Ambrosia Beetle – An Emergent Apple Pest

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The ambrosia beetle *Xylosandrus germanus* (Blandford) (Coleoptera: Curculionidae: Scolytinae), also known as the black stem borer, is a serious pest in ornamental tree nurseries and landscapes in North America. A native of Asia (mainly Japan, Korea, Vietnam, China, and Taiwan), it now occurs in central Europe and the US, first documented here in New York, in greenhouse-grown grape stems (Felt 1932; Weber and McPherson 1983). Since then, it has become established in much of the United States. It has previously been noted as a pest in ornamental nurseries, with a wide host range including oak, elm, red maple, beech, hickory, chestnut, magnolia, dogwood, tupelo, cypress, black cherry, and black walnut (Hoffmann 1941; Weber and McPherson 1983).

> **"In 2013, infestations of ambrosia beetle also known as black stem borer were seen for the first time in commercial apple trees, in multiple western NY sites. To date, at least 20 additional infestation sites have been documented, extending from western NY to Long Island. The beetle has caused the death of hundreds of trees."**

Figure 1 A. Black stem borer adult, Xylosandrus germanus (photo: Steve Valley, Oregon Dept. of Agriculture); 1B. Adult and entry holes in tree trunk.

This tiny beetle (Figure 1A), which is about 2 mm in length, attacks and bores holes 1 mm in diameter (Figure 1B) to form galleries into the wood of trunks or limbs of apparently healthy trees and those that are stressed, dying or recently dead. Galleries are excavated by the females, and comprise entrance tunnels, brood chambers containing eggs and immatures (Figure 2), and branch tunnels where the young develop; this arrangement accommodates all life stages and developmental processes of the insect's life history. Larvae pass through 3 instars, and development from egg to the adult stage takes approximately 30 days. The species is bivoltine and overwinters as adults, primarily females, in galleries of its host plants that are frequently located at the base of the trunk (Figure 3), and which can contain dozens of beetles.

The term "ambrosia beetle" refers to species that derive nourishment during the larval and adult stages from a mutualistic "ambrosia" fungus carried by the adult female in mycangia (internal pouches) and introduced into host plants during gallery excavation. The ambrosia fungus associated with *X. germanus* is *Ambrosiella hartigii* Batra, visible in the galleries as an abundant grayish-white mycelium growth (Figure 4). It is this fungal growth that the insects feed on, and not the host plant tissue. However, its presence signals the tree that it is under attack, and as the tree walls off its vascular system in response, symptoms develop including wilting, dieback, tree decline and death (Gilrein 2011) (Figure 5).

Figure 2. Black stem borer brood chamber showing mixed immature life stages. (photo: Liz Tee)

Figure 3. Entry holes and sawdust at the trunk base of an established Macoun tree, Long Island.

Figure 4. Brood chamber containing eggs and immatures, showing grayish-white mycelium of the symbiotic fungus. (photo: Liz Tee)

The NY Apple Infestation

In 2013, infestations of *X. germanus* were seen for the first time in commercial apple trees, in multiple western NY sites; some affected trees additionally exhibited fire blight symptoms. Indeed, 1 of 6 was carrying streptomycin-resistant fire blight, but the other four exhibited normal fire blight. This is one of the few instances of streptomycin-resistant fire blight in 2013, and it was obtained from an *X. germanus* infestation. In addition to fire blight, mycelium of *Fusarium* was observed in some heavily infested samples in 2013, and *Nectria haematococca* (*Fusarium* *solani*) was recovered from several beetles in 2014. By the end of 2013, hundreds of trees had been removed in high density apple plantings during the growing season. In 2014, trapping and inspection efforts were initiated in the general apple-growing region along Lake Ontario. To date, at least 20 additional infestation sites have been documented, extending as far as Long Island, and it appears that these ambrosia beetles may have been present in the area for some years before first being detected, as they are now able to be found in nearly every orchard showing these types of tree decline symptoms; several hundred trees have already been destroyed. Reports of similar apple infestations were received in 2014 from researchers in New Jersey and Michigan, although in the former case the insect responsible was likely a related species, *X. crassiusculus*, known as the graniculate ambrosia beetle.

In addition to the impact that infestations have on tree health, there is added concern related to the potential for the beetles' ability to vector pathogens. Some affected trees exhibit sap or fire blight ooze issuing from beetle entry holes (Figure 6), which can occur more than 6 feet high on the trunk, so there is a possibility the insects could be contributing to the spread of this disease. Other researchers have identified a symbiosis between ambrosia beetles and canker-causing *Fusarium solani*, initiated by a buildup of beetle populations on prunings or dead trees and branches that are allowed to remain in plantings. We have isolated five isolates of *Fusarium solani* in beetles from Western NY plantings. Other fungi, including *Cephalosporium* sp. and *Graphium* sp., have also been isolated from these beetles (Baker and Norris 1968; Kuhnholz et al. 2001). These could also potentially reduce overall tree health if found in association with ambrosia beetle attacks.

Figure 5. Infested NY-2 tree in midsummer, showing severe symptoms of wilt and decline.

Figure 6. Infested Fuji tree in early May, exhibiting fire blight-like ooze from borer entry sites.

Factors Associated with Infestation

Current studies suggest that this species invades from nearby wooded areas, but there is relatively little research on movement of ambrosia beetles from wooded areas into nurseries or orchards. The insects attack stressed (including some "apparently healthy") trees, boring into the trunk or limbs to create galleries where the young develop. As the beetles excavate their tunnels, they push out small "toothpicks" of compressed wood pieces that stick out from the trunk and are easily detected unless dislodged by wind or rain (Figure 7). A variety of stressors, including flooding, drought, and freezing exposure have been identified as potential causes of physiological stress that preferentially attract ambrosia beetles (Hoffmann 1941; Kühnholz et al. 2001; Ranger et al. 2013). Trees under this type of stress produce several types of volatiles, among them ethanol, which has been documented to be a strong attractant to the beetles (Kuhnholz et al. 2001; Ranger et al. 2013). Several factors have been proposed as underlying an increasing prevalence of attack by ambrosia beetles on living trees, including 1) early flight before the host tree has acquired the ability to resist attack in the spring (possibly associated with climate change); 2) potentially pathogenic fungal attack that can predispose the host to beetle infestation; 3) cryptic behavior that facilitates transport over long distances and establishment in new habitats; 4) a complex chemical ecology that enables the adults to locate stressed living trees that may temporarily appear to be suitable hosts for the beetles.

Possible Control and Monitoring Measures

In commercial ornamental tree nurseries, growers routinely rely on insecticide trunk sprays to prevent new infestation and colonization of trees by ambrosia beetles. Because of their small size and cryptic nature, early attack often occurs before the realization that the beetles are active, which results in damage occurring before the protective sprays are applied. For effective protection against these insects, pesticide applications must be closely timed with insect attack, applied repeatedly, and/or have long residual activity. Pesticide sprays that are closely timed with beetle activity have been proposed as being the most efficacious, economical, and environmentally sustainable approach in ornamentals plantings (Oliver and Mannion 2001), although the suitability of this tactic in apple orchards has yet to be demonstrated. A reliable

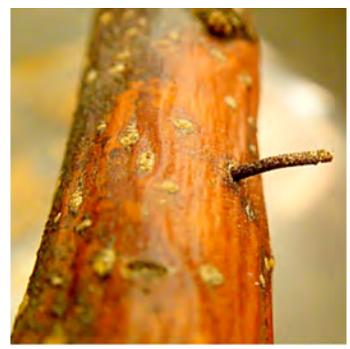

Figure 7. Compressed sawdust "toothpick" and bark discoloration characteristic of black stem borer infestation.

Figure 8. Adult trap made out of a juice bottle and baited with an ethanol lure.

monitoring system would give growers the ability to coordinate any needed control treatments with beetle activity.

Ethanol-baited traps have been shown to be useful for monitoring the flight activity of ambrosia beetles in ornamental nurseries (Oliver and Mannion 2001; Reding et al. 2010). Reding et al. (2013) detected no attack or flight activity for *X. germanus* unless temperatures reached at least 68°F for 1–2 days, with a mean occurrence of first capture in ethanol-baited bottle traps of 137 DD (base 50°F) from Jan. 1. Studies to determine how well tree attacks correspond with beetle flight activity have found that, although *X. germanus* is active and can be captured in traps through the summer and into the fall, tree attacks on chestnut in Tennessee were not attributed to this species after early June (Oliver and Mannion 2001). Furthermore, the phenological state of tree growth is apparently an important determinant of the tree's susceptibility to ambrosia beetle attack, which was found to cease for certain hosts after leafing out was complete (Hudson and Mizell 1999). Ranger et al. (2010) determined that injecting trees with ethanol could induce attacks by ambrosia beetles under field conditions, and that *X. germanus* has an efficient olfactory-based mechanism for differentiating among host volatile cues. They speculated that injecting select trees with stress-related volatiles, especially ethanol, could be a promising trap-tree strategy for this and other ambrosia beetle species. Further studies demonstrated that *X. germanus* preferentially lands on and attacks physiologically stressed hosts, and that ethanol plays a primary role in mediating this interaction (Ranger et al. 2013).

Figure 9. Ethanol-soaked beech "loglet" affixed to a training wire as an attractant for beetle attacks. (photo: Liz Tee)

Monitoring of Black Stem Borer in 2014

In 2014, ethanol-baited traps (Figure 8) hung on metal garden hangers at a 2–3-ft height were placed along the edges of six orchards in Wayne and Orleans Counties containing trees showing symptoms of tree death, and from which black stem borer adults had previously been collected. These traps were made of inverted "Simply"® plastic juice bottles, which had rectangles cut out of the sides and used low-toxicity antifreeze as a capture medium. These high-density plantings of dwarf trees were bordered by hedgerows and woods, which were assumed to be a source of immigrating beetles. Additional traps were located in the orchard interiors, adjacent to previously attacked trees, to verify their attractiveness. Traps were checked 1–2 times per week starting in mid-April, before maximum temperatures of 68°F began to occur, and through the summer until mid-September. Beetles trapped were collected, sorted and identified. Additional trapping trials were conducted by soaking 1-ft sections of beech limbs (bolts, or "loglets", 1–2" in diam) in 15% ethanol for 3 days and placing them in infested orchards (hung, or staked onto metal poles at 1-ft height) to serve as "trap tree" targets (Figure 9), and checked and replaced every 2–3 days for a 7–10-day period, to determine their utility in optimizing beetle capture rates in specific areas of an orchard.

Results indicated that the ethanol-baited bottle traps worked the best for purposes of detecting and monitoring the presence of *X. germanus*, with first activity noted in western NY on April 24, after a few warm days over 68°F. After this date, captures fell off until May 13, owing to colder temperatures that did not exceed 65°F for the entire period (Figure 10A). Peak adult capture occurred on June 11, for beetles emerging from overwintering sites in search of new trees

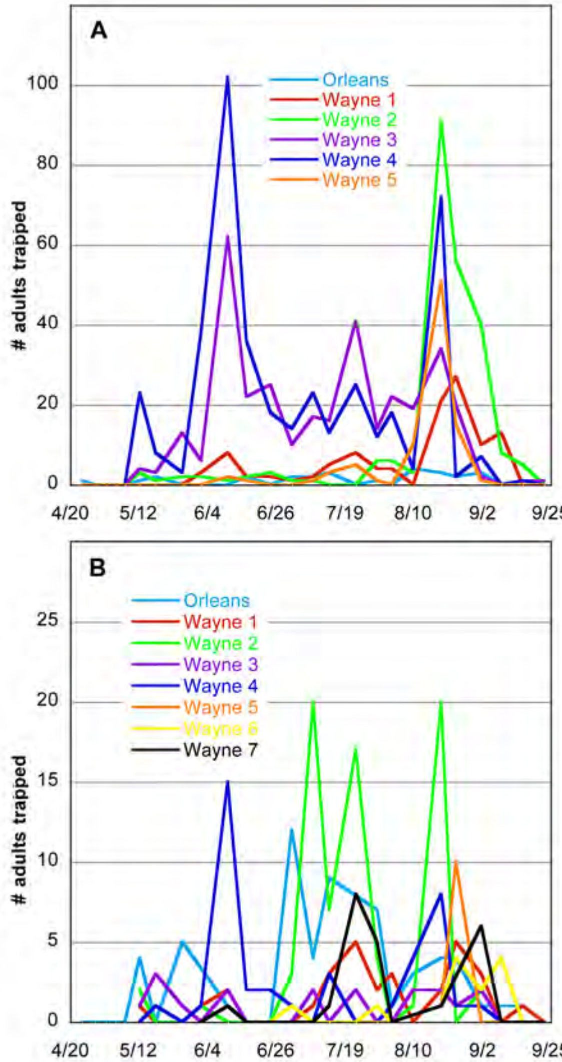

Figure 10. Captures of black stem borer adults in bottle traps located (A) at the edges of orchards adjacent to woods and hedgerows, and (B) in orchard interiors, Wayne Co. 2014

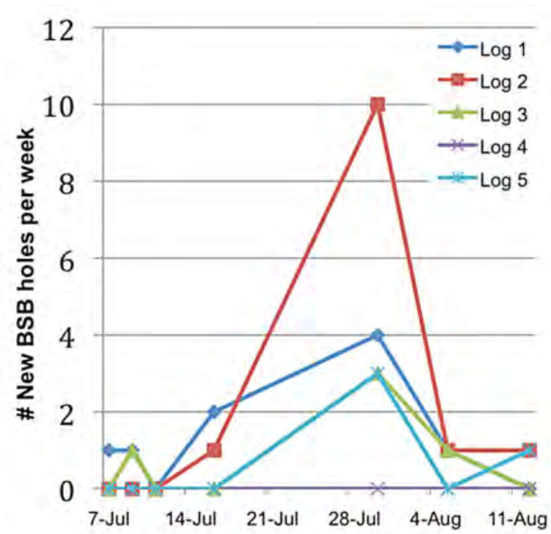

Figure 11. New black stem borer entry holes detected in beech "loglets" hung in orchard over a 1-month period, Wayne Co. 2014.

to attack, and the first generation adults emerged from July 9–23. Second generation adults emerged on August 20, but continued to be active through September 16. Higher counts were obtained in traps along the block edges adjacent to woods than in those hung in the orchard interiors (Figure 10B). The ethanol-soaked beech loglets also caught beetles, although at lower levels, and were effective for a much shorter period, needing to be replaced every 3 days to maintain enough attraction to provide a useful indication of flight activity (Figure 11).

Control Trials in 2014

Also in 2014, a preliminary insecticide control trial was conducted in a commercial orchard having a history of *X. germanus* infestation, which involved insecticide applications to the trunk and central leader of trees using a motorized mist blower. Lorsban (chlorpyrifos), Danitol (fenpropathrin), and Cobalt (chlorpyrifos+lambda-cyhalothrin) were each applied to a group of trees in early May; a grower standard consisting of sequential airblast applications of chlorpyrifos and lambda-cyhalothrin was also included. Inspections of the trees to determine active black stem borer infestations later in the season showed the least amount of damage in the Lorsban-treated trees, although the trial setup prevented proper statistical analysis.

Conclusions

Control of this pest is a challenge, as it is not possible to determine whether or when an orchard might be subject to ambrosia beetle attack, nor to identify which trees will be targeted. This insect has been present in and around apple growing regions for a number of years, but has only recently begun attacking apples, and the reasons for this shift in behavior are unknown. A succession of growing seasons featuring stresses such as low winter temperatures and drought conditions has been proposed as one possible factor. Preventive trunk sprays of insecticides are not necessarily practical, or even effective enough to be economically warranted in all cases. Possible alternative approaches under consideration include biological controls (e.g., *Trichoderma* or *Metarhizium*) targeted against either the beetles or the symbiotic fungus. Current recommendations generally advise immediate removal and burning of infested trees, but there is some debate over whether it might be advisable rather to leave them in the orchard for the season – where they can act as attractants for other adults – before being removed. Infested trees tend to occur in batches, with dozens in one location showing die-off or decline, with others that are adjacent being unaffected. Inspections of infested orchards in western NY show a tree loss of up to 30% in some cases; however, not all trees that are attacked die, and many apparently recover. Finally, there are reports from other regions (e.g., Nova Scotia) where this problem has occurred in the past and, after several years, simply disappeared. For the time being, there are still many questions needing to be addressed before good solutions and recommendations are available.

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