The IPM Practitioner
Monitoring the Field of Pest Management

IPM for the Brown Marmorated Stink Bug

By William Quarles

The brown marmorated stink bug (BMSB), *Halyomorpha halys*, is an invasive species native to China, Japan, and Korea. It was first noticed in Pennsylvania in the late 1990s and was established in Pennsylvania by 2001. Genetic analysis shows the initial U.S. introduction likely came from Beijing, China, possibly from shipping containers. Populations are growing exponentially, and it spreads by hitchhiking on shipping containers and vehicles. Adults can fly, which aids local dispersal (Hoebeke and Carter 2003; Nielsen et al. 2013; Lee et al. 2013; Xu et al. 2014).

From the original introduction, the pest has now spread in 13 years to 41 states and Canada (Lee et al. 2013; StopBMSB.org 2014). It appeared in Oregon in 2004, and has been in California since 2005. Large breeding populations have established near Los Angeles and Sacramento (Hoddle 2013; StopBMSB.org 2014; Ingels and Varela 2014).

H. halys will eat almost anything. It attacks more than 170 different plant species, and prefers to eat many of the same foods as humans, especially beans, garden vegetables, and tree fruit. It is a threat to commercial agriculture, landscape ornamentals, and backyard gardens. It is also a structural pest, as large populations invade houses, trying to overwinter (StopBMSB.org 2014; Lee et al. 2013; Inkley 2012).

More than $37 million damage was done to apples in the mid-Atlantic states in 2010. Growers reacted by a four fold increase in pesticide applications. Pesticides disrupted IPM programs and led to secondary outbreaks of mites, aphids, and scales in orchards (Leskey et al. 2012a).

The black pyramid trap, shown here, can be used to monitor brown marmorated stink bug populations. Bugs are attracted by aggregation pheromones at the top of the pyramid. *Photo courtesy B. Butler, Northeastern IPM Center, StopBMSB.org*

Most pyrethroids had limited effectiveness, as about one-third of the bugs recovered after knockdown. As a result, growers turned to endosulfan, methomyl, and neonicotinoids. Though more effective, these pesticides have environmental problems, including toxicity to bees (Leskey et al. 2012b; Funayama 2012; Quarles 2014a).

This article outlines an IPM program that will help control the brown marmorated stink bug (BMSB), while sparing beneficial insects and bees.

Why More Successful than Native Stink Bugs

We have many species of native stink bugs in the U.S. These have always been rather low level pests. The invasive *H. halys* is more successful due to lack of specific natural enemies, reproduction in large numbers, wide host range, resistance to cold weather, effective overwintering strategies, and increased survival due to global warming (Lee et al. 2013). At crop sites throughout the mid-Atlantic states, *H. halys* is now the predominant stink bug pest (Nielsen and Hamilton 2009ab).

Though there is some predation, our native parasitoids have not yet adapted to the pest. Reproduction is prolific, as one female can lay an average of 240 eggs per generation. *H. halys* overwinters as adults, emerging in spring to start feeding when temperatures exceed 17°C (63°F). Long daylight hours, warm temperatures, and food lead to sexual maturation

Adult, *H. halys*. *Photo courtesy Northeastern IPM Center, StopBMSB.org*

within about two weeks. In the Northeast there is one breeding generation a year, but two generations have been seen in West Virginia, and five generations a year are possible in tropical climates (Leskey et al. 2012a; Lee et al. 2013).

Survive Cold Weather

H. halys is more cold resistant than most stink bug species now living in the U.S. For example, mean winter temperatures of 4°C (39.2°F) will kill 81% of the southern green stink bug, *Nezara viridula*, but only 31% of *H. halys* (Kiritani 2006). U.S. spring populations of *H. halys* in 2014 were not reduced by the unusually cold winter of 2013 (StopBMSB.org 2014).

H. halys has effective overwintering strategies. Most U.S. stink bugs overwinter in weeds and crop debris. So crop sanitation and weed removal can discourage overwintering populations. But *H. halys* overwinters with a forest theme. It chooses leaf litter, crawls underneath tree bark, and can hide in wooded areas that make it more difficult to intercept. And hordes of *H. halys* invade structures to spend the winter in comfort (Lee et al. 2013).

Increased Survival from Global Warming

Global warming is contributing to the increase and spread of many pests. Pest ranges are spreading, and early springs increase the number of generations a year (Quarles 2007; IPCC 2013). Global warming may have contributed to increase and spread of *H. halys*. Temperatures in Japan and the U.S. have increased by nearly 1°C (1.8°F) over the last 100 years. When mean winter temperatures are averaging about 4°C (39.2°F), every 1°C (1.8°F) increase can increase winter survival rates of *H. halys* by about 16.5% (Kiritani 2006; 2007).

Stink Bug Damage

Adult bugs are about the size of a dime (see Box A), but they are way more than ten cents worth of trouble. *H. halys* sucks plant juices through a feeding stylet. Injection of saliva can cause enzymatic damage, brown spots, surface depression, and mealy consistency in apples. Individual kernels of sweet corn are destroyed. Bean pods are scarred and deformed. Grape berries are destroyed, and wine may be tainted. Though most damage is to fruit trees, greater than 20% damage has been seen in pepper, tomato, eggplant and okra (Leskey et al. 2012a). Damage to soybean includes deformed seeds, delayed maturity and reduced yields (Nielsen et al. 2011). *H. halys* can also vector diseases such as *Paulownia* witches' broom (Lee et al. 2013).

In the Northeast, adults of *H. halys* feed on apples both early and late in the season. Eggs are laid on apple, nymphs hatch, then walk away from apples to another host. After nymphs develop into winter adults in July and August, they fly back to feed on apples. Damage to apples at harvest can exceed 25% in New Jersey and more than 70% in Pennsylvania. Pears and peaches are also damaged (Nielsen and Hamilton 2009b; Leskey et al. 2012b).

In the Northeast, adults are first found in late April on ornamentals such as princess tree, *Paulownia tomentosa*, and crop hosts such as apple and pear. Egg laying starts at the end of May, and this coincides with the first appearance of adults in blacklight traps (see Monitoring below). Egg masses are seen by mid-June. Preferred hosts in July are viburnum and ash. Peak appearance in blacklight traps is in August, showing late season movement of fall adults to feeding sources (Nielsen and Hamilton 2009a). Pheromone traps also show peak populations in August (Weber et al. 2014).

H. halys feeds through bark on trees and ornamentals, leaving weeping holes of exudates. Martinson et al. (2013) found two-thirds of trees surveyed in Maryland had *H. halys* present, and about 15% of trees had exudates from feeding injuries. Native hymenoptera such as paper wasps, yellowjackets and ants feed on the injuries. This feeding can be viewed as good for native species, or if there are a lot of problems with yellowjackets, ants, and wasps as structural pests, a bad thing.

What Makes a Stink Bug Stink?

H. halys invades structures, and one of the problems is the odor produced. Stink bugs produce odorous secretions, probably to deter predators (Aldrich 1988; Millar 2005). The defensive secretions vary with each species, but often contain unsaturated aldehydes (Borges and Aldrich 1992; Noge et al. 2012). The major stink chemical of *H. halys* is (*E*)-2-decenal. It can be detected in concentrations of 0.3 micrograms per liter (Baldwin et al. 2014).

Stink bug defensive secretions can actually attract enemies such as spiders and parasitoids (Aldrich and Barros 1995; Mattiacci et al. 1993). As well as defensive secretions, stink bugs produce aggregation pheromones, and these may or may not have a noticeable odor (Weber et al. 2014). Aggregation pheromones are commercially available (see Resources), and are especially useful for monitoring and for attract and kill formulations (see Box B).

Monitoring

Monitoring can be done with pheromone traps or light traps, visual estimation, beat samples and sweep net samples (Leskey et al. 2012b; Lee et al. 2013; Nielsen et al. 2013; Nielsen and Hamilton 2009b).

Blacklight traps are useful to monitor for adult activity and mobility (see Resources). *H. halys* is more active at night, and males and females are equally attracted to light. White light

Box A. Biology of BMSB

Life stages are eggs, 5 nymphal instars, and adults. Females lay clusters of barrel shaped, white to light green eggs (1.6 mm) every 5–7 days on the underside of leaves. About 9–16 batches of eggs are laid over a 2–3 month period. Batch size averages about 28, and lifetime egg production ranges from 100–500, averaging about 240 (Lee et al. 2013; Medal et al. 2012; 2013; Hoebeke and Carter 2003).

Adult *H. halys* are about the size of a dime, approximately 17 mm (5/8 in) long. They have typical stink bug "shield" shape, and are almost as wide as they are long. Adults are marbled brown in color, antennae have white bands, and edges of the abdomen have alternating light and dark markings. Nymphs range from 2.5 to 12 mm (1/10 to 1/2 in), according to age of instar. Later instars have marbled brown bodies with red, black and white abdomen markings and white banded legs and antennae. Only adults have functional wings, so nymphs must walk everywhere they go (Ingels and Varela 2014; Jacobs 2014).

Nymph, *H. halys*. *Photo courtesy EPA*

Empty egg cases, *H. halys*. *Photo courtesy Wil Hershberger*

Eggs hatch in 4–5 days, and each nymphal instar lasts about a week, except the 5th instar continues for two weeks. Development from egg to adult is about 1.5 to 2 months. Adults live an average of about one year, and overwintering spring adults usually die after egg laying is completed (Lee et al. 2013).

Adults emerge in the spring, spend about two weeks feeding, then mate and start laying eggs at about the end of May. Eggs hatch in June and July, and fall adults have developed by August. Fall adults usually go into reproductive diapause and start looking for overwintering sites in September. These fall adults overwinter, emerge next spring, lay eggs and die in the summer. Life cycle of *H. halys* is determined by day length and temperature. In warmer areas, there can be two or more breeding generations each year (Lee et al. 2013; Medal et al. 2012; 2013).

attracts more *H. halys* than blue light. Blacklight populations can provide timing for taking beat samples (Nielsen et al. 2013; Leskey et al. 2012c).

Black pyramid traps baited with pheromones are useful monitoring tools, and they are commercially available (see AgBio Resources). [See photo on the front page.] Larger traps give better results than small ones, and placement on the ground is more effective than in a tree canopy (Leskey et al. 2012c).

Pyramids are about 1.22 m (4 ft) high, and on top is a 1.9 liter (2 qt) jar containing a lure (see Box B) and a killing strip of pesticide. In apples, traps were spaced 5 m (16.4 ft) from orchard edges, 20–25 m (65.6–82 ft) apart. The black pyramid shape is attractive probably because bugs mistake it for the trunk of a tree. Initial tests were done with MDT aggregation lures (see Box B). Attraction increased with the amount of MDT in the lures (Leskey et al. 2012c).

Beat samples are used for trees or woody shrubs. Limbs are tapped three times with a rubber bat at height of 1.5 to 3 m (5 to 9.8 ft). Startled insects drop into a canvas beat sheet 71 cm by 71 cm (28 in by 28 in) (see BioQuip Resources). One early season adult per 10 trees could result in economic damage. If first instar nymphs are found in beat samples, the tree should be visually inspected for egg masses (Nielsen and Hamilton 2009b).

Sweep nets are better than beat samples for monitoring soybeans (see Resources BioQuip). But large pyramid traps baited with aggregation pheromones can detect bugs earlier in the season than sweep net samples. Bugs move into soybean during critical bean development times. The full pod (R4) stage is most vulnerable, and 4 bugs per 0.3 m-row (4 per 1.0 ft-row) could cause economic damage (Nielsen et al. 2011; Owens et al. 2013).

Physical Barriers

Row covers could be effective in a garden situation. Sticky barriers around tree trunks could stop nymphs and many adults. Bags have been used to protect fruit, but this would be impractical for large orchards (Lee et al. 2013; Jacobs 2013). Netting has been used to protect houses (see below) (Watanabe et al. 1994).

Traps

Successful traps include light traps and pyramid traps. Light traps outside are mostly used for monitoring. Properly placed light traps inside may help with reduction of overwintering populations (see Sterling Resources). Pyramid traps are mostly used for monitoring, but the pheromone lures can be used to cause *H. halys* aggregations that can be destroyed by biopesticides (Leskey et al. 2012c).

Trap crops may be successful. Early maturing soybeans have been used as a trap crop to protect late season varieties (Lee et al. 2013). Fall planted triticale, crimson clover and vetch, and spring planted sunflower and buckwheat have been recommended as trap crops in the Southeast. Bugs can be removed with vacuums or sweep nets (Mizell 2014).

Boxes packed with straw, paper, or straw mats have been used as overwintering traps. Slit traps made of layered wood have also been used in this way (see below) (Watanabe et al. 1994; Lee et al. 2013).

Repellents

H. halys is repelled by essential oils. Clove, lemongrass, spearmint, and ylang-ylang oils are nearly 100% repellent. Wintergreen, geranium, and rosemary are 60–85% repellent. The aggregation pheromone of the spined soldier bug, *Podisus maculiventris*, is also repellent. The pheromone is a mixture of *alpha*-terpineol and (*E*)-2-hexenal (Aldrich et al. 2007; Zhang et al. 2013).

Though essential oils are repellent, they volatilize quickly and do not provide ongoing protection. Effectiveness might be improved with encapsulated, slow release formulations. Repellents might also be used in combination with *H. halys* aggregation pheromones in a "push pull" strategy to augment mass trapping or increase effectiveness of attract and kill formulations.

Biological Control

Biological control is an important component of brown marmorated stink bug IPM. Since they are not mobile, eggs are the most vulnerable stage of *H. halys*. Though eggs hatch within 4–5 days, females lay clusters about every 5–7 days, providing a continuous supply of eggs vulnerable to parasitoids and predators for at least 10–12 weeks (Medal et al. 2013).

Our native parasitoids have not yet adapted to *H. halys*, and parasitism rates are less than 5% (Aldrich et al. 2007). Classical biological control may provide a solution. The *H. halys* U.S. introduction likely came from Beijing (Xu et al. 2014). *Trissolcus halyomorphae* is an effective *H. halys* egg parasitoid from that area. Parasitism rates of 20–70%, averaging 50%, are common. The parasitoid overwinters as an adult, and its populations are synchronized with *H. halys*. The parasitoid produces 10 generations a year. Female to male ratios are about 5:1, and one female parasitizes all the eggs in a typical 28-egg BMSB cluster before moving on. *T. halyomorphae* is identical with *T. mitsukurii*, which is found in Japan (Yang et al. 2009).

Stink bugs produce stinky defensive secretions to deter predators. But birds eat nymphs and adults anyway (Ingels and Varela 2014). General predators such as lacewings, ladybugs, and pirate bugs, *Orius* sp. feed on *H. halys* eggs. Predation of *H. halys* eggs by spiders and bigeyed bugs, *Geocoris* sp. in Maryland soybeans can approach 50% (Leskey et al. 2012a). Many of the same predators attack our native stink bugs, following them from crop to crop (Tillman 2010; 2011).

Tachinid flies such as *Euclytia flava* are attracted by MDT aggregation pheromones. So pheromone monitoring can increase biocontrol when both tachinids and pests are drawn to the same areas (Aldrich et al. 2007).

Trissolcus halyomorphae*. Photo courtesy S. Valley. OR Dept. Ag.*

Biopesticides

Conventional management of BMSB is multiple applications of pesticides. However, of 37 pesticides tested, residues of about one-third killed less than 50% of the bugs. Pyrethroids tend to knock them down, but many bugs recover within 7 days (Leskey et al. 2012e).

Biopesticides may be just as effective as more toxic or environmentally destructive materials. As well as mortality, they can have valuable sublethal effects. Neem (azadirachtin) formulations act as antifeedants and may decrease fecundity. Pyrethrins are repellent and can be lethal (Lee et al. 2013). The combination of neem and pyrethrins (Azera™) can be used in organic agriculture (Jacobs 2014).

Chitin synthesis inhibitors such as novaluron and diflubenzuron are not effective against eggs or adults, but will kill nymphal stages. Sprays applied during June and July will target developing nymphs (Kamminga et al. 2012).

Some microbial biopesticides show promise (Quarles 2013). *Chromobacterium* sp. (Grandevo®) (see Marrone Resources) is more effective than the pyrethroid esfenvalerate and many other conventional pesticides (Leskey et al. 2012d). Laboratory tests of *Chromobacterium* showed 100% mortality against the southern green stink bug, *Nezara viridula* (Martin et al. 2007).

The Japanese fungus, *Ophiocordyceps nutans*, specifically attacks stink bugs (Sasaki et al. 2012). Fungi such as *Beauveria bassiana* or *Metarhizium anisopliae* are effective against *H. halys* (see Resources). Lab tests showed several isolates of *B. bassiana*, including a commercial formulation (Botanigard™) gave 100% mortality to *H. halys*. Isolates of *M. anisopliae* produced about 85% mortality. MET52™ is a commercial formulation of *M. anisopliae* (see Resources) (Gouli et al. 2012).

Pesticide Reductions

In soybeans *H. halys* accumulates on field edges. Spraying only the periphery reduces pesticide use by 85%, while retaining effectiveness. Most of the damage done in apples and sweet corn is also done in outer rows (Leskey et al. 2012ac).

Spray reductions may result from a knowledge of *H. halys* behavior. Adults fly up to the trunk of a tree, then walk up the trunk into the canopy. Since nymphs have no wings, they also walk into the canopy. Banding tree trunks with pesticides or sticky barriers could reduce the amount of pesticides applied. Pyramid traps baited with aggregation pheromones may also be used to lure the pest to discreet locations, reducing applied pesticides (Leskey et al. 2012ac).

Leskey et al. (2012c) baited trees with aggregation pheromones to reduce pesticide applications. Nine trees in a border row were baited with pheromones, then pesticides were used to destroy the bugs.

At temperatures of 21°C (70°F) or less, Li et al. (2007) achieved an 88% reduction in pesticides applied to trees by beating trees with sticks, causing BMSB to drop to the ground. Pesticides were then applied to bugs on the soil.

Organic Home Gardens

H. halys will eat tomatoes, corn, beans and other garden vegetables. It will also feast on apples, peaches and pears. Shade trees and roses are part of the menu. A list of 170 host plants can be found at the website StopBMSB.org. If there are large populations overwintering in your neighborhood, you may have to use row covers. Row covers of lightweight polyester or polypropylene will protect crops, but you will have to remove them to allow pollination (Nielsen and Hamilton 2009a; Ingels and Varela 2014).

Fruit tree protection is difficult, but BMSB prefers to fly up to the trunk of a tree, then walk up the trunk into the canopy (Leskey et al. 2012c). Sticky barriers around the trunk might stop nymphs and adults from climbing. Applying a 1 ft wide (30 cm) band of natural pyrethrins around the trunk might also prevent colonization. Ultimately, this approach may fail if adults adapt their behavior and fly directly into the canopy.

Destroy egg masses on the underside of leaves starting in June. Hand pick bugs and drop into soapy water or use a hand held vacuum cleaner to remove them from plants (Ingels and Varela 2014).

As usual, providing floral resources for natural enemies such as lacewings, parasitoids and ladybugs to encourage biocontrol is worthwhile (Quarles 2014a).

Box B. Aggregation Pheromones

A late season attractant for *H. halys* is the aggregation pheromone of the related stink bug, *Plautia stali*. This pheromone, methyl (*E*,*E*,*Z*)-2,4,6 decatrienoate (MDT), is useful for late season monitoring and mass trapping of *H. halys*. The pheromone also attracts other stink bugs, and acts as a kairomone, attracting stink bug natural enemies, such as tachinids and wasps (Cottrell et al. 2014; Aldrich et al. 2009; Aldrich et al. 2007; Khrimian et al. 2008). The *P. stali* pheromone (MDT) is used in the commercial pyramid trap sold by AgBio (see Resources).

Addition of murgantiol (10,11-epoxy-1-bisabolen-3-ol), the aggregation pheromone of the harlequin bug, *Murgantia histrionica*, makes the *P. stali* pheromone more attractive to BMSB earlier in the season. Sterling Intl. (see Resources) uses this combination for a commercial monitoring trap (Zhang et al. 2013; Zhang et al. 2014ab).

Natural Pheromone

The USDA has recently isolated the true aggregation pheromone secreted by *H. halys* adult males. A major component is (3*S*,6*S*,7*R*,10*S*)-10-11-epoxy-1-bisabolen-3-ol (SSRS). This is related to 1,10-bisaboladien-3-ol (zingiberenol) which occurs in ginger, *Zingiber officinale* (Weber et al. 2014).

A minor component is (3*R*,6*S*,7*R*,10*S*)-10,11-epoxy-1-bisabolen-3-ol (RSRS). The SSRS to RSRS ratio in the natural pheromone is 3.5 to 1. Donald Weber of the USDA tested the *H. halys* pheromone and found mixtures of these two components attract and capture both *H. halys* adults and nymphs (Weber et al. 2014).

Addition of the *H. halys* pheromone to MDT is synergistic, and the combined mixture (COMB) is attractive throughout the year. The combined lure catches 3–4 times more adults and 2–4 times more nymphs than MDT alone. COMB is attractive to spring adults, fall adults, and nymphs. Field tests showed the first *H. halys* adults appeared in April, and largest numbers of adults and nymphs were found in August (Weber et al. 2014).

COMB makes it possible to monitor early season populations, establish economic thresholds for IPM, implement mass trapping, and produce attract and kill formulations. The all-season attractant is a giant step toward effective, reduced risk IPM management of BMSB.

Pheromone Traps in Gardens

Pheromone traps (see Resources) may give early warning, but if populations are large, trap spillover may lead to plant damage. Sargent et al. (2014) found that pheromone traps led to increased bug colonization and increased damage in Maryland tomatoes. Traps were placed near tomato plants. About 300 bugs were caught in each trap, but bugs aggregated near the trap, damaging plants nearby and up to 6 m (18 ft) away.

If you use pheromone traps in your garden, you should space them away from desirable plants. The traps will give you early warning, but you must be prepared to vacuum up the trap spillover, or kill the bugs with least-toxic pesticides such as (Azera®).

House Invasions

Brown marmorated stink bugs are rude guests, as they eat your garden and then move in with you. Some houses have seen more than 25,000 bugs invade. These bugs fly toward lights, colliding with people. Fortunately, the bugs do not reproduce or feed while overwintering. They do not bite or carry diseases, but they produce unpleasant smells when crushed, and fill a house with excrement. Proteins associated with the bugs can cause allergies (Inkley 2012; Mertz et al. 2012).

Reproduction is prolific. If your house is invaded by 25,000 *H. halys*, this group of bugs could produce a summer population of almost three million in the immediate vicinity of your home (Lee et al. 2013; Kawada and Kitamura 1983).

Overwintering bugs like to hide in dark, tight places. Attics are favorite hideaways. Inkley (2012) found about 60% of the invading population was in the attic. The rest were captured in the living space. Bugs may hide in cracks and crevices along baseboards, door and window trim, and in light fixtures (Toyama et al. 2011; Ingels and Varela 2014).

Exclusion Is Best

The best approach is exclusion. Pay especial attention to the side of the house facing the sunset. Caulk up all holes, and make sure that window screens fit tightly. Pay attention to sealing around window air conditioners. Cover attic and foundation vents with screens. Make sure the chimney is protected with a screen. Weather-strip doors, and make sure each one has functional door sweep (Ingels and Varela 2014).

In Japan, boxes filled with straw,

***H. halys* damages apples.** *Photo courtesy J. Oberg, MD Dept. Ag.*

paper, or straw mats are used as traps outside to attract overwintering bugs. They also use special "slit" traps of layered pieces of plywood. Bugs crawl into the slits cut between the boards and are trapped. One 90 x 90 cm (36 by 36 in) slit trap placed on the ground trapped 2693 bugs (Watanabe et al. 1994).

Near complete exclusion was achieved by covering exterior walls with 1 cm (0.4 in) mesh netting treated with pyrethroids. Deet repellent around windows also helped exclude bugs (Watanabe et al. 1994). Deet also repels the ladybug, *Harmonia axyridis*, another structural invader (Riddick et al. 2004). In the U.S., pheromone traps are available for use outside that attract overwintering bugs, reducing the number of invaders (see Sterling Resources).

Do Not Use Pesticides Inside

If they get inside your living space, do not use foggers. Any that you kill will just be replaced by others crawling from wall voids. If pesticides are applied to kill populations in wall voids, large numbers of dead bugs may attract flies and carpet beetles (Jacobs 2014).

The best approach is to use a vacuum cleaner to remove them from your living space. Bugs can give a vacuum cleaner an odor, so having an old one just for this purpose is the best idea. Bugs can be killed by dropping them into soapy water. Live bugs should not be dropped into garbage. Bugs inside are attracted to a light trap. These are commercially available (see Sterling Resources). Or you can use a desk lamp over a pan of soapy water as a trap (StopBMSB.org 2014).

Conclusion

The BMSB invasion will likely increase and spread. The invasive pest is favored by prolific reproduction, wide host range, lack of specific natural enemies, cold tolerance, global warming, and overwintering skills. There can be a short lag time between initial invasion and population explosions. Monitoring is extremely important, and pheromone monitoring can now give an early warning.

Biological control of eggs is a promising approach. Predators in the U.S. are effective, but parasitoids have not adapted. Importation of a more effective egg parasitoid may be necessary. Biopesticides are available that can help manage populations without killing bees. Special techniques such as banding trees, using aggregation pheromones in attract and kill formulations, and spraying perimeters of row crops and orchards can reduce amount of pesticide applied. Overwintering traps and efficient exclusion can reduce the impact of BMSB inside houses. The brown marmorated stink bug is not going to go away, but IPM techniques can limit the damage.

Acknowledgement

The author wishes to thank Erin Berg for helping with the research on this article.

William Quarles, PhD, is an IPM Specialist, Managing Editor of the *IPM Practitioner*, and Executive Director of the Bio-Integral Resource Center (BIRC). He can be reached by email at birc@igc.org.

References

Aldrich, J.R. 1988. Chemical ecology of the Heteroptera. *Annu. Rev. Entomol.* 33:211–238.

Aldrich, J.R. and T.M. Barros. 1995. Chemical attraction of male crab spiders and kleptoparasitic flies. *J. Arachnol.* 23(3):212–214.

Aldrich, J.R., A. Khrimian, X. Chen et al. 2009. Semiochemically based monitoring of the invasion of the brown marmorated stink bug and unexpected attraction of the native green stink bug in Maryland. *Fla. Entomol.* 92(3):483–491.

Aldrich, J.R., A. Khrimian and M.J. Camp. 2007. Methyl 2,4,6-decatrienoates attract stink bugs and tachinid parasitoids. *J. Chem. Ecol.* 33(4):801–815.

Baldwin, R.L., A. Zhang, S.W. Fultz et al. 2014. Hot topic: brown marmorated stink bug odor compounds do not transfer into milk by feeding bug-contaminated corn silage to lactating dairy cattle. *J. Dairy Sci.* 97:1877–1884.

Borges, M. and J.R. Aldrich. 1992. Instar-specific defensive secretions of stink bugs (Heteroptera: Pentatomidae). *Experentia* 48:893.

Cottrell, T.E., P.J. Landolt, Q.H. Zhang et al. 2014. A chemical lure for stink bugs is used as a kairomone by *Astata occidentalis*. *Fla. Entomol.* 97(1):233–237.

Funayama, K. 2012. Control effect on the brown marmorated stink bug, *Halyomorpha halys*, by combined spraying of pyrethroid and neonicotinoid insecticides in apple orchards in Northern Japan. *Appl. Entomol. Zool.* 47:75–78.

Gouli, V., S. Gouli, M. Skinner et al. 2012. Virulence of select entomopathogenic fungi to the brown marmorated stink bug, *Halyomorpha halys*. *Pest Man. Sci.* 68(2):155–157.

Hoebeke, E. R. and M.E. Carter. 2003. *Halyomorpha halys*: a polyphagous plant pest from Asia newly detected in North America. *Proc. Entomol. Soc. Wash.* 105(1):225–237.

Hoddle, M. 2013. Pheromone trapping program for the brown marmorated stink bug. Blog, U.C. Riverside, June 17, 2013.

Ingels, C. and L. Varela. 2014. Brown marmorated stink bug. Pest Notes, Pub. 74169, University of California Statewide IPM. 4 pp.

Inkley, D.B. 2012. Characteristics of home invasion by the brown marmorated stink bug. *J. Entomol. Sci.* 47(2):125–130.

IPCC. 2013. *Climate Change 2013: Summary for Policy Makers.* T.F. Stocker, D. Qin, G.-K. Plattner et al. eds. Online and Cambridge Univ. Press, UK and New York.

Jacobs, S. 2014. Brown marmorated

stink bug, *Halyomorpha halys*. Penn State Coop Extn. 4 pp.

Joseph, S.V., J.C. Bergh, S.E. Wright and T.C. Leskey. 2013. Factors affecting captures of brown marmorated stink bug, *Halyomorpha halys*, in baited pyramid traps. *J. Entomol. Sci.* 48(1):43–51.

Kamminaga, K.L., T.P. Kuhar, A. Wimer et al. 2012. Effects of insect growth regulators novaluron and diflubenzuron on the brown marmorated stink bug. Online. *Plant Health Prog.* Doi:10.1094/PHP-2012-1212-01-RS.

Kawada, H. and C. Kitamura. 1983. The reproductive behavior of the brown marmorated stink bug, *Halyomorpha mista. Appl. Ent. Zool.* 18(2):234–242.

Khrimian, A., P.W. Shearer, A.J. Zhang et al. 2008. Field trapping of the invasive brown marmorated stink bug, *Halyomorpha halys*, with geometric isomers of methyl 2,4,6-decatrienoate. *J. Agric. Food Chem.* 56(1):197–203.

Kiritani, K. 2006. Predicting impacts of global warming on population dynamics and distribution of arthropods in Japan. *Popul. Ecol.* 48:5–12.

Kiritani, K. 2007. The impact of global warming and land use change on the pest status of rice and fruit bugs in Japan. *Global Change Biol.* 13:1586–1595.

Lee, D-H., B.D. Short, S.V. Joseph et al. 2013. Review of the biology, ecology, and management of *Halyomorpha halys* in China, Japan, and the Republic of Korea. *Environ Entomol.* 42(4):627–641.

Leskey, T. C., G.C. Hamilton, A.L. Nielsen et al. 2012a. Pest status of the brown marmorated stink bug, *Halyomorpha halys* in the USA. *Outlooks Pest Man.* 23(5):218–226.

Leskey, T.C., B.D. Short, B.R. Butler et al. 2012b. Impact of the invasive brown marmorated stink bug, *Halyomorpha halys*, in mid-Atlantic tree fruit orchards in the United States: case studies of commercial management. *Psyche 2012*: Article ID 535062.

Leskey, T.C., S.E. Wright, B.D. Short, et. al. 2012c. Development of behaviorally based monitoring tools for the brown marmorated stink bug in commercial tree fruit orchards. *J. Entomol. Sci.* 47(1):76–85.

Leskey, T.C. 2012d. Emergence of the brown marmorated stink bug, *Halyomorpha halys*, as a serious pest of agriculture. USDA Appalachian Fruit Research Station, Kearneysville, WV. 75 pp.

Leskey, T.C., D.-H. Lee, B.R. Short et al. 2012e. Impact of insecticides on the invasive *Halyomorpha halys*: analysis of insecticide lethality. *J. Econ. Entomol.* 105(5):1726–1735.

Li, X., X.-Y. Yin, L. Ma et al. 2007. *Halyomorpha halys* behaviors and application for their control. *J. Northwest Agric. and For. Univ.* (Nat. Sci. Edition) 35(10:139–145. [CAB Abstracts]

Martin, P.A.W., E. Hirose and J.R. Aldrich. 2007. Toxicity of *Chromobacterium subtsugae* to southern green stink bug and corn rootworm. *J. Econ. Entomol.* 100(3):680–684

Martinson, H.M., M.J. Raupp, and P.M. Shrewsbury. 2013. Invasive stink bug wounds trees, liberates sugars, and facilitates native hymenoptera. *Ann. Entomol. Soc. Am.* 106(1):47–52.

Mattiacci, L., S.B. Vinson, H.J. Williams, J.R. Aldrich et al. 1993. A long range attractant kairomone for egg parasitoid *Trissolcus basalis*, isolated from defensive secretions of its host, *Nezara viridula. J. Chem. Ecol.* 19(6):1167–1181.

Medal, J., T. Smith, A. Fox et al. 2012. Rearing the brown marmorated stink bug *Halyomorpha halys. Fla. Entomol.* 95(3):800–802.

Medal, J., T. Smith, and A. Santa Cruz. 2013. Biology of the brown marmorated stink bug *Halyomorpha halys* in the laboratory. *Fla. Entomol.* 96(3):1209–1212.

Mertz, T.L., S.B. Jacobs, T.J. Craig et al. 2012. The brown marmorated stink bug as a new aeroallergen. *J. Allergy Clin. Immunol.* 130(4):999–1001.

Millar, J.G. 2005. Pheromones of true bugs. *Top. Curr. Chem.* 240:37–84.

Mizell, R.F., III. 2014. Stink bug management using trap crops in organic farming. eOrganic, online. www.extension.org

Nielsen, A.L. and G.C. Hamilton. 2009a. Life history of the invasive species *Halyomorpha halys. Ann. Entomol. Soc. Am.* 102(4):608–616.

Nielsen, A.L. and G.C. Hamilton. 2009b. Seasonal occurrence and impact of *Halyomorpha halys* in tree fruit. *J. Econ. Entomol.* 102(3):1133–1140.

Nielsen, A.L., G.C. Hamilton and P.W. Shearer. 2011. Seasonal phenology and monitoring of the non-native *Halyomorpha halys* in soybean. *Environ. Entomol.* 40(2):231–238.

Nielsen, A.L., K. Holmstrom, G.C. Hamilton et al. 2013. Use of blacklight traps to monitor the abundance, spread, and flight behavior of *Halyomorpha halys. J. Econ. Entomol.* 106(3):1495–1502.

Noge, K., K.L. Prudic and J.X. Becerra. 2012. Defensive roles of (*E*)-2-alkenals and related compounds. *J. Chem. Ecol.* 38:1050–1056.

Owens, D.R., D.A. Herbert, Jr., G.P. Dively et al. 2013. Does feeding by *Halyomorpha halys* reduce soybean seed quality and yield? *J. Econ. Entomol.* 106(3):1317–1323.

Quarles, W. 2007. Global warming means more pests. *IPM Practitioner* 29(9/10):1–8.

Quarles, W. 2013. New biopesticides for IPM and organic production. *IPM Practitioner* 33(7/8):1–9.

Quarles, W. 2014a. Neonicotinoids, bees, birds, and beneficials. *Common Sense Pest Control Quarterly* 28(1–4):3–10.

Quarles, W. 2014b. IPM for Asian citrus psyllid and huanglongbing disease. *IPM Practitioner* 34(1/2):1–7.

Riddick, E.W., J.R. Aldrich and J.C. Davis. 2004. DEET repels *Harmonia axyridis* adults in laboratory bioassays. *J. Entomol. Sci.* 39(3):373–386.

Sargent, C., H.M. Martinson and M.J. Raupp. 2014. Traps and trap placement may affect location of brown marmorated stink bug and increase injury to tomato fruits in home gardens. *Environ. Entomol.* 43(2):432–438.

Sasaki, F., T. Miyamoto, A. Yamamoto et al. 2012. Relationship between intraspecific variations and host insects of *Ophiocordyceps nutans* collected in Japan. *Mycosci.* 53:85–91.

StopBMSB.org. 2014. Stop Brown Marmorated Stink Bug Website. www.stopbmsb.org

Tillman, P.G. 2010. Parasitism and predation of stink bug eggs in Georgia corn fields. *Environ. Entomol.* 39(4):1184–1194.

Tillman, P.G. 2011. Natural biological control of stink bug eggs in corn, peanut, and cotton farmscapes in Georgia. *Environ. Entomol.* 40(2):303–314.

Toyama, M., F. Ihara, and K. Yaginuma. 2011. Photo-response of the brown marmorated stink bug, *Halyomorpha halys*, and its role in the hiding behavior. *Appl. Entomol. Zool.* 46(1):37–40.

Watanabe, M., R. Arakawa, Y. Shinagawa et al. 1994. Anti-invading methods against the brown marmorated stink bug, *Halyomorpha mista*, in houses. *Japanese J. Sanit. Zool.* 45(4):311–317.

Weber, D.C., T.C. Leskey, G. Cabrera-Walsh and A. Khrimian. 2014. Synergy of aggregation pheromone with methyl (*E,E,Z*)-2,4,6-decatrienoate in attraction of *Halyomorpha halys. J. Econ. Entomol.* 107(3):1061–1068.

Xu, J.W., D.M. Fonseca, G.C. Hamilton et al. 2014. Tracing the origin of US brown marmorated stink bugs, *Halyomorpha halys. Biol. Invasions* 16(1):153–166.

Yang, Z.-Q., Y.-X. Yao, L.-F. Qiu et al. 2009. A new species of Trissolcus (Hymenoptera: Scelionidae) parasitizing eggs of *Halyomorpha halys* in China with comments on its biology. *Ann. Entomol. Soc. Am.* 102(1):39–47.

Zhang, Q.-H., R.G. Schneidmiller, D.R. Hoover et al. 2013. Essential oils as spatial repellents for the brown marmorated stink bug. *J. Appl. Entomol.* 4 Dec 2013. Online

Zhang, Q.-H., R.G. Schneidmiller, G. Zhou and D.R. Hoover. 2014a. Murgantiol as an indoor stink bug attractant. U.S. Patent No. 8,663,619, March 4, 2014.

Zhang, Q.-H., R.G. Schneidmiller, G. Zhou and D.R. Hoover. 2014b. Murgantiol as a synergistic attractant for use outdoors. U.S. Patent No. 8,663,620, March 4, 2014.

Stop BMSB.org

This reprint was produced in partnership between the Bio-Integral Resource Center and the Northeastern IPM Center, December 2014. USDA-NIFA SCRI Coordinated Agricultural Project, grant #2011-51181-30937.

Resources

Beauveria (Botanigard®)—Laverlam International, 117 South Parkmont, PO Box 4109, Butte, MT 59702; 406/782-2386. Fax 406/782-9912; www.laverlamint.com. BioWorks Inc., 100 Rawson Road, Suite 205, Victor, NY 14564; 800/877-9443, 585/924-4362, Fax 800/903-2377; www.bioworksinc.com

Chromobacterium (Grandevo®)—Marrone Bio Innovations, 2121 Second St., Suite B-107, Davis, CA 95618; 877/664-4476, 530/750-2800; www.marronebioinnovations.com

Indoor Light Trap—Sterling International, Inc., 3808 N. Sullivan Rd., Bldg 16, Spokane, WA 99216; 800/666-6766, 509/926-6766, Fax 509/928-7313; www.rescue.com

Metarhizium (MET52®)—Novozymes Biologicals, 77 Perry Chapel Church Rd., Franklinton, NC 27525; 919/494-3000, Fax 919/494-3450; www.novozymes.com

Neem plus pyrethrins (Azera®)—MGK Company, 8810 10th Avenue North, Minneapolis, MN 55427; 800/645-6466, 763/544-0341, Fax 763/544-6437; www.mgk.com

Pheromone Baited Black Pyramid Trap (Dead Inn™)—AgBio Inc., 9915 Raleigh St., Westminster, CO 80031; 877/268-2020, 303/469-9221, Fax 303/469-9598; agbio-inc.com

Pheromone Lures—Trécé Inc., PO Box 129, Adair, OK 74330; 866/785-1313, 918/785-3061, Fax 918/785-3063; www.trece.com

Pheromone Trap—Sterling, see above

Sweep Nets, Beat Sheets, Black Lights—BioQuip Products, 2321 Gladwick Street, Rancho Dominguez, CA 90220; 310/667-8800, Fax 310/667-8808; www.bioquip.com

Sticky Barriers (Tanglefoot®)—Contech Enterprises, 7572 Progress Way, Delta, BC, Canada V4G 1E4; 604/940-9944, Fax 604/940-9433; www.contech-inc.com