Effects of Pheromone Trap Design and Placement on Capture of Male *Cydia caryana* (Lepidoptera: Tortricidae: Olethreutinae) in Alabama Pecan Orchards and the Relationship of Trap Captures to Fruit Infestation[1]

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ABSTRACT The Pherocon Ic trap captured the greatest number of *Cydia caryana* (Fitch) adult males and all trap designs appeared to represent population trends equally well. Pooled data from all trap height experiments indicate that traps placed 9.14 m above the orchard floor captured significantly more adult males than those placed at 4.57 m height. Horizontal placement of traps within the tree canopy indicated a significantly greater capture in the central portion of the canopy than at other locations. Correlations between the total capture of male adults and the rate of fruit infestation were not significant.

KEY WORDS *Cydia caryana,* Hickory shuckworms, Pheromone, Trap design, Trap placement, Capture - infestation ratio.

The hickory shuckworm, *Cydia caryana* (Fitch), is a key pest of pecan throughout the major production areas of the United States (Osburn et al. 1963, Payne et al. 1979). Assessment of damage due to pre-shell hardening nut drop and reduced quality as a result of larval shuck mining is difficult. Losses from damage and control costs have been estimated as high as $11.3 million annually in Georgia (Suber and Todd 1980).

Trap design and placement have been shown to be important in the use of pheromones for monitoring pests in orchards and vineyards (e.g., Taschenberg et al. 1974, Younce et al. 1976, Sanders 1978, Steck and Bailey 1978, Younce et al. 1979, AliNiazee 1983, Danko and Jubb 1983, Sanders 1986). Trap height, directional orientation and other locational factors within the tree canopy have proven important (Riedl et al. 1979, McNally and Barnes 1981, Hoyt et al. 1983, David and Horsburgh 1989).

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Studies on relationships of captures to fruit infestation have been made in other orchard crops, especially for the codling moth, *Cydia pomonella* (L.), in apples (Madsen and Vakenti 1972, Hagley 1973, Madsen and Vakenti 1973, Riedl and Croft 1974, Riedl et al. 1976, Vakenti and Madsen 1976, Rock et al., 1978, Baker et al. 1980). No research has yet been reported for *C. caryana* in pecan concerning pheromone trap design, trap placement or the relationship of male captures to fruit infestation.

Research was conducted to investigate the effects of pheromone trap design and placement on capture of male *C. caryana* and relationship of numbers of males captured to levels of fruit infestation.

Materials and Methods

General. All studies were conducted in commercial orchards in Alabama. Orchards used were well maintained with a good record of production, had a history of recent hickory shuckworm infestation, and consisted primarily of 'Stuart' variety trees uniform in size (18 to 26 m in height) and age (mature trees 50-yr-old or older).

Individual data trees were healthy Stuarts with no visible damage. The trees were surrounded by individuals of the same variety and no data tree was adjacent to a "skip" in the orchard. Data trees were separated by at least two non-data trees and none were located on the orchard perimeter. Once data trees were identified, treatments were assigned in a completely random design.

Unless otherwise indicated, all traps were suspended at the desired height in each data tree with rope and pulley arrangements. Pulleys were affixed to limbs with coated wire to prevent limb damage. Traps were raised and lowered to the height of the pulley with 3.18-mm nylon cord. Nylon twine was attached to trap bottoms to facilitate lowering.

All studies were conducted with the commercial hickory shuckworm sex pheromone lure manufactured by Scentry, Inc. (Buckeye, AZ). Each lure consisted of a grey rubber septum charged with 50-μg of field blend (100:0.6 ration of E, E-8, 10-DDA and E, Z-8, 10-DDA). This pheromone blend was based on the elucidation work reported by McDonough et al. (1990) and by Smith et al. (1987). In all studies, lures and trap liners were replaced at 28-day intervals and old materials removed from the site. Monitoring was at 7-day intervals and the capture of male hickory shuckworm was the basis of all evaluations. All data were subjected to analysis of variance and tested for least significant differences (Cochran and Cox 1957, Steel and Torrie 1980, SAS Institute 1988a, SAS Institute 1988b) with the exception of the capture vs infestation study.

Trap Design. Three trap designs were tested: Pherocon Ic traps with spacers; Pherocon Icp traps with notched bottoms and spacers; and Pherocon II traps. Each design has been recommended for monitoring of other tortricid moths (Bode et al. 1973, Sanders 1978, Riedl 1980, AliNiazee 1983, Danko and Jubb 1983, David and Horsburgh 1989).

The study was conducted in a 16.2-ha pecan orchard in Mobile Co. Fifteen trees were chosen and randomly assigned a treatment (trap type). Five traps of each type were installed 9.14 m above the orchard floor on the west side of the tree but near the vertical centerline of the canopy. In 1989, traps and lures were

installed on 2 May 1989 and monitored until 25 October; 1990 installation was on 6 March and traps were monitored until 29 May. The number of hickory shuckworm males captured in each trap was recorded on each monitoring date.

Trap Height. The study was conducted in a 32.3-ha orchard in Baldwin Co. Two Pherocon Ic traps were suspended in each of seven data trees in the west face of the canopy near the vertical center of the tree. One trap was located 9.14 m above the orchard floor the other at 4.57 m. Trees in the orchard were approximately 21.3 to 27.4 m tall.

Baited traps were installed on 25 April 1989 and monitored until 30 October. The number of adult male shuckworm moths captured in each trap during each 7-day period was recorded.

In 1990, an additional 14 trees were included in the trial. Seven trees were equipped with a single Pherocon Ic trap located 9.14 m above the orchard floor. A single trap was suspended 4.57 m above the soil surface in the other seven. The original seven trees were equipped in the same manner as in 1989. Traps were placed on 20 March and monitored until 30 October. Data were recorded as in 1989.

Within-Canopy Horizontal Placement. A 16.2-ha orchard in Bullock Co. was selected for this study. In 1989, Pherocon Ic traps were suspended at three locations in the canopy of each of 9 trees. To ensure that all traps were at the same height 9.14 m), a 3.18-mm diameter rope was stretched from the primary trunk of each data tree to the neighboring tree to the west at that height. The attachment point in the data tree was slightly east of the vertical center of the canopy. Pulleys were affixed to the rope at each of three locations and secured to prevent any movement out of position. Locations were: the center of canopy; the midpoint between the center and the dripline of the canopy; and at the canopy dripline (approximately 9.14 m from the tree center).

Traps were installed on 26 April 1989 and monitored until 27 October. The study was repeated in the same location and trees during the spring of 1990, except that installation was on 23 April and the test was terminated on 12 June. The number of males captured on each monitoring date for each trap was recorded.

In 1990, the study was redesigned to monitor hickory shuckworm activity in the late summer and fall. Seven trap arrangement schemes were installed with four replications of each. Trap arrangements were: three traps per tree, one at each of the three locations; two traps, one each at the tree center and the canopy midpoint location; two traps, one each at the tree center and dripline locations; two traps, one each at the canopy midpoint and dripline locations; one trap at the tree center location; one trap at the canopy midpoint location and, one trap at the dripline location. This arrangement was to minimize confounding effects of trap competition on trap location effects. Traps were baited and installed on 7 August 1990 and monitored until 30 October.

Male Capture vs. Fruit Infestation. In 1989, the study was conducted in a 32.3-ha commercial pecan orchard located in Baldwin Co. On 15 August, 20 trees were each equipped with a single baited Pherocon Ic trap. Traps were monitored until 6 November. Male hickory shuckworm captures were recorded on each monitoring date.

The timing of this study coincided with the generation 5 activity period of *C. caryana*. This generation was evaluated because fruit infested by larvae during

this time remain on the tree; fruit entered by larvae of earlier generations abscise (Smith 1985, McVay and Estes 1989). No pesticide was applied to the trees for control of any insect or mite pest during the study

On 11 November, pecans on each tree were shaken to the ground with a commercial tree shaker. The area under under the tree canopy was divided into four quadrants. Demarcation of the quadrants corresponded to the four cardinal directions on line from the dripline to the tree trunk. A total of 25 pecans, both with and without shucks, was picked at random from each quadrant. Samples from all quadrants were combined into a 100-pecan sample for each tree. Each pecan was inspected for indications of shuckworm infestation.

Due to a scarcity of 1990 crop in the orchard used in 1989, the study was relocated in 1990 to an orchard in Mobile Co., approximately 40 km west of the original study site on the same latitude. This orchard consisted of approximately 16.2 ha of mature pecan trees which met all criteria previously discussed. Fifteen data trees were selected at random and traps were installed on 15 August 1990. Monitoring was terminated on 31 October. No pesticide was applied to the data trees.

Trees were shaken on 3 November 1990, and samples were taken as in 1989. Data were analyzed by Pearson's correlation coefficient and linear regression to determine the relationship between trap captures and levels of infestation (Steel and Torrie 1980, SAS Institute 1988a, SAS Institute 1988b).

Results and Discussion

Trap Design. The Pherocon Ic trap captured significantly more hickory shuckworm males during both years than did the Pherocon II trap (Table 1). Pherocon Icp traps tended to capture more than did the Pherocon II but the differences were not significant.

Table 1. Effect of trap design on captures of hickory shuckworm males.

	Mean* No. of Males / Trap / 7-day Period		
Trap Design	1989	1990	Mean
Pherocon Ic	1.67 a	6.18 a	3.04 a
Pherocon Icp	1.09 ab	5.29 ab	2.37 ab
Pherocon II	0.62 b	3.45 b	1.49 b

*Means not followed by the same letter in the same column are significantly different (LSD; $P = 0.05$), (in 1989, no. of observations = 55, SEM = 0.50; for 1990, no. of observations = 125, SEM = 0.33; and for the two-year average, no. of observations = 180, SEM = 0.29).

More males were captured in 1990 than in 1989. There was no evidence of an interaction of trap type by year and the response pattern of capture to trap type was the same for both years (ANOVA, $P = 0.01$). Significant differences due to monitoring date were also evident in both years, corresponding to the successive generations (Fig. 1).

These results agree with those found with several other tortricid moth species (Bode et al. 1973, Danko and Jubb 1983, AliNiazee 1983, David and Horsburgh 1989). The Pherocon Ic trap type has a larger retentive surface than the other trap types but its greater efficiency in capturing hickory shuckworm males may not be due to that alone. AliNiazee (1983) found no significant relationship between total capture and retentive surface when comparing several traps, including the three tested here. He suggested that trap design efficiency was related to plume characteristics of the attractant, male response behavior, entrance and landing convenience of the trap, and the efficiency of the retentive surface.

Trap Height. Pheromone traps baited with the hickory shuckworm sex lure do not appear to be greatly effective for monitoring of generations 2, 3, and 4 of the species. Although the original pheromone blend was isolated from generation 1

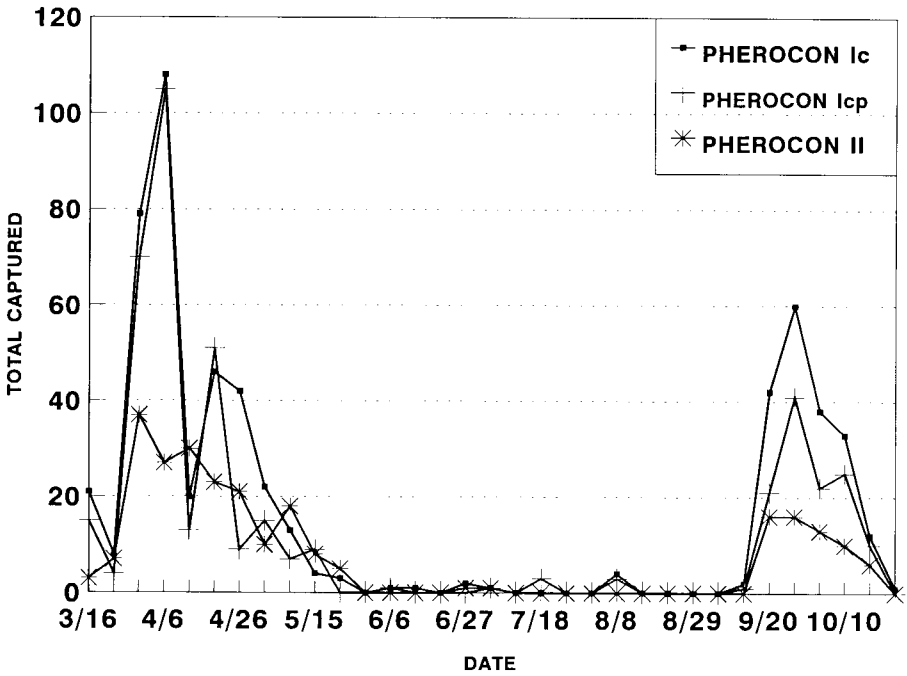

Fig. 1. Captures of Adult Male Hickory Shuckworms by Trap Type.

females, and it is possible that pheromones of later generations differ slightly, it is more likely that damage due to generations 2, 3, and 4, in pecan orchards is caused primarily by progeny of previously-mated migrants entering from nearby foci in native hickories. It is known that the first-generation adults move primarily to hickory which sets fruit earlier than pecan which is not a particularly good host at the time of spring emergence. Only trap counts of adults of the overwintering generation (generation 1) and those of generation 5 were sampled adequately, although traps were monitored throughout the season. Therefore, data for both 1989 and 1990 were subjected to analysis by generation. Additionally, all data for each year were analyzed as a single entity and, finally, data from both years were pooled and subjected to analysis. Total captures of male hickory shuckworm and the mean numbers captured per trap are presented in Table 2 by year, generation, trap height and experimental method (one or two traps per tree).

Table 2. Capture of hickory shuckworm males by trap height.

			Total* by Trap Height		Mean** Males/ Trap/7-day Period	
Year	Gen.†	Method‡	9.14 m	4.75 m	9.14 m	4.75 m
1989	1	2 Trap	443	186	15.82 a	6.64 a
	5	2 Trap	141	22	2.52 a	0.39 b
	Gen.	Combined	584	208	6.95 a	2.48 b
1990	1	2 Trap	187	111	2.97 a	1.76 a
	5	2 Trap	58	23	0.83 a	0.33 a
	Gen.	Combined	245	134	1.84 a	1.03 a
	1	1 Trap	230	224	3.65 a	3.56 a
	5	1 Trap	73	54	1.04 a	0.77 a
	Gen.	Combined	303	278	2.28 a	2.09 a
			1132	620	2.79 a	1.06 b

* Combined totals for 7 traps (replications) in each method at each height.

** Paired means not followed by the same letter are significantly different (ANOVA; $P = 0.05$), (in 1989; Gen. 1 obs. = 28; Gen. 5 obs. = 56; Combined Gen. obs. = 84), (in 1990; Gen. 1 two trap obs. = 63; Gen. 5 two trap obs. = 63; Gen. 5 one trap obs. = 63; Gen. combined two trap obs. = 126; Gen. 1 one trap obs. = 63; Gen. combined one trap obs. = 126) (Pooled two year obs. = 329).

† Generation.

‡ Method = 1 trap or 2 traps per tree.

Analysis of 1989 data, collected from trees containing traps at both heights, indicated no differences due to trap height in number of males captured during generation 1. Analysis of data for generation 5 indicated highly significant differences ($P = 0.01$) in captures due to height. When all data for 1989 were pooled and subjected to analysis, there were significant differences for capture by trap height ($P = 0.01$), generation ($P = 0.08$), dates in generation ($P = 0.001$), and height by dates in generation ($P = 0.05$).

Data for 1990 were analyzed in the same manner with the addition of method (one trap or two traps per tree) as a variable. There were no significant differences in captures during the first generation except for date. The same was true for data from generation 5. A pooled analysis of 1990 data indicated significant differences only between generations ($P = 0.01$) and dates in generations ($P = 0.001$).

Analysis of pooled data for the two years indicated significant differences ($P = 0.01$) due to trap height, date, and height by date interaction within years. Apparent differences in total captures between the two years were not significant (Table 2).

Smaller differences due to trap height during generation 1 are not as important to an IPM program as the adults of this generation do little damage to pecans (Moznette et al. 1931, Payne and Heaton 1975). This lack of differences, however, may be partially explained by the fact that most moths of this generation emerge from shucks on the orchard floor. When attempting to fly, they may be limited by the relatively strong spring breezes common to the Southeast and the lack of protective foliage on the pecan trees. Thus, moths appearing in early spring may not be able to fly as high as those of later generations. Additionally, there is no fruit present at this time to attract them higher into the tree. It appears that during the late summer, which is the most critical time for shuckworm damage, the placement of traps at the higher level would be preferable for IPM implementation.

Within-Canopy Horizontal Placement. The only differences due to trap location in the 1989 data were between the canopy center and dripline sites ($P = 0.05$). Data from the spring of 1990 showed decreasing numbers of captures from traps located at the tree center to the midpoint location and to the canopy dripline. Moth captures at the tree center were significantly higher than at the dripline location ($P = 0.05$) but similar to captures at the midpoint location. Means are presented in Table 3.

Data obtained from a separate, restructured trial during the late summer and early fall of 1990 presented a clearer picture of locational effects (Table 4). In the redesigned test, main effects due to trap location became obvious. Analyses indicated that traps placed in the tree center consistently captured significantly more shuckworm males than those placed at either of the other locations. Also, traps at the midpoint location captured significantly more than those at the dripline ($P = 0.05$). This trend was repeated in all comparisons. Only those data where tree center and midpoint locations were compared in the same tree exhibited non-significance ($P = 0.05$).

The results indicate that the center of the tree canopy may be the optimum site for hickory shuckworm sex pheromone trap placement. Such placement should tend to negate the effect of directional placement. The nature of pecan tree

Table 3. Effect of horizontal placement of traps on capture of hickory shuckworm males with 3 traps per tree*.

Year	Trap Location	Mean** No. Males / Trap / 7-day Period by Generation	
		Generation 1	Generation 5
1989	Canopy Center	0.42 a	3.17 a
	Midway Between Center and Dripline	0.21 ab	3.20 a
	Canopy Dripline	0.14 b	2.85 a
1990	Canopy Center	1.48 a	1.56 a
	Midway Between Center and Dripline	1.55 a	0.93 b
	Canopy Dripline	0.65 b	0.27 c

* East of nine data trees (replications) was equipped with three traps; one each at all three locations.
** Means not followed by the same letter in the same column within each year are significantly different (LSD; $P = 0.05$), (values for 1989 were; Gen. 1, obs. = 72; Gen. 5, obs. = 54), (values for 1990 were; Gen. 1, obs. = 63; Gen. 5, obs. = 44).

growth is such that trap positioning and maintenance are as easy or easier in the canopy center than among outer branches.

Male Capture vs. Fruit Infestation. Pearson's correlation coefficient of total male shuckworm captures with levels of fruit infestation were 0.17 and 0.19 for 1989 and 1990, respectively ($P = 0.4$). Linear regression indicated a non-significant relationship between total captures and level of infestation. For 1989 and 1990 data, respectively, R^2 values were 0.03 and 0.04. These low values were probably due to variation. Analyses indicate that total capture was not an accurate estimator of infestation level.

These data indicate that traps baited with the sex pheromone of *C. caryana* may not provide an accurate indicator of potential damage by the hickory shuckworm when used alone as it is now formulated. Additional information concerning the biology of this species is needed for true implementation of IPM systems in commercial orchards. The pheromone lure may provide crucial information concerning biofix points and movement of the shuckworm moths. The information reported here should be of benefit to further efforts in this area.

Table 4. Effect of horizontal placement of traps on capture of hickory shuckworm males with 1, 2 or 3 traps per tree, 1990.

Comparison	Trap Location*	Mean** No./Trap /7 days	EMS
I	Canopy Center	1.34 ± 0.14 a	8.91
	Midway Between Center and Dripline	0.70 ± 0.12 b	
II	Canopy Center	1.56 ± 0.20 a	31.92
	Dripline	0.34 ± 0.12 b	
III	Midway Between Center and Dripline	0.79 ± 0.07 a	11.64
	Dripline	0.07 ± 0.04 b	
	Canopy Center	1.56 ± 0.18 a	18.46
IV	Midway Between Center and Dripline	0.93 ± 0.18 b	
	Dripline	0.27 ± 0.09 c	
	Canopy Center	1.50 ± 0.25	
V‡	Midway Between Center and Dripline	0.77 ± 0.15	
	Dripline	0.23 ± 0.07	

* Data compare four replicates of each comparison with 4 observations for each.

** Values within comparisons not followed by the same letter are significantly different at the following levels: I - ANOVA; $P = 0.08$; II - ANOVA; $P = 0.01$; III - ANOVA; $P = 0.01$; IV - ANOVA; LSD; $P = 0.05$; (0.326).

† Error Mean Squared

‡ Data compare four replicates each of trees equipped with a single trap at one of the three locations for informational purposes.

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