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THE DEVELOPMENT OF A SEX PHEROMONE LURE FOR THE AMERICAN PLUM BORER, *EUZOPHERA SEMIFUNERALIS* (LEPIDOPTERA: PYRALIDAE), A MAJOR PEST OF CHERRY IN MICHIGAN.

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ABSTRACT

Pheromone components of the American plum borer, *Euzophera semifuneralis*, were defined by use of the electroantennogram screening technique and capillary gas chromatographic retention times of sex pheromone gland constituents. Field studies showed that greatest attraction was achieved with a 1 mg load rate of a 4-component blend in a rubber septum. This blend consisted of a 2:1 ratio of Z,E-9,12-14:ALD and Z9-14:ALD and an equal amount of the corresponding alcohols in a 2:1 ratio, respectively. Commercial lures were used to compare the flight patterns of the American plum borer, peachtree borer (*Synanthedon exitiosa)*, and lesser peachtree borer (*Synanthedon pictipes)* adults in Michigan in 1988.

The cambium feeding lepidopteran pest complex in Michigan cherry orchards currently consists of the lesser peachtree borer, *Synanthedon pictipes* (Grote & Robinson); the peachtree borer, *Synanthedon exitiosa* (Say); and the American plum borer, *Euzophera semifuneralis* (Walker) (Brunner & Howitt 1981, Biddinger 1989, Jones et al. 1989). The first two pests are Sesiidae whose biologies are well known because of their long-standing status as major pests of peaches and apricots in the U.S. and for which specific or general pheromones have been available for monitoring purposes for many years (Brunner & Howitt 1981). The American plum borer has only been considered a significant pest of tart and sweet cherries in Michigan since the early 1970's (Brunner and Howitt 1981). At that time, cherry harvesting shifted from manual picking to the use of mechanical harvesters with hydraulic clamps that physically shake a limb or the entire tree causing the cherries to fall onto a collecting canvas below. Pressures of over 70 kg/cm^2 (1,000 p.s.i.) from the clamps frequently cause cracking of the bark and extensive bruising and crushing of the underlying cambium. These cracks in the bark are ideal avenues of entry for the cambium feeding larvae of both American plum borer and lesser peachtree borer. *Synanthedon pictipes* was a common but relatively minor pest of cherry orchards in the state before mechanical harvesting was introduced (King 1917, Weiner and Norris 1982), but *E. semifuneralis* was previously unknown as a pest of cherries. Tree and limb mortality quickly increased due to cambium girdling by the larvae of these two pests in many

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commercial cherry orchards with *S. pictipes* generally causing only scaffold limbs mortality.

The American plum borer was found commonly to cause a much more serious girdling injury of the entire trunk below the scaffolds which resulted in the death of mature trees in 5–10 years. Girdling of large scaffold limbs was also observed in as little as 2–3 years, especially where limb shakers were used (Biddinger 1989, Weiner and Norris 1983). From 1985 to 1987, many commercial orchards in Leelenau county were found to average 8–12 *E. semifuneralis* larvae per tree and those in Oceana County averaged 3–5 larvae per tree (Biddinger 1989). Weiner and Norris (1983) also found high numbers of both American plum borer and lesser peachtree borer larvae in tart cherry orchards in Door County, Wisconsin.

As mechanical harvesting became more widespread throughout Michigan damage from *E. semifuneralis* and *S. pictipes* became much more abundant and it was soon necessary to initiate chemical control measures for both species. In some areas of the state the commercial life of the orchard was considered to be shortened by 20 to 30% by the combination of shaker and borer damage (Biddinger 1989). The lesser peachtree borer was found to be adequately controlled using dilute handgun applications of long residual insecticides to the trunk and scaffold limbs of cherries in early to mid June (Jones et al. 1989). The American plum borer, however, had previously been a minor pest on a wide range of fruit and nut crops throughout most of the U.S. (Biddinger and Howitt 1992), and little was known of its life cycle. Previous work on this insect indicated that it has a single brood in the eastern U.S. (Forbes 1891, Hulst 1890, Johnson and Lyon 1988), but Blackslee (1915) in Virginia, Sanderson (1901) in Delaware, and previous work in Michigan (Howitt, unpublished data) indicated that it was double brooded. Slingerland & Crosby (1914), however, thought there were three broods in Delaware and Van Steenwyk (pers. comm.) believed there to be at least a partial third generation in California. Pierce and Nichols (1941) indicated up to five generations in Texas. The purpose of this study was to develop an attractant trap for *E. semifuneralis* as a monitoring tool for commercial cherry growers in Michigan to assess populations in the orchard and to help time control measures in conjunction with control programs for *S. pictipes*.

METHODS AND MATERIALS

During the spring of 1985, over 400 live pupae were collected from a commercial orchard of 28 year old 'Montmorency' tart cherry trees in Oceana County (near Mears), Michigan. The pupae were removed from their silken hibernacula, separated by sex and kept refrigerated at 5 °C in closed containers with moist towels to prevent dessication before shipment. The pupae were sent to Geneva, New York for the characterization of the sex pheromone components.

Electroantennograms were recorded from male moths to generate activity profiles from 12-, 14- and 16-carbon mono- and di-unsaturated acetates, alcohols, and aldehydes (Roelofs 1984). The library of standards (10 μl chemical on filter paper/cartridge) contained almost every Z- and E-monounsaturated isomer from position 2 to the terminus. Sex pheromone extract was obtained by excising the female pheromone gland from the moth abdominal tip and placing it in 50 μl of hexane. The glands were removed from the solvent after soaking for 1 h and aliquots were then injected (splitless injector) on a polar (25 m Carbowax 20M) capillary GLC column for comparison of retention times to those of standard chemicals. After holding for 2 min. at 60°C, the temperature was raised at 5°C/min. to 200°C.

Treatments consisting of three blends of potential pheromone components suggested by the above analysis were loaded onto rubber septa and shipped to Michigan for field trials in commercial tart cherry orchards. Treatments were arranged in a randomized complete block design using Pherocon@ II traps (Trece Incorporated, Salinas, CA) in two different 6-ha commercial cherry blocks in the county. Each of the 4 treatments and two control traps (1 with unloaded septum and 1 blank) were replicated in three 14-tree blocks at each location in the center of each orchard for a total of 6 replicates. Treatments within a block were placed in a single row of trees with at least 15 m between traps, and each block was separated by at least 90 m from an adjacent block. The blocks were staggered along the length of the orchard to minimize overlap of pheromone plumes within each block and from other blocks.

Care was taken to avoid cross-contamination of the treatments during initial placement of the caps in the traps by dipping the forceps used for the placement of the caps in the traps in acetone between treatments and by using disposable rubber gloves during handling in the field. All traps were placed in the orchard on 22 May and trap catches were recorded every other day until the end of the flight period in late June. At each observation, the traps were rerandomized on the trees within each block, and the moths trapped in the tanglefoot were scraped out or a new trap used.

The second set of treatments consisted of a blank and 5 concentrations of the active blend of 4 components from the first field test. The traps were again deployed in a randomized complete block design in the orchard in the same manner as used for the spring field test. In order to evaluate response by American plum borer populations in different geographic locations, three 20+ year old tart cherry blocks in Oceana County and a 25-year-old block in the more northern Leelenau County were used . The methods used for the placement of traps, rerandomization, and avoidance of cross-contamination were as described above. Both of the orchards at Mears were again used, one with two replicates, one with 1 replicate, and a new third block approximately 16 km removed near Shelby with 1 replicate. Another 4 replicates were placed in the Leelenau County tart cherry orchard. The traps were placed on 6 July and monitored twice weekly until the end of adult emergence on 10 September. The rubber septa were not replaced during this period. The total number of moths caught per block at the Oceana and Leelenau County orchards were pooled and the means separated by Duncan's Multiple Range Test ($P = .05$).

Commercial lures (Trece Incorportated, Salinas, Ca.) were used to compare the flight patterns of *E. semifuneralis*, *S. exitiosa*, and *S. pictipes* adults throughout the year in Michigan in 1988. Weekly observations were made and the male catches in 3 traps/location were average for each species.

RESULTS

Only a small number of adults were available just prior to the first adult flight in the field, and so only a 2-day evaluation was conducted to define possible pheromone components. The electroantennogram screening assay of all monounsaturated standards in the library showed that the highest male moth antennal responses were elicited by (*Z*)-9-tetradecenal (Z9–14:ALD), (*Z*)-9-tetradecenol (Z9–14:OH), (*E*)-12-tetradecenal, and (*E*)-12-tetradecenol. Further testing of the 4 possible geometric isomers each of 9,12-tetradecadienal and 9,12-tetradecadienol showed that the greatest responses were elicited by

Table 1. Field attractancy test with first generation American plum borer moths in Oceana County (May 22-June 28, 1985).

Treatments (rubber septa)	Mean # Males/traps*
Trap +	
Blank (O μg)	0a
500 μg Z,E-9,12-14:ALD+250 μg Z9-14:ALD	0a
500 μg Z,E-9,12-14:OH+250 μg Z9-14:OH	0a
500 μg Z,E-9,12-14:ALD+250 μg Z9-14:ALD +Z,E-9,12-14:OH+250 μg Z0-14:OH	7.3b

*Total of 6 traps rerandomized 8 times. Means followed by the same letter are not statistically different (P=0.05; DMRT).

(*Z,E*)-9,12-tetradecadienal (Z,E-9,12-14:ALD) and (*Z,E*)-9,12-tetradecadienol (Z,E-9,12-14:OH). Capillary GLC analysis confirmed that there were components in the pheromone gland extracts with retention times identical to those of Z9-14:ALD; Z9-14:OH; Z,E-9,12-14:ALD; and Z,E-9,12-14:OH, and that the these were present in a ratio of ca. 1:1:2:2, respectively.

A field test was conducted utilizing combinations of the 4 compounds defined in the laboratory study (Table 1). Field observations of pupae indicated that the peak flight period was over by the time the test was initiated in the first week of June, but trap catches accumulated before the end of the first generation adult flight period were considered to be sufficient for evaluation. Only the treatment containing both the alcohols and aldehydes caught any moths during the 2-week testing period, with a total of 44 moths caught in 6 traps.

A second test conducted during the summer flight with various concentrations of the 4-component mixture showed that traps baited with the highest dosage was the most attractive (Fig. 1). This rate (1 mg/Lure) was standardized in 1986 by Zoecon Corporation (Paolo Alto, Ca.) as a commercially available American plum borer lure. Commercial lures were used in 1988 to define the flight pattern of American plum borer moths in Michigan (Fig. 2), and to compare it to the flight patterns for lesser peachtree borer and peachtree borer adults in cherry orchards.

DISCUSSION

In Michigan, this pheromone blend has been very specific toward *E. semifuneralis*. Only one other species of *Euzophera*, *E. ostricolleralla* Hulst, is found in Michigan and it is relativley uncommon and found only in the southernmost counties (M. Nielsen, pers. commun.). It is not known if this or any of the other species of *Euzophera* are attracted to the American plum borer blend. The individual components of the blend are commonly used by species from several families, and have been reported in the following number of pyralid species: Z9-14:ALD= 8; Z9-14:OH= 10; Z,E-9,12-14:ALD= 7; Z,E-9,12-14:OH= 16 (Arn et al. 1992). Development of a sex pheromone lure for monitoring *E. semifuneralis* has led to a more complete understanding of its life cycle on Michigan cherries, thus aiding the development of effective control strategies for lepidopteran cambium feeding pests. Control strategies previous to this study centered around the single application of relatively low rate of a long residual insecticide to the trunk and lower scaffold limbs in early to mid June (Howitt, unpublished data). This coincided well with the peak emergence and egg laying of the lesser peachtree borer and gave excellent

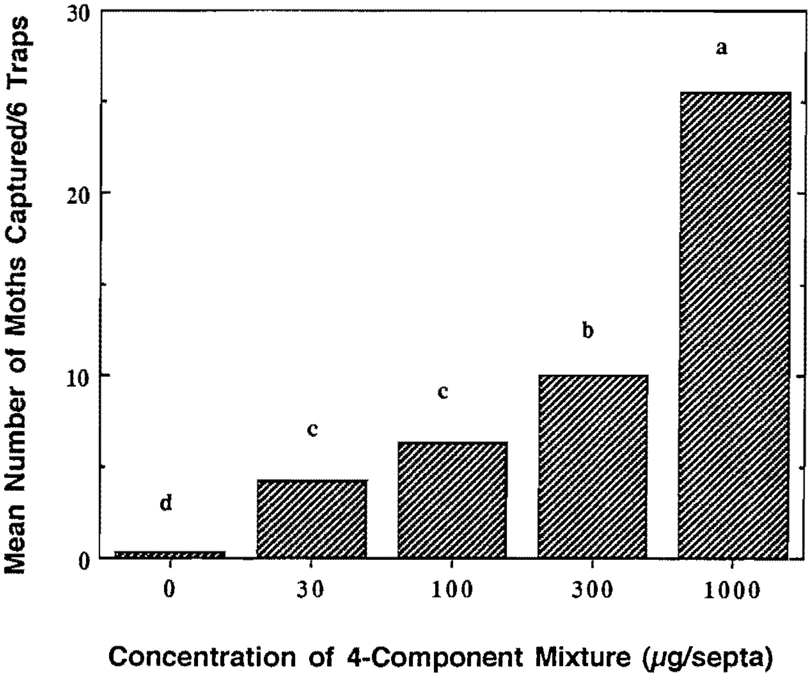

Figure 1. American plum borer pheromone concentration test with second generation males in Oceana and Leelenau counties (July – Sept. 1985). Means followed by the same letter were not statistically different ($P = 0.05$; DMRT).

control of that pest, but was 2-3 weeks late for the control of first brood American plum borer neonate larvae (See Fig. 2). Those American plum borer larvae would be feeding under the bark on the cambium in June and would be protected from dilute trunk applications.

Euzophera semifuneralis is distinct among the cambium boring pests of tree fruits in Michigan in that it has two generations per season (See Fig. 2). This has been substantiated by several years of field observations of larvae and pupae as well as adult emergence data (Biddinger 1989). As aready mentioned, the overwintering brood reaches peak adult emergence around mid-May (white bud stage of tart cherries). The second brood emergence occurs over a relatively long period of time from late June to the end of September. Peak emergence occurs from mid-July to early August and coincides with tart cherry harvest. It was found that the lower insecticide rates used in the conventional *S. pictipes* June spray program gave little residual control of the neonate *E. semifuneralis* larvae of this summer brood (Howitt and Biddinger 1986, Biddinger 1989). An additional application to the trunk in July would have been needed to control the second generation with the conventional lesser peachtree borer program, but this timing conflicted with harvest tolerances for pesticide residues on the fruit. Eventually control programs centered on a single petal fall application of a much higher rate of insecticide to the trunk and scaffold limbs that gave seasonal control of both generations of

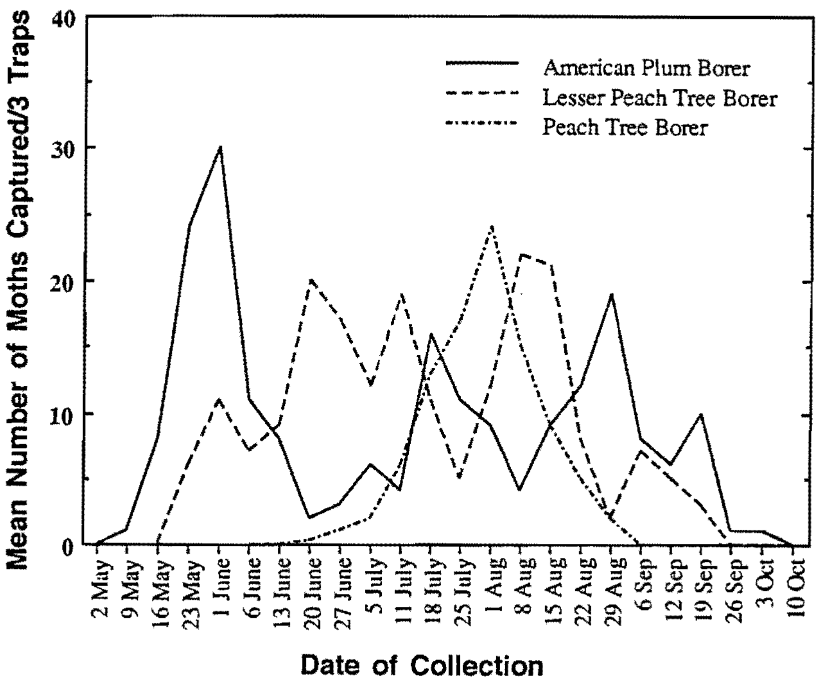

Figure 2. Adult emergence of three borer pests of stone fruit in midwestern Michigan, 1988.

E. semifuneralis and the single generation of *S. pictipes* (Biddinger 1989, Howitt and Biddinger 1986, Jones et al. 1992). Cherry growers in Michigan now use American plum borer pheromone lures to monitor populations to determine if they have exceeded economic thresholds and as an aid for the timing of insecticide applications (J. Johnson, pers. commun.).

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