

BROWN MARMORATED STINK BUG

BIOLOGY AND MANAGEMENT IN MID-ATLANTIC SOYBEANS



MISSION

The mission of the Delaware Soybean Board (DSB), Maryland Soybean Board (MSB), and Virginia Soybean Board (VSB) is to maximize the profitability of soybean producers in their respective states by investing soybean checkoff funds in targeted domestic and international research, promotion and communication initiatives. The volunteer farmer-leaders who serve on the DSB, MSB and VSB boards of directors invest your checkoff dollars in research to improve soybean production practices to make your farm more profitable and ensure the sustainability of Mid-Atlantic soybean production.

This guide reviews the biology and threat of brown marmorated stink bug and management strategies in soybeans to help you continue to be successful in your soybean operation. DSB, MSB and VSB would like to thank the collaborating researchers from the University of Delaware, University of Maryland and Virginia Tech for contributing information and providing technical editing for this guide.



University of Delaware

Bill Cissel Joanne Whalen



University of Maryland

Galen Dively, Ph.D. Terry Patton
Cerruti Hooks, Ph.D. P. Dilip Venugopal, Ph.D.



Virginia Tech

Ben Aigner Tom Kuhar, Ph.D.
Jamie Hogue Sean Malone, Ph.D.
Ames Herbert, Ph.D. Ed Seymore



Delaware Soybean Board

3203 Greenstone Way
Oak Hill, VA 20171
www.desoybeans.org



Maryland Soybean Board

27137 Scotland Parkway
Salisbury, MD 21801
www.mdsoy.com



Virginia Soybean Board

102 Governor Street
Room 319
Richmond, VA 23219
www.vasoybean.com

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INTRODUCTION AND DISTRIBUTION IN SOYBEANS



Susan Ellis, Bugwood.org

The brown marmorated stink bug (BMSB), *Halyomorpha halys*, is an invasive species from Asia that was first detected in the U.S., near Allentown, Pennsylvania, in the mid-1990s. Since its accidental introduction, BMSB has rapidly spread throughout much of the Mid-Atlantic region of the United States and is in at least 42 states and the District of Columbia. BMSB is native to Japan, Korea, China and Taiwan, where it is considered

a pest of fruit trees, ornamental plants, vegetables and legume crops. In the U.S., BMSB has been observed feeding on more than 100 different plant species, including many of economic importance. Soybeans, in particular, are a preferred host for BMSB, which is capable of causing economic losses due to yield and quality reductions.

BMSB was first detected in U.S. soybean fields in Pennsylvania and New Jersey in 2009. It advanced into soybean fields in Maryland, Delaware and Virginia in 2010. By 2012, soybean-field infestations were widespread throughout these states. In some Mid-Atlantic states, BMSB is now the predominant stink bug species found in soybeans.

As of 2014, minor infestations also have been reported in soybeans in North Carolina, Tennessee, Kentucky and northern Georgia. Although the presence and spread of BMSB has been documented in these other states, the area where populations and the risk to soybean crop damage is currently the greatest is in the Mid-Atlantic region.

Because of the imminent threat to the soybean crop and general lack of knowledge of BMSB effects on soybeans, entomologists from University of Delaware, University of Maryland and Virginia Tech formed a collaborative team to develop information on this pest's biology, ecology and management. The team was funded by a three-year grant of soy checkoff funds provided by the United Soybean Board, as well as state funds from the Delaware, Maryland and Virginia soybean boards. This publication provides a summary of the findings of these studies.

IDENTIFICATION

BMSB adults have a shield-shaped body, approximately 5/8-inch in length. It has a mottled-brown appearance, with alternating black and white markings around the perimeter of its abdomen and a white or tan underside, sometimes with grey or black markings. The antennae have a white band on the fourth antennal segment, and faint white banding may be observed on the legs (Photo 1).

Eggs are white to light-green in color, barrel-shaped and typically laid on the underside of leaves in clusters of 20 to 30 eggs (Photo 2).

There are five nymphal instars (developmental stages), ranging in length from 0.1-inch (1st instar) to 0.5-inch (5th instar). Newly hatched, first-instar BMSB are black with bright orange to red markings on their backs, have a tick-like appearance and are typically clustered around the egg mass (Photo 3). Later instars are black with prominent white banding on the legs and antennae. As with all immature insects, they lack wings (Photo 4).



Photo 1: BMSB Adult. Nick Sloff, Penn State



Photo 2: BMSB Egg Mass. Wil Hershberger, Nature Images and Sounds LLC



Photo 3: First Instar BMSB Nymphs. Wil Hershberger, Nature Images and Sounds LLC



Photo 4: Late Instar BMSB Nymph. David Owens, Virginia Tech

BIOLOGY AND LIFE CYCLE

In central Pennsylvania and New Jersey, BMSB produces one generation per year. In West Virginia, BMSB has been documented as producing two generations per year. In much of its native home range in Asia, BMSB also produces one generation per year, but in some regions it has been reported to have multiple generations annually.

BMSB overwinters as adults in protected spaces in natural areas or aggregates in large numbers inside hay bales, log piles and man-made structures where they are often a nuisance. Overwintering adults emerge in late spring (late April to mid-May), mate and begin laying eggs in early June. A single female can lay over 400 eggs in her lifetime. It takes approximately five days for eggs to hatch and three to eight days to develop through each of the five nymphal instars before molting into an adult. So, under favorable conditions, the egg-to-adult cycle occurs in about 33 days. In the Mid-Atlantic, adult populations peak between late July and early September. This is the generation that moves into soybean fields and poses the greatest risk to the crop. Beginning in late September and continuing throughout the month of October, adults migrate from summer hosts, including soybean fields, back to overwintering sites where they seek shelter.



BMSB Life Cycle - Eggs and Young Nymphs. Gary Bernon, USDA APHIS, Bugwood.org

FACTORS INFLUENCING REGIONAL AND LOCAL POPULATION DISTRIBUTION

The distribution of BMSB throughout the Mid-Atlantic is influenced by a number of regional, large-scale factors. Local abundance of BMSB in soybeans is influenced largely by landscape factors. Temperature is the most important factor that affects BMSB, directly influencing their development, survival, distributional range and abundance. Surveys in soybean fields in the Mid-Atlantic region identify a clear increase in BMSB abundance moving inland from the coast. This correlates with the decreasing temperature, along an east-west movement. High temperatures (95°F and above) during summer are lethal for developing eggs and early instars. This significantly regulates the overall population that develops into adults and later invades crops. On a regional scale, temperature is the primary factor that influences abundance and distribution of BMSB throughout the Mid-Atlantic.

The primary landscape factors that influence local abundance patterns include proximity to developed areas and adjacent habitats comprised of suitable, alternate host plants. BMSB are considered “seed feeders,” and like many other mobile pests, efficiently move throughout the landscape among host plants at preferred growth stages. Trees represent the primary hosts for BMSB emerging from overwintering sites. Studies show that the movement of adults off trees generally occurs during mid-to-late July. Hence, forested areas with many host plant species provide a continuous supply of food to support the first generation of BMSB, which can result in a high abundance of adults that invade corn and then move to soybeans later in the season. When soybeans begin producing pods and seed, they become most attractive to BMSB. It is at this time that BMSB move from alternate hosts such as trees and corn into soybeans.

Landscape features are important predictors of BMSB abundance at smaller spatial scales but are not the primary drivers of BMSB patterns at the regional scale. While habitats adjacent to crop fields heavily impact BMSB density in soybeans, the influence of landscape factors on BMSB populations is localized.

FIELD-INFESTATION PATTERNS

To gain a better understanding of the infestation habits and distribution of BMSB in soybeans, field surveys were conducted by sampling alternate host plants along the field edge, field edges bordered by woods, at 50 feet from the field edge and 100 feet from the field edge (field middle). **Findings confirm that BMSB infestations are greatest on field edges bordered by woods.** In July, BMSB populations increased on alternate hosts, such as tree of heaven. By August, in many of the fields, BMSB began appearing on the adjacent soybean field edges. However, in all of the fields surveyed, BMSB did not move far from the invading field edge and did not disperse throughout the entire field. Approximately half as many BMSB were detected at 50 feet into the field, and very few BMSB were present at 100 feet from the field edge (Figure 1). Sampling at set intervals from the field edge – 0, 10, 30, 50, 80 and 110 feet – revealed BMSB populations quickly decrease beyond 50 feet from the field edge (Figure 2).

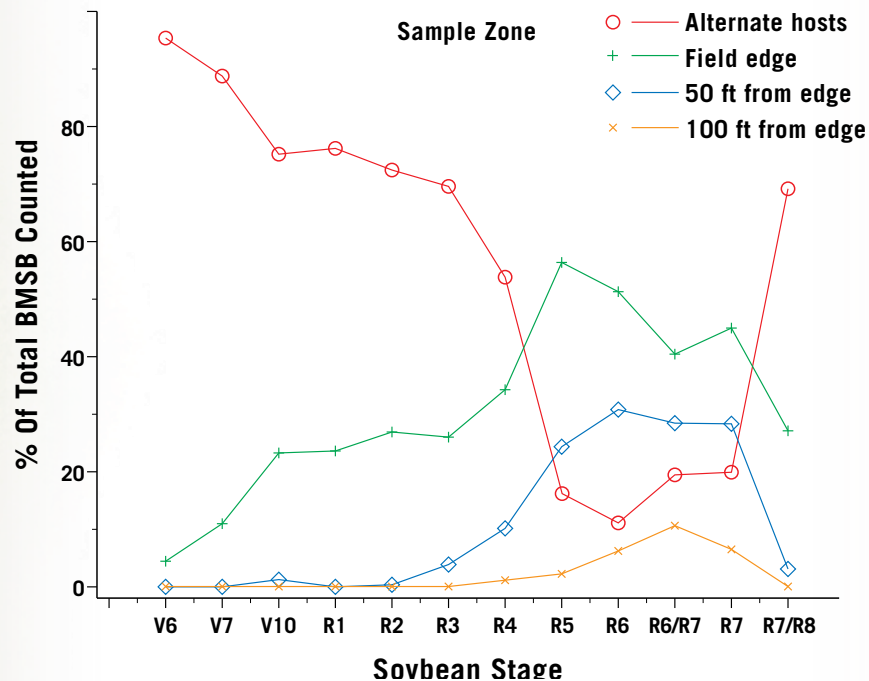


Figure 1. Typical seasonal infestation patterns of BMSB in soybean fields for years 2013 and 2014 in Virginia. The graph depicts the average percentage of BMSB adults and nymphs per two-minute-count on alternate hosts (mostly tree of heaven) along soybean field edges, on soybean field edges, 50 feet from field edges and 100 feet from field edges (middle of field), throughout the season.

This information can be used to focus scouting efforts and identify the portions of the field that are at greatest risk for damage. This also provides an opportunity to concentrate control efforts on field edges to manage BMSB in soybeans.

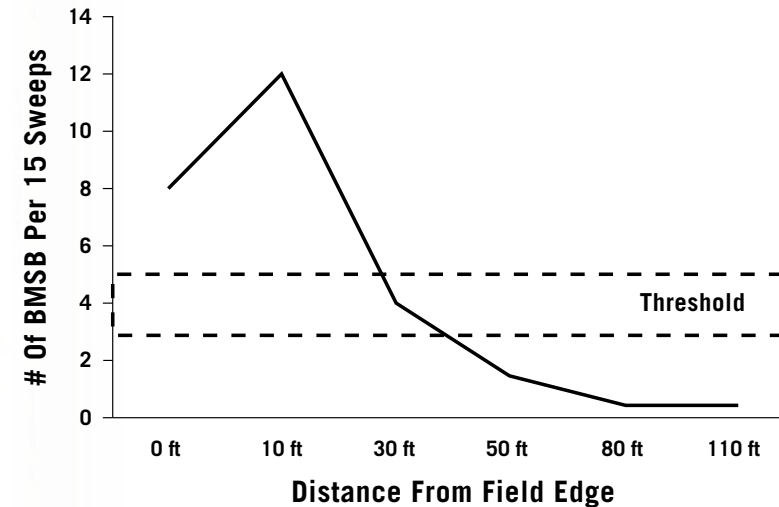


Figure 2. Typical distribution of BMSB adults and nymphs in a soybean field at set distances from the field edge.



2nd Instar BMSB Nymph. Gary Bernon, USDA APHIS, Bugwood.org

CROP INJURY

BMSB adults and nymphs, with the exception of first instar nymphs, which are non-feeding, attack soybean pods and seeds. Similar to our native stink bug species, they feed on these plant parts by inserting their piercing-sucking mouth parts, injecting plant digestive enzymes and extracting the plant fluids. Feeding injury to seed in the early stages of pod development – from R3 (beginning pod) to R4 (full pod) – can result in aborted pods or underdeveloped flat pods (Photos 5). Feeding injury to larger developing seeds – between R5 (beginning seed) and R6 (full seed) – results in shriveled, deformed or even aborted seeds (Photo 6). In the field, BMSB-damaged pods are prematurely yellow with brown speckles where BMSB have punctured the pod wall (Photo 7). Opening those pods will reveal damage to the seed (Photo 8). BMSB feeding has also been shown to cause delayed plant development, often referred to as stay green syndrome (Photo 9). In response to stink bug feeding, soybeans will delay development in an effort to produce more seed to compensate for what may have been lost. As a result, portions of the field with heavy BMSB infestations remain green while the remainder of the field dries down, reaching R8 (full maturity). Stay green syndrome can result in complete yield loss because of the challenges associated with harvesting soybeans that have not fully matured at the same time as the remainder of the field.



Photo 5: Flat Pod Damage. David Owens, Virginia Tech



Photo 6: BMSB Damaged Seed. David Owens, Virginia Tech



Photo 7: BMSB Damaged Pod. David Owens, Virginia Tech



Photo 8: BMSB Damaged Seed. David Owens, Virginia Tech



Photo 8: Field With 'Stay Green Syndrome'. Jamie Hogue, Virginia Tech

FIELD-EDGE-ONLY TREATMENTS FOR CONTROLLING BMSB IN SOYBEANS

Research and surveys conducted in the Mid-Atlantic region have documented that BMSB have a behavioral habit of infesting only the outer edges of host crops, including orchards, vegetables and row-crop fields. University personnel conducted research to test the strategy of controlling infestations by treating only soybean field edges with insecticide. From 2011–2014, 35 commercial soybean fields with BMSB infestations at or above threshold on field edges were treated with a single insecticide application by making one sprayer pass around the field edge. In each field included in the study, farmers chose the insecticide and rate and used their field sprayers to make the application. Fields were scouted after the treatments until crop maturity to determine if edge-only treatments are an effective control strategy for managing BMSB in soybeans.

Table 1. Number of BMSB adults and nymphs per 15 sweeps after an edge treatment was applied. Data presented is from nine of the 35 commercial soybean fields included in the study.

Location	Date Treated	Growth Stage	Days After Treatment (DAT) – Number of BMSB per 15 sweeps									
			Date 1	Date 2	Date 3	Date 4	Date 5					
Field 1	Aug. 23	R-5	Aug-30 (7 DAT)	0	Sep-6 (14 DAT)	0	Sep-13 (21 DAT)	0	Sep-19 (27 DAT)	<1	Sep-25 (25 DAT)	0
Field 2	Aug. 8	R-5	Aug-23 (15 DAT)	0	Aug-30 (22 DAT)	0	Sep-6 (29 DAT)	0	Sep-19 (42 DAT)	0	Sep-25 (48 DAT)	<2
Field 3	Aug. 22	R-5	Aug-30 (8 DAT)	0	Sep-6 (15 DAT)	0	Sep-13 (22 DAT)	0	Sep-19 (28 DAT)	18	Sep-25 (34 DAT)	<1
Field 4	Aug. 24	R-5	Aug-30 (6 DAT)	0	Sep-6 (13 DAT)	0	Sep-13 (20 DAT)	0	Sep-25 (27 DAT)	<3		
Field 5	Aug. 24	R-5	Aug-31 (7 DAT)	0	Sep-7 (14 DAT)	0	Sep-14 (21 DAT)	0	Sep-25 (32 DAT)	0		
Field 6	Sep. 3	R-5	Sep-7 (4 DAT)	0	Sep-12 (9 DAT)	0	Sep-26 (23 DAT)					
Field 7	Sep. 3	R-5	Sep-7 (4 DAT)	0	Sep-12 (9 DAT)	0	Sep-26 (23 DAT)					
Field 8	Sep. 4	R-5	Sep-7 (3 DAT)	0	Sep-12 (8 DAT)	0	Sep-26 (22 DAT)					
Field 9	Aug. 30	R4-R5	Sep-7 (8 DAT)	0	Sep-14 (15 DAT)	0	Sep-24 (25 DAT)					

Results showed that in all but one case, treating field edges with a single, well-timed insecticide application was successful in reducing BMSB populations (Table 1). The one case that was not successful was an unusual case where the soybean field was next to a late-planted field of sweet corn (another preferred host of BMSB), and stink bugs migrated back into the soybean field after the corn was harvested. In all of the other cases, the single field-edge-only treatment provided field-wide and season-long control. It is important to note that all treatments were applied at the correct time for achieving the best control of stink bugs – that is, when plants were developing seed in the pods, from R4 (full pod) through R6 (full seed), and are the most attractive and susceptible to stink bugs.

SAMPLING FOR BMSB IN SOYBEANS: A NEW VISUAL PLANT INSPECTION SAMPLING METHOD

Sampling soybean fields for BMSB has proven to be a challenge compared with sampling for native stink bug species. Adults and nymphs have a strong ‘startle response’ and drop to the ground with even the slightest disturbance. This makes using the traditional sampling method, i.e., sweep-net sampling, difficult and could lead to underestimating densities. To overcome this challenge, an alternative method has been developed. It involves a visual plant-inspection sampling method that consists of recording all BMSB adults and nymphs observed in a two-minute-long inspection.

To evaluate the effectiveness of this new method and compare it with sweep-net sampling, more than 2,000 comparisons of the two sampling methods were conducted in 2013 and 2014 in 76 soybean fields in Delaware, Maryland and Virginia. Sampling was conducted 15 feet from the edge of the field as the sampler walked carefully between planted rows, viewing a 3-foot-wide area parallel to the field edge. The boundaries of each sample area were flagged to ensure that the same area would be used for the subsequent sweep-net sample. After a 30-minute interval, which allowed the stink bugs to reposition in the plant canopy, 15 sweeps with a standard 15-inch-diameter sweep net were used to sample each flagged area. All stink bug adults and nymphs found in the sweep net after sampling were counted. In Delaware and Virginia, fields included in the study were planted on narrow rows (7.5-18-inch row centers), and in Maryland, fields were on wide rows (36-inch row centers). Standard statistical regression procedures were used to compare the number of BMSB observed during the two-minute visual inspection with the number caught in 15 sweeps.

Overall, results indicate that there is a close relationship between the numbers of BMSB sampled by the two methods. For example, when data were combined from scouting the fields in Delaware, Maryland and Virginia for the two years of the study (2,042 total comparisons), 5.4 BMSB were observed vs. 5 captured in 15 sweeps. In Maryland fields, visual counts tended to be higher compared with sweep-net counts (11.4 observed vs. 5 per 15 sweeps). That is, more could be observed in two minutes than could be caught in 15 sweeps. However, the Maryland fields differed from the others in the study in that some had very high numbers, up to 45 BMSB per 15 sweeps and 146 observed in two minutes. It appears that in fields with very high BMSB populations, the sampler can see more BMSB in relation to what can be caught in 15 sweeps. But fields with such high populations would likely be so obviously above threshold that sampling using any method would not be necessary to determine the need for treatment.

We were able to make a direct comparison of data from narrow- vs. wide-row-planted fields by comparing the 2014 Virginia (narrow-row) and Maryland (wide-row) data. Results showed that at 5 per 15 sweeps, higher numbers of BMSB were seen in two minutes in wide-row-planted fields (8.0) than in narrow-row-planted fields (4.3). This difference could be due to several factors, for example, walking in wide-row middles causes less disturbance with fewer BMSB dropping from plants, so more are seen compared with walking narrow-row fields which would cause more disturbance.

From this study, our conclusion is that the number of BMSB observed in two minutes on plants is approximately equal to the number caught per 15 sweeps (Figure 3). The visual inspection method is an effective and preferred alternative method for determining the action threshold for BMSB in soybeans, especially in fields with narrow-row-spacing. Stepping a few rows into a field and doing a two-minute visual count while carefully walking down a row middle appears to be an easy and relatively accurate way of assessing the need for a field-edge insecticide treatment for BMSB in soybeans. Having an easy assessment method could encourage more sampling by farmers and crop advisers and lead to more accurate treatment decisions regarding BMSB management.

THRESHOLDS

In 2013, we established 14 pairs of stink bug-free and stink bug-infested zones in two soybean fields at the University of Maryland-Western Maryland Research & Education Center

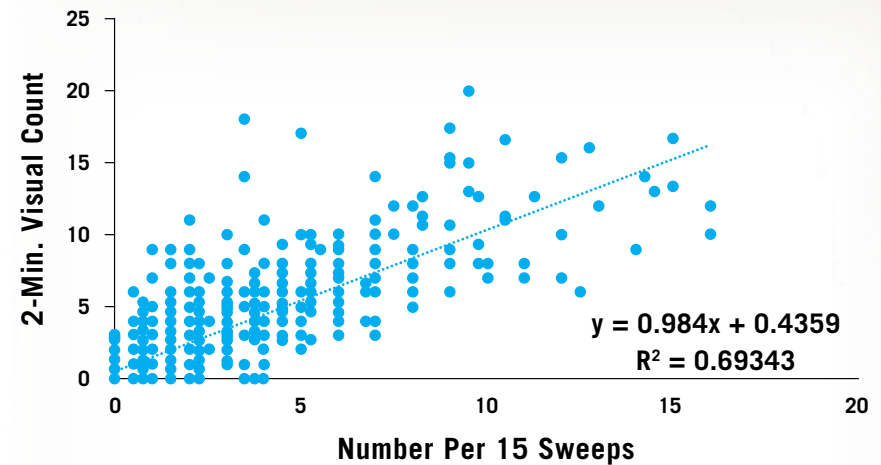


Figure 3. Number of BMSB adults and nymphs observed in a two-minute visual count compared with the number caught in a 15-sweep-net sample — 2,042 comparisons in Virginia, Delaware and Maryland in 2013 and 2014.

in Keedysville, Maryland. This research aimed to identify the infestation density of BMSB nymphs and adults required to cause reductions in seed quality and yield and delayed senescence (stay green syndrome). These study fields were selected because of the high numbers of BMSB on the field edges. Although some fields in the Mid-Atlantic area do experience similarly high infestations, many fields have few to no BMSB during the season. This study provided information to help determine which fields may be at risk and need protection. Based on study results and after incorporating the estimated cost of treatment based on current local prices and soybean value, we determined thresholds for field edges with high BMSB densities.

Total adults + medium and large nymphs:

- Visual: 3-5 in 2-minute count
- Sweep net: 3-5 in 15 sweeps
- Beat cloth: 0.5 per row foot

Note: Many fields will not have BMSB field edge infestations, but will have a more normal mix of stink bug species (BMSB, green, brown) throughout the field. Take multiple samples. Total all species, adults and nymphs, and use thresholds of 5 in 15 sweeps or 1 per row foot.

RECOMMENDED MANAGEMENT OPTIONS

WHERE AND WHEN TO SCOUT – Soybean fields near structures and bordered by woods are at greatest risk from BMSB. BMSB infestations are concentrated on field edges and rarely reach thresholds in the middle of fields. Scout field edges from late R4 or early R5 through pod maturity..

HOW TO SAMPLE AND WHEN TO TREAT – Use sweep nets to take 15-sweep samples. Beat cloths can be used in wide rows, but are not preferred. A two-minute visual plant inspection is an effective alternative method for sampling BMSB. From the edge, step 10-20 feet into the field and take a two-minute visual count of all adults and nymphs seen while carefully walking down a row middle. Take several samples in different parts of the field edge and determine the average number of stink bugs per sample (number per 15 sweeps, number per row foot, or number in two-minute visual count). If a threshold is met, R5 is the best time to treat to prevent seed quality and yield losses. For BMSB, a single, well-timed field-edge-only treatment can provide season-long control.

INSECTICIDE RECOMMENDATIONS (GENERAL)

CONVENTIONAL INSECTICIDES

Over a three-year period, multiple insecticides were evaluated in trials conducted in Delaware, Maryland and Virginia. All chemical classes evaluated provided effective control of BMSB adults and nymphs. Chemical classes evaluated included:

- Pyrethroids (e.g., beta-cyfluthrin, bifenthrin, lambda-cyhalothrin, zeta-cypermethrin)
- Carbamates (methomyl)
- Organophosphates (acephate)
- Neonicotinoid/pyrethroid mixtures (thiamethoxam + lambda-cyhalothrin, imidacloprid + beta-cyfluthrin)

Overall, treatment effects for adults and nymphs were highly significant and all treatments provided greater than 97 percent control of stink bugs compared with levels in the untreated control plots. Results clearly demonstrated high levels of control efficacy against BMSB with one well-timed insecticide application.

ORGANIC INSECTICIDES

Experiments to evaluate the efficacy of 13 organic insecticides against nymphal and adult stages of the BMSB were conducted in Maryland in 2013. Based on overall percent reduction relative to the untreated control, insecticides providing over 80 percent control of early nymphs were:

- Spinosad + potassium salts of fatty acids
- Azadirachtin + pyrethrins + potassium salts of fatty acids
- Spinosad
- Azadirachtin

Efficacy from these same materials against late-instar nymphs ranged between 65 and 74 percent control. None of the treatments significantly suppressed adults.



Late Instar BMSB Nymph. Gary Bernon, USDA APHIS, Bugwood.org

BIOLOGICAL CONTROL

Various natural enemies have been observed feeding on BMSB. Chewing and sucking predators of BMSB (eggs and/or nymphs) include the big-eyed bug, robber flies, minute pirate bugs, praying mantis, larvae of soft-winged flower beetles, assassin bugs and various spiders, mainly jumping spiders. Mortality of BMSB eggs due to predation and other unknown causes reached 40–70 percent in soybean plots monitored in some northeastern states. In many instances, eggs were found sunken and discolored and failed to hatch. It is assumed that in most instances, sunken eggs are due to feeding from sucking predators. In other instances, it is believed that eggs which failed to hatch may have been attacked by parasitic wasps. Some local wasp species are known to lay their eggs inside BMSB eggs and, though their eggs may not develop into mature wasps and/or successfully emerge from BMSB eggs, they may still contribute to BMSB management by preventing BMSB eggs from developing.

Though parasitic wasps are known to use BMSB eggs as a host for depositing their eggs, rates of parasitism of BMSB eggs in which the wasp develops and emerges from BMSB eggs is generally low (< 5 percent). When compared with other stink bugs encountered in soybeans, such as the brown stink bug and rice stink bug, this percentage is especially low considering that parasitism of these species is in the upper 90 percent. However, the parasitic wasp, *Trissolcus japonicus* has been recently found in two sites in Maryland and one site in Virginia attacking BMSB eggs. This is a significant discovery, as this species of wasp, unlike some of the local parasitic wasps found attacking BMSB eggs, is native to Asia where BMSB originates. In its native habitat, this parasitoid is known to attack BMSB eggs at a high rate. If this wasp does get established in the United States and finds soybean and other agronomic crops suitable habitats for searching for BMSB eggs, it has the potential to be a significant contributor to the management of BMSB in soybean and other agronomic crops.

In addition to parasitic wasps, parasitic tachinid flies are known to parasitize adult stink bugs by laying their eggs on the stink bug body. After hatching, tachinid maggots feed internally in the stink bug body and then exit to pupate. Eggs of parasitic tachinid flies have been found on the exterior body of BMSB adults but have not been observed to successfully develop into maggots or kill BMSB adults. This suggests that BMSB is not a suitable host for these tachinid flies, but recently, there has been evidence that some adult tachinids found in West Virginia are capable of successfully using BMSB as a host for development to the adult stage. As local natural enemies become more adapted to BMSB, their contribution to BMSB management is expected to increase.

PROJECT SUMMARY

- BMSB feed on developing soybean pods and seed, resulting in quality and yield reductions.
- Under heavy infestations, BMSB feeding injury can result in stay green syndrome.
- Soybean fields in proximity to developed areas and those bordered by woods are at greatest risk for BMSB infestations.
- BMSB are not usually distributed evenly throughout soybean fields and are typically concentrated on field edges, rarely reaching the economic threshold within the field middles.
- A single, well-timed field-edge-only treatment can be successful in reducing BMSB populations below the economic threshold.
- Sampling for BMSB using a two-minute visual count is an effective and preferred method for determining the action threshold for BMSB in soybeans, especially in narrow-row fields.
- Scouting efforts should begin during the late R4 (pod elongation) to early R5 (seed development) growth stages.
- The best time to make an insecticide application is during the early R5 (seed development) growth stage to prevent seed quality and yield losses.
- The recommended threshold is 0.5 BMSB per linear foot of row or at least 3 BMSB per 15 sweeps or two-minute visual count.
- High levels of control can be achieved with a well-timed insecticide application of products in the following chemical classes: pyrethroid, carbamate, organophosphate and neonicotinoid/pyrethroid mixtures.
- Organic insecticides, such as spinosad + potassium salts of fatty acids, azadirachtin + pyrethrins + potassium salts of fatty acids, spinosad, and azadirachtin, are effective against BMSB nymphs, but none have been found to provide satisfactory control of adults.
- Various natural enemies have been observed feeding on BMSB in soybeans, including predators, both chewing and sucking, and egg parasitoids.



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