Pest Status of American Plum Borer (Lepidoptera: Pyralidae) and Fruit Tree Borer Control with Synthetic Insecticides and Entomopathogenic Nematodes in New York State

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ABSTRACT Surveys were conducted in 1994 and 1995 to determine the pest status of the American plum borer, *Euzophera semifuneralis* (Walker), in New York State stone fruit crops. These surveys indicate that American plum borer is the most important of the wood-boring insects infesting tart cherries and also is an important pest in peaches suffering from canker diseases. It is not prevalent in plums or in healthy peaches. Trials to control American plum borer were conducted in tart cherry and peach by using chlorpyrifos, esfenvalerate, and 2 commercially available formulations of entomopathogenic nematodes, *Steinernema feltiae* (Filipjev) and *Heterorhabditis bacteriophora* (Poinar). Two applications of chlorpyrifos, timed at petal fall and at the beginning of the 2nd flight, effectively controlled the pest. One application of chlorpyrifos applied at petal fall did not provide effective season-long control, except where numbers were very low. Programs using 1 (petal fall) or 3 applications of esfenvalerate were ineffective. Control by either nematode formulation was insignificant.

KEY WORDS *Euzophera semifuneralis,* pest status, insecticide efficacy, entomopathogenic nematodes

THE AMERICAN PLUM borer, *Euzophera semifuneralis* (Walker), has been identified as the most important fruit tree-boring pest of tart cherries, *Prunus cerasus* (L.), and plums, *Prunus domestica* (L.), in Michigan (Biddinger 1989). It is implicated as a major contributor to a 33% decline (from 30 to 20 yr) in the life span of the average tart cherry orchard in Michigan and has been considered a major pest in that state only since the early 1970s. It is associated with bark wounds (in the form of longitudinal splits in the bark extending to the cambium layer) caused by mechanical harvesters. Without the presence of some sort of damage to the bark to provide an entryway, larvae are not able to enter the cambium layer where they feed throughout their development (Biddinger 1989, Biddinger and Howitt 1992). Canker diseases, which provide an entryway for borers in stone fruits (Swift 1986, Biddinger 1989), may be spread from diseased to healthy tissues by insects associated with bark injury in stone fruit trees (Moller and DeVay 1968).

Before our studies, it was not known to what extent American plum borer may have been a pest of New York State stone fruits. It has long been known to exist in New York (Blackslee 1915), and adult males were caught in traps in cherries and plums with the aid of a recently developed pheromone lure (Biddinger et al. 1994) during the 1993 growing season. These moths could have been lured from wild hosts. Their presence in traps placed in cultivated fruit trees exhibiting borer damage was cause to investigate further. Until recently, the severe bark injury seen in many New York orchards had been attributed to lesser peachtree borer, *Synanthedon pictipes* (Grote & Robinson); peachtree borer, *S. exitiosa* (Say); and dogwood borer, *S. scitula* (Harris) or to other causes of bark injury such as sunscald, winter damage, canker diseases, or harvester damage. Much of this type of damage, however, may be attributable to American plum borer. It is important to know whether or not this is the case for 3 main reasons. First, identification of American plum borer as a major fruit tree-boring pest would alert growers, extension agents, agrichemical personnel, and others that it may be a problem in many New York State orchards.

Second, American plum borer feeding is generally more destructive than that caused by the other borers. Lesser peachtree borer larvae feed locally or vertically within the cambium, whereas American plum borer feeds horizontally, girdling scaffold limbs or the entire tree (Biddinger 1989). American plum borer also is generally more abundant within a particular wound (Wiener and Norris 1983). American plum borer infestation of young pecan trees has led to death of the young trees or crotch splitting later in the life of the tree (Pierce and Nickels 1941). Its feeding can lead to cankers and rots by providing suitable entryways for pathogens and actually may account for much of the damage attributable to borers (Wiener and Norris 1983). American plum borer also may increase the spread of some of these diseases, as has been demonstrated with mallet wound canker of almond, *Prunus* *amygdalus* Batsch, caused by the fungus *Ceratocystis fimbriata* (Moller and DeVay 1968).

Third, American plum borer phenology is different from the major clearwing moth pests; therefore, timing of chemical controls is different. Proper identification will lead to better timing of insecticide applications. Misidentification will lead to mistimed, ineffective chemical applications, resulting in overuse of insecticides and lack of control.

The 1995 New York State recommendation for control of peachtree and lesser peachtree borers in cherries was to apply up to 3 trunk sprays of chlorpyrifos or a pyrethroid, early, mid-, and late summer (Wilcox et al. 1995). In peaches, *Prunus persicae* (L.), 3 sprays of pyrethroids or methyl parathion, or 1 midsummer or postharvest spray of chlorpyrifos or endosulfan was recommended. No recommendation was provided at that time for control of American plum borer. If insecticides are applied midseason or postharvest only, damage by the 1st summer brood of American plum borer larvae will not be prevented. The recommendation for chemical control of American plum borer in Michigan is to apply 1 trunk spray of chlorpyrifos at tart cherry petal fall, to coincide with the peak of the 1st moth flight. This practice reportedly provides season-long control of all important borers (Biddinger and Howitt 1992). American plum borer flight phenology, in relation to crop phenology, is the same in New York as that reported in Michigan (Biddinger and Howitt 1992), leading to the hypothesis that the same chemical control strategy would work in New York. Adoption of this strategy presumably would lead to reduced insecticide use and better control; however, this strategy needs to be tested under local conditions before it can be recommended.

Alternatively, a number of field trials have been conducted (Kaya and Brown 1986, Davidson et al. 1992, Gill et al. 1992) on control of clearwing borers in trees by using entomopathogenic nematodes. These studies indicate that commercially available formulations of steinernematid nematodes can provide control of these borers comparable to that achieved with chemical insecticides. Cossentine et al. (1990) successfully controlled peachtree borer with the nematode *Heterorhabditis bacteriophora* (Poinar) (formerly *Heterorhabditis heliothidis* (Khan, Brodas and Hirschmann)). Georgis and Gaughler (1991) reported that control of larvae of Japanese beetle, *Popillia japonica* Newman, in the soil with *H. bacteriophora* was comparable to control with chemical insecticides and superior to that with *Steinernema carpocapsae* because of its more active host seeking behavior.

Our objectives were to determine the pest status of American plum borer in stone fruit crops, particularly tart cherries, in the important production areas in New York State; to evaluate the efficacy of chlorpyrifos applied once, versus twice, versus current local recommendations for the control of borers in stone fruits against both American plum borer and the clearwing borers; and to evaluate the efficacy of entomopathogenic nematodes for control of borers infesting tart cherry and peach.

Materials and Methods

Adult Survey, 1994. To determine American plum borer adult flight phenology and to determine its prevalence as a pest throughout New York State, wing traps baited with pheromone lures (Trécé, Salinas, CA) were placed in 5 tart cherry, 4 peach, and 4 plum orchards located in important production areas (western New York, Wayne County, the Hudson Valley, and Long Island). Traps were checked and cleaned weekly.

Larval Survey, 1994. To estimate the level of infestation and the relative abundance of borers present in orchards where adults were caught, tree trunks were sampled for larvae during the fall. Fifty trees per orchard that exhibited bark wounds were examined for the presence of frass to estimate the percentage of trees infested by borers. In tart cherry orchards, bark wounds were associated with mechanical harvesters and subsequent cambium loss caused by borer feeding. No formal measurements of bark damage were taken. As an approximation, however, we consider damage to be slight if vertical splits in the bark are <15 cm long and cambium loss in both directions from the edges of the split is <5 cm, and severe if vertical splits are >30 cm long and cambium loss from the edges is >15 cm or $>25\%$ of the diameter of the trunk or limb. In peach orchards, cankers on trunks and lower scaffold limbs were examined. In plum orchards, trunk wounds were uncommon and were not due to any particular primary cause. To determine which borers were present, a hammer and a long screwdriver were used to pry back the bark around wounds (Biddinger 1989) on 5 infested trees per orchard. All larvae that could be found in each tree were identified as either American plum borer or clearwing borer, including both peachtree and lesser peachtree borer (Peterson 1967, Biddinger 1989). In 1 plum orchard, samples of galls caused by black knot, *Apiosporina morbosa,* of plum were collected and examined in the laboratory for borer larvae that might be found within.

Adult Survey, 1995. One peach orchard in which cankers were widespread was included in the 1994 survey, and it was found to be infested by American plum borer. Because the highest concentration of peaches in western New York is located in Niagara County, where many orchards are infected by canker diseases that make them more susceptible to borer infestation, we decided to determine the prevalence of American plum borer infesting peach trees in this area. Long Island also is a fairly important peach-producing region, but was not included in this survey because no American plum borer larvae were found there in the 1994 survey. Wing traps baited with pheromone lures (Trécé) were placed in 6 commercial peach orchards extensively infected by canker diseases in Niagara County. Traps were checked and cleaned weekly.

Larval Survey, 1995. To estimate the relative abundance of each borer species present, trees were sampled for larvae during the fall by prying back the bark, as previously described, around infested cankers on

Table 1. Insecticide treatments for control of *E. semifuneralis*, 1995

Insecticide	Formulation	Rate, AI/liter[a]	Timing
		Tart cherry	
Chlorpyrifos	Lorsban 4EC	3 g	6 June
Chlorpyrifos	Lorsban 4EC	3 g	6 June, 12 July
Esfenvalerate	Asana XL 0.66 EC	0.025 g	6 June
Esfenvalerate	Asana XL 0.66 EC	0.025 g	6 June, 12 July, 15 Aug.
Steinernema feltiae	Scanmask	65,000 ij	28 June
Steinernema feltiae	Scanmask	65,000 ij	28 June, 15 Aug.
		Peach	
Chlorpyrifos	Lorsban 4EC	3 g	7 June
Chlorpyrifos	Lorsban 4EC	3 g	7 June, 13 July
Esfenvalerate	Asana XL 0.66 EC	0.025 g	7 June
Esfenvalerate	Asana XL 0.66 EC	0.025 g	7 June, 13 July, 17 Aug.
Steinernema feltiae	Scanmask	65,000 ij	27 June
Steinernema feltiae	Scanmask	65,000 ij	27 June, 17 Aug.

[a] g, grams; ij, infective juveniles.

trunks and lower scaffold branches of 5 randomly selected trees per orchard. Larvae present were identified as American plum borer or clearwing borer.

Efficacy Studies, Nematode Bioassay, 1995. Using American plum borer larvae collected in the field during the hibernating period, a preliminary bioassay was conducted with a commercial formulation of *Steinernema feltiae* (Scanmask, BioLogic, Willow Hill, PA) to confirm nematode infectivity and viability before field application. A piece of filter paper was fitted into the bottom of a 29.6-ml plastic dose cup and treated with 1 ml of distilled water (untreated control) or a nematode–distilled water solution mixed to contain either 50 or 500 infective juveniles per milliliter (Woodring and Kaya 1988). Counts from the (calculated) 500 infective juveniles per milliliter stock solution (from which the dilution to a solution of 50 infective juveniles per milliliter was made) indicated that the actual concentration was ≈385 total nematodes per milliliter; approximately half of these were living. Large larvae (4th–7th instars) were used to assess nematode infectivity. Field applications of Scanmask were aimed at large larvae because small larvae (Kaya 1985) and pupae (Kaya and Hara 1980) may be less susceptible to infection. Larvae were collected and treated the same day. Twenty single-larva replications per nematode treatment, and 18 replications in the untreated control (because of lack of specimens) were used. Each larva was placed in a dose cup on the treated filter paper and covered with moistened sawdust. A lid was then fitted onto the dose cup. Larvae were held in the dose cups in a growth chamber at 25°C, in plastic bags containing wet paper towels to maintain high humidity, and examined 4 and 13 d after treatment to determine mortality.

Efficacy Studies, Field Control, 1995. Field efficacy trials were conducted in 2 orchards (a tart cherry orchard in Wayne County and a peach orchard in Niagara County) identified in 1994 as relatively heavily infested with American plum borer and with an average number (2–3 per tree) of clearwing borers. Treatments using chlorpyrifos (Lorsban 4 EC, Dow AgroSciences, Indianapolis, IN), esfenvalerate (Asana XL 0.66 EC, DuPont, Wilmington, DE), and *S. feltiae* (Scanmask) are summarized in Table 1. There also was an untreated control at each site. Insecticides were applied as coarse sprays to trunks and, in peaches to lower scaffold branches, by using a handgun sprayer at 400 psi. Care was taken to direct the spray stream into openings in the bark. An average of ≈9.5 liters of spray solution per tree was applied. Infective juvenile nematodes are known to withstand spray pressures of up to 1,000 psi (Dutky 1974). To guard against nematodes being destroyed or lost by being passed through the sprayer, all filters and screens were removed before Scanmask applications. A sample of the tank mix was taken just before each application and compared with a sample of the spray solution. There was no significant difference between the number of live nematodes in the tank mix and spray solution samples (analysis of variance [ANOVA]: June application $P = 0.30$; df = 1, 18; $F = 1.128$; August application $F = 0.269$, df = 1, 18; $P = 0.61$).

Each treatment consisted of 5 single-tree replicates arranged in a completely randomized design. The trial was performed in moderately to heavily damaged trees because these trees tend to contain higher numbers of both kinds of borers.

The 6–7 June applications were applied at the time of tart cherry petal fall (shuck split in peaches), which also approximately coincided with the peak of the 1st flight of American plum borer. The 12–13 July applications were timed to coincide with the beginning of the 2nd flight. Applications of *S. feltiae* were made when American plum borer larvae were present during each generation. Control was evaluated in the fall (September–October) by prying back the bark as previously described and by counting living American plum borer and clearwing borer larvae.

Efficacy Studies, Nematode Bioassay, 1996. Concurrent with field control treatments, a bioassay was conducted in the field by injecting *H. bacteriophora* into infested trees and sampling larvae 4 d later. Injector applications were made using a backpack sprayer equipped with a single adjustable stream nozzle (model 5500 Adjustable Conejet, size 18×, Spraying Systems, Wheaton, IL), driven by CO_2 at 70 psi. The nozzle was inserted into all openings found in the bark, from ground level to the 1st scaffold limbs, and sprayed until the point of flooding.

Efficacy Studies, Field Control, 1996. Two commercial tart cherry ('Montmorency') orchards in Wayne County were used for insecticide evaluations. In addition to chlorpyrifos, we tested the efficacy of the entomopathogenic nematode *H. bacteriophora* (Cruiser, Ecogen, Langhorne, PA). Efficacy of the (following) treatments was evaluated in each orchard—chlorpyrifos applied at a rate of 3.6 g (AI)/liter on 24 May or 24 May and 30 July; and *H. bacteriophora* applied at a rate of 390,000 infective juveniles per liter by either handgun or injector on 26 June or 26 June and 16 August. There also was an untreated control. Sprays were timed to coincide with the following events: 24 May, petal fall; 30 July, 2nd flight peak; 26 June, 1st-generation larvae present; 16 August, 2nd-generation larvae present.

There were 5 single-tree replicates of each treatment in each orchard. Chlorpyrifos was applied by handgun only. Handgun treatments were applied using a standard high-pressure (350 psi) handgun sprayer. All filters and screens were removed before Cruiser applications. Samples were taken of the sprayate to confirm that the desired concentration of live nematodes was being applied. The entire trunk from ground level to the lowest scaffold limbs was sprayed to runoff, with care taken to direct the spray stream into openings in the bark. An average of 7.6 liters of solution was applied per tree per application. Injector applications were made as described for the field bioassay. Approximately 1.1 liters of solution was applied per tree per application with the injector.

Control of borers was evaluated in October by removing bark from the point of all openings, between ground level and 1.25 m, to the edge of live cambium. All live larvae found were counted and identified as either American plum borer or clearwing borer.

Statistical Analysis. Insecticide efficacy data were transformed by $\log_{10}(x + 1)$ and evaluated using ANOVA. The Fisher least significant difference test ($P = 0.05$) was used to determine differences among means (SuperANOVA version 1.11, Abacus Concepts 1991).

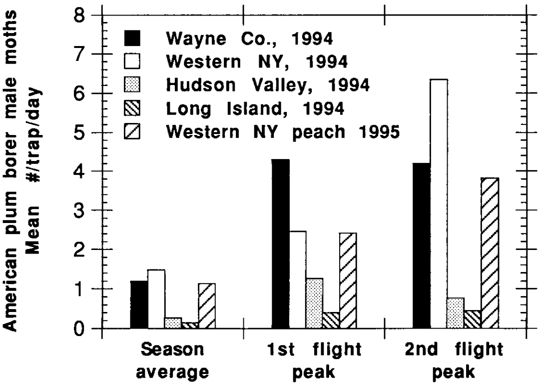

Fig. 1. Magnitude of American plum borer flight by region and year.

Results

Adult Survey, 1994. More moths were caught in western New York (Orleans and Niagara counties) and in Wayne County than in the Hudson Valley or on Long Island (Fig. 1). Most of the orchards monitored in Wayne County and western New York are tart cherries that are mechanically harvested. Mechanically harvested trees are known to be especially vulnerable to infestation by borers (Biddinger 1989). The 1 peach orchard monitored in western New York was heavily infected with a canker disease, and 1 of the 2 plum orchards with black knot. Damage from these diseases also is known to lead to lesser peachtree borer (Swift 1986) and American plum borer (Biddinger 1989) infestation. It is likely that the greater concentration of mechanically harvested tart cherry trees in western New York and Wayne County has resulted in a buildup of populations of American plum borer and the greater likelihood that other susceptible stone fruit orchards will be infested.

The 1st flight of male moths began around petal fall (tart cherry) and peaked shortly thereafter in both Wayne County and western New York (Table 2). The earliest catch was 12 May. The earlier catches in Wayne County and western New York were at sites farther from Lake Ontario. Surprisingly, 1st trap catches in the Hudson Valley, where temperature-

Table 2. Phenology of American plum borer adult male trap catches in surveyed orchards, Wayne County and western New York (n = 13), 1994–1995

Event	Yr	Range		1994–1995 mean (± SD)	
		Date	DD[a] (10°C)	Date	DD (10°C)
1st catch	94	12 May–25 May	119–163		
	95	5 May–19 May	31–115	17 May (±7)	107 (±52)
1st flight peak	94	25 May–16 June	152–334		
	95	19 May–6 June	74–277	1 June (±6)	186 (±62)
2nd flight start	94	7 July–13 July	595–703		
	95	6 July–13 July	576–616	12 July (±2)	619 (±43)
2nd flight peak	94	26 July–3 August	859–917		
	95	13 July–31 July	576–914	26 July (±6)	814 (±116)
2nd flight subsides	94	6 Sept.–22 Sept.	1,223–1,324		
	95	6 Sept.–20 Sept.	1,295–1,445	17 Sept. (±6)	1,349 (±60)

[a] Degree days from 1 January.

Table 3. Comparison of density of American plum borer versus clearwing borer larvae infesting surveyed orchards, 1994

Orchard	Age, yr	% trees infested	Larvae/5 trees[a] APB	Larvae/5 trees[a] CWB	% APB[b]	Proportion APB[c]
WNY Cherry 1[d]	17	92	96	16	86	0.82
WNY Cherry 2	13	50	45	10	82	0.57
WNY Cherry 3	15	30	33	7	83	0.47
WNY Cherry 4	13	30	18	14	56	0.54
WNY Cherry 5	20	38	40	15	73	0.67
WNY Peach 1	25	74	29	11	73	0.75
WNY Plum 1	20	0	—	—	—	—
WNY Plum 2	—	28	4	2	67	0.58
LI Peach 1[e]	5	20	0	6	0	0
LI Peach 2	15	30	0	4	0	0

[a] APB, American plum borer; CWB, clearwing borers.
[b] Percentage of total number of larvae per 5 trees.
[c] Average of proportion found in each tree.
[d] Western New York.
[e] Long Island, New York.

Table 4. Density of American plum borer and clearwing borer larvae infesting cankers in peaches, 1995

Orchard	Avg no. larvae per canker[a] APB	Avg no. larvae per canker[a] CWB
Sanger	0.57	0.64
T. Tower	0.14	1.14
D. Tower	0.09	1.36
Sievert	0.40	1.0
Kappus	0.33	1.33
Average	0.31	1.09

[a] APB, American plum borer; CWB, clearwing borer.

dependent events typically occur 1–2 wk in advance of those in western New York, were at approximately the same time, or even a little later than the western New York sites. On eastern Long Island, the 1st flight began during the 1st week of May. Duration of the 1st flight in the Wayne County–western New York region was ≈4 wk, with the peak catch occurring 1 June at most sites. The 2nd flight began about the same time, but peaked slightly earlier in Wayne County (26 July) than in western New York (3 August). Flights in Geneva, Wayne County, and western New York were complete by the 3rd wk in September.

Larval Survey, 1994. In western New York, at least 30% of the trees surveyed in every cherry orchard were infested by some kind of borer (Table 3). In 1 orchard, 92% was infested. In orchards more heavily infested by borers in general, the greater proportion of larvae was American plum borer. In orchards where fewer trees were infested and bark damage was generally slight, the species found were at least as likely to be clearwing borers. In trees suffering from severe bark damage, American plum borer often was found in high numbers. There were usually 2 or 3 clearwing borers in every infested tree, regardless of the severity of damage. One peach orchard was monitored in western New York; this orchard was widely infected with a canker disease. Each of the 5 trees sampled contained American plum borer larvae, 4 contained clearwing borers, and the greater proportion was American plum borer.

In plum orchards monitored in this survey, which were not mechanically harvested, tree trunks were not heavily infested by borers, presumably because there were fewer entryways into the bark. In a plum orchard that was infected with black knot, however, 78% of the galls examined was infested by ≥1 borers. In contrast to tart cherry and peach tree trunk infestation, black knot galls contained predominantly clearwing borer larvae. In total, there were .3 times as many clearwing borers as American plum borer, and they infested 60% of the galls examined; American plum borer larvae were found in only 20% of the galls. Twelve percent of the galls contained both types of borers.

No larval sampling was done in the Hudson Valley. In 2 cases, no adults were caught, and 1 orchard was removed before samples could be taken. No American plum borer larvae were found in the orchards monitored on Long Island (Table 3), although some old hibernaculae were found in 1 tree in an orchard that was lightly infected with a canker disease. This result is consistent with numbers of adult males caught in pheromone traps in those orchards, which were much lower than in Wayne County and western New York (Fig. 1). Across all orchards, however, there was no correlation between the number of American plum borer larvae per tree and the season average number of adults caught per trap per day ($r^2 = 0.19$, $P = 0.12$); American plum borer larvae per tree was correlated with the percentage of trees infested ($r^2 = 0.69$, $P < 0.01$).

Adult Survey, 1995. All of the orchards surveyed were peaches located in Niagara County and within 1.6 km of Lake Ontario. American plum borer male moths were caught in each orchard surveyed. Phenological events occurred at approximately the same times in all of the orchards. First catch was noted on 5 May in the Sanger and Bittner orchards, but the 1st significant catch was on 19 May in all orchards (Table 2). First flight peak trap catch occurred on 2 June in the 4 orchards closer to Lake Ontario, and slightly earlier in the 2 orchards farther south. The 2nd flight began 13 July in all orchards, peaked around 21 July, and was finished by 20 September.

Larval Survey, 1995. In 1995, American plum borer adult male trap catches were as high as in the 1994 survey (Fig. 1). Numbers of American plum borer larvae infesting peach trees in 1995 were lower than those found in tart cherries in 1994, and clearwing borer larvae outnumbered American plum borer larvae (Table 4). In 1994, in the western New York peach orchard included in the 1994 survey, American plum borer larval numbers were moderate and outnumbered clearwing borers by ≈3 to 1. In 1995, in the same peach orchard, numbers of American plum borer larvae were low and were about equal in number to the clearwing borers. Therefore, it is unclear whether American plum borer larval numbers are lower in peaches than in tart cherries, and lower in peaches than are clearwing borers, or whether American plum borer larval numbers were lower in 1995 than in 1994

Table 5. Efficacy of insecticides tested against the American plum borer, 1995 and 1996

Material	Rate, (AI)/liter[a]	Timing	Mean (± SD) American plum borers/tree			
			n	Larvae	n	Larvae
		1995				
				Tart cherry		Peach
Chlorpyrifos	3 g	6–7 June, 12–13 July	4	1.25 ± 1.89a	5	0.4 ± 0.55a
Esfenvalerate	0.025 g	6–7 June, 12–13 July, 15 Aug.	3	6.0 ± 3.46bc	4	0.5 ± 1a
S. feltiae	65,000 ij	27–28 June, 15 Aug.	4	7.0 ± 3.46bcd	5	1.2 ± 1.79a
Esfenvalerate	0.025 g	6–7 June	3	11.0 ± 5.29bcd	5	1.2 ± 1.30a
Chlorpyrifos	3 g	6–7 June	5	12.8 ± 8.35cd	5	2.2 ± 2.28a
S. feltiae	65,000 ij	27–28 June	3	17.0 ± 7.94d	5	2.2 ± 2.28a
Untreated control	—	—	5	5.0 ± 1.87b	5	2.0 ± 2.45a
		1996				
				Tart cherry, Sonneville		Tart cherry, VanAcker
Chlorpyrifos	3.6 g	24 May, 30 July	4	0.25 ± 0.50a	4	0a
Chlorpyrifos	3.6 g	24 May	4	0a	5	1.8 ± 1.64ab
H. bacteriophora						
Injector	390,000 ij	26 June	3	1.7 ± 1.53ab	5	1.8 ± 1.92ab
Handgun	390,000 ij	26 June	5	2.4 ± 1.67b	5	4.2 ± 5.12b
Injector	390,000 ij	26 June, 16 Aug.	5	3.2 ± 3.11b	5	3.8 ± 2.95b
Handgun	390,000 ij	26 June, 16 Aug.	5	3.6 ± 4.28b	5	3.6 ± 2.61b
Untreated control	—	—	4	3.0 ± 2.16b	5	4.8 ± 1.64b

Means followed by the same letter are not significantly different ($P \leq 0.05$, Fisher LSD test). Analysis performed on data transformed by $\log(x + 1)$.

[a] g, grams; ij, infective juveniles.

[b] *H. bacteriophora.*

because of some unknown factor such as drought or disease. Many more cadavers of apparently diseased American plum borer larvae were observed in 1995 than in 1994. It also may be that the concentration of mechanically harvested cherries in eastern Niagara, Orleans, and Wayne counties has resulted in a buildup of American plum borer that has not occurred in western Niagara County, where peaches are the predominant stone fruit crop. Of peach orchards surveyed in 1995, 2 of the 3 which had the highest numbers of American plum borer larvae are in an area dominated by tart cherries and the other is virtually abandoned.

Efficacy Studies, Nematode Bioassay, 1995. *S. feltiae* was shown in the laboratory bioassay to infect American plum borer larvae. Mortality occurred more quickly when larvae were treated with 500 infective juveniles per milliliter than with 50 infective juveniles per milliliter, but after 13 d the level of mortality was essentially the same. To determine whether cadavers were indeed infected by nematodes, dead larvae from the nematode treatments were placed individually in water in dose cups for several days to allow nematodes to reproduce. After 2 or 3 generations, infective juveniles should exit cadavers in visible numbers (Woodring and Kaya 1988). Problems with sanitation were encountered, so it could not be determined if every cadaver contained nematodes. However, nematodes did stream from 3 of the larvae from the 500 infective juveniles per milliliter treatment, and all cadavers in the nematode treatments had the same general appearance in death (changed color, limpness), which was consistent with symptoms of *Steinernema* spp. infection described by Woodring and Kaya (1988).

Efficacy Studies, Field Control, 1995. In the field, numbers of American plum borer found in each tree varied considerably, probably depending on the existing level of damage to the bark and the condition of the exposed edge of the cambium underneath dead bark. If the cambium was alive and fresh, larvae were generally abundant. Cambium was sometimes dead and rotted or dried out and would not support borers. A number of cherry trees died during the course of the study because of extensive borer damage coupled with drought.

Bark damage was extensive in the Brownell tart cherry orchard. Splits in the bark were large and bark was peeling away from the wood so that there were usually large, direct pathways to allow the spray stream to reach the cambium, where borers are found. Therefore, nematodes in the *S. feltiae* treatments should have been able to come into contact with the host. Two applications of *S. feltiae* resulted in significantly fewer American plum borers per tree than 1 application, indicating some level of control (Table 5); however, the only commercially effective program was 2 applications of chlorpyrifos.

Numbers of American plum borer larvae in the Bittner peach orchard were too low to discern any differences among treatments for this insect (Table 5). All chemical treatments provided adequate control of clearwing borers. The untreated control and both *S. feltiae* treatments contained about the same number of clearwing borer larvae, indicating a lack of control with *S. feltiae.*

Efficacy Studies, Nematode Bioassay, 1996. In the field bioassay, too few larvae could be found to evaluate efficacy, but 3 of 5 larvae found in 2 trees exhibited typical symptoms of *H. bacteriophora* infection, including brick red coloration and limpness (Woodring and Kaya 1988).

Efficacy Studies, Field Control, 1996. In 1995, borer control trials were performed in a tart cherry orchard where American plum borer larval numbers were extremely high and clearwing borers were absent. In that trial, 2 applications of chlorpyrifos provided the only acceptable control. Based on control trials in Michigan, we suggest that in orchards where American plum borer numbers were low, 1 application of chlorpyrifos at petal fall should be sufficient. Therefore, we selected 2 orchards for the 1996 trials where the level of bark damage was low to moderate. Numbers of American plum borer larvae were comparatively low in both orchards. Clearwing borer numbers in the Sonneville orchard were about average (2 or 3 larvae per tree) for a tart cherry orchard in this region. Clearwing borers were virtually absent from the VanAcker orchard, however.

Similar to *S. feltiae*, *H. bacteriophora* provided little or no control. Although both nematodes will infect American plum borer larvae, we apparently were unable to contact active larvae in the field adequately with the methods used. In the Sonneville orchard, American plum borer numbers were significantly different from the untreated control and all *H. bacteriophora* treatments, except 1 in trees receiving 1 or 2 applications of chlorpyrifos (Table 5). Analysis of clearwing borer control is inconclusive because of the variability of the data. In the VanAcker orchard, only the treatment using 2 applications of chlorpyrifos provided American plum borer control significantly better than the untreated control. There were no differences in clearwing borer control among treatments; they were virtually absent from this orchard.

Discussion

Our survey data indicate that the most common wood-boring insect pest of tart cherries in New York State is the American plum borer. It is also the most damaging because of its horizontal (girdling) feeding behavior (Biddinger 1989). Tart cherry orchards in which tree trunks are heavily infested by borers will almost certainly contain a large number of American plum borer larvae and rarely more than a few clearwing borer larvae per tree. In peaches infected with canker diseases, American plum borer may be more numerous than clearwing borers in some years or in some locations, but in other cases clearwing borers are more abundant. Stone fruit trees in general are more heavily infested by American plum borer in the western New York and Wayne County fruit growing regions than in Hudson Valley or Long Island. This is probably because of the greater concentration of mechanically harvested tart cherry orchards in western New York and Wayne County, resulting in a buildup in American plum borer. These surveys provide a good indication of the pest status of American plum borer in the major stone fruit growing areas of New York.

Results of our insecticide efficacy trials are not in agreement with studies done in Michigan, in which 1 application of chlorpyrifos provided season-long control in tart cherry (Biddinger 1989). In 1995 this may have been because a slightly lower rate of chlorpyrifos was used (3 g [AI]/liter versus 3.6 g [AI]/liter in the Michigan study) or because of higher populations of American plum borer in our study. Numbers in the Brownell orchard were about twice as high as in a high-pressure cherry orchard used in the Michigan studies. In a plum orchard used in the Michigan studies, which had higher numbers of larvae (comparable with the Brownell orchard), results were very similar to our tests; 1 application of chlorpyrifos alone was ineffective and a 2-spray program provided significantly better control. In 1996, only a population of American plum borer that might be considered low (2 or 3 larvae per tree) in the Sonneville orchard, was controlled by 1 chlorpyrifos application. In the VanAcker orchard, where the American plum borer population was only slightly higher, larval numbers were not significantly reduced by 1 application of chlorpyrifos. Therefore we conclude that, under high pest pressure, 1 application (of any of the materials tested) will not provide season-long control in tart cherry.

Neither *S. feltiae* nor *H. bacteriophora* controlled either borer at any population level at the rates used. Both nematodes were capable of infecting larvae in laboratory and field bioassays, respectively. Failure of these nematodes to control American plum borer in tart cherry and peach trees may have resulted from inadequate larval contact with the spray. Applications of insecticides to peach trees were made using only topical trunk sprays and no injection treatments. Peach bark wounds were not as gaping as those in cherries because the original damage was caused by canker diseases rather than by mechanical splitting. Cankers also are usually filled with gum secreted by the tree, which may block the spray from reaching the cambium. Lesser peachtree borer larvae tend to bore vertically through the cambium, creating galleries rather than feeding along an exposed edge, also making them more difficult to reach with a topical application. All of these factors could have contributed to inadequate larval contact with the nematode sprays in the peach trials. However, the injection application in the 1996 tart cherry trials is unlikely to have failed in delivering spray solution to the area where American plum borer larvae are found. Cossentine et al. (1990) were able to control *S. pictipes* with the nematode *H. heliothidis* in peach trees with injection and trunk sprays. Kaya and Brown (1986) concluded that steinernematid nematodes are particularly effective in controlling borers, such as the clearwing borers, that inhabit moist galleries because those galleries provide an environment suitable for their survival and prey searching behavior. It is possible that the nature of American plum borer bark damage, where large areas of cambium often are destroyed, may result in an environment that is not moist enough to support the entomogenous nematodes tested.

It has been reported that recent increases in the numbers of American plum borer in Michigan have contributed to a 33% decline in the life of tart cherry orchards there (Biddinger 1989). We do not know at this time what effect seasonal feeding by these borers has on the current year's crop, nor do we know whether control is needed each season or only periodically. However, American plum borer is the prevalent trunk borer in western New York and it is decreasing the productive lives of some tart cherry orchards in this area, using a minimum of 20 to an optimum of 30 yr as a basis (R. L. Andersen, personal communication). In the Brownell orchard in 1995, its 18th yr, many trees were dead or severely pruned back, primarily because of American plum borer damage. A number of trees died during the course of that trial because of plum borer damage coupled with drought. Many of the other tart cherry orchards included in the 1994 survey suffered similarly; none was older than 20 yr. Therefore, an understanding of this pest and action to limit its damage will not only reduce potential current season production losses but will increase the life span of the orchard. Currently, little or nothing is being done about this problem in New York State because growers probably are not aware that American plum borer is the cause of much of the decreased vigor or death of their tart cherry trees, and because poor cherry prices have made trunk spraying uneconomical.

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