ISSN-0430-8603 Folia Entomol. Mex., 47(2): 61-70(2008)

EXPLORATION OF FACTORS TO INCREASE THE EFFICIENCY OF CAPTURE OF *COSMOPOLITES SORDIDUS* (COLEOPTERA: DRYOPHTHORIDAE) IN PHEROMONE BAITED TRAPS

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ABSTRACT: The design of the trap and the effectiveness of the attractants are key factors in the success of mass trapping of insects. The purpose of this study was to increase the efficiency of capture of the banana weevil *Cosmopolites sordidus* evaluating three types of traps and different plant tissues of the plantain *Musa* AAB as coattractants in pheromone baited traps. The radius of pheromone + corm attraction was estimated, as well as its effectiveness in the capture of *C. sordidus* in two commercial plantations of plantain with different levels of damage in Tabasco State, Mexico. Captures in the pitfall type trap, ramp white trap and ramp yellow™ trap were not statistically different to each other. However, the ramp white trap is recommended because of its lower cost and good performance to local environmental conditions. The addition of corm to pheromone baited traps significantly increased capture. Other plantain tissues such as pseudostem, foliage or fruits did not increase capture. In a plantation with 9.7% corm damage, the capture of the banana weevil in pheromone + corm baited traps was significantly greater than in pheromone baited traps. However, these differences were not observed in every month of trapping in another plantation with 4.4% corm damage.
This study sets the base for a meticulous research of new compounds in the corm of plantain that may be synergistic with the banana weevil aggregation pheromone.
KEY WORDS: banana weevil, mass trapping, plantain.

RESUMEN: El diseño de trampa y la efectividad de los atrayentes son factores clave para el éxito de la captura masiva de insectos. El objetivo de este estudio fue incrementar la eficiencia de captura del picudo del plátano *Cosmopolites sordidus* mediante la evaluación de tres tipos de trampas y diferentes tejidos vegetales del plátano macho *Musa* AAB como coatrayentes en trampas cebadas con feromona. Asimismo, se estimó el radio de atracción de feromona + cormo, y su efectividad para la captura de *C. sordidus* en dos plantaciones comerciales de plátano macho con diferente nivel de daño en el estado de Tabasco, México. Las capturas en las trampas tipo pitfall, blanca tipo rampa y amarilla tipo rampa™ no fueron estadísticamente diferentes entre sí. Sin embargo, debido a su menor costo y buen desempeño a las condiciones ambientales locales se recomienda la trampa blanca tipo rampa. La adición de cormo en trampas cebadas con feromona incrementó significativamente las capturas. Otros tejidos del plátano como pseudotallo, follaje o frutos no incrementaron las capturas. En una plantación con 9.7% de daño en cormos, las capturas del picudo del plátano en trampas cebadas con feromona + cormo fueron significativamente más altas que en trampas cebadas con feromona. No obstante, estas diferencias no se observaron en todos los meses de trampeo en otra plantación con 4.4% de daño. Este estudio abre la posibilidad de una búsqueda más minuciosa de nuevos compuestos provenientes del cormo del plátano macho que sean sinergistas con la feromona de agregación del picudo del plátano.

INTRODUCTION

The greatest and most successful applications of pheromones are for insect pest management, with significant cost and environmental benefits to the farmer, the consumer, and society (Wyatt, 2003). Pheromones are the safest of all currently available insect control insects (Minks and Kirsch, 1998). The main ways of exploiting and understanding of pheromones to control pests are monitoring, mating disruption, and mass trapping (Wyatt, 2003). The efficiency of pheromone baited traps depends on various factors, among which are the type of trap (Murad, 2001; Tinzaara *et al.*, 2005b), the distance of attraction of the attractant bait (Byers *et al.*,1989; Schlyter, 1992) and the use of plant kairomones as coattractants (Giblin-Davis *et al.*, 1996a), among others. In consequence, it is important to fully understand these factors to efficiently design a trapping system based on pheromones (Tinzaara *et al.*, 2005b).

The banana weevil *Cosmopolites sordidus* (Germar, 1824) (Coleoptera: Dryophthoridae) is the most important insect pest in plantains and bananas (*Musa* spp.) (Gold *et al.*, 2001). The larvae bore into the corm reducing nutrient uptake and weakening the stability of the plant. In established fields, weevil damage can result in reduced bunch weights, mat (= banana stool) die-out and shortened stand life. Damage and yield losses tend to increase with time (Gold *et al.*, 2001). Recent studies in Tabasco State, Mexico recorded a damage of up to 20% in corms of recently harvested plantain plants (*Musa* spp, genome group AAB) (Osorio *et al.*, 2007). The insecticides terbuphos, fenamiphos and cadusaphos are suggested for the control of this pest (Ramírez y Rodríguez, 2003), however, these are highly toxic products that affect both wild and domestic fauna in small scale farms, adjacent to houses.

Adult *C. sordidus* are free living, though most commonly found between leaf sheaths, in the soil at the base of the mat or associated with crop residues. Adults may remain in one same mat for extended periods of time, while only a small proportion will move >25 m within 6 months. The weevils rarely fly (Gold and Messiaen, 2000). Many adults live one year, while some survive up to four years. The sex ratio is 1:1. Oviposition rates of more than 1 egg/day have been recorded, but most commonly, oviposition has been estimated at 1 egg/day (Gold and Messiaen, 2000).

Males produce an aggregation pheromone that is attractive to both males and females (Budenberg *et al.*, 1993). The most abundant component in this pheromone was identified as sordidin (Beauhaire *et al.*, 1995). This has been synthesized and commercialized under the trade name Cosmolure™ by ChemTica Internacional S.A. Alpizar *et al.* (1999) reported that the use of this pheromone in a trapping system is a promising option to reduce weevil populations and the damage caused by *C. sordidus* in plantations in Costa Rica. However, evaluations carried out in the district of Masaka, Uganda over a period of 21 months did not provide significant reductions in populations and damage (Tinzaara *et al.*, 2005a).

Laboratory studies have reported that the weevils *C. sordidus* responded significantly stronger to the combination of synthetic pheromone and fermented pseudostem (*Musa* spp., genome group AAA-EA) than to pheromone or pseudostem alone (Tinzaara *et al.*, 2003). It is believed that banana plant volatiles may be used to enhance the attractiveness of synthetic pheromones (Jayaraman *et al.*, 1997), particularly those in corm tissues which are the most attractive of all residues part of banana plant (Masanza *et al.*, 2004). In the case of other species of weevils such as *Rhynchophorus palmarum* (Oehlschlager *et al.*, 1993; Osorio *et al.*, 2003), *R. cruentatus* (Giblin-Davis *et al.*, 1994) and *Metamasius hemipterus sericeus* (Giblin-Davis *et al.*, 1996b), capture in traps baited with pheromone, increased significantly when host plant tissues were added. In these cases, none of the volatiles identified in the host plant tissues were as synergic as the tissues themselves (Giblin-Davis *et al.*, 1996a).

Another important factor is the design of the trap. Traps used up to now include the «pitfall» traps (Tinzaara *et al.*, 2005a; Tinzaara *et al.*, 2005b) and the ramp type traps (ChemTica Internacional, 2005). However, it is recommended that more studies considering capture efficiency with respect to the production system of a crop and the climatic conditions of each region be carried out (Tinzaara *et al.*, 2005b). The purpose of this study was to evaluate the efficiency of three types of traps and different tissues of the plantain *Musa* spp., genome group AAB, to increase the capture efficiency of *C. sordidus*. It is believed that the development of a trapping system based on pheromones for small scale farmers in the Mexican tropics may aid in reducing the use of insecticides to control this pest, and consequently improve the environment and safety for the banana production.

MATERIALS AND METHODS

Experiments took place in plantain *Musa* spp., genome group AAB, plantations in the Ranchería Plátano y Cacao 1ra. Sección, Centro municipality, Tabasco State, Mexico (17°58.80´ N, 93°11.46´ W, 12 m above sea level), from July 2005 to June 2006.

Experiment 1. Evaluation of types of traps baited with commercial pheromone.

This study was carried out from July 9th to September 3rd 2005. Three types of traps were evaluated: a) pitfall trap, b) ramp white trap, and c) ramp yellowÔ trap. A plastic bag with 90 mg of the pheromone sordidin (Cosmolure™) was used as trap attractant, with a liberation rate of 3 mg/day (Tinzaara *et al.*, 2005a). A mixture of 500 ml of water and 2 g of detergent was added to each trap to catch and kill the specimens. The ramp type yellowÔ trap and the pheromone CosmolureÔ were obtained from the company ChemTica Internacional S.A. (Apdo. 159-2150, San José, Costa Rica). The pitfall type trap and the ramp type white trap were fabricated using 4 l white plastic buckets (20 cm diameter and 20 cm height) bought locally in Villahermosa, Tabasco, Mexico.

The experiment followed a completely randomized block design with three treatments and six repetitions. The response variable was the number of weevils caught per trap per week during two months. The pheromone was replaced each month and the water each week. The following orthogonal contrasts were evaluated:

1. Capture in pitfall type trap *versus* ramp type traps. Q_1) Ho: $_1$-(m_2 + m_3)/2 = 0.
2. Capture in commercial ramp type yellowÔ trap *versus* home-made ramp type white trap. Q_2) Ho: $m_{2-}m_3 = 0$.

The cost of the units was calculated to obtain an economic analysis of the traps. Values were: ramp type yellowÔ trap $11.00, pitfall type trap $2.50 and ramp type white trap $3.00 (in USD, June 2005).

Experiment 2. Evaluation of plant tissues as coattractants.

This experiment took place from September 3rd to October 8th 2005. The synergic effect of four types of plant tissue of plantain *Musa* spp., genome group AAB, was recorded in traps baited with commercial pheromone to capture adult *C. sordidus*. Treatments were: a) pheromone + corm, b) pheromone + pseudostem, c) pheromone + foliage, d) pheromone + fruit, and e) pheromone alone (control). Ramp type white traps were used in which a container with plant tissues and pheromone were placed. The tissues were obtained from plants recently harvested from the plantation under study. The pheromone was replaced after four weeks and the plant tissues and soapy water were replaced at one-week intervals.

The experiment followed a completely randomized block design with five treatments and four repetitions. The response variable was the number of weevils caught per trap per week during five weeks.

Experiment 3. Radius of attraction of pheromone + corm

This experiment was carried out from October 15th to November 26th 2005 in a five year old plantain plantation. Three experimental sites were selected separated one from the other by a distance of 100 m. Approximately 250 adult *C. sordidus* per experimental site were captured during the first week in traps prepared with pieces of pseudostem and corms of recently harvested plants. These weevils were marked with StaedtlerÒ oil-based white or gold indelible ink, previously proved to resist the outdoors and to be harmless to the insect. The marked weevils were liberated the following week at different distances (2, 4, 8, 16 and 32 m) from the center of the experimental site, throughout a concentric route. Forty weevils were liberated at each attraction distance. The weevils liberated at a distance of 2 m were marked with white ink on the prothorax, those at 4 m with white ink on the right elytron, those at 8 m with white ink on the left elytron, those at 16 m with gold ink on the prothorax and those at 32 m with gold ink on the right elytron. Recapture initiated three days after weevil liberation using pheromone + corm baited traps placed at the center of each experimental site. The response variable was the number of weevils caught in the traps during one month. The percent of weevils recaptured per distance of liberation was obtained from the average of the three trap sites.

Experiment 4. Efficiency of trapping with pheromone versus pheromone + corm in two plantations with different damage levels by C. sordidus

It is common to find plantain plantations of different ages and levels of infestation by the weevil *C. sordidus* in the State of Tabasco, Mexico. Preliminary observations allowed us to establish the hypothesis that traps baited with pheromone + corm captured significantly more weevils than traps baited with pheromone alone. With this in mind, two plantations were selected for this experiment with 4.4% and 9.7% damage to the corms ($n = 30$), following the method of Gold *et al.* (2005). At the start of the experiment, the first plantation was 3 years old with a surface of 6,400 m^2, and the second plantation was 5 years old with a surface of 10,400 m^2. Each plantation was divided by an imaginary line into two approximately equal lots in which the following trapping methods were randomly established: a) traps baited with pheromone + corm (from experiment 2) *versus* b) traps baited with pheromone alone. All traps were placed at 20 m intervals. The pheromone was replaced each month and the corm and soapy water each week. The response variable was the number of weevils caught per trap per week from February to June 2006.

Statistical analysis

Shapiro & Wilk´s tests were applied for preliminary analyses to estimate the normality of errors, as well as Bartlett´s test to detect heterogeneity of variances (Zar, 1996). Orthogonal contrasts were carried out to compare captures among the different types of traps previous to the transformation of the captures to $(x + 0.5)^{0.5}$. The average captures of the traps baited with pheromone + different plant tissues were compared with the control treatment (traps baited with pheromone) using a Dunnett test, previous to the transformation of data to $\log(x + 1)$. The average distance of attraction of the traps baited with pheromone + corm was calculated with a regression analysis of the percent of recapture with respect to the distance of liberation of the weevils. A *t*-Student test was used to compare the trapping with pheromone *versus* pheromone + corm. A $P = 0.05$ was considered significant in all cases. Analyses were done using the procedures of Software SAS (SAS Institute Inc., 1999).

RESULTS

Experiment 1. Evaluation of trap types

The planned comparisons with respect to the number of captured weevils per treatment are presented in Table 1. The original captures were transformed to $(x + 0.05)^{0.05}$ to homogenize the treatment variances. In accordance with the evaluated contrasts, no significant differences were detected in the captures obtained with the pitfall traps *versus* the ramp traps, as well as between the ramp yellow™ trap *versus* the ramp white trap ($P>0.05$). On average (±SD), 7.6±3.5 weevils were captured per trap per week with the pitfall type trap, 6.4±2.6 with the ramp type white trap and 6.2±1.7 with the ramp type yellow™ trap.

Experiment 2. Evaluation of plant tissues as coattractants

Figure 1 shows the mean number of weevils captured per trap per week in traps baited with pheromone plus different coattractants, and a significant increase in capture in traps baited with pheromone + corm ($P < 0.05$). In contrast, treatments that included other plantain tissues such as pseudostem, foliage and fruit, showed captures that were not statistically different with respect to the control treatment (traps baited with pheromone). On average (± SD), the traps with pheromone + corm captured 16.5±2.9 weevils per trap per week, those with pheromone + pseudostem captured 10.6±1.8 weevils, those with pheromone + foliage captured 9.5±2.9, those with pheromone + fruit captured 6.8±2.6, and those with pheromone alone captured 9.4±1.5 weevils per trap per week.

Experiment 3. Radius of attraction of pheromone + corm

Figure 2 presents the mean of *C. sordidus* adults recaptured after being released at different distances from a trap baited with pheromone + corm. On average (± SD), the percent of weevils recaptured per distance of release were: at 2 m 64.2 ± 10.4, at 4 m 31.7 ± 8.8, at 8 m 22.5 ± 5.0, at 16 m 1.7 ? 1.4, and at 32 m 0%. Considering the obtained regression equation of $y = 79.16\text{-}28.37ln(x)$, ($R^2 = 0.89$), the maximum radius of attraction of the pheromone + corm baited traps is 16.3 m.

Table 1.

Comparison of the number of *C. sordidus* adults captured in different types of traps baited with sordidin pheromone ($n = 8$) in a farm of plantain *Musa* spp., genome group AAB, in Tabasco, Mexico, from July 9th to September 3rd 2005.

Contrast	Number of weevils per treatment[1]			Q	$r\sum C_i^2$	$SC(Q)=\frac{Q^2}{r\sum C_i^2}$	P > F
	PT 7.75	RWT 7.21	RYT 6.76				
Q_1	2	-1	-1	0.8941	8(6)	0.0166555	0.3809
Q_2	0	1	1	0.0042	8(2)	0.0000011	0.9942

[1] Captures were transformed to log $(x + 1)$. Variance analysis results were $F = 1.13$; $P > 0.401$; $MSE = 0.0203$; $df = 9, 14$. PT = pitfall trap, RWT = ramp white trap, RYT = ramp yellow™ trap.

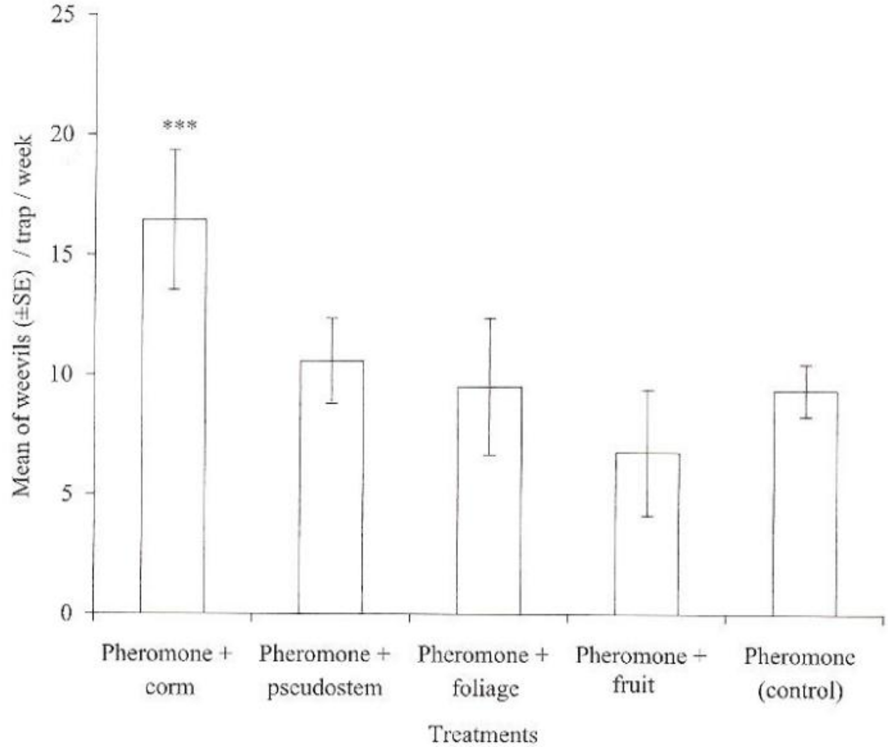

FIGURE 1. Mean number of *C. sordidus* adults (± SD) captured in traps baited with pheromone + different coattractants ($n = 4$) of plantain *Musa* spp. genome group AAB in Tabasco, Mexico from September 3rd to October 8th 2005. Captures were transformed to $(x + 0.5)^{0.5}$ for the variance analysis. Results were: $F = 3.81$; $P < 0.0206$; $MSE = 0.174$; $df = 7, 12$). ***Significantly different mean with respect to the control treatment (Dunnett's test, $P < 0.05$).

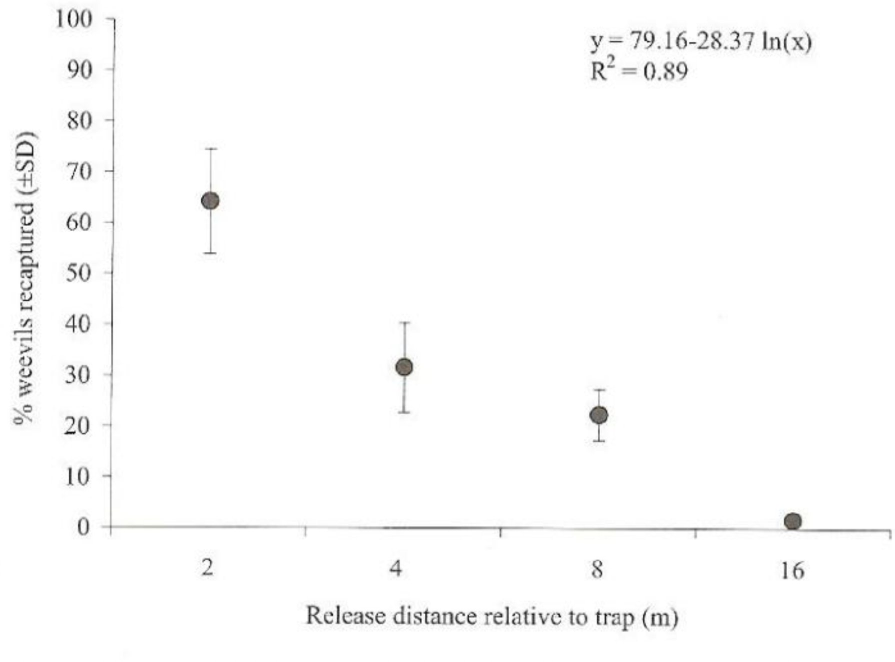

FIGURE 2. Percentage of *C. sordidus* recaptured when released at different distances from the pheromone + corm baited trap, in a farm of plantain *Musa* spp. genome group AAB, in Tabasco, Mexico from October 15th to November 26th 2005. Distances were transformed to *ln* (*x*) for the regression analysis. The ANOVA results were: $F = 81.62$; $P < 0.0001$; $MSE = 71.08$ and $df = 1, 10$.

Experiment 4. Efficiency of trapping with pheromone versus pheromone + corm in two plantations with different damage levels by C. sordidus

Figures 3 and 4 compare the number of weevils captured per trap per week in traps baited with pheromone *versus* traps baited with pheromone + corm, evaluated in two plantain plantations of different age and intensity of damage caused by *C. sordidus*. The 3 year old plantation, with 4.4% corm damage, showed no significant differences between both trapping methods during the months of February, March and April (Figure 3). Significant differences were recorded when captures increased, in May and June ($P < 0.05$) (Figure 3). In contrast, the 5 year old plantation, with 9.7% corm damage, presented a significantly greater number of insects captured per trap per week, during all the months of trapping ($P < 0.05$), in the traps baited with pheromone + corm (Figure 4). On average, the traps baited with pheromone and pheromone + corm captured 3.3 ± 1.4 and 4.9 ± 1.1 weevils per trap per week respectively in the plantation with 4.4% damage. In the plantation with 9.7% damage, the captures in the traps baited with pheromone and pheromone + corm recorded 4.5 ± 1.4 and 10.9 ± 2.9 weevils per trap per week respectively.

DISCUSSION

The numbers of weevils captured in the pitfall type traps, the ramp type white traps and the commercial ramp type yellowÔ traps were statistically similar. We recommend the use of the pitfall traps or the ramp white traps as they are up to three times cheaper than the ramp yellowÔ traps. The pitfall traps, however, presented serious operative restrictions in the field. During the rainy season, which is prevalent in Tabasco, Mexico, it easily becomes water-logged if placed in low-lying areas. Tinzaara *et al.* (2005a) also observed the formation of cracks around the trap during the dry season that limit the access of the weevils to the trap. It also requires a careful installation and upkeep in the field for optimum performance. In contrast, the ramp white traps represent a technically and economically viable option for trapping *C. sordi-*

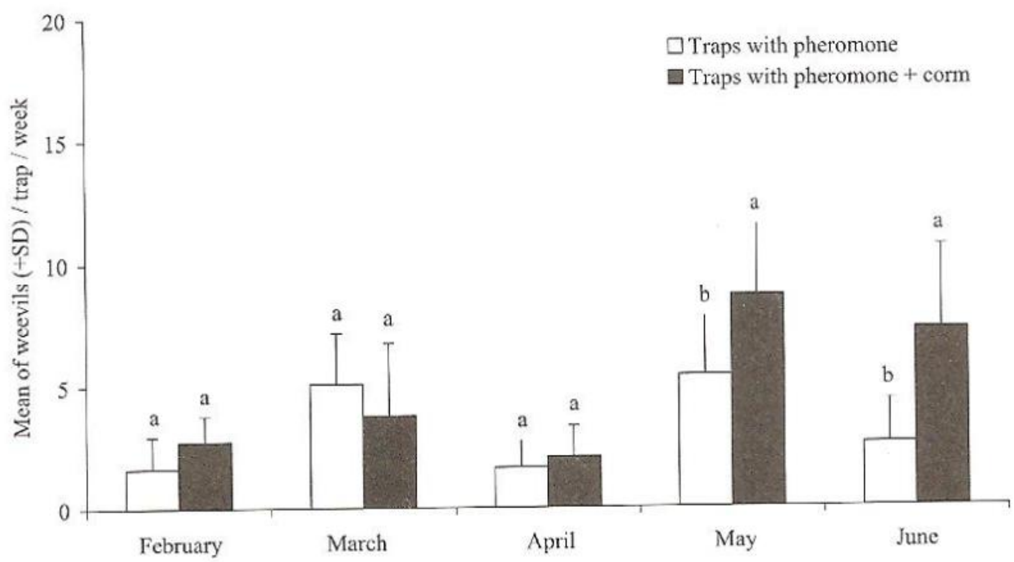

FIGURE 3. Comparison of mean number of *C. sordidus* adults (± SD) captured in pheromone baited traps *versus* pheromone + corm in a three year old plantain *Musa* spp. genome group AAB (4.4% damage) farm in Tabasco, Mexico from February to June 2006. Bars with the same letter in each month of capture are not significantly different (*t*-Student, $P>0.05$).

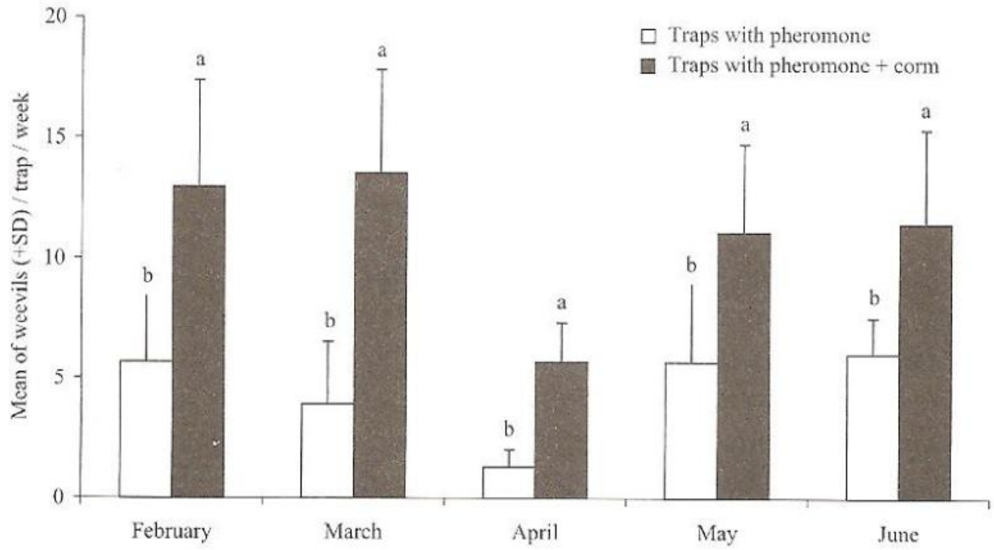

FIGURE 4. Comparison of mean number of *C. sordidus* adults (± SD) captured in pheromone baited traps *versus* pheromone + corm in a five year old plantain *Musa* spp. genome group AAB (9.7% damage) farm in Tabasco, Mexico from February to June 2006. Bars with the same letter in each month of capture are not significantly different (*t*-Student, $P>0.05$).

dus under the conditions of plantain production in Tabasco, Mexico.

With respect to the synergism of host plant volatiles and synthetic male-produced aggregation pheromone for the capture of *C. sordidus*, a significant increase in capture was observed only when plantain corm was added to the traps baited with pheromone. In general, captures increased by 75% with respect to the control treatment (pheromone alone). Cerda *et al.* (1998) observed that captures in the field increased up to 10 times when using sordidin pheromone + corm as attractant, in comparison with pheromone alone. Masanza *et al.* (2004) found that corms are the most attractive of all residual parts of banana to *C. sordidus*. This fact is better documented for other weevil species of the Family Curculionidae. For example, in the case of *Rhynchophorus palmarum* (Oehlschlager *et al.* 1993; Osorio *et al.*, 2003), *R. cruentatus* (Giblin-Davis *et al.*, 1994) and *Metamasius hemipterus sericeus* (Giblin-Davis *et al.*, 1996), captures in traps baited with pheromone significantly increase when plant host tissues are included. This study did not evidence a significant increase in captures when pseudostem, foliage and fruit tissues were used as coattractants. In contrast, Tinzaara *et al.* (2003) recorded an additive effect, in the response of *C. sordidus*, with the combination of pseudostem volatiles + synthetic pheromone under laboratory conditions indicating it is possible to combine synthetic pheromones with volatiles of the host plant to improve trapping efficiency. Cerda *et al.* (1996) mentioned that, under laboratory conditions, both corm and pseudostem volatiles of the plantain *Musa* spp., genome group AAB attract *C. sordidus* adults likewise. We believe that remnant harvest residues in the plantation under study contributed to reducing the effect of the capture in the traps baited with pseudostem or foliage. The smallest captures were recorded for the traps baited with pheromone + fruit, as premature ripening in the traps attracted a great amount of other insects that interfered with the capture. Based on these results, we consider that the most attractive volatiles of the plantain for the *C. sordidus* weevil are located in the corm, and this opens the possibility of using traps baited with pheromone + corm and of searching for new compounds in the corm to be used together with synthetic pheromones.

Considering the percent of recaptured marked weevils for each distance of release from the trap, can be established that the efficiency of attraction of the traps baited with pheromone + corm decreases drastically with distance, with only 1.7% of the freed insects recovered at a distance of 16 m. This implies that, in a system of massive capture, the traps must be placed at the most at 32 m one from the other to insure a good cover of the trapping area. In accordance with Tinzaara *et al.* (2005b), this is similar to observations of traps baited with synthetic pheromone alone that reach a radius of attraction of 10.1 to 15 m. This excludes the possibility that the addition of plantain corm to the traps baited with synthetic pheromone might increase the distance of attraction for *C. sordidus* adults.

With respect to the efficiency of trapping with pheromone *versus* pheromone + corm to capture *C. sordidus* in plantain farms, a direct relationship was observed between the intensity of pest infestation and the efficiency of capture in traps baited with pheromone + corm. This is possibly a result of the additive effect of the synthetic pheromone + corm, and perhaps from the effect of the natural pheromone that is liberated by the greater number of insects that aggregate around the trap before being captured. It is noteworthy that in Australia, traps baited with synthetic pheromone are covered with banana leaves to maintain humidity and reduce the temperature around the trap and this, according to Murad (2001), leads to a greater activity of the weevils and eventually to an increase in the capture.

In brief, the results of this study establish a base from which to develop a massive capture system based on a low-cost locally made trap that is appropriate for the conditions of plantain production in the Mexican humid tropics, and allows corm to be added as a coattractant to significantly increase the capture of *C. sordidus* in highly infested plantations. In consequence this should reduce populations in a relatively shorter period of time. It also opens the possibility of studying with greater depth the kairomones in plantain corms *Musa* spp., genome group AAB, to establish a more efficient trapping system.

CONCLUSIONS

Because of its lower cost and good performance to local environmental conditions, the ramp white trap is recommended to capture of adults of *Cosmopolites sordidus*. The capture in pheromone baited traps was improved with addition of plantain corm. Pheromone + corm baited traps captured greater number of weevils that pheromone baited traps in a plantain plantation with higher corm damage. This study sets the base for a meticulous research of new compounds in the corm of plantain that may be synergistic with the banana weevil aggregation pheromone.

ACKNOWLEDGEMENTS

We acknowledge the financial support of the Fondo Sectorial SAGARPA-CONACYT, grant no. 2004-C01-187.

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