



RESPONSE OF *SPODOPTERA EXIGUA* AND *S. ERIDANIA*
(LEPIDOPTERA: NOCTUIDAE) MALES TO SYNTHETIC
PHEROMONE AND *S. EXIGUA* FEMALES¹

EVERETT R. MITCHELL AND JAMES H. TUMLINSON
Insect Attractants, Behavior, and Basic Biology
Research Laboratory, Agricultural Research Service
U.S. Department of Agriculture, Gainesville, FL 32604

ABSTRACT

The seasonal occurrence of the beet armyworm, *Spodoptera exigua* (Hübner), and the southern armyworm, *Spodoptera eridania* (Cramer), was monitored over a 2-year period using International Pheromones, Ltd. Moth Traps[®] baited with rubber septa impregnated with pheromone blends identified from conspecific females and also with pheromone emitted by live female beet armyworm moths. The pheromone blend for beet armyworm was (Z)-9-tetradecen-1-ol (2.5%), (Z,E)-9,12-tetradecadien-

¹This article reports the results of research only. Mention of a proprietary product does not constitute an endorsement or the recommendation of its use by USDA.

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1-ol acetate (87.2%), and (Z)-11-hexadecen-1-ol acetate (10.3%). The pheromone blend used for southern armyworm was (Z)-9-tetradecen-1-ol acetate (55.78%), (Z,E)-9,12-tetradecadien-1-ol acetate (21.23%), (Z,E)-9,11-tetradecadien-1-ol acetate (8.67%), and (Z)-11-hexadecen-1-ol acetate (14.32%). Although subtropical in habit, both species apparently can survive in North-Central Florida even when temperatures drop below freezing for several days. The response of male southern armyworm moths to traps baited with beet armyworm females was remarkably similar to that recorded for southern armyworm males to their synthetic pheromone. This response was consistent over two years.

Key Words: Cross sex attraction, southern armyworm, beet armyworm, (Z)-9-tetradecen-1-ol, (Z,E)-9,12-tetradecadien-1-ol acetate, (Z,E)-9,11-tetradecadien-1-ol acetate, (Z)-11-hexadecen-1-ol acetate.

RESUMEN

La dinámica poblacional del trozador de la remolacha, *Spodoptera exigua* (Hübner), y del trozador sureño *Spodoptera eridania* (Cramer), fué estudiada durante 2 años, al usar trampas con feromonas de polillas de la compañía International Pheromones. El cebo utilizado consistió en un tabique de caucho impregnado con mezclas de feromonas de hembras conespecíficas y con feromonas provenientes de hembras de la polilla de la remolacha. La mezcla de feromona para la polilla de la remolacha fué (Z)-9-tetradecen-1-ol (2.5%), (Z,E)-9,12-tetradecadien-1-ol acetato (87.2%), y (Z)-11-hexadecen-1-ol acetato (10.3%). La mezcla de feromona para el trozador *S. eridania* fué (Z)-9-tetradecen-1-ol acetato (55.78%), (Z,E)-9,12-tetradecadien-1-ol acetato (21.23%), (Z,E)-9,11-tetradecadien-1-ol acetato (8.67%), y (Z)-11-hexadecen-1-ol acetato (14.32%). Aunque ambas especies son subtropicales, ellas pueden sobrevivir en la parte central y norte de Florida, aún en aquellos días en que la temperatura es bajo zero. La respuesta de las polillas del trozador sureño a las trampas con hembras de polilla de la remolacha fué muy similar a aquellas trampas con feromona sintética de su misma especie. Esta respuesta fué consistente durante dos años.

Members of the genus *Spodoptera* are distributed throughout the world and include a number of species that cause significant economic damage to agricultural crops. The beet armyworm (BAW), *S. exigua* (Hübner), and southern armyworm (SAW), *S. eridania* (Cramer), are two of three major North American pests in this genus. Both the BAW and SAW are present in much of Florida throughout the year where they often cause considerable economic damage on commercial vegetable crops. In recent years, the BAW also has become a threat to cotton production in the southeastern U.S. The SAW also has demonstrated a propensity to broaden its host range and include sunflower, often defoliating plants to a degree that yields are greatly reduced (Mitchell 1984).

Growers in North-Central Florida are experimenting with alternate crops such as cotton, sunflower, and vegetables to replace declining acreages of tobacco and field corn. Not only are growers planting replacement crops, but they also are investigating ways of intensifying production using double-cropping practices. For example, some growers are following spring planted corn grown for silage with cotton planted in mid-summer; still others are following winter vegetables, such as cabbage, with plantings of sorghum or corn in late spring or early summer.

The changing cultural practices have heightened grower awareness of possible shifts in insect pest complexes, especially if plant hosts and suitable habitats become available throughout most of the year. Although subtropical in habit, both the BAW and SAW are potential threats to most of the crops undergoing evaluation by North-Central Florida growers. Therefore, traps baited with synthetic sex pheromone and

live BAW female moths were used to monitor the seasonal occurrence of BAW and SAW in this area over a 2-year period beginning in fall 1988.

The synthetic pheromone blend used to monitor the BAW was identified by Tumlinson et al. (1990). They detected and identified five compounds from the volatiles emitted by virgin BAW females: (Z)-9-tetradecen-1-ol acetate; (Z)-9-tetradecen-1-ol; (Z,E)-9,12-tetradecadien-1-ol acetate; (Z,Z)-9,12-tetradecadien-1-ol acetate; and (Z)-11-hexadecen-1-ol acetate in a ratio of 47.9:4.0:2:6.5:1.7, respectively. Field tests of these components in various formulations on rubber septa using bucket traps indicated that a blend of (Z)-9-tetradecenol, (Z,E)-9,12-tetradecadien-1-ol acetate, and (Z)-11-hexadecen-1-ol acetate was most effective for trapping BAW males and that (Z)-9-tetradecen-1-ol acetate actually decreased trap captures. Blends that did not contain both (Z)-9-tetradecen-1-ol and (Z,E)-9,12-tetradecadien-1-ol acetate were ineffective as trap baits (Tumlinson et al. 1990).

Analysis of sex pheromone glands and volatile pheromone components collected from calling female SAW indicated that a number of 14-carbon mono- and di-unsaturated acetates and a mono-unsaturated 16-carbon acetate were produced and released (Teal et al. 1985). In the same study, the results of field trapping experiments indicated that a blend of (Z)-9-tetradecen-1-ol acetate (Z9-14:AC), (Z,E)-9,12-tetradecadien-1-ol acetate (Z9,E12-14:AC), (Z,Z)-9,12-tetradecadien-1-ol acetate (Z9,Z12-14:AC), (Z,E)-9,11-tetradecadien-1-ol acetate (Z9,E11-14:AC), and (Z)-11-hexadecen-1-ol acetate (Z11-16:AC) was an effective lure for SAW males capturing significantly greater numbers of moths than did female-baited traps. Of these five components, only Z9,Z12-14:AC did not appear to affect trap capture significantly. Gland extracts also indicated the presence of (Z)-9-tetradecen-1-ol (Z9-14:OH), but this compound was not found in volatiles emitted by females (Teal et al. 1985).

MATERIALS AND METHODS

The study was conducted over a period of 34 months from October 1988 through June 1991. International Pheromones, Ltd. Moth Traps[®] (i.e., bucket traps), of the type previously used in field evaluations of the pheromone components emitted by calling virgin BAW female moths (Tumlinson et al. 1990), were set out in northwest Alachua County, Florida. Two traps were placed about 1 m above the ground on metal poles at each of three different locations adjacent to cultivated (field corn) and fallowed fields. The distance between traps at each location was about 100 m, and the distance between locations was about 1 km. One of the two traps at each location was baited with four virgin BAW females (2-3 days old). The second trap was baited with a 5 x 9 mm rubber septum (A. H. Thomas Co.) treated with a 100 μ l hexane solution containing 200 μ g of a pheromone blend previously identified from BAW females: (Z)-9-tetradecen-1-ol (2.5%), (Z,E)-9,12-tetradecadien-1-ol acetate (87.2%), and (Z)-11-hexadecen-1-ol acetate (10.3%) (Tumlinson et al. 1990).

In June 1989, a third bucket trap baited with synthetic SAW pheromone was added to each location and positioned as described for the traps containing the BAW females and BAW septum. The SAW septum was treated with a 100 μ l hexane solution containing 200 μ g of a pheromone blend previously identified from SAW females: (Z)-9-tetradecen-1-ol acetate (55.78%), (Z,E)-9,12-tetradecadien-1-ol acetate (21.23%), (Z,E)-9,11-tetradecadien-1-ol acetate (8.67%), and (Z)-11-hexadecen-1-ol acetate (14.32%) (Teal et al. 1985). No SAW females were available for comparative studies with the synthetic pheromone blend.

Septa were Soxhlet-extracted with methylene chloride for 24 h and air dried before loading. The percentage of each component in the pheromone blend loaded onto septa was calculated on the basis of its relative volatility. This was determined from retention indices on liquid crystal capillary GC columns (Heath & Tumlinson 1986)

by a method developed to predict release ratios of components of a blend from rubber septa (Heath et al. 1986).

A Vapona[®] insecticide strip (Vaportape II, Hercon Environmental Company, Emigsville, PA) was placed inside the buckets as a killing agent for trapped moths. The traps were checked 1-3 times per week depending upon the season. During winter (December-February), the traps were checked and rotated between positions weekly. The rest of the year, the traps were checked and rotated on Monday, Wednesday, and Friday of each week. Bait females were replaced at each inspection; the bait septa and Vaportape II were replaced every two weeks.

RESULTS AND DISCUSSION

Seasonal Response to Pheromone

Captures of BAW in traps baited with rubber septa lures impregnated with the 3-component pheromone blend and virgin BAW females are presented in Fig. 1. Moth captures were greatest during summer and fall both years. Trap capture peaks and valleys for both pheromone and female baits were remarkably similar with the synthetic lure generally capturing more males during most periods. A total of 3,328 BAW males were captured in traps baited with BAW females in 1988-89 and 5,817 were captured in 1989-90. In the traps baited with septa impregnated with pheromone, 7,383 males were captured in 1988-89 and 9,354 were captured in 1989-90.

Captures of SAW in traps baited with rubber septa impregnated with synthetic pheromone are shown in Fig. 2. Moth captures were greatest during summer and fall as for the BAW. A total of 2,611 SAW males were captured during 1989-1990 and 1,558 were captured during 1990-1991.

The apparent growth in populations of both BAW and SAW, as indicated by the number of moths captured from July through October, was comparatively more uniform during 1990. Although the number of BAW and SAW males captured in pheromone-baited traps during this period were similar to the numbers captured during the same period in 1989, BAW and SAW populations appeared to start increasing about two weeks later in 1990 than in 1989.

The steady growth of BAW and SAW moth captures in fall of 1990 likely was due to weather conditions that were conducive to growth of wild hosts common to this area of Florida, especially *Amaranthus* spp. Based upon weather data compiled by the Agronomy Department, IFAS, University of Florida, Gainesville, drought conditions prevailed throughout Florida from January 1989 through June 1990. During this period, the monthly rainfall deficit, i.e., deviation from expected rainfall, averaged -14.09 cm with a range of -28.21 cm in May 1989 to -0.86 cm in June 1990. The drought was broken in July 1990 and followed by near normal levels of rainfall through November 1990. December 1990 was very dry; the rainfall deficit was -5.38 cm below the normal rainfall level of 8.10 cm for the month.

Numbers of BAW and SAW captured in spring and early summer 1991 tended to be lower than numbers captured in the same period of 1990. Again, this probably was due to the level of rainfall received. Unlike spring 1990, which was unusually dry, 1991 was marked by abnormally high levels of rainfall. From January through July 1991, rainfall averaged 17.98 cm above normal, ranging from +0.33 cm in February to +26.41 cm in July. The torrential rains that often occurred during this period possibly helped keep the armyworm populations low, by destroying young larvae soon after they hatched, and also by increasing the level of natural control via disease organisms.

Both BAW and SAW are subtropical species that cannot diapause and thus are unable to survive during extended periods of near- or sub-freezing temperatures. The species' overwintering range appears to be governed by the occurrence of frost

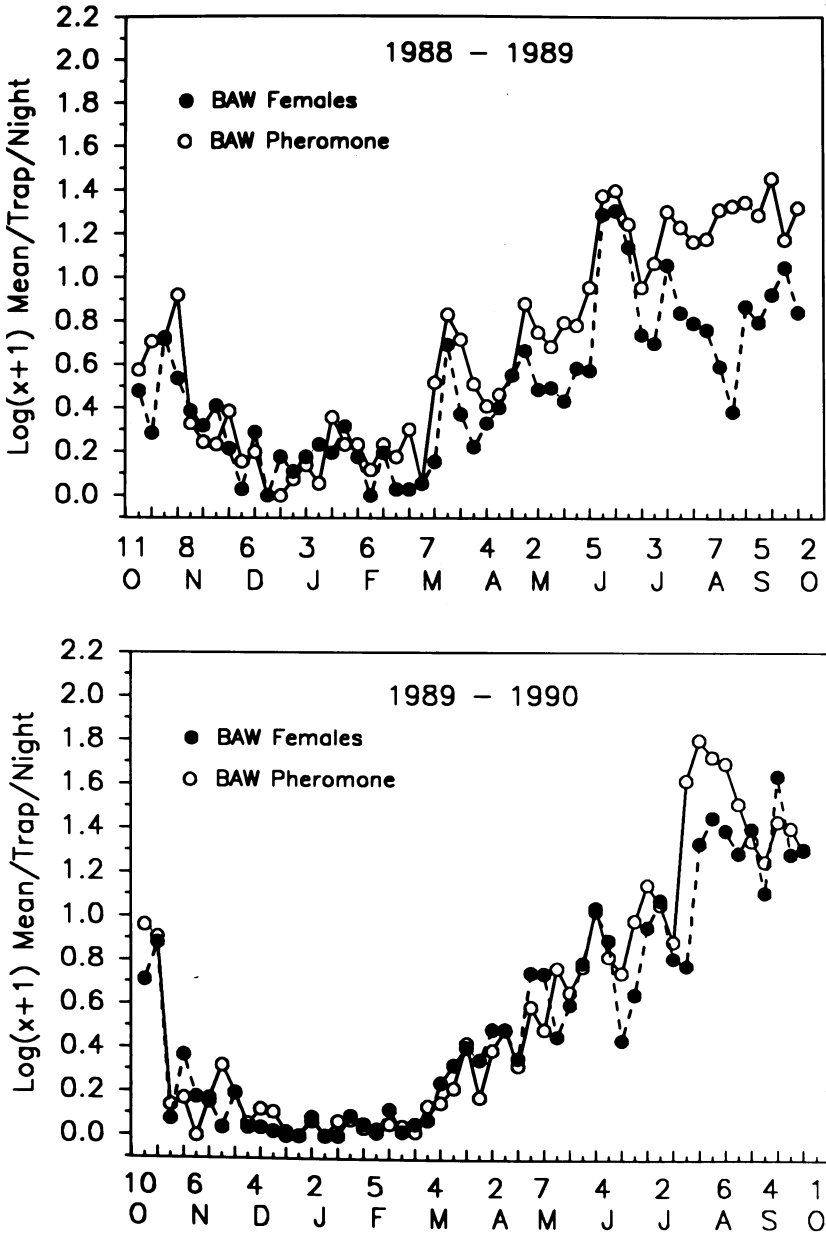


Fig. 1. Weekly captures of male beet armyworm moths in bucket traps baited with rubber septa lures treated with synthetic sex pheromone simulating conspecific females and beet armyworm females. Numbers above months are reference dates for beginning of weekly periods. October 1988-September 1990. Alachua County, Florida.

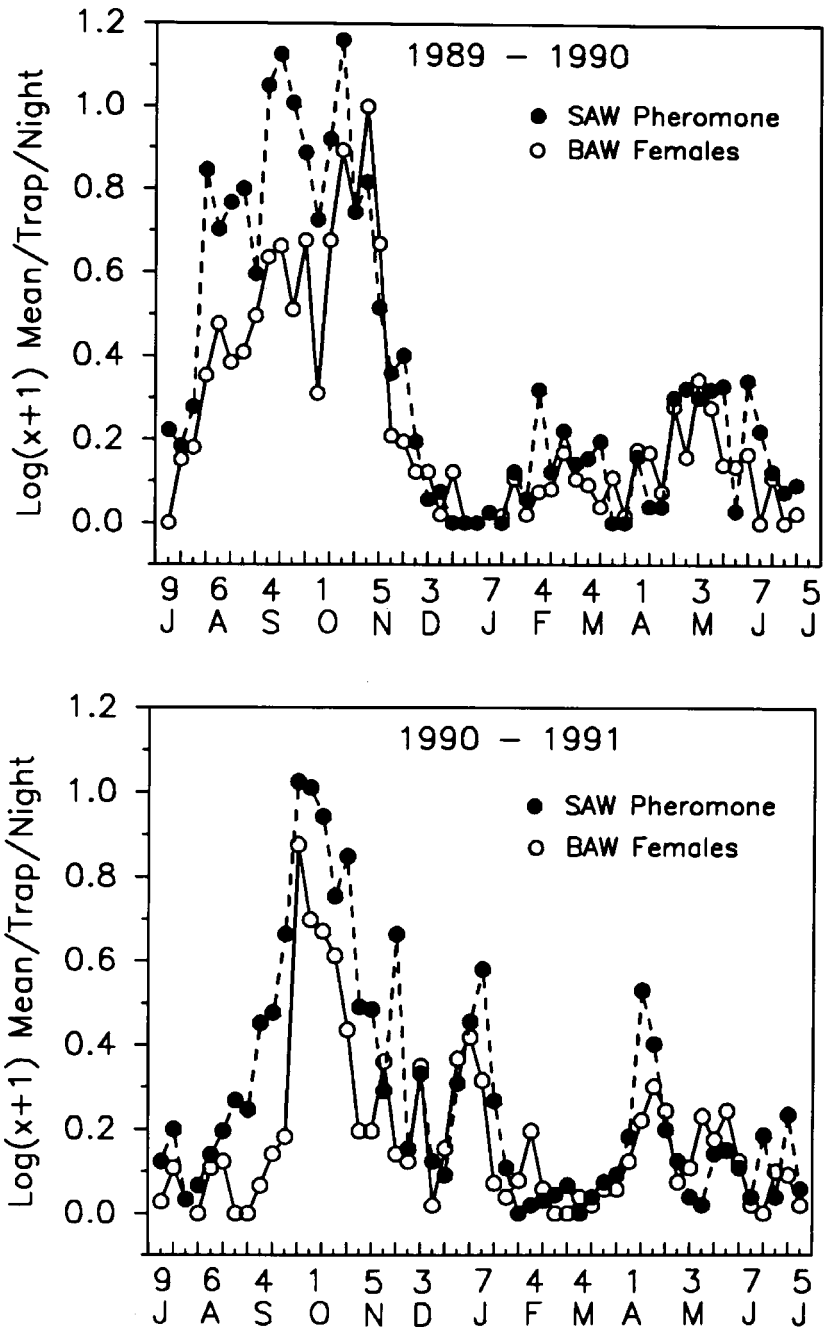


Fig. 2. Weekly captures of male southern armyworm moths in bucket traps baited with rubber septa lures treated with synthetic sex pheromone simulating conspecific females and with natural sex pheromone emitted by beet armyworm females. Numbers above months are reference dates for beginning of weekly periods. July 1989-June 1991. Alachua County, Florida.

that kills host plants and by prolonged temperatures below about 10°C. Thus, the BAW and SAW are very similar in habit, overwintering by continuous generations in subtropical areas of Florida and Texas, and in a few areas along the Gulf Coast (Mitchell 1979). Both species appear to disperse from these areas into more temperate zones of the United States each spring and summer.

The data on moth captures for the winter of 1989-1990 and 1990-1991 present paradoxical situations relative to survival of BAW and SAW in North-Central Florida. Three days of continuous sub-freezing temperatures were recorded in this area during late December 1989, with snow and ice recorded on the 23rd and 24th. Departures from the normal maximum, minimum and average temperature for December were -23°, -23.7°, and -23.4° C., respectively.

The effect of the unusually cold temperatures was reflected in zero moth captures in traps baited with BAW females and synthetic SAW pheromone, respectively, during the last two weeks of December 1989 and the first week of January 1990. Nevertheless, a few BAW and SAW males were captured early in January 1990, and captures of both species continued into spring. These results suggest that the BAW and SAW possibly survived winter in North-Central Florida even under the rather extreme conditions of below freezing temperatures. Of course, the possibility that the insects captured during this period were migrants cannot be discounted completely.

In contrast to winter 1989-1990, the winter of 1990-1991 was extremely mild, allowing continuous growth of herbaceous species that normally would have been killed by frost. These conditions probably allowed for reproduction by BAW and SAW later in fall 1990; hence, accounting for possible local emergence of the moths captured during December 1990-January 1991. Comparative data on capture of BAW in traps baited with synthetic pheromone in the same period are not available because these traps were discontinued in October 1990.

Cross Sex Attraction

Mitchell & Doolittle (1976) reported cross sex attraction between BAW and SAW. This intriguing relationship is demonstrated also in these studies (Figs. 2 and 3). Mitchell and Doolittle used females of each species in Pherocon® 1C sticky traps and about 13% of the moths captured in traps baited with BAW females were SAW males. Conversely, about 8% of the males captured in traps baited with SAW females were BAW males.

In the present study, a total of 8,420 BAW males were captured in traps baited with BAW females from July 1989 through June 1991 (2,742 in 1989-1990 and 5,678 in 1990-1991). A total of 2,019 SAW males also were captured in the same traps (1,253 in 1989-1990 and 766 in 1990-1991).

A total of 4,169 SAW males were captured in traps baited with lures treated with synthetic SAW sex pheromone. However, no BAW males were captured in any of these traps over the course of the two-year survey. Interestingly, the percentage of SAW males captured in traps baited with BAW females equaled 48.4% of the number of SAW males captured in traps baited with synthetic SAW sex pheromone.

The pattern of capture of SAW males in traps baited with BAW females paralleled closely the capture of SAW in traps baited with synthetic SAW sex pheromone (Fig. 2). The results of regression analysis of the number of SAW males captured in traps baited with BAW females versus the numbers captured in traps baited with synthetic SAW pheromone are presented in Fig. 3. These results suggest that cross sex attraction of SAW males to BAW females was consistent and independent of possible seasonal effects that may have been caused by positioning the traps close to host plants. Moreover, the capture of SAW males in traps baited with BAW females was as good an indicator of seasonal occurrence and population peaks of SAW (Fig. 2), as was the synthetic pheromone blend identified from conspecific females.

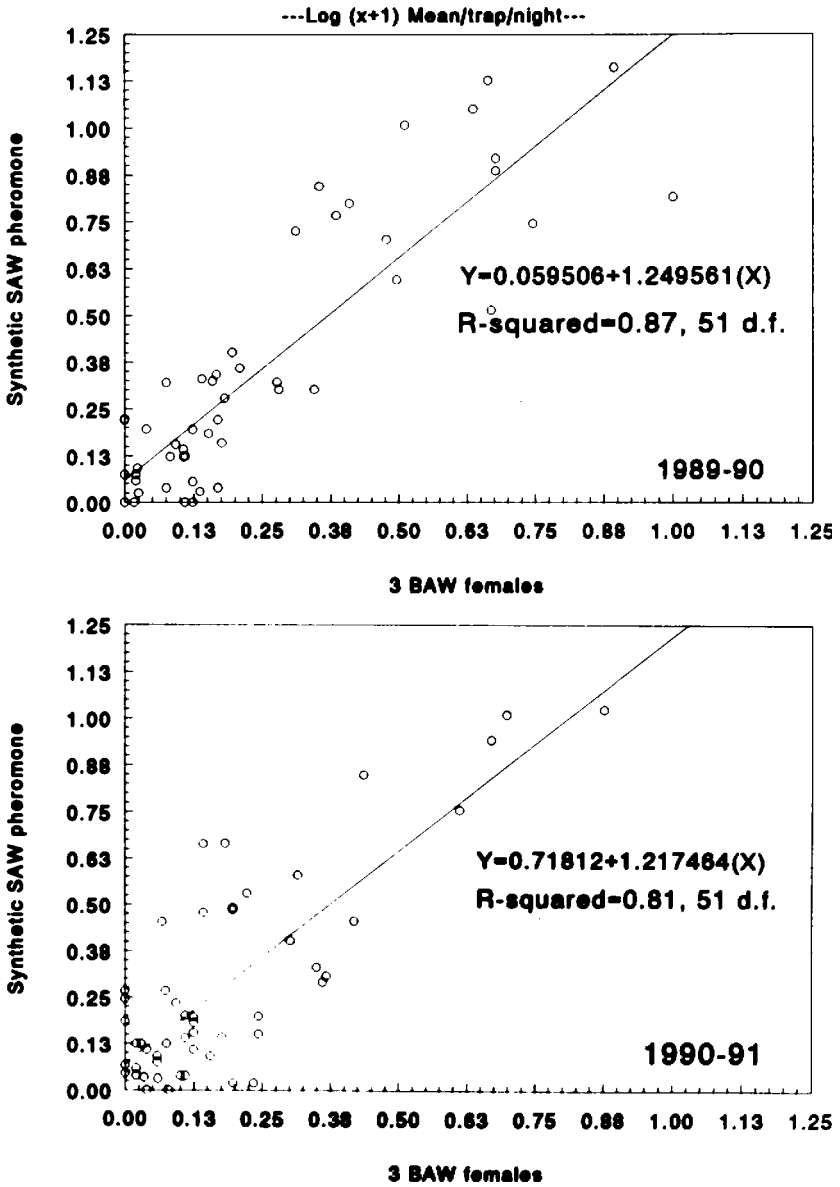


Fig. 3. Relationship between the number of male southern armyworm moths captured in traps baited with beet armyworm females and numbers captured in bucket traps baited with synthetic sex pheromone simulating pheromone produced by southern armyworm females.

The reason for attraction of SAW males to BAW females is indeed puzzling. However, the chemical composition of the sex pheromone blend volatized by the two species may partially explain the unusual cross attraction reported here.

The BAW and SAW have four chemicals in common in their pheromone blend (Table 1). Of these, (Z)-9-tetradecen-1-ol acetate is the major component volatized by females of both species; it is a critical component for attraction of SAW males (Teal et al. 1985) but not for BAW (Tumlinson et al. 1990). The role of (Z)-9-tetradecen-1-ol acetate in the sexual behavior of BAW is unknown; but, addition of this compound to the attractive pheromone blend (Table 1) actually decreases capture of BAW males.

Interestingly, (Z)-9-tetradecen-1-ol was not found among the chemicals volatized by calling SAW females (Teal et al. 1985), but it was found in gland extracts from SAW females. It is possible, of course, that (Z)-9-tetradecen-1-ol was emitted by SAW females but escaped detection because it occurs in such minute quantities. This component is essential to attraction of BAW males (Tumlinson et al. 1990), and it is volatized by BAW females. When Teal et al. (1985) added (Z)-9-tetradecen-1-ol to the SAW pheromone blend, trap captures of SAW were not affected.

In an earlier study, Mitchell (1976) found no evidence of cross mating among these species in the laboratory. Thus, it is unlikely that SAW males would mate with BAW females in nature even when attracted to them. Perhaps (Z)-9-tetradecen-1-ol acts as a reproductive isolating mechanism for BAW and SAW during close range courtship encounters.

The design of the bucket trap used in this study is such that the insects captured must come within a few centimeters of the lure. Observations on the response of other noctuid species, namely *S. frugiperda* (J. E. Smith) and *Anticarsia gemmatilis* Hübner, to synthetic sex pheromone lures in bucket traps indicated that the male moths became very excited when in close proximity to the bait source. Generally, the frenzied moths tumbled into the bucket receptacle after 'bumping' into the wall of the open funnel immediately beneath the lure. Therefore, it is probable that chemicals other than those previously identified from females of the BAW and SAW are responsible for their reproductive isolation in nature.

TABLE 1. VOLATILE PHEROMONE COMPONENTS EMITTED BY FEMALES OF SPODOPTERA EXIGUA (BAW) AND *S. ERIDANIA* (SAW). A (+) INDICATES THE COMPONENT IS NECESSARY IN THE PHEROMONE BLEND FOR CAPTURING CONSPECIFIC MALES IN NUMBERS = OR > THAN THE NUMBERS CAPTURED IN THE SAME TYPE OF TRAP BAITED WITH VIRGIN FEMALES OF THE SAME SPECIES. ADDITION OF THE COMPONENT INDICATED BY (*) TO THE PHEROMONE BLEND RESULTED IN CAPTURE OF BAW MALES. ADDITION OF THE COMPONENT INDICATED BY (!) TO THE PHEROMONE BLEND DIMINISHED CAPTURE OF BAW MALES.

Chemical ¹	BAW ²		SAW ³	
Z9,E12-14:AC	(+)	(40.2) ⁴	(+)	(16.9) ⁴
Z9,Z12-14:AC		(6.50)		(15.2)
Z9,E11-14:AC			(+)	(4.60)
Z9-14:OH	(+)	(4.00)	(*)	
Z9-14:AC	(!)	(47.9)	(+)	(60.6)
Z11-16:AC	(+)	(1.70)	(+)	(2.70)

¹ See text for explanation of chemical abbreviations.

² Tumlinson et al. 1990.

³ Teal et al. 1985.

⁴ Numbers in () are release ratios [%] of pheromone components volatized by calling females. Load ratios used to achieve the desired release ratios when applied on rubber septa used as lures in bucket traps for SAW were: Z9,E12-14:AC, 21.23%; Z9,E11-14:AC, 8.67%; Z9-14:AC, 55.78%; and Z11-16:AC, 14.32%.

CONCLUSIONS

Synthetic pheromone lures for the BAW were as reliable an indicator of seasonal occurrence as were virgin BAW females. Although trap catches with the synthetic blend are well-correlated with live females, this does not necessarily mean that the catches with either of these lures is well-correlated with actual population densities in any given field. Indeed, the senior author often has recorded large captures of these species as well as others including *S. frugiperda* (J. E. Smith), *Heliothis virescens* (Fabricius), and *Helicoverpa zea* (Boddie), in traps baited with synthetic pheromone; but the trap catches usually did not reflect population densities based upon actual egg, larval, or adult counts in crops such as cotton, corn, and sorghum (unpublished).

Although pheromone release rates from septa are influenced by temperature, there was no indication that the cooler temperatures of winter and spring or the hot, humid conditions of summer in North-Central Florida had any more influence on capture of BAW in traps baited with synthetic pheromone than captures in similar traps baited with virgin BAW females. Indeed, the economy of labor, ease of handling, and consistency of delivering a precise quantity of a pheromone at a relatively modest cost, compared with rearing and maintaining live insect baits and the confidence that the results obtained with synthetic lures are as meaningful as those obtained with live insects, warrants the continued use of synthetic pheromone for long-term monitoring of BAW.

Also, the synthetic sex pheromone lure used for the SAW appeared to provide a realistic picture of the seasonal occurrence and shifts in population numbers of this pest. Although SAW female baits were not available for comparison with the synthetic lure, it is not unreasonable to assume that a comparative study would have yielded results similar to those recorded for the BAW.

Captures of SAW males in traps baited with BAW females presented as accurate an assessment of its seasonal occurrence as was defined by captures of SAW males in traps baited with synthetic SAW pheromone. As desirable as such a dual monitoring scheme may be, the use of BAW females to monitor SAW populations is unrealistic. As demonstrated here, synthetic BAW pheromone, not BAW females, is the bait of choice for monitoring this pest. Unfortunately, SAW males are not captured in traps baited with synthetic BAW pheromone.

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