The Challenges Posed by the Invasive Brown Marmorated Stink Bug, *Halyomorpha halys* (Stål), to U.S. Agriculture

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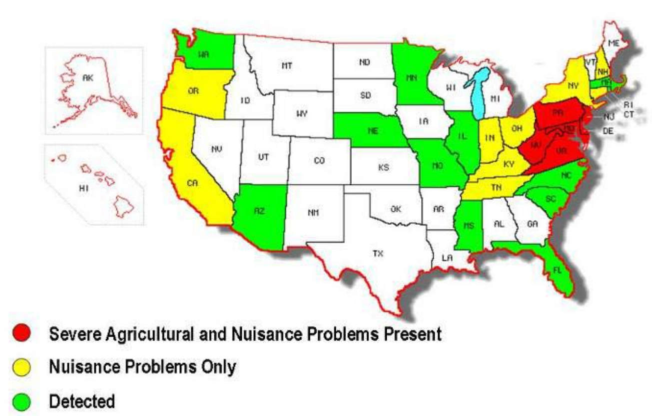
Fig. 1. BMSB adults on mature nectarine.

Introduction. The brown marmorated stink bug (BMSB), *Halyomorpha halys* (Stål), is an invasive stink bug native to Japan, Korea, Taiwan, and China. In 2010, BMSB emerged as a pest of unprecedented importance in orchard crops, small fruit, grape, vegetables, row crops, and ornamentals in the mid-Atlantic. The likelihood of continued if not increasing problems from BMSB on a national scale are based on the following: (1) BMSB has a very broad host range, including numerous specialty crops, field crops, and wild hosts that can support tremendous populations; (2) BMSB has unusual movement and dispersal behaviors, making detection and management more challenging, (3) there is no established detection method, treatment threshold or control strategy for BMSB in any cropping system; (4) BMSB is an excellent hitchhiker and has been officially detected in 27 states and the District of Columbia; (5) multiple generations per year could occur in more southerly locales within the U.S.; and (6) long-term solutions for BMSB such as classical biological control programs are years away from potentially being implemented.

BMSB Distribution. BMSB was officially identified in 2001 from specimens collected in Allentown, PA (Hoebeke and Carter 2003). Currently, large populations are now established in PA, NJ, DE, MD, WV, and VA; all of these states have documented severe losses in a number of specialty crops. Furthermore, established populations have recently been detected in CA, CT, IN, KY, NH, NC, NY, OH, OR, and TN, though crop losses have been minimal at this early stage of infestation. Additional states where BMSB has been detected include AZ, FL, IL, MA, MN, MS, MO, RI, SC, and WA.

Fig. 2. Current BMSB Distribution in the United States.



Host Range. BMSB is considered a polyphagous pest based on its broad host range within Asia with over 300 host plants mentioned. Crops mentioned in the Asian literature as being susceptible to attack broadly include tree fruit, vegetables, shade trees, and leguminous crops with specific mention of specialty crops including apple, cherry, peach, pear, citrus, lima beans, and fig (Panizzi et al. 2000, Hoebeke and Carter 2003). Surveys conducted in the United States identified a number of specialty crops that serve as hosts for BMSB (Bernon 2004). Among them, hazelnut (Molnar, pers. Comm.), apple, plum, peach, pear, pecan and cherry were identified (Bernon 2004, Nielsen and Hamilton 2009a, b). Vegetable hosts include bell peppers, tomatoes, pole and bush beans, cucumber (Bernon 2004) and sweet corn (Dively, pers. comm.). In addition, row crops including soybean and field corn

Fig. 3. Adult BMSB feeding on immature Loring peach.

are also attacked. Identified small-fruit hosts include raspberries (Bernon 2004) and blueberries (Polk pers. comm.). Grape also has been identified as a host (Bernon 2004), as have many trees and shrubs (Welty et al. 2008), including maple, dogwood (Bernon 2004), crabapples, hawthorns, elms, sycamores, and serviceberries (Shrewsbury and Raupp, unpublished).

Biology and Behavior. BMSB overwinters as an adult (Watanabe et al. 1994) in a state of facultative diapause. Diapause can be broken in the laboratory by holding adults under long-day conditions for several weeks. Adults emerge in the spring and begin mating approximately two weeks later (Hoebeke and Carter 2003). A female can produce eggs for about half her life if mated only once. However, females commonly mate multiple times, even up to five times a day, with duration of copulation averaging 10 minutes (Kawada and Kitamura 1983). Females typically deposit eggs in masses on the undersides of leaves (Takahashi 1930). Each egg mass contains ~28 eggs (Kawada and Kitamura 1983, Nielsen et al. 2008) with the average number of eggs deposited per female throughout her lifetime ranging from ~212 (Nielsen et al. 2008) to as high as ~486 (Kawada and Kitamura 1983). Nielsen et al. (2008) determined that development from egg to adult required 538 DD, with an additional 148 DD for a preovipostional period.

Fig. 4. BMSB egg mass. Photo courtesy of Wilbur Hershberger.

BMSB is univoltine in central NJ and PA (Nielsen et al. 2008), but the number of generations likely will be greater in southern areas. Indeed, bivoltine populations were documented in Kearneysville, WV, ~180 miles southwest of Allentown, PA (Leskey et al., unpubl data). Hoffmann (1931) reported that in parts of China, up to six generations occurred in the southern part of the range. BMSB could have several generations per year in more southerly locations within the U.S. Multivoltinism in southern locations will decrease the length of time needed for BMSB establishment, increase the number of specialty crops threatened by BMSB (e.g., citrus has been reported as a host in the Asian literature), and increase the duration of the risk period for damage. Furthermore, Kiritania (2006, 2007) pointed to the potential impact of climate change on BMSB populations, with winter mortality predicted to decrease by 15% with a rise in temperature of 1°C, and potential for increased numbers of generations per year for BMSB and other rice- and fruit- attacking bug species. The biology of BMSB suggests the potential for greater levels of damage than currently observed.

Fig. 5. First instar BMSB nymphs.

BMSB has unusual movement and dispersal behaviors to and from overwintering sites (e.g., natural areas such as woodlots and rocky outcroppings, human built structures) and within and between crop resources throughout the growing season. Elucidating movement patterns and the factors that initiate movement (likely environmental or host plant cues) is critical to the detection and management of BMSB.

In addition to the agricultural threat posed by BMSB, this invasive species also is a serious nuisance pest for homeowners and business. In the fall, BMSB adults move from host plants and seek overwintering sites, including homes and other buildings. During this behavioral shift, profound numbers of adults will move toward and aggregate on the outside of structures and eventually seek entry within. After entry into overwintering sites, BMSB will often be found aggregating in tremendous numbers in small confined spaces such as behind bookshelves, beneath mattresses, inside filters of window-mounted AC units within homes or between layers of stacked building materials in garages. Businesses such as hotels, restaurants, and wineries have been forced to display signs explaining the presence of BMSB within their facilities during the fall. Furthermore, during warm days in the winter months and in the spring, BMSBs will become active and move from overwintering sites in structures and subsequently invade living spaces leading to perpetual problems with this pest. These observations highlight the societal impact imposed by the presence of BMSB and the need to address homeowner and business owner concerns as well.

Fig. 6. BMSB nuisance problems in Burkittsville, MD. Photo by Steve Ruark, and accompanying story entitled "Move over, bedbugs: Stink bugs have landed" by Ken Maguire, New York Times, September 26, 2010.

Monitoring. Monitoring tools are typically used by growers to assess the presence, abundance, and seasonal activity of a pest to determine the need for and timing of insecticide applications. Typically, stink bug species are monitored in cropping systems using sweep nets, beating samples, pheromone-baited traps, and/or black light traps. Among native stink bugs in tree fruit, yellow ground- and tree-deployed pyramid traps baited with methyl (2*E*,4*Z*)-decadienoate were effective at monitoring native *Euschistus* spp. (Leskey and Hogmire 2005, Hogmire and Leskey 2006), while *Acrosternum hilare* has been successfully monitored in vegetable and row crops using black light traps (Kamminga et al. 2009).

Unfortunately, reliable monitoring tools for BMSB are lacking. Black light traps have been evaluated in Japan (Moriya et al., 1987) and New Jersey (Nielsen and Hamilton 2009a), and in 2010 ground-deployed black pyramid traps baited with a known attractant, methyl (2*E*,4*E*,6*Z*)-decatrienoate, were tested in commercial orchards in WV, MD, VA, NJ, and PA (Leskey et al. unpubl. data). However, these studies are very preliminary, and none have attempted to relate trap captures to crop injury. Consequently, there is currently no system to effectively and reliably monitor BMSB in any cropping system.

Fig. 7. USDA-ARS-AFRS prototype BMSB monitoring trap

Chemical Ecology. Aldrich et al. (2007) and Khrimian et al. (2008) confirmed that the aggregation pheromone of the Asian brown-winged green bug, *Plautia stali* Scott, methyl (2*E*,4*E*,6*Z*)-decatrienoate (Sugie et al. 1996), is cross-attractive to BMSB, as was previously reported in Asia (Lee et al. 2002, Tada et al. 2002 a,b). This compound reliably attracted nymphs to ground-deployed pyramid traps in the mid-Atlantic in 2010 (Leskey et al. unpubl). However, adults were reliably attracted only very early (Tada et al. 2002a) and late in the season (Leskey et al. unpubl. data, Khrimian et al. 2008, Tada et al. 2002a). Thus, the need for a reliable, season-long attractant for BMSB is crucial. Recently, a tentative identification of the male-produced BMSB aggregation pheromone was made (Zhang, unpubl data). It is hoped that this identification will lead to a reliable bait for use in monitoring traps, and also provide the foundation for behaviorally based, spatially precise attract-and-kill approaches for managing adult BMSB populations.

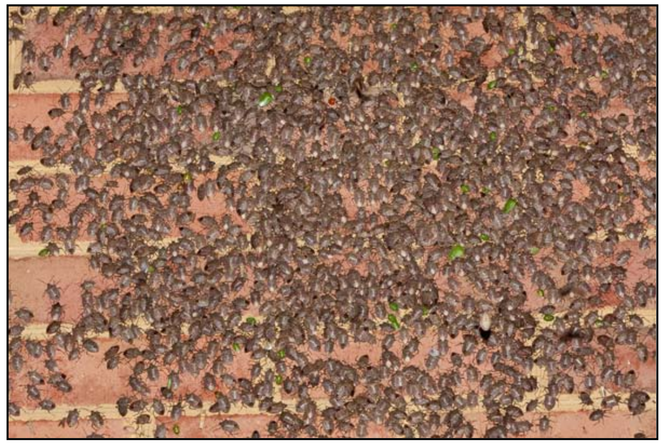


Fig. 8. Nighttime aggregation of BMSB adults in mid-July, 2010.

Biological Control. Surveys of native natural enemies were initiated by Dr. Kim Hoelmer ~5 years ago, but have been limited to ornamental garden environments in just a handful of mid-Atlantic locations. Under these circumstances, egg and adult parasitoids have been documented attacking BMSB, but at very low levels (typically less than 5%). Native natural enemies include specialist egg parasitoids of Pentatomidae, *Trissolcus* species (Hymenoptera: Scelionidae), and *Trichopoda* spp.—tachinid flies that lay eggs on adults—to date, none have been reared successfully from BMSB adults (Hoelmer, unpubl. data). A limited survey of adult BMSB aggregating on houses near orchards in Pennsylvania in 2010 found approximately 10% parasitism by tachinid flies (Biddinger, unpubl. data). Only limited information exists for natural enemies attacking BMSB in nature or in agroecosystems, although some tachinids are attracted to chemicals used to monitor BMSB (Aldrich et al. 2006). Similar to many native stink bugs attacking specialty crops (Krupke and Brunner 2002, McGhee 1997, Schoene and Underhill 1933), and based on injury patterns recorded in specialty crops such as tree fruit (Leskey et al. unpubl), BMSB source populations responsible for most damage originate from wild hosts or overwintering sites surrounding cropping systems or from nearby field crops such as soybean and corn. Further studies on the impact of native parasitoids and predators in a diversity of managed and natural habitats are needed to fully understand the role of natural enemies in regulating BMSB populations, and how to devise strategies to conserve or enhance biological control.

Foreign exploration has been conducted in China, Japan, and South Korea to identify natural enemies adapted to BMSB in its native range. Egg parasitoids appear to be the most promising agents, and there are currently at least four *Trissolcus* species obtained from BMSB in Asia in culture at the USDA-ARS quarantine facility in Newark, DE. The *Trissolcus* species attacking BMSB in Asia typically cause very high rates of parasitism (50-80%) and are clearly adapted to BMSB. Currently, at Newark, DE, host range experiments have been initiated against

North American pentatomids. Results are still preliminary, and more extensive evaluations that include a broader range of species will be required before any agents can be identified as suitable for field release (Hoelmer, unpubl. data). However, classical biological control may provide one of the most promising long-term solutions, though still years away from potentially being implemented.

Chemical Management. As BMSB is a newly established invasive pest, there is a lack of background knowledge from which to devise sustainable pest management programs, and insecticides will play a key role in managing this pest on specialty crops in the short term. Stink bugs are generally highly mobile, polyphagous pests that are difficult to manage (McPherson and McPherson 2000). Native stink bugs were long managed with broad-spectrum chemistries such as organophosphates, but since the passage of FQPA in 1996, many broad-spectrum materials have been, or will soon be lost through regulatory measures. Unfortunately, newer reduced-risk and OP-replacement insecticides are generally not effective against stink bugs. Management is further complicated by the tremendous season-long pressure exerted by BMSB.

Fig. 9. BMSB damage to immature Pink Lady apple.

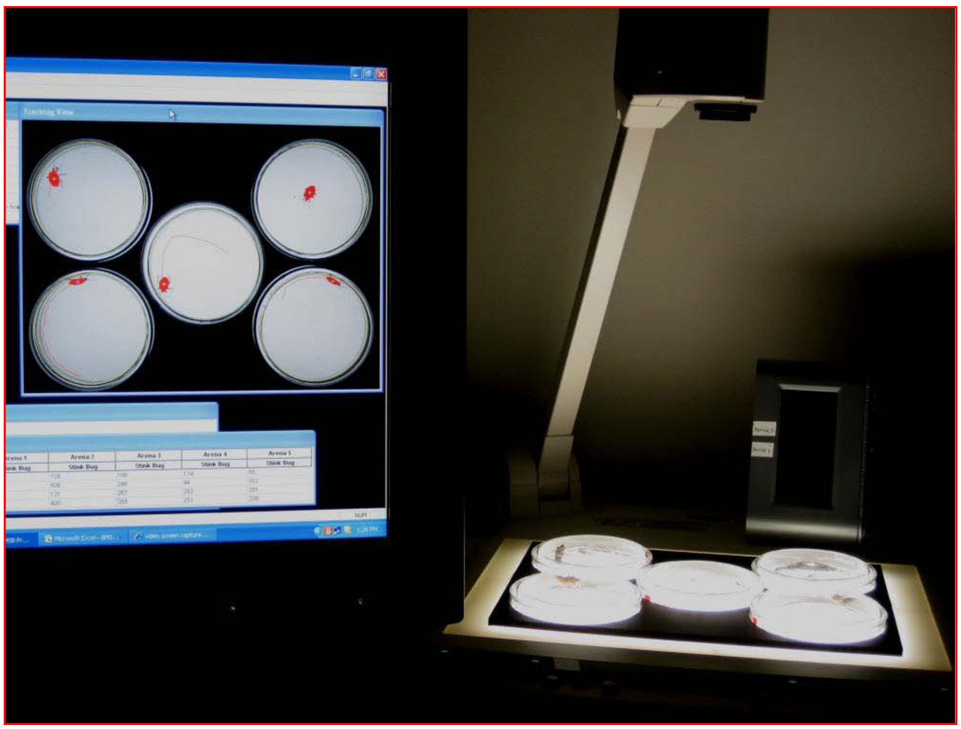
Although a number of compounds have been evaluated against BMSB in the laboratory (Nielsen et al. 2008b, Leskey et al., unpubl. data), no field-based management recommendations for any specialty crop specific to BMSB were available during the 2010 season. Thus, growers relied on recommendations made for native stink bugs, which unfortunately resulted in very poor control of BMSB. Pyrethroid insecticides, generally considered to provide good control of native stink bugs while having a poor fit for IPM programs because of their negative impact on beneficial arthropods, proved problematic for BMSB control because many stink bugs recovered after initial knock-down. This knock-down/recovery phenomenon has been observed in the laboratory (Nielsen et al. 2008b, Leskey et al., unpubl. data) and field (Leskey et al., unpubl data), and in the latter case, >33% of moribund adult BMSB recovered after direct exposure to cyfluthrin. In commercial orchards, BMSB recovery rates of up to 80% from insecticide exposure were reported.

Fig. 10. BMSB adults feeding on heirloom tomatoes.

Fig. 11. BMSB damage to bell pepper.

Several compounds including the pyrethroid bifenthrin (Nielsen et al. 2008b, Leskey et al., unpubl. data), the carbamate methomyl, the chlorinated hydrocarbon endosulfan, and the organophosphate chlorpyrifos (Leskey et al, unpubl. data) have shown good efficacy based on direct contact with dried insecticide residues under laboratory conditions. Unfortunately, many of the newer, "reduced-risk" insecticides have proven far less efficacious. It is imperative that across crops, we are able to identify effective insecticides that can be incorporated into sustainable management strategies for BMSB, enabling growers to remain both productive and profitable.

Impact of Incidental Contact with 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 27 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 insecticides is not known for control of BMSB. In order to provide the foundation for determination of potential field effectiveness of insecticides 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.

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. Insecticide classes evaluated to date include: carbamate, organophosphate, pyrethroid, neonicotinoid, organochlorine, pyridinecarboxamide, pyridazinone, oxadiazine, tetramic acid, a ranodine receptor activator, and particle film. Water alone was used as a control.

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

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, moribund, dead) was assessed immediately following the insecticide exposure period, then daily for seven days.

Fig. 5. Adult BMSBs following mobility trials.

USDA-ARS-Appalachian Fruit Research Station BMSB Lethality (Dry Residue, Glass) <u>Carbamates</u>

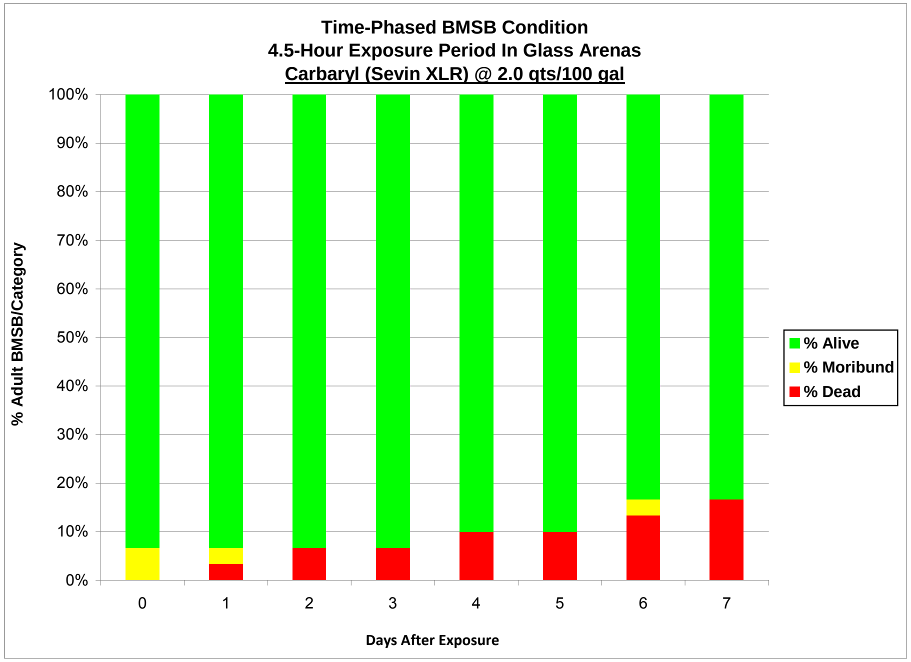
Trade Name	Formulation	A.I.	Class	Crops	Field Rates	Tested Rate	Label Restrictions	Label Notes	Stink Bug on Label
Sevin	XLR Plus	Carbaryl (44.1%)	1a/Carbamate	Pome Fruit	0.5-3 qts/A	2 qts/100 gal	Max: 15 qts/A/yr on pome fruit and 8 applications/crop/yr.	Use from bloom through 30d after full bloom may result in apple fruit thinning.	No
				Stone Fruit	2-3 qts/A		Max: 9 qts/A/yr on stone fruit during growing season and 3 applications/crop/yr.		No
Lannate	SP	Methomyl (90%)	1a/Carbamate	Apple	0.5–1 lb/A	1 lb/100 gal	Max: 5 lbs/A/yr and 5 applications/crop/yr. Min: 50 gal water/A.		No
				Peach	1 lb/A or ¼ lb/100-400 gal		Max: 6 lbs/A/yr and 6 applications/crop/yr.		Yes
				Pear	0.5-1 lb/A		Max: 2 lbs/A/yr and 2 applications/crop/yr		No
Vydate	L	Oxamyl (24%)	1a/Carbamate	Apple	2-8 pts/A	4 pts/100 gal	Max: 8 pts/A/yr and 4 applications/crop/yr. Use in 50-400 gal water.	Use from bloom through 30d after full bloom may result in apple fruit thinning.	No
				Pear	6-8 pts/A		Max: 8 pts/A/yr and 1 application/crop/yr. Use in 100-600 gal water.		No
				Peach	**No label**				
Carzol	SP	Formetanate Hydrochloride (92%)	1a/Carbamate	Apple	2-5 oz/100 gal or 0.5-1.25 lb/A	1.25 lbs/100 gal	Max: 1.25 lbs/A/yr. Use in 100-400 gal water dilute. Min. 50 gal water concentrate. Apply only at petal fall.		No
				Pear	4-5 oz/100 gal or 1-1.25 lbs/A		Max: 1.25 lbs/A/yr. Use in 100-400 gal water dilute. Min. 50 gal water concentrate. Do not apply after petal fall, unless written approval obtained by State agency responsible for FIFRA enforcement in CA, OR, WA and ID.*		No/Conditional listing in label for late season application*
				Peach/Nectarine	4 oz/ 100 gal or 1-1.25 lbs/A		Max: 1.25lbs/A/yr. Use in 100-500 gal water dilute. Min. 50 gal water concentrate. Do not apply after petal fall.		Yes

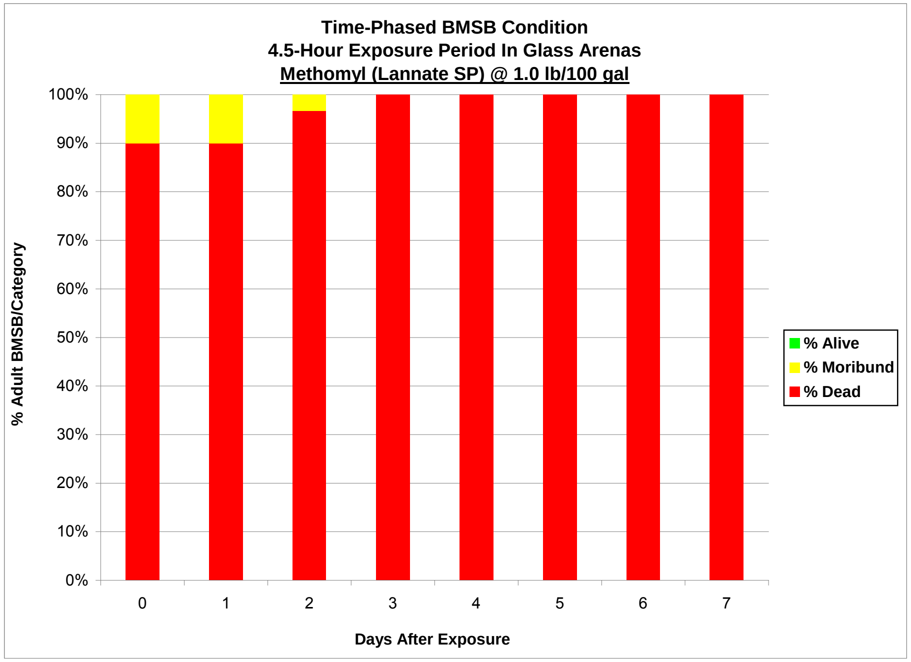
USDA-ARS-Appalachian Fruit Research Station BMSB Lethality (Dry Residue, Glass) <u>Carbamates</u>

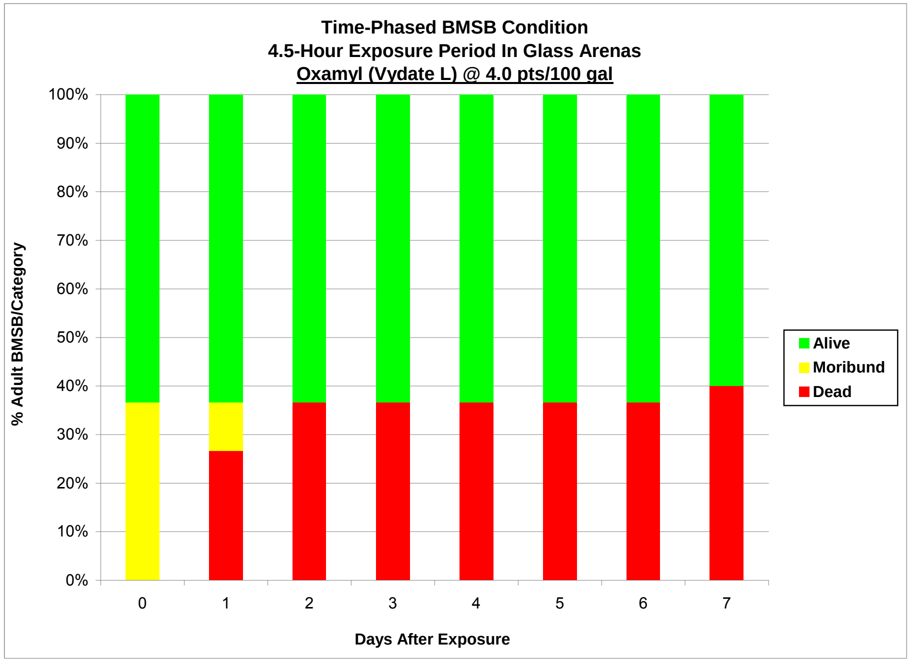
Chemical Name	Horizontal Mobility Distance (cm ± SE)				Horizontal Mobility Duration (s ± SE)			
	0.0h	1.5h	3.0h	4.5h	0.0h	1.5h	3.0h	4.5h
Methomyl	34.5 ± 18.7	0.5 ± 0.4	0.0 ± 0.0	0.0 ± 0.0	33.6 ± 18.8	1.7 ± 1.1	0.0 ± 0.0	0.0 ± 0.0
Oxamyl	7.2 ± 3.4	1.1 ± 0.6	5.2 ± 3.3	14.0 ± 4.4	9.1 ± 4.6	1.2 ± 1.1	5.7 ± 4.5	19.1 ± 7.0
Carbaryl	24.2 ± 7.9	16.1 ± 4.6	36.2 ± 7.8	57.2 ± 20.5	31.5 ± 12.0	16.9 ± 6.5	45.4 ± 12.4	60.0 ± 20.2
Formetanate Hydrochloride	43.5 ± 9.7	28.4 ± 9.5	27.6 ± 19.8	5.4 ± 4.4	63.2 ± 14.9	35.7 ± 10.4	25.2 ± 13.0	10.3 ± 9.6
Water	***21.7 ± 6.3***	***9.6 ± 3.4***	***26.9 ± 10.6***	***36.0 ± 13.3***	***24.3 ± 9.9***	***8.2 ± 4.7***	***33.3 ± 17.4***	***44.0 ± 17.8***

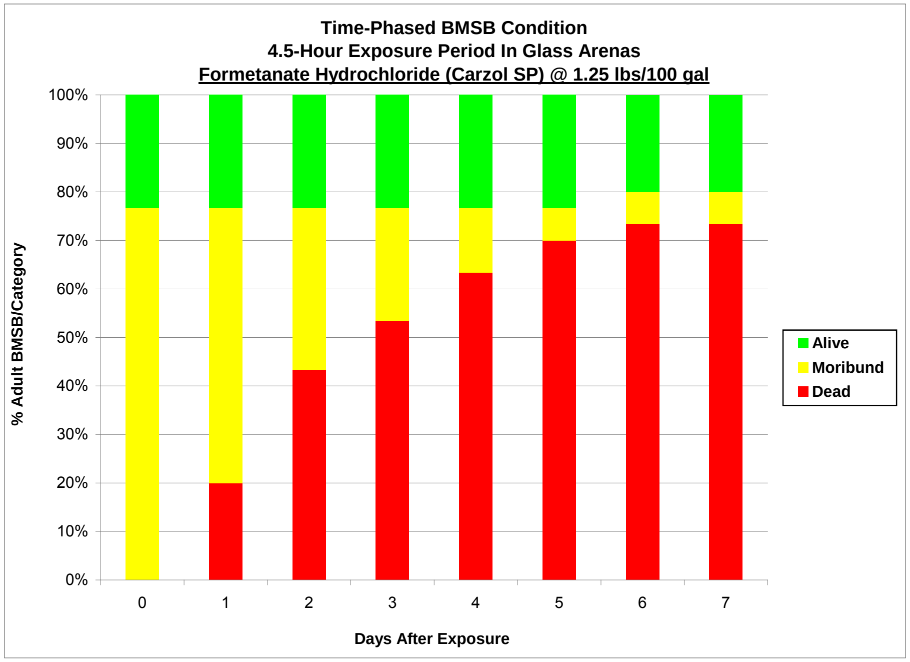
Chemical Name	Vertical Mobility (cm ± SE)	
	4.5h	7d
Methomyl	0.0 ± 0.0	0.0 ± 0.0
Oxamyl	146.3 ± 37.7	72.3 ± 18.6
Carbaryl	117.9 ± 28.4	264.3 ± 47.9
Formetanate Hydrochloride	9.6 ± 8.2	36.7 ± 20.3
Water	***193.3 ± 21.9***	***102.5 ± 14.5***

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









USDA-ARS-Appalachian Fruit Research Station   BMSB Lethality (Dry Residue, Glass)   <u>Organophosphates</u>

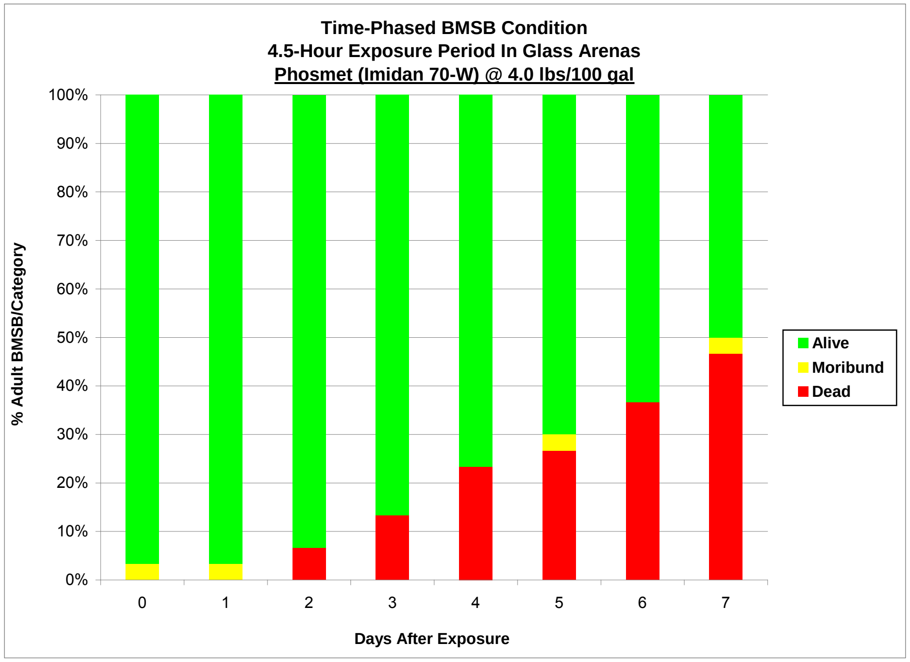
Trade Name	Formulation	A.I.	Class	Crops	Field Rates	Tested Rate	Label Restrictions	Label Notes	Stink Bug on Label
Imidan	70-W	Phosmet (70%)	1b/Organophosphate	Apple	¾ - 1 lb/100 gal or 2 $^{1}/_{8}$-5 $^{1}/_{3}$ lbs/A	4 lbs/100 gal	Max: 30 lbs/A/yr		No
				Apricot	¾ - 1 lb/100 gal or 2 $^{1}/_{8}$- 4 ¼ lbs/A		Max: 13 lbs/A/yr		No
				Cherry (Sour)	¾ - 1 lb/100 gal or 1 $^{1}/_{3}$ – 2 ½ lbs/A		Max: 7.5 lbs/A/yr		No
				Nectarine	¾ - 1 lb/100 gal or 2 $^{1}/_{8}$- 4 ¼ lbs/A		Max: 13 lbs/A/yr		No
				Peach	¾ - 1 lb/100 gal or 2 $^{1}/_{8}$- 4 ¼ lbs/A		Max: 17 lbs/A/yr		No
				Pear	¾ - 1 lb/100 gal or 2 $^{1}/_{8}$-5 $^{1}/_{2}$ lbs/A		Max: 16 lbs/A/yr		No
				Plum	¾ - 1 lb/100 gal or 2 $^{1}/_{8}$- 4 ¼ lbs/A		Max: 13 lbs/A/yr		No
Orthene	SP	Acephate (75%)	1b/Organophosphate	Pome Fruit	**No label**	445.34 g/100 gal	Selected 825g/ha (a.i.) based on high rate label for food crops.		
				Stone Fruit	**No label**				
Lorsban	4E	Chlorpyrifos (44.9%)	1b/Organophosphate	Apple, Cherry, Nectarine, Peach, Pear, Plum	1.5-4 pts/A	4 pts/100 gal	Max: 1 application/crop/yr as pre-bloom dormant/delayed dormant foliar/trunk spray or post-bloom spray to lower 4 ft of trunk. Avoid foliar contact in sweet cherry due to premature leaf drop.		No
Supracide	2-E	Methidathion (24.4%)	1b/Organophosphate	Pome and Stone Fruit (Apple, Pear, Apricot, Cherry, Nectarine, Peach, Plum)	1-2 pts/100 gals dilute (300-600 gal/A) or 3-12 pts/A concentrate		Min: 50 gal water concentrate. For rates < 2 pts/100 gal mix with oil.	Apply during dormant-dormant delayed period.	No

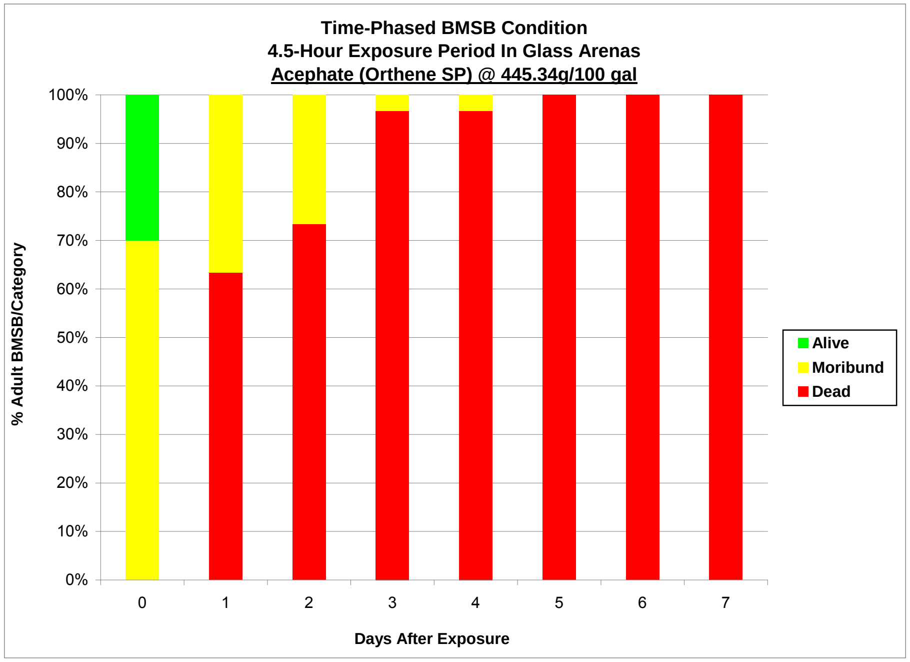
USDA-ARS-Appalachian Fruit Research Station **BMSB Lethality (Dry Residue, Glass)** **<u>Organophosphates</u>**

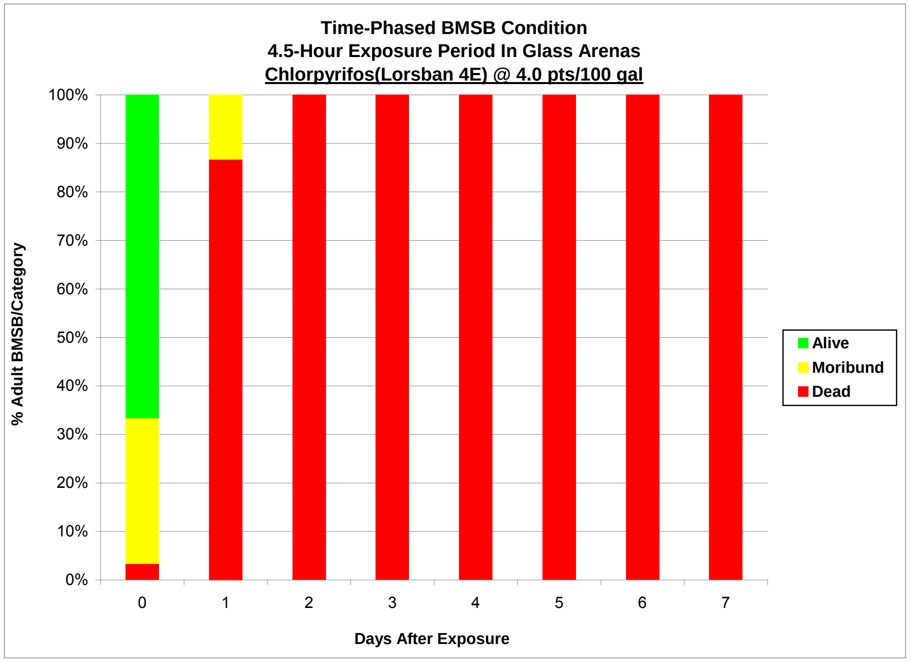
Chemical Name	Horizontal Mobility Distance (cm ± SE) 0.0h	1.5h	3.0h	4.5h	Horizontal Mobility Duration (s ± SE) 0.0h	1.5h	3.0h	4.5h
Chlorpyrifos	88.9 ± 24.9	182.6 ± 31.4	191.4 ± 33.3	137.6 ± 32.6	99.6 ± 25.3	193.6 ± 31.8	204.6 ± 31.2	171.9 ± 35.5
Acephate	40.5 ± 21.6	33.9 ± 14.4	23.2 ± 5.5	23.4 ± 5.8	43.4 ± 18.3	41.8 ± 14.8	31.8 ± 9.1	35.2 ± 8.8
Phosmet	26.7 ± 9.9	19.9 ± 7.1	24.8 ± 6.7	33.3 ± 6.4	32.7 ± 13.4	23.1 ± 8.8	30.1 ± 9.8	47.1 ± 11.4
Water	***21.7 ± 6.3***	***9.6 ± 3.4***	***26.9 ± 10.6***	***36.0 ± 13.3***	***24.3 ± 9.9***	***8.2 ± 4.7***	***33.3 ± 17.4***	***44.0 ± 17.8***

Chemical Name	Vertical Mobility (cm ± SE) 4.5h	7d
Chlorpyrifos	48.6 ± 23.5	0.0 ± 0.0
Acephate	0.8 ± 0.6	0.0 ± 0.0
Phosmet	375.8 ± 48.7	73.7 ± 28.0
Water	***193.3 ± 21.9***	***102.5 ± 14.5***

USDA-ARS-Appalachian Fruit Research Station BMSB Lethality (Dry Residue, Glass) <u>Organophosphates</u>







USDA-ARS-Appalachian Fruit Research Station BMSB Lethality (Dry Residue, Glass) <u>Pyrethroids</u>

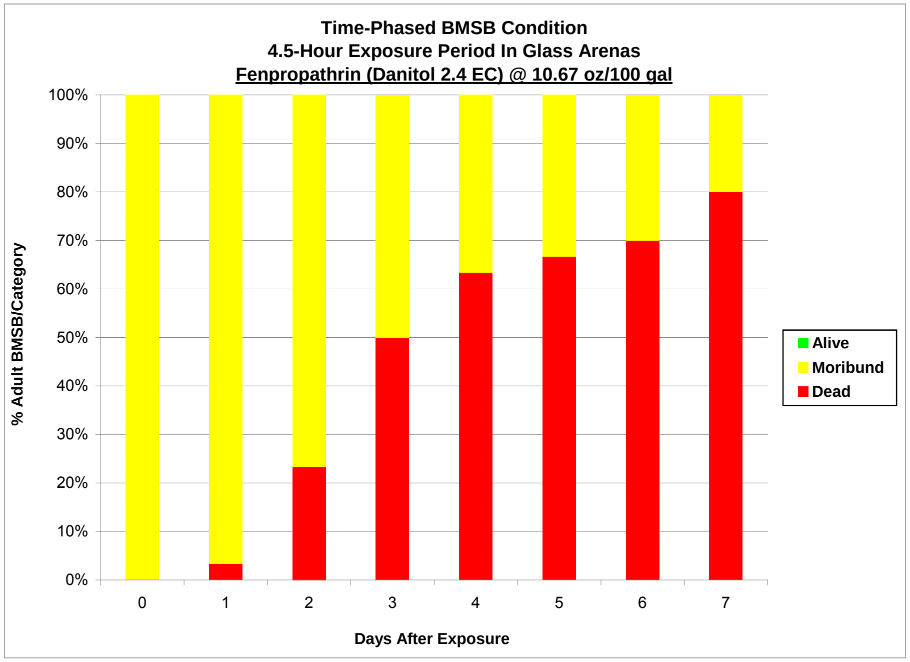
Trade Name	Formulation	A.I.	Class	Crops	Field Rates	Tested Rate	Label Restrictions	Label Notes	Stink Bug on Label
Danitol	2.4 EC	Fenpropathrin (30.9%)	3a/Pyrethroid	Pome Fruit (Apple)	$10^{2}/_{3}$-$21^{1}/_{3}$ oz/A	10.67 and 18.0 oz/100 gal	Max: $42^{2}/_{3}$ oz/A/yr	Recommends no more than 2 applications per year for resistance management.	Yes
				Pome Fruit (Pear, Oriental Pear)	16-$21^{1}/_{3}$ oz/A				Yes
				Stone Fruit (Apricot, Cherry, Nectarine, Peach, Plum)	$10^{2}/_{3}$-$21^{1}/_{3}$ oz/A				Yes
Tombstone	2.0 EC	Cyfluthrin (25%)	3a/Pyrethroid	Pome Fruit	1.4-2.8 oz/A	2.6 oz/100 gal	Max: 2.8 oz/A/yr and 2 applications at low rate. Use 100-400 gal water.		Yes
				Stone Fruit			Max: 5.6 oz/A/yr and 4 applications at low rate. Use 50-250 gal water.		Yes
Brigade	WSB	Bifenthrin (10%)	3a/Pyrethroid	Pear	6.4-32.0 oz/A	32 oz/100 gal	Max: 80 oz/A/yr. Min. 200 gal water for dilute spray and 50 gal concentrate. Min: 30-d spray interval.		Yes
				Apple, Stone Fruit	**No label**				
Proaxis		Gamma-Cyhalothrin	3a/Pyrethroid						
Mustang Max	EC	Zeta-Cypermethrin (9.6%)	3a/Pyrethroid	Pome Fruit	1.28-4.0 oz/A	4.0 oz/100 gal	Min: 100 gal water for dilute spray and 20 gal concentrate. Max: 24 oz/A/yr.		Yes
				Stone Fruit					Yes
Baythroid XL	EC	Beta-Cyfluthrin (12.7%)	3a/Pyrethroid	Pome Fruit	1.4-2.8 oz/A	2.6 oz/100 gal	Max: 2.8 oz/A/yr.		Yes
				Stone Fruit			Max: 5.6 oz/A/yr. Min: 50 gal water.		Yes
Permethrin	3.2 EC	Permethrin (38.4 %)	3a/Pyrethroid	Apple	4-16 oz/A	16 oz/100 gal	Max: 24 oz/A/yr. Do not apply after petal fall.		No
				Cherry	4-8 oz/A		Max: 6 applications/crop/yr and no more than 4 after petal fall.		No
				Nectarine, Peach	4-12 oz/A		Max: 60 oz/A/yr.		No
				Pear	8-16 oz/A		Max: 32 oz/A/yr. Dormant through Pre-bloom sprays only.		No

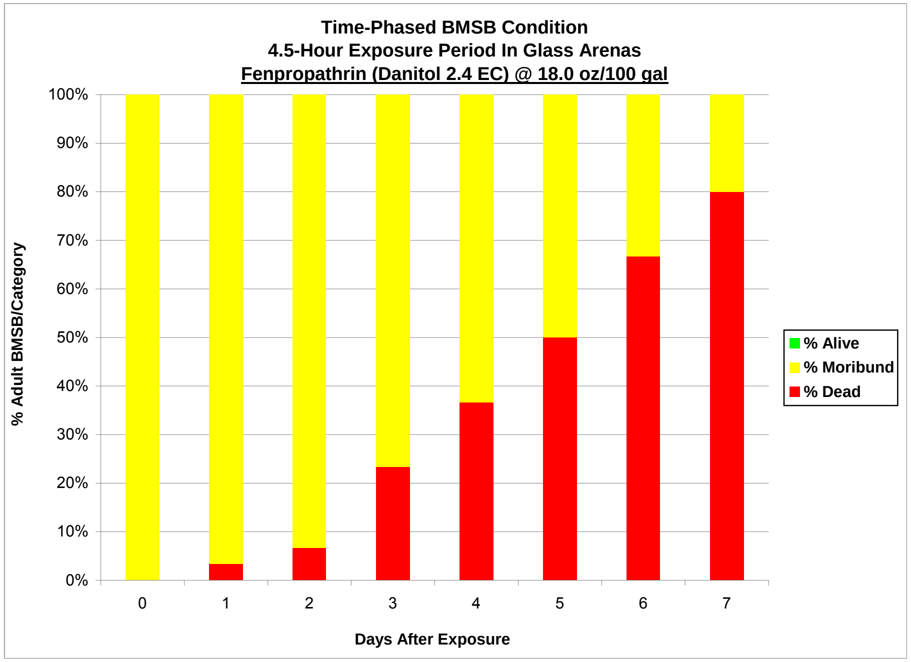
USDA-ARS-Appalachian Fruit Research Station BMSB Lethality (Dry Residue, Glass) <u>Pyrethroids</u>

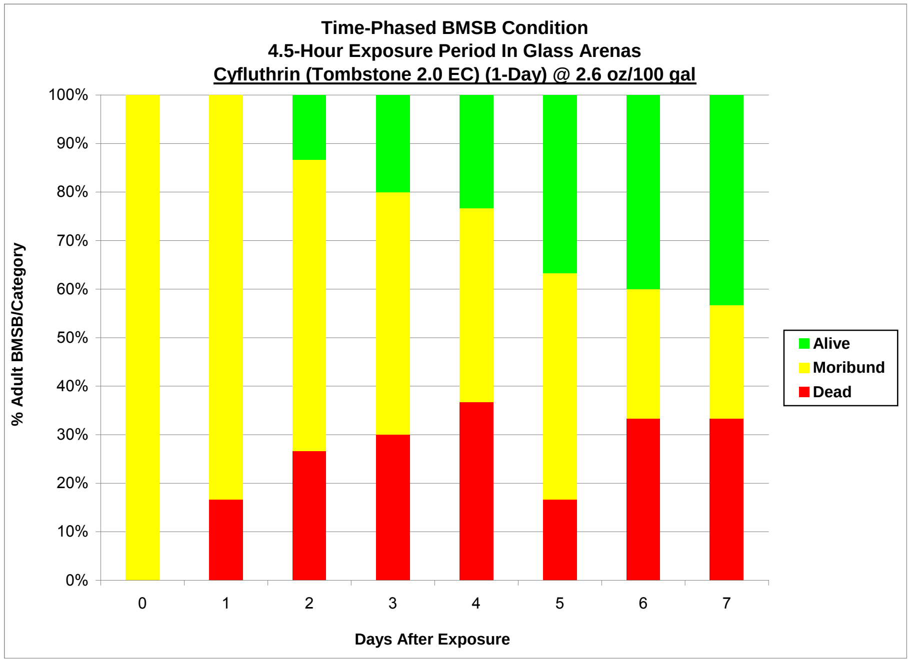
Chemical Name	Horizontal Mobility Distance (cm ± SE) 0.0h	1.5h	3.0h	4.5h	Horizontal Mobility Duration (s ± SE) 0.0h	1.5h	3.0h	4.5h
Bifenthrin	60.7 ± 12.2	18.1 ± 11.9	0.0 ± 0.0	0.0 ± 0.0	73.8 ± 15.7	23.8 ± 14.0	0.0 ± 0.0	0.0 ± 0.0
Fenpropathrin (18 oz/A)	344.6 ± 27.3	0.1 ± 0.0	0.1 ± 0.0	0.2 ± 0.1	315.6 ± 16.5	0.1 ± 0.0	0.0 ± 0.0	0.2 ± 0.1
Fenpropathrin (10.67 oz/A)	180.2 ± 21.7	0.3 ± 0.1	0.1 ± 0.0	0.1 ± 0.1	253.5 ± 23.3	0.3 ± 0.2	0.0 ± 0.0	0.1 ± 0.0
Cyfluthrin (1 day)	61.6 ± 10.5	3.8 ± 3.0	0.0 ± 0.0	1.1 ± 1.2	91.9 ± 17.1	8.4 ± 6.6	0.0 ± 0.0	2.6 ± 2.8
Cyfluthrin (6 day)	119.9 ± 23.9	34.3 ± 17.7	0.9 ± 0.8	0.1 ± 0.0	145.2 ± 27.9	34.8 ± 14.9	0.8 ± 0.6	0.2 ± 0.2
Permethrin	390.3 ± 31.0	4.0 ± 3.9	0.6 ± 0.6	0.7 ± 0.6	365.0 ± 14.1	13.0 ± 12.9	0.1 ± 0.1	0.6 ± 0.4
Beta-cyfluthrin	149.6 ± 25.2	0.0 ± 0.0	0.0 ± 0.0	0.2 ± 0.2	172.0 ± 21.4	0.0 ± 0.0	0.0 ± 0.0	0.7 ± 0.5
Zeta-cypermethrin	201.8 ± 26.7	0.1 ± 0.0	1.6 ± 0.3	1.0 ± 0.6	196.1 ± 20.7	0.3 ± 0.2	2.6 ± 0.5	0.3 ± 0.1
Esfenvalerate	Pending	Pending	Pending	Pending	Pending	Pending	Pending	Pending
Water	***21.7 ± 6.3***	***9.6 ± 3.4***	***26.9 ± 10.6***	***36.0 ± 13.3***	***24.3 ± 9.9***	***8.2 ± 4.7***	***33.3 ± 17.4***	***44.0 ± 17.8***

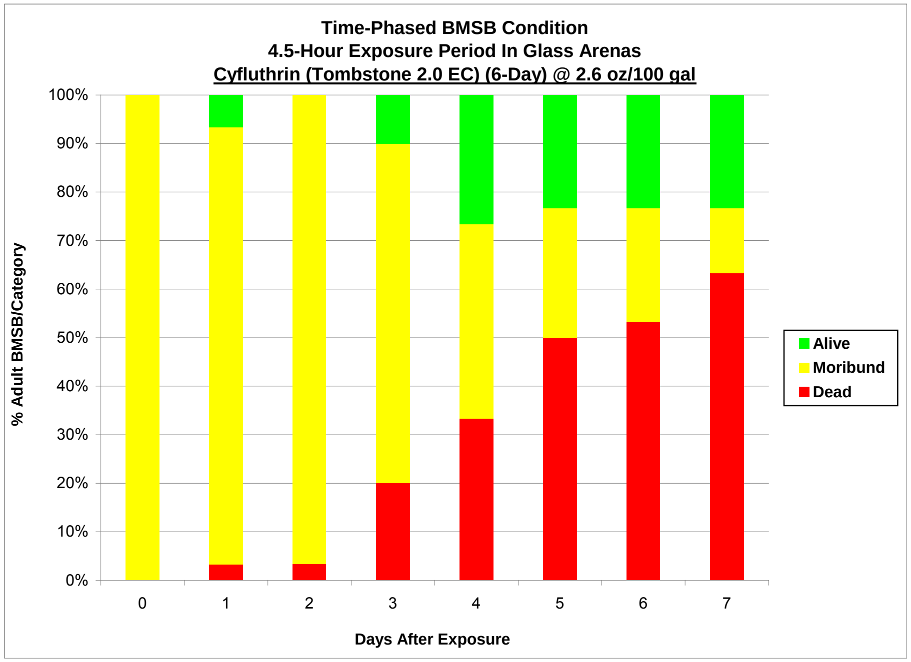
Chemical Name	Vertical Mobility (cm ± SE) 4.5h	7d
Bifenthrin	0.0 ± 0.0	0.0 ± 0.0
Fenpropathrin (18 oz/A)	0.0 ± 0.0	0.0 ± 0.0
Fenpropathrin (10.67 oz/A)	0.0 ± 0.0	0.0 ± 0.0
Cyfluthrin (1 day)	0.0 ± 0.0	15.8 ± 7.6
Cyfluthrin (6 day)	0.0 ± 0.0	0.0 ± 0.0
Permethrin	0.0 ± 0.0	0.0 ± 0.0
Beta-cyfluthrin	0.0 ± 0.0	Pending
Zeta-cypermethrin	0.0 ± 0.0	Pending
Esfenvalerate	10.3 ± 6.8	Pending
Water	***193.3 ± 21.9***	***102.5 ± 14.5***

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

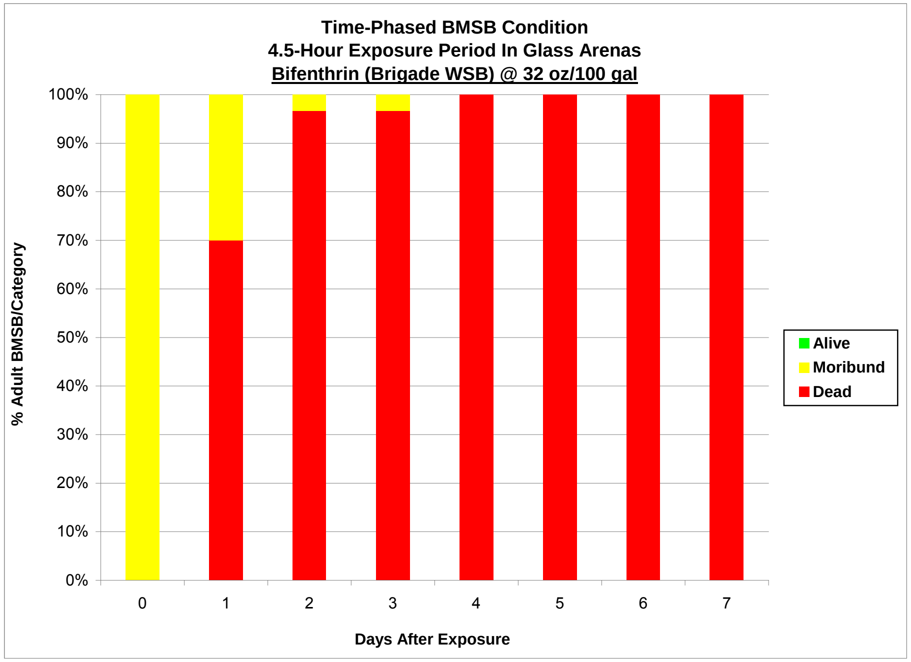


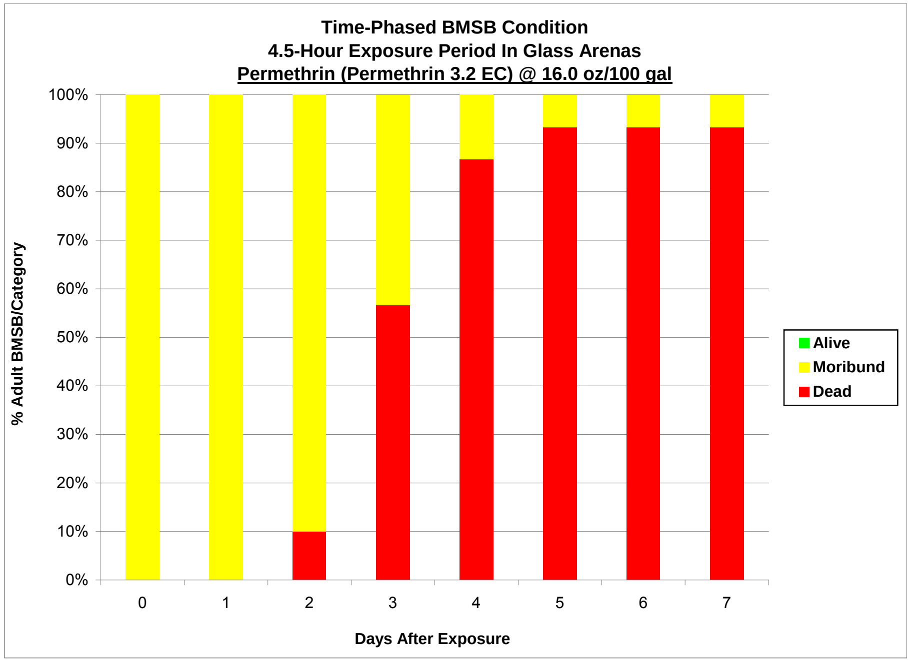


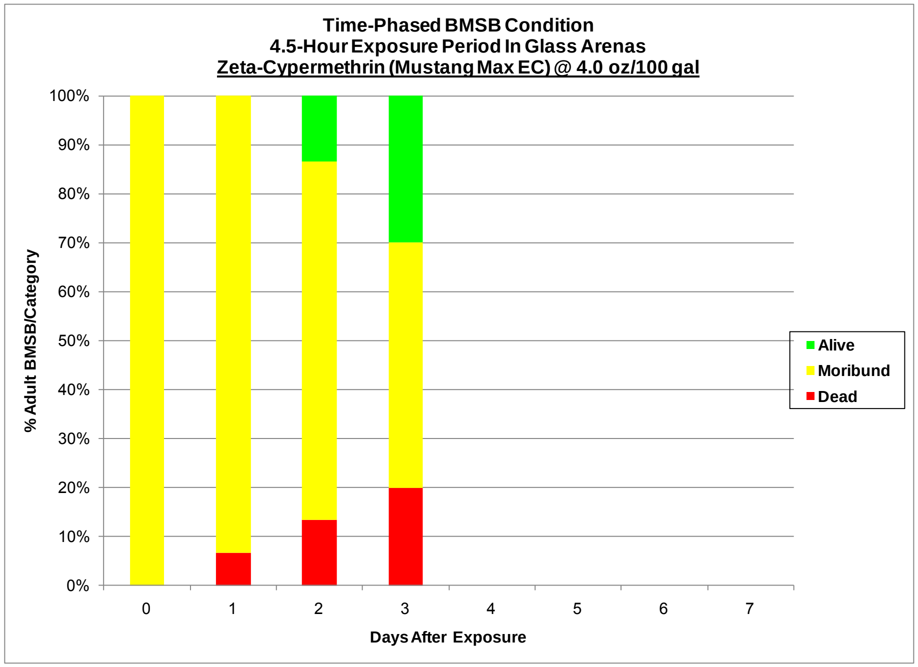


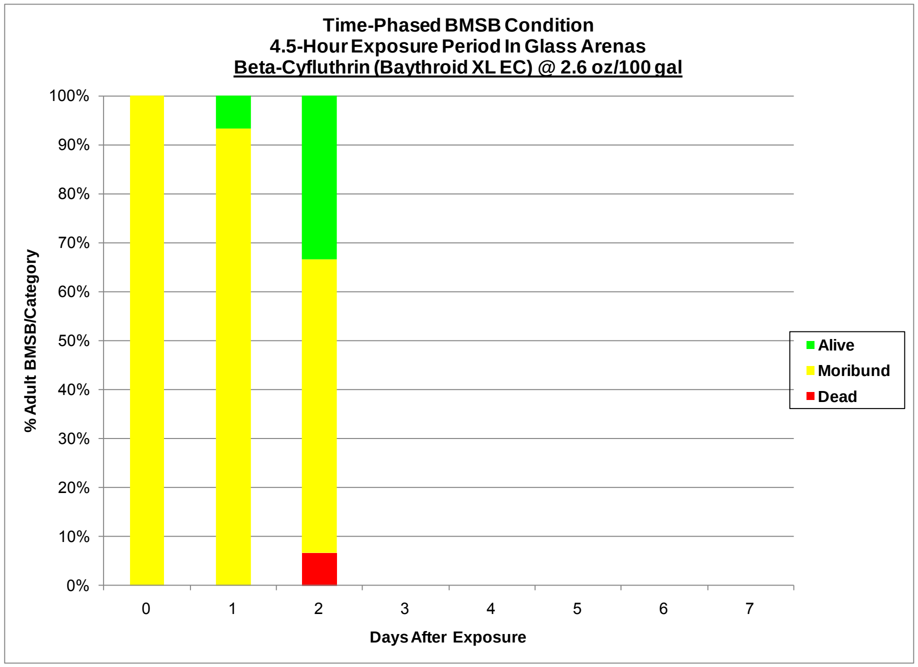


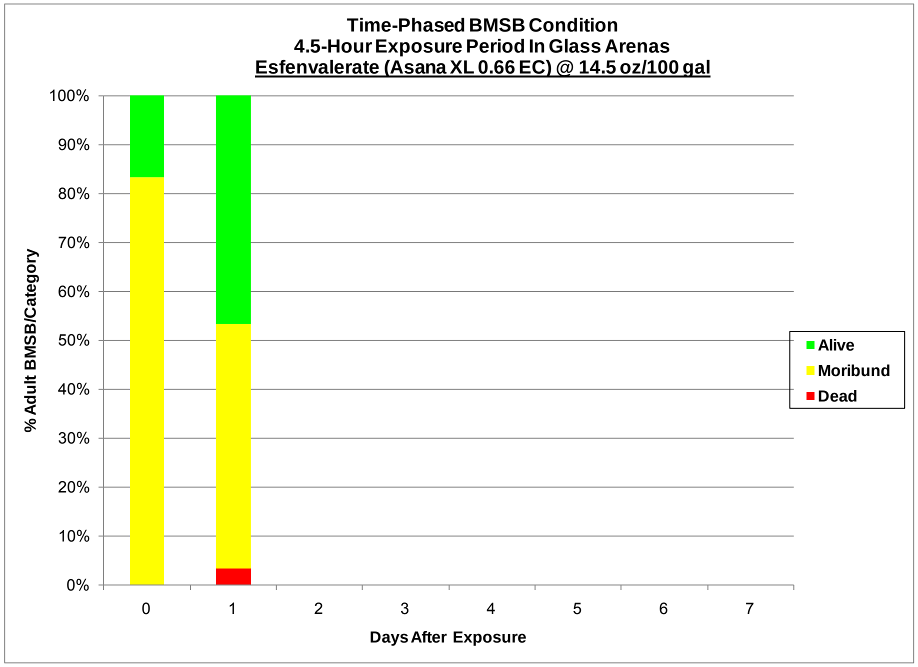
USDA-ARS-Appalachian Fruit Research Station   BMSB Lethality (Dry Residue, Glass)   <u>Pyrethroids (2)</u>










Time-Phased BMSB Condition
4.5-Hour Exposure Period In Glass Arenas
Esfenvalerate (Asana XL 0.66 EC) @ 14.5 oz/100 gal
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
% Adult BMSB/Category
0
1
2
3
4
5
6
7
Days After Exposure
Alive
Moribund
Dead

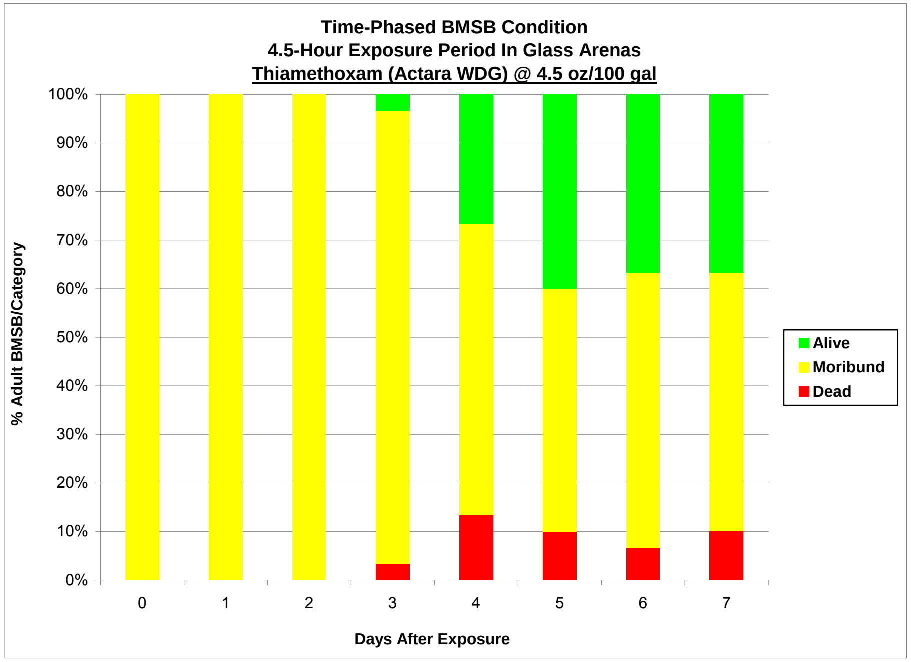
USDA-ARS-Appalachian Fruit Research Station BMSB Lethality (Dry Residue, Glass) <u>Neonicotinoids</u>

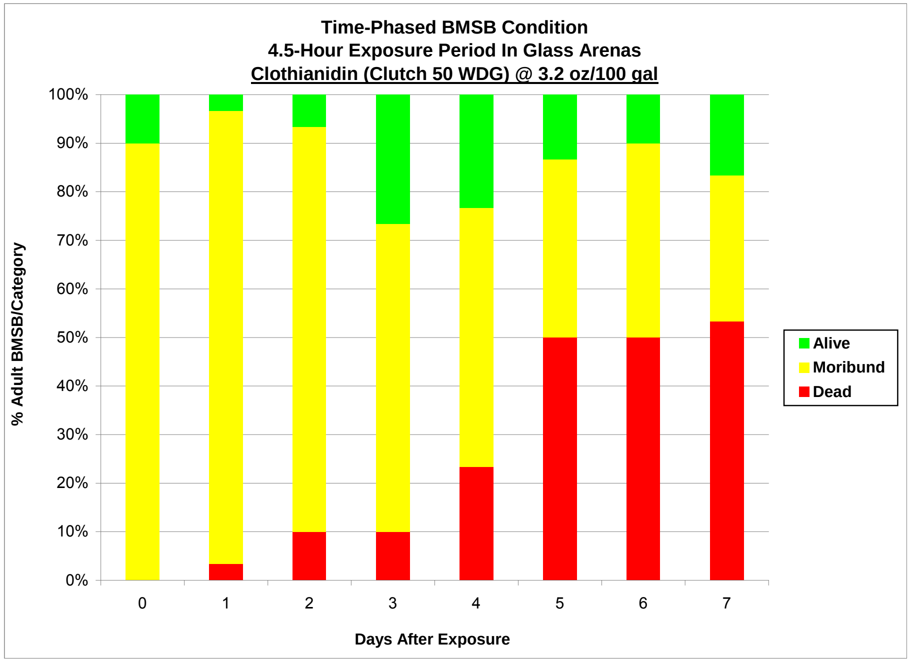
Trade Name	Formulation	A.I.	Class	Crops	Field Rates	Tested Rate	Label Restrictions	Label Notes	Stink Bug on Label
Actara	WDG	Thiamethoxam (25%)	4a/Neonicotinoid	Pome Fruit (Apple)	2.0-5.5 oz/A	4.5 oz/100 gal	Max: 16.5 oz/A/yr. Min: 50 gal water.	PHI = 35d if rate > 2.75 oz/A; otherwise 14d.	No
				Pome Fruit (Pear, Oriental Pear)					No
				Stone Fruit			Max: 11.0 oz/A/yr. Min: 50 gal water.		Yes
Clutch	50 WDG	Clothianidin (50%)	4a/Neonicotinoid	Apple	2-6 oz/A	3.2 oz/100 gal	Max: 6.4 oz/A/yr in 100-400 gal.		No
				Pear					No
				Stone Fruit	**No label**				
Safari	20 SG	Dinotefuran (20%)	4a/Neonicotinoid	Pome Fruit	**No label**	16 oz/100 gal			
				Stone Fruit	**No label**				
Provado	1.6 F	Imidacloprid (17.4%)	4a/Neonicotinoid	Pome Fruit (Apple)	4.0-8.0 oz/A	8.0 oz/100 gal	Max: 40 oz/A/yr. No pre-bloom applications.		No
				Pome Fruit (Pear, Oriental Pear)	4.0-20.0 oz/A				No
				Stone Fruit	4.0-8.0 oz/A		Max: 24 oz/A/yr (Apricot, Nectarine, Peach) and 40 oz/A/yr (Cherry, Plum). No pre-bloom applications. Min: 50 gal water.		Yes (Suppression)
Calypso	4 F	Thiacloprid (40.4%)	4a/Neonicotinoid	Pome Fruit (Apple, Oriental Pear)	2-8 oz/A	8.0 oz/100 gal	Max: 16 oz/A/yr		No
				Pear	4-8 oz/A				No
				Stone Fruit	**No label**				
Assail	30 SG	Acetamiprid (30%)	4a/Neonicotinoid	Pome Fruit (Apple, Pear, Oriental Pear)	2.5 -8.0 oz/A	8.0 oz/100 gal	Max: 32 oz/A/yr and 4 applications/crop/yr		No
				Stone Fruit					Yes

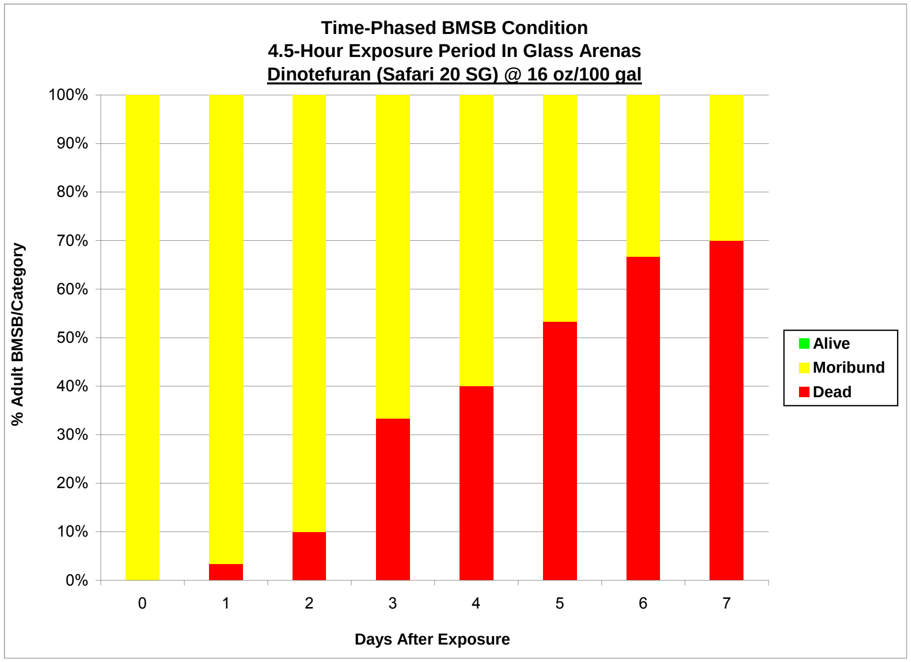
USDA-ARS-Appalachian Fruit Research Station   BMSB Lethality (Dry Residue, Glass)   <u>Neonicotinoids</u>

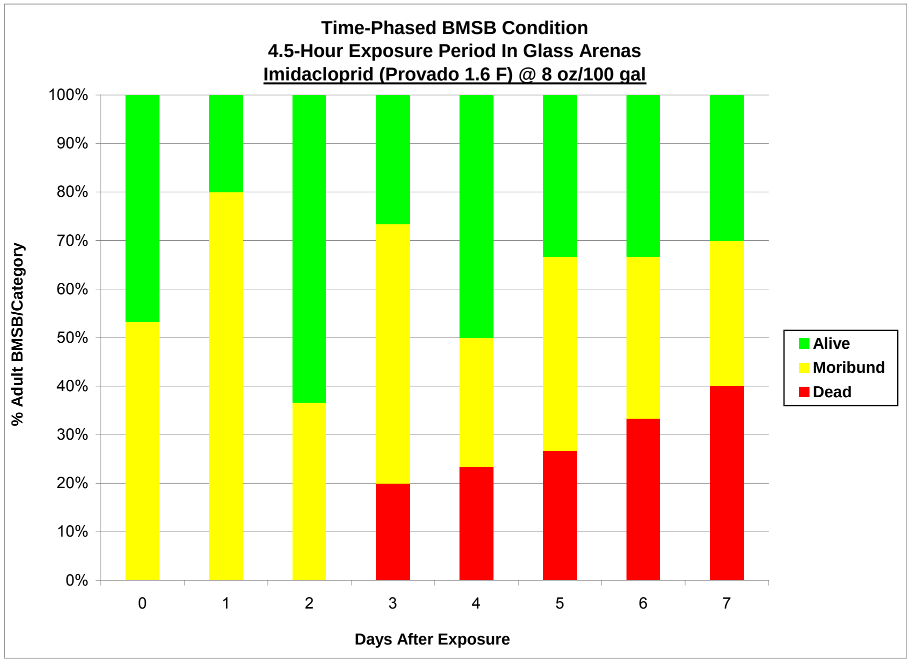
Chemical Name	Horizontal Mobility Distance (cm ± SE) 0.0h	1.5h	3.0h	4.5h	Horizontal Mobility Duration (s ± SE) 0.0h	1.5h	3.0h	4.5h
Dinotefuran	13.0 ± 3.0	10.4 ± 4.7	7.0 ± 5.5	0.3 ± 0.1	14.8 ± 5.1	17.1 ± 8.7	13.2 ± 13.5	0.1 ± 0.1
Thiamethoxam	43.7 ± 11.1	46.2 ± 18.7	28.6 ± 9.3	8.2 ± 6.2	78.6 ± 19.8	47.0 ± 21.2	48.7 ± 18.3	15.2 ± 12.3
Clothianidin	14.2 ± 5.1	14.6 ± 6.1	8.3 ± 4.7	3.6 ± 2.1	17.1 ± 7.4	20.2 ± 10.5	10.5 ± 6.8	7.3 ± 5.2
Imidacloprid	93.3 ± 24.1	98.0 ± 21.3	31.2 ± 9.0	17.0 ± 10.9	122.2 ± 28.2	136.1 ± 32.0	43.0 ± 13.0	22.5 ± 15.3
Thiacloprid	61.1 ± 18.3	81.4 ± 29.5	19.8 ± 8.1	16.0 ± 7.4	86.9 ± 25.3	91.1 ± 31.2	25.2 ± 10.9	22.7 ± 12.3
Acetamiprid	29.4 ± 8.8	2 4.2 ± 14.1	9.5 ± 7.3	3.2 ± 1.8	37.7 ± 12.6	28.3 ± 15.5	11.0 ± 6.9	5.7 ± 4.3
Water	***21.7 ± 6.3***	***9.6 ± 3.4***	***26.9 ± 10.6***	***36.0 ± 13.3***	***24.3 ± 9.9***	***8.2 ± 4.7***	***33.3 ± 17.4***	***44.0 ± 17.8***

Chemical Name	Vertical Mobility (cm ± SE) 4.5h	7d
Dinotefuran	0.0 ± 0.0	0.0 ± 0.0
Thiamethoxam	0.0 ± 0.0	3.3 ± 3.1
Clothianidin	0.3 ± 0.3	13.0 ± 9.8
Imidacloprid	8.4 ± 4.9	45.8 ± 18.1
Thiacloprid	51.9 ± 20.3	93.1 ± 23.4
Acetamiprid	1.8 ± 1.7	Pending
Water	***193.3 ± 21.9***	***102.5 ± 14.5***

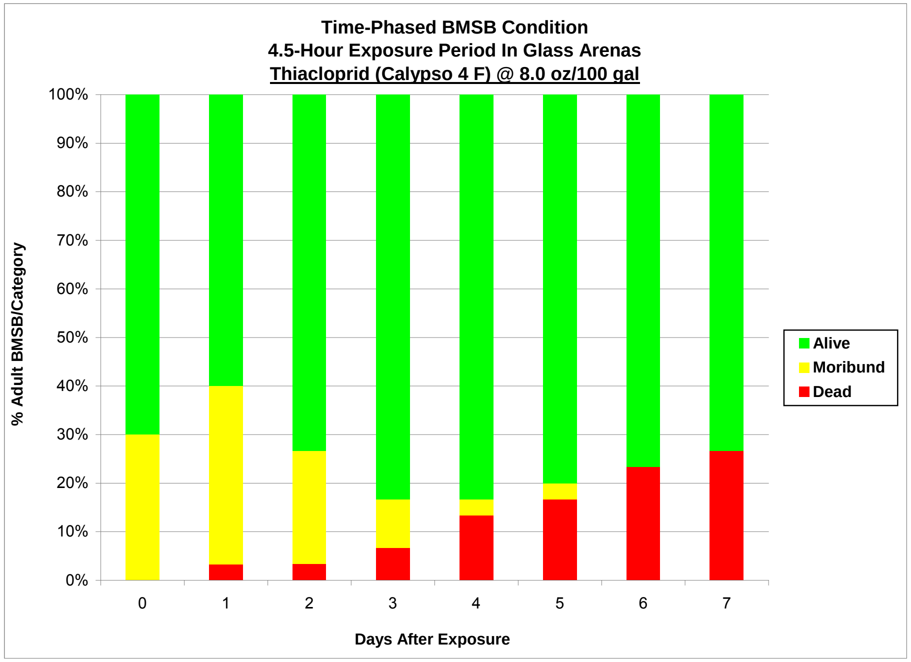

Time-Phased BMSB Condition
4.5-Hour Exposure Period In Glass Arenas
Thiamethoxam (Actara WDG) @ 4.5 oz/100 gal
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
% Adult BMSB/Category
0
1
2
3
4
5
6
7
Days After Exposure
Alive
Moribund
Dead

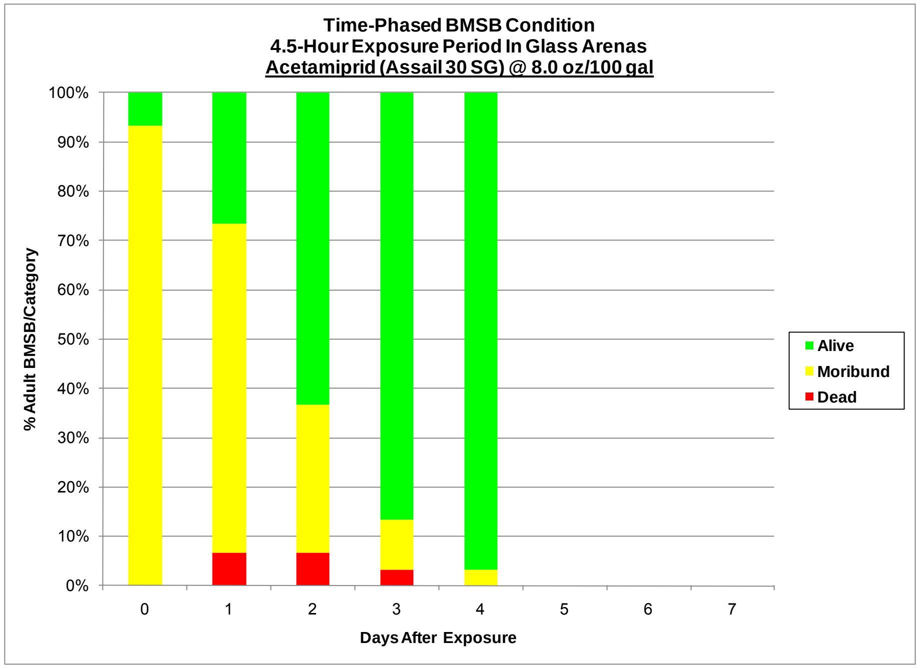

Time-Phased BMSB Condition
4.5-Hour Exposure Period In Glass Arenas
Clothianidin (Clutch 50 WDG) @ 3.2 oz/100 gal
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
% Adult BMSB/Category
0
1
2
3
4
5
6
7
Days After Exposure
Alive
Moribund
Dead


Time-Phased BMSB Condition
4.5-Hour Exposure Period In Glass Arenas
Dinotefuran (Safari 20 SG) @ 16 oz/100 gal
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
% Adult BMSB/Category
0
1
2
3
4
5
6
7
Days After Exposure
Alive
Moribund
Dead


Time-Phased BMSB Condition
4.5-Hour Exposure Period In Glass Arenas
Imidacloprid (Provado 1.6 F) @ 8 oz/100 gal
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
% Adult BMSB/Category
0
1
2
3
4
5
6
7
Days After Exposure
Alive
Moribund
Dead

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





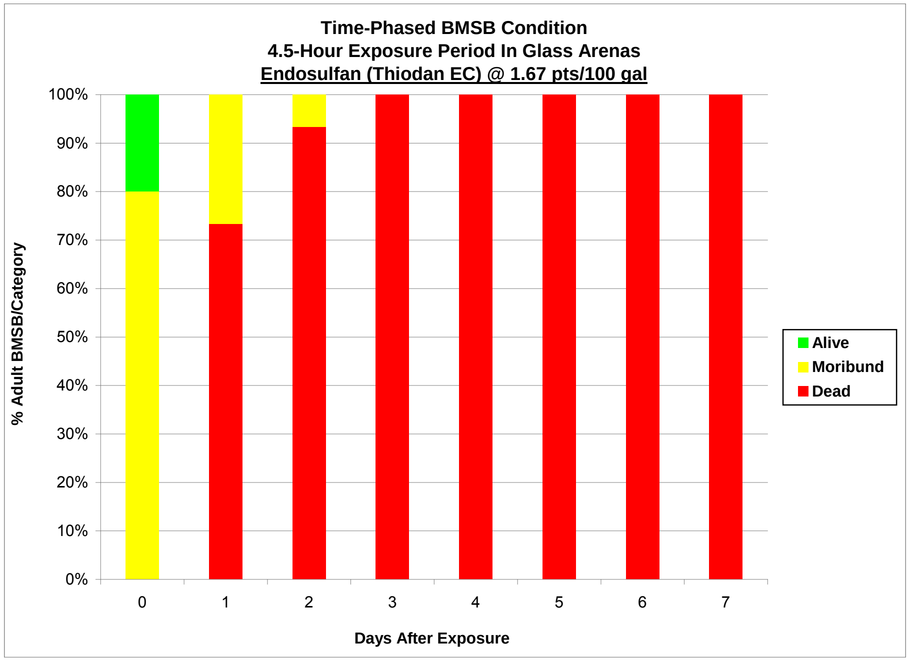
USDA-ARS-Appalachian Fruit Research Station BMSB Lethality (Dry Residue, Glass) <u>Organochlorine</u>

Trade Name	Formulation	A.I.	Class	Crops	Field Rates	Tested Rate	Label Restrictions	Label Notes	Stink Bug on Label
Thiodan	EC	Endosulfan (33.7%)	2/Cyclodiene organochlorine	Apples	$^{2}/_{3}$ qt./100 gal – 3 $^{1}/_{3}$ qts/A	1.67 pts/100 gal	Max: 3 $^{1}/_{3}$ qts/A/yr and 3 applications/crop/yr (2 applications during fruiting)		No
				Apricots, Nectarines, Peaches			Max: 3 $^{1}/_{3}$ qts/A/yr and 2 applications/crop/yr		Yes
				Cherry	$^{2}/_{3}$ qt./100 gal or 2$^{2}/_{3}$- 3 $^{1}/_{3}$ qts/A				No
				Pear					Yes
				Plum					No

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
Endosulfan	46.6 ± 12.2	54.6 ± 15.1	31.5 ± 7.4	29.0 ± 12.0	60.6 ± 15.6	81.6 ± 22.6	46.6 ± 12.5	48.9 ± 21.0
Water	***21.7 ± 6.3***	***9.6 ± 3.4***	***26.9 ± 10.6***	***36.0 ± 13.3***	***24.3 ± 9.9***	***8.2 ± 4.7***	***33.3 ± 17.4***	***44.0 ± 17.8***

Chemical Name	Vertical Mobility (cm ± SE)	
	4.5h	7d
Endosulfan	7.5 ± 8.4	0.0 ± 0.0
Water	***193.3 ± 21.9***	***102.5 ± 14.5***

USDA-ARS-Appalachian Fruit Research Station BMSB Lethality (Dry Residue, Glass) <u>Organochlorine</u>



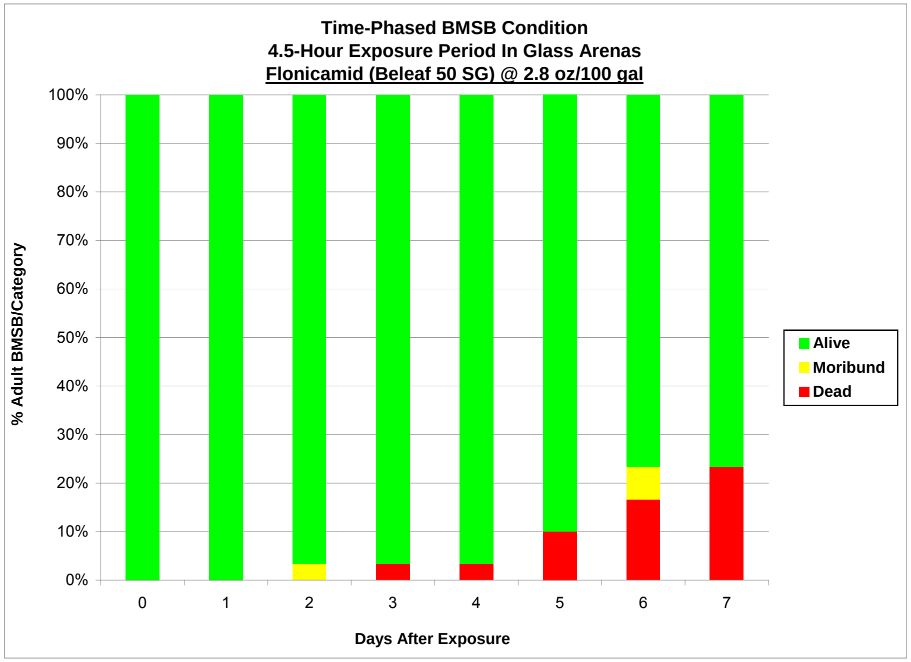
USDA-ARS-Appalachian Fruit Research Station BMSB Lethality (Dry Residue, Glass) <u>Pyridinecarboxamide</u>

Trade Name	Formulation	A.I.	Class	Crops	Field Rates	Tested Rate	Label Restrictions	Label Notes	Stink Bug on Label
Beleaf	50 SG	Flonicamid (50%)	9c/Pyridinecarboxamide	Pome Fruit (Apple, Pear and Oriental Pear)	2.0-2.8 oz/A	2.8 oz/100 gal	Max: 8.4oz/A/yr and 3 applications at high rate. Min: 50 gal water.		No
				Stone Fruit (Apricot, Cherry, Nectarine, Peach, Plum)					No

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

Chemical Name	Horizontal Mobility Distance (cm ± SE) 0.0h	1.5h	3.0h	4.5h	Horizontal Mobility Duration (s ± SE) 0.0h	1.5h	3.0h	4.5h
Flonicamid	39.7 ± 15.6	50.1 ± 17.4	41.8 ± 15.5	49.3 ± 24.1	61.9 ± 22.7	65.5 ± 23.0	58.3 ± 25.4	64.7 ± 31.1
Water	***21.7 ± 6.3***	***9.6 ± 3.4***	***26.9 ± 10.6***	***36.0 ± 13.3***	***24.3 ± 9.9***	***8.2 ± 4.7***	***33.3 ± 17.4***	***44.0 ± 17.8***

Chemical Name	Vertical Mobility (cm ± SE) 4.5h	7d
Flonicamid	107.3 ± 19.5	88.2 ± 22.8
Water	***193.3 ± 21.9***	***102.5 ± 14.5***


Time-Phased BMSB Condition
4.5-Hour Exposure Period In Glass Arenas
Flonicamid (Beleaf 50 SG) @ 2.8 oz/100 gal
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
% Adult BMSB/Category
0
1
2
3
4
5
6
7
Days After Exposure
Alive
Moribund
Dead

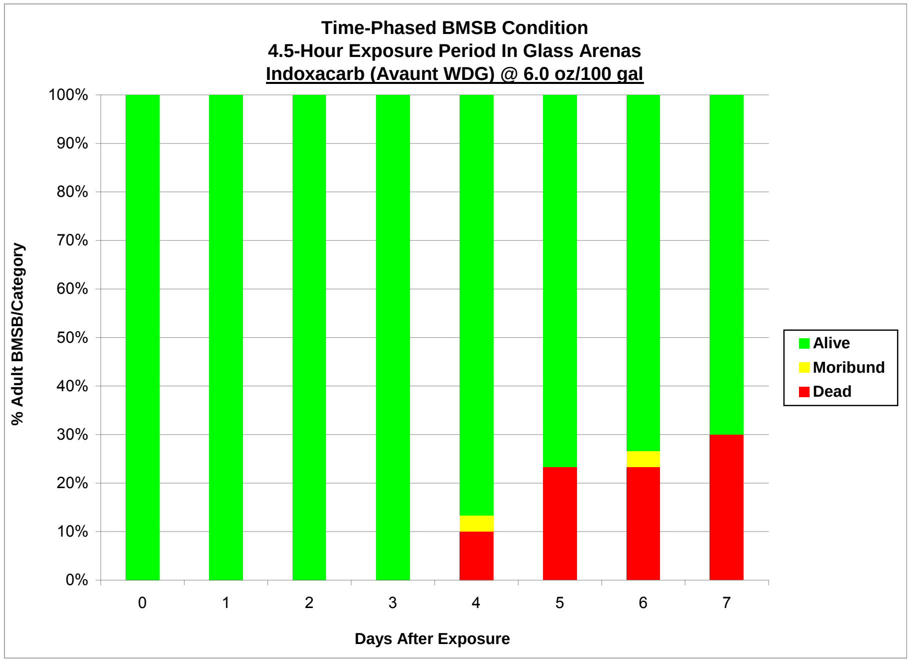
USDA-ARS-Appalachian Fruit Research Station BMSB Lethality (Dry Residue, Glass) <u>Oxadiazine</u>

Trade Name	Formulation	A.I.	Class	Crops	Field Rates	Tested Rate	Label Restrictions	Label Notes	Stink Bug on Label
Avaunt	WDG	Indoxacarb (30%)	22/Oxadiazine	Pear	5.0-6.0 oz/A	6.0 oz/100 gal	Max: 24 oz/A/yr and 4 applications/crop/yr. Max: 200 gal in dilute sprays. Max 3 applications before hand-thinning and no hand-thinning after 4th spray.		No
				Pome Fruit (Apple)	3.0-6.0 oz/A				No
				Stone Fruit (Apricot, Cherry, Nectarine, Peach, Plum)	5.0-6.0 oz/A				No

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

Chemical Name	Horizontal Mobility Distance (cm ± SE) 0.0h	1.5h	3.0h	4.5h	Horizontal Mobility Duration (s ± SE) 0.0h	1.5h	3.0h	4.5h
Indoxacarb	42.9 ± 7.4	23.4 ± 7.4	12.4 ± 3.0	17.6 ± 6.8	68.8 ± 15.3	35.4 ± 12.0	16.3 ± 5.5	23.8 ± 14.1
Water	***21.7 ± 6.3***	***9.6 ± 3.4***	***26.9 ± 10.6***	***36.0 ± 13.3***	***24.3 ± 9.9***	***8.2 ± 4.7***	***33.3 ± 17.4***	***44.0 ± 17.8***

Chemical Name	Vertical Mobility (cm ± SE) 4.5h	7d
Indoxacarb	283.4 ± 31.3	143.2 ± 24.2
Water	***193.3 ± 21.9***	***102.5 ± 14.5***



Time-Phased BMSB Condition
4.5-Hour Exposure Period In Glass Arenas
Indoxacarb (Avaunt WDG) @ 6.0 oz/100 gal
% Adult BMSB/Category
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
6
7
Days After Exposure
Alive
Moribund
Dead

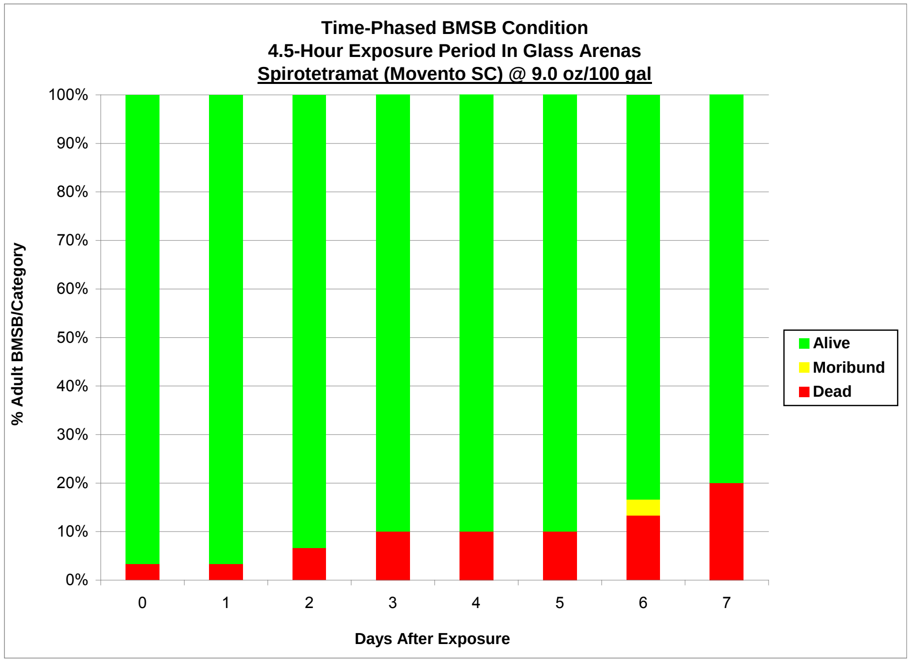
USDA-ARS-Appalachian Fruit Research Station BMSB Lethality (Dry Residue, Glass) <u>Tetramic Acid</u>

Trade Name	Formulation	A.I.	Class	Crops	Field Rates	Tested Rate	Label Restrictions	Label Notes	Stink Bug on Label
Movento	SC	Spirotetramat (22.4%)	23/Tetramic acid	Pome Fruit (Apple and Pear)	6.0-9.0 oz/A	9.0 oz/100 gal	Cannot use with Induce adjuvant when fruit are on tree; however a spray adjuvant should be used. Do not apply prior to petal fall. Max: 25 oz/A/yr		No
				Stone Fruit (Apricot, Cherry, Nectarine, Peach, Plum)			Cannot use with Induce adjuvant when fruit are on tree; however a spray adjuvant should be used. Do not apply prior to petal fall. Max: 15.3 oz/A/yr		No

USDA-ARS-Appalachian Fruit Research Station   BMSB Lethality (Dry Residue, Glass)   <u>Tetramic Acid</u>

Chemical Name	Horizontal Mobility Distance (cm ± SE) 0.0h	1.5h	3.0h	4.5h	Horizontal Mobility Duration (s ± SE) 0.0h	1.5h	3.0h	4.5h
Spirotetramat	78.4 ± 16.9	106.7 ± 23.7	80.7 ± 20.9	70.2 ± 21.7	110.6 ± 24.0	132.7 ± 29.8	101.5 ± 26.7	88.9 ± 26.7
Water	***21.7 ± 6.3***	***9.6 ± 3.4***	***26.9 ± 10.6***	***36.0 ± 13.3***	***24.3 ± 9.9***	***8.2 ± 4.7***	***33.3 ± 17.4***	***44.0 ± 17.8***

Chemical Name	Vertical Mobility (cm ± SE) 4.5h	7d
Spirotetramat	140.1 ± 35.2	106.2 ± 39.5
Water	***193.3 ± 21.9***	***102.5 ± 14.5***

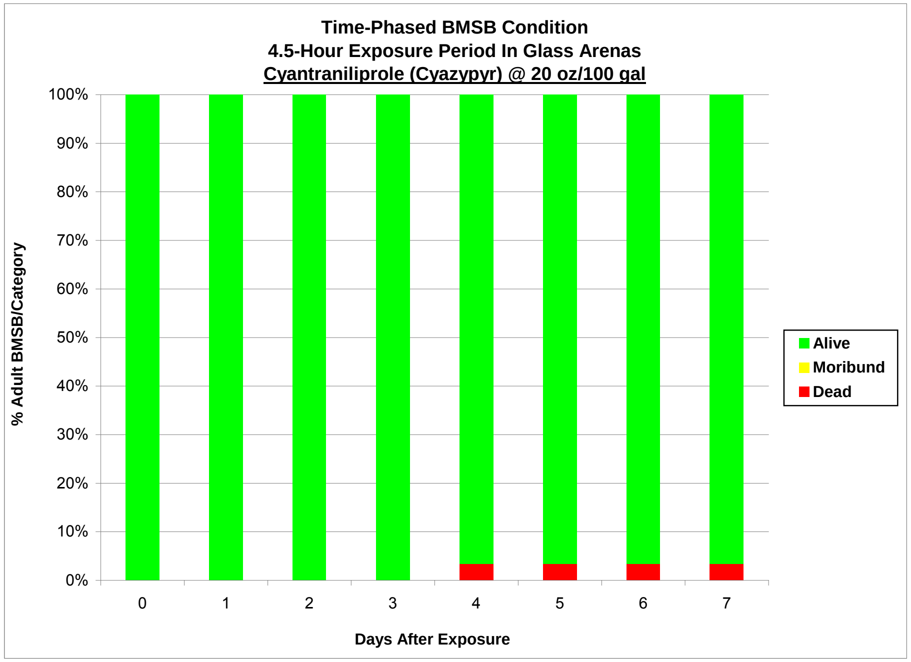

Time-Phased BMSB Condition
4.5-Hour Exposure Period In Glass Arenas
Spirotetramat (Movento SC) @ 9.0 oz/100 gal
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
% Adult BMSB/Category
0
1
2
3
4
5
6
7
Days After Exposure
Alive
Moribund
Dead

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

Trade Name	Formulation	A.I.	Class	Crops	Field Rates	Tested Rate	Label Restrictions	Label Notes	Stink Bug on Label
Cyazypyr	100g/L	Cyantraniliprole	28/Ryanodine receptor activator	**No label**	Suggested 20 oz/A (Don Ganske; DuPont)	20oz/100 gal			

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**
Cyantraniliprole	73.8 ± 31.6	45.5 ± 20.8	20.0 ± 14.1	20.3 ± 9.4	64.0 ± 22.0	50.4 ± 21.7	25.4 ± 18.1	34.8 ± 17.1
Water	***21.7 ± 6.3***	***9.6 ± 3.4***	***26.9 ± 10.6***	***36.0 ± 13.3***	***24.3 ± 9.9***	***8.2 ± 4.7***	***33.3 ± 17.4***	***44.0 ± 17.8***

Chemical Name	Vertical Mobility (cm ± SE)	
	4.5h	**7d**
Cyantraniliprole	142.2 ± 30.7	115.0 ± 25.8
Water	***193.3 ± 21.9***	***102.5 ± 14.5***


Time-Phased BMSB Condition
4.5-Hour Exposure Period In Glass Arenas
Cyantraniliprole (Cyazypyr) @ 20 oz/100 gal
% Adult BMSB/Category
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
6
7
Days After Exposure
Alive
Moribund
Dead

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

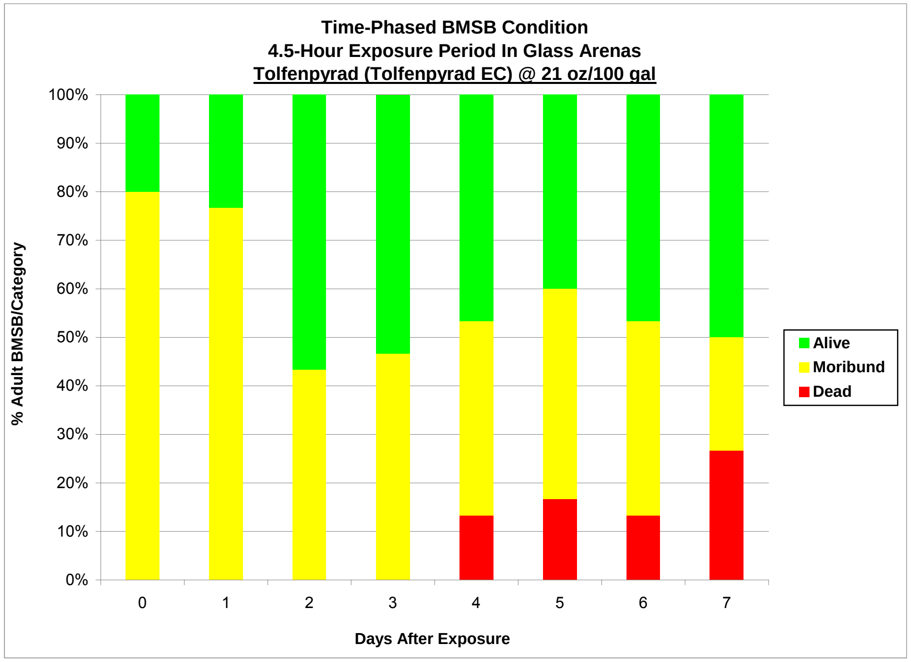
Trade Name	Formulation	A.I.	Class	Crops	Field Rates	Tested Rate	Label Restrictions	Label Notes	Stink Bug on Label
Tolfenpyrad	EC	Tolfenpyrad	21a/Pyridazinone			21 oz/100 gal			

USDA-ARS-Appalachian Fruit Research Station BMSB Lethality (Dry Residue, Glass) <u>Pyridazinone</u>

Chemical Name	Horizontal Mobility Distance (cm ± SE) 0.0h	1.5h	3.0h	4.5h	Horizontal Mobility Duration (s ± SE) 0.0h	1.5h	3.0h	4.5h
Tolfenpyrad	100.8 ± 23.2	104.4 ± 20.2	45.7 ± 10.8	14.5 ± 5.1	116.0 ± 23.2	130.6 ± 23.5	70.1 ± 18.7	24.9 ± 11.3
Water	***21.7 ± 6.3***	***9.6 ± 3.4***	***26.9 ± 10.6***	***36.0 ± 13.3***	***24.3 ± 9.9***	***8.2 ± 4.7***	***33.3 ± 17.4***	***44.0 ± 17.8***

Chemical Name	Vertical Mobility (cm ± SE) 4.5h	7d
Tolfenpyrad	1.2 ± 1.2	13.0 ± 8.6
Water	***193.3 ± 21.9***	***102.5 ± 14.5***

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



USDA-ARS-Appalachian Fruit Research Station BMSB Lethality (Dry Residue, Glass) <u>Particle Film</u>

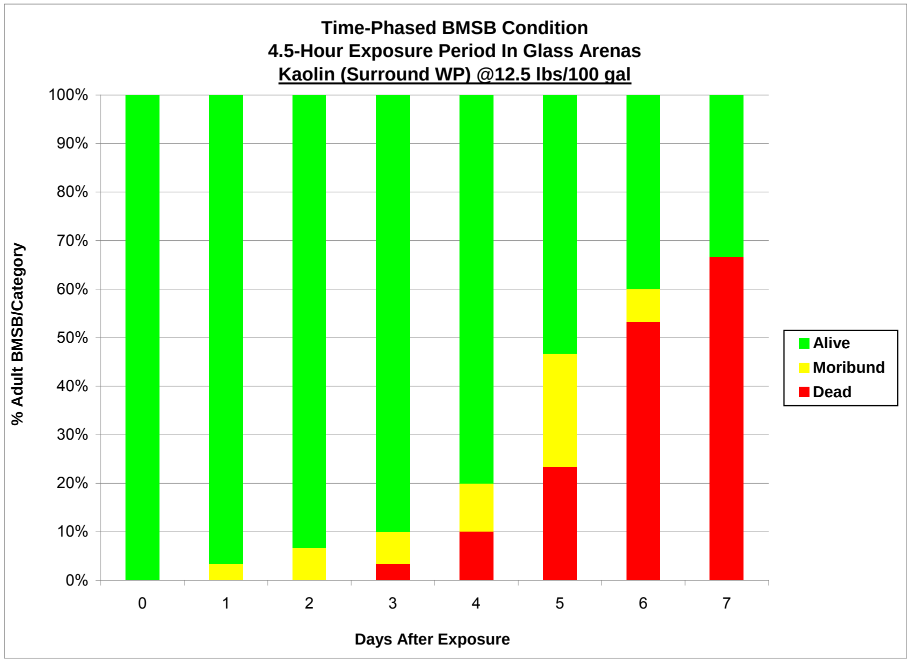
Trade Name	Formulation	A.I.	Class	Crops	Field Rates	Tested Rate	Label Restrictions	Label Notes	Stink Bug on Label
Surround	WP	Kaolin (95%)	Particle Film	Pome Fruit (Apple and Pear)	25-100 lbs/A	12.5 lbs/100 gal	100 lbs/A allowed only on pear for pre-bloom heavy infestations.	May clog filters, intakes and/or nozzles.	Yes (Suppression)
				Stone Fruit (Apricot, Cherry, Nectarine, Peach, Plum)	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) Particle Film

Chemical Name	Horizontal Mobility Distance (cm ± SE) 0.0h	1.5h	3.0h	4.5h	Horizontal Mobility Duration (s ± SE) 0.0h	1.5h	3.0h	4.5h
Kaolin	47.8 ± 10.5	26.0 ± 7.4	45.9 ± 10.6	68.5 ± 9.8	56.8 ± 13.7	41.2 ± 15.9	67.7 ± 17.7	109.1 ± 19.4
Water	***21.7 ± 6.3***	***9.6 ± 3.4***	***26.9 ± 10.6***	***36.0 ± 13.3***	***24.3 ± 9.9***	***8.2 ± 4.7***	***33.3 ± 17.4***	***44.0 ± 17.8***

Chemical Name	Vertical Mobility (cm ± SE) 4.5h	7d
Kaolin	23.0 ± 14.8	35.0 ± 21.8
Water	***193.3 ± 21.9***	***102.5 ± 14.5***

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

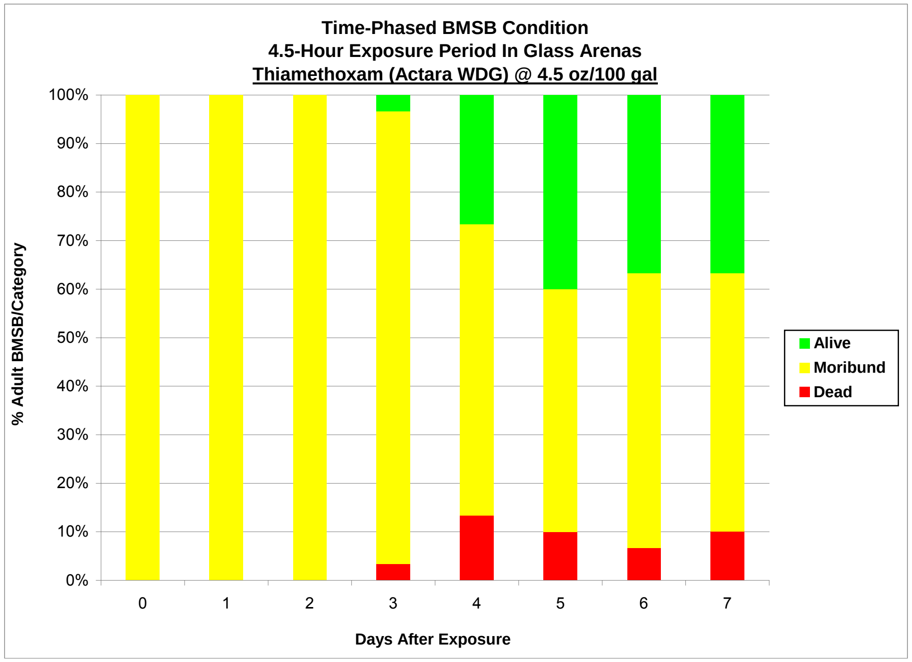


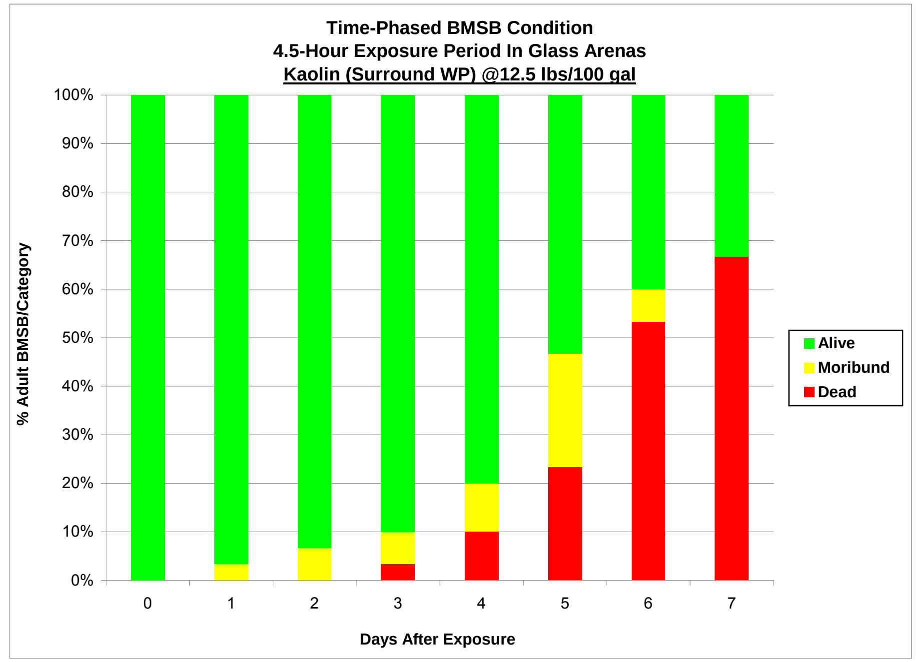
USDA-ARS-Appalachian Fruit Research Station BMSB Lethality (Dry Residue, Glass) Particle Delivery

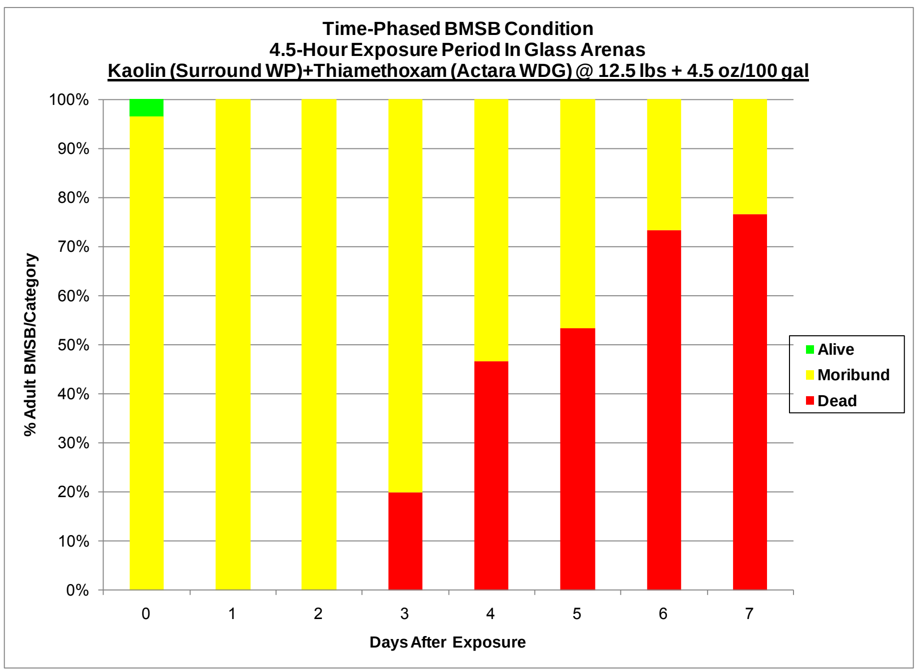
Chemical Name	Horizontal Mobility Distance (cm ± SE)				Horizontal Mobility Duration (s ± SE)			
	0.0h	**1.5h**	**3.0h**	**4.5h**	**0.0h**	**1.5h**	**3.0h**	**4.5h**
Kaolin+Thiamethoxam	35.1 ± 16.5	30.8 ± 17.0	94.3 ± 22.8	64.9 ± 16.2	36.6 ± 17.1	31.8 ± 17.3	130.8 ± 25.2	121.7 ± 24.5
Water	***21.7 ± 6.3***	***9.6 ± 3.4***	***26.9 ± 10.6***	***36.0 ± 13.3***	***24.3 ± 9.9***	***8.2 ± 4.7***	***33.3 ± 17.4***	***44.0 ± 17.8***

Chemical Name	Vertical Mobility (cm ± SE)	
	4.5h	**7d**
Kaolin+Thiamethoxam	0.0 ± 0.0	0.0 ± 0.0
Water	***193.3 ± 21.9***	***102.5 ± 14.5***

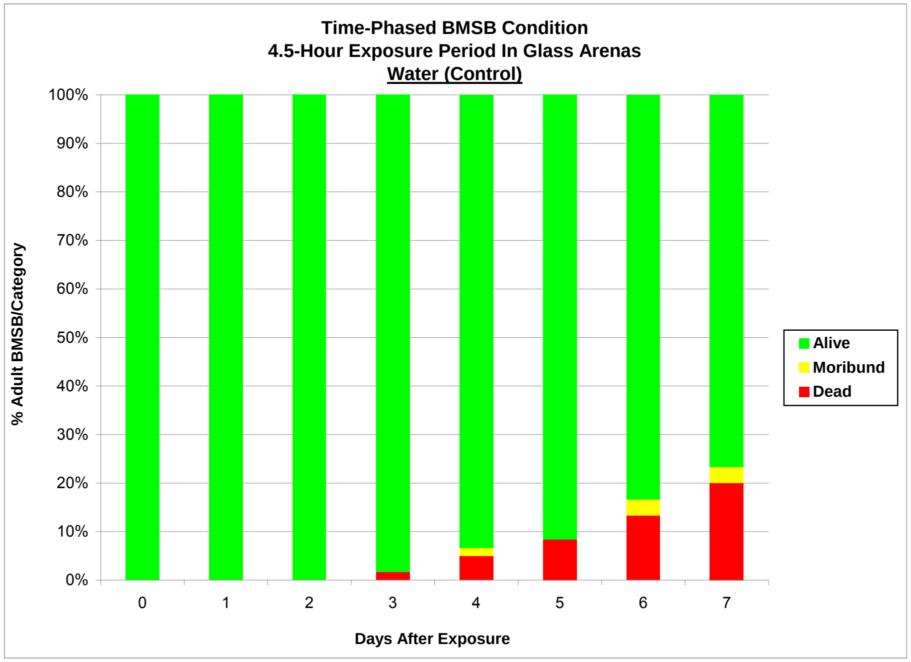
USDA-ARS-Appalachian Fruit Research Station BMSB Lethality (Dry Residue, Glass) **Particle Delivery**







USDA-ARS-Appalachian Fruit Research Station BMSB Lethality (Dry Residue, Glass) <u>Water (Control)</u>



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

Lethality Index

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, 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 7 days after exposure. To directly compare candidate insecticides and maintain consideration of both the intensity of insecticide effects and speed of onset, we have developed a Lethality Index, which is calculated using the following formula:

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

The maximum value of the Lethality Index in this trial is 100.0; the minimum value is 0.0, and compounds are ranked in descending order of value.

Active Ingredient	Lethality Index	Status
Methomyl	98.5	Complete
Bifenthrin	91.5	Complete
Endosulfan	90.4	Complete
Chlorpyrifos	89.0	Complete
Acephate	87.5	Complete
Permethrin	77.1	Complete
Fenpropathrin (Low Rate)	72.3	Complete
Dinotefuran	67.3	Complete
Fenpropathrin (High Rate)	66.7	Complete
Kaolin Clay + Thiamethoxam	66.7	Complete
Formetanate HCl	63.5	Complete
Cyfluthrin (6-Day Residue)	57.1	Complete
Thiamethoxam	56.3	Complete
Clothianidin	55.6	Complete
zeta-Cypermethrin	49.6	Day 3
Cyfluthrin (1-Day Residue)	49.0	Complete
beta-Cyfluthrin	44.4	Day 2
Imidacloprid	40.0	Complete
Esfenvalerate	35.0	Day 1
Oxamyl	34.2	Complete
Tolfenpyrad (EC)	33.3	Complete
Acetamiprid	23.7	Day 4
Kaolin Clay	23.1	Complete
Phosmet	20.0	Complete
Thiacloprid	18.3	Complete
Indoxacarb	11.3	Complete
Spirotetramat	9.8	Complete
Carbaryl	9.2	Complete
Flonicamid	7.7	Complete
Water (Control)	6.6	Complete
Cyantraniliprole	1.7	Complete