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

Egg Mass

1st

- 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.

2nd 3rd 4th 5th

Adult Male

Adult Female

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

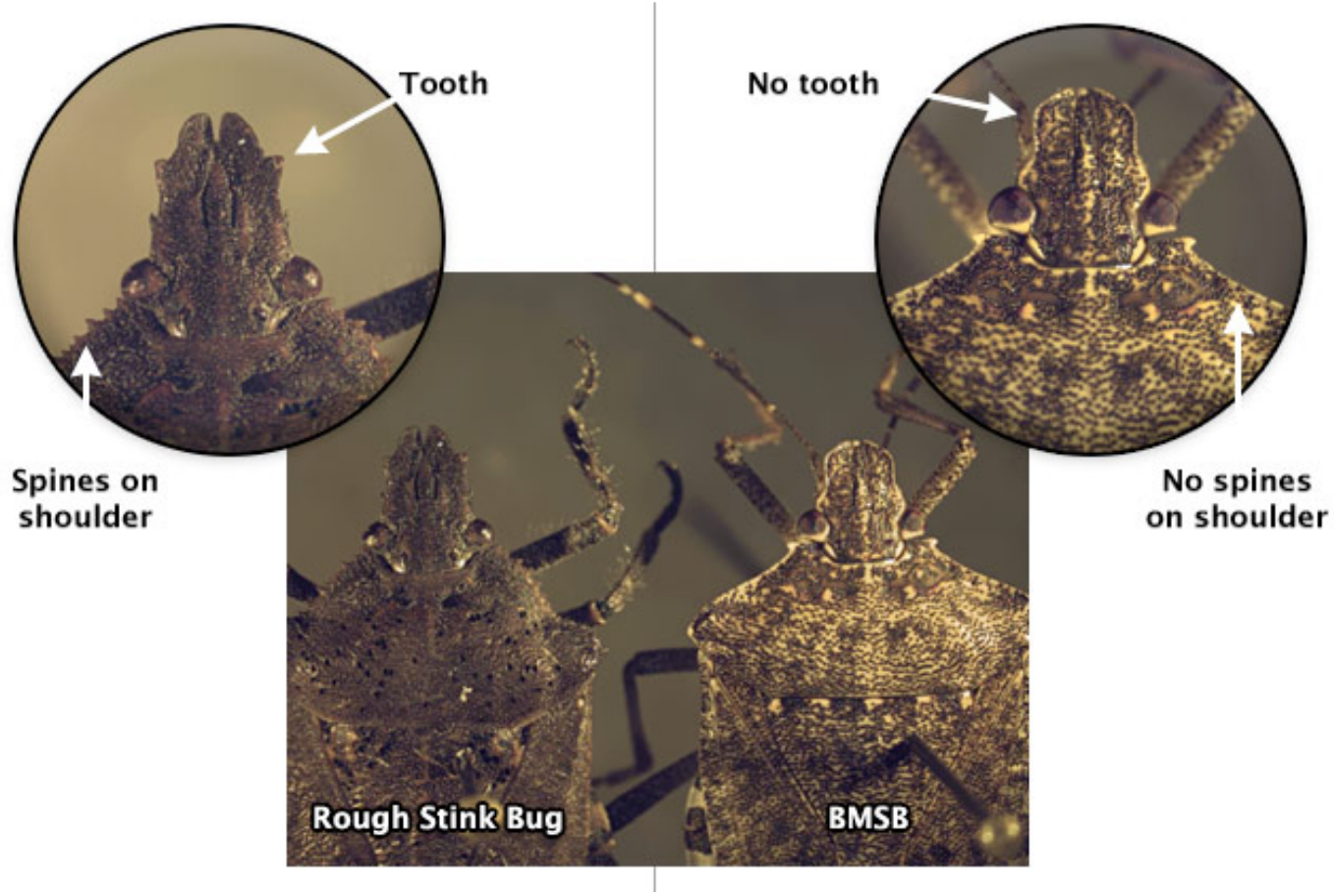
Peach Injury
Cat-facing and gummosis (early season)

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

Introduced into USA?

First suspected specimens collected in Allentown, PA

First properly identified specimen in the USA. Collected in Allentown, PA

First confirmed MD specimen

First confirmed WV specimen

Localized reports of injury in Allentown area

First reports of late season injury in tree fruit

Serious late season injury in tree fruit

Severe crop injury and serious nuisance problems throughout the mid-Atlantic.

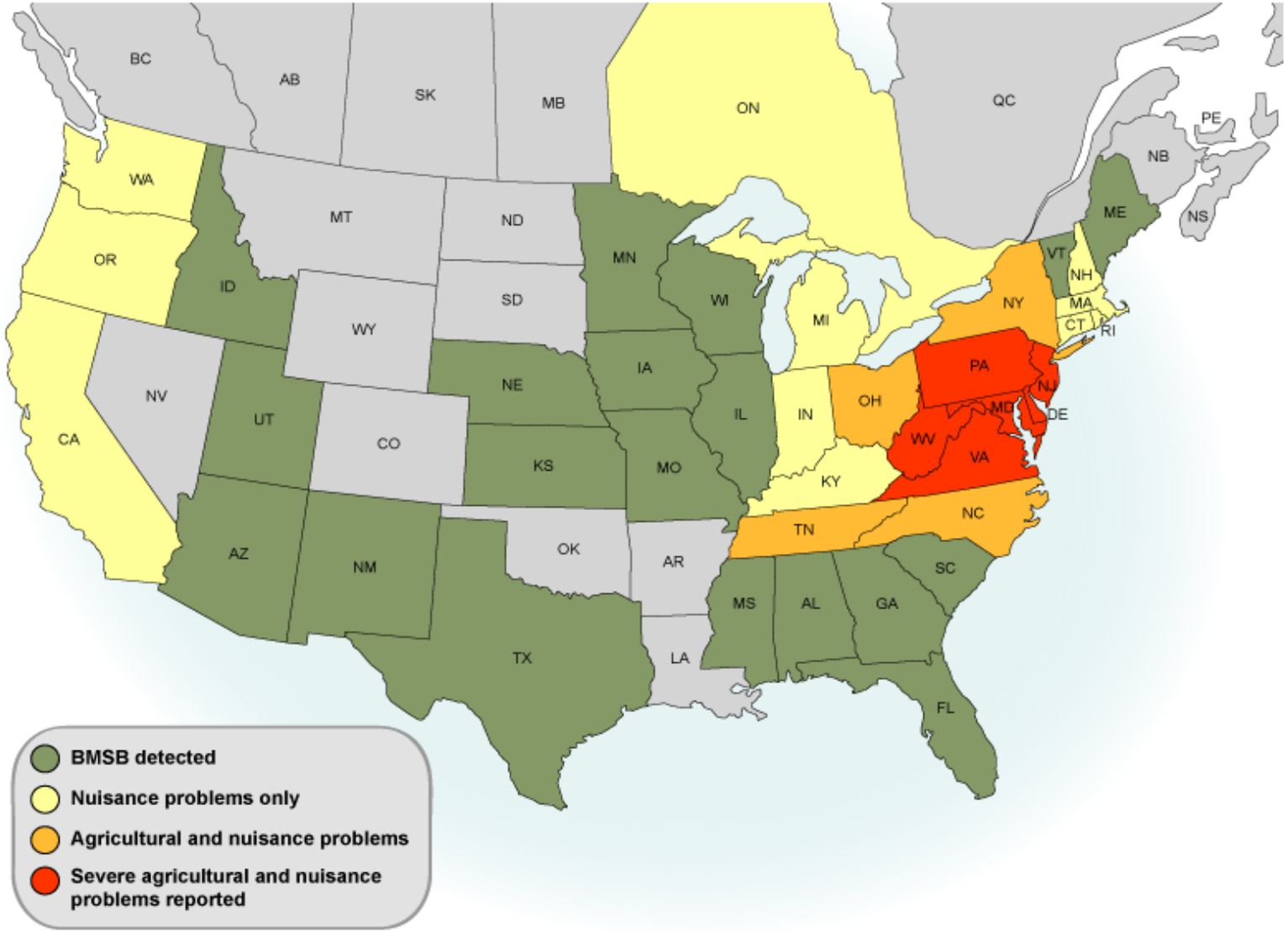
Aggressive chemically-based management. Late-season populations down in most locations, higher than others.

Very large population heading into overwintering.

Overwintering survivorship?

1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013

Current Distribution of BMSB in the United States



Updated by BMSB Working Group, November 2012

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 CANCELATIONS
DISRUPTIVE SNOWFALL
HEAVIEST
STRONG
WINDS
L
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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

July 29, 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

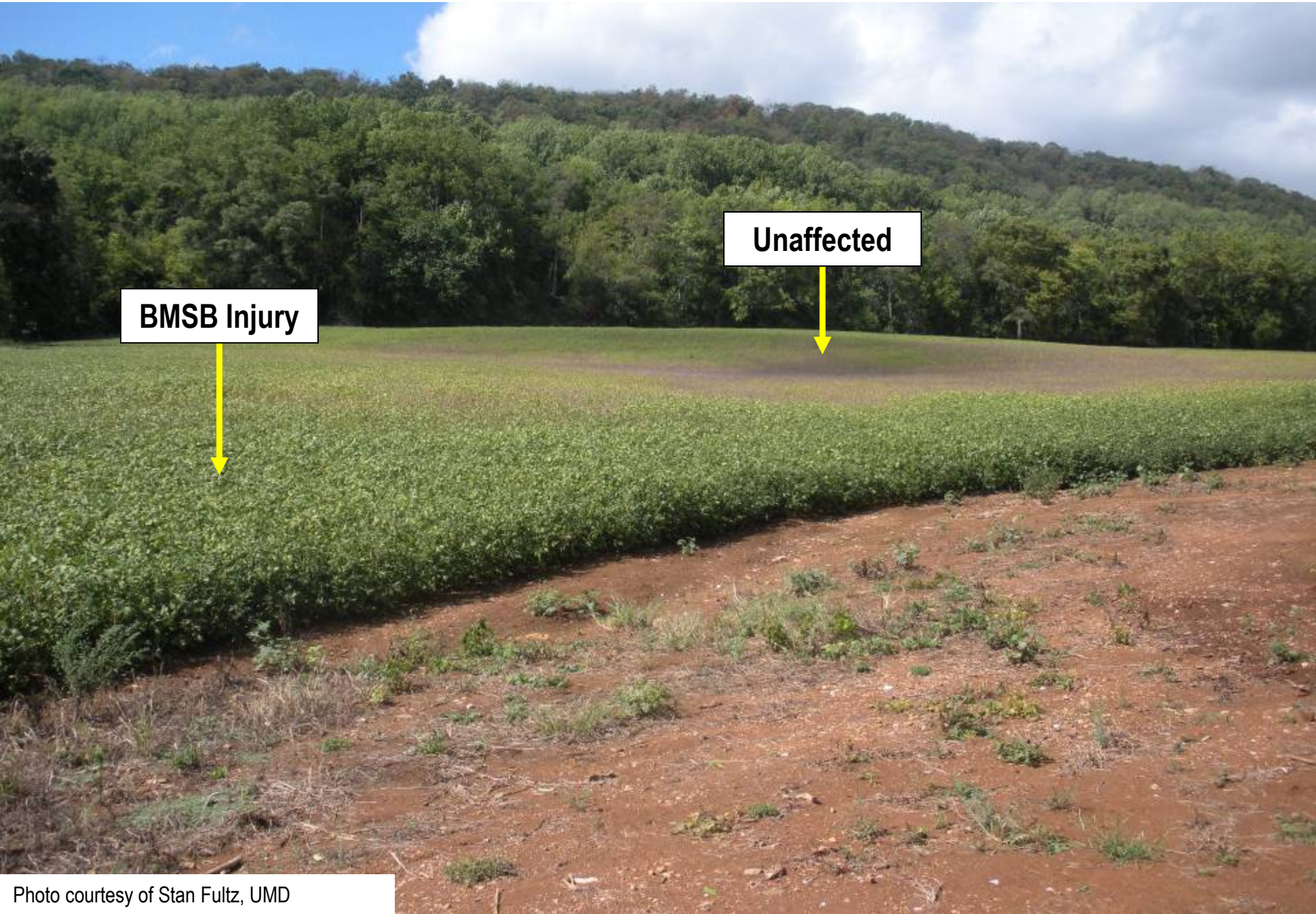


Photo courtesy of Stan Fultz, UMD

August 26, 2010 Late-Season Injury on Apple

Ornamentals, Nursery Crops, and Non-Bearing Fruit Trees

Photo courtesy of Kim Hoelmer

BMSB in Grape

Photos courtesy of Dean Polk and Doug Pfeiffer

Early September 2010

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.

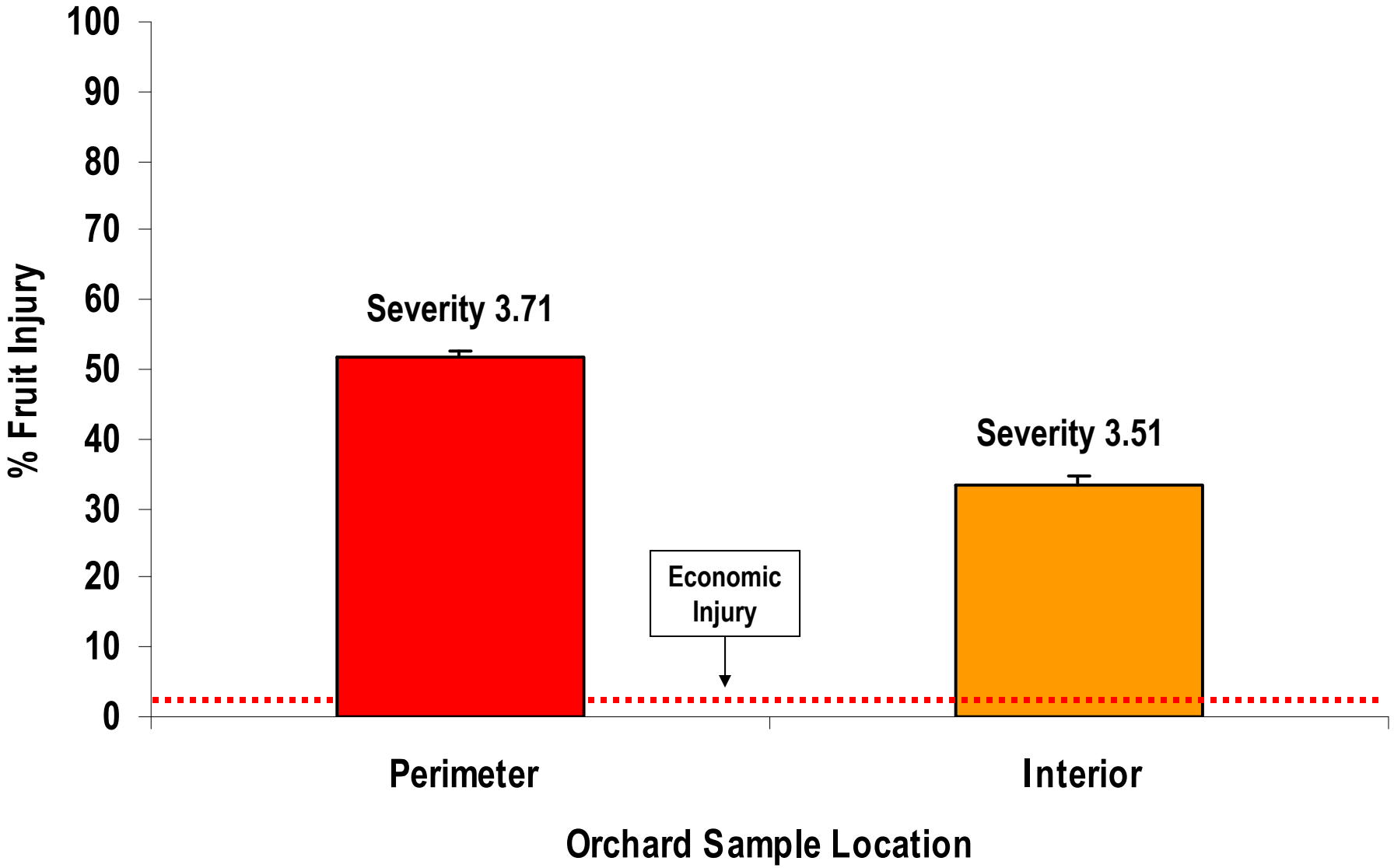
Grower Participants

Damage Evaluation Methods

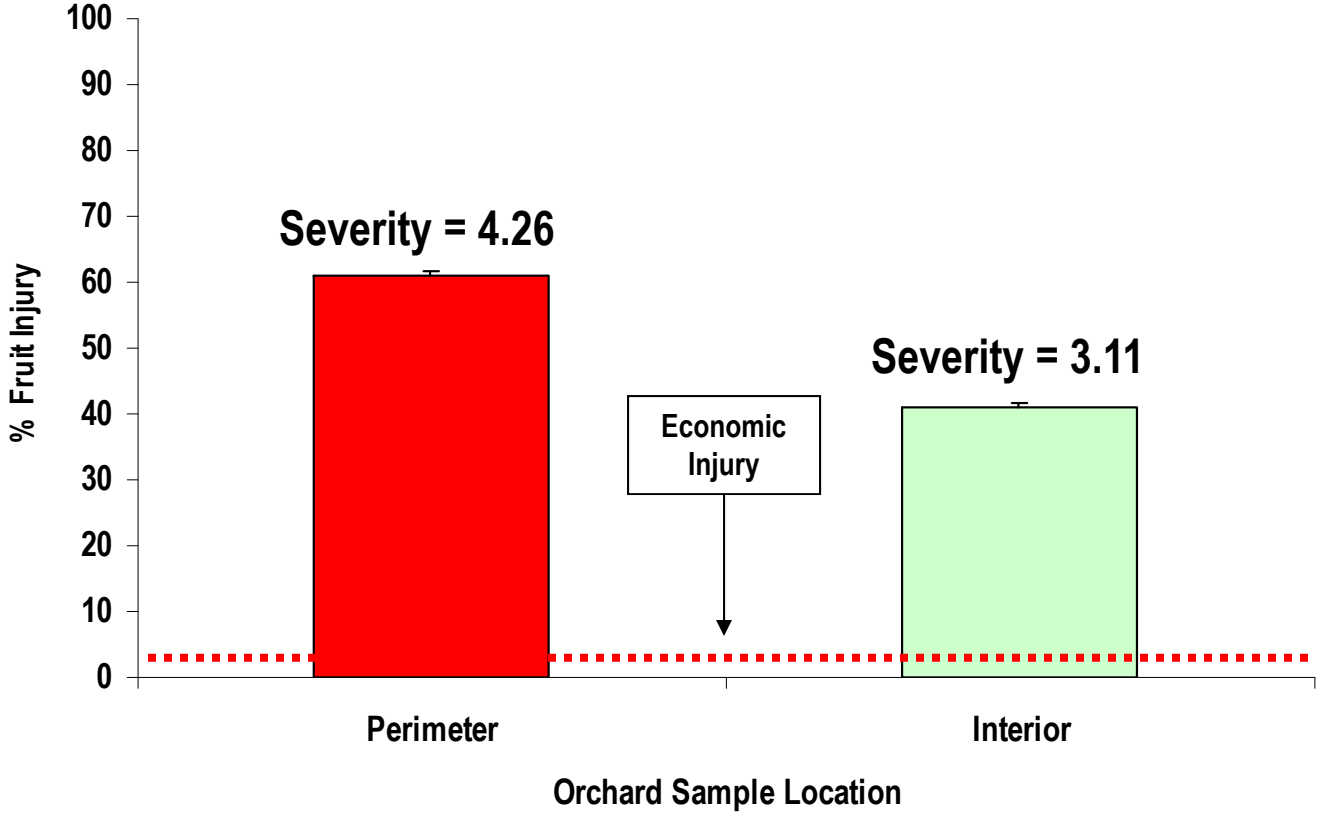
- Select 100 fruit from the perimeter row and from the interior of each block.
- Ideally, 10 fruit from 10 trees.
- Choose the side of the fruit that appears to exhibit the greatest potential for BMSB injury.
- Cut fruit in thin sections until reaching the core or pit.
- Count the number of distinct injury sites per fruit.

Damage Survey

Results From Commercial Peach Orchards



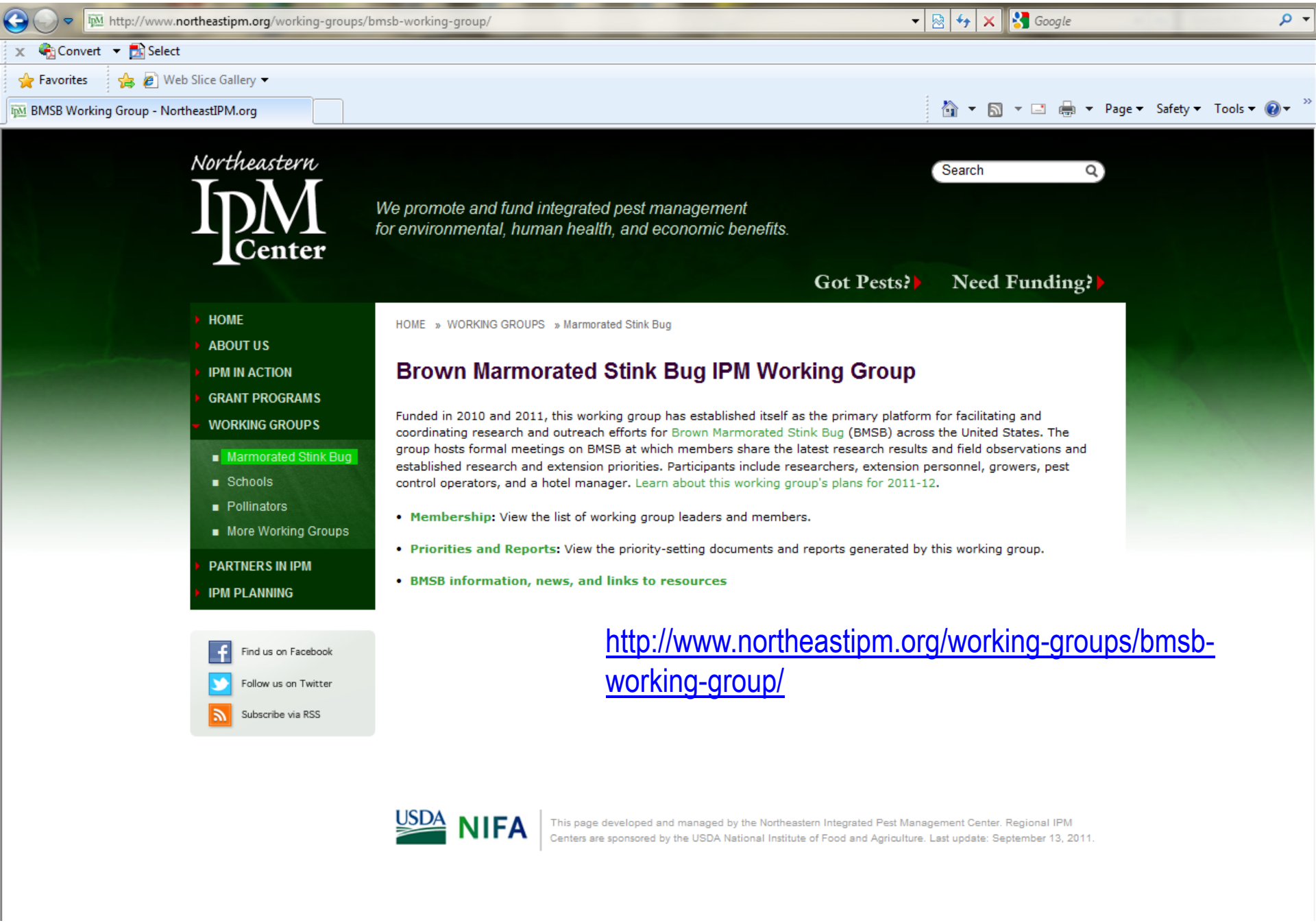
BMSB Feeding Injury—Rate and Severity
Regional Commercial Apple Orchards
2010 Growing Season



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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Select
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BMSB Working Group - NortheastIPM.org
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Brown Marmorated Stink Bug IPM Working Group
Funded in 2010 and 2011, this working group has established itself as the primary platform for facilitating and coordinating research and outreach efforts for Brown Marmorated Stink Bug (BMSB) across the United States. The group hosts formal meetings on BMSB at which members share the latest research results and field observations and established research and extension priorities. Participants include researchers, extension personnel, growers, pest control operators, and a hotel manager. Learn about this working group's plans for 2011-12.
Membership: View the list of working group leaders and members.
Priorities and Reports: View the priority-setting documents and reports generated by this working group.
BMSB information, news, and links to resources
http://www.northeastipm.org/working-groups/bmsb-working-group/
USDA NIFA
This page developed and managed by the Northeastern Integrated Pest Management Center. Regional IPM Centers are sponsored by the USDA National Institute of Food and Agriculture. Last update: September 13, 2011.

The New York Times

The Washington Post

TIME

CNNMoney

CBS NEWS

The Philadelphia Inquirer

Move Over, Bedbugs: Stink Bugs Have Landed

Steve Ruark for The New York Times

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.

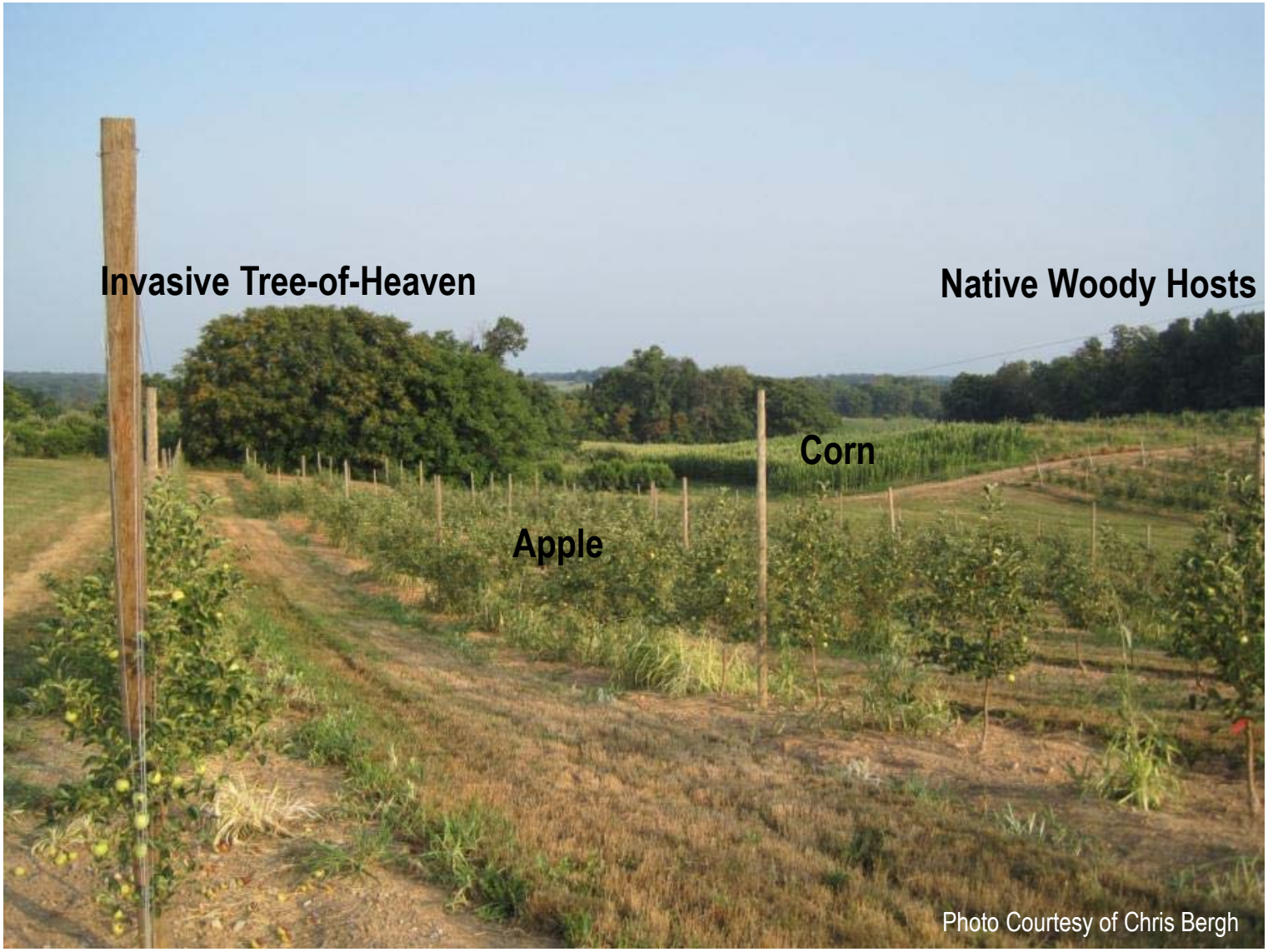
BMSB is a Serious Nuisance Pest

One Homeowner's Plight

"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*)

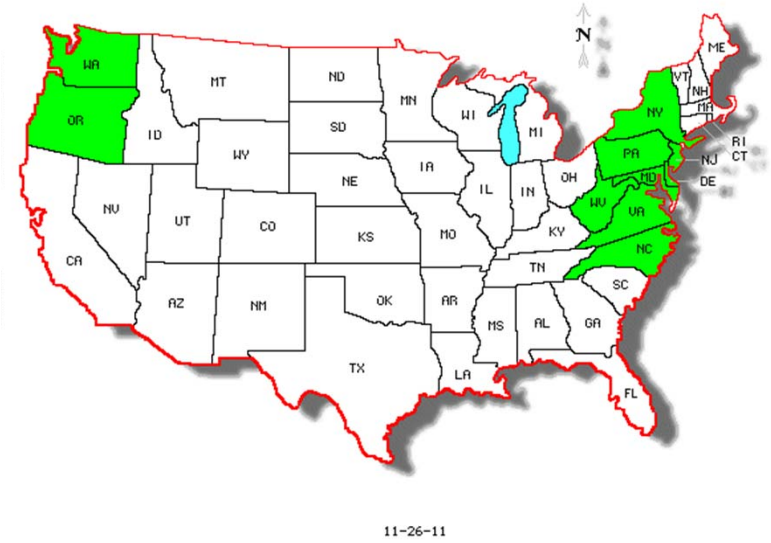
Landscape-Level Threat To Crops



Biology, Ecology, and Management of Brown Marmorated Stink Bug in Orchard Crops, Small Fruit, Grapes, Vegetables, and Ornamentals

USDA-NIFA SCRI Project

- **USDA-ARS**
  - **Appalachian Fruit Research Station, Kearneysville, WV**
  - **Beneficial Insects Introduction Research Unit, Newark, DE**
  - **Invasive Insect Biocontrol and Behavior Laboratory, Beltsville, MD**
  - **Horticultural Crops Research Unit, Corvallis, OR**
- **The Pennsylvania State University**
- **Washington State University**
- **North Carolina State University**
- **Virginia Polytechnic Institute and State University**
- **Rutgers University**
- **Northeastern IPM Center**
- **Oregon State University**
- **University of Maryland**
- **University of Delaware**
- **Cornell University**

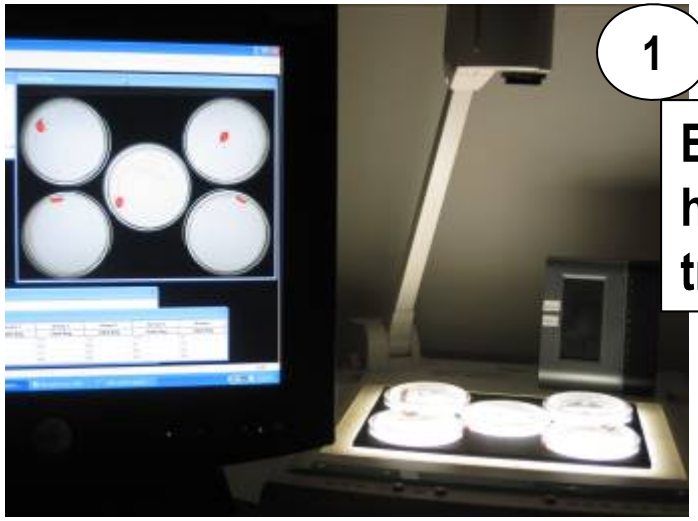


What Have We Learned So Far?

BMSB Insecticide Evaluations
Defining the Targeted Population

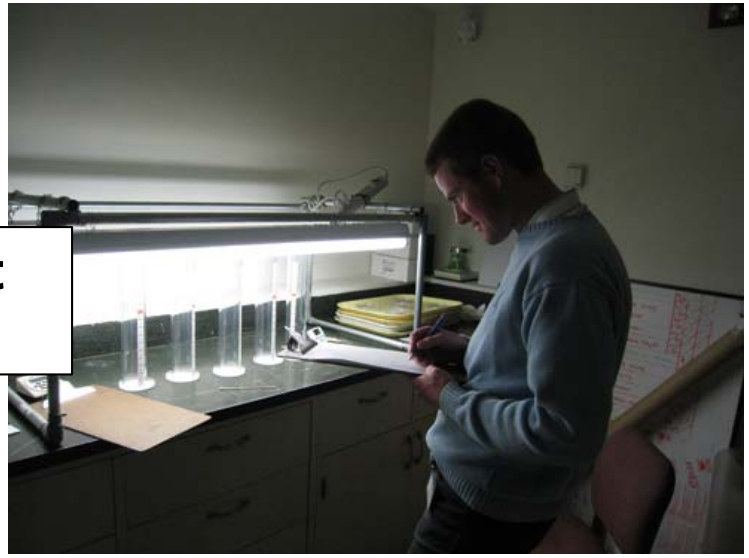
- BMSB capable of reproduction within orchard plots. Control of this population targets all life stages.
- Constant, season-long pressure from outside orchards leads to constant re-infestation of plots.
- Dispersing adult unlikely to encounter direct contact with finished (wet) spray material. Avoidance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

Experimental Trials



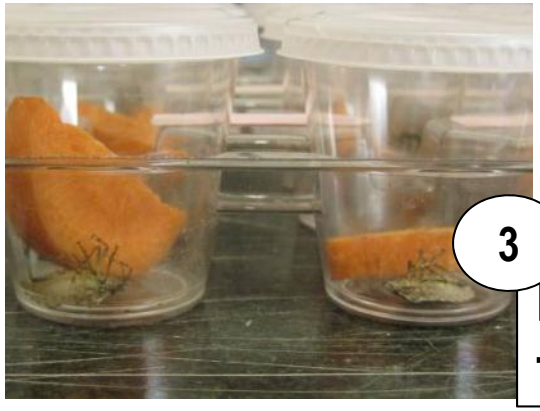
1

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



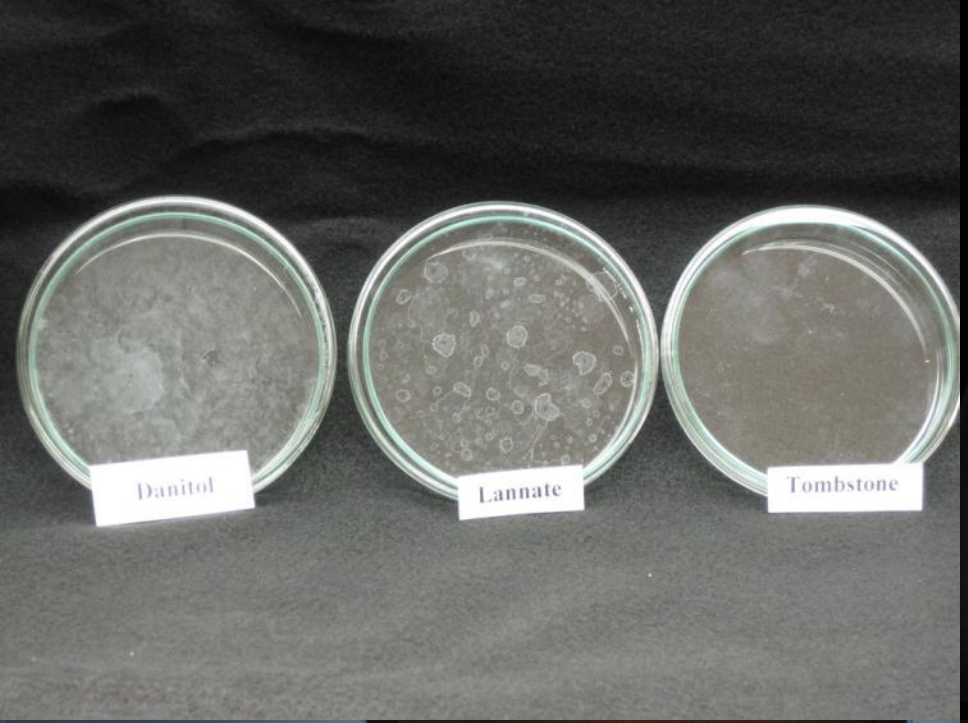
2

Direct observations of vertical movement capacity following insecticide exposure.



3

Mortality tracked for 7-d followed by final vertical movement trial.


Danitol
Lannate
Tombstone

BMSB Insecticide Evaluations
Material Selections

Pyrethroids
Bifenthrin
Fenpropathrin
Permethrin
Gamma-Cyhalothrin
Beta-Cyfluthrin
Lambda-Cyhalothrin
Zeta Cypermethrin
Cyfluthrin
Esfenvalterate

Organophosphates
Dimethoate
Malathion
Methidathion
Chlorpyrifos
Acephate
Azinphosmethyl
Diazinon
Phosmet

Neonicotinoids
Dinotefuran
Thiamethoxam
Clothianidin
Imidacloprid
Acetamiprid
Thiacloprid

Other Classes
Endosulfan
Tolfenpyrad (SC and EC)
Pyrifluquinazon
Kaolin Clay
Abamectin
Indoxacarb
Spirotetramat
Flonicamid
Cyantraniliprole

Carbamates
Methomyl
Formetanate HCl
Oxamyl
Carbaryl

Biopesticides
MBI-203
MBI-205
MBI-206

Combination Materials

Chlorpyrifos+
Gamma-Cyhalothrin

Kaolin Clay+
Thiamethoxam

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

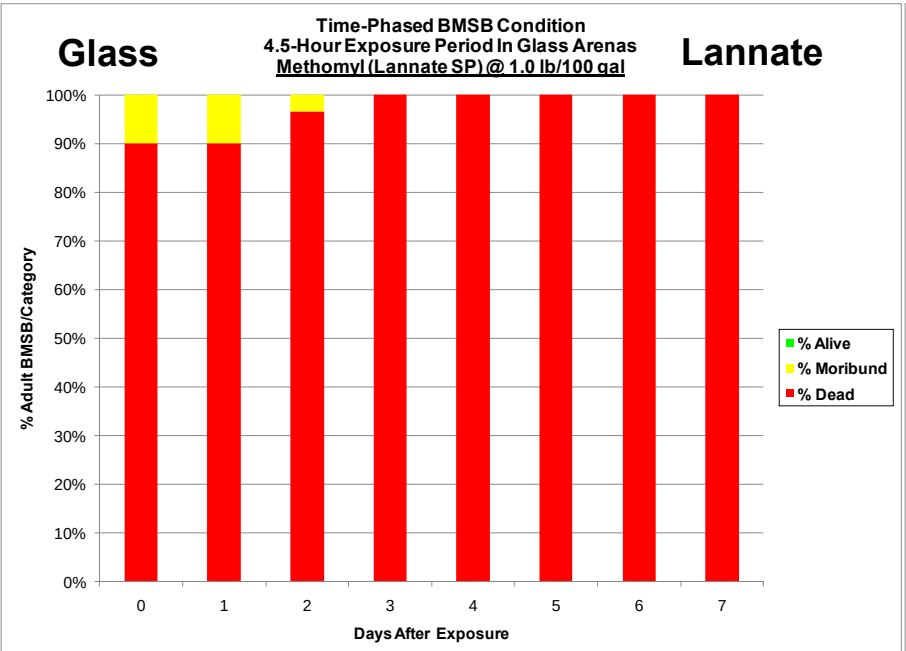
0 Hours Exposure
Track 00073
147.78 cm
343.34 sec

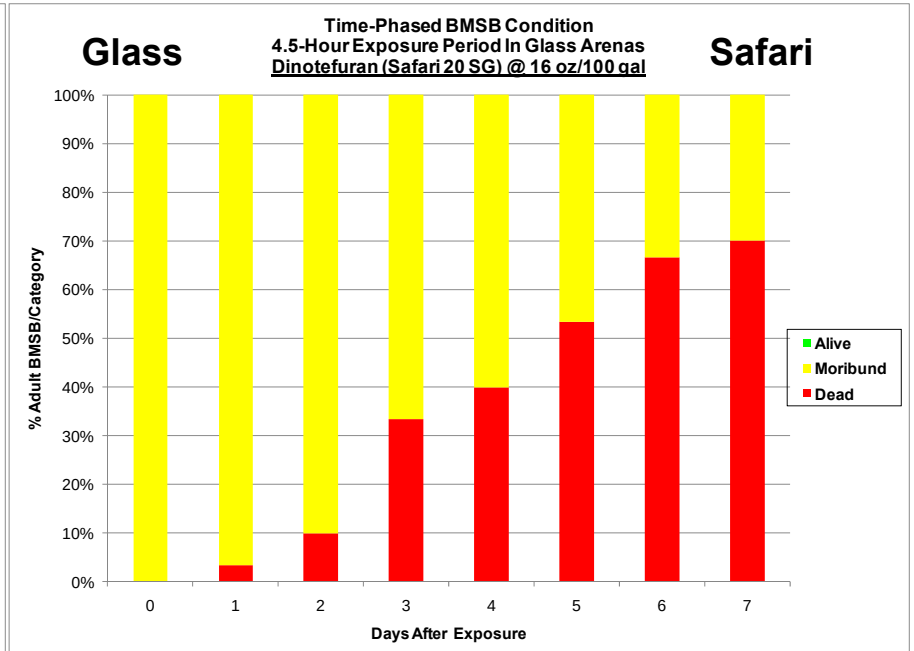
1 Hour Exposure
Track 00098
42.34 cm
79.41 sec

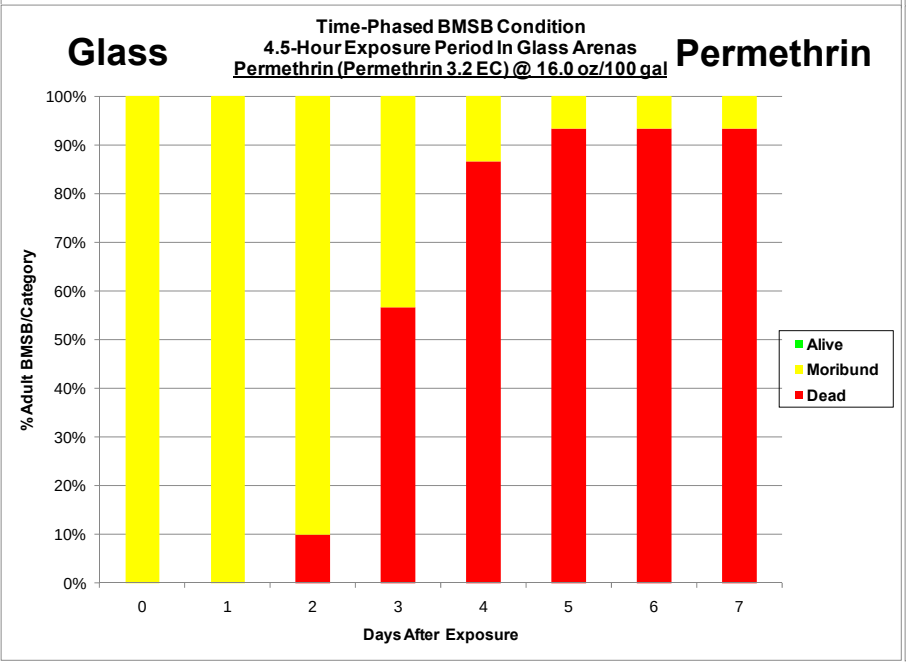
2 Hours Exposure
Track 00117
0.54 cm
0.83 sec

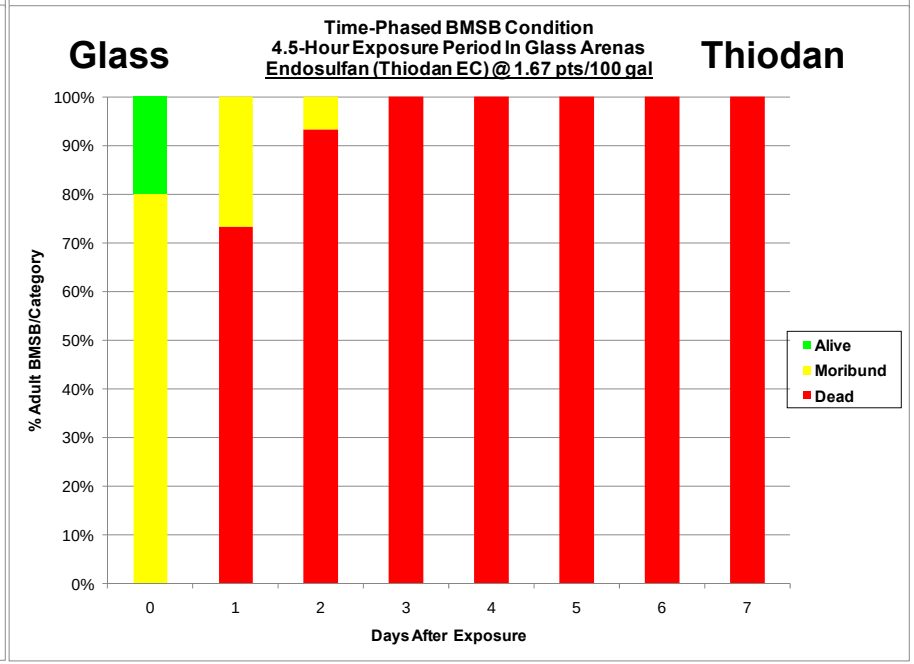
BMSB Insecticide Evaluations
7-Day Survivorship

Promising Compounds

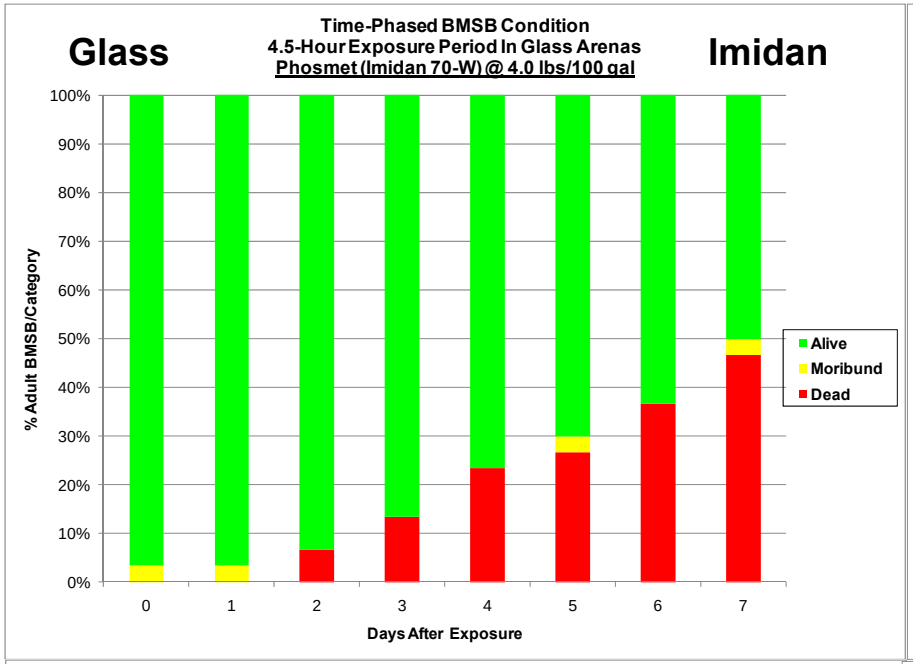


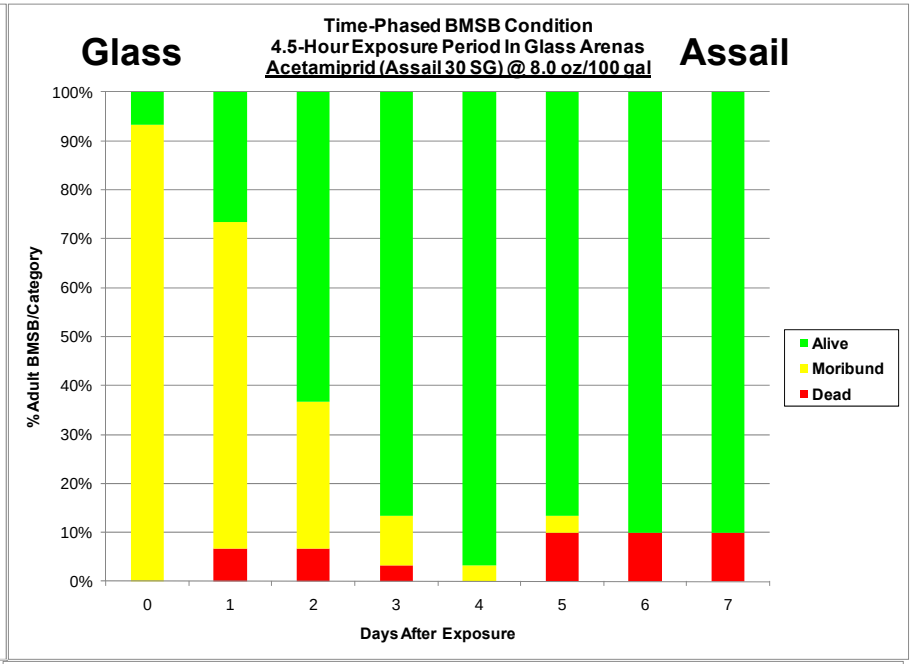


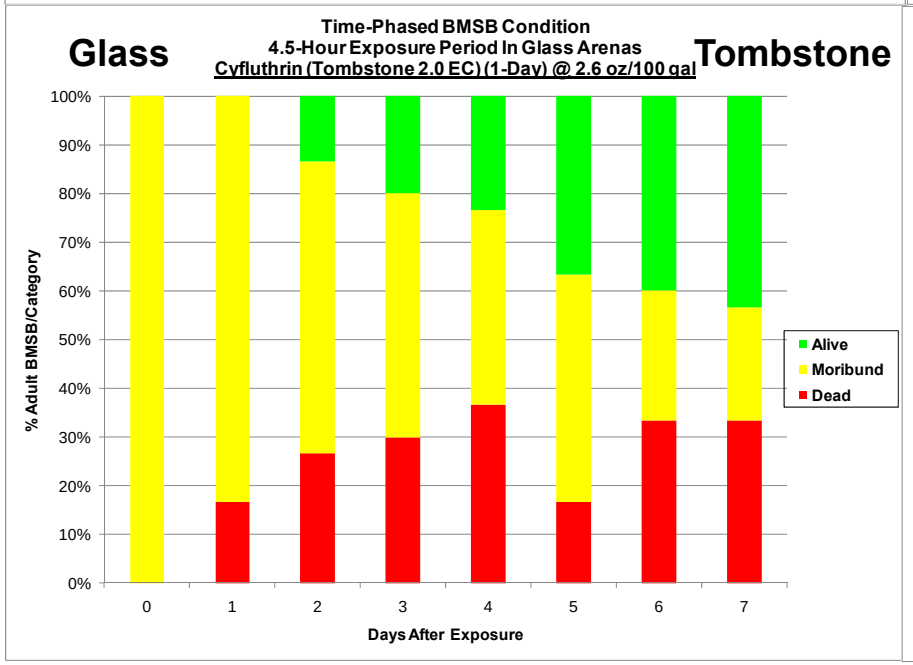


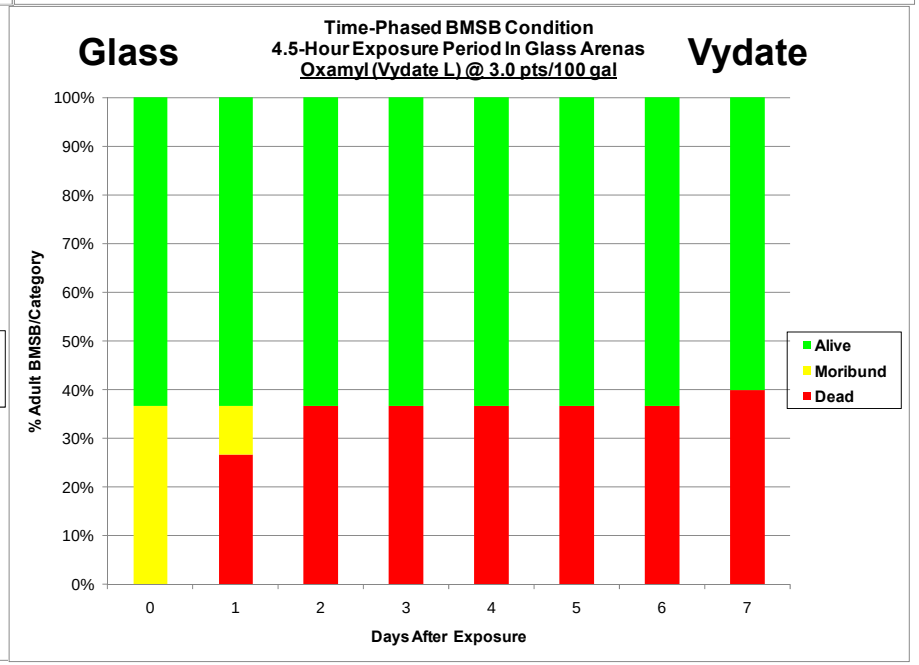


Weaker Materials









BMSB Insecticide Evaluations
Lethality Index

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

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.

BMSB Laboratory-Based Testing
Lethality Index

Active Ingredient	Trade Name	Lethality Index	Active Ingredient	Trade Name	Lethality Index
Chlorpyrifos/Gamma-Cyhalothrin	Cobalt	**95.4**	Oxamyl	Vydate	**46.8**
Dimethoate	Cygon	**93.3**	MBI-203	MBI-203	**43.4**
Malathion	Malathion	**92.5**	Esfenvalerate	Asana	**43.3**
Bifenthrin	Brigade	**91.5**	Imidacloprid	Provado	**40.0**
Endosulfan	Thionex	**90.4**	Tolfenpyrad SC	Tolfenpyrad SC	**36.5**
Methidathion	Supracide	**90.4**	MBI-205	MBI-205	**35.7**
Methomyl	Lannate	**90.1**	Tolfenpyrad EC	Tolfenpyrad EC	**33.3**
Chlorpyrifos	Lorsban	**89.0**	Pyrifluquinazon	Pyrifluquinazon	**28.3**
Acephate	Orthene	**87.5**	Kaolin Clay	Surround	**23.1**
Fenpropathrin	Danitol	**78.3**	Diazinon	Diazinon	**20.4**
Permethrin	Permethrin	**77.1**	Phosmet	Imidan	**20.0**
Azinphosmethyl	Guthion	**71.3**	Acetamiprid	Assail	**18.8**
Dinotefuran	Safari	**67.3**	Thiacloprid	Calypso	**18.3**
Kaolin Clay/Thiamethoxam	Particle Delivery	**66.7**	Abamectin	Agri-Mek	**16.3**
Formetanate HCl	Carzol	**63.5**	Indoxacarb	Avaunt	**11.3**
Gamma-Cyhalothrin	Proaxis	**59.0**	Spirotetramat	Movento	**9.8**
Zinc Dimethyldithiocarbamate	Ziram	**57.5**	Carbaryl	Sevin	**9.2**
Thiamethoxam	Actara	**56.3**	Water	Control 6	**9.2**
Clothianidin	Clutch	**55.6**	Flonicamid	Beleaf	**7.7**
Beta-Cyfluthrin	Baythroid	**54.8**	Water	Control 2	**6.9**
Lambda-Cyhalothrin	Warrior	**52.9**	Water	Control 3	**6.3**
Zeta-Cypermethrin	Mustang Max	**52.1**	Water	Control 5	**6.0**
Cyfluthrin	Tombstone	**49.0**	Water	Control 4	**4.2**
MBI-206	MBI-206	**48.4**	Cyantraniliprole	Cyazypyr	**1.7**

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.

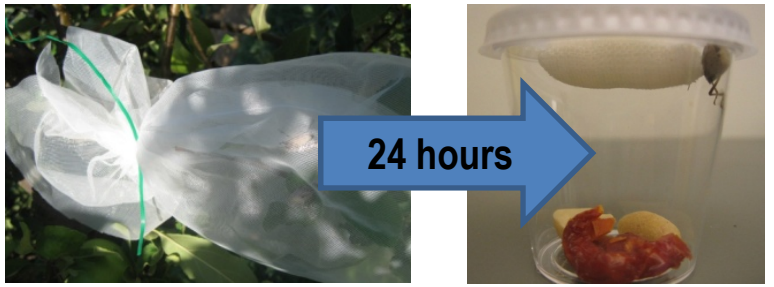
2012 Field-Based Residual Trials

- <u>3 Trials:</u>
  - July 2nd
  - August 13th
  - September 10th
- Wild-collected bugs exposed for 24h
- Conditional assessments for 5 days

0 Days

3 Days

5 Days



Why Test Field Residual Efficacy?

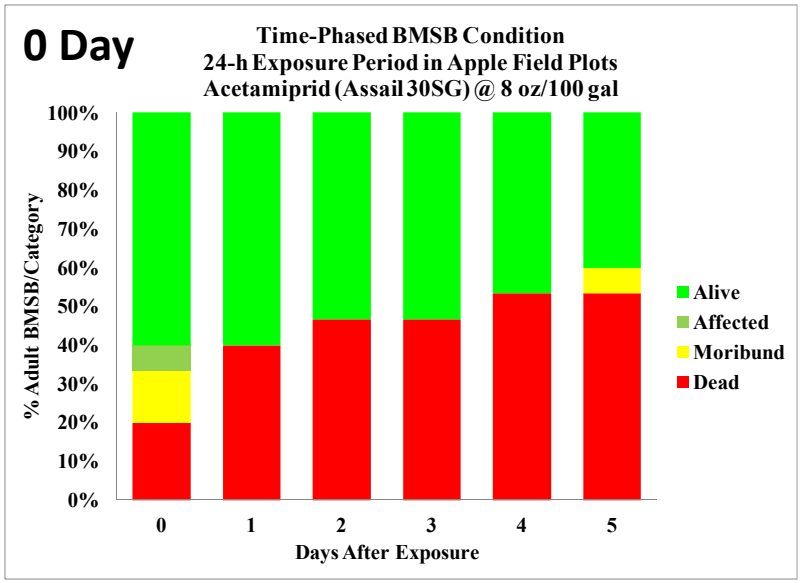
- BMSB dispersal and avoidance behavior.
- Contribution to rational spray programs/recommendations.
- Continued comparisons with laboratory testing.
- Foundation for testing newly labeled or experimental materials.

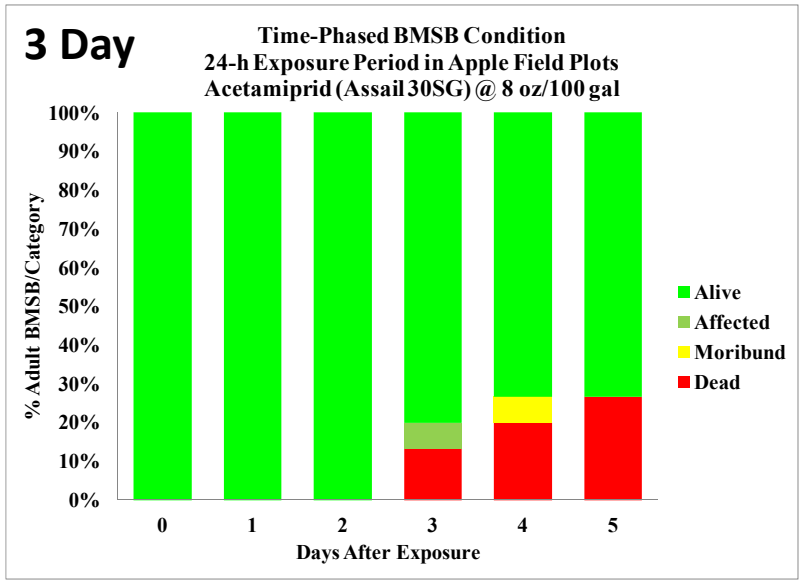
2012 Materials, Field Residual Evaluations

- 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)

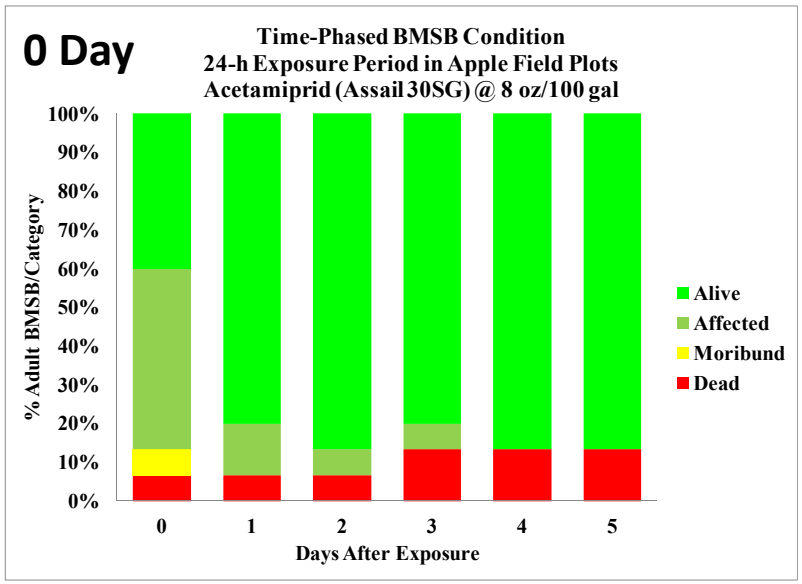
Assail (acetamiprid): Fresh Residue vs. 3-Day Residual
Overwintered Adults vs. New Adults

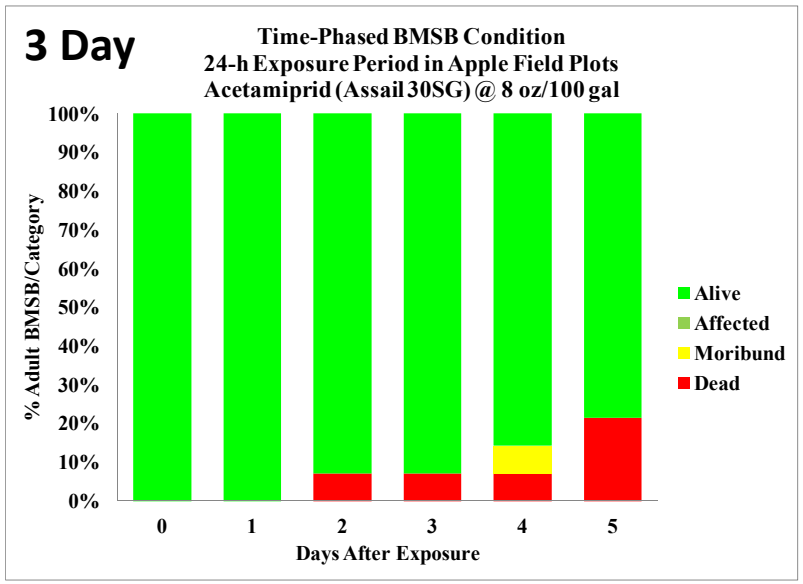
July 2





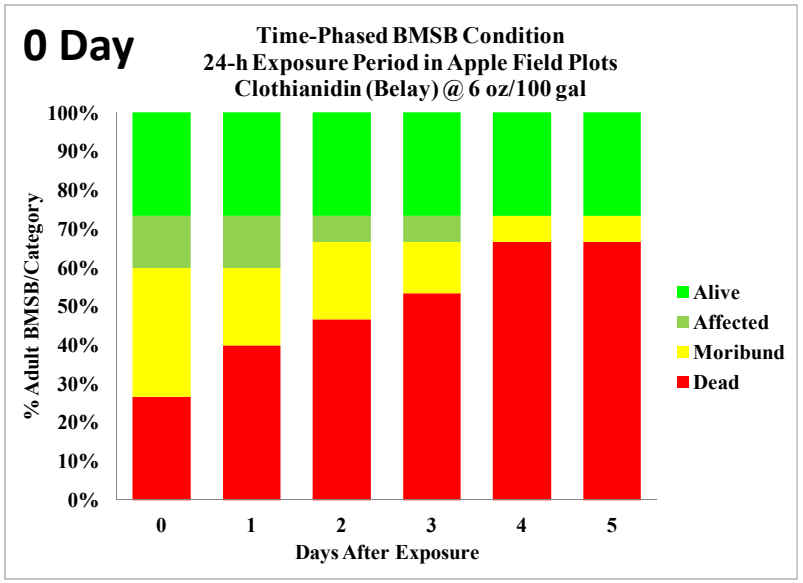
August 13

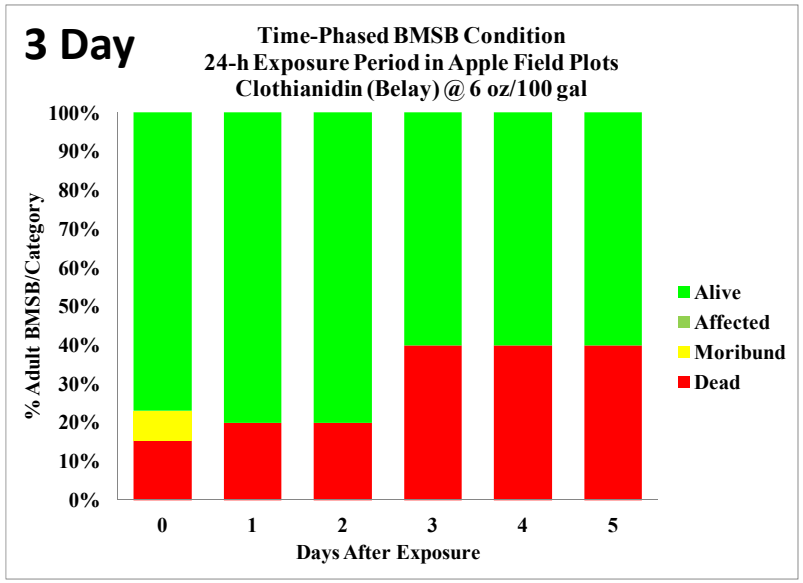




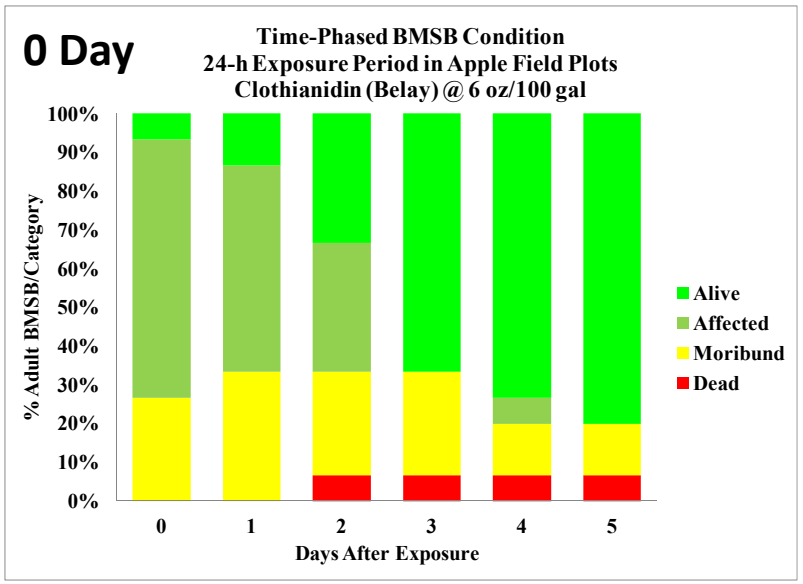
Belay (clothianidin): Fresh Residue vs. 3-day Residual
Overwintered Adults vs. New Adults

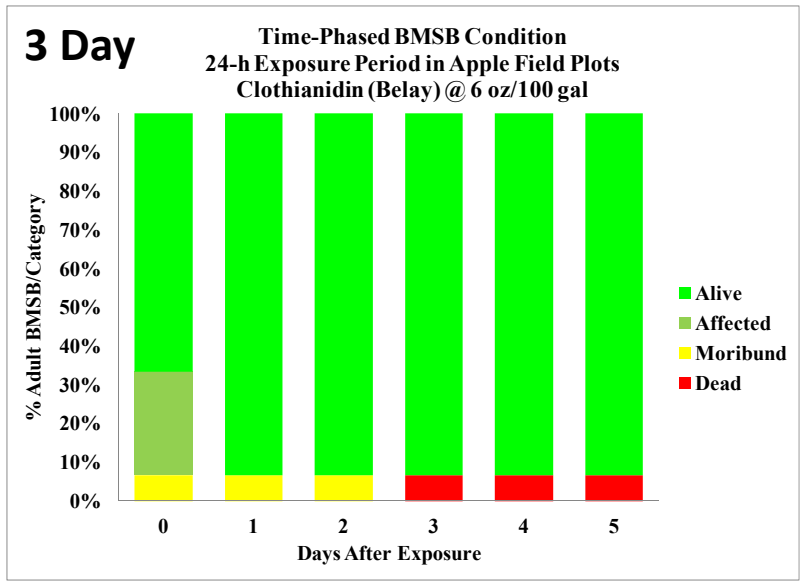
July 2





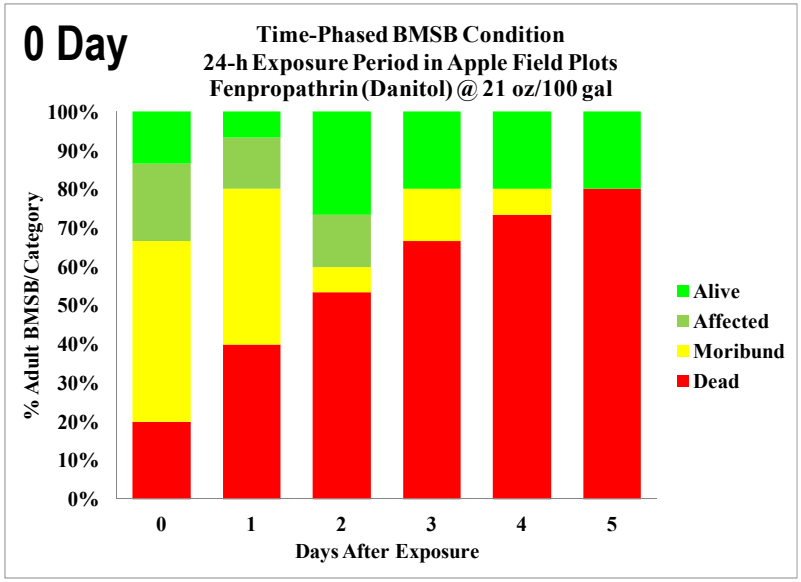
September 10

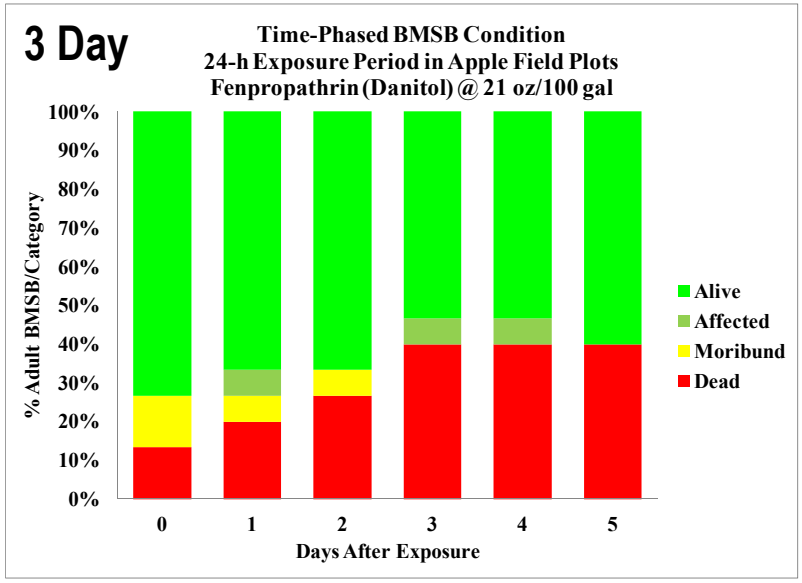




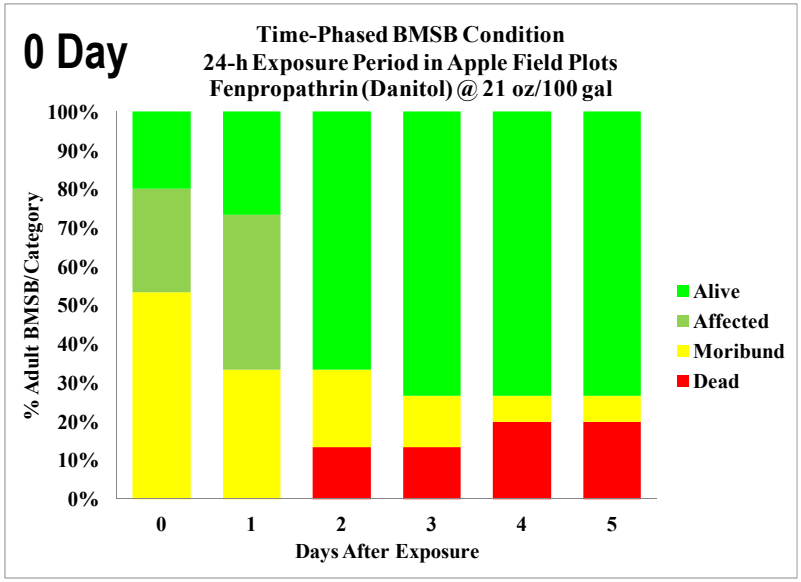
Danitol (fenpropathrin): Fresh Residue vs. 3-Day Residual
Overwintered Adults vs. New Adults

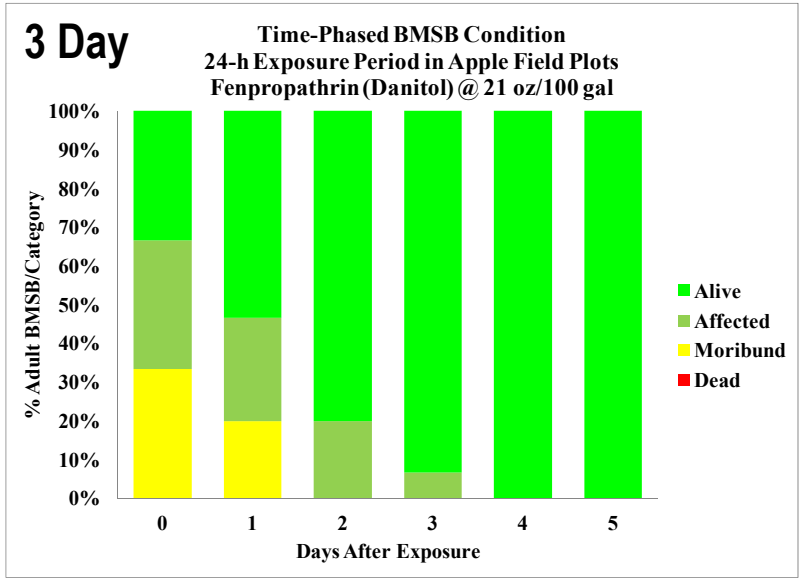
July 2





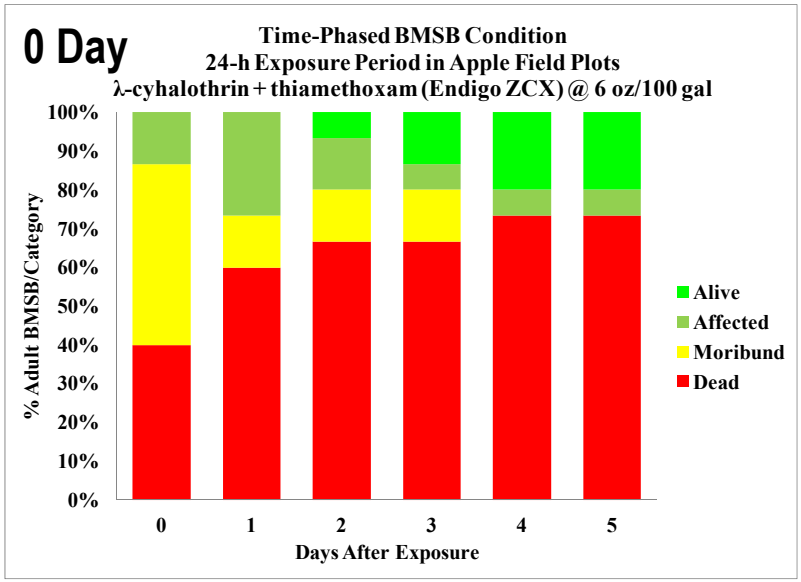
September 10

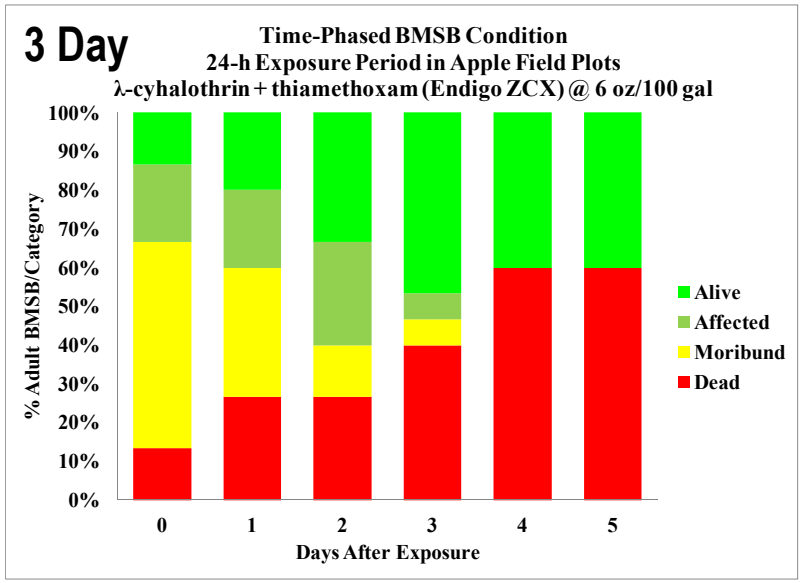




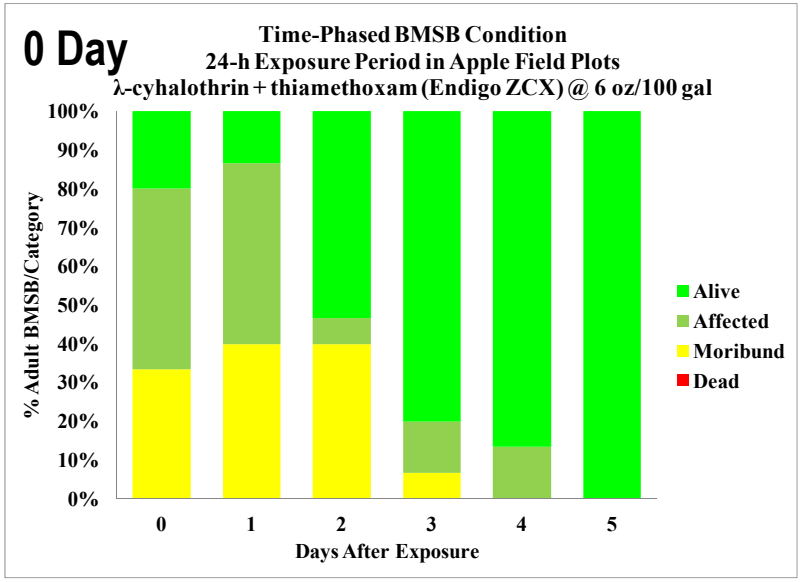
Endigo (thiamethox/λ cy): Fresh Residue vs. 3-Day Residual Overwintered Adults vs. New Adults

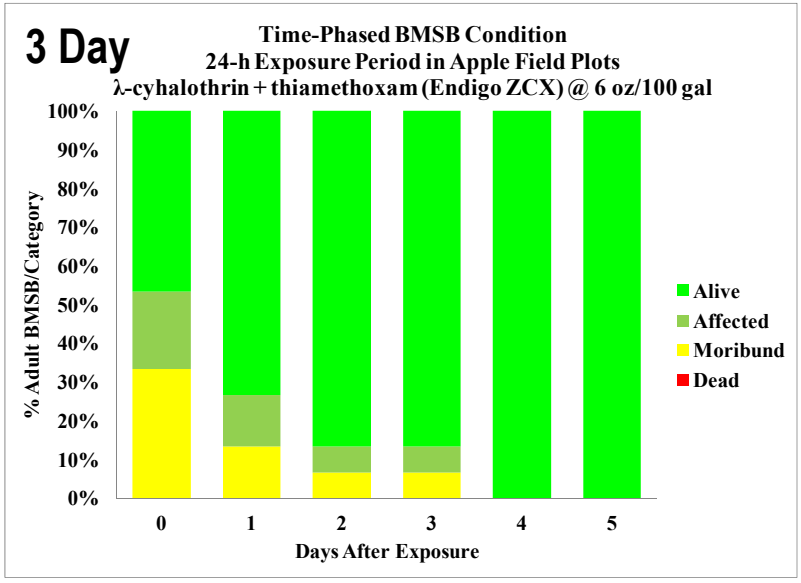
July 2





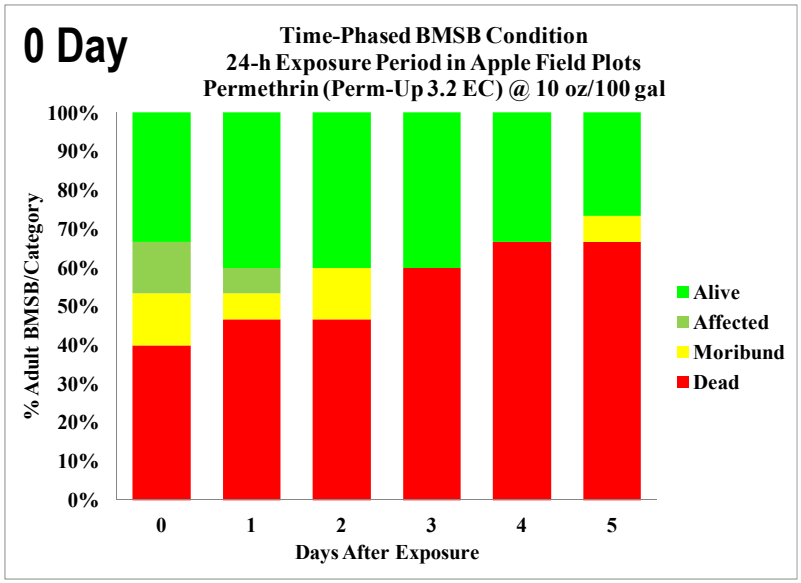
September 10

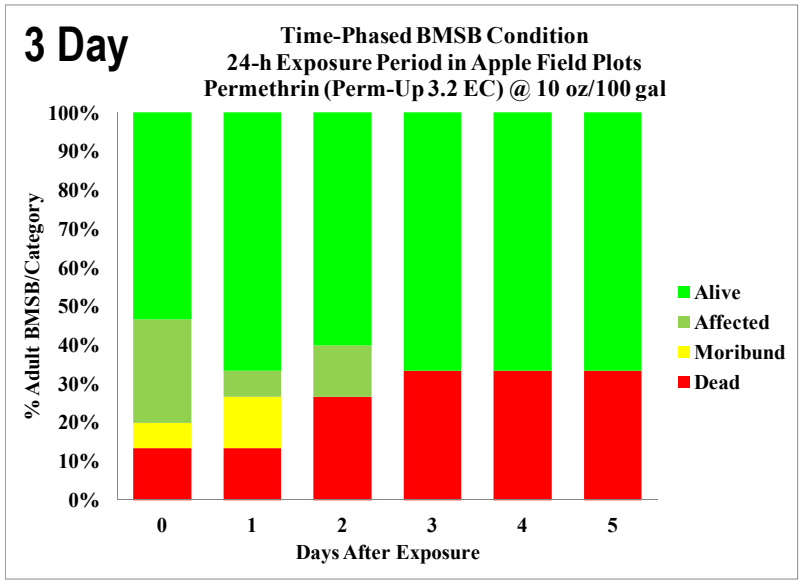




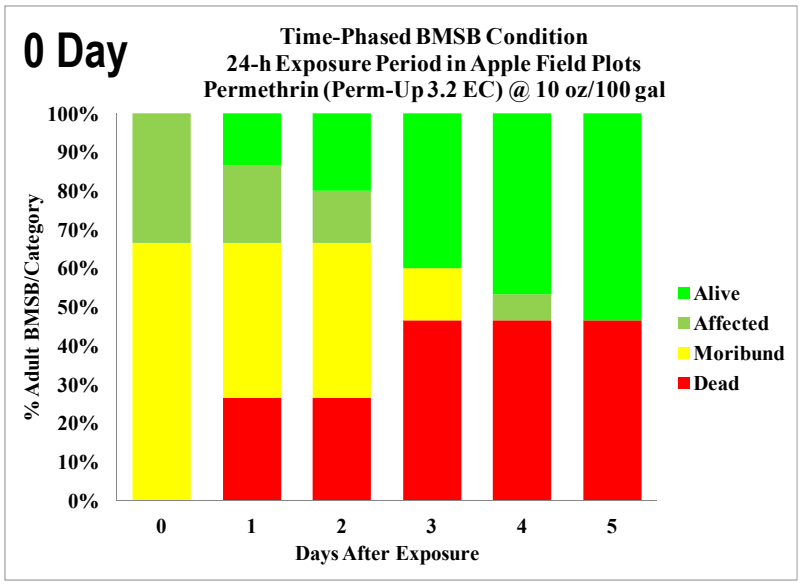
Perm-Up (permethrin): Fresh Residue vs. 3-Day Residual
Overwintered Adults vs. New Adults

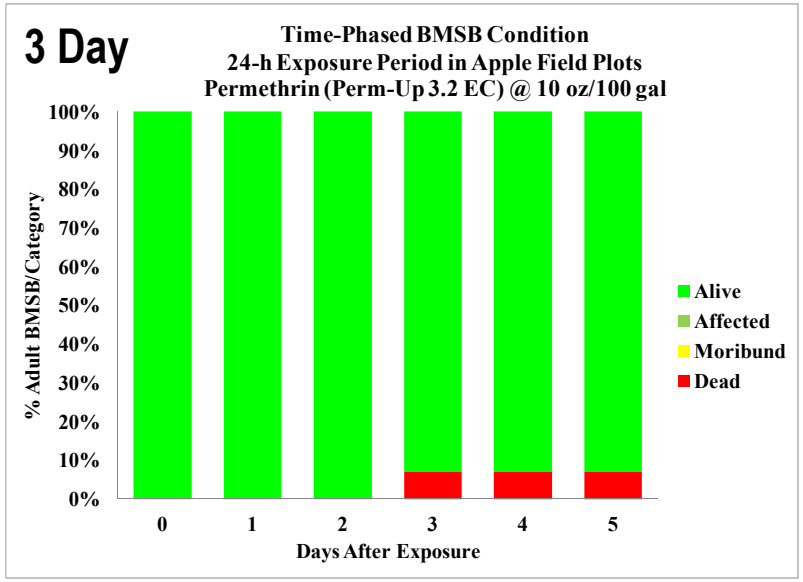
July 2





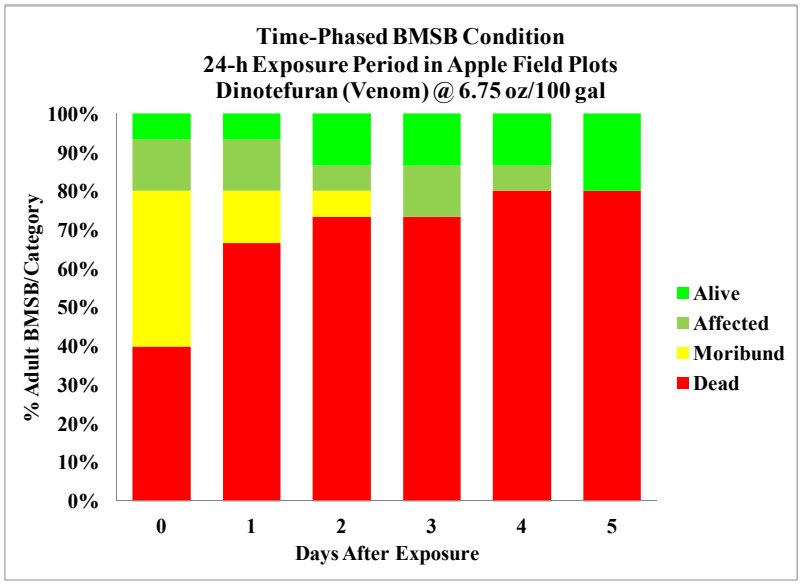
August 13

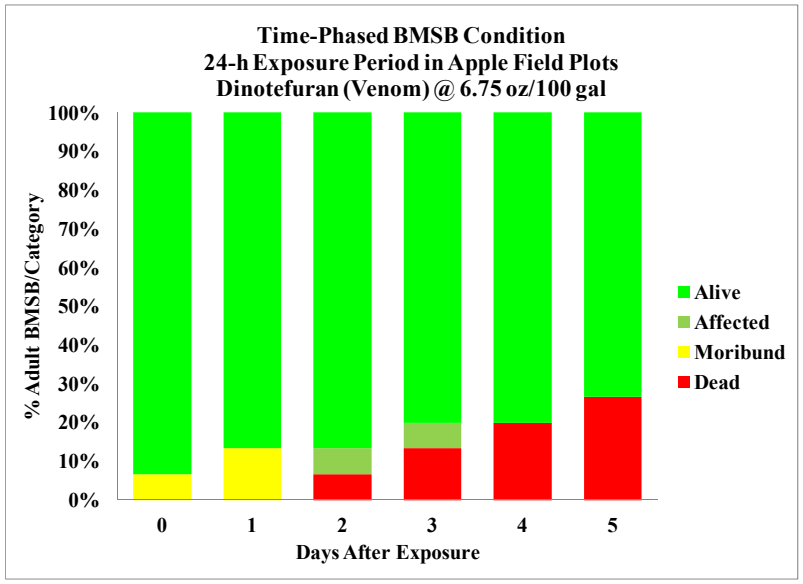




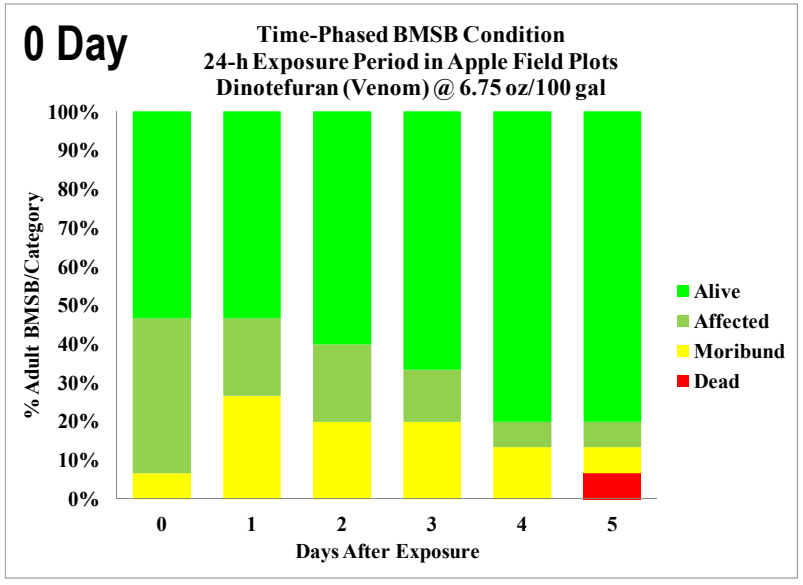
Venom (dinotefuran): Fresh Residue vs. 3-Day Residual
Overwintered Adults vs. New Adults

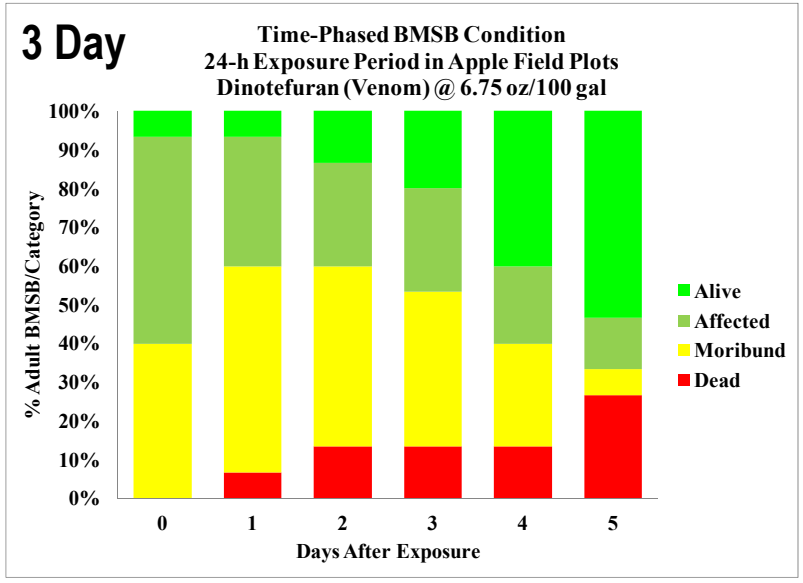
July 2





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.**

JUNE 2011

SPRAY SCHEDULE - BMSB

* every other row lg. apples, peaches
* every 4th row Bellis apples

1

— ARMS in STONE FRUIT POME FRUIT + Brambles

2

apples - peaches -

3

McHenry Highland Festival*
Blueberries
Brambles
Cherries
4th

apples peaches plums strawberries (OUTSIDE)

6

cherries ½ potatoes tomatoes vegetables

7

cherries ½
½ Brambles
½ Blueberry
Blackberry

8

apples peaches plums (INSIDE)

9

blueberries 39/40 44
Brambles 13, 15, 16, 44, 41

10

Early Summer Season rates begin this weekend
Crack spray Cherries

11

Apples Peaches (OUTSIDE)

12

veg tomatoes cherries grapes, gooseb plums, apricot

13

Blueberries Brambles

14

Apples peaches (INSIDE)

Blueb. (admired)

15

Crack spray Cherries
cherries tomatoes, flowers

16

Blueberries brambles vegetables

Cherries Crack spray

17

Peach Apple (OUTSIDE)

18

Father's Day

Brambles, Blueberries, grapes, gooseberries (OUTSIDE)

20

Peaches apples (INSIDE)

21

cherries/plums (inside)

22

Bramble (inside)
Blueberry (inside)

23

peach apple (outside)

24

Summer Season rates begin this weekend

25

Brambles Blueberries (outside)

(#50/48) 26

apple pear inside cherry

27

tomatoes veg. flowers potatoes

28

Brambles Blueberries (inside)

29

Apples Peaches (OUTSIDE)

30

tomatoes, veg, potatoes, flowers

7/1

woods edge ornbens

7/2