be hampered by climatic factors, including summer and winter temperatures, day length, and possibly host plant availability

North Central Pest Status Update

**Presented by: Matt Grieshop
Michigan State University**

Summary:

- Ohio - Pheromone traps in 17 of 88 counties, most in sweet corn or brambles
- Indiana - Confirmed in 26 of 92 counties
 - Greatest concentration in north
 - Increasing damage to crops in last 2 years
 - Levels still quite low
 - Sweet corn, soybeans, tomato, peppers, apples
- Illinois - Confirmed in 19 counties (+1 from 2014)
 - Highest near Chicago & St Louis
 - Some fruit growers seeing bugs in buildings near orchards
 - No significant crop damage reported
- Iowa - Since 2011
 - Specimens from 11 counties
 - One new county in winter 2014
 - All from buildings
- Wisconsin - Confirmed in 11 counties (orange +3 from 2014)
 - Suspected in 2 counties (yellow -1 from 2014)

- Sightings sparse
- No crop damage reported
- Minnesota - 1st detection in 2010
 - 13 Counties as of 2015
 - Increasing frequency & magnitude of household invasions
 - Wyoming, MN:
 - Reproducing population
 - Successful overwintering (2013-2015)
 - No observations as plant pest
- Change Michigan to AG problem- Orange

Western Pest Status Update

Presented by: Nik Wiman
Oregon State University

Summary:

- OR relatively stable
 - (2 new detects)
 - New Counties in WA, UT
 - New Counties in CA
 - Wasatch Front
 - Urban Problems
 - Urban/ag interface
 - \$30 mill tree fruit
 - Apples/cherries
 - New established pops
 - Other “Intermountain”
 - Higher elevation (4-5 k feet)
 - Cold winters
 - Less deciduous forest
- Commercial Damage
 - Milton-Freewater Apples
 - 3,000 acres
 - 45% damage to grannies
 - -Clive Kaiser, OSU Extension
 - WSU – Easy to find BMSB in Walla Walla wine grapes
 - Nuisance problems in Walla Walla
- Other Commercial Finds
 - White Salmon WA
 - Commercial pears
 - Mosier OR
 - Tree fruits and grapes
 - Maryhill WA

- Wine grapes
- Irrigated Desert
 - High production :
 - Tree fruits
 - Wine grapes
 - SO far, no damage - Few nuisance issues
- New specialty crop issues
 - State tests for 51 pesticides on legal marijuana begins spring '16
- OR has the unfortunate distinction of having the first nut crop to be affected by BMSB, next CA?
- SB problematic on nuts worldwide
- BMSB in Hazelnuts
 - Huge growth in this Willamette Valley industry:
 - 40k acres to 100k acres in 10 years
 - Soon eclipse pears as OR's biggest orchard crop
 - Processors reporting damage 2015 – corking
 - Few products for BMSB and little experience with SB
- BMSB Damage
 - Early feeding: blank nuts
 - Kernel expansion: shriveling
 - Mature nut: corking
- More WV commercial damage
 - European pear
 - ~200 ac farm
 - Heavy BMSB losses on pear
 - Will be spraying BMSB 2016

BMSB in California, Its Current Distribution and Potential for Biological Control

**Presented by: Charles Pickett and Jesus Lara
California Department of Food and Agriculture**

Summary:

- Trees associated with BMSB in California
 - Surveys
 - Sacramento
 - Chico
 - San Jose
 - Most common hosts
 - Tree of heaven
 - Chinese pistachio

- Elm (*Ulmus davidiana*)
 - Maple (*Acer buergerianum*)
 - Catalpa sp.
 - Crepe-myrtle
- Biological Control of BMSB
 - Resident Natural Enemies?
 - Parasitoids
 - Predators
- Results from Sentinel Eggs
 - Predation
 - 11% of eggs removed (263 masses deployed)
 - Carabid, *Laemostunus complanatus*
 - Earwig, *Euborellia annulipes*
 - *Astata*, predacious wasp
 - Resident parasitoids
 - Less than 3% of masses attacked (n=546)
 - *Trissolcus* & *Telonomus*

BMSB Expansion in Georgia

Presented by: Glynn Tillman

USDA-ARS-Crop Protection & Management Research Lab

Summary:

- Detected in 25 counties
- Status: limited establishment, major nuisance pest, reproductive populations in some agricultural crops
- In 2016, we will use pheromone-baited traps to monitor BMSBs and will sample plants to determine BMSB density and percent damage in various orchard and row crops in Georgia.
- Known crop (corn, soybean, cotton, apples, and peaches) and non-crop hosts (black cherry, mimosa) of BMSB are common in Georgia. Parasitoids that parasitize native stink bug eggs in these crops and non-crop hosts are known to parasitize BMSB eggs; the two *Anastatus* species attacking eggs of native stink bugs are found only in woodland habitats. In 2016, we will continue to determine host and food plants of BMSB and also to assess parasitism of natural and sentinel BMSB eggs in a variety of plant species/habitats.

***Halyomorpha halys* – a new invader in Hungary**

Presented by Gábor Véték

Corvinus University of Budapest

Summary:

- Some Asian insect species recently reported as pests in Hungary
 - Zigzag elm sawfly (*Aproceros leucopoda*) (Hymenoptera: Argidae) - 2003
 - Albizia psyllid (*Acizzia jamatonica*) (Hemiptera: Psyllidae) – 2005
 - Chestnut gall wasp (*Dryocosmus kuriphilus*) (Hymenoptera: Cynipidae) – 2008
 - Box tree moth (*Cydalima perspectalis*) (Lepidoptera: Crambidae) – 2011
 - Spotted wing drosophila (*Drosophila suzukii*) (Diptera: Drosophilidae) – 2012
- Budapest, 11 October 2013
 - The first *Halyomorpha halys* specimen intercepted within an office in the Buda Campus of the Corvinus Univ. of Budapest
- Dr. Dávid Rédei, taxonomic specialist of Heteroptera
 - Buda Campus
 - a 7.5 ha large nature reserve in the heart of Budapest: Buda Arboretum
- Budapest, 30 October 2013
 - ca 12 km SE from Buda Campus
 - 4 males
 - 2 females
 - 1 fifth instar nymph
 - collected with beating from
 - •*A. negundo*
 - •*E. europaeus*
 - •*S. japonica*
- Article – First record of the brown marmorated stink bug, *Halyomorpha halys* (Hemiptera: Heteroptera: Pentatomidae), in Hungary, with description of the genitalia of both sexes
- The currently (2015) known distribution of *H. halys* in Hungary
 - Mass occurrence in several parts of Budapest!
 - *H. halys* records outside Budapest
- Article - Occurrence and genetic diversity of new populations of *Halyomorpha halys* in Europe

Engineering Computer Vision Tools for Entomology Research

Presented by: Henry Medeiros¹ and Amy Tabb²
 Marquette University¹ and USDA-ARS-AFRS²

Summary: No slides will be posted.

- Presented skin and skeleton models
- Showed lab robot that can be used outdoor and can be self-propelled
- Reflection looks like craters
- Target tracking using mobile platform in Aug 2014
- Cameras and sensors and fuse drum together (backlight problem)
- TLD & CMT = Kalman filter
- Move robot and response of robot at same time

Review of Outreach and Grower Survey

Presented by: Chris Gonzales
Northeastern IPM Center

Summary:

- Efforts of the Northeastern IPM Center
 - Website – StopBMSB.org
 - Network
 - 3,500 stakeholders on Center e-mail list
 - 375 recipients on BMSB e-mail lists
 - 4,600 regional addresses receive print
 - Facebook: 267 likes
 - Twitter: 1,911 followers / 225 retweets (past year)
 - YouTube (over 27,000 views in past year, 52 subscribers)
 - Flipboard (81 viewers)
 - Tracking the Brown Marmorated Stink Bug Video Series
 - Stink Bug in a Bottle
 - Cross Promotion Pamphlet
 - Stink Bug ID Kit
 - Video postcard, ID specimen, Stink Bug guide, article, factsheet, crops at risk flyer
- Impact on Homes and Businesses
 - For homeowners, BMSB is mainly a nuisance.
 - The bug causes a lot of aggravation.
 - People's tolerance of the pest is low.
 - For commercial settings, such as hotels and restaurants, the bugs' presence can have economic consequences.
- Prevent Bugs from Getting Inside
 - Sealing and caulking
 - BMSB congregate on southern and western sides of buildings
 - Often the size of the building may prevent access points that are high off the ground from being treated, so screening and caulking from the interior will still be necessary.
 - Timing: not too early, or chemicals degrade. Not too late, or they'll already be inside.
- Control after They Get Inside
 - Skip insecticide
 - Head straight for vacuum
 - Stocking over nozzle catches them before they enter machine
 - The aluminum foil water pan trap was the most effective device for trapping BMSB in homes during the winter and spring.

- Damage in Vegetables
 - Peppers and tomatoes: white or yellow scars
 - Sunken areas in fruit with tissue collapsing below
 - In corn, aborted, collapsed, or discolored kernels
 - Beans: scarred, faded, or sunken areas; deformed pods
 - Okra: deformed pods
- National and Regional Outreach
 - Cornell University, New York
 - University of Delaware, Delaware
 - Oregon State University, Oregon
 - Rutgers University, New Jersey
 - Virginia Tech University, Virginia
- Outputs by the Numbers
 - Over 650 peer-reviewed publications, presentations, and workshops.
- Cornell University
 - BMSB present in the lower and mid-Hudson Valley in low to moderate populations, but this can change quickly and some fields may be hot spots.
 - Late summer/harvest is a critical time to check fields for BMSB
 - Pay close attention to field edges that are bordered by trees and/or brush/weeds.
 - Highest populations are 90 feet in from field edges bordered by Tree of Heaven, Black Walnut, Catalpa, Maple, and Ash.
 - Damage typically begins along field edges.
 - Scout along edges in cool, early morning.
 - Inspect fruit for damage; inspect undersides of leaves for eggs and nymphs.
 - Thresholds are not established
- University of Delaware
 - We looked at feeding that occurs prior to and during pollination, before the kernels even begin to develop, and we found that brown marmorated stink bug feeding injury can result in aborted kernels. The reason we think that's the case is because they're actually interrupting pollination by damaging some of the silk channels," said Bill Cissel of the University of Delaware Cooperative Extension.
 - The stink bugs are capable of causing substantial economic losses due to quality reductions at densities as low as one bug per ear of corn.
 - "We did see some pretty high levels of kernel injury at all the growth stages that would likely result in quality reductions for sweet corn growers."
- Oregon State University
 - BMSB found in areas of the north Willamette valley on commercial farms.
 - Wine quality can be compromised due to taint.
 - Two publications on identification available, including one in Spanish.
 - List of products that control stink bugs, including BMSB

- BMSB findings have been increasing in commercial hazelnut growing regions in the northern Willamette Valley.
- BMSB may pose a significant risk to nut quality, causing corking during the latter portion of the season.
- Monitor for BMSB using commercially available pheromone traps placed close to surrounding vegetation.
- Alternate hosts include English holly, broadleaf maple, tree of heaven, and empress tree.
- BMSB populations tend to build up during the latter portion of the season and move from surrounding vegetation into orchards.
- Current insecticide programs in the eastern USA are based upon pyrethroid, carbamate, organophosphorus and nicotinoid insecticides. All of these insecticides are disruptive to various natural enemies and have the potential to cause secondary pest outbreaks.
- Gardeners and growers with small plots may be able to exclude BMSB with fine netting, but this is not feasible for larger farms.
- Rutgers University
 - Nielsen Lab: The influence of photoperiod was investigated and based on preliminary results strongly suggests that a long-day photoperiod cue is required for BMSB to leave overwintering sites. Validation of the voltinism model and tests at 8 geographic locations were run. The models suggest that photoperiod restricts populations' size at certain locations.
 - Hamilton Lab: Results from the diel visual sampling study suggest that time of day does significantly impact the numbers found on trees during sampling. Time of day also significantly impacted the movement of nymphs within and between trees.
 - Barriers to Success: The most significant barrier to success has been the low population size of BMSB emerging from overwintering sites. The second barrier has been the availability of the pheromone lures in the early season. The third barrier has been the inability to continuously rear BMSB.
- IPM for Stink Bugs
 - IPM combines biological control from predators with selective chemical application for maintaining pest populations below economic threshold levels.
 - Inadequate monitoring or implementation of IPM practices will lead to unsatisfactory results.
- Caution with some materials
 - Some materials don't effectively kill BMSB, and some should be delayed if spotted wing drosophila will be a target later, in order to comply with the seasonal maximum number of applications.

- After application of some materials, wait at least five days before placing beehives in treated fields. If flowering plants are present in the ground cover, mow before applying.
- Section 18 Exemption
 - While having utility against plum curculio, possibly the native stink bugs and a few others, the highest rate labeled for both products may not provide adequate protection from brown marmorated stink bug. For this reason, both products have received a Section 18 Emergency Exemption for use in pome and stone fruit each year since 2011.
 - The Section 18 label permits their use at rates higher than those described above, specifically to manage injury from brown marmorated stink bug, but must be renewed before each growing season. Contact your Extension Specialist to confirm whether a Section 18 label has been granted for the upcoming season before using these products in pome fruit or before using them in peaches and nectarines at the higher rates. REI = 12 hours; PHI = 3 days.
- Endosulfan (Thionex) Discontinuation
 - ENDOSULFAN (THONEX) is an organochlorine insecticide formulated as a 50W and 3EC and registered for use in apple for controlling aphids, leafhoppers, plant bugs and stink bugs.
 - Due to concerns about worker health and safety and environmental effects of endosulfan use a phase-out of the product will end all uses in apple on July 31, 2015.
 - Uses of Thionex primarily target brown marmorated stink bug (2 lb or 1.33 qt per acre). Do not use more than two applications during the fruiting period in apples. Seasonal maximum use per acre is 4 lb or 2.66 qt.
 - Endosulfan is highly poisonous and must be used with caution. REI = 7 days, PHI = 21 days (EC), 20 days (WP), PHI = 7 days.
- PHOSMET (IMIDAN) and BMSB
 - PHOSMET (IMIDAN) is a broad-spectrum organophosphate insecticide formulated as a 70W powder. It is registered for use on a number of fruit pests, including codling moth, plum curculio, redbanded leafroller, oriental fruit moth, apple maggot, and others. Imidan may not be used on sweet cherries.
 - While phosmet is rated as good against native stink bugs, it is ineffective against brown marmorated sting bug.
 - REI = 96 hours, PHI = 7 days (apple, pear, tart cherry, and plum), and 14 days (peach and nectarine).
- Effective products
 - Since it has been a long-standing policy of tree fruit Extension Specialists to not recommend the use of pyrethroids in the post-bloom period, due to their disruptive effects on natural enemies of secondary pests, we have not included

them or products containing them in most cover sprays. However, the most effective products against BMSB continue to include Belay (neonicotinoid), Baythroid, Danitol, Warrior II and products containing permethrin (pyrethroids), Lannate (carbamate), and the premixtures, Engido ZC and Leverage 360.

- As in recent years, Section 18 Emergency Exemptions were issued for the pyrethroid, bifenthrin (Bifenture and Brigade) and the neonicotinoid, dinotefuran (Venom and Scorpion). Residual effectiveness of products for BMSB may vary considerably, particularly following rain, and may not extend beyond about 3 days.
- Alternate-row-middle spray applications
 - As in recent years, Section 18 Emergency Exemptions were issued for the pyrethroid, bifenthrin (Bifenture and Brigade) and the neonicotinoid, dinotefuran (Venom and Scorpion). Residual effectiveness of products for BMSB may vary considerably, particularly following rain, and may not extend beyond about 3 days.
 - For this reason, we continue to recommend the use of alternate-row-middle spray applications at about 7-day intervals during much of the growing season in pome and stone fruit. Peaches and nectarines are vulnerable to injury from BMSB from fruit-set onward while injury to apples is detectable from about mid-June onward. Section 18 Exemptions for use of bifenthrin and dinotefuran will again be submitted in advance of the 2015 season. Do not use bifenthrin in apples or stone fruit until notified of the Section 18 approval. Although Venom and Scorpion are registered for use in stone fruit, the highest labeled rate may not provide adequate BMSB control. The Section 18 label for these products enables their use at higher rates against BMSB in both crop groups, but these rates must not be used until notified of the Section 18 approval. BMSB researchers are actively evaluating promising tactics to manage BMSB effectively and reduce or eliminate the disruptive effects of current programs.
- Sweet Corn and BMSB
 - Brown marmorated stink bug pest pressure is typically highest on the edges of fields
 - Insecticide sprays should be initiated at tasseling if bugs are present and repeated as needed until harvest
 - List of insecticides registered for use on sweet corn that have demonstrated efficacy against brown marmorated stink bug in research trials.
- Integrated Pest Management Update for BMSB: Key Points
 - Use alternate-row-middle spray applications: The idea of spraying alternate rows from the middle.
 - Bergh has observed and read about outbreaks of secondary pests in apple orchards: woolly apple aphid, San Jose scale, and spider mites.

- Alternate-row-middle spray applications allow you to reduce insecticide inputs and reduce potential negative effects of insecticides.
- BMSB is a landscape-scale pest. It's widely distributed, and can't be controlled on a landscape scale by insecticides, traps, or other human tactics.
- Biological control is going to represent the ultimate solution to bring pest damage down to economically acceptable levels.
- Populations may remain at low levels before outbreaks occur
 - Brown marmorated stink bug (BMSB):
 - The 2014 season began with a rather low BMSB population, which to some extent may have been due to the effects of the cold winter. As in 2013, favorable environmental conditions during the growing season resulted in lush growth of wild hosts through August, which may favor the growth of BMSB populations during the summer. However, despite BMSB captures in pheromone traps that again were highest in August and September and instances of some buildings and homes being heavily invaded between late September and early October, the general consensus was that BMSB populations were lower throughout the entire season than in 2013.
 - In general, acceptable levels of BMSB management in commercial orchards were reported.

Home Invasion by the Brown Marmorated Stink Bug

Presented by: Ben Chambers
Virginia Tech

Summary:

- Efforts to Understand Home Invasion
 - Movement direction on building exteriors
 - Minimum gap size navigable
 - Effects of piles of dead left from previous years
 - Attic access and site selection
- BMSB Movement on Building Exteriors
 - Through September and October, BMSB movement on building exteriors was recorded
 - One data point taken per insect, repeat observations limited by time or by specimen collection
 - Data taken from 12 buildings, but largely from one single-story house
- Summed Movement Directions
 - 269 measurements
 - 66% with upward component

- Attic Inspections
 - Identify and characterize locations where BMSB entering diapause are likely to settle within attics
 - Check attics for all possible points of ingress
 - Evaluate presence of live and dead BMSB in and around openings
 - Evaluate presence of live and dead BMSB in other “cozy” attic features
 - Insulation
 - Storage clutter
 - Building materials
- Other Plans
 - Preferred elevation of refuge entry relative to ground
 - Preferred degree of tightness in refuge
 - Preferred depth in refuge
 - Effects of night-time exterior lighting on overwintering site selection
 - Timing of entry and exit

Biological Control of BMSB

Presented by: Christine Dieckhoff

University of Delaware & USDA-ARS-BIIR

Summary:

- Foreign exploration for Asian natural enemies of BMSB (2007-2015)
 - 30+ parasitoid populations in culture at ARS BIIR for host range and efficacy testing
- *Trissolcus japonicus* (Hymenoptera: Scelionidae)
 - (first described as *T. halyomorphae*)
 - solitary egg parasitoid
 - 2 - 3 weeks/generation
 - multiple generations/season
 - female-biased sex ratio
 - 65 to 90% parasitism on BMSB reported in Asia
 - *Trissolcus japonicus* is oligophagous - it attacks several Asian pentatomid species
 - Host Range Evaluations: Progress
 - 62 species total tested nationwide
 - 22 species completed
 - 40 species in progress
 - Recovery of *Trissolcus japonicus* in Maryland in 2014
 - 2015 Survey - *T japonicus* recovered in:
 - MD Beltsville – BARC
 - MD Laytonville (tree nursery)

- MD Adamstown (tree nursery)
 - Washington DC U.S. National Arboretum
 - VA Winchester
 - WA Vancouver
- Origin of the adventive *T. japonicus* populations
 - Principal coordinates analysis of genetic diversity among 23 microsatellite markers in *T. japonicus*
 - These populations are adventive – they were not released nor did they escape quarantine!
 - DC area populations genetically similar to populations sampled in Japan and S. Korea
 - WA population genetically similar to populations sampled in S. Korea
- Logical next steps – Asian Natural Enemies
 - Quarantine Host Range Evaluations:
 - Continue laboratory host range research (pending evidence of establishment and dispersal of adventive populations) towards a Petition to Release (APHIS requires a Petition to Release for each state)
 - Adventive *Trissolcus japonicus*:
 - Expand surveys initiated in 2015 to determine the extent of establishment, incl. an increased focus on wooded habitats and a widened survey area to see how quickly populations spread
 - Analyze recovered parasitoid microsatellite DNA to determine heterogeneity of the adventive populations
 - Increase monitoring of parasitism of BMSB & non-target pentatomid egg masses in the field

Update on host-specificity testing of *Trissolcus japonicus*

Presented by: Del Delfosse
Michigan State University

Summary:

- Results *T. japonicus* Emergence
 - Wasps attacked only one egg mass 87% of the time (33 of 38 reps).
- Conclusions
 - BMSB was strongly preferred in multiple-species choice tests using eggs of non-target species attacked in PHST.
 - Native non-target pentatomid eggs that were attacked in no-choice tests were frequently rejected.
 - BMSB was never rejected by wasps reared on BMSB.
 - Wasps reared on non-target native hosts preferred BMSB, but also continued to attack the native hosts to a lesser degree.

- Possibly due to a combination of genetic inclination, training, and chemical cues.
- Wasps reared on *T.c. accerra* and *P. maculiventris* produce fewer offspring than those reared on BMSB.
- Future Research on Ecological Sieves
 - Effects of egg age on successful parasitization by *T. japonicus* and emergence in non-target hosts.
 - Effects of habitat partitioning on host location and attack on non-target hosts.
 - On-going olfactometry to determine chemical cues associated with host location.

Attack and success of exotic and native parasitoids on BMSB

Presented by: Liz Fread and Megan Herlihy
USDA-ARS-IIBBL

Summary:

- Results: *Trissolcus japonicus*
 - 18 egg masses (total of 320 eggs) parasitized by *T. japonicus*: approx. 1% of all egg masses deployed
 - High rate of successful emergence (95%) in all egg mass types
 - Habitats: soybean, 0 of 4 sites; scattered trees (or orchard): 5 egg masses (2 of 5 sites); woods: 13 egg masses, only at the original 2014 site (of 17 total woody sites)
 - Egg types: Fresh BMSB, 3 Frozen BMSB, 11 Fresh *Podisus*, 4 (detected at all three sites)
- Preliminary summary for 2015
 - Predation was significant, consuming >25% of eggs deployed.
 - Successful parasitism was ~15% in *Podisus* and frozen BMSB eggs, but <4% in fresh sentinel BMSB eggs.
 - All parasitoids had distinct habitat preferences.
 - Among native parasitoids, *Anastatus* showed the most successful parasitism of fresh BMSB eggs, but native *Trissolcus* and *Telenomus* usually failed to emerge.
 - *Trissolcus japonicus* was present in 3 sites, all either open woods or scattered trees, within 600m of 2014 discovery.
 - *T. japonicus* was not present in abundance, and only after mid-July. It successfully parasitized all egg mass types, including sentinel *Podisus* eggs.

United Soybean Project

Presented by: Joanne Whalen
University of Delaware

Summary:

- Research conducted at Virginia Tech, Universities of Maryland and Delaware

- Guide Produced by the United Soybean Board
- The research to develop management recommendations and the creation of this guide was funded by soy check off dollars (3 yr. USB grant, State Soybean Boards) (<http://unitedsoybean.org/brown-marmorated-stink-bugs/>)
- Stink bugs begin to migrate in large numbers into soybean fields at the R4 (full pod) soybean development stage
- Injury to soybeans includes undeveloped (flat) pods, punctured and deformed seed
- Stink bug feeding can also delay maturity, causing ‘stay green’ syndrome
- 7 Research Objectives
 - Determine the density needed to cause reductions in seed quality, yield and stay green – i.e. treatment thresholds
 - Compare and evaluate the efficiency of visual counts and sweep net sampling related to thresholds
 - Quantify within field distribution and spatiotemporal dynamics and examine the influence of adjacent habitats
 - Determine the influence of different landscape, environmental and topographical variables on BMSB abundance
 - Monitor the expansion in the Mid-Atlantic Region
 - Determine if natural enemies of native stink bugs will shift to BMSB and if natural control is significant
 - Information delivery to stakeholders
- Highlights of the Bulletin
 - Visual identification reference
 - A new visual plant-inspection sampling method
 - Where and when to scout
 - How to sample and when to treat
 - General insecticide recommendations
 - See more at: http://unitedsoybean.org/wp-content/uploads/54407_FINAL_Mid-Atlantic_StinkBug_book.pdf
- Project Summary
 - BMSB feed on developing soybean pods and seed, resulting in quality and yield reductions
 - Under heavy infestations, BMSB feeding injury can result in stay green syndrome
 - Soybean fields in proximity to developed areas and those bordered by woods – are at the greatest risk
 - BMSB are not usually distributed evenly throughout soybean fields and are typically concentrated on field edges, rarely reaching the ET within the field middles.
 - A single, well-timed field-edge-only treatment can be successful in reducing pops below ET

- Sampling for BMSB using a two-minute visual count is an effective and preferred method for determining the action threshold for BMSB in soybeans, especially in narrow-row fields.
- Scouting efforts should begin during the late R4 (pod elongation) to early R5 (seed development) growth stages.
- The best time to make an insecticide application is during the early R5 (seed development) growth stage to prevent seed quality and yield losses.
- The recommended threshold is 0.5 BMSB per linear foot of row or at least 3 BMSB per 15 sweeps or two-minute visual count.
- Control can be achieved with a well-timed insecticide application of a pyrethroid, carbamate, organophosphate and neonicotinoid/pyrethroid mixtures.
- Organic insecticides, such as spinosad + potassium salts of fatty acids, azadirachtin + pyrethrins + potassium salts of fatty acids, spinosad, and azadirachtin, are effective against BMSB nymphs, but none have been found to provide satisfactory control of adults.
- Various natural enemies have been observed feeding on BMSB in soybeans
- Card You Can Take to the Field
 - Ames was successful with this approach in cotton (Cotton Inc.) – so he and Sean took the lead on developing the card
 - Modeled after the bulletin
 - Wanted to include decision making information on native stink bugs – still more important /as important in the region

OREI Project

**Presented by: Anne Nielsen
Rutgers University**

Summary:

- Project Objectives
 - Habitat manipulation – identify and evaluate trap crops
 - Identify whole-farm movement patterns and behaviors
 - Natural enemy identity and impact in organic systems
 - Evaluate organic management tactics
 - Develop extension materials
- Objective 1: Trap Crops
 - Evaluated 4 potential organic trap crops: sunflower, millet, sorghum, and okra
 - Tested across 4 states: MD, NJ, PA, and WV
 - Sunflower and sorghum were the most attractive to BMSB
 - Sunflower most attractive to native stink bugs
 - Attraction varied throughout the season
- Trap Crop Findings
 - Sorghum was generally the most attractive trap crop tested for BMSB

- Sunflower was more attractive earlier in the season with sorghum becoming more attractive in August
- Sunflower is attractive to natural enemies
- Colonization of cash crop was delayed
- Higher damage in peppers occurred under ‘high’ pressure
- Also attractive to native stink bugs
- Objective 2: Whole Farm Movement
 - Nymphal dispersal behavior
 - Capacity
 - Dispersal between host plants
 - Whole-farm sampling
 - Tracking population hot spots
 - Overwintering behavior
 - Trapping experiment
 - Citizen Science
- Nymphal Dispersal Capacity
 - Nymphs have a strong walking capacity.
 - Can disperse 10m in 3 hours
 - Nymphs show strong response to the olfactory attractant and traverse large distances to reach source
 - Nymphs select host plants
 - Based off of phenology
 - Preference for fruiting bodies
 - Identified common odors correlated with attraction
- Great Stink Bug Count
 - Crowd-sourcing data collection from volunteers
 - 2013: 162 datasets
 - 2014: 134 datasets
 - September 15 – October 15
 - Rural or rural-forest landscapes had highest counts
- Objective 3: Natural Enemies
 - 8 states observed fate of sentinel BMSB eggs
 - Two sites per state
 - Two week intervals from June through August
 - Selected egg masses under video surveillance
 - Laboratory trials
 - Identify stage-specific predation
 - Identify type of damage caused
 - Gut content analysis
 - Supporting natural enemy populations
 - Parasitism is much lower than native brown stink bugs
- Who Are the Predators?

- Activity is largely at night
- Orthopterans caused high predation and spent a lot of time on the egg masses
- In cages, damsel bugs, wheel bugs, *Orius* sp. cause high predation of multiple life stages
- Minimal predation in the field by lady beetles
- Insectary Plantings
 - Identify natural enemies and impact
 - Cup plant, *Silphium perfoliatum*
 - Golden Alexanders, *Zizia aurea*
 - Horsemint, *Monarda punctata*
 - Sand coreopsis, *Coreopsis lanceolata*
 - Partridge pea, *Chamaecrista fasciculata*
 - Determine biological control with partridge pea companion plantings in corn
- Wildflowers to Support Natural Enemies of BMSB
 - Flowers support higher numbers of natural enemies
 - No difference in chewing predation of egg masses
 - Higher sucking predation
 - Most egg removal likely due to opportunistic orthopterans
 - % predation in the control (rye) is much, much higher than we normally see in other systems, likely due to grasshoppers and katydids. There are higher populations of chewing predators and parasitoids in the flowering plants. Those with a disc shape (like the coreopsis) also had higher numbers of sucking predators
- Biological Control Summary
 - Egg mass predation is higher in organic systems than conventional
 - Most predators are generalists or opportunists
 - Sucking predators, orthopterans
 - Can be increased through habitat manipulation
 - Until *T. japonicus* is widespread, focus should be on plants that increase predator community
 - Horsemint (*Monarda*) and Coreopsis
 - Insecticides like Entrust decrease NE populations
 - Parasitism is increasing
- Objective 4: Evaluate Barrier Fabrics for BMSB and Endemic Stink Bug Management
 - Investigated efficacy of barrier fabrics
 - Treatments:
 - Fine mesh
 - 1/8" mesh
 - 1/6" mesh
 - No screen

- Scouted pepper plants weekly for:
 - BMSB and native stink bugs
 - Natural enemies
- Peppers were harvested and assessed for damage
 - TN (high pressure)
 - KY (low pressure)
- Percentage Stink Bug Damage to Peppers in Screened and Unscreened Plots
 - Follows a similar trend as the number of BSMB found within the cages
 - Beneficial insects were also excluded, significantly so in the 1/25” netting
 - Any size netting significantly increased the marketable fruit in both years and there was no effect of netting size there
- Is Organic Management Feasible?
 - Yes, *under moderate pressure!*
 - Understand hot spots on the farm
 - Key early season host plants
 - Crops that are preferred hosts by all life stages
 - Manipulate the habitat surrounding these areas
 - Support natural enemies
 - Trap crop using sunflower and sorghum
 - Re-design trap crop layout
 - Under intense BMSB pressure the finest mesh netting provides protection from stink bug injury
 - Remove overwintering populations on-farm

SCRI Project

Presented by: Tracy Leskey
USDA-ARS-AFRS

Summary:

- Grower And Consultant Experiences
 - Tree Fruit Grower
 - Extreme damage to tree fruit and small fruit crops. May go out of business if things continue.
 - Crop Consultant
 - Relying on mid- and late-season pyrethroids, creating a treadmill effect.
 - Need a monitoring tools and control options that do not disrupt beneficials.
 - Organic Grower
 - Severe damage on a range of fruiting vegetables including snap peas, green beans, heirloom and hybrid tomatoes, peppers, and raspberries. May have to stop growing particular crops.
- USDA-NIFA SCRI CAP

- Bring together a multi-state, multi-institutional, trans-disciplinary team to integrate scientific discoveries with practical application; and provide complementary extension efforts to bring science-based information to relevant audiences.
- Reduce duplication of efforts and integrate activities among individuals, institutions, states, and regions.
- Progress Made By BMSB SCRI CAP Team
 - Established BMSB Risk, Phenology, and Damage Symptoms in Specialty Crops – Publication – The Pest Potential of BMSB on Vegetable Crops
 - Chart - Specialty Crops at Risk to BMSB Damage
 - Host Plants of BMSB Includes >170 Records made by collaborating researchers
 - Insecticide Efficacy and Management Programs
 - Effective Short-Term Mitigation Strategies adopted on >85,000 acres of specialty crops
 - Voltinism – Generations Per Year
 - ONE generation per year in northerly locations
 - TWO in the Mid-Atlantic and Pacific Northwest
 - Overwintering Ecology in the Natural Landscape
 - Publication – Characterization of Overwintering Sites of the Invasive BMSB in Natural Landscapes Using Human Surveyors and Detector Canines
 - Dispersal Capacity of Adults and Nymphs
 - Publication – Factors affecting flight capacity of BMSB
 - Adults can fly >2 km/day
 - Nymphs can walk >25 m/day
 - We know that a significant portion of the BMSB populations are coming from unmanaged block especially during the early growing season.
 - Identifying Risk Factors For Spread and Establishment
 - Publication – Landscape Factors Facilitating the Invasive Dynamics and Distribution of the BMSB after Arrival in the United States
 - BMSB can be monitored successfully throughout the U.S. season-long using pheromone-baited traps
 - Publication – Discovery of the Aggregation Pheromone of the BMSB through the Creation of Stereoisomeric Libraries of 1-Bisabolen-3-ols
 - Publication – Attraction of the Invasive *Halyomorpha halys* (Hemiptera: Pentatomidae) to Traps Baited with Semiochemical Stimuli Across the United States
 - Gut Symbionts, Transcriptome, and Salivary Proteins Novel Approaches for Management
 - Publication – The Importance of Gut Symbionts in the Development of the BMSB
 - Publication – Rapid transcriptome sequencing of an invasive pest, the BMSB
 - Publication – Insights into the Saliva of the BMSB

- Biological Control Offers Long-Term Landscape-Level Solutions
 - Native Predators and Parasites
 - Classical Biological Control
 - Biological Control Game Changer?
 - *Trissolcus japonicus* found in MD in 2014 and MD, VA and OR in 2015
- BMSB Outreach Efforts include
 - >50,000 stakeholder contacts,
 - >150,000 via online efforts, and
 - millions more through popular press
- Key Personnel Trained
 - Undergraduates and H.S. – 147
 - Graduate Students - 39
 - Post-Docs and Visiting Scholars - 30
 - Technical Staff – 43
- Pending Questions – Many questions left to answer
- Future Project Directions
 - Continued cooperative, collaborative and integrated approach to research and Extension on a national level.
 - Developing IPM-based strategies including trap-based treatment thresholds, border sprays, cultural control, behavioral control, etc.
 - Strong emphasis on long-term, landscape-level solutions including conservation biological control as well as classical biological control.

Next Steps for National Projects

Presented by Peter Shearer
Oregon State University

- A new SCRI pre-application
- 5 year proposal, \$10 million budget
- Project directors – P Shearer, T Leskey, E Beers, K Daane, L Gut, T Kuhar and J Walgenbach
 - Current team
 - Project director (1);co-Project directors (6);co-Project Investigators (27+); Institutions (19 universities, USDA-ARS); Post docs (TBD), Students (TBD)
 - More PIs will be added if we are invited to submit a full proposal
- Objectives and Hypotheses:
 - *Objective 1.* Predict risk from BMSB damage through enhanced understanding of agroecology and landscape ecology.
 - *Hypothesis:* The impact of near-crop sources of BMSB that invade at-risk specialty crops can be predicted from information on host suitability, dispersal triggers and biotic and abiotic landscape-level factors.
 - *Objective 2:* Implement widespread biological control of BMSB with the exotic Asian parasitoid and native natural enemies.

- *Hypothesis:* The presence of a well-adapted parasitoid such as *Trissolcus japonicus*, and a community of native natural enemies have the potential to reduce BMSB from an outbreak pest to an occasional pest.
- *Objective 3:* Develop management tools and strategies that are compatible with biological control and informed by risk from landscape factors.
 - *Hypothesis:* Using biological control as a foundation of IPM, all management strategies become more effective. Integration of IPM tactics such as sampling and threshold protocols will improve decision-making.
- *Objective 4:* Determine the economic consequences of BMSB damage, and how it is reduced by specific management strategies.
 - *Hypothesis:* Measuring economic impacts of classical biological control and IPM strategies and tactics will lead to the development and implementation of long-term cost-effective BMSB management programs.
- *Objective 5:* Educate stakeholders, develop resources and deliver new information on BMSB, and assess the effectiveness and impact of delivery information programs.
 - *Hypothesis:* An effective evaluation program will lead to high impact information delivery programs that alter stakeholder behavior and improve conditions.