Abstract

Ethanol-baited bottle traps were used to monitor spring flight activity of the ambrosia beetles *Xylosandrus crassiusculus* and *Xylosandrus germanus* in Ohio, Tennessee, and Virginia. The traps were deployed at three different heights to determine if height influenced captures. *X. germanus* was captured in all three states, while *X. crassiusculus* was captured in TN and VA only. Traps 0.5 m above the ground captured more *X. germanus* than traps at 1.7 or 3.0 m. Traps 0.5 or 1.7 m above the ground captured more *X. crassiusculus* than traps at 3.0 m. In TN and VA, first activity of *X. crassiusculus* and *X. germanus* occurred from mid-March to early April. In OH, first activity of *X. germanus* occurred early to mid-April. Analysis of attacks by *X. germanus* on *Cornus florida* revealed that more than 90% of the attacks occurred on the main trunk within 1 m (3 ft) of the ground. Monitoring will be most effective when traps are suspended 0.5 or < 1.7 m above the ground for *X. germanus* or *X. crassiusculus*, respectively. To detect first flight of *X. crassiusculus* or *X. germanus*, traps should be deployed by early to mid-March in TN and VA and late March in OH.

Index words: *Xylosandrus crassiusculus, Xylosandrus germanus*, spring flight, bottle traps, ethanol baits.

Significance to the Nursery Industry

The ambrosia beetles *Xylosandrus crassiusculus* and *Xylosandrus germanus* are serious pests in ornamental nurseries, attacking a wide variety of tree species. Management of ambrosia beetles in nurseries relies primarily on preventive treatments of insecticides applied to the trunks of trees. Timing insecticide controls for *X. crassiusculus* and *X. germanus* will be improved with a greater knowledge of their seasonal activity and ecological interactions with the nursery ecosystem. To develop a reliable monitoring system, ethanol-baited bottle traps were used to monitor spring flight activity of *X. crassiusculus* and *X. germanus*; and the effect of trap height on captures of *X. crassiusculus* and *X. germanus* was determined. Bottle traps suspended 0.5 m (19 in) above the ground were the most effective at capturing *X. germanus*, while traps at 0.5 or 1.7 m (67 in) were similarly effective for *X. crassiusculus*. Our data indicate that bottle traps should be placed within 0.5 or 1.7 m of the ground for best results in monitoring *X. germanus* or *X. crassiusculus*, respectively. If the trapping goal is to monitor both *Xylosandrus* species, the low height should be used. Spring activity of *X. crassiusculus* and *X. germanus* varied depending on year and location.

First emergence of both species began late March to mid-April and was similar for both species where they occurred together. Peak activity varied depending on species, year and location, with peaks occurring from early April to late May. Monitoring should begin early in the season to effectively time preventive controls for these pests.

Introduction

Ambrosia beetles (Coleoptera: Curculionidae, Scolytinae) are serious pests in ornamental tree nurseries where attacks by some species can kill trees (3, 4, 7). The adult beetles bore into the sapwood and heartwood of trees creating tunnels that they inoculate with symbiotic fungi, the source of food for the larvae and adults (11). Ambrosia beetles were generally considered secondary pests of trees, attacking stressed or unhealthy trees (4, 11). As a result, previous recommendations for their management emphasized keeping trees healthy. However, some exotic species of ambrosia beetles, such as *Xylosandrus crassiusculus* (Motschulsky) [the granulate (formerly Asian) ambrosia beetle] and *Xylosandrus germanus* (Blandford), were found attacking trees that appeared healthy (2, 4, 7, 10, 11). Oliver and Mannion (7) found *X. crassiusculus* and *X. germanus* attacking healthy chestnut trees (Castanea mollissima Blume) transplanted along the wooded border of a research nursery. Hudson and Mizzell (3) reported *X. crassiusculus* as a serious pest in ornamental nurseries in Florida and Georgia where they attacked apparently healthy trees.

Nursery trees attacked by *X. crassiusculus* are often severely damaged and can be killed (7). Colonization (attacks) by five to ten *X. crassiusculus* in the same year frequently killed trees less than 7.6 cm (3 in) in caliper (5). After breaking dormancy in the spring, leaves on attacked trees often expand normally then wilt and the trees die. Staining from the ambrosia fungus can usually be found in infested trees (10). It is uncertain whether mortality of trees attacked by ambrosia beetles is due to mechanical injury from tunneling beetles, pathogenicity of the symbiotic fungi, incidental pathogens that enter through the tunnels, blockage of the
trees vascular tissues by fungal growth, or combinations of these factors (4, 7, 10).

In nurseries, the standard strategy for managing wood-boring insects like ambrosia beetles is to apply preventive treatments of insecticides to the trunks of trees. However, timing insecticide treatments for ambrosia beetles is difficult because their small size makes them difficult to detect before damage occurs, and their behavior and ecology in ornamental tree nurseries is still not fully understood (7). Monitoring pest populations is a common strategy for accurately timing controls, and is often used to develop profiles of seasonal pest activity. An understanding of the seasonal activity of problematic ambrosia beetle species combined with reliable monitoring methods, would assist growers in timing control treatments and improve management of these pests. Trapping might be an effective technique for monitoring ambrosia beetles to time control treatments (3). Oliver and Mannion (7) found that attacks on trees by X. crassiusculus and X. germanus in the spring coincided with their captures in traps. Most of the attacks by these species appear to occur during spring (7, 10). However, procedures and recommendations for using traps to monitor important species of ambrosia beetles are not well developed. Previous trapping research suggests that captures of some ambrosia beetle species, including X. germanus, were influenced by the height traps were suspended above the ground (9, 10), but further research is needed. Traps deployed at optimal height, location, and timing will be the most effective at detecting the beginning of ambrosia beetle emergence, when the application of preventive treatments should start.

In Tennessee and Virginia, X. crassiusculus appears to be the most problematic species in ornamental nurseries with some attacks by X. germanus reported in TN (7). In Ohio, serious damage by ambrosia beetles in nurseries has been relatively recent, occurring primarily during the past 10 years. However, the damaging species were not previously identified, nor was it known whether X. crassiusculus was present. The objectives of this study were to monitor spring flight activity of X. crassiusculus and X. germanus using ethanol-baited traps in commercial nurseries; evaluate the influence of trap height on captures of X. crassiusculus and X. germanus; develop profiles of their spring flight periods; identify the species of ambrosia beetles damaging trees in Ohio nurseries and examine the vertical distribution of attacks on nursery trees by those species. The vertical distribution of attacks might be related to flight behavior (7, 10), which would influence attraction of traps in relation to the height traps are suspended above the ground (9).

Materials and Methods

Trapping X. crassiusculus and X. germanus in commercial nurseries. Trapping for ambrosia beetles was conducted in commercial ornamental nurseries in three states (Ohio, Tennessee, Virginia) that have experienced losses of nursery trees from ambrosia beetle attacks. Traps were deployed during spring in 2006, 2007 (Lake County, OH; Warren County, TN; Isle of Wight and Suffolk Counties, VA), and 2008 (Isle of Wight and Suffolk Counties, VA only) in two nurseries per state each year. A randomized complete block design was used with three height treatments [0.5, 1.7, and 3.0 m (1.6, 5.6, and 9.8 ft, respectively)]. In 2006 and 2007, there were four replications per nursery for a total of eight replications per state each year. In 2006 and 2007, data for X. germanus were not recorded in VA. Therefore in 2008, monitoring in VA focused on X. germanus and there were 12 replications per nursery for a total of 24. Traps were suspended on poles so that each pole had a trap suspended at each height (0.5, 1.7, and 3.0 m) (Fig. 1). The poles were made of PVC pipe [1.9 cm (0.75 in) diameter and 3.0 m (10 ft) long] and attached by cable ties to two 3-m-long (10 ft) metal posts driven into the soil for support. Poles with traps were placed along woody borders of nurseries and spaced at least 25 m (82 ft) apart. Traps were made from two clear plastic bottles [0.5 and 2 liter (16.9 and 67.6 fl oz)] with the mouth ends connected by a plastic threaded tube (‘Tornado Tube’, item # WTUB-500, Steve Spangler Science, Englewood, CO), and the 2-liter bottle on top (Fig. 1). Three rectangular openings approximately 12.5 cm long by 6 cm (4.9 by 2.4 in) wide were cut in the 2-liter bottle to allow entrance of ambrosia beetles. Each trap was baited with ethanol in a commercially available bag-style dispenser (Standard Release ethanol lures) (AgBio, Inc., Westminster, CO) suspended in the 2-liter bottle section of the trap. The lures were loaded with 15 ml (0.5 fl oz) of 95% ethanol with a release rate of 65 mg (0.002 oz) day⁻¹. The small bottle (0.5 liter) functioned as the collection receptacle.

Fig. 1. The method used to deploy ethanol-baited bottle traps to determine the influence of trap height on captures of Xylosandrus crassiusculus and Xylosandrus germanus. The poles were replicates with traps deployed at three heights (0.5, 1.7, and 3.0 m) which were treatments.
and was filled with approximately 100 ml (3.4 fl oz) of a 50% solution of propylene glycol (Sierra Antifreeze/Coolant, Old World Industries, Inc., Northbrook, IL) as the killing agent. Oliver et al. (8) compared the efficacy of a similar 2-liter bottle trap design (only differing from the bottle traps in the present study by not having the smaller collecting bottle attached with a tornado tube; hereafter referred to as bottle traps) with a variety of other traps, including several commercially available traps, and the bottle trap was the most effective at capturing *X. crassiusculus*. The bottle trap is relatively inexpensive (< $4.00 U.S. total for the bottles and connecting tube) and easy to produce, which should encourage grower acceptance.

In 2006, traps were deployed March 10, 10, and 6 in OH, TN, and VA, respectively. In 2007, traps were deployed March 30, 26, and 13 in OH, TN, and VA, respectively. In 2008, traps were deployed March 23 in VA. Traps were made March 17, 2006, with peak captures of both species on March 30, 2007, the date first checked in TN (Figs. 3 and 4). In VA, first captures of *X. crassiusculus* were made March 13, 2006, and March 20, 2007, with peak captures of *X. crassiusculus* and *X. germanus* in TN. Therefore, the first and peak captures of both species were recorded on March 30, 2007, the date traps were first checked in TN (Figs. 3 and 4). In VA, first captures of *X. crassiusculus* were made March 13, 2006, and March 20, 2007, with peak captures mid-April in 2006 and late May in 2007 (Fig. 5). The number of beetles captured during peak activity in 2007 were similar to the number captured at the same timing in 2006. In VA, *X. germanus* captures were recorded in 2008 only, and the first captures occurred April 1 with relatively high captures by late April and peak captures in early May (Fig. 6).

In general, there were dips and peaks in the flight activity of *X. germanus* and *X. crassiusculus*. In TN, the peaks in *X. crassiusculus* activity in late May through July (Figs. 3 and 4), may represent activity of a second generation. Oliver and Mannion (7) found that in TN *X. crassiusculus* that colonized trees in early spring produced offspring that emerged from

**Fig. 2.** Seasonal flight activity of *X. germanus* in OH nurseries during spring in 2006 and 2007 based on captures in ethanol baited bottle traps.
mid-May to late June. However, in most cases the decline in activity between the peaks usually coincided with periods of cool or wet weather. Currently, it’s unknown whether *X. germanus* and *X. crassiusculus* don’t fly during wet or cool weather, or the traps are less attractive during those weather conditions.

There was variability in beetle trap catch abundance and timing of flight activity. The first captures of *X. crassiusculus* and *X. germanus* probably represent the initial flight activity of these species in each state (except TN 2007). First capture and peak activity of *X. crassiusculus* were different between years in TN and VA; however, within years activity was similar between nurseries within states (Figs. 3 and 5). In Ohio, peak flight activity of *X. germanus* occurred at a similar timing in 2006 and 2007 and was similar between nurseries each year. In TN, emergence and peak activity of *X. germanus* was similar to *X. crassiusculus* with captures of the latter much higher. The fact that timing of emergence and peak activity of *X. crassiusculus* and *X. germanus* was similar between nurseries within states, suggests emergence might be related to environmental factors such as temperature. If a relationship between temperature or plant phenology and activity of *X. crassiusculus* or *X. germanus* can be identified, development of models that predict emergence or peak activity should be possible. Similar models are important tools for timing controls for key pests in a number of other cropping systems (6).

In OH, TN, and VA, there were significant differences in captures of *X. germanus* among trap heights each year.
In TN, there was a significant difference in the numbers of *X. crassiusculus* captured among trap heights in 2006 and 2007 (*F* = 34.47, df = 2, 14, *P* < 0.0001; and *F* = 21.36, df = 2, 14, *P* = 0.0001, respectively). In TN during 2006, more *X. crassiusculus* were captured in the 0.5 m traps than the other heights with more captured in the 1.7 than 3.0 m traps (Table 1); and in 2007, more *X. crassiusculus* were captured in the 1.7 m traps than the 0.5 or 3.0 m traps (Table 1). In VA, there were significant differences in the numbers of *X. crassiusculus* captured among trap heights in 2006 and 2007 (*F* = 8.61, df = 2, 14, *P* = 0.004; and *F* = 3.93, df = 2, 14, *P* = 0.044, respectively). In 2006, more *X. crassiusculus* were captured in the 0.5 and 1.7 m traps than the 3.0 m traps; and in 2007, more *X. crassiusculus* were captured in the 0.5 m than 3.0 m traps (Table 1).

When overall activity was low, almost no *X. germanus* were captured in the 3.0 m traps. In TN, where numbers of *X. germanus* were low (23 total in 2006), 87% were captured in the 0.5 m trap. On the dates *X. germanus* were first captured in OH, 90% (328 total in all traps) and 92% (48 total in all traps) were captured in the 0.5 m traps (2006 and 2007, respectively). In VA, the first captures of *X. germanus* were made in the 0.5 m traps (100%, total of 21 beetles on that date). In all our sites, the 0.5 m traps caught the most *X. germanus*; however, there was variation in trap performance for *X. crassiusculus*. The 0.5 or 1.7 m traps captured the most *X. crassiusculus* depending on state and year, although, 75% of the time there was no difference between those heights. Consequently, in locations where it’s necessary to monitor both *X. germanus* and *X. crassiusculus*, traps should be deployed at the 0.5 m height. If only *X. crassiusculus* is monitored, traps deployed within 1.7 m of the ground should be effective.

**Table 1.** Mean ± (SD) cumulative totals of *Xylosandrus crassiusculus* and *Xylosandrus germanus* captured in ethanol-baited traps deployed at various heights in commercial ornamental nurseries.

<table>
<thead>
<tr>
<th>State</th>
<th>Species</th>
<th>Trap height</th>
<th>2006</th>
<th>Cumulative beetles per trap</th>
<th>2007</th>
<th>Cumulative beetles per trap</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>OH</td>
<td><em>X. germanus</em></td>
<td>0.5 m</td>
<td>513.6 (305.7)a</td>
<td>336.6 (155.3)a</td>
<td>109.4 (65.9)b</td>
<td>62.4 (33.3)b</td>
<td>28.6 (9.5)c</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.7 m</td>
<td>2.5 (2.3)a</td>
<td>14.0 (9.6)a</td>
<td>0.3 (0.5)b</td>
<td>1.5 (2.0)b</td>
<td>0.1 (0.4)b</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.0 m</td>
<td>10.0 (3.6)a</td>
<td>59.9 (45.9)b</td>
<td>5.4 (3.4)b</td>
<td>102.9 (72.3)a</td>
<td>1.9 (1.9)c</td>
</tr>
<tr>
<td>TN</td>
<td><em>X. germanus</em></td>
<td>0.5 m</td>
<td>10.0 (3.6)a</td>
<td>59.9 (45.9)b</td>
<td>5.4 (3.4)b</td>
<td>102.9 (72.3)a</td>
<td>1.9 (1.9)c</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.7 m</td>
<td>5.4 (3.4)b</td>
<td>102.9 (72.3)a</td>
<td>1.9 (1.9)c</td>
<td>65.9 (47.4)b</td>
<td>1.9 (1.9)c</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.0 m</td>
<td>1.9 (1.9)c</td>
<td>65.9 (47.4)b</td>
<td>1.9 (1.9)c</td>
<td>65.9 (47.4)b</td>
<td>1.9 (1.9)c</td>
</tr>
<tr>
<td>VA</td>
<td><em>X. germanus</em></td>
<td>0.5 m</td>
<td>39.6 (38.0)a</td>
<td>21.9 (18.8)a</td>
<td>36.5 (45.1)a</td>
<td>5.4 (7.8)b</td>
<td>2.7 (3.6)b</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.7 m</td>
<td>44.8 (49.0)a</td>
<td>20.9 (21.4)ab</td>
<td>44.8 (49.0)a</td>
<td>20.9 (21.4)ab</td>
<td>44.8 (49.0)a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.0 m</td>
<td>27.6 (36.1)b</td>
<td>12.0 (11.9)b</td>
<td>27.6 (36.1)b</td>
<td>12.0 (11.9)b</td>
<td>27.6 (36.1)b</td>
</tr>
</tbody>
</table>

*Data were log(X+1) transformed for analysis and the untransformed data are presented. Means within columns, states, and species followed by the same letter are not significantly different (Tukey’s HSD, α = 0.05).*
in forestry plantations, primarily (10, 11). Although, Oliver and Mannion (7) report it attacking chestnut trees (C. mollissima) in a nursery in TN. In 2008, there was a mean of 70.8 attacks (entrance holes) per tree with > 91% in the lower 100 cm (39.4 in) of the trunk. These data suggest that X. germanus colonizes lower sections of the tree initially, which might explain their greater attraction for traps set at 0.5 m versus 1.7 or 3.0 m.

The higher capture rates in the 0.5 and 1.7 m traps versus the 3.0 m traps are probably related to the flight behavior of X. crassiusculus and X. germanus. These beetles may generally fly near the ground and then attack trees relatively low on the trunk. Weber and McPherson (10) reported that X. germanus fly low, which corresponded with attack patterns in their study. Oliver and Mannion (7) found the average heights of attack (entrance holes) by X. crassiusculus and X. germanus were < 30 cm above the ground. Our data on the vertical distribution of X. germanus entrance holes supports the hypothesis that this species attacks trees low on the trunk. This study provides relevant data that demonstrates traps set too high would be less sensitive for detecting initial flight activity of X. crassiusculus and X. germanus, which could result in failure to apply controls in time to prevent damage to trees in nurseries.

Literature Cited