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EVALUATION OF COMMERCIAL PHEROMONE LURES FOR MONITORING ARMYWORM (*SPODOPTERA* SPP.) IN ORGANIC SWEET CORN (*ZEA MAYS* L.)

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ABSTRACT

A study of the attractiveness of commercially available pheromone lures for monitoring fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith) was conducted in spring 2007 and 2008 in organically grown sweet corn. Corn earworm, *Helicoverpa zea* (Boddie), beet armyworm (BAW) *Spodoptera exigua* (Hübner), southern armyworm (SAW) *Spodoptera eridania*, and natural enemies were also monitored in this study. In 2007, FAW populations were low and there was no significant difference in FAW captures among lure types. In 2008, FAW populations were higher compared with 2007, and traps baited with Trécé lures captured significantly more FAW compared with the Hercon and Scentry lures. Lure type did not have a significant effect on cob weight infested with FAW and marketable yield. Beet armyworm populations were significantly higher than southern armyworm populations in both 2007 and 2008. The ladybird beetle, *Hippodamia convergens* Guerin Meneville was the only natural enemy captured consistently throughout the study period. There was no significant difference in *H. convergens* captures among lure types. The findings from this study suggest that traps baited with Trécé lures attracted more FAW in the study site. As expected, the higher trap captures had no significant effect on the number of cobs infested with FAW and marketable yield. Commercial lure formulations vary in attractiveness to FAW. Growers need to select the most attractive lure for early detection of FAW so that management strategies can be applied before they reach damaging levels.

Keywords: *Spodoptera frugiperda, Spodoptera exigua, Spodoptera eridania*, organic, sweet corn, pheromone lures

INTRODUCTION

Fall armyworm (FAW) *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) is native to the tropical regions of the western hemisphere and a primary pest of sweet corn in Florida (Foster, 1989). The larva feeds on more than 60 different species of plants, which include maize, sorghum, forage grasses, turf grasses, rice, sugarcane, cotton, and peanuts (Nagoshi *et al*., 2006; Luginbill, 1928; Sparks, 1979). Adults are nocturnal (Sparks, 1979), and females oviposit on silk, developing kernels, and ears of sweet corn (Ni *et al*., 2007; Beserra *et al*., 2002).

In the US, FAW survives winter in the southern tips of Florida and Texas as it lacks diapause mechanisms (Sparks, 1979; Fleischer *et al*., 2005). Nagoshi and Meagher (2004) used pheromone baited traps and molecular markers to show that two host strains of FAW (rice-strain and corn strain) with different population dynamics overwinter in agricultural areas in Florida. These populations migrate to Central and Eastern United States causing significant crop losses during the summer (Nagoshi and Meagher, 2008). Routine insecticide sprays are usually employed for controlling FAW (Malo *et al*., 2001), which include Dipel DF (*Bacillus thuringiensis* subspecies *kurstaki*) at 1.3-5.0 kg ha^{-1}, or Entrust (Spinosad) at 6 – 23 g ha^{-1} in organically planted sweet corn (Olson and Simonne, 2009). Generally, growers employ field scouts to determine armyworm population levels in sweet corn. This can be a time consuming and labor intensive operation depending on the size of the farm. An effective trap and lure system can reduce labor costs and the need for frequent applications of organically approved pesticides to manage armyworm populations.

Another significant pest of sweet corn is the corn earworm, *Helicoverpa zea* (Boddie), which can be distinguished from

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FAW by the presence of black horn-like micro spines along the body of the larvae (Capinera, 2007). Beet armyworm (BAW) *Spodoptera exigua* (Hübner) and southern armyworm (SAW) *Spodoptera eridania* (Stoll) are polyphagous in feeding habits (Liburd *et al*., 2000) and are occasional pests of corn.

Pheromone lures have long been used in monitoring programs to improve trap catch and timing of insecticide applications. Mitchell (1979) and Pair *et al*. (1989) used Pherocon 1C sticky traps baited with the pheromone (Z)-9-dodecenol-1-ol acetate (Z9-12: AC) alone or in combination with small quantities of (Z)-9-tetradecen-1-ol acetate (Z9-14: AC) to successfully monitor male FAW moths. More recently, Nagoshi and Meagher (2004) used commercial FAW lures in Unitraps to show that populations of male FAW adults peaked in spring (March-May) and fall (October-December), while decreased in summer (July-October) in South Florida.

Although some lures may attract the target pest, they may also have negative effects on key natural enemies. *Hippodamia convergens* Guerin-Meneville is a common natural enemy in the Southern United States that is used frequently in inundative biological control programs for control of arthropod pests (Rankin and Rankin, 1980; Obrycki and Kring, 1998). Other occasional natural enemies that have been frequently caught in traps in graminaceous agro-ecosystems include the bigeyed bug, *Geocoris punctipes* (Say) and the minute pirate bug, *Orius insidiosus* (Say). These natural enemies are generalist predators that feed on the eggs of lepidopterous pests, which may help to regulate armyworm populations in these systems (Tillman *et al*., 2009).

In the current study, three FAW lures manufactured by different companies were compared for their attractiveness to male FAW moths in North-Central Florida. In addition, *S. exigua* and *S. eridania* lures were used for monitoring the abundance of their populations in organic sweet corn. It was hypothesized that there are no differences in the attraction of commercial FAW armyworm lures and that these lures have little or no impact on natural enemies. The specific objectives were to compare various commercially available FAW pheromone lures for their attractiveness to male FAW moths and natural enemy species.

MATERIALS AND METHODS

The study was conducted on certified organic land at the University of Florida, Plant Science Research and Education Unit, Citra, Florida (29°16.7′ N, 82° 7.7′ W). On 5 March 2007, the field was flail-mowed with a NewHolland 918H flail mower (Purdy Tractor and Equipment, Inc. Hillsdale, MI). Later, it was disked to a depth of 20 cm. On 7 March 2007, a broadcast application of organic fertilizer (10-2-8 of N_2, P_2O_5, K_2O, NatureSafe, Cold Springs, KY) was applied at 2232 kg/ha based on University of Florida nitrogen recommendations for sweet corn (Olson and Simonne, 2006). After planting, the same fertilizer was band applied on 10 April 2007. Sweet corn (Montauk F1 untreated, Johnny's Selected Seeds, Winslow, Maine) was planted on 12 March 2007 with a Monosem planter (Monosem Inc., Edwardsville, KS) with a between-row spacing of 76 cm and 18 cm between plants within the row for a total population of approximately 74,444 plants ha^{-1}. The plot size was 144 m^2 (12 m length x 12 m width). Hand weeding was performed two times in 2007 (2 April and 18 April) and one time in 2008 (14 April). In spring 2008, sodium nitrate (Probooster, 10-0-0- N-P_2O_5-K_2O, North Country Organics, Bradford, VT) was applied in bands in response to nitrogen deficiency symptoms.

Cobs were randomly sampled for FAW or *H. zea* by visually inspecting every third plant in each plot for ~ 30 sec and those infested with larvae were counted, weighed and recorded. Sweet corn was harvested from 31 May to 12 June in 2007 with two harvests, while in 2008 it was harvested from 29 May to 4 June with two harvests. Marketable yield was recorded and graded as per the USDA standards (USDA-AMS, 2009).

Experimental design was a randomized complete block with four replications and four treatments: three fall armyworm (FAW) lures 1) Trécé lure (Trécé Inc., Salinas, USA), 2) Hercon lure (Great Lakes, IPM, Vestaburg, MI) 3) Scentry lure (Scentry Biologicals Inc., Billings, Montana) and a control (trap with no lure). The Trécé lure consisted of a rubber septum loaded with a pheromone blend (Z-9 tetradecenyl acetate, Z-11 hexadecenyl acetate, Z-7 dodecenyl acetate, and hexane), while the Hercon lure was a laminate strip with the same components excluding hexane. The Scentry lure was a rubber septum loaded with the same components as Trécé lure without Z-11 hexadecenyl acetate and hexane. Because of proprietary information, we cannot give the lure load rates of the individual companies; however, it varied from 2 to 5 mg/lure. In addition to FAW lures, beet armyworm and southern armyworm Scentry lures (Scentry Biologicals Inc., Billings, Montana) were placed in the field to monitor their populations.

Pheromone lures were placed in the center of white sticky winged traps (Great Lakes IPM, Vestaburg, MI). Traps were hung ~100 cm above the ground on 12 April 2007, suspended from a tripod formed by three wooden stakes. Insects (pests and natural enemies) were collected from the traps at two-week intervals until 25 May 2007. This experiment was repeated in spring 2008. Plot size, planting space, fertilizer regime, and production practices were similar to 2007. Sweet corn was planted on 11 March 2008 while traps containing lures were placed on 2 April 2008. Similar to 2007, insects (pests and natural enemies) were collected at two-week intervals until 30 May 2008.

Captured insects were carefully removed from the traps using forceps and placed into zip-lock bags. These bags were transported to the Small Fruit and Vegetable IPM laboratory at the University of Florida for insect identification. Fall armyworm, BAW, SAW, and selected natural enemies (ladybird beetle Coleoptera: Coccinellidae) were assessed separately.

Statistical Analysis

Data from FAW and ladybird beetle counts were log transformed [$\log_{10}(x+1)$] to increase the homogeneity of variance and normality; however, original means (±SEM) are presented in the tables. Repeated measures were performed to examine the interaction between lures and sampling dates using PROC MIXED in SAS 9.1 software (SAS, 2003). The type, compound symmetric was used as a covariance structure due to the largest value of Akaike's Information Criterion among covariance structures (Littell *et al*., 1996). No interaction occurred between sampling time and FAW lure type in 2007; however, significant interaction occurred in 2008. Fall army worm counts were pooled over sampling time and analyzed using ANOVA, and reported in tables. Since significant interaction occurred between sampling time and FAW lures in 2008, FAW lures were also compared within sampling dates using ANOVA and reported in figure 1. Similarly, sweet corn marketable yield and infested cobs data were pooled over harvesting dates and analyzed using ANOVA. Treatment means were compared using Least Significant Difference (LSD) tests [$P < 0.05$] GLM. Interaction between FAW lures and years (2007 and 2008) were also assessed, and their means were compared by using least square means (LSMEANS) and PDIFF statement in GLM. Zero frequency was calculated as the percentage of traps that fail to capture FAW moths over a two-week sampling period. Finally, BAW and SAW populations were examined through repeated measures to study the interaction between each population captured at different sampling dates. Different sampling dates were compared through LSMEANS [$P < 0.05$] and PDIFF statement in PROC MIXED.

RESULTS

In 2007, the numbers of male FAW captured were low (1.5 or less) in all the treatments (Table 1). There was no significant interaction between sampling time and FAW pheromone lure types (P=0.8). Only traps baited with the Trécé lure caught significantly more male moths than unbaited traps. Captures of male FAW in traps baited with Trécé lure were fairly consistent on all sampling dates and irregular for traps baited with other lures. The percentages of zero frequency captures for traps baited with the Trécé, Hercon, and Scentry lures and the unbaited traps were 58.3%, 75%, 83%, and 100% respectively (Table 1).

In 2008, the total number of FAW captured in traps baited with pheromone lures and unbaited traps was significantly higher than 2007 ($P < 0.029$). When the data were pooled over sampling weeks, the Trécé lure captured significantly more male moths than any other lures evaluated, averaging 2.6 times as many FAW adults as the other lures (Table 1). Also, among the pheromone lures evaluated, only traps baited with the Trécé lure captured more male FAW in 2008 compared with 2007 (Table 1). There was a significant interaction between FAW lures and sampling dates ($P < 0.0001$). Trécé lure captured more male FAW than other lures at 34 days after planting sweet corn (16 April, Fig. 1). There was no significant difference in male captures between Hercon and Scentry lures; however, both lures captured significantly more FAW adults than control (Table 1). Similar to 2007, the percentages of zero frequency in 2008 were 100% for the unbaited traps (control), 62.5% for the Trécé lure, and 68.8% for both the Hercon and Scentry lures. This suggests that the traps baited with Trécé lure caught more male FAW than other lures evaluated in 2008 (Table 1).

Population of corn earworm, *H. zea.* was very low during both years and only on a few instances we recorded larvae of these moths. For southern armyworm, they were caught in traps throughout the six-week sampling period 2007. There was no significant interaction between sampling time and SAW populations in 2007; however, there was a significant interaction in 2008 ($P = 0.02$). The highest number of SAW was recorded on the second sampling date (11 May 2007) averaging 1.5 times more SAW moths than other sampling dates (Fig. 2). The number of SAW recorded on 11 May 2007 was also significantly higher than those captured on 25 May 2007. In 2008, the highest number of SAW (2.8 ± 0.59) was captured on the first sampling date (16 April). Only the SAW sample recorded on 30 May was significantly lower than the 16 April sample (Fig. 3).

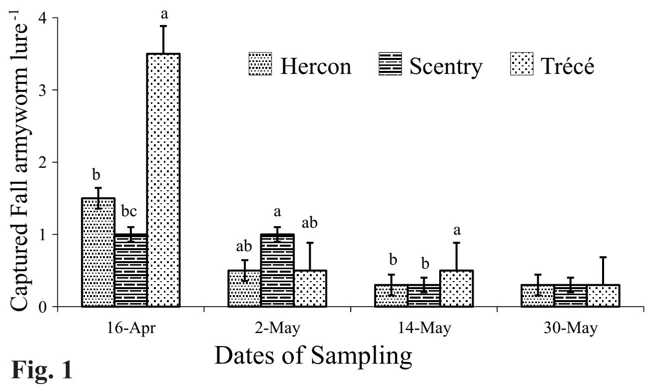

Fig. 1
Fall armyworm captured at different sampling dates in spring planted sweet corn, 2008. A significant interaction (P < 0.0001) was observed between lures and sampled dates, hence lures were compared within sampling dates. Lure means within each sampling date were analyzed using ANOVA and compared with least significant difference (P ≤ 0.05). Lure means followed by the same letters were not different.

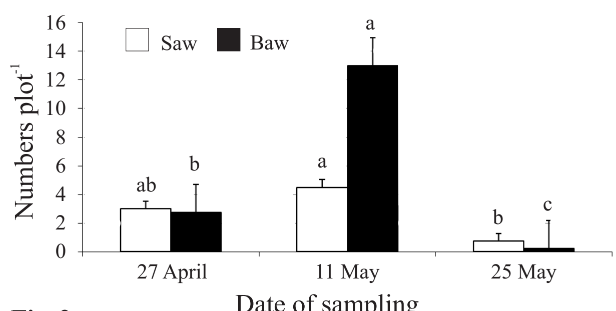

Fig. 2
Monitoring Southern (SAW) and Beet (BAW) armyworms populations captured at different dates of sampling in sweet corn in 2007. Columns with same color and letters were not significantly different ($P \leq 0.05$). Data in columns were averaged within sampling dates and untransformed means (± SEM) were reported.

There was a significant interaction between sampling dates and BAW population in both 2007 ($P = 0.002$) and 2008 ($P = 0.03$). In 2007, BAW were recorded throughout the six-week sampling period. The highest number of BAW (13.0 ± 3.9) was collected on 11 May (the second date of sampling) averaging 4.7 times more BAW than other dates (Fig. 2). All sampling dates in 2007 had significantly different numbers of BAW. In 2008, the highest number (5.0 ± 0.94) was recorded on 16 April (the first sampling date) averaging 1.7 times more BAW than other sampling dates (Fig. 3). Only the 30 May sampling date had significantly lower BAW than the other sampling date.

Table 1
Spodoptera frugiperda adults captured in winged style trap in organic sweet corn.

Fall armyworm lure	Number of moths ± SEM[a]		Zero frequency (%)		
	2007	2008	Pr > |t|[b]	2007	2008
No lure (Control)	0.0 ± 0.0 b	0.0 ± 0.0 c	-	100.0	100.0
Trécé lure	1.5 ± 0.9 a	4.0 ± 0.7 a	0.0017	58.3	62.5
Hercon lure	1.0 ± 0.4 ab	1.8 ± 0.5 b	0.3049	75.0	68.8
Scentry lure	0.5 ± 0.3 ab	1.5 ± 0.7 b	0.1746	83.3	68.8

Data were means of four replications. Means were pooled over 3 sampling dates in 2007 and 4 sampling dates in 2008. Means in columns followed by the same letters were not different according to least significant difference (LSD) at $P \leq 0.05$ based on the log-transformed [$\log_{10}(x+1)$] value.
[a] Reported means and SEM values are untransformed.
[b] P-values are for comparisons between 2007 and 2008.

Table 2
Hippodamia convergens populations captured in winged-style traps using fall armyworm lures in organic sweet corn.

Fall armyworm lures	*H. convergens*[a] (Mean ± SEM)	
	2007	2008
Trécé lure	0.3 ± 0.3	2.5 ± 1.4
Hercon lure	0.3 ± 0.3	1.3 ± 0.5
Scentry lure	0.8 ± 0.5	1.0 ± 0.4

Data were means of four replications. Means were pooled over 3 sampling dates in 2007 and 4 sampling dates in 2008. Means in columns were not different ($P \leq 0.05$) according to LSD performed on log-transformed [$\log_{10}(x+1)$] data.
[a] Reported means and SEM values are untransformed.

Table 3
Key insects other than armyworm captured in 2007 and 2008.

Insect order	Insect Family	Frequency 2007 (%)[a]	Frequency 2008 (%)[a]
Coleoptera	Chrysomelidae	6	8
Hemiptera	Cicadellidae	26	8
Coleoptera	Carabidae	27	31
Lepidoptera	Sessidae	8	7
Coleoptera	Elateridae	5	4

[a] Percentage of total insects other than armyworms collected at the given site.

Table 4
Relative performance of fall armyworm lures and their effect on infested cob and market yield.

Fall armyworm lures	Number of larvae plot^{-1} (± SEM)[a]	Cob weight infested with Fall armyworm (kg ha^{-1} ± SEM)[b]	Marketable yield (kg ha^{-1} ± SEM)[b]
2007			
Trécé lure	160 ± 23	3123 ± 404	4626 ± 2124
Hercon lure	139 ± 17	2872 ± 219	2556 ± 973
Scentry lur e	185 ± 30	3537 ± 520	4682 ± 1088
2008			
Trécé lure	161 ± 24	2861 ± 407	3539 ± 580
Hercon lure	143 ± 22	2564 ± 310	4536 ± 1113
Scentry lure	151 ± 13	2893 ± 229	4569 ± 285

Data were means of four replications. Means were pooled over 2 harvesting dates in 2007 and 2008. Means in columns were not different ($P \leq 0.05$) according to LSD performed on log-transformed [$\log_{10}(x+1)$] data.
[a] Sweet corn cobs were harvested from a 9.0 m x 7.2 m centered area within the plot.
[b] Extrapolated to kg ha^{-1}, based on per 12 m x 12 m plot area.

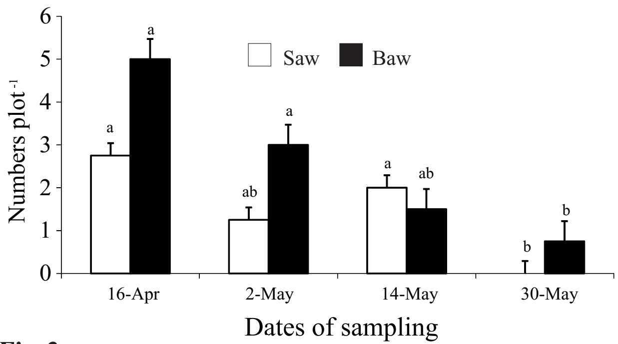

Fig. 3
Monitoring Southern (SAW) and Beet (BAW) armyworms populations captured at different dates of sampling in sweet corn in 2008. Columns with same color and letters were not significantly different ($P \leq 0.05$). Data in columns were averaged within sampling dates and untransformed means (± SEM) were reported.

Several other insects were recorded in baited traps including those belonging to the families Chrysomelidae; Cicadellidae; Carabidae; Sessidae; and Elateridae (Table 3). The only natural enemy that was prevalent in the traps is the common ladybird beetle, *Hippodamia convergens* Guerin-Meneville and their numbers were not significantly different among FAW lures in both 2007 and 2008 (Table 2). Other occasional catches included the bigeyed bug, *Geocoris punctipes* (Say) and the minute pirate bug, *Orius insidiosus* (Say).

Marketable yield: There was no significant difference among treatments in cobs infested with FAW. Similarly there were no significant differences among sweet corn marketable yield in 2007 and 2008 (Table 4).

DISCUSSION

Effective monitoring is an essential component of any IPM program and developing an effective trap and lure system for a key pest like fall armyworm is of immense significance. In our study, the Trécé lure performed better than other lures evaluated for fall armyworm. This was apparent in 2008 when FAW populations were higher. Malo *et al*. (2001) also found that the Trécé lure captured more FAW moths than the Scentry lure and an unbaited trap (control) in Mexico. In addition, Meagher and Mitchell (2001) saw similar results using Trécé lures with unitraps when compared with Scentry lures.

The performance of a pheromone lure is related to the composition of the pheromone blend, load rate, and the type of material in which the pheromones are impregnated, often a rubber septum. In addition, external factors such as temperature, wind-speed, relative humidity and light may also affect lure effectiveness. Due to proprietary regulations we are not able to provide specific information about the load rates of the individual compounds. However, in our studies, all of the lures were exposed to the same conditions with slight variations in lure components (pheromone blends), load rates and materials used to construct the lure. For instance, the Trécé and scentry lures were applied to rubber septa but the Hercon lure used a laminate strip. Additionally, the Hercon lure had a similar pheromone blend as the Trécé lure (except hexane) but the load rates were slightly different. A combination of the material in which the pheromones are impregnated (a laminate strip for Hercon lure) as well as the lure composition and load rates may account for the poor performance of the Hercon lure. Similarly, since the Trécé and scentry lures were made from the same material, it appears that the composition of the lure and / or the load rate may account for the overall better performance of the Trécé lure over the scentry lure.

In 2007, only traps baited with the Trécé lure attracted more moths than the control. This may be related to the low population of FAW caught in the traps. Total captures for the entire season only averaged 1.5 ± 0.9 FAW male moths. Malo *et al*. (2001) have suggested that low populations of FAW may affect the results obtained when lure performance is evaluated. The observed low populations of FAW may be due to the fact that sweet corn was never planted in the study site before and therefore it is possible that there were no resident populations of FAW and *H. zea*. Also, it may be possible that the 2-week intervals between data collections were too long, and may have allowed birds and other predators to remove moths from the winged traps.

Trap color may have also played a role in the number of FAW captured. Pair *et al*. (1989) found that standard green, yellow, and white colored unitraps captured more FAW moths than solid green, while Meagher (2001) noticed more FAW moths in yellow unitraps compared to white in peanut and corn fields. In our experiment we used white sticky winged traps, which are known to capture lower number of moths in other unrelated species compared with unitraps (Weihman and Liburd, 2007).

An effective trap-and-lure system must catch target pests without adversely affecting key natural enemies. All of the lures captured some beneficial insects, mainly ladybird beetle, *H. convergens* with occasional catches of bigeyed bug, *G. punctipes* and minute pirate bug, *O. insidiosus*. The fact that none of the lures captured high numbers of natural enemies suggests that lures may not have a negative impact on the beneficial insect populations. Several studies have reported that baited traps may attract beneficial insects (Malo *et al*., 2001; Mitchell *et al*., 1989). Meagher and Mitchell (1999) suggested that the reason for high captures of beneficial insects may be related to trap design while Mitchell *et al*. (1989) suggested trap color as a plausible reason.

As expected, we recorded no differences between lure types and marketable yields. Our cob counts recorded high population of larvae, which can directly affect marketable yield. The best treatment (Trécé lure) attracted more FAW male moths than other lures evaluated. However, the number of male moth may have been too low to negatively affect overall FAW population. It should be noted that although we caught a relatively low population of male moths, their numbers may have been sufficient to mate with FAW female moths to produce enough eggs, which can increase larval population inside the cob, and subsequently affect the marketable yield.

Throughout the season, monitoring data revealed higher mean captures for SAW than BAW. The highest population for SAW and BAW was recorded on 11 May 2007 and on 16 April 2008. The observed differences in SAW and BAW populations on the various sampling dates may be related to pest phenology. These species are also important pests in the sweet corn system and their populations need to be monitored to prevent them from reaching damaging levels (Azidah and Azirun, 2006; Capinera, 1999).

CONCLUSION

Our results indicate that the Trécé lure was the best of three sex pheromone lures for monitoring FAW populations in white winged-styled sticky traps in organically grown sweet corn. The use of this commercial lure for monitoring may save labor and cost associated with hiring field scouts. However, more research needs to be done to determine the number of lures per hectare and how often these lures should be replaced. The manufacturer (Trécé Inc.) estimates that one lure should last the entire season for a crop such as sweet corn. Growers who are developing IPM programs need to use the most attractive lure for monitoring key pests. This will give early indication of population size so that management strategies can be applied before they reach damaging levels.

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