Developing Behaviorally Based Monitoring and Management Tools for the Invasive Brown Marmorated Stink Bug, *Halyomorpha halys* (Stål)

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Brown Marmorated Stink Bug is an Invasive Species

Native to China, Japan, Korea, and Taiwan.
Brown Marmorated Stink Bug Life History

- Deposit eggs on undersides of leaves. Five nymphal stages. One to two generations per year in areas where it is established.

- Over 100 host plants including tree fruit, small fruit, grapes, vegetables, legumes, and ornamentals.

- Limited biological control from native natural enemies.
Native Stink Bug Pests

Brown Stink Bug
*Euschistus servus*

Dusky Stink Bug
*Euschistus tristigmus*

Green Stink Bug
*Acrosternum hilare*
Damage from Native Stink Bug Pests

Peach Injury
Cat-facing and gummosis (early season)

Apple Injury
Corky, indented depressions (late season)
Look-Alikes

ROUGH STINK BUG
The rough stink bug, *Brochymena quadripustulata*, has a small point or "tooth" on each side of the face. BMSB does not have this marker. Also look at the shoulder area, just behind the head. Rough stink bugs have a small row of spines or "teeth," whereas BMSB is fairly smooth. On many rough stink bug specimens, the abdomen fans out on the sides so that it is more visible from the top when the wings are at rest than on BMSB. The rough stink bug is generally a more uniform dark gray or nearly black color.
First Maryland BMSB Specimen

Collected October 8, 2003
Shell Service Station and Snax Store, Hagerstown, MD
History of BMSB in the United States

- **1996**: First suspected specimens collected in Allentown, PA.
- **1997**: First properly identified specimen in the USA. Collected in Allentown, PA.
- **1998**: First confirmed WV specimen.
- **1999**: First confirmed MD specimen.
- **2000**: First reports of late season injury in tree fruit.
- **2001**: Localized reports of injury in Allentown area.
- **2002**: First confirmed WV specimen.
- **2003**: First confirmed WV specimen.
- **2004**: First confirmed WV specimen.
- **2005**: First confirmed WV specimen.
- **2006**: First reports of late season injury in tree fruit.
- **2007**: Very large population heading into overwintering.
- **2008**: Severe late season injury in tree fruit.
- **2009**: Severe crop injury and serious nuisance problems throughout the mid-Atlantic.
- **2010**: Aggressive chemically-based management. Late-season populations down in most locations, higher than others.
- **2011**: Aggressive chemically-based management. Late-season populations down in most locations, higher than others.
- **2012**: Serious late season injury in tree fruit.
- **2013**: Overwintering survivorship?
Increasing Populations of BMSB
2007-2010
2008-2009 Late Season Problems
2008-2009 Late Season Problems

- 1,100 acre commercial fruit orchard that produces 500,000 bushels of fruit annually.

- In 2009, nearly 10% of all fruit harvested redirected from fresh market to processing due to BMSB injury.

- Loss in value can reach 80-90%.
Large Overwintering Population, Eastern Panhandle, WV. Fall 2009
Winter 2010

MAJOR WINTER STORM
IMPACT FRI NIGHT-SAT
• WHITEOUT CONDITIONS • ROAD CLOSURES • FLIGHT CANCELLATIONS

DISRUPTIVE SNOWFALL
HEAVIEST

STRONG WINDS

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BMSB Early Season Activity
April – June 2010

Montmorency Cherry
May 5, 2010
Loring Peach (20 mm Fruit)
May 10, 2010
Appearance of BMSB Injury in Stone Fruit
Late June – early July 2010
Adult and Nymphal Feeding on Peach
July 21, 2010
Many mid-Atlantic growers in WV, MD, PA and VA had significant losses.

Numerous growers lost over 50% of their peach crop in 2010.

Some lost their entire crop.
Adult and Nymphal Feeding on Corn
August 3, 2010
Adult and Nymphal Feeding on Tomato and Pepper  
Early-Mid August 2010
Adult and Nymphal Feeding on Soybean

Late Summer 2010

Photo courtesy of Stan Fultz, UMD
August 26, 2010  Late-Season Injury on Apple
Ornamentals, Nursery Crops, and Non-Bearing Fruit Trees
BMSB in Grape

Early September 2010

Photos courtesy of Dean Polk and Doug Pfeiffer
Hazelnuts

Photo courtesy of Peter Shearer
Post-Harvest Issues

No sign of injury when put into cold storage, but ~4-5 weeks later BMSB injury apparent.
2010 Tree Fruit Damage Survey

• Determine the scale of the threat to tree fruit.

• Develop a repeatable method for assessing total amount and severity of injury to stone and pome fruit.

• Monitor adult and nymphal populations in tree fruit orchards.

• Survey from mid-July to harvest.
Grower Participants
Damage Evaluation Methods

- Select 100 fruit from the perimeter row and from the interior of each block.

- Ideally, 10 fruit from 10 trees.

- Choose the side of the fruit that appears to exhibit the greatest potential for BMSB injury.

- Cut fruit in thin sections until reaching the core or pit.

- Count the number of distinct injury sites per fruit.
Damage Survey
Results From Commercial Peach Orchards

- **Perimeter**: Severity 3.71
- **Interior**: Severity 3.51

Economic Injury
BMSB Feeding Injury—Rate and Severity
Regional Commercial Apple Orchards
2010 Growing Season

2010 economic loss in mid-Atlantic apples due to BMSB feeding estimated at 37 million dollars (US Apple Association)
Catoctin Mountain and Gardenhour Orchards
Emergency BMSB Meeting
September 3, 2010

Photos courtesy of Doug Pfeiffer
Move Over, Bedbugs: Stink Bugs Have Landed

Kelli Wilson and her father, Richard Lee Pry, cleared stink bugs from her porch Friday in Burkittsville, Md. The shield-shaped invaders have damaged fruit and vegetable crops.
BMSB is a Serious Nuisance Pest
“This weekend I vacuumed up more than 8,000 stink bugs (vast majority were alive) in my attic, to add to the now more than 4,000 I’ve removed from my living space since 1/1/2011. I have now destroyed 12,348 stink bugs in my home in 45 days since January 1, 2011.

After all the effort this weekend, another 100+ found their way into my kitchen (a two year old addition) Sunday afternoon.” (mid-Feb, Resident near Harpers Ferry, WV)
Landscape-Level Threat To Crops

Invasive Tree-of-Heaven

Native Woody Hosts

Corn

Apple

Photo Courtesy of Chris Bergh
What Have We Learned So Far?
BMSB Insecticide Evaluations
Defining the Targeted Population

- BMSB capable of reproduction within orchard plots. Control of this population targets all life stages.
- Constant, season-long pressure from outside orchards leads to constant re-infestation of plots.
- Dispersing adult unlikely to encounter direct contact with finished (wet) spray material. Avoidance behaviors. Knock-down and recovery.
- Control of this population depends on sustained effectiveness of dry residue.
Experimental Trials

1. EthoVision trials for measuring horizontal mobility on insecticide-treated surfaces.

2. Direct observations of vertical movement capacity following insecticide exposure.

3. Mortality tracked for 7-d followed by final vertical movement trial.
BMSB Insecticide Evaluations
Material Selections

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<tr>
<th>Pyrethroids</th>
<th>Neonicotinoids</th>
<th>Carbamates</th>
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<td>Gamma-Cyhalothrin</td>
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Concentrations of insecticide per unit carrier (water alone) determined based on application of 100 gallons per acre, applied at field volume.
BMSB Insecticide Evaluations
Sample Tracks

Water (Control)
505 microliters per arena

0 Hours Exposure
Track 00006
94.11 cm
145.31 sec

1 Hour Exposure
Track 00029
121.00 cm
125.13 sec

2 Hours Exposure
Track 00064
53.68 cm
105.11 sec

Warrior (Pyrethroid)
1.0 fl. oz. per 100 gallons

0 Hours Exposure
Track 00073
147.78 cm
343.34 sec

1 Hour Exposure
Track 00098
42.34 cm
79.41 sec

2 Hours Exposure
Track 00117
0.54 cm
0.83 sec
BMSB Insecticide Evaluations
7-Day Survivorship
Promising Compounds

**Glass**

**Time-Phased BMSB Condition**

4.5-Hour Exposure Period In Glass Arenas

**Methomyl (Lannate SP) @ 1.0 lb/100 gal**

- % Alive
- % Moribund
- % Dead

**Days After Exposure**

0, 1, 2, 3, 4, 5, 6, 7

---

**Lannate**

**Time-Phased BMSB Condition**

4.5-Hour Exposure Period In Glass Arenas

**Permethrin (Permethrin 3.2 EC) @ 16.0 oz/100 gal**

- % Alive
- % Moribund
- % Dead

**Days After Exposure**

0, 1, 2, 3, 4, 5, 6, 7

---

**Safari**

**Time-Phased BMSB Condition**

4.5-Hour Exposure Period In Glass Arenas

**Dinotefuran (Safari 20 SG) @ 16 oz/100 gal**

- % Alive
- % Moribund
- % Dead

**Days After Exposure**

0, 1, 2, 3, 4, 5, 6, 7

---

**Thiodan**

**Time-Phased BMSB Condition**

4.5-Hour Exposure Period In Glass Arenas

**Endosulfan (Thiodan EC) @ 1.67 pts/100 gal**

- % Alive
- % Moribund
- % Dead

**Days After Exposure**

0, 1, 2, 3, 4, 5, 6, 7
Weaker Materials

Time-Phased BMSB Condition
4.5-Hour Exposure Period In Glass Arenas

**Phosmet (Imidan 70-W) @ 4.0 lbs/100 gal**

**Imidan**

**Glass**

**Acetamiprid (Assail 30 SG) @ 8.0 oz/100 gal**

**Assail**

**Glass**

**Cyfluthrin (Tombstone 2.0 EC) (1-Day) @ 2.6 oz/100 gal**

**Tombstone**

**Glass**

**Oxamyl (Vydate L) @ 3.0 pts/100 gal**

**Vydate**

**Glass**
BMSB Insecticide Evaluations

Lethality Index

\[
\text{Lethality Index} = \frac{\sum_{	ext{Day 0-7}} \left[ (\text{BMSB Alive } \times 0.0) + (\text{BMSB Moribund } \times 0.5) + (\text{BMSB Dead } \times 1.0) \right]}{240} \times 100
\]

The maximum value of the Lethality Index for each material is 100.0; the minimum value is 0.0, and compounds are ranked in descending order of value.
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<th>Active Ingredient</th>
<th>Trade Name</th>
<th>Lethality Index</th>
<th>Active Ingredient</th>
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Conclusions

• There is a huge range of insecticide effects within chemical classes. No chemical class uniformly outperformed all others, but representatives of each major class demonstrated potential value for field use.

• Even at highest doses of the most effective insecticides, BMSB are very hard to kill via contact with a dry residue.

• Potential for recovery from “moribund” state was demonstrated for some pyrethroids and neonicotinoids.

• Success in laboratory evaluations does not always translate to field…but failure does.

• Residual activity very short in the field.
2012 Field-Based Residual Trials

- **3 Trials:**
  - July 2\textsuperscript{nd}
  - August 13\textsuperscript{th}
  - September 10\textsuperscript{th}

- Wild-collected bugs exposed for 24h

- Conditional assessments for 5 days

24 hours

0 Days

3 Days

5 Days
Why Test Field Residual Efficacy?

- BMSB dispersal and avoidance behavior.
- Contribution to rational spray programs/recommendations.
- Continued comparisons with laboratory testing.
- Foundation for testing newly labeled or experimental materials.
2012 Materials, Field Residual Evaluations

- Acetamiprid: Assail 30 SG (8 oz/100 gal)
  - + Induce (2 pts/100 gal)

- Clothianidin: Belay (6 oz/100 gal)
  - + Induce (2 pts/100 gal)

- Fenpropathrin: Danitol (21 oz/100 gal)
  - + HyperActive (1 pt/100 gal)

- Thiamethoxam + λ-cyhalothrin: Endigo ZCX (6 oz/100 gal)
  - + Induce (2 pts/100 gal)

- Permethrin: Perm-Up 3.2 EC (10 oz/100 gal)
  - + HyperActive (1 pt/100 gal)

- Dinotefuran: Venom (6.75 oz/100 gal)
  - + Induce (2 pts/100 gal)
Assail (acetamiprid): Fresh Residue vs. 3-Day Residual
Overwintered Adults vs. New Adults

July 2

Time-Phased BMSB Condition
24-h Exposure Period in Apple Field Plots
Acetamiprid (Assail 30SG) @ 8 oz/100 gal

Days After Exposure

% Adult BMSB/Category

0 1 2 3 4 5

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Alive
Affected
Moribund
Dead

August 13

Time-Phased BMSB Condition
24-h Exposure Period in Apple Field Plots
Acetamiprid (Assail 30SG) @ 8 oz/100 gal

Days After Exposure

% Adult BMSB/Category

0 1 2 3 4 5

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Alive
Affected
Moribund
Dead
Belay (clothianidin): Fresh Residue vs. 3-day Residual
Overwintered Adults vs. New Adults

0 Day

Time-Phased BMSB Condition
24-h Exposure Period in Apple Field Plots
Clothianidin (Belay) @ 6 oz/100 gal

% Adult BMSB/Category

Days After Exposure

July 2

September 10

3 Day

Time-Phased BMSB Condition
24-h Exposure Period in Apple Field Plots
Clothianidin (Belay) @ 6 oz/100 gal

% Adult BMSB/Category

Days After Exposure
Danitol (fenpropathrin): Fresh Residue vs. 3-Day Residual
Overwintered Adults vs. New Adults

July 2

September 10
Endigo (thiamethox/λ cy): Fresh Residue vs. 3-Day Residual Overwintered Adults vs. New Adults

**July 2**

**0 Day**
Time-Phased BMSB Condition
24-h Exposure Period in Apple Field Plots
λ-cyhalothrin + thiamethoxam (Endigo ZCX) @ 6 oz/100 gal

Days After Exposure

% Adult BMSB/Category:
- Alive
- Affected
- Moribund
- Dead

**3 Day**
Time-Phased BMSB Condition
24-h Exposure Period in Apple Field Plots
λ-cyhalothrin + thiamethoxam (Endigo ZCX) @ 6 oz/100 gal

Days After Exposure

% Adult BMSB/Category:
- Alive
- Affected
- Moribund
- Dead

**September 10**

**0 Day**
Time-Phased BMSB Condition
24-h Exposure Period in Apple Field Plots
λ-cyhalothrin + thiamethoxam (Endigo ZCX) @ 6 oz/100 gal

Days After Exposure

% Adult BMSB/Category:
- Alive
- Affected
- Moribund
- Dead

**3 Day**
Time-Phased BMSB Condition
24-h Exposure Period in Apple Field Plots
λ-cyhalothrin + thiamethoxam (Endigo ZCX) @ 6 oz/100 gal

Days After Exposure

% Adult BMSB/Category:
- Alive
- Affected
- Moribund
- Dead
Perm-Up (permethrin): Fresh Residue vs. 3-Day Residual
Overwintered Adults vs. New Adults

July 2

0 Day

Time-Phased BMSB Condition
24-h Exposure Period in Apple Field Plots
Permethrin (Perm-Up 3.2 EC) @ 10 oz/100 gal

Days After Exposure

Alive
Affected
Moribund
Dead

August 13

3 Day

Time-Phased BMSB Condition
24-h Exposure Period in Apple Field Plots
Permethrin (Perm-Up 3.2 EC) @ 10 oz/100 gal

Days After Exposure

Alive
Affected
Moribund
Dead
Venom (dinothefuran): Fresh Residue vs. 3-Day Residual Overwintered Adults vs. New Adults

July 2

September 10
Conclusions

• As the season progresses, the bugs are harder to kill.

• No materials demonstrated clear residual lethality for 3 days after treatment.

• Adjuvants tested (Induce and HyperActive) had no positive effect on lethality of wet spray material, and appear to have reduced residual effects.
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**Notes:**
- June 2011
- Father's Day: June 16
- Summer Season start: July 1