A New Threshold-Based Management Tool for Brown Marmorated Stink Bug in NY

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Over the past eight years, the invasive Brown Marmorated Stink Bug (BMSB), Halyomorpha halys (Stål), has become an important urban and agricultural pest in New York State. The BMSB arrived in the US in the mid-1990s, with the first documented specimen collected in 1998 from Allentown, PA. Since then, through flight and human transport, the pest made its way to NY in 2007 (Hoebeke and Carter 2003). Although the insect prefers an arboreal habitat, we do find very high aggregations in agricultural and urban areas during various times of the year. Although woodland tree species provide ample nutritional and reproductive resources, movement of BMSB out of the forest in the late summer and fall is often associated with drought and the need for intensive late season feeding of the adults as they transition to overwintering shelters. Migrant BMSB seek out dry structures such as storage barns, residential and commercial buildings in the urban setting, as well as the upper canopy of deciduous forest trees, beneath shedding bark or limb hollows.

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As an arboreal insect, the BMSB prefers deciduous trees, yet having a broad host range, it utilizes over 300 plant species in its native range and 170 wild, ornamental and agricultural hosts, according to surveys conducted over the past 15 years (Neilson 2009; Northeastern IPM Center 2015). Of interest is its preference for establishing in the Asian "Tree of Heaven", Ailanthus altissima. The clustered seedpods of this tree provide a humid niche, protection from predators, and food for developing nymphs. While adults can be found feeding on leaves and stems of the tree throughout the season, they will move from Ailanthus to other host plants if there is not sufficient moisture and sap quality. It is believed that the insect has two generations in the Hudson Valley of New York (Figure 1).

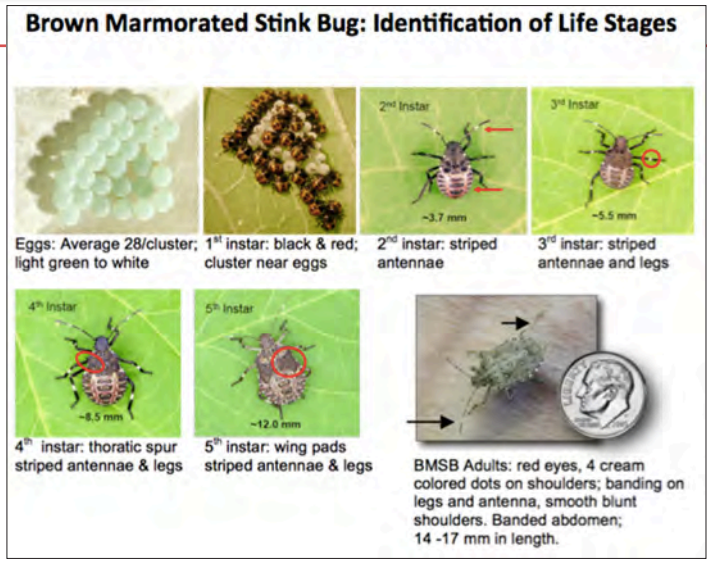

Figure 1. Life stages of the BMSB.

Urban-Based Citizen Science Study

Since the first NY observance of BMSB in suburban homes outside of NYC, it became apparent that monitoring its spread across NYS could effectively be conducted if NY homeowners assisted in determining its urban spread within the state. With this in mind, a Citizen Science Study (CSS) was developed to document the presence and spread of BMSB in New York's urban environment beginning in the fall of 2011. The CSS began by providing articles on BMSB to regional print and digital media news centers. The insect description included images and video for readers to review and use in participating in our request for specimens. Homeowners responded through submissions of "live" insects in 2012, followed by "iPhone" and digital specimen images for simplified submission, identification and mapping. Digital news media distribution throughout the Hudson Valley was further amplified through media replication to other NY regions who "picked up the story" and expanded our reach.

The first of 17 featured articles, including a Westchester-based news center, LoHud Patch, provided a BMSB video, plus a poll for Westchester County residents, in which 90% of 757 participants who responded stated seeing the insect in their homes. In all, we received over 800 specimens, verifying 540 BMSB of both live and digital submissions, from 87 distinct zip code locations in 38 NYS counties. When CSS participants were queried by email in the spring of 2012, 57% of NY respondents perceived increases in the adult BMSB overwintering populations moving into their home, compared with the 2010–2011 fall migrations. Hudson Valley participants perceived a 71% increase over the previous year (n = 62). Two websites, iMapinvasives.org and EDDMapS.org, display specimen location by county and individual site using GPS lat/long data.

BMSB as an Agricultural Pest

Agricultural plant hosts of economic importance utilized by the pest include jalapeño and bell pepper, soybean, sweet corn, apple, pear, peach, and cherry. These crops provide reproductive habitat and food availability from mid-spring until BMSB

prepare to enter overwintering sites. Damage by BMSB to their host plant results from their stylet-type mouthparts, which are designed to pierce and penetrate various plant tissues such as bark, corn husks and newly formed hazelnut and peach fruits. The insect removes cellular fluids as it feeds through the surface, skin, leaf, stem, and fruit of its host plant. In tree fruit such as peach, BMSB feeding initially causes the death of fruit cells that in spring can cause abscission of the peach shortly after fruit set. As more mature fruit are fed upon, the feeding location becomes evident over a 1–2-week period, resulting in surface depressions, skin darkening and brown corking beneath the skin at the feeding site (Figure 2). Late season BMSB activity can also result in deposits of distasteful aldehyde compounds, which produce odor in the fruit and act as a skin irritant. Mid-Atlantic fruit pickers experienced this phenomenon in 2010 during harvest, resulting in severe eye and skin irritations, much like a burn in those with a high sensitivity to the chemical.

Subsequently, feeding by BMSB results in unmarketable fruit in most fresh market crops, especially in peach, providing limited processing options near harvest. In 2010, the insect was responsible for pome fruit injury in the mid-Atlantic growing region estimated to exceed $26 million. By 2012, BMSB populations had increased dramatically in the Hudson Valley fruit-growing region. Late season conditions were favorable for the pest to build to very high numbers, with the development of a second generation and migration to orchards in late August (Figure 3). Late season feeding injury exceeded 20% crop loss in blocks of Pink Lady, Golden and Red Delicious apples in Ulster, Dutchess and Orange Counties in the Hudson Valley.

Agricultural Monitoring of BMSB

To determine the presence and potential threat of BMSB in NY's agricultural systems, pheromone-based trapping efforts have become the standard method to determine woodland edge populations of BMSB. In coordinated efforts by Cornell University faculty and Cornell Cooperative Extension, Lake Ontario Fruit Team members in Eastern and Western NY, ENY Commercial Horticulture Program Team members, and Long Island CCE faculty and staff, this pest has been monitored statewide since 2011. In 2015, county-based monitoring for statewide BMSB mapping included 44 sites in 14 counties, primarily in tree fruit orchards and vegetable field edges (Figure 4). Trap captures of BMSB were followed up by visual scouting along the perimeter rows of the orchards and field crop wooded edges.

BMSB IPM

FQPA regulations, combined with recent advances in mating disruption and development and use of "Reduced Risk" and "soft insecticides", have provided greater safety to agricultural workers, the environment, and preservation of biological control organisms to suppress pest populations. All these elements have become very important components of northeast fruit production.

One of the cornerstones of IPM in tree fruit production includes scouting for insects to determine pest presence. However, the adult BMSB is skittish, very mobile, and avoids encounters by taking flight or moving between fruit or behind leaves. The nymph is less mobile and much

Figure 2. BMSB damage to Red Delicious apple.

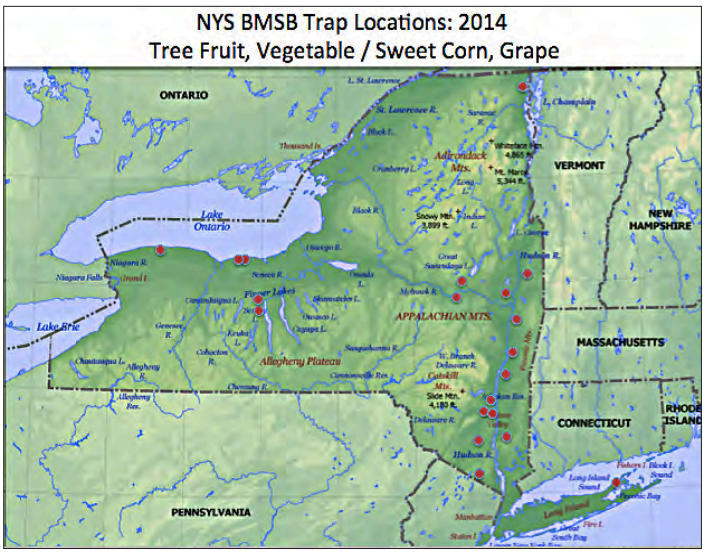

Figure 3. BMSB generations in the Hudson Valley of NYS.

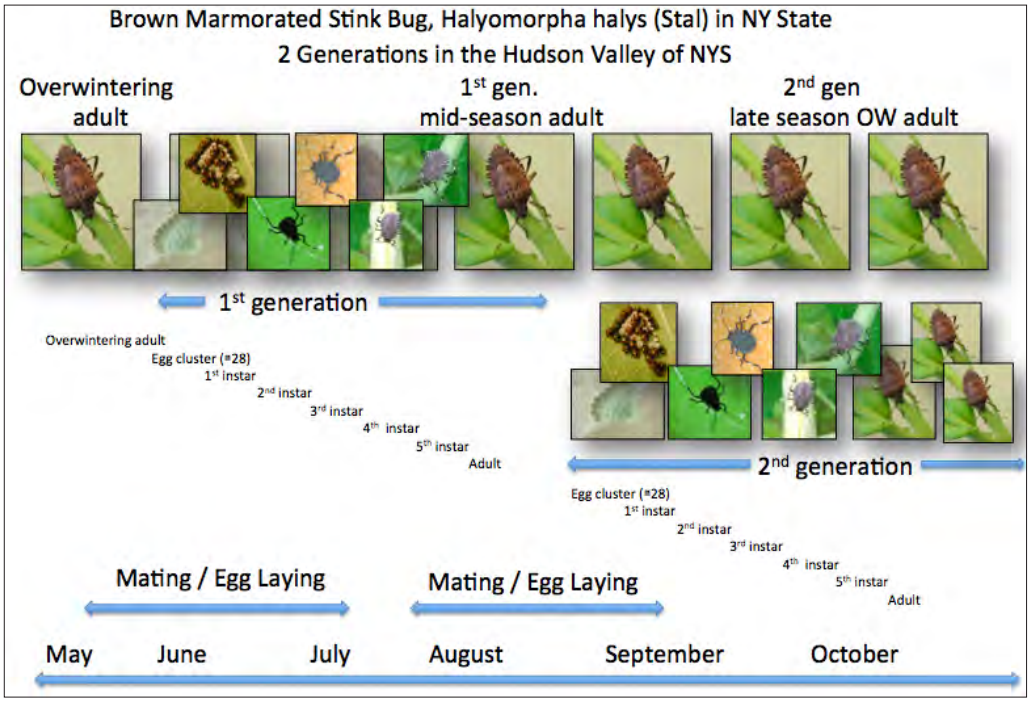

Figure 4. 2015 NYS agricultural BMSB pheromone trap sites.

easier to see. Once in the orchard, the insect tends to move to the upper canopy, where most feeding takes place. Scouting to determine adult presence and density is difficult until the pest migrates into agricultural crops in higher numbers. In other words, use of scouting for early adult presence, when it is needed, appears to be relatively ineffective.

Another tenet of IPM is the use of economic injury thresholds as a trigger for a management decision. This requires observational assessment of fruit injury, using percent damage correlated with crop value. Upon reaching an economic threshold, treatment with an effective insecticide is critical to prevent further injury. One of the difficulties in managing this insect is the ability of both nymphs and adults to cause feeding injury, as all but the 1st instar will feed on fruit. Upon insertion of its stylet to feed, the BMSB will remove fruit cell contents and cause cell death. The discoloration, depression and corking associated with feeding requires 7–21 days for expression, while the feeding site itself is nearly impossible to see without magnification. If economic assessments of injury are used as a threshold, damage levels will be incorrectly interpreted. Increased damage and significant losses will follow well after feeding has ended; therefore, use of economic damage thresholds are not recommended.

Reducing the Risk

There are few insecticides effective enough to eliminate BMSB from the orchard while possessing the residual activity needed to keep the pest at bay for more than just a few days. During years when populations are high and drought conditions prompt continued BMSB migration, the use of management programs on tight spray intervals of 3–7 days would be required to maintain a marketable crop. This is especially true beginning in late August and through to harvest. However, label restrictions, including Pre-Harvest Intervals (PHIs), limit their frequency and the close intervals required for control.

Of the few materials effective against the BMSB, the majority fall into the older and more disruptive classes of insecticides that include the pyrethroids, organophosphates or carbamates. Over the past two seasons, we have been able to obtain a Section 18 Emergency Exemption in apples for a highly effective pyrethroid, bifenthrin, which was submitted again in 2015 and expanded to four counties, including Columbia County. However, for early harvested varieties, bifenthrin can only be used once per season, given its 30-day PHI. Replicated field trials have shown only a limited degree of efficacy against BMSB of most reduced risk insecticides commonly used to manage the apple pest complex. Assail (acetamiprid) is moderately effective against the nymph population, and Actara (thiamethoxam) has moderate efficacy against the adult, yet it too has a 35-d PHI when used at the high labeled rate, with two applications allowed per season in NY. One of the few reduced risk neonicotinoid insecticides effective against BMSB contains the active ingredient dinotefuran, available through a Section 18 label only to mid-Atlantic pome fruit growers. New York apple producers should consider lobbying the NYS DEC to obtain this reduced risk insecticide, sold under the trade names of Scorpion 35SL (Gowan) and Venom 70SG (Valent USA), as it has not yet been granted a label for use in New York State.

BMSB Management Threshold

To reduce commercial losses from this newly invasive pest, we should lean heavily on historical records of damage in blocks bordered by woodlands seen to be prone to stink bug injury in dry years. Utilizing real-time presence of the insect by employing pheromone trap data to determine population density along the orchard edge, we hope to further aid growers in predicting the potential for pest migration, feeding and fruit loss (Figure 5).

Recent studies to derive correlations between trap number and management timing have done just that. Based on research conducted at the USDA-ARS Appalachian Fruit Research Station in Kearneysville, West Virginia, Dr. Tracy Leskey has developed management threshold protocols using weekly orchard perimeter trap captures of adults. Nymphs are not used in the weekly tally, as they often represent localized pockets and not orchard-wide presence, in contrast to migrating adults. Using this approach, growers would set one "Tedders" trap per block having a history of stink bug injury. The trap comprises two black, fitted, narrow pyramid-shaped panels 4' high, on top of which is an inverted funnel and adult collection jar with clip to hold a toxicant strip of Vapona, a single 66-mg packet of methyl (E,E,Z)-2,4,6-decatrienoate as a synergist, and a single 10-mg #10* USDA lure (Figure 6). Trap placement along a wooded edge intercepts the insect as it moves from deciduous trees into fruit trees. Weekly trap captures of 10 or more adult BMSB per trap serve as a treatment threshold to trigger a management spray in tree fruit. Continued weekly trap accumulations exceeding 10 adults per trap would trigger successive management sprays as the season progresses.

NY Management Recommendations

Once a trap threshold is reached in apple blocks, there are various options growers should consider. In studies conducted by Rutgers University tree fruit entomologist Anne Nielsen and mid-Atlantic SARE project collaborators, trap-based thresholds were used to trigger a border application, found to be an effective and economical management strategy. When border applications were compared with a 7–10-day calendar-based, alternate row middle (ARM) program, no differences in fruit injury were found between the two types of application method.

The rationale behind the use of perimeter management is based on two important facts. First, BMSB adults move from woodlands and/or infested fields of vegetable crops into the orchard edge and remain concentrated in the orchard rows adjacent to deciduous trees. Second, historical orchard damage measurements show BMSB injury occurring within the 90' perimeter along a wooded edge. In early August, 2012, we observed BMSB developing into the F2 or second generation, followed by increased feeding in Red Delicious apples, beginning in late August along the wooded edge of the farm (Figure 7).

In 2014, the use of ARM applications every 7 days in the Hudson Valley reduced the incidence of BMSB damage in conventional orchards, with only 1.5% damage observed in late- season varieties. The use of trap threshold-based perimeter applications, followed by successive applications applied after each threshold is reached, has yet to be tested in commercial orchards, but should be considered by growers looking to both manage BMSB and achieve reduced management costs.

Agricultural Mapping : A New On-Demand Threshold Tool

Working with Joe LaForest, IPM Program Coordinator at the Center for Invasive Species and Ecosystem Health at the Southern IPM Center (Tifton, GA), we've developed a NY Statewide Ag.

trapping and monitoring network with weekly trap results and historical urban presence, updated weekly to the EDDMapS web site (http://www.eddmaps.org/BMSB). The website displays representative BMSB county-wide threshold information for traps monitored in all 44 NY agricultural sites. The use of colored counties based on BMSB populations and fruit injury provides growers with quick access to assist in the management of the insect, with trap data reset every 7–10 days (Figure 8).

Email and Blog Site Access. During the 2014–2015 growing season, weekly communications were sent to over 275 regional fruit growers, CCE extension staff, researchers and stakeholders, using email-embedded links to web-based documents and blogging updates. The links provide direct access to map updates of BMSB statewide presence, pest alerts, trapping, monitoring management updates, and progress on the Section 18 insecticides. NY growers can now subscribe to the entomology blog (http://blogs.cornell.edu/jentsch/bmsb-resources/) and access EDDMapS site to employ regional trapping threshold-based management to assist them in management decision making.

Footnotes. * The true aggregation pheromone secreted by H. halys adult males is composed of (3S,6S,7R,10S)-10-11-epoxy-1-bisabolen-3-ol (SSRS) and (3R,6S,7R,10S)-10,11-epoxy-1- bisabolen-3-ol (RSRS), (Khrimian et al. 2014).

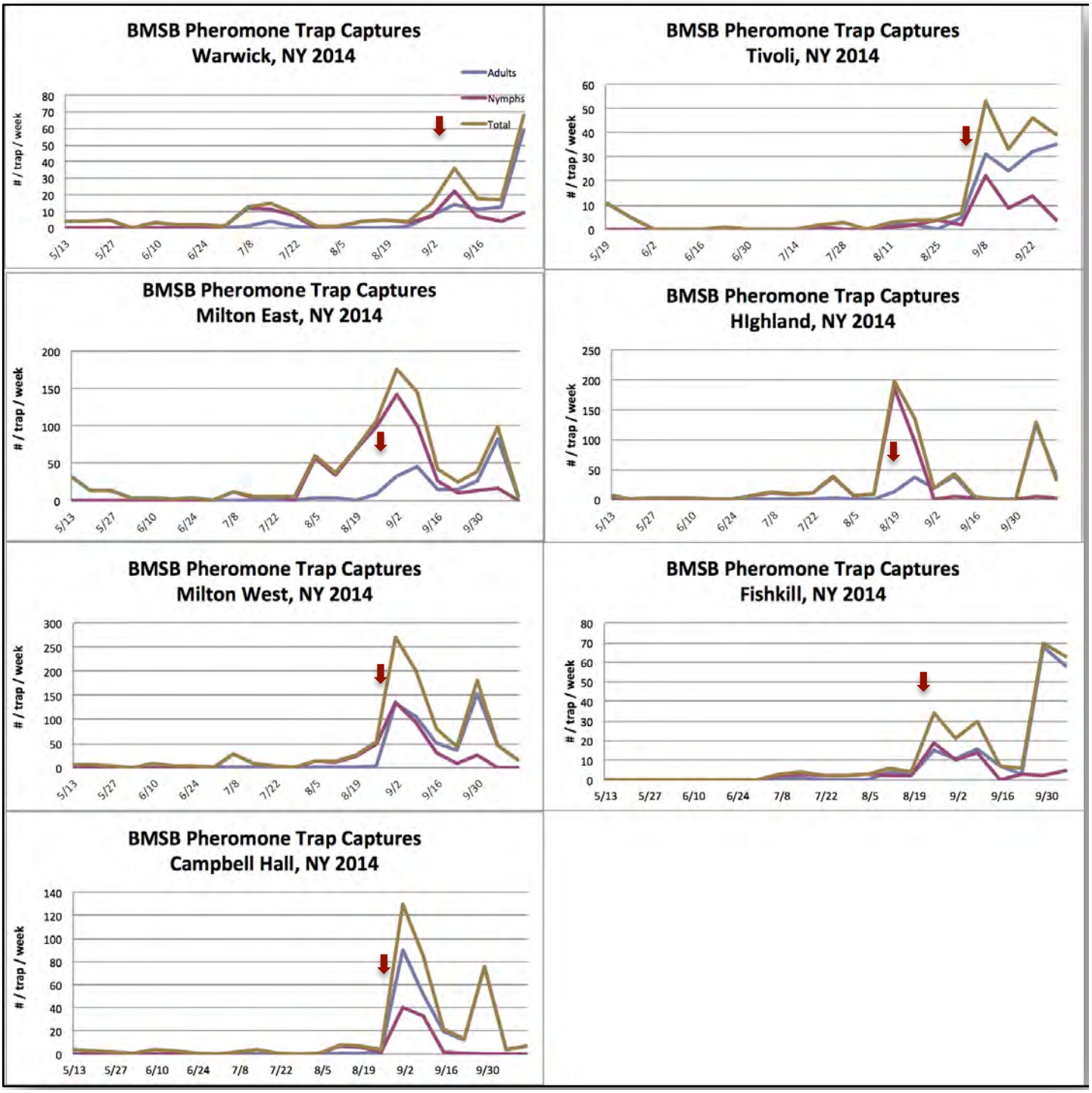

Figure 5. 2014 sites reaching BMSB trap threshold, with red arrow indicating date.

Figure 6. Tedders trap for monitoring BMSB populations along wooded orchard edge.

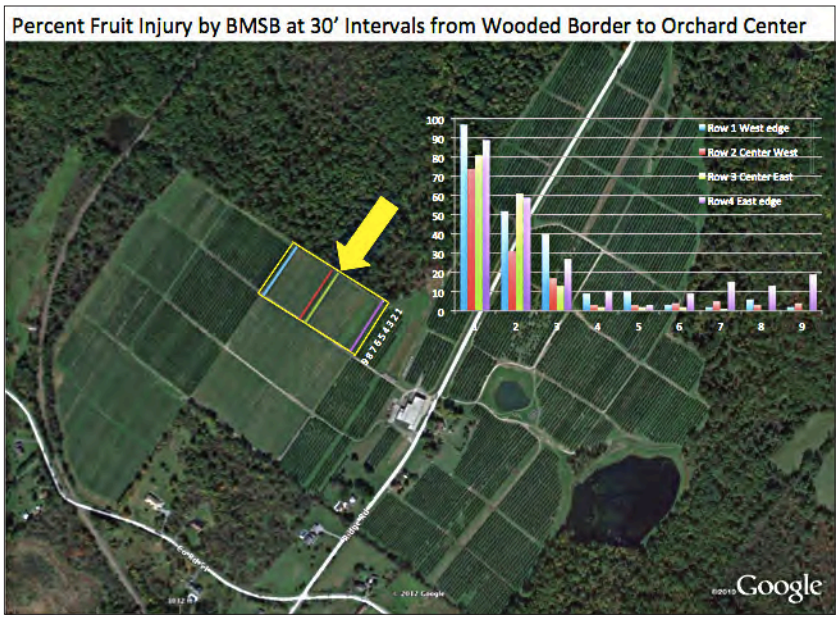

Figure 7. BMSB damage to Pink Lady occurring at highest levels along the wooded orchard edge.

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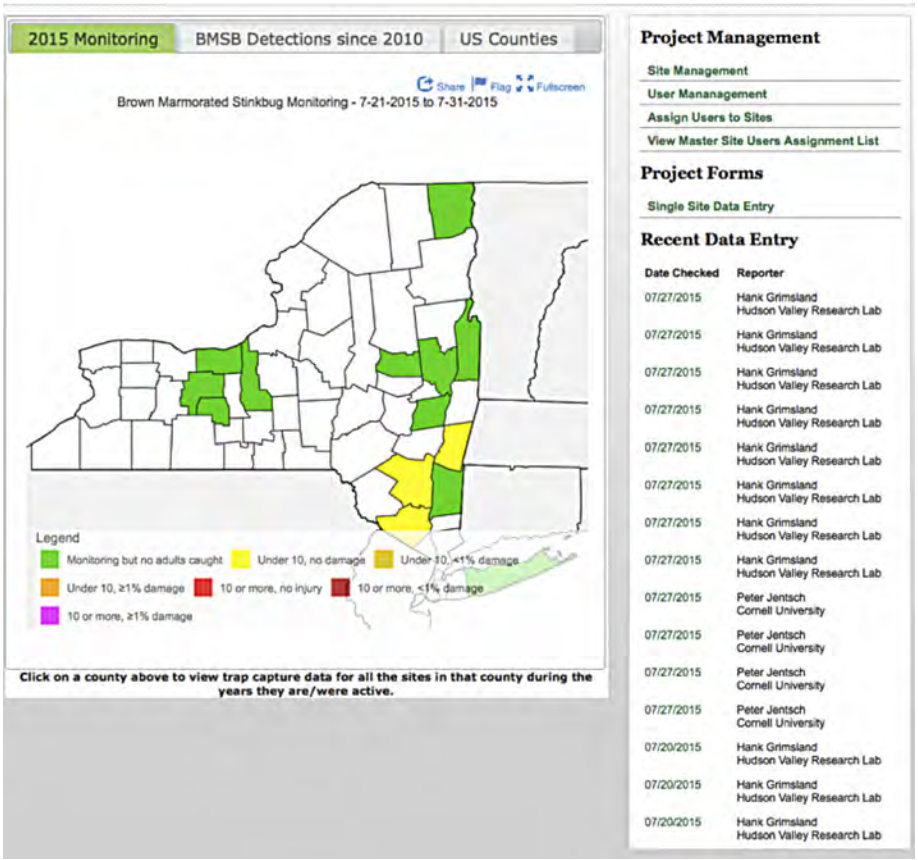

Figure 8. 2015 threshold of 10 BMSB (adults only)/trap at "EddMapS.org/BMSB".

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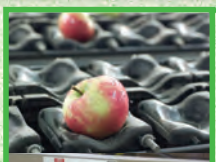

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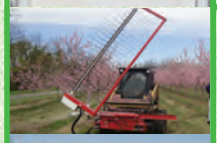

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