Collection of Fall Armyworm (Lepidoptera: Noctuidae) Using Selected Pheromone Lures and Trap Designs[1]

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Abstract Two trap designs and three sources of commercially-produced pheromone lures were used to capture fall armyworm, *Spodoptera frugiperda* (J. E. Smith), males in silage corn and peanuts in north-central Florida. Unitraps baited with Trécé and Scenturion lures captured more moths than Scentry-baited traps. Gas chromatographic detection of the pheromone blend suggested no differences in acetate component ratios among lures. Unitraps collected more moths than *Heliothis* cone traps. Behavioral observations at night showed that equal percentages of moths were initially collected in both traps but that moths were able to escape from cone traps.

Key Words Behavior, trapping, monitoring, Noctuidae, *Spodoptera frugiperda*

Adult fall armyworms, *Spodoptera frugiperda* (J. E. Smith), have been monitored for over 30 yrs with sex pheromones as lures and a diverse array of trap designs as collectors. The sex pheromone was initially isolated and identified as (Z)-9-tetradecen-1-ol acetate (Z9-14:AC) (Sekul and Sparks 1967); however, it was not an effective lure in the field when placed on polyethylene caps (Mitchell and Doolittle 1976). Another component, (Z)-9-dodecen-1-ol acetate (Z9-12:AC), was later identified (Sekul and Sparks 1976) and was considered to be the primary sex pheromone. Mixtures of Z9-12:AC with other pheromone components, Z9-14:AC and (Z)-11-hexadecen-1-ol acetate (Z11-16:AC) did not increase moth capture (Mitchell et al. 1983). Further investigation demonstrated that volatiles from *S. frugiperda* consisted of a blend of five acetates (Tumlinson et al. 1986). Field studies determined that either two [Z9-14:AC and (Z)-7-dodecen-1-ol acetate (Z7-12:AC)], three (plus Z11-16:AC), or four (plus Z9-12:AC) components successfully attract male *S. frugiperda* (Mitchell et al. 1985, Tumlinson et al. 1986).

Various pheromone dispensers and trap designs have been tested under agricultural situations. Rubber septa, compared to polyvials or hollow fibers, have been shown to be highly effective dispensers for the acetates used as *S. frugiperda* lures (Mitchell et al. 1985, Adams et al. 1989). However, commercial producers provide pheromone blends formulated on either red or gray septa, which for other noctuid species lures have been shown to emit these blends in different ratios (Mitchell and Mayer 2000). Electric grid and sticky traps were used to capture male *S. frugiperda* (Tingle and Mitchell 1975), until development of Hartstack screenwire cone traps and

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plastic funnel traps (Universal Moth Traps or Unitraps), which captured more moths (Mitchell et al. 1985). When population densities are low, most trap designs tested did equally well in capturing *S. frugiperda* males (Mitchell et al. 1985, Adams et al. 1989, Pair et al. 1989). For more dense populations, Hartstack traps generally performed better than Unitraps (Mitchell et al. 1985, Pair et al. 1989). However, Hartstack traps are bulky and must be constructed locally. Nylon-mesh cone traps (Scentry *Heliothis* cone traps) are not as bulky as Hartstack traps and are commercially available, but have only been tested under conditions of very low (≈1 moth per night) fall armyworm populations (Adams et al. 1989).

Our objective for this research was to compare pheromone lures and trap designs in the collection of fall armyworm moths under field conditions. Gas chromatography methods were used to compare the released pheromone volatiles of three commercial lures. Observations of moth behavior were conducted under field conditions to compare trap efficiency (number of moths collected versus number of moths attracted).

Materials and Methods

Pheromone lure and trap design experiments. All-white Unitraps (white top, funnel, and bucket) (Great Lakes IPM, Vestaburg, MI) were placed during early April 1998 in northwestern Alachua Co., FL, to capture male fall armyworm. This part of the county was planted to over 470 ha of silage corn (*Zea mays* L.) and offered fields separated by paved and unpaved roads and forested strips. The experiment consisted of four treatments: Unitraps with either Trécé® (Trécé, Inc., Salinas, CA) red septa *S. frugiperda* pheromone lures or Scentry® (Ecogen, Inc., Langhorne, PA) gray septa *S. frugiperda* pheromone lures, and Scentry *Heliothis* cone traps (Scentry, a division of Ecogen, Inc., Billings, MT) with either Trécé or Scentry lures. In the Unitraps, pheromone lures were attached to the bottom of a cork that was placed in the center hole in the top, and traps contained insecticide strips (Hercon® Vaportape II containing 10% 2,2-dichlorovinyl dimethyl phosphate, Hercon Environmental Co., Emigsville, PA) to kill insects that were captured. The *Heliothis* cone traps were designed as described by Webster et al. (1986) and Meagher and Mitchell (1999), and the lure was placed in the middle of the base cone. No insecticide strips were used with the *Heliothis* cone traps.

Traps were placed on 1.5-m metal poles along farm roads and edges in one 80-ha field, and the experiment was designed as a randomized complete block with four replications of the four treatments. Trap location within a replication was randomized weekly, and trapping began 8 April and ended 12 June. Trap contents were removed three times per week, and pheromone lures were replaced every 2 wks. Moth numbers per night were compared among treatments with a split-block analysis of variance (ANOVA) (Steel and Torrie 1980). To satisfy ANOVA assumptions, counts were *log* (x + 1) transformed before analysis. Means of the lure and traps designs were separated with orthogonal comparisons (PROC GLM, CONTRAST statement, SAS Institute 1996). Untransformed means (±SE) are given in text and figures; whereas, statistical results refer to transformed data.

Moth behavior was observed on six separate nights between 2030 and 2330 in the same fields described previously. Standard Unitraps (green top, yellow funnel, and white bucket) and *Heliothis* cone traps, baited with Trécé pheromone lures, were placed on 2.1-m metal poles. Observers were positioned so that they could observe moths that exhibited flight response towards the traps. The number of moths observed within ≈0.3 m of the traps were counted. At evening's end, all captured moths were noted and trap efficiency was recorded as number of moths captured divided by number of moths attracted to traps. These data were subjected to a *t* test (PROC TTEST, SAS Institute 1996) after arcsin square root transformation.

In another experiment, standard Unitraps were placed during mid-May 1999 in southern Levy Co., FL, to capture male fall armyworm. Traps were placed in an area of over 400 ha of peanuts (*Arachis hypogaea* L., cv. 'Georgia Green' and 'Andrew 93'). Treatments consisted of traps baited with either Trécé red septa, Scentry gray septa, or Scenturion® (Scenturion Inc., Clinton, WA) gray septa lures. Traps with no pheromone lures completed the four treatment, four-randomized block design experiment. Trap location within a replication was randomized weekly, and moths were collected until 22 July. Moth numbers per night were compared across treatments with a split-block ANOVA, and counts were square root (y + 0.5) transformed before analysis.

Pheromone volatile emissions. The volatile emissions from Trécé (Lot # 28751389), Scentry (Lot # LFA 8020-102), and Scenturion (Lot # 09091390) lures were analyzed by the methods of Mayer and Mitchell (1998). Lures were stored in their original containers before testing, and were aged in open glass vials in the laboratory (24 ± 2°C). Collections from these lures were made at least four times during a 15-d interval to determine the emission characteristics.

Volatile compounds were collected in filters fabricated from capillary glass (12.5 cm long, 3 mm diam) (Pyrex®, Corning, Inc., Corning, NY) (Mayer and Mitchell 1998). Within the filters, a 1.0-cm long bed of Super Q (Alltech Associates, Deerfield, IL) was placed one-third of the way from one end on a stainless steel screen and packed at the upper end with glass wool. In practice, air was drawn in from the end with the screen. A vacuum pump system (Mayer and Mitchell 1998) pulled volatiles through the filter at 300 ml/min. Laboratory temperature during the collections was maintained at 24 ± 2°C.

Analytical methods and gas chromatography. Absorbed sex pheromones were eluted from the filtrant by washing the filter bed with 5 100-µl aliquots of methylene chloride (GC/GC-MS Grade, Burdick & Jackson, Muskegon, MI) into 3-ml chromatography microvials, ending with ~300 µl final volume. Tetradecane (100 ng) was added as internal standard prior to analysis. The samples were analyzed on a Hewlett-Packard (HP) Model 6890 gas chromatograph equipped with a fused silica capillary column. Injections were made in the splitless mode and the injector was purged after 1 min. The column was operated under the following conditions: the oven temperature program began at 60°C for 1 min, then was programmed to increase at 10°C/min. to 260°C; injector, 200°C; FID detector, 250°C; helium carrier was constant at 9.5 psi. The linear flow velocity was 32 cm/sec, and a minimum of three injections of each sample was made.

The resulting emission rate (ng/h) of each pheromone component was converted to the percentage of the total blend. These percentages were compared among lures with ANOVA (PROC GLM, SAS Institute 1996).

Results and Discussion

The first experiment compared two lures and two trap designs. Male fall armyworm trap captures in corn were low (<5 moths per night) until May (Fig. 1); therefore,

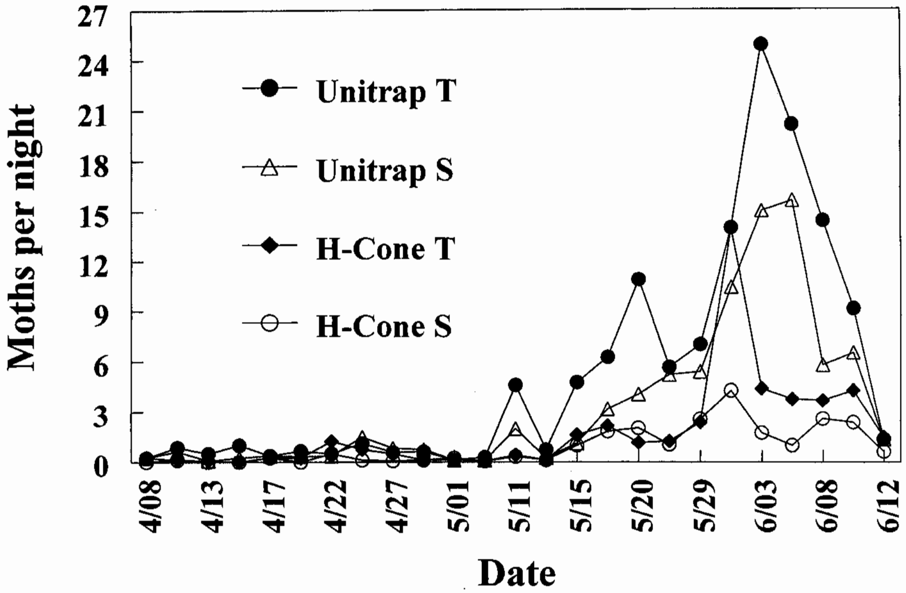

Fig. 1. Capture of male fall armyworm in Unitraps or *Heliothis* cone traps (H-Cone) baited with either Trécé (T) or Scentry (S) pheromone lures, Alachua, FL, 1998.

results of moth captures from 11 May to 12 June were analyzed separately from those samples collected earlier. Moth collection was largest in Unitraps baited with Trécé lures (mean ± SE: 9.5 ± 1.4 moths per night) and smallest in *Heliothis* cone traps baited with Scentry lures (1.7 ± 0.2). Collection in Unitraps with Scentry lures and *Heliothis* cone traps with Trécé lures was intermediate (5.8 ± 0.9 and 3.1 ± 0.7, respectively). Contrasts showed that moth collection in traps baited with Trécé lures was more numerous but not significantly higher than Scentry-baited traps (Trécé 6.3 ± 0.8 per night, Scentry 3.7 ± 0.5) ($F = 3.2$; df = 1, 9; $P = 0.1083$). Separate contrasts between Unitraps baited with Trécé lures and Scentry lures, and cone traps baited with Trécé lures and Scentry lures, again showed larger moth capture in Trécé lures but no significant differences ($P > 0.05$). Unitraps collected more moths per night than *Heliothis* cone traps on eight of 13 sampling dates ($P < 0.05$), and the average capture over the last seven sampling dates also showed more moths per night in Unitraps versus *Heliothis* cone traps (7.7 ± 0.8 vs 2.4 ± 0.4, respectively) ($F = 25.2$; df = 1, 9; $P = 0.0007$).

The behavior of males approaching traps and their behavior once within traps affected final capture. Nocturnal observations showed that the efficiency of both the Unitrap and *Heliothis* cone trap was similar (16.0 ± 6.1% vs 19.3 ± 5.0% of moths attracted to trap were captured, respectively, $P > t = 0.4799$), but lower final numbers of moths were collected in *Heliothis* cone traps because many moths that successfully entered the large base cone either did not enter the apex cone or escaped from the apex cone during the night (Lopez 1998).

These results suggest that the numbers of males that enter both traps are similar, but the rate of escape from the *Heliothis* cone traps, especially for smaller moths, results in a smaller number of moths being captured. Unitraps have successfully captured lepidopterous pests including *Diatraea grandiosella* (Dyar) (Goodenough et al. 1989), *Eoreuma loftini* (Dyar) (Shaver et al. 1991), and *S. exigua* (Hübner) (Lopez 1998), but generally have performed poorly capturing *Heliothis virescens* (F.), *Helicoverpa zea* (Boddie) (Gauthier et al. 1991, Lopez et al. 1994) and *Ostrinia nubilalis* (Hübner) (Bartels and Hutchison 1998). The cone traps took longer to service than Unitraps (Adams et al. 1989) and were plagued by predation of captured moths by imported fire ants (*Solenopsis invicta* Buren).

The experiment in 1999 was designed to compare pheromone lures with Unitraps. Male fall armyworm captures in peanut fields were low throughout the trapping period, except for late June and early July (Fig. 2). Analysis for the period 14 May through 22 July showed that more moths per night were collected in Trécé (2.6 ± 0.6) and Scenturion baited-traps (2.5 ± 0.4) than Scentry baited-traps (1.3 ± 0.2) ($F = 27.7$; df = 3, 9; $P < 0.0001$). When each date was analyzed individually, 7 of the 20 dates showed significant differences among traps in moth capture. On those dates, Scentry-baited traps were either intermediate or lowest in numbers of males collected. The placement of fresh lures did not seem to affect the significance, as only 2 of 7 dates were after new lures were placed in the field. The unbaited traps collected very few moths (0.01 ± 0.007).

Differences in moth capture among the different company lures were unexpected, especially because gas chromatography analysis of volatiles showed all lures re-

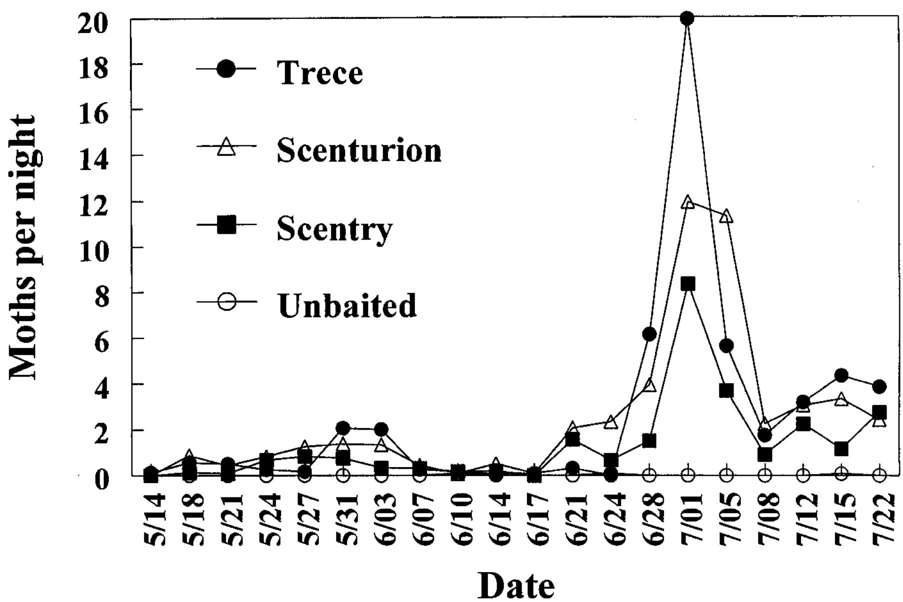

Fig. 2. Capture of male fall armyworm in unbaited Unitraps or in Unitraps baited with either Trécé, Scenturion, or Scentry pheromone lures, Levy Co., FL, 1999.

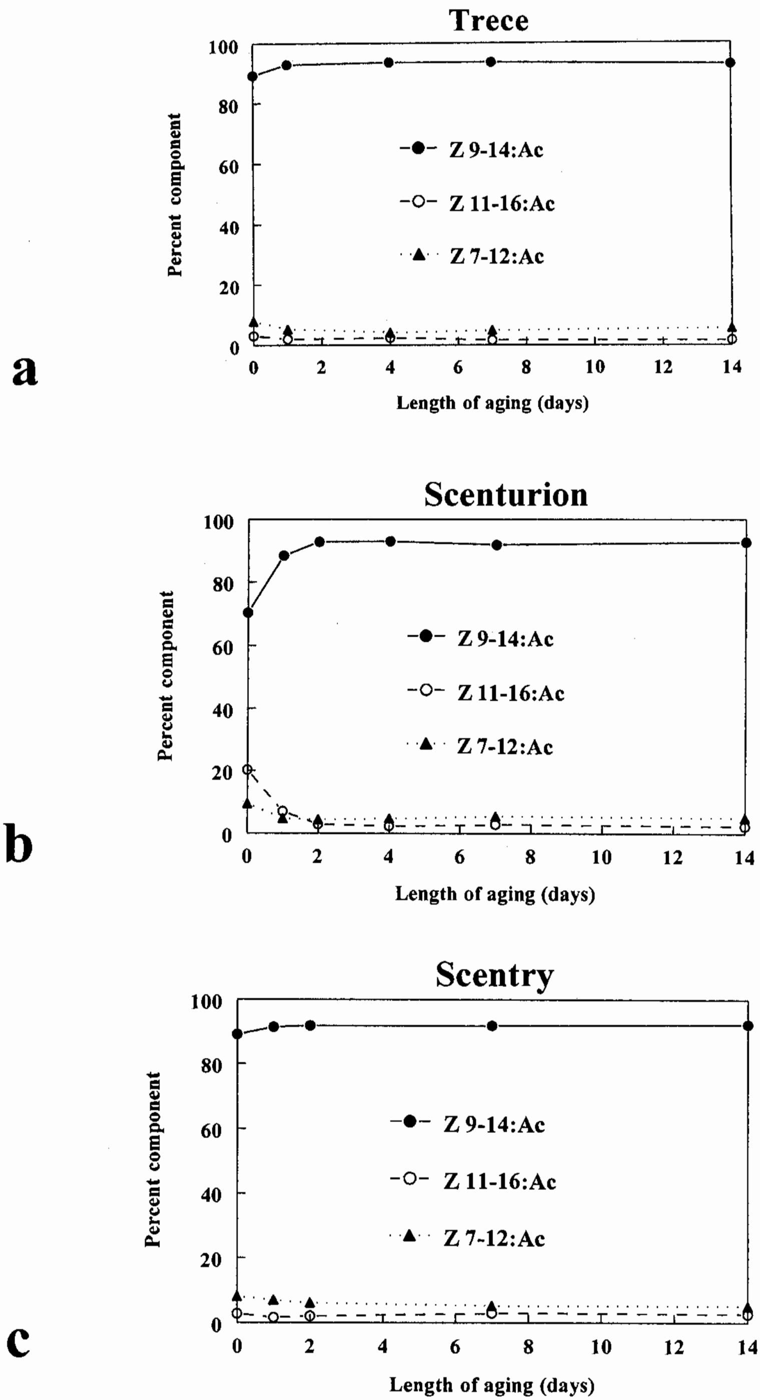

Fig. 3. Percentages of three fall armyworm pheromone components eluted from three commercial lures.

leased similar ratios of Z9-14:AC, Z11-16:AC, and Z7-12:AC. The ratio of the emission rates for each sampling interval of the three major fall armyworm pheromone acetate components was calculated, and Z9-14:AC was found to comprise over 90% of the emissions (90.5 ± 1.4%), followed by Z7-12:AC (5.8 ± 0.4%) and Z11-16:AC (3.7 ± 1.1%) (Fig. 3). Comparisons of each ratio component showed no differences among lures ($P < 0.05$). Tumlinson et al. (1986) found the highest trap capture of fall armyworm resulted from release ratios formulated on rubber septa of 92.9%, 3.3%, and 3.8% for Z9-14:AC, Z7-12:AC, and Z11-16:AC, respectively. The Scentry-baited traps generally caught 50% fewer moths than the other lures. However, on individual nights trap capture was similar or even higher than Trécé- or Scenturion-baited traps.

Many of the parameters for monitoring fall armyworm with pheromone traps have already been described (Mitchell et al. 1985, Mitchell et al. 1989, Pair et al. 1989). Our results show that all three commercial pheromone lures placed in Unitraps were successful in capturing male moths, but that Trécé and Scenturion lures collected more moths. During the last 30 yrs, noctuid pest management using insect behavior has progressed from simple monitoring to control measures such as mating disruption and attracticides. However, increased moth attraction and collection will be required to propel advanced monitoring systems and control tactics such as autodissemination of a pathogen (Jackson et al. 1992).

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