High-efficiency Pheromone Trap for the European Corn Borer (Lepidoptera: Pyralidae)

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ABSTRACT A *Heliothis* cone trap captured significantly higher numbers of male European corn borers, *Ostrinia nubilalis* (Hubner), than a sticky wing trap. Behavioral observations revealed that the difference in number of males captured was related to the proportion of moths approaching the traps that was subsequently captured. Cone traps baited with a 97:3 blend of (Z)- and (E)-11-tetradecenyl acetate captured 87% of those males that entered the trap compared with 6% for the wing traps.

KEY WORDS *Ostrinia nubilalis*, pheromone, attractant, trap

THE EUROPEAN CORN BORER (ECB), *Ostrinia nubilalis* (Hubner), is a major pest of corn and a significant pest of several other crops. A simple and efficient mean for monitoring ECB populations is requisite for integrated pest management (IPM) programs. Blacklight traps have been used to monitor ECB, but are not well suited for IPM use because of their lack of specificity, cost, and low portability (Showers et al. 1974, Kennedy & Anderson 1980). Traps baited with sex pheromones constitute another method for monitoring ECB adult populations. Although pheromone traps offer high specificity and are easy to use, in several cases they were shown to be insufficiently reliable for ECB detection programs (Oloumi-Sadeghi et a1. 1975, Kennedy & Anderson 1980). In studies by Roelofs et al. (1972) and Carde et al. (1975), few ECB were caught in pheromone traps during the second generation even though many moths were observed in the vicinity of the traps. In addition, attractancy of sticky pheromone traps was shown to decline rapidly with age due to the formation of inhibitory or repellent substances in the lures (McLeod & Starratt 1978). Nonetheless, Starratt & McLeod (1976) and Fletcher-Howell et al. (1983) found pheromone traps to be as efficient or better than blacklight traps for tracking the emergence of ECB, although the effectiveness of the traps appeared to depend partially on trap placement in the field (Fletcher-Howell et al. 1983).

The disparate conclusions of these studies may be attributable in part to the effectiveness of the pheromone traps used. In none of these studies was the behavior of the males near the traps evaluated for trap efficiency (proportion of moths approaching the traps that are captured). Our preliminary field tests suggested that the *Heliothis* Scentry trap (Pest Select), based on the cone design trap of Hartstack et al. (1979), might be more efficient for capturing ECB than the widely used sticky Pherocon 1C trap (Zoecon), based on the wing trap of Howell (1972). In the study reported here, we compared the effectiveness of these two pheromone trap designs for capturing ECB, and evaluated their respective efficiencies using behavioral observations.

Materials and Methods

Field tests were conducted 11-13 June and 14-20 August 1984 in Amity Hall, Pa. In this region, two populations of ECB coexist: one is maximally attracted to a 97:3 (Z) to *(E)* blend of the ~11-tetradecenyl acetates and the other is maximally attracted to a 2:98 Z to E blend of the acetates. Putative heterozygotes for the locus controlling pheromone response are attracted to a 35:65 (Z) to *(E)* blend of the isomers and also occur at this site (Carde et al. 1975, 1978, Klun & Cooperators 1975, Klun & Maini 1979).

The (E)-11-tetradecenyl acetate (E11-14:Ac) pheromone component contained <0.07% impurities with no detectable amounts of the (Z) isomer; the (Z)-11-tetradecenyl acetate (Z11-14:Ac) contained <3.2% impurities with no discernible *(E)* isomer. Purity was determined by capillary chromatography (50-m fused silica WCOT CPsil 88 column at 150°C). Hexane solutions of three pheromone blends (97:3, 3:97, and 35:65 *Z:E)* were formulated gravimetrically. Ratios were verified by GLC analysis using a 30 m fused silica SP-2340 column (100% biscyanopropyl polysiloxane) that provided baseline resolution of the two isomers. A 100-µl amount of each of the three mixtures was pipetted onto rubber septa dispensers (9 by 5 mm) (Arthur Thomas, Philadelphia, Pa.) to give a total load of 100 µg for each blend. Septa were ventilated in a fume hood for 24 h before use in the field.

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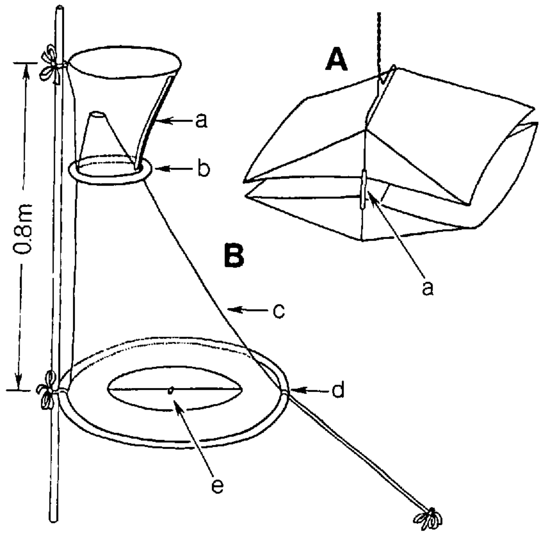

Fig. 1. Two trap designs evaluated for effectiveness in capturing male ECB. (A) Pherocon 1C trap: a, Support strut that maintains a 2.5- to 3.0-cm opening between upper and lower portions of trap. (B) Cone trap: trap constructed of mesh (3 by 3 mm). a, Containment portion of trap with velcro strip for access into trap. Note upper cone with 5.0-cm opening into containment portion of trap; b, support hoop; c, lower cone; d, support hoop surrounding base of trap; e, lower opening (entrance) of trap (30 cm diam) with a surrounding shelf (11 cm width) showing a lure strung across opening.

Traps were deployed in a linear, randomized complete block design with treatments replicated four times and 30 m between traps. Each replicate consisted of four sticky wing traps and four cone traps (Fig. 1) baited with one of three different lures (97:3, 3:97, or 35:65 *Z:E*), or unbaited. The rubber septa were placed on the bottom sticky surface in the wing traps or suspended in the center of the lower opening of the cone traps with a taut string. Wing traps deployed during the June test were provided with sticky tops and bottoms. However, due to the negligible capture of males on the upper sticky panel, only sticky bottoms were used in the August trials. Traps were hung on metal stakes and positioned so that the pheromone source was ca. 1 m above ground. During the June test, traps were placed at the edge of the cornfield over bare ground and young (10-20 cm) corn plants. In the August trials, the traps were set out 1 m from the edge of corn plants in an adjoining grassy field. In another experiment, lure placement in the wing traps was investigated. Lures (97:3 *Z:E*) were placed either on the upper or lower sticky panels or the trap was unbaited, with treatments replicated five times. Daily trap captures were transformed to $\sqrt{x + 0.5}$ and analyzed with a one-way analysis of variance. Treatment mean differences based on daily trap catch were tested for significance with Student-Newman-Keuls multiple range test ($P < 0.05$; Steel & Torrie 1960).

Observations on behavior of males to the two trap types were made between 2400 and 0400 hours on 15 August, under natural lighting from a full moon. Randomly chosen traps baited with the 97:3 *Z:E* blend were monitored for ca. 20-min intervals; observation bouts alternated between the two trap types. Light intensity was sufficient to clearly observe positions of moths near and within the traps. Temperature was 19-20°C and relative humidity was ca. 100% (light fog). The position of each male relative to various portions of the traps (Fig. 1) was recorded continuously on a tape recorder until the moth either flew away or was captured. Only behaviors of those males that approached within 25 cm of the traps were recorded.

Results and Discussion

The cone trap was far more effective at capturing male ECB than was the sticky wing trap (Table 1). Cone traps baited with the 97:3, 3:97, and 35:65 *Z:E* blends of ~11-14:Ac captured 9.4-, 2.3-,

Table 1. Comparison of male ECB captures in two different trap designs baited with various blends of Z and E11-14:Ac in Amity Hall, Pa.

	Pheromone blend	Sticky wing: Capture per trap per day, f ± SD	Sticky wing: %	Cone: Capture per trap per day, f ± SD	Cone: %
12-14 June 1984	97:3 *Z:E*	5.1 ± 4.5b	82.0	48.0 ± 22.9a	91.9
	3:97 *Z:E*	0.4 ± 0.7cd	4.0	0.9 ± 1.1cd	1.7
	35:65 *Z:E*	0.8 ± 1.4cd	12.0	3.4 ± 2.5bc	6.4
	Unbaited	0.0d		0.5 ± 0.8cd	
15-20 Aug. 1984	97:3 *Z:E*	6.2 ± 5.2b	79.5	45.0 ± 18.0a	82.1
	3:97 *Z:E*	0.3 ± 0.2e	3.8	2.9 ± 2.0c	5.3
	35:65 *Z:E*	1.3 ± 0.8d	16.7	6.9 ± 2.8b	12.6
	Unbaited	0.0e		0.2 ± 0.3e	

Each trapping trial mean followed by the same letter is not significantly different ($P > 0.05$; Student-Newman-Kuels multiple range test; data transformed to $\sqrt{x + 0.5}$ [Steel & Torrie 1960]). Values include males that were found in plastic bags. %, percentage responding to each blend.

and 4.3-fold more males, respectively, than similarly baited wing traps during the June test and 7.3-, 9.7-, and 5.3-fold more males, respectively, during the August test. The mean capture per trap per day was significantly higher in the cone traps for all pheromone blends tested except for traps baited with the 35:65 and 3:97 *Z:E* blends of .111-14:Ac during the June test.

The difference in number of males captured in the two trap designs with the 97:3 *Z:E* blend appeared to be related to the proportion of moths approaching the traps that subsequently were captured (trap efficiency). For the cone trap, of 18 males that approached within 25 cm of the trap, 15 (83%) entered and 13 (72%) were caught.. In contrast, of 22 males that approached within 25 cm of the wing traps, 16 (73%) entered, but only 3 became entangled on the bottom sticky surface of the trap and 2 of these eventually escaped. Males that entered the wing traps seldom approached the lure or sticky surface of the trap even though they spent up to 154 s within the trap ($x \pm SD = 52 \pm 37$ Sj $n = 16$). Instead, within the trap, males typically engaged in a slow or hovering flight, usually near the top portion of the trap, sometimes landing on one of the struts. Despite a propensity to fly near the top of the trap, indusion of a sticky trap top did not augment catchj of 50 males captured in wing traps during the June trials, only 1 male was caught on the upper sticky surface. Furthermore, in a separate test, placement of lures on the top sticky surface did not influence trap capture. The mean capture per trap per day for traps with the top panel baited was ($x \pm SD$) 12.67 ± 12.38 and did not differ from capture in traps with the lower panel baited (14.07 ± 9.23). The low trap efficiency for the wing traps, thus, can be attributed mainly to the behavior of the males after they enter the trap, but also to a lesser extent to an ineffective sticky surface.

Males that entered cone traps usually flew upward and, if they reached the upper cone, they were invariably captured. Most males approached the base of the trap and then flew under it, occasionally flying near or even landing on the lure. Once under the trap, males usually flew in an upward direction, intermittently flying or landing and walking while wing fanning on the interior side of the lower cone. Sometimes a male flew downward to the base of the trap and briefly landed on the upper side of the shelf or left the trap, but most males eventually flew upward into the trap. The time between entering the trap and capture in the containment portion of the trap ranged between 30 and 227 s ($f \pm SD = 92 \pm 55$ Sj $n = 13$). These observations suggest why the cone trap is more efficient than the wing trap. Because males hover inside the wing trap rather than land on or near the lure, the probability of entanglement on the sticky surface is reduced. The tendency for males to fly upward after entering the cone traps facilitates capture.

One important drawback of the *Heliothis* Scentry traps is that the mesh size (3 by 3 mm) is large enough to allow male ECB to escape. To determine the proportion of moths that might have escaped, plastic bags were placed over the containment portion of the traps. Because the plastic bag was in partial contact with the containment part of the trap, egress of males from the inner mesh container was hampered. Thus, the number of escapees was underestimated. Nevertheless, in traps baited with the 97:3 *Z:E* blend, 21.7 and 7.3% of the males captured during the June and August tests, respectively, were found in the plastic bags surrounding the containment part of the trap. It is thus desirable to modify the upper portion of the trap by using a mesh size that prevents ECB from escaping.

Studies conducted between 1973 and 1977 by Carde et al. (1975, 1978) and Klun & Cooperators (1975) in Amity Hall, Pa., showed that the (Z)- and (E)-responding ECB occurred sympatrically and synchronously. Individuals attracted to a 50:50 blend of the Z and Ell-14:Ac also occurred and these were either heterozygous for the locus controlling pheromone response or possibly individuals that also could respond to either predominantly Z or E blends (Carde et al. 1978, Klun & Maini 1979). During that period the proportions of individuals responding to the Z, E, and *Z:E* blends showed considerable variation. However, the low efficiency of wing traps in capturing and retaining (Z)-responding ECB indicates that within-population comparisons of the distribution of *(Z)-, (Z):(E)-* and (E)-responding males usin:; capture in wing traps as an index must be viewed with caution. Future definition of the geographical and temporal distributions of phenotypes will be facilitated by use of high-efficiency traps such as the cone trap described here.

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