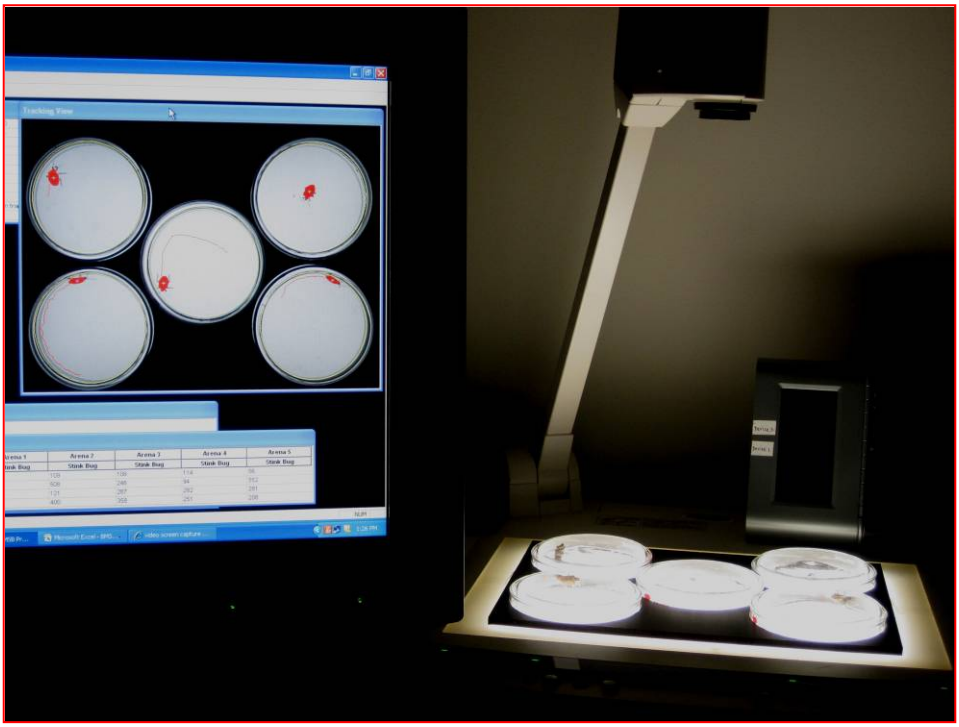
Impact of Incidental Contact with Organic Insecticide Residues on Brown Marmorated Stink Bug, *Halyomorpha halys* (Stål), Mobility and Mortality



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Introduction. The brown marmorated stink bug (BMSB), *Halyomorpha halys* (Stål) is an invasive insect native to China, Taiwan, Korea, and Japan that was introduced to the United States in the Allentown, PA region in the mid-1990s. Currently, BMSB is well established throughout the mid-Atlantic region and has been officially detected in 33 states and the District of Columbia. BMSB is a highly polyphagous pest, and threatens numerous agricultural crops; in 2010, BMSB populations increased dramatically and attacked many high-value crops in the mid-Atlantic region. Damage in commercial tree fruit orchards reached critical levels, with some growers losing entire blocks of stone fruit and Asian pears, and producers endured widespread injury to apples, peppers, tomatoes, raspberries, grapes, sweet corn, field corn, soybeans, and blueberries. As the spread, expansion, and threat to US agriculture posed by BMSB continues to increase, there are no established detection methods, treatment thresholds, or control strategies for BMSB in any cropping system, and relative lethality of labeled organic insecticides is not known for control of BMSB. In order to provide the foundation for determination of potential field effectiveness of organically approved materials against BMSB, we performed a series of laboratory trials to examine the impact of incidental contact with dry insecticide residues on BMSB mobility and survivorship.

Fig. 1. Adult BMSB feeding on Montmorency cherry.

Materials and Methods.

Subject BMSBs. For all insecticide assays, wild BMSB adults were collected from overwintering sites in Jefferson and Berkeley Counties, WV and immediately brought back to the laboratory. Field-collected adults were then placed in 30 cm^3 screen cages for a minimum of two weeks at 16:8 (L:D), 25ºC, and 70% RH. Each cage was provisioned with a potted soybean plant and peanuts, carrots, and/or sunflower seeds as food sources. Food was changed twice-weekly. Approximately 200 adults were held in each cage. Only those adults that began to actively forage and feed after the two-week holding period were used as test subjects in subsequent insecticide bioassays.

Fig. 2. Adult BMSB introduced into a treated dish.

Insecticide Formulation and Application. Insecticides were mixed (with water alone as carrier) in accordance with the tree fruit-specific label recommendations, at a concentration equal to use of 100 gallons of finished spray material per acre. Finished sprays were atomized onto 100 mm x 15 mm glass Petri dish arenas at a volume equal to field delivery per unit area (505 microliters per arena). Insecticide residues were allowed to dry completely for 18 h in a fume hood prior to testing. Insecticides evaluated included azadirachtin, potassium salts, pyrethrins, pyrethrins + kaolin clay, and spinosad. Water alone was used as a control.

Fig. 3. EthoVision display of BMSB horizontal mobility tracks.

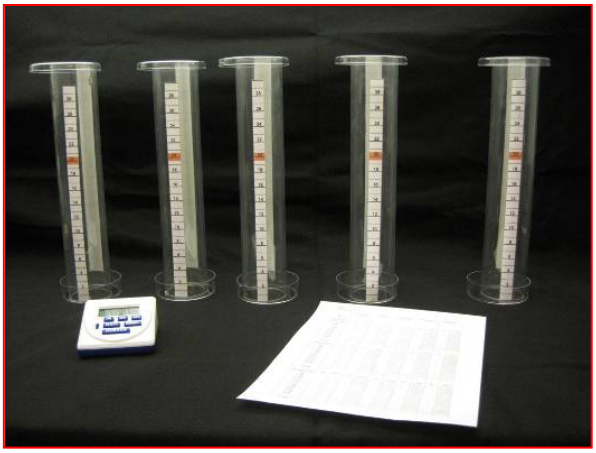


Fig. 4. Vertical mobility bioassay cylinders.

Horizontal Mobility with EthoVision. Horizontal mobility, including distance moved, duration of movement and mean velocity was assessed on individual BMSBs in 100 mm x 15 mm glass Petri dish test arenas treated with candidate insecticides. Dishes were lidded to contain single test subjects, and five arenas were tested simultaneously. To aid in detection of test subjects and limit glare, trials were conducted in a darkened room, and arenas were backlit using a fluorescent Canon video visualizer stand (model RE-350, Canon, Inc., Japan). Images were captured using a Canon digital video recorder (12x zoom, 5.4-65 mm, 1:1.8) suspended directly above the array of test arenas. Movement tracks were captured live using Noldus EthoVision software (Version 3.1.16, Noldus Information Technologies, The Netherlands), and each trial consisted of a 10 minute recording duration at a capture rate of six samples per second. Horizontal mobility was evaluated at 0.0 h, 1.5 h, 3.0 h and 4.5 h after introduction into the dish.

Vertical Mobility. The effect of pesticide exposure on the vertical mobility of adult BMSB was performed immediately after the 4.5-hour exposure period of horizontal mobility trials and seven days later. Adults were placed individually into 30 cm tall x 7 cm inner diameter clear polycarbonate vertical mobility bioassay cylinders. Subject BMSB were evaluated for 5 minutes in each of 3 separate but consecutive trials. Bug position was recorded at 30-second intervals, and climbing arenas were inverted if bugs reached the top of the cylinder. Total upward distance moved was recorded.

Mortality. After 4.5 hours of exposure in treated dishes and following vertical mobility trials, BMSB adults were placed in clean isolation cups with food and water resources. Individual bug condition (alive, affected, moribund, dead) was assessed immediately following the insecticide exposure period, then daily for five days.

Fig. 5. Adult BMSBs following mobility trials.

USDA-ARS-Appalachian Fruit Research Station **BMSB Lethality (Dry Residue, Glass)** **Organics (1)**

Trade Name	Formulation	A.I.	Class	Crops	Field Rates	Tested Rate	Label Restrictions	Label Notes	Stink Bug on Label
Neemix	4.5 EC	Azadirachtin (4.5%)	26/Tetranortriterpenoid	Pome Fruit Stone Fruit	4.0-16.0 oz/A	16 oz/100 gal	Max: 20 g a.i./A/yr and min. of 30 gal water	OMRI Listed	No

Trade Name	Formulation	A.I.	Class	Crops	Field Rates	Tested Rate	Label Restrictions	Label Notes	Stink Bug on Label
M-Pede	S.L.	Potassium Salts of Fatty Acids (49%)	Soaps	Pome Fruit	1-2% v/v	2% v/v	Not recommended for use after delayed dormant for fresh market pears.	OMRI Listed	No
				Stone Fruit			Do not make dilute sprays on smooth skinned fruit after fruit formation. Not recommended for use on yellow skinned nectarines. Do not apply to sweet cherries between fruit formation and harvest.		

Trade Name	Formulation	A.I.	Class	Crops	Field Rates	Tested Rate	Label Restrictions	Label Notes	Stink Bug on Label
Pyganic	EC 1.4 II	Pyrethrins (1.4%)	Botanical	Pome Fruit Stone Fruit	3.5-7 pts/100 gal	7 pts/100 gal		OMRI Listed	Yes

USDA-ARS-Appalachian Fruit Research Station **BMSB Lethality (Dry Residue, Glass)** **Organics (2)**

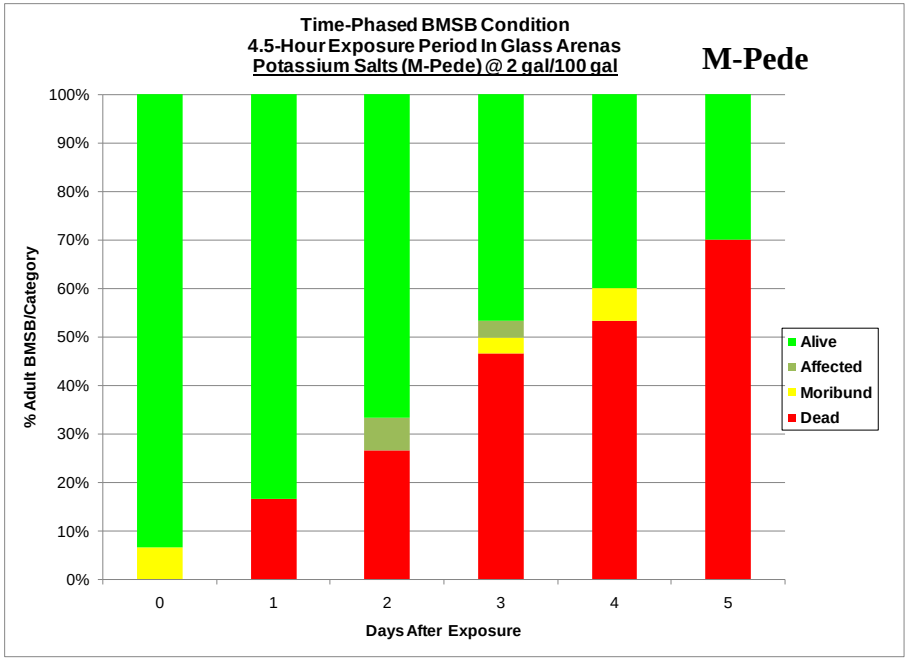
Trade Name	Formulation	A.I.	Class	Crops	Field Rates	Tested Rate	Label Restrictions	Label Notes	Stink Bug on Label
Entrust	WP	Spinosad (80%)	5/Spinosyns	Pome Fruit	1.5-3.0 oz/A	3.0 oz/100 gal	Max: 9 oz/A/yr	OMRI Listed	No
				Stone Fruit	1.25-2.5 oz/A				

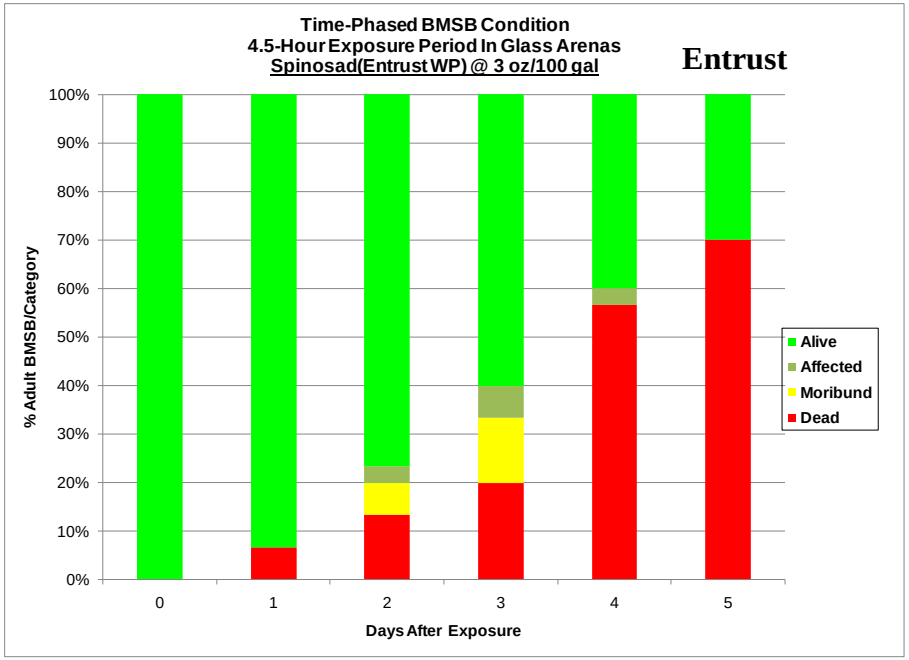
Trade Name	Formulation	A.I.	Class	Crops	Field Rates	Tested Rate	Label Restrictions	Label Notes	Stink Bug on Label
Surround	WP	Kaolin (95%)	Particle Film	Pome Fruit	25-100 lbs/A	12.5 lbs/100 gal	100 lbs/A allowed only on pear for pre-bloom heavy infestations.	May clog filters, intakes and/or nozzles.	Yes (Suppression)
				Stone Fruit	25-50 lbs/A			Special washing required for fresh market fruit; particularly fuzzy peaches. If washing unavailable then discontinue sprays at ¾ and ¼ inch for peach and cherry, respectively.	No

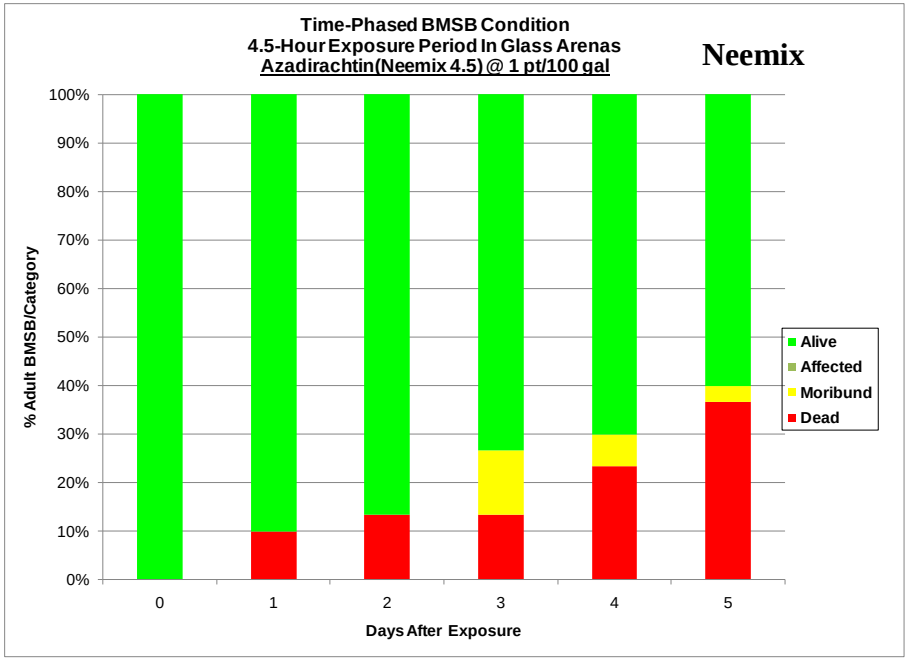
USDA-ARS-Appalachian Fruit Research Station **BMSB Lethality (Dry Residue, Glass)** **Organics**

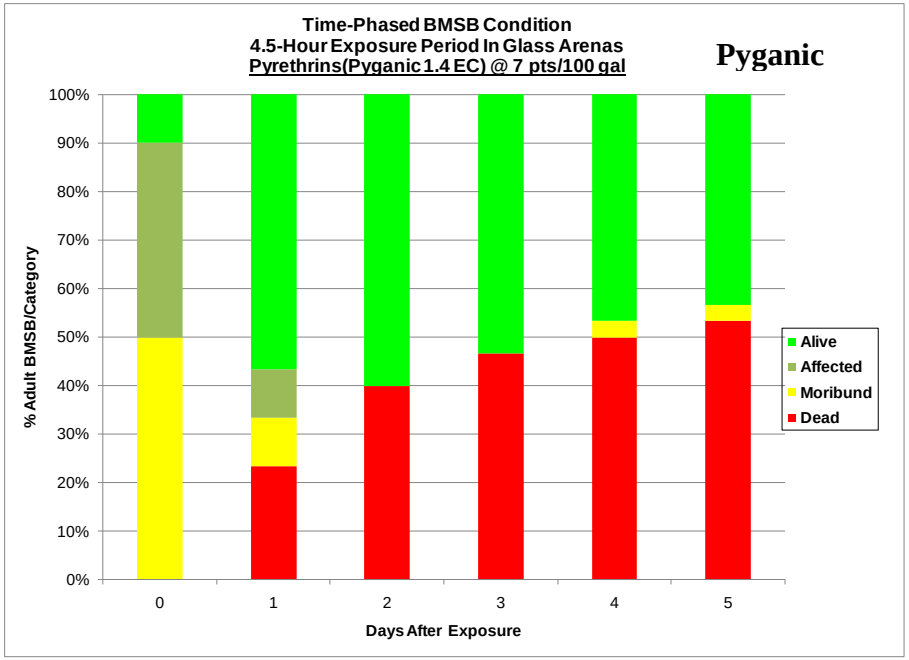
Chemical Name	Horizontal Mobility Distance (cm ± SE)				Horizontal Mobility Duration (s ± SE)			
	0.0h	1.5h	3.0h	4.5h	0.0h	1.5h	3.0h	4.5h
Azadirachtin	73.6 ± 14.8	96.2 ± 34.9	156.9 ± 46.0	117.4 ± 32.4	100.9 ± 20.9	92.9 ± 29.9	142.5 ± 33.3	108.4 ± 25.2
Potassium Salts of Fatty Acids	83.5 ± 26.3	65.5 ± 21.4	53.3 ± 16.8	98.3 ± 26.2	87.7 ± 24.5	73.7 ± 21.7	61.4 ± 19.6	133.1 ± 35.0
Pyrethrins	148.6 ± 33.6	99.4 ± 21.9	95.3 ± 26.3	124.9 ± 32.0	147.5 ± 26.8	108.8 ± 21.6	98.5 ± 22.4	128.5 ± 26.3
Pyrethrins + Kaolin	59.5 ± 17.5	24.4 ± 9.0	33.0 ± 17.7	16.4 ± 6.1	77.6 ± 22.2	38.5 ± 12.5	41.7 ± 18.9	32.1 ± 11.8
Spinosad	22.9 ± 6.5	92.5 ± 33.9	92.6 ± 33.5	90.5 ± 37.7	38.8 ± 12.5	87.2 ± 27.3	92.1 ± 29.5	81.3 ± 26.9
Water	***50.0 ± 12.5***	***84.5 ± 32.8***	***93.2 ± 35.8***	***108.0 ± 36.1***	***67.8 ± 16.0***	***84.9 ± 27.4***	***93.8 ± 30.4***	***111.8 ± 27.3***

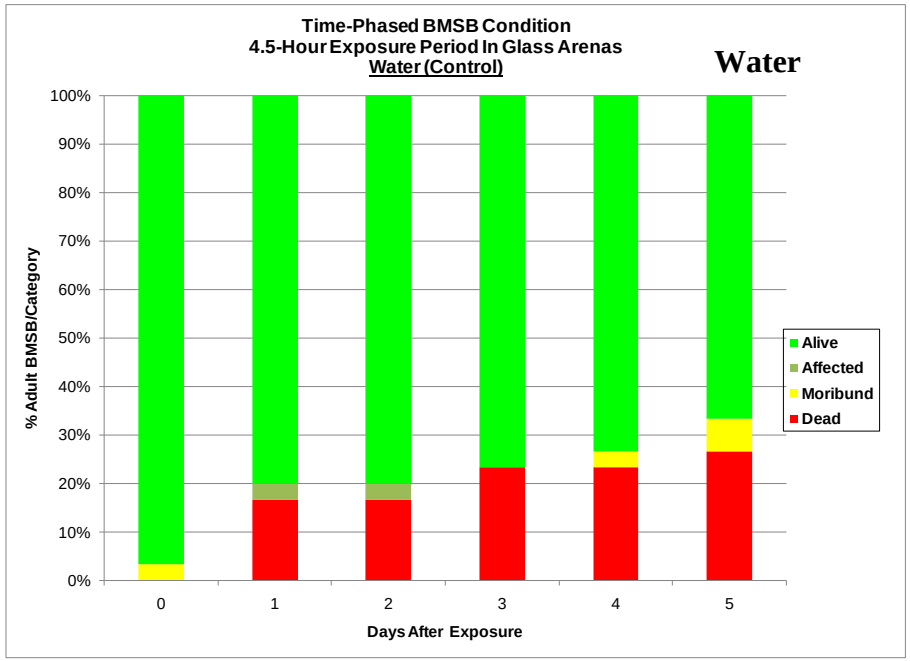
Chemical Name	Vertical Mobility (cm ± SE)	
	4.5h	7d
Azadirachtin	143.7 ± 33.8	21.9 ± 16.9
Potassium Salts of Fatty Acids	2.8 ± 1.5	6.8 ± 4.3
Pyrethrins	11.7 ± 9.1	44.5 ± 26.0
Pyrethrins + Kaolin	2.4 ± 1.7	0.5 ± 0.3
Spinosad	148.1 ± 37.7	3.7 ± 2.5
Water	***56.4 ± 20.5***	***7.2 ± 3.3***

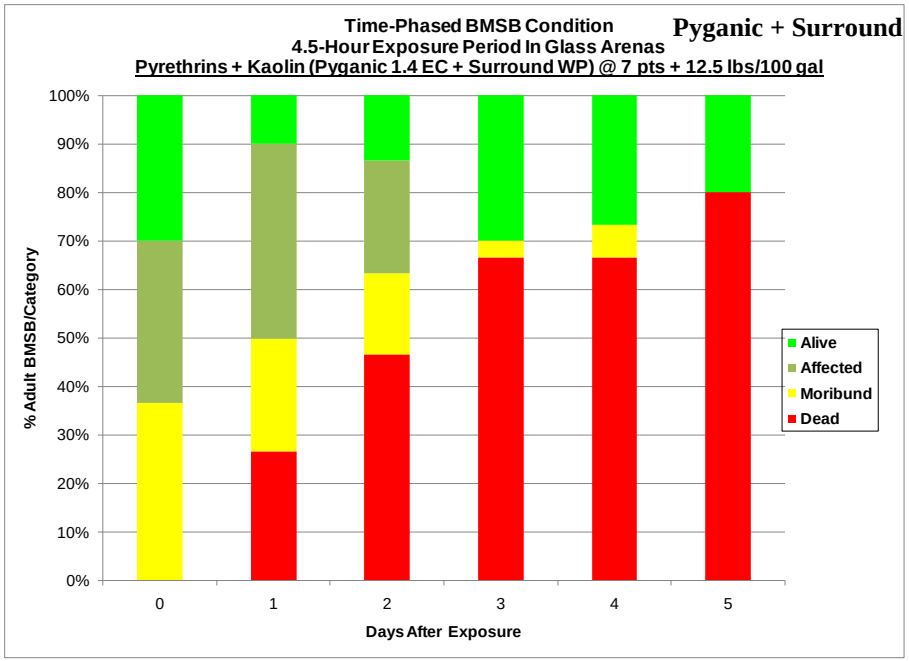

Time-Phased BMSB Condition
4.5-Hour Exposure Period In Glass Arenas
Potassium Salts (M-Pede) @ 2 gal/100 gal
M-Pede
% Adult BMSB/Category
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Days After Exposure
Alive
Affected
Moribund
Dead


Time-Phased BMSB Condition
4.5-Hour Exposure Period In Glass Arenas
Spinosad(Entrust WP) @ 3 oz/100 gal
Entrust
% Adult BMSB/Category
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Days After Exposure
Alive
Affected
Moribund
Dead


Time-Phased BMSB Condition
4.5-Hour Exposure Period In Glass Arenas
Azadirachtin(Neemix 4.5) @ 1 pt/100 gal
Neemix
% Adult BMSB/Category
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Days After Exposure
Alive
Affected
Moribund
Dead


Time-Phased BMSB Condition
4.5-Hour Exposure Period In Glass Arenas
Pyrethrins(Pyganic 1.4 EC) @ 7 pts/100 gal
Pyganic
% Adult BMSB/Category
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Days After Exposure
Alive
Affected
Moribund
Dead


Time-Phased BMSB Condition
4.5-Hour Exposure Period In Glass Arenas
Water (Control)
Water
% Adult BMSB/Category
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Days After Exposure
Alive
Affected
Moribund
Dead


Time-Phased BMSB Condition
4.5-Hour Exposure Period In Glass Arenas
Pyrethrins + Kaolin (Pyganic 1.4 EC + Surround WP) @ 7 pts + 12.5 lbs/100 gal
Pyganic + Surround
% Adult BMSB/Category
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Days After Exposure
Alive
Affected
Moribund
Dead

USDA-ARS-Appalachian Fruit Research Station
BMSB Lethality (Dry Residue, Glass)

$$\text{Lethality Index} = \left[\frac{\text{Day 0-5 (BMSB Alive x 0.0)} + \text{Day 0-5 (BMSB Affected x 0.25)} + \text{Day 0-5 (BMSB Moribund x 0.75)} + \text{Day 0-5 (BMSB Dead x 1.0)}}{180} \right] \times 100$$

Rationale and Methods. Thirty adult brown marmorated stink bugs were exposed (individually) in 100 mm x 15 mm glass Petri dishes treated with candidate materials, applied at field-recommended rates. Insecticide residues were allowed to cure for 18 hours in a fume hood, and bugs were introduced singly into arenas. After 4.5 hours of exposure, bugs were removed from treated dishes, subjected to secondary testing, and then placed in isolation cups with food and water resources. Bug condition (alive, moribund, dead) was recorded immediately after the exposure period, and daily for 5 days after exposure. To directly compare candidate insecticides and maintain consideration of both the intensity of insecticide effects

Active Ingredient(s)	Trade Name(s)	Lethality Index
Pyrethrins + Kaolin	Pyganic + Surround	62.6
Pyrethrins	Pyganic	46.0
Potassium Salts	M-Pede	38.1
Spinosad	Entrust	30.8
Water	Water (control)	19.7
Azadirachtin	Neemix 4.5	19.0