Journal of Chemical Ecology, Vol. 28, No. 8, August 2002 (© 2002)

PHEROMONE-BASED TRAPPING OF WEST INDIAN SUGARCANE WEEVIL IN A SUGARCANE PLANTATION

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(Received January 15, 2002; accepted April 14, 2002)

Abstract—Attraction of *Metamasius hemipterus* (Oliver) to gallon and bamboo traps baited with insecticide-treated sugarcane, the male-produced pheromone, 4-methyl-5-nonanol, and 2-methyl-4-heptanol is more efficient if ethyl acetate is added. The optimal traps are ground-level gallon traps baited with insecticide-laced sugarcane, pheromone, and ethyl acetate. Capture rates of ground-level gallon traps are doubled by placing an insecticide-laced pad under the trap, but significantly decreased by placing the trap on a stick above ground. The efficiency of ground-level gallon traps is the same as ground level ramp traps. Mass-trapping *M. hemipterus* in newly planted sugarcane using ground level bamboo traps baited with insecticide-laced sugarcane and pheromone over six months revealed populations were low for the first two months, became maximum at five months, and declined thereafter. Capture rates of traps bordering newly planted and mature sugarcane were not significantly different from capture rates of traps in the interior of the plots. Capture rates of bamboo traps containing only insecticide-laced sugarcane and deployed at 30 traps/ha averaged 6 weevils/trap/week compared with 66 weevils/trap/week for traps additionally containing pheromone lures and deployed at 5 traps/ha. Capture rates for bamboo traps baited with insecticide-laced sugarcane and pheromone and deployed at 10 and 15 traps/ha were 43 and 38 weevils/trap/week, respectively. Total captures were higher in those plots with a higher density of insecticide-laden sugarcane and pheromone baited traps, and the differences were approximately proportional to trap density in the range of 5–15 traps/ha. Capture rates of traps containing insecticide-laced sugarcane and pheromone were always higher than of traps containing only insecticide-laced sugarcane, but in the first two months after planting the differences were much greater than in months 3–6 after planting.

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0098-0331/02/0800-1653/0

Key Words—4-Methyl-5-nonanol, 2-methyl-4-heptanol, aggregation pheromone *Metamasius hemipterus*, West Indian sugarcane weevil, pheromone trapping, sugarcane.

INTRODUCTION

The West Indian sugarcane weevil, *Metamasius hemipterus sericeus* (Oliver), is a pest of sugarcane, *Saccharum officinarum* L., in regions of Central and South America above 1100 m in which climatic conditions provide cool and humid conditions for weevil reproduction and where crop cultivars may be restricted to varieties that are susceptible to weevil attack (Badilla et al., 1985). Weevils are attracted to the cut ends of sugarcane stalks (billets) laid in the ground during replanting. Females oviposit in and larvae mine the replanting stock, thus destroying nodal tissue and decreasing germination frequency. In some regions, damage to billets can reach as high as 60% and can result in production losses estimated at over 25% (Badilla et al., 1985). Development time from egg to emergent adult is approximately two months (Badilla et al., 1985).

Recommended practice to manage economically damaging populations of this weevil is to place bamboo traps containing insecticide-treated sugarcane in fields at planting for two months. In this work, we initially examined the relative efficiency of different trap designs, trap elevation, and baiting protocols. We also examined the relative efficiency of different mass-trapping protocols by using ground-level bamboo traps baited with insecticide-laced sugarcane or this component as well as male-produced aggregation pheromone (Perez et al., 1997).

METHODS AND MATERIALS

Field Site. Experiments were carried out in the 1200-ha Hacienda Juan Viñas sugarcane plantation in central Costa Rica. This is an elevated wet tropical region. The plantation has sugarcane of all ages, with most plantings bordered by roads. Mass-trapping plots were newly replanted sugarcane surrounded on three sides by 8-months-old sugarcane and on the fourth side by a road bordered by 8-month-old sugarcane. Mass-trapping plots were separated by at least 100 m of 8-month-old sugarcane.

Traps. Bamboo traps consisted of halved 4–5 cm diameter 0.8 m bamboo into which were cut on each side $\sim$0.6-m $\times$ 0.5-cm-wide slits for insect entry. Into these traps were placed four or five pieces of halved sugarcane stalk ($\sim$20 cm) previously immersed in Sevin 80 (3% A.I., 1-naphthyl *N*-methylcarbamate). Pheromone lures were laid in the trap with the sugarcane. Each trap was bound together with two pieces of wire, placed on the ground, and covered with litter from the field to preserve moisture. Gallon traps were 4-liter yellow plastic containers with 10-cm × 15-cm windows cut in each large side ∼5 cm from the bottom to allow insect entry. Ramp traps consisted of two yellow square molded plastic containers 13.5 × 13.5 × 3 cm mounted with open ends toward each other and separated by 5 cm. To the lower container were attached four ramps 12 × 12 cm that inclined between the top of the lower container and the ground. A picture of the trap is in Alpizar et al. (2000). Each trap contained four or five pieces of insecticide-treated halved sugarcane stalk (20 cm). Pheromone and ethyl acetate lures were hung from a wire just under the top of the trap.

Comparison of Gallon and Ramp Traps. Each trap contained five pieces of 20-cm-long halved sugarcane stalk previously immersed in Sevin 80 (3% AI), a pheromone lure, and an ethyl acetate lure. Traps were placed 50 m apart in 6- to 10-week planted sugarcane in Hacienda Juan Viñas, Costa Rica, November 30–December 14, 2001. Insects were counted and removed and traps were rerandomized between the first and second weeks.

Lures. Pheromone lures were commercially available Metalure [4-methyl-5-nonanol–2-methyl-4-heptanol (8:1)] formulated in membrane release devices that released ∼3 mg/day. Ethyl acetate was formulated in membrane release devices that released ∼100 mg/day (ChemTica Internacional, Apdo. 159-2150, San Jose, Costa Rica). Release rates were determined by weight loss under a daily temperature regime of 28 ± 2°C maximum and 17 ± 2°C minimum.

Statistics. Captures were analyzed for normal distribution and, where necessary, transformed to achieve homoscedasticity. ANOVA (fully factorial routine) was conducted using Systat 5.2.1. Means are always presented untransformed. Means followed by different letters in the figures are significantly different by Bonferonni t test ($P < 0.05$).

RESULTS AND DISCUSSION

A previous elucidation of the aggregation pheromone of *M. hemipterus* identified 4-methyl-5-nonano and 2-methyl-4-heptanol as the two components that yielded the highest biological responses in field trapping (Perez et al., 1997). While the participation of 4-methyl-5-nonanol in the aggregation pheromone of this weevil is undisputed, it was reported that either 2-methyl-4-octanol or 2-methyl-4-heptanol could be used with 4-methyl-5-nonanol to attract *M. hemipterus* in Colombia (Ramirez-Lucas et al., 1996). The present study used a mixture of 4-methyl-5-nonanol and 2-methyl-4-heptanol that has repeatedly been more attractive in Costa Rica than other mixtures of male-produced volatiles. Previous work established that addition of pheromone to insecticide-laced sugarcane-containing traps significantly increases capture rates of *M. hemipterus* (Giblin-Davis et al., 1996; Perez et al., 1997). Although other food additives have been investigated,

TABLE 1. SUMMARY OF EXPERIMENTS[a]

Exp.	Dates	Treatments	Design	Replicates
1	Oct 22–Nov 8, 1996	1 Bamboo traps (ground)—S, P 1 Gallon traps (ground)—S, P	CRBD	9
2	Nov. 8–22, 1996	1 Gallon traps, S, P 2 Gallon traps, S, P, EA	CRBD	10
3	Dec. 15–23, 1996	1 Gallon traps (∼0.5 m above ground)—S, P, EA 2 Gallon traps (ground)—S, P, EA 3 Bamboo traps (ground)—S, P 4 Bamboo traps (ground)—S, P, EA	CRBD	10
4	Jan. 29–Feb 2, 1997	1 Gallon traps (ground)—S, P, EA (1.2 ml/day release) 2 Gallon traps (ground)—S, P, EA (1.2 ml/day release) with pad under trap	CRBD	7
5	Nov 30–Dec 14, 2001	1 Gallon traps (ground level)—S, P, EA 2 Ramp traps (ground level)—S, P, EA	CRBD	20
6 and 7	Sept. 1996 Feb 1997	30 bamboo traps (ground)/ha—S 15 bamboo traps (ground)/ha—S, P 10 bamboo traps (ground)/ha with—S, P 5 bamboo traps (ground)/ha with—S, P	CRBD	3 plots of 1 ha of each trap density

[a] Abbreviations: CRBD = complete random block design. S = 4–5 pieces of 20-cm-long halved sugarcane stalk previously immersed in 3% AI Sevin 80. P = pheromone lure emitting ∼3 mg/day of 4-methyl-5-nonanol and 2-methyl-4-heptanol from a membrane lure containing these components in a ratio of 8:1. EA = ethyl acetate released at ∼100 mg/day.

none has been found to be a better synergist for the aggregation pheromone than insecticide-laced split sugarcane stalk (Oehlshlager et al., unpublished results; Cerda et al., 1999).

Trap Optimization Experiments. Our initial experiment established that ground level gallon traps and bamboo traps were equally efficient when similarly baited and that insecticide-laced sugarcane in traps remained effective for at least two weeks (experiment 1; Figure 1). In this experiment, we found that captures during the second week were greater than captures during the first week. This is not unexpected since attractiveness of sugarcane to *M. hemipterus* is associated with its fermentation, the rate of which varies under field conditions. We next investigated the effect of addition of ethyl acetate to gallon traps (experiment 2; Figure 2). This experiment confirmed the earlier report that a combination of insecticide-laced sugarcane, pheromone, and ethyl acetate was more attractive than the binary combination of sugarcane and pheromone (Giblin-Davis et al., 1996).

Since it is common practice in sugarcane plantations to use ground-level bamboo traps to capture *M. hemipterus* (Badilla et al., 1985), we conducted a

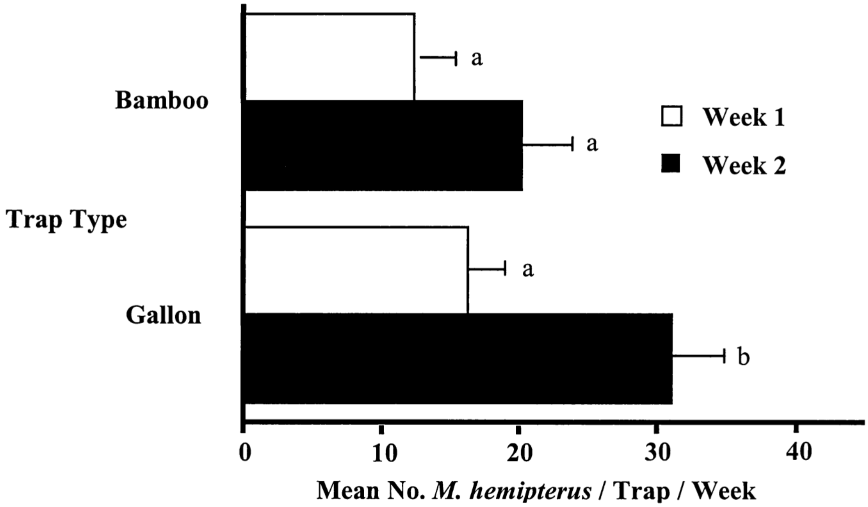

FIG. 1. Effect of trap type on *M. hemipterus* captures. Mean (+SEM) weekly capture of *M. hemipterus* in ground-level gallon and ground-level bamboo traps, each containing a pheromone lure and four pieces of 20-cm-long halved sugarcane stalk previously immersed in Sevin 80 (3% AI). Traps were placed 20 m apart in newly planted sugarcane (within one month of test) in Hacienda Juan Viñas, October 22–November 8, 1996. No significant difference between capture rates of the two trap types was detected in the first week (no statistical analysis presented), but in the second week ANOVA ($N = 9$) of log $(X + 1)$-transformed data gave $F_{1,16} = 4.49$, $P < 0.05$. Bars followed by different letters are statistically significant.

further experiment that determined that the addition of ethyl acetate to bamboo traps containing insecticide-laced sugarcane and pheromone increased capture rates (experiment 3; Figure 3). In experiment 3, we also determined that gallon traps baited with insecticide-laced sugarcane, pheromone, and ethyl acetate were more effective if placed on the ground than if elevated on sticks 0.5 m above the ground (Figure 3). The higher capture rate of ground-level traps is consistent with the preference of *M. hemipterus* for buried sugarcane stalk. The higher efficiency of ground-level traps is at variance with earlier reports in which it was observed that capture rates were higher in traps elevated above ground compared to those on the ground (Giblin-Davis et al., 1996; Cerda et al., 1999). The differences most probably reside in the ease with which *M. hemipterus* can enter the present ground-level traps. The present ground traps were surrounded by crop residue that was pushed along the sides of the gallon traps so that weevils landing on the ground near the trap could easily walk into the open sides of the trap. The higher capture rate of ground-level traps is consistent with our observations that *M. hemipterus* fly to the area of a trap, land, and then walk in. This is similar to

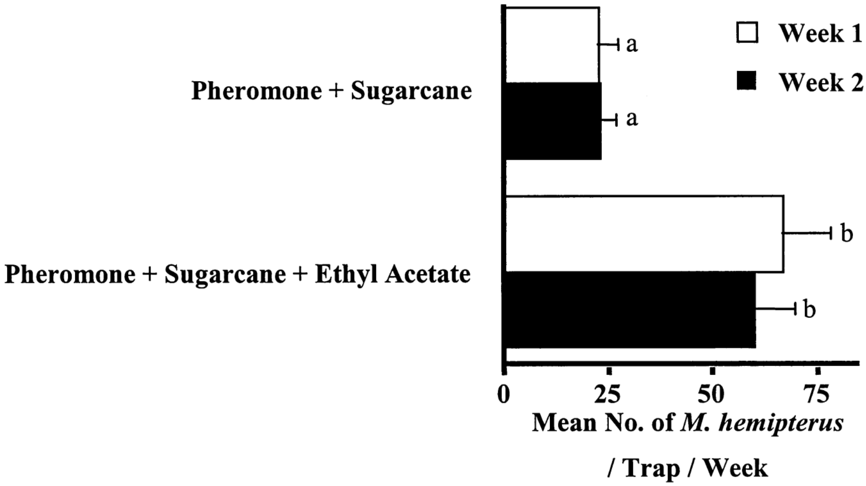

FIG. 2. Effect of semiochemical bait on *M. hemipterus* capture in gallon traps. Mean (+SEM) weekly capture of *M. hemipterus* in gallon traps each containing four pieces of 20-cm-long halved sugarcane stalk previously immersed in Sevin 80 (3% AI). Traps were placed 20 m apart in newly planted sugarcane in Hacienda Juan Viñas, November 8–22, 1996. ANOVA ($N = 10$) of week one captures gave $F_{1,18} = 7.88$, $P < 0.05$, week two $F_{1,18} = 7.15$, $P < 0.05$. Bars followed by different letters are statistically significant.

the behavior of *R. palmarum* that is also more efficiently captured if large landing surfaces are present within easy crawling distance of the traps (Oehlschlager et al., 1993a,b).

The above suggested that a ground-level killing agent might increase the efficiency of the trap. With the goal of intercepting weevils attracted to the area of the trap but not entering, we placed 20- × 20- × 0.5-cm insecticide-soaked sponge pads under gallon traps (experiment 4; Figure 4). Capture rates of ground-level gallon traps baited with insecticide-laced sugarcane, pheromone, and ethyl acetate were similar to equivalently baited gallon traps that were placed on insecticide-laced pads, and the insecticide-laced pads captured similar numbers of *M. hemipterus*. The trap–pad combination captured twice as many insects as the trap without pads. When this experiment was conducted in drier climates, it was found that if the pad is dry it does not retain significant numbers of insects compared to normal traps (D. Alpizar and M. Fallas, unpublished observations). In the present experiment, we used a very high (1.2 ml/day) release rate of ethyl acetate for all traps. It has been determined that capture rates in ground-level gallon traps baited with insecticide-laced sugarcane and pheromone and ethyl acetate steadily increase as the release rate of ethyl acetate is increased from 100 to 1.2 ml/day, the highest release rate studied (McDonald et al., 1996). The most effective trap is the insecticide-laced

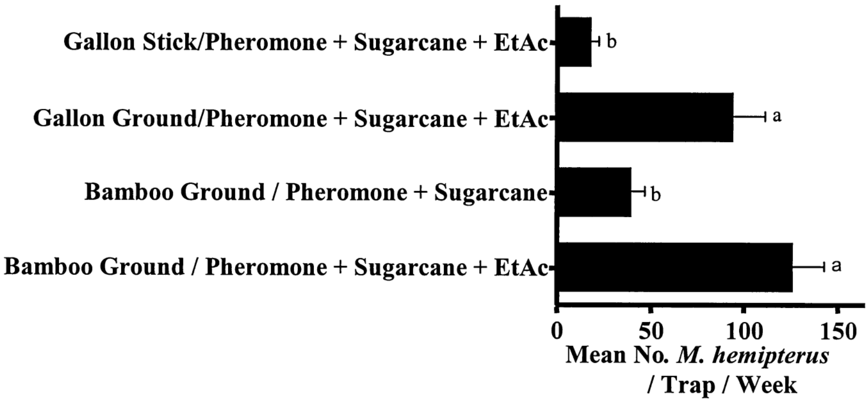

FIG. 3. Effect of trap type, trap elevation, and semiochemical bait on *M. hemipterus* captures. Mean (+SEM) weekly capture of *M. hemipterus* in bamboo or gallon traps in Hacienda Juan Viñas in 3-month-old sugarcane December 15–23, 1996. All traps contained four or five pieces of 20-cm-long halved sugarcane stalk previously immersed in Sevin 80 (3% AI). While all gallon traps additionally contained pheromone and ethyl acetate lures, bamboo traps were additionally baited with pheromone or pheromone and ethyl acetate lures. Additionally, gallon traps were filled to the lower window with Sevin 80 (3% AI) suspension that immersed the sugarcane. Gallon traps on sticks were ~0.5 m above ground level or on the ground. All bamboo traps were on the ground. All traps were ~20 m part between treatments and replicates. ANOVA ($N = 10$) gave $F_{3,32} = 15.38$, $P < 0.05$. Bars followed by different letters are statistically significant.

sugarcane–pheromone–ethyl acetate gallon trap placed on an insecticide-laced pad at ground level.

We have previously examined the relative effectiveness of the ground-level open gallon trap with a ramp trap, a plastic trap that allows weevils to crawl in easily and that is effective in the capture of *Cosmopolites sordidus* (Alpizar et al., 2000). These traps were equally effective when baited with insecticide-laced sugarcane, pheromone, and ethyl acetate. During the two-week trial (experiment 5), the total mean capture of *M. hemipterus*, in gallon traps and ramp traps was forty nine and thirty five, respectively [ANOVA ($N = 20$) $F_{1,18} = 1.82$, NS].

Mass-Trapping Experiments. The usual practice to manage populations of *M. hemipterus* in freshly planted sugarcane is to place 30 insecticide-laced sugarcane-containing bamboo traps/ha at the time of planting and leave them in place for two months. Since the above experiments demonstrated that bamboo traps containing insecticide-laced sugarcane and phermone were more effective, we conducted mass-trapping experiments using bamboo traps baited with both insecticiede-laced sugarcane and pheromone. Although addition of ethyl acetate lures to these traps would have made them even more effective, this component

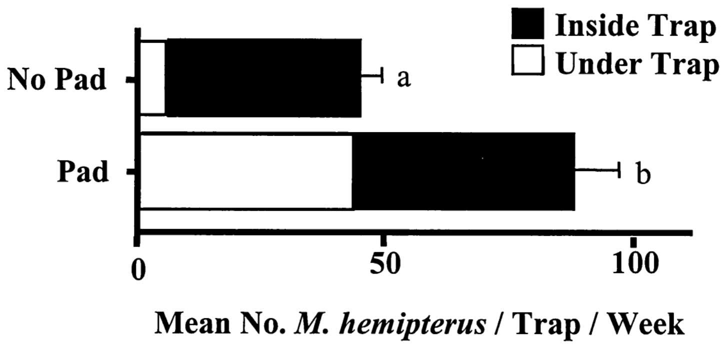

FIG. 4. Effect of the presence of an insecticide-laced pad under semiochemical-baited gallon trap on *M. hemipterus* captures. Mean (+SEM) weekly capture of *M. hemipterus* in gallon traps in Hacienda Juan Viñas sugarcane plantation, January 29–February 2, 1997. All gallon traps contained pheromone and 12 ethyl acetate lures (releasing ~1.2 ml/day of ethyl acetate) as well as four or five pieces of 20-cm-long halved sugarcane stalk previously immersed in Sevin 80 (3% AI). Traps were placed on ground with or without a 20- × 20- × 0.5-cm sponge pad presoaked in Sevin 80 (3% AI). ANOVA ($N = 7$) gave $F_{1,12} = 21.34$, $P < 0.05$. Bars followed by different letters are statistically significant.

was not used in the mass-trapping experiments because the release device available required frequent replacement, and it was not considered acceptable for extended field use. In the mass-trapping experiments, we deployed bamboo traps baited only with insecticide-laced sugarcane at a density of 30 traps/ha and bamboo traps baited with insecticide-laced sugarcane and pheromone at densities of 15, 10, and 5 and traps/ha (experiments 6 and 7, respectively). Each trap density was deployed in three 1-ha plots of newly planted sugarcane for 6 months.

The capture rate of *M. hemipterus* in all mass-trapping plots was low during first two months after planting but increased in months three to five before decreasing in the sixth month (Figure 5).

For two mass-trapping protocols, we examined the capture rates of bamboo traps baited with insecticide-laced sugarcane and pheromone that were located on the perimeter of the trapping plots with those traps that were located on the interior of the trapping plots. In the three 1-ha mass-trapping plots with 30 sugarcane-baited bamboo traps/ha, traps were placed on an approximately 18-m grid, with 16 traps on the perimeter of each plot and 14 traps located in interior positions. In each of the three mass-trapping plots with 15 insecticide-laced sugarcane- and pheromone-baited bamboo traps/ha, traps were placed on an approximately 25-m grid, with 14 traps in each plot on the perimeter and 9 traps located in interior positions. For these two trapping protocols, we found capture rates in perimeter traps to be within 20% of the capture rates of interior traps for each date during the entire six-month trial. That is, there was no evidence for migration of weevils

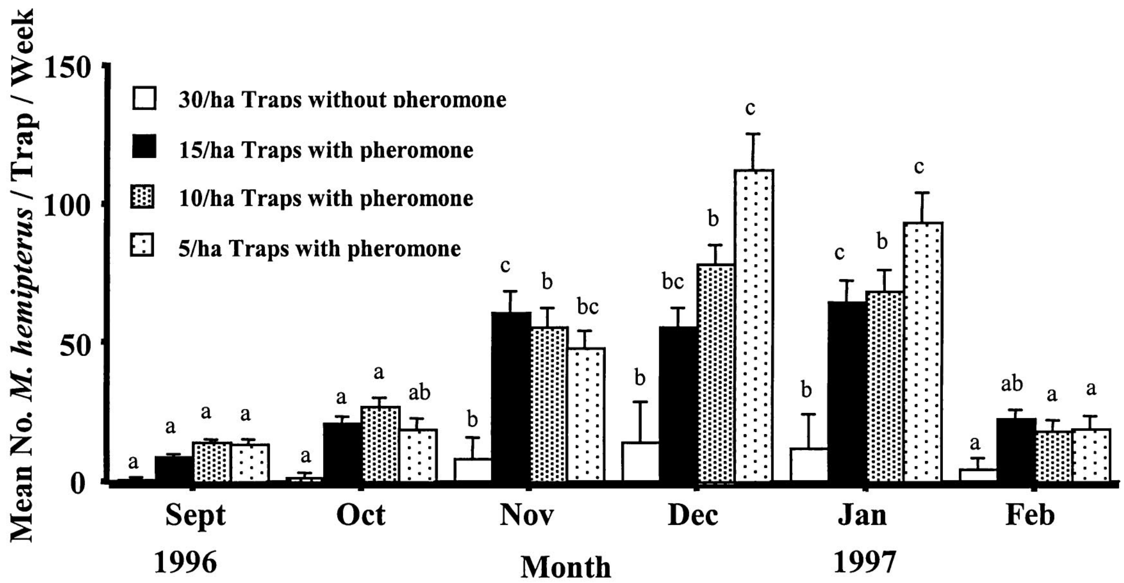

FIG. 5. Effect of trap bait and trap density on *M. hemipterus* captures. Mean (+SEM) weekly capture of *M. hemipterus* in ground level bamboo traps placed in 1-ha plots of newly planted sugarcane in Hacienda Juan Viñas, Costa Rica, September 1996–February 1997. All traps contained five pieces of 20-cm-long halved sugarcane stalk previously immersed in Sevin 80 (3% AI). Traps in plots with 15, 10, or 5 traps/ha additionally contained pheromone lures. Insects were counted and removed weekly, sugarcane was renewed biweekly, and pheromone lures were renewed when liquid was no longer visible in the lure. ANOVA for 30 traps/ha: $F_{5,834} = 24.93$, $P < 0.05$; for 15 traps/ha: $F_{5,414} = 20.64$, $P < 0.05$; for 10 traps/ha: $F_{5,274} = 17.99$, $P < 0.05$; for 5 traps/ha: $F_{5,129} = 30.73$, $P < 0.05$. Captures in plots containing the same trap density were averaged for each month and averages statistically compared month to month for the same trap density. Bars followed by different letters are statistically significant.

to the mass-trapping plots in the early stages of the trapping or for a build up of *M. hemipterus* in the center of the newly replanted mass-trapping plots during the latter part of the trapping. When similar trapping experiments were conducted in mature oil plam with *R. palmarum,* which is a much stronger flier, we found perimeter traps consistently captured two to three times more insects than those in the interior of the trapping area (Oehlschlager et al., 1995).

Bamboo traps baited only with insecticide-laced sugarcane and deployed at 30/ha were the least efficient, capturing an average of only 6 weevils/trap/week, while those baited with sugarcane and pheromone and deployed at 5/ha were the most efficient, capturing an average of 66 weevils/trap/week over the entire six-month trial. Traps baited with sugarcane and pheromone and deployed at 10 traps/ha (43 weevils/trap/week) and 15 traps/ha (38 weevils/trap/week) were of intermediate efficiency.

In the three 1-ha plots receiving 30 insecticide-laced sugarcane-containing bamboo traps (no pheromone lure)/ha, a total of 5217 weevils/ha were captured over the six-month trial. In the three 1-ha plots containing 15 insecticide-laced sugarcane- and pheromone-containing traps/ha, a total of 15,608 weevils/ha were captured during the six-month trial. This is ∼1.3 times more than the 11,636 weevils/ha captured in the plots containing 10 similarly baited traps/ha, and ∼2.3 times more than the 6676 weevils/ha captured in the plot containing only 5 similarly baited traps/ha. It is clear that use of insecticide-laced sugarcane- and pheromone-baited traps offers advantages and that use of as many traps as is economically feasible, at least up to 15/ha, results in removal of proportionally more weevils.

Month-by-month comparison of relative capture rates of bamboo traps baited only with insecticide-laced sugarcane with traps containing insecticide-laced sugarcane and pheromone revealed that in the first two months of the experiment, traps baited with insecticiede-laced sugarcane and pheromone captured ∼17 times as many insects as those with only insecticide-laced sugarcane (Figure 6). The relative efficiency of traps baited with insecticide-laced sugarcane and pheromone dropped to ∼6 times that of traps containing only insecticide-laced sugarcane during months 3–6 of the trials (Figure 6). This significant change is attributed to a difference in the attractiveness of the two components. In the early part of the trial, sugarcane had just been planted, and migrating weevils are expected to be primarily searching for mates and sites for oviposition. Additionally, in the early stages of infestation, there are few pheromone sources in the mass-trapping plots to compete with pheromone emanating from traps. During this period, it is reasonable that traps containing pheromone would be relatively more attractive than those without it. As colonization proceeds, location of unoccupied oviposition sites is likely to be dominant factor, and reliance on pheromone might be expected to decrease. Additionally, in the latter stages of infestation, there are many pheromone sources in the mass-trapping plots to compete with

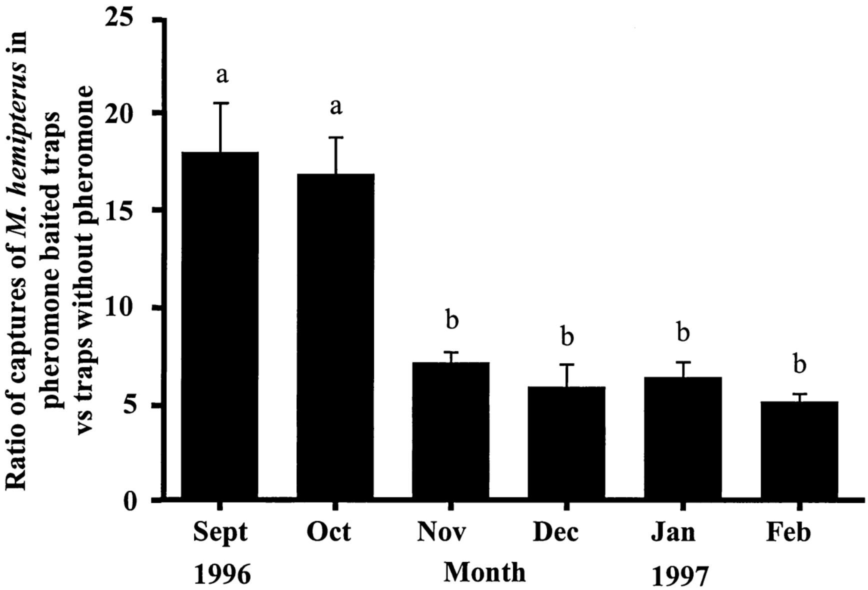

FIG. 6. Ratios of weekly capture of *M. hemipterus* in sugarcane vs. sugarcane and pheromone-baited bamboo traps over time. Ratios of weekly captures of *M. hemipterus* in 30 sugarcane-only bamboo traps containing only insecticide-laced sugarcane to weekly captures in bamboo traps containing insecticide-laced sugarcane and pheromone lures (experimental details as for Figure 5) placed at densities of 15, 10, and 5 traps/ha in newly planted sugarcane at Hacienda Juan Viñas, Costa Rica 1996–1997. ANOVA ($N = 3$) gave $F_{5,12} = 17.52$, $P < 0.05$. Bars followed by different letters are statistically significant.

pheromone emanating from traps. In these circumstances, one would expect differences in attraction between pheromone-containing and pheromone-free traps to decrease.

Acknowledgments—We wish to thank the technical staff at Hacienda Juan Viñas for excellent field assistance.

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