CONTROLLING BANDED ASH CLEARWING MOTH BORER USING ENTOMOPATHOGENIC NEMATODES

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Abstract. The banded ash clearwing moth, *Podosesia aureocincta*, in 24 green ash growing in a nursery were treated with the nematode, *Steinernema carpocapsae* (strain 25) at two different rates. Eight infested green ash were controls in the field trial. Nematodes were applied in July using a backpack sprayer. Applications of entomopathogenic nematodes significantly reduced the number of living larvae associated with the plants.

When grown under proper conditions ash trees, (*Fraxinus*) are valuable landscape plants with many desirable traits including rapid growth rate, adaptability in transplanting, and pleasing growth habits. These desirable characteristics have contributed to the extensive use of ash species in street tree plantings, lawns, parks, and commercial office building landscapes. Unfortunately many landscape sites in urban and suburban locations lack the growing conditions needed for proper performance of ash. In a 1993 survey of 15 Maryland commercial pesticide applicators (arborists, landscape companies and government personnel) in Maryland, "borers" were identified by 12 of the participants as the number one pest problem associated with growing ash trees in landscape and street tree plantings.

Ash trees were long thought to be attacked by two subspecies of clearwing moth borers (Lepidoptera: Sesiidae). Purrington and Nielson (8) determined that two distinct species attacked ash: the lilac borer, *Podosesia syringae* and the banded ash clearwing, *Podosesia aureocincta*. Color variation in these two species still causes identification problems in some areas of the country.

The range of clearwing moth borers that damage ash trees in the United States and Canada is extensive. Santamour (10) reported 81% of several hundred 9-year-old ash trees from 43 different geographic origins were attacked by borers, and only a few of the trees not attacked had acceptable growth rates. Nielson and Balderson (6) commented that in northeast Ohio, clearwings moth borers had made ash culture impossible and damage in nurseries has been estimated at $5000/0.7 hectare/cropping cycle. Peterson (7) found that 50% of the green ash trees in urban centers in the Prairie regions of Canada suffered from borer damage. In most parts of North America, infestations of ash by borer occur primarily in green ash, *Fraxinus pennsylvanica*. In California (2) Raywood ash, *F. oxycarpa* 'Raywood', and Moraine ash, *F. holotricha* 'Moraine'were most seriously affected.

Open-grown trees are apparently more susceptible than those in dense stands, probably because moths prefer well-lighted trunks for oviposition (11). In Maryland, ash trees planted in open landscapes and in compacted, restricted or poorly drained soil have been observed to have a high incidence of clearwing moth borers. Solomon (11) reported that infestation of ash by borers in Mississippi is usually in the lower trunk, but damage occurs in both trunks and branches as high as 9 meters above the ground. Bone and Koehler (2) found that ash borer's galleries occurred from ground level through nearly the entire canopy of infested trees. They also established that *Podosesia* spp. frequently re-attacked trees at sites injured by previous generations as well as new wound sites inflicted by mowers or improper staking of trees.

The banded ash clearwing and the lilac borer

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look similar. Both are about the size of Polistes paper wasps. The adult banded ash clearwing has a narrow orange-yellow band around the fourth abdominal segment which the latter lacks. Both have brownish black bodies. The lilac borer overwinters in several larval instars. Those that overwinter in the last larval instar begin to emerge in April in Maryland. The banded ash clearwing overwinters as early instar larvae. Larvae feed through most of the summer and adults do not start to emerge until late August in Maryland.

The larvae of both species damage ash trees in a similar manner. Day flying females lay eggs in wounds and bark crevices. Hatching larvae chew into the bark and feed both laterally and vertically in the phloem tissue. The externally visible symptom of injury is a slight sap flow mixed with frass at the penetration site. Later most larvae excavate upward in the sapwood where they concentrate most of their feeding. Completed galleries are about 7 - 32 cm long and 5 - 7 mm in diameter. The sapwood galleries physically weaken the structure of the tree. Prior to pupation, the gallery is extended almost to the bark surface. The larva plugs the passage behind it with wood chips and encloses itself in a pupal chamber. An empty pupal case can be found protruding from a circular hole in the bark after emergence of the adult clearwing moth (11).

Georgis and Gaugler (4) reported that *Steinernema carpocapsae* (All strain) is the most widely field tested entomopathogenic nematode, largely because it is easily cultured and stored and readily available. Because of our earlier successes in controlling dogwood borer and peachtree borer with Steinernema carpocapsae we chose to use it in our field trials for control of banded ash clearwing borer.

Materials and Methods

The site for this field trial was a wholesale nursery in Laytonsville, Maryland with .4 hectare planting of 10 - 13 cm caliper green ash, *F. pennsylvanica*. Over 95% of these trees were infected with borers. The damage was extensive enough that the Maryland Department of Agriculture condemned the trees and required that they be removed and destroyed. We requested the nurseryman to leave a row of 25 borer infested trees for conducting field trials using entomopathogenic nematodes. The trees had numerous entry sites on the main trunk at crotches and on side branches at branch junctures. An abundance of wood frass was found extruding from the openings during the summer months.

In March 1991, we cut down 2 trees from the 0.4 hectare planting block and extracted larvae which were identified as clearwing moth borers. Pheromone traps with synthetic clearwing moth sex attractant were placed in the nursery in April of 1991. The county extension agent hung traps 2 meters from the ground and inspected them weekly until no moths were captured for at least 10 days. Lilac borer adults were captured in the traps from May through early July. At adult emergence, the pupal case protrudes from the bark. Tree trunks were examined on a weekly basis from May through early July but relatively few pupal cases were found (9 pupal cases on 25 trees, >.4/tree). Fresh pheromone traps with synthetic clearwing moth sex attractant were placed in the nursery in August and remained in place until October when banded ash clearwing moths ceased to be captured. Large numbers were captured in the traps from mid- August through early October. The trunks of the 25 trees were examined weekly from mid-August until October 1,1991 for presence of pupal cases. Large numbers of pupal cases (283 for 25 trees, > 11/tree) were recorded. The majority of pupal cases were found at junctures where branches intersected the main trunk, but were also found on the trunk and major branches. The most heavily infested trees showed early signs of dieback of upper canopy branches.

In July 1992, one of 25 trees involved in the field trial was cut down and dissected into 1 meter bolt lengths. The bark was removed and the wood split. Three larvae were obtained and identified as the banded ash clearwing borer. The 24 remaining trees were planted in a linear, nursery row 3 meters apart. Three applications were evaluated including water-treated control; nematode treatment at the rate of 500 per 2.53 cm^2 of bark area; and the rate of 1000 nematodes per 2.53 cm^2 of bark. The trial design was a randomized, complete block design with eight single tree replications.

Steinernema carpocapsae (strain 25) obtained from Biosys Company of Palo Alto, California and Ciba-Geigy were used in the field trail. The container supplied by Biosys and Ciba-Geigy, under the brand name Exhibit, contained 250,000,000 nematodes immobilized in an alginate clay. The nematodes were mixed with 4 liters of water to which was added a bio-activator containing sodium citrate which dissolves the alginate clay. To determine the area of the trunk to receive treatment, 5 trees from the treatment blocks were measured at ground level, 1 meter, and 2 meter from the ground. The area of bark surface was calculated based on the average of the measurements of the 5 trees.

Treatments were applied on July 23, 1993 from 10:00 a.m. - 12:00 p.m. The temperature and relative humidity were measured at the start of the treatments using an Omega RH-20 portable meter. Temperature was 25°C and relative humidity was 54% at the start of applications. By 12:00 the temperature was 28°C and relative humidity had dropped to 44%. Nematodes were mixed with well water that had a pH of 6.3. It was determined that 2000 ml of water was sufficient to treat each individual tree to a point of runoff using a Birschmeyer backpack sprayer.

For each treatment at the rate of 500 nematodes/sq. in. (2.5 cm^2), 10.5 ml from the original mix was drawn off and mixed with well water to make a final spray solution of 2000 ml. This volume was applied from ground level to a 3 meter height on each tree. Similar methods were used for treating the trees receiving 1000 nematodes/ sq. in., but with 21 ml being drawn off the original mix and mixed with well water to make a final spray solution of 2000 ml.

Based on the number of pupal cases found in late summer on the trees it was determined that most borer damage was from the banded ash clearwing. Treatments were applied in July to kill late instar banded ash clearwing larvae before they pupated. A pheromone trap baited with clearwing moth sex attractant was placed in the nursery in early August. When the first adult banded clearwing was captured, the trees were cutdown and the trunks were cut into 4 roughly equal bolts of 75 cm length. The bolts from each tree were placed in individual rearing cages in the laboratory. The number of emerged adults and pupal cases protruding from the wood were recorded. No adults emerged after Oct. 3. A few adults escaped from the cages so the number of adults emerged and number of pupal cases found protruding from the bark were recorded separately.

Two field trial response variables were analyzed: number of adults and number of pupal cases. Each response was fitted to an analysis of variance model by weighted least squares. Weighted least squares estimation was used to account for variance inequality.

Results and Discussion

Applications of entomopathogenic nematodes produced significant reductions in the number of emerging adults from trees treated at the 500 nematodes/2.5 cm^2 rate (Table 1). The rate of 1000 nematodes/sq. in. rate did not give significant control.

The 500 nematodes/sq. in. rate was applied earlier in the morning, at lower temperatures, higher humidity levels, and less intense sunlight. When the 1000 nematodes/sq. in. rate was completed 2 hours later the temperature had increased 3°C to 28°C, the relative humidity had decreased by 10% and the sunlight was more intense. Perhaps this holding time under field conditions reduced nematode pathogenicity. It seems best to apply nematodes early in the morning or in the evening. In addition, we suggest nematode applications be applied in the spring when the frass is first detected. In the spring the galleries of the banded ash clearwing are short making it easier for nematodes to contact the borer larvae. This will

Table 1. Evaluation of entomopathogenic nematodes applied in July of 1992 for control of banded ash clearwing moth borer.

	Mean number of borers	
Nematodes/ sq. in.	Adults	Pupal cases
0	2.28a	2.66a
500	0.67b	0.91b
1000	1.25ab	1.41ab

prevent structural damage from occurring during the growing season.

The results of the 500 nematodes/sq. in. support results of previous effacy investigations of entomopathogenic nematodes for control of clearwing moth borers (3,5).

Entomopathogenic nematodes, as a biological insecticide, have reached a level where they are both cost effective and practical for an arborist to apply to control certain shade tree lepidopteran boring pests. These insect specific pathogens have many positive aspects for arborist and landscape managers including their ability to kill hosts within 48 hours, ease of application, safety to humans and wildlife, and exemption from E.P.A.

Solomon (11) reared three parasites, including six Phorocera signata, four Apanteles sp., and one Lissonota sp. from ash borer infested ash bolts. In 7% of the galleries, both plug and larvae were missing, indicating ant predation. Woodpeckers were noted as the most important predator of the banded ash clearwing larvae.

Effective control options are worth investigating since Santamour and Steiner (9) indicated that selection and breeding of green ash, *Fraxinus pennsylvanica* , for resistance to the sesiid ash borers, *Podosesia syringae* and *P. aureocincta*, would be very difficult. There are four residual chemicals labeled for bark treatment applied as a preventative measure. These chemicals must be timed to kill newly hatched borer larvae. Synthetic, long residual pesticides could possibly impact predator and parasite activity. Use of entomopathogenic nematodes for control of clearwing borers may be more compatible with insect predator and parasite activity.

Arborists are interested in an effective means of killing borer larvae after they penetrate tree bark. As a mechanical measure, Appleby (1) suggested probing the larval gallery with flexible wire or knife. This method is generally too time consuming and costly for arborist to implement. Public sensitivity to chemical pesticide use in urban and suburban landscapes encourages arborists to investigate alternative, non-traditional controls of tree borers. Entomopathogenic nematodes offer a viable, alternative method of controlling clearwing moth borers.

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