EVALUATION OF COMMERCIAL PHEROMONE LURES AND TRAPS FOR MONITORING MALE FALL ARMYWORM (LEPIDOPTERA: NOCTUIDAE) IN THE COASTAL REGION OF CHIAPAS, MEXICO

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ABSTRACT

Commercially available sex pheromone lures and traps were evaluated for monitoring male fall armyworm (FAW), *Spodoptera frugiperda*, in maize fields in the coastal region of Chiapas, Mexico during 1998-1999. During the first year, Chemtica and Trécé lures performed better than Scentry lures, and there was no difference between Scentry lures and unbaited controls. In regard to trap design, Scentry *Heliothis* traps were better than bucket traps. In 1999, the pattern of FAW captured was similar to that of 1998, although the number of males captured was lower. The interaction between both factors, traps and lures, was significant in 1999. Bucket traps had the lowest captures regardless of what lure was used. Scentry *Heliothis* traps with Chemtica lure captured more males than with other lures or the controls. Delta traps had the greatest captures with Chemtica lure, followed by Trécé and Pherotech lures. Several non-target insects were captured in the FAW pheromone baited traps. The traps captured more non-target insects than FAW males in both years. Baited traps captured more non-target insects than unbaited traps.

Key Words: *Spodoptera frugiperda*, sex pheromone, monitoring, maize, Mexico

RESUMEN

Se evaluaron feromonas y trampas comercialmente disponibles para el monitoreo del gusano cogollero *Spodoptera frugiperda* en cultivo de maíz en la costa de Chiapas, México durante 1998-1999. El patrón de captura de machos del gusano cogollero fue muy similar para ambos años, aunque el número de machos capturados en el segundo año fue muy bajo. En el primer año, la trampa Scentry *Heliothis* fue mejor que la bucket. En cuanto a los cebos, la feromona de Chemtica y Trécé fueron mejores que la Scentry. La captura obtenida con la feromona de Scentry fue muy similar al control. En 1999, la interacción de trampas-cebo fue significativa. La trampa bucket tuvo las más bajas capturas independientemente del cebo usado. La trampa Scentry *Heliothis* capturó mejor con los cebos Chemtica que los otros cebos. La trampa delta tuvo las más altas capturas con el cebo Chemtica, seguido de los cebos Trécé y Pherotech. En las trampas, también se capturaron otros insectos con la feromona del gusano cogollero y se observó que la entomofauna asociada capturada fue mayor que la captura de gusano cogollero en ambos años. Las trampas cebadas con feromona capturaron significativamente más entomofauna asociada que las trampas que no contenían feromona.

The fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith), is a generalist noctuid moth that is distributed from Brazil northward, throughout Central and North America (Mitchell 1979). FAW larvae feed on more than 60 different species of plants, particularly graminaceous hosts, such as maize, sorghum and Bermuda grass (Mitchell 1979). *S. frugiperda* is one of the most important constraints to maize production throughout Mexico, where this crop plays a principal role in both farming production and human diet. Chemical insecticides are routinely employed as control agents against this insect pest in Mexico, although recently, some alternatives to chemical control have begun to be explored, particularly the use of entomopathogenic agents (e.g., Williams et al. 1999). However, complementary strategies of pest management remain to be tested, including the use of pheromones. Lepidopteran pheromones have been successfully used for insect monitoring, mass trapping, and mating disruption of a diversity of insect pests (Wyatt 1998).

The FAW sex pheromone was reported by Tumlinson *et al*. (1986), as a mixture of (*Z*)-9-tetradecen-1-ol acetate, (*Z*)-9-14:Ac; (*Z*)-7-dodecen-1-ol acetate, (*Z*)-7-12:Ac; (*Z*)-9-dodecen-1-ol acetate, (*Z*)-9-12:Ac and (*Z*)-11-hexadecen-1-ol acetate, (*Z*)-11-16:Ac in the ratio of 81: 0.5: 0.5: 18, respectively. These four components have been formulated and this mixture has been quite effective in monitoring populations of *S. frugiperda* from the USA and the Caribbean Basin (Mitchell et al. 1985). Commercially available FAW sex pheromones have been used in the USA, and have been shown to be a useful tool for monitoring FAW males (Adams et al. 1989; Mitchell et al. 1989; Gross & Carpenter 1991). The efficacy of these commercial sex pheromones towards Mexican populations of FAW is largely unknown. Gutiérrez-Martínez et al. (1989) evaluated lures but did not report the source of lures. This study was therefore undertaken to evaluate the capture of commercial pheromone formulations and trap designs as a first step for developing a system for monitoring FAW in Mexican maize crops.

Materials and Methods

Study Area

Trials were performed during the late summer growing cycle of 1998 and 1999. Both trials were conducted in the municipality of Suchiate (14°42'N, 92°16'W), Chiapas, in maize fields planted with Cristiani Burkard hybrid (1998) or TACSA 2000 hybrid (1999) sown at the usual density of 50,000 plants per ha with a 0.75 m row spacing.

1998 Trial

Three commercially available FAW sex pheromone lures and two trap designs were evaluated in a 2 × 4 factorial design. The treatments were arranged in a fully randomized block design with four replicates of each treatment. The replicate blocks were arranged in parallel lines approximately 30 m apart within the field (5 ha). The lures tested were Scentry (Scentry Inc., Buckeye, Ariz.), a grey rubber septum dispenser; Trécé (Trécé Inc., Salinas, Calif.) a red rubber septum dispenser, obtained through Gempler's Inc., Belleville, WI, (USA); and Chemtica, a bubble cap (Chemtica, Heredia, Costa Rica). Traps without lures were used as a control. The traps evaluated were the Scentry *Heliothis* trap, a white double cone collapsible plastic net (Ecogen Inc. Billings, MT); and a green reusable bucket trap (Gempler`s, Belleville, WI). Traps with the lures were hung approximately 1.5 m above the ground on wooden stakes placed at 30 m intervals along planted rows. The traps were placed on 18 July, when the maize plants were 15 d old, and they remained in place over the two- month trial. All lures were changed monthly. Trap captures were recorded every 3-4 d from 18 July to 3 September, a total of 16 observation dates. However, at end of the trial, male capture was very low (3 FAW males in total), and for this reason the last two observation dates were not included in the statistical analysis. On each date, we emptied the traps and recorded the numbers of FAW males and non-target insects captured. All non-target insects captured were identified to order (Borror et al. 1989). Voucher specimens were placed in the insect collection held at El Colegio de la Frontera Sur, Tapachula, Mexico.

1999 Trial

The second experiment evaluated four commercial FAW pheromone lures, which were Scentry, Trécé, Chemtica and Pherotech (Pherotech, Delta, BC) and three trap designs, Scentry *Heliothis*, bucket and white delta plastic (Pherotech, Delta, BC) arranged in a 3 × 5 factorial design. The traps were placed one day after planting at 1 m above the ground in the first month, at 1.5 m in the second month and at 2 m in the third month. Traps were checked as described above and a total of 14 observation dates were recorded, although the last three observation dates were not analyzed because no FAW males were caught.

Collection of Volatiles

Volatiles emitted by the pheromone lures were collected by using the dynamic headspace (air-entrainment) technique (Heath & Manukian 1992). New lures (unaged) were individually confined in a 100 ml glass entrainment container (4.8 cm ID × 12.5 cm height). Volatiles were drawn from the container, using purified air that had previously passed through an activated charcoal trap, onto a glass volatile collection trap (4 mm ID × 40 mm long) containing 50 mg of Super Q adsorbent (Alltech Associates, Deerfield, IL, USA) (Heath & Manukian 1992). Air was drawn through the trap at a rate of 1 liter/min by a vacuum pump. The volatiles were collected for a period of 5 h. Volatiles were eluted from the adsorbent with 100 µl of methylene chloride (Baker, HPLC grade), and 100 ng of octyl acetate was added as an internal standard for subsequent quantification. The collection of volatiles was replicated 5 times.

Chemical Analysis

Gas chromatographic-mass spectrometry (GC-MS) was performed with a Varian Saturn III, equipped with a DB5-MS column (30 m × 0.25 mm). Gas chromatographic conditions were as follows: Injector temperature, 200°C; column temperature, isothermal at 80°C for one minute, then increasing to 250°C at 8°C/min and held at this temperature for 3 min. The mass spectrum was obtained at 70 eV by electronic impact. The chemical identification was made by comparing the spectra and the retention times of the natural products with those of authentic synthetic standards.

Statistical Analysis

The number of FAW males captured per trap per sample period in both years were converted to percent of moths captured by each trap and lure combination within each block (Mitchell et al. 1985). Percentage values were arcsine of square root transformed to increase the homogeneity of variance and normality. Data were analyzed by two-way ANOVA (trap × lure), and treatments means were compared by least significant difference (LSD) ($P = 0.05$).

Results

The total capture of FAW males for all traps pooled throughout the 1998 study was 703 males, with a mean of 1.37 FAW moths per trap per observation date (0.37 male/trap/night) (Fig. 1a). The number of males captured steadily decreased until 14 September when trapping ceased due to damage caused by a tropical storm. A greater number of males were captured at the beginning of the experiment than at the end ($r^2 = 0.48$, $P < 0.01$). Scentry *Heliothis* traps captured significantly more FAW males than bucket traps ($F = 38.25$; df = 1, 21; $P = 0.0001$) (Fig. 2). Chemtica and Trécé lures captured significantly more FAW males than Scentry lures or the controls ($F = 4.16$; df = 3, 21; $P = 0.01$) (Fig. 2). The interaction between traps and lures was not significant ($F = 1.75$; df = 3, 21; $P = 0.18$).

A similar pattern of captures to that in 1998 was observed in the second year, although the overall number of males captured was substantially lower (only 380 males) in 1999 (Fig. 1b). As in 1998, a greater number of male FAW were captured at the beginning of the trial than at the end ($r^2 = 0.60$, $P < 0.05$). There were differences in capture rates among traps ($F = 36.6$; df = 2, 42; $P = 0.0001$) and lures ($F = 7.59$; df = 4, 42; $P = 0.0001$). In this year, the interaction between trap type and lure was significant ($F = 2.72$; df = 8, 42; $P = 0.01$). Bucket traps had the lowest captures no matter what lure was used. Scentry *Heliothis* traps captured more males with Chemtica lure than with other lures and control. Delta traps had the greatest captures with Chemtica lure, followed by Trécé and Pherotech lures (Fig. 3).

Many non-target insects also were captured in the FAW pheromone traps. The traps captured more non-target insects than FAW males in both years. In 1998, 67.7% of the total insects captured were non-target insects, while in 1999, the percentage of non-target species captured was 86.6 (Fig. 4). The insects captured included non-target moths such as *Diatraea lineolata;* Hymenoptera (mainly honey bees, *Apis mellifera*, and bumble bees); and species of Diptera, Coleoptera, and Homoptera (Fig. 4). The bucket traps with pheromone (all lures) captured 2.5 times more non-target insects than the same unbaited trap in 1998 and 1.5 times more in 1999. Baited Scentry *Heliothis* traps captured three times more than control traps in 1998 and 4.5 times more in 1999. Baited delta traps caught four times more than unbaited delta traps in 1999 (Table 1).

Chemical analysis of the commercial unaged pheromone lures indicated the presence of (Z)-9 tetradecen-1-ol acetate as the major component in all lures (Table 2). With respect of the minor components, (Z)-7 dodecen-1-ol acetate was found in all lures, with a release rate ranging from 2.9 ng/h/lure (Trécé) to 14.1 ng/h/lure (Chemtica). In addition, (Z)-11 hexadecen-1-ol acetate was found in quantifiable amounts (12.2 ng/h/lure) only in the Chemtica lure, while in the other lures it was found only in trace quantities.

Discussion

The number of males caught was very low in comparison with other studies where FAW sex pheromone lures have been evaluated (Mitchell et al. 1985; Adams et al. 1989; Gonzalez & Caballero 1990; Gutiérrez-Martínez et al. 1989). For example, Gutiérrez-Martínez et al. (1989) reported captures as high as 150 moths/trap/night in the central area of Chiapas State, Mexico. The reason of the low capture in our study is not known, but several factors may be involved. One possibility is that the low capture may reflect the low FAW population during the study. There is no published data about seasonal abundance of *S. frugiperda* in the region where the study was conducted. Another possibility may be that the traps used in this study were not efficient in catching FAW males. However, the same traps performed well elsewhere (Mitchell et al. 1985; Gutiérrez- Martínez et al. 1989). Still another possibility may be that FAW males from this region respond less to the commercial sex pheromone lures compared with populations elsewhere. In Costa Rica, sex pheromone lures from North America and England gave erratic capture rates under field conditions (Andrade et al. 2000). A re-examination of four acetates for *S. frugiperda* from Costa Rica showed that (Z)-7-dodecen-1-ol acetate and (Z)-9-dodecen-1-ol acetate were highly attractive to FAW males when present alone. The binary combination of (Z)-7-dodecen-1-ol acetate (0.6%) and (Z)-9-tetradecen-1-ol acetate (99.4%) was at least 10 times more attractive to *S. frugiperda* in Costa Rica than North American or English lures (Andrade et al. 2000).

The good performance of Chemtica and Trécé lures can not be explained by qualitative difference in its components because all lures had the same active components. Also, the type of dispenser used for releasing the pheromone did not explain the better performance of Chemtica and Trécé because the pheromone of Trécé was loaded into rubber septa, whereas the Chemtica lure was in a bubble cap. Other studies have shown that the type of substrates used for releasing the pheromone can influence trap captures. For example, Mayer & Mitchell (1999) have shown that more *Plutella xylostella* males were captured with pheromone mixtures loaded into grey septa than with red septa.

Scentry *Heliothis* traps captured more FAW males compared with bucket traps. These results

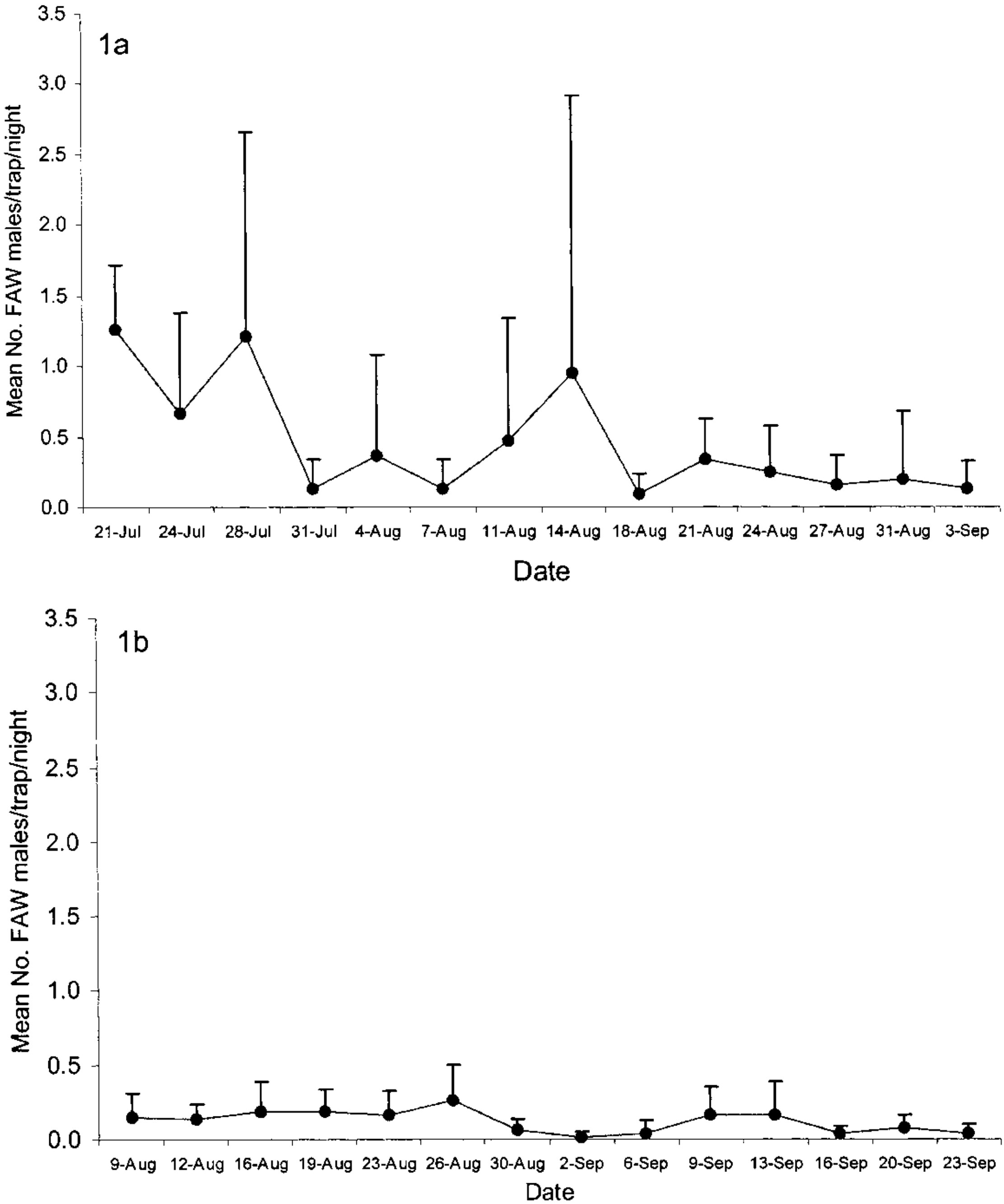

Fig. 1. Seasonal mean number (+SEM) of captures of male *Spodoptera frugiperda* with sex pheromone traps in a maize field in southern Mexico. a) 1998, b) 1999.

are in agreement with Mitchell et al. (1985), who reported that Scentry *Heliothis* traps performed better than bucket traps. However, other studies have shown that FAW capture was the same with Scentry *Heliothis* traps, multi-pher, bucket and pherocon traps (Adams et al. 1989).

Un baited traps, mainly Scentry *Heliothis* traps, captured 9% of all FAW males caught in both years. Others have reported that unbaited control traps caught few or no moths (Mitchell et al. 1985). However, the differences between our results and those of Mitchell et al. (1985) may be

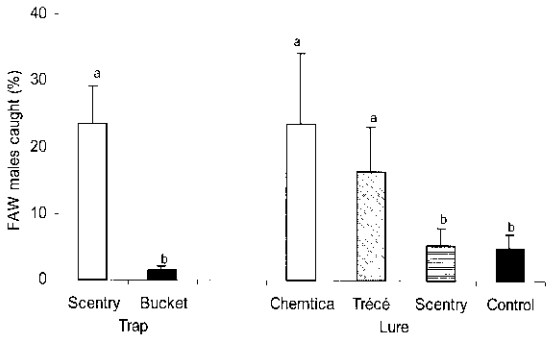

Fig. 2. Percent capture of male fall armyworm (+SEM) in different traps and lures evaluated during 1998. Significant differences within trap and lures are shown by different letters over the bars (LSD test, $P = 0.05$).

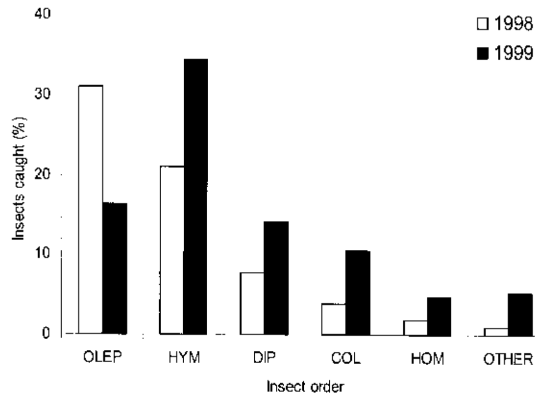

Fig. 4. Percentage non-target and target insects captured in fall armyworm traps during 1998 and 1999 in a maize field in southern Mexico. (OLEP = Other Lepidoptera; HYM = Hymenoptera; DIP = Diptera; COL = Coleoptera; HOM = Homoptera; Other = Hemiptera + Orthoptera + Neuroptera + Dermaptera).

due to the type of trap used. They utilized bucket traps, a trap that in our study captured only very few males. It is not known why males were attracted to unbaited traps. Mitchell et al. (1989) have reported that color and design of traps may influence trap capture, although the sex pheromone is fundamental for attracting males.

Baited traps caught more non-target insects than unbaited traps, suggesting that some of the pheromone components may attract non-target insects. In the case of other moth species, this is not surprising because some of these non-target moths may use similar or identical pheromone components to those of *S. frugiperda*. For example, Weber & Ferro (1991) reported that the noctuids *Leucania phragmitidicola*, *Sideridis rosea* and *Eurois occulta* were commonly captured in FAW traps in Massachusetts, USA. Several studies have documented the phenomenon that baited traps attract non-target and even beneficial insects (Adams et al. 1989; Mitchell et al. 1989; Gauthier et al. 1991; Gross & Carpenter 1991; Meagher & Mitchell 1999). Apparently, trap color may play a role in the attraction of insects. For instance, several studies have documented that white or yellow traps attracted large numbers of *Bombus* spp. (Hamilton et al. 1971; Mitchell et al. 1989). However, Gross & Carpenter et al. (1991) and the results of our study, where a control trap was used, suggest that chemical compounds from pheromones may be involved in the attraction of non-target insects captured. In the case of *Bombus* spp., Gross & Carpenter (1991) reported that insects approached only the yellow traps, but they did not enter the traps unless olfactory stimuli were present. Meagher & Mitchell (1999) speculated that *Bombus* spp. are attracted to any of the FAW sex pheromone components. The problem of capturing non-target insects has been discussed in detail elsewhere (Adams et al. 1989; Weber & Ferro 1991).

In conclusion, the results of this study showed that some lures and traps performed better than

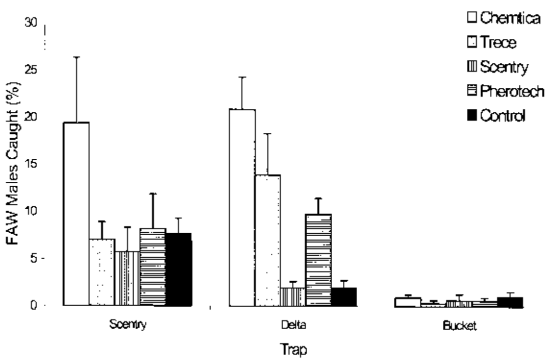

Fig. 3. Percent capture of male fall armyworm in three traps with four different lures during 1999 in a maize field in southern Mexico.

TABLE 1. TOTAL NUMBER OF NON-TARGET INSECTS CAPTURED IN TRAPS IN MAIZE FIELDS IN SOUTHERN MEXICO.

	Year	
Trap type	1998	1999
Unbaited bucket	38	50
Baited bucket	99	78
Unbaited Scentry	366	332
Baited Scentry	1078	1497
Unbaited delta	*	98
Baited delta	*	392

*Not tested.
Total numbers of non-target insects were 1581 in 1998 and 2447 in 1999.

TABLE 2. RELEASE RATES (MEAN ± SEM, N = 5) OF PHEROMONE COMPONENTS IN UNAGED COMMERCIAL LURES COLLECTED BY DYNAMIC HEADSPACE AND DETERMINED BY GAS CHROMATOGRAPHIC-MASS SPECTROMETRY.

Pheromone component	Mean (±SEM) Lure Release Rate (ng/h/lure)			
	Chemtica	Trécé	Scentry	Pherotech
(Z)-7-12: Ac	14.1 ± 11.5	2.9 ± 2.0	6.4 ± 3.0	4.1 ± 1.9
(Z)-9-14: Ac	92.4 ± 54.2	21 ± 7.5	46 ± 20.0	71 ± 42.0
(Z)-11-16:Ac	12.2 ± 9.2	1.28 ± 0.68	0.6 ± 0.01	0.08 ± 0.04

others. However, we found that the abundance of FAW populations may affect the results obtained. Therefore future studies with high density populations of *S. frugiperda* will be necessary to confirm these results.

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