JOURNAL OF PLANT PROTECTION RESEARCH
Vol. 48, No. 4 (2008)

A PHEROMONE-BASED TRAPPING SYSTEM FOR MONITORING THE POPULATION OF *COSMOPOLITES SORDIDUS* (GERMAR) (*COLEOPTERA: CURCULIONIDAE*)

Gadi V.P. Reddy[1], Zerlene T. Cruz[1], Fritz Naz[1], Rangaswamy Muniappan[2]*

[1] Western Pacific Tropical Research Center, College of Natural and Applied Sciences
University of Guam, Mangilao, Guam 96923, USA
[2] IPM CRSP, OIRED, Virginia Tech, 1060 Litton-Reaves Hall, Blacksburg, VA 24061, USA

Received: October 22, 2008
Accepted: November 20, 2008

Abstract: The banana root borer *Cosmopolites sordidus* (*Coleoptera: Curculionidae*) is native to Malaysia and Indonesia but is found in nearly all banana-growing areas of the world. Studies were conducted to determine the pheromone trap efficacy, effect of shade on trap catches and to monitor the population of *C. sordidus* using pheromones in Guam. In Guam, pheromone traps were used to monitor the population level of *C. sordidus*. Before monitoring began, two basic studies were carried out, which established that pheromone-baited ramp traps positioned in the shade of the banana crop canopy caught significantly more adults than those placed in sunlight and that ramp traps baited with pheromone lures caught significantly more adults than did identical traps without pheromone lures. Ramp traps baited with pheromone lures were set up at each of 10 locations throughout the island in November 2005. Weekly counts were made of the borers caught by the pheromone traps. The data indicated higher population levels (>10 per week) in the northern region and low (<5 per week) to medium level (5–10 week) populations in the southern part of the island. These differences among sites were highly significant. Linear and quadratic effects of rainfall on the number of borers captured were statistically significant, but according to quadratic regression models, the significance was due to differences at just one site.

Key words: Banana root borer, monitoring, Ramp trap, pheromones, Cosmolure+

INTRODUCTION

The banana root borer *Cosmopolites sordidus* (Germar) (*Coleoptera: Curculionidae*), is considered one of the foremost pests in most banana growing regions (Stover and

*Corresponding address:
reddy@uguam.uog.edu

Simmonds 1987). Although it attacks all types of bananas, including dessert and brewing, highland bananas and plantains, *Musa paradisica* L., also known as cooking bananas, are more susceptible (Gold *et al*. 2001; Sikora *et al.* 1989). The borers cause yield reductions by impeding sucker establishment in newly planted crops (McIntyre *et al.* 2001), loss of plant vigour and reduction in bunch size (Rukazambuga *et al.* 1998). The larvae of *C. sordidus* feed by boring or tunnelling through the plant, eventually causing corm decay by facilitating invasion by secondary organisms and leaving a mass of rotten tissue (Franzmann 1972; Gold *et al*. 2001). Such injury to the corm prevents nutrient uptake by the plant (Gold *et al*. 2001). If left uncontrolled, *C. sordidus* can reduce yield by up to 100% (Sengooba 1986; Koppenhoeffer *et al.* 1994).

The banana root borer is native to Malaysia and Indonesia but has spread to nearly all banana-growing areas of the world, including Australia, Africa, Central and South America, Florida, Mexico, the West Indies, some islands in the Pacific and South and Southeast Asia (Gold *et al.* 2001). It has been reported from the Marianas since the early 1940s (Gressitt 1954). In recent years, this borer has become a serious problem in commercial banana farms of Guam as well as other parts of Micronesia. All varieties of banana are attacked in Guam, although some preference has been noted for the Manila variety. Currently over 50% of the bananas marketed in these islands are imported, but quite a few commercial farms exist, and bananas are also grown commonly in many backyards and under subsistence farming conditions. Local farmers are steadily developing commercial farms. Currently, farmers in Guam and the Northern Mariana Islands use no definite control method against the banana borer.

Classical biological control of the banana borer, using natural enemies from Asia, has so far been unsuccessful (Gold *et al.* 2001). Only 15 generalist predators of the banana borer have been reported (Ostmark 1974). Several attempts at biological control throughout the Pacific have used predatory beetles, especially *Plaesius javanus* (*Coleoptera: Histeridae*) and *Dactylosternus hydrophiloides* (*Coleoptera: Hydrophilidae*), but they have been mostly ineffective (Weddell 1932; Ostmark 1974; Waterhouse and Norris 1987). Although the predators were established (usually after several attempts of introduction), their effectiveness was not well known and suspected to be minimal (Waterhouse and Norris 1987). Factors contributing to their poor effectiveness are their lack of specificity to the banana borer and the protected location of borer larvae and pupae in the tunnels within the banana plant (Ostmark 1974). These factors corroborate the findings of Gold *et al*. (2001) that biological-control programs for the banana borer have not been successful.

Synthetic pheromones can be used as tools for management of *C. sordidus* (Tinzaara *et al.* 2002). Evidence of a male-produced aggregation pheromone, to which both females and males of *C. sordidus* respond, was first provided by Budenberg *et al*. (1993). Beauhaire *et al*. (1995) detected six male-specific compounds in volatile collections that elicited electroantennogram (EAG) activity. They identified and synthesized sordidin, which was the most abundant of the volatiles. The absolute stereochemistry of the natural sordidin ((1S,3R,5R,7S)-(+)-1-ethyl-3,5,7-trimethyl-2,8-diosabicyclo[3.2.1]octane) was subsequently determined (Mori *et al.* 1996; Fletcher *et al*. 1997). Ndiege *et al*. (1996) and Jayaraman *et al*. (1997) developed a large-scale synthesis of racemic sordidin that made field-testing possible. Its attractiveness to both males and females confirmed its function as an aggregation pheromone, and it was formulated at ChemTica International in Costa Rica as cosmolure + pheromone

(Tinzaara *et al.* 2003). Use of cosmolure for trapping the borer in Costa Rica has been reported as a promising option (Alpizar *et al.* 1999; Oehlschlager *et al.* 2000). Preliminary studies conducted in Uganda showed the pheromone to be up to 18-fold more attractive to *C. sordidus* than pseudostem traps (Tinzaara *et al.* 2000).

Farmers often complain about *C. sordidus* problems and the heavy damage sometimes caused to banana plantations, but there are limited studies for the control of this pest that have been conducted in the Pacific region. The objectives in the present study are to determine: (i) pheromone trap efficacy, (ii) effect of shading on pheromone trap catches, and (iii) population dynamics of *C. sordidus* in different areas of Guam using pheromone traps. Therefore, we have undertaken efforts to study the successful trapping method could increase our knowledge of the pest's status so that appropriate methods could be adopted for its control. Such control could enhance economic development by reducing the cost of production and increasing the yield of bananas.

MATERIALS AND METHODS

Site description

Study sites were at Yigo (13°31.864′N, 144°54.618′E), Dededo (13°31.875′N, 144°54.095′E), Yigo Western Pacific Tropical Research Center (WPTRC) (13°31.930′N, 144°52.351′E), Tamuning (13°30.102′N, 144°46.355′E), Hagåtña (13°31.864′N, 144°54.618′E), Yoña (13°24.591′N, 144°45.921′E), Inarajan WPTRC (13°61.963′N, 144°45.353′E), Malesso (13°16.035′N, 144°40.570′E), Agat (13°22.736′N, 144°39.231′E) and Mangilao (13°28.508′N, 144°44.897′E).

Trap

The ramp trap used is commercially available from ChemTica Internacional S.A. (San José, Costa Rica) (Fig. 1) (Reddy 2007). It was made of yellow durable polyvinyl chloride (PVC) and consisted of two square trays, each 14 cm on a side by 4 cm deep (inside dimensions). Four sloping ramps led from each of the four directions into the sides of the lower tray. Each ramp was 4 cm high, 13 cm long, and 12 cm wide and slid into a slot in the bottom tray. We ensured that each of the four ramps was in complete contact with the ground to allow borers to crawl into the traps. The upper tray, inverted and supported on four 6-cm posts, formed a roof over the bottom tray. Water mixed with Joy concentrated dishwashing liquid detergent (Procter & Gamble, Cincinnati, OH) (1–3%) was poured into the bottom tray to retain adults that walked into the traps.

Pheromone lures

Pheromone lures (Cosmolure+), sealed into polymer membrane release devices and optimized for *C. sordidus*, were obtained from ChemTica Internacional S.A. (San José, Costa Rica). The lure packs, each containing 90 mg of pheromone and having a release rate of 3 mg/day (Tinzaara *et al.* 2005), were stored at 4°C until use. A lure was hung on a wire hook 2 cm below the centre of the roof of each trap. The lures were changed once or twice a month, although occasionally, more frequent changes were necessary. Old lures were discarded once liquid compounds were no longer visible.

Fig. 1. A ramp trap used to monitor *Cosmopolites sordidus*

Pheromone trap efficacy

Pheromone-baited and unbaited traps were placed at randomly chosen locations about 5 m apart on the ground in banana plantations in the villages of Dededo, Yigo, Hagåtña and Yoña (Guam, USA). The banana root borers trapped were removed and counted every week during this experiment. The traps were washed and rinsed, and new soapy water was added. We randomized the traps across the field to avoid any possible trap-placement effect. The locations of the traps were regularly changed throughout the infested areas once every month. The number of borers captured, temperature, relative humidity, and wind velocity were recorded each time a trap was emptied. Trapping continued for three months.

Effect of shade on trap capture efficiency

Ramp traps baited with pheromone lures were placed in the shade and in sunlight at each of the four locations listed above about 5 m apart on the ground in banana plantations. The location and direction of the traps were regularly changed throughout the experimental areas once every month. Each treatment was replicated four times at each village and trapping continued for three months.

Population trend of *Cosmopolites sordidus*

Monitoring was conducted on banana plantations in Guam for one year. At each location, a pheromone-baited ramp trap was set up, in the shade of banana trees. The traps were checked weekly, captured borers were removed and counted, and soapy water was added as needed. The locations and directions of the traps were regularly changed throughout the experimental areas once every month. Data on the daily temperature, relative humidity, wind velocity, and rainfall during the experiment were obtained from the National Weather Service Forecast Office, Tiyan (Guam) for the analysis.

Statistical analysis

Because the response variables were count variables, a one-way Poisson ANOVA model was fitted by the GLIMMIX Procedure SAS Version 9.13 (SAS Institute Inc. 2004). The least-square means test was used to make multiple comparisons for significant differences between treatments. Data on the mean weekly trap catches were analysed, and the correlations between weekly mean trap densities and accumulated rainfall were fitted.

RESULTS

Pheromone trap efficacy

Ramp traps baited with pheromone lures caught significantly more adults (11.1 ± 0.4 adults per trap) than did identical traps without pheromone lures (0.6 ± 0.1 adults per trap) ($F = 54.24$, df = 1, $P < 0.0001$; Fig. 2). The average temperature, relative humidity, and wind velocity during the experimental period were 28.6°C, 72.0%, and 5.4 m/s, respectively.

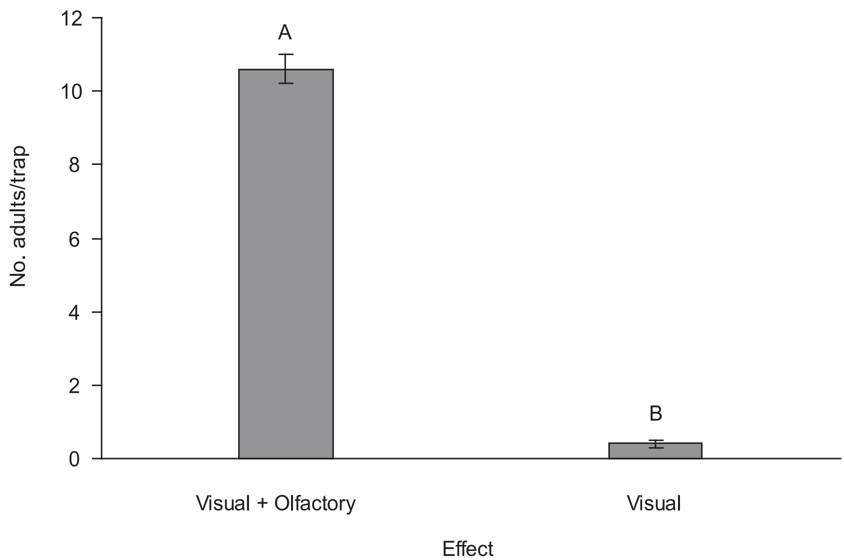


Fig. 2. Mean (± SE) numbers of adult *C. sordidus* caught in traps with and without pheromone lures. Different letters indicate significant differences between treatments (one-way ANOVA using Poisson model, least square means, $P < 0.0001$). Bars represent means of four replicates

Effect of shade on trap capture efficiency

Ramp traps positioned in the shade of banana plants caught significantly more adults (7.7 ± 0.1 adults per trap) than did similar traps placed in unshaded locations (4.3 ± 0.1 adults per trap) ($F = 16.17$, df = 1, $P < 0.05$; Fig. 3). The average temperature, relative humidity, and wind velocity during the experimental period were 27.9°C, 73.0%, and 4.2 m/s, respectively.

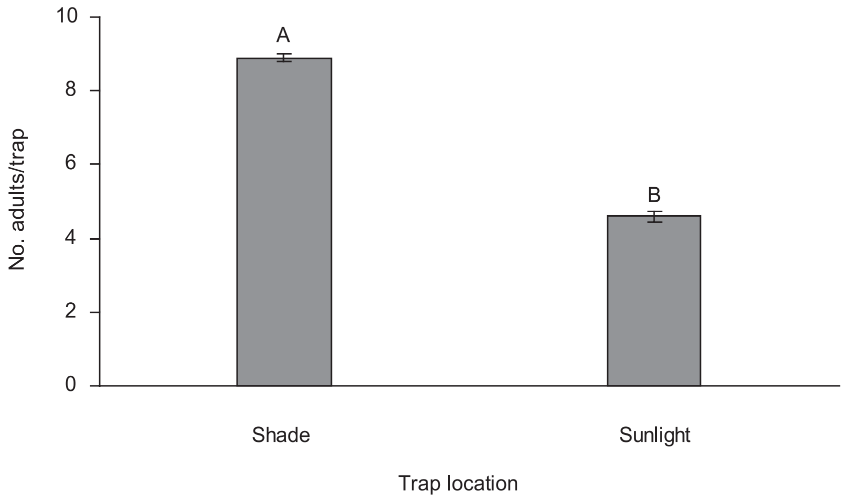


Fig. 3. Mean (± SE) numbers of adult *C. sordidus* caught in pheromone-baited traps placed in shaded and unshaded locations. Different letters indicate significant differences between treatments (one-way ANOVA using Poisson model, least square means, $P < 0.05$). Bars represent means of four replicates

Population trend of *Cosmopolites sordidus*

The highest mean monthly trap catches of *C. sordidus* was recorded at Dededo (36.1 ± 11.0) and the lowest was recorded at WPTRC (0.9 ± 1.0) (Fig. 4). The number of *C. sordidus* captured was higher in August (53.0 adults per trap) and September (59.5) than in other months (24.2 to 43.0) (Fig. 5). The average temperature, relative humidity, and wind velocity during the experimental period were 27.9°C, 73.0%, and 4.2 m/s, respectively.

Linear and quadratic effects of rainfall on the number of catches were statistically significant ($F = 5.70$; df = 1; $P = 0.0182$). Also, sites differed very highly significantly in catch rates ($F = 34.35$; df = 9; $P < 0.0001$), but quadratic regression models showed that only at Dededo were the regression relationships, R^2, and the correlation between trap catches and rainfall statistically significant ($P = 0.05$; Fig. 6). No significant correlation was observed between trap catches and rainfall at other locations (Table 1).

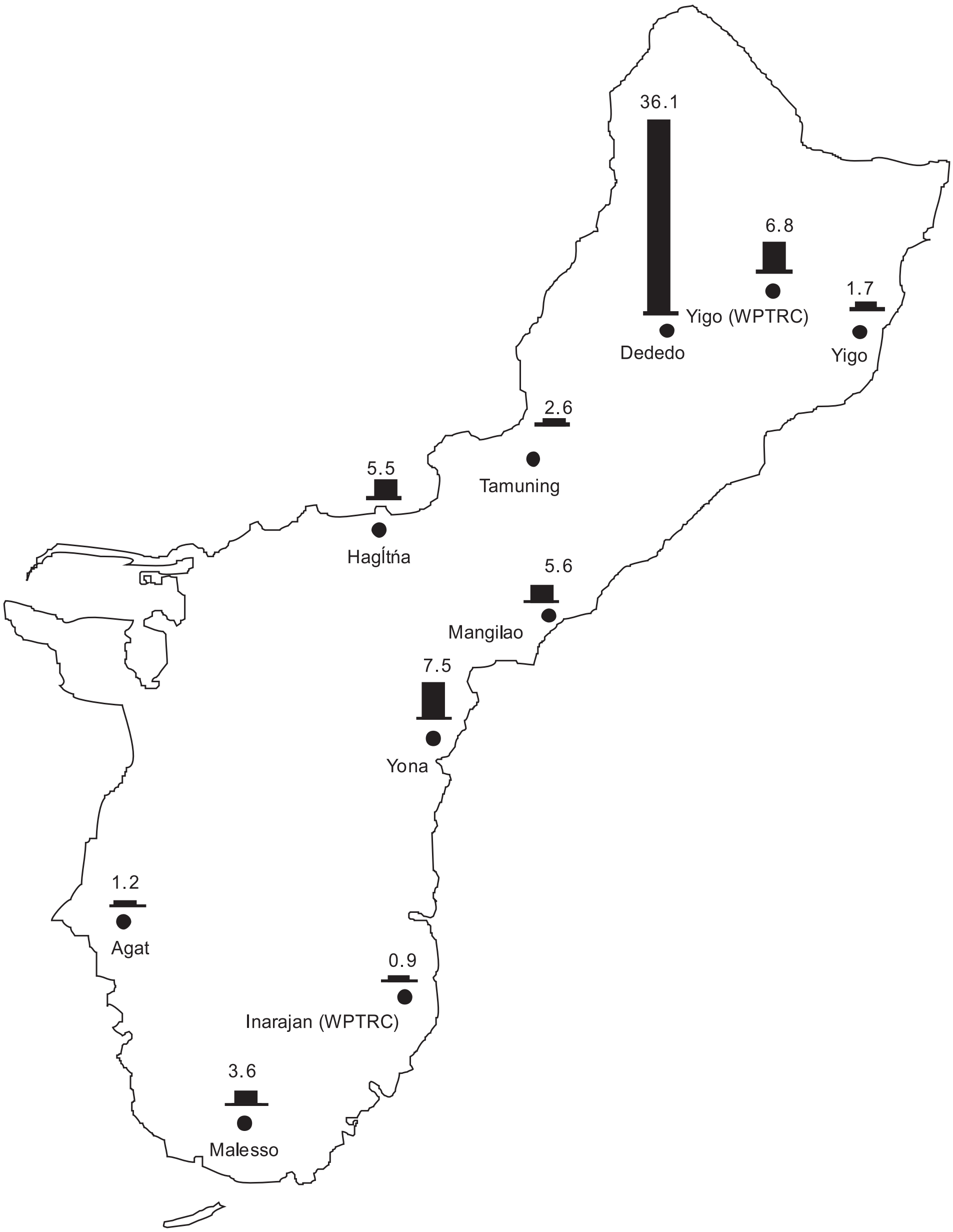


Fig. 4. Mean numbers of adult *C. sordidus* caught per week in ramp traps baited with pheromone lures at 10 locations on Guam

Table. 1. Linear effects (The GLM Procedure) of rainfall on the number of catches of C. sordidus for different sites.

Location	Mean ± SD	*F*-value	DF	Sum of squares	Mean square	*P*-value	R^2-value
Hagåtña	5.02 ± 1.68	1.31	2	7.12	3.56	0.30	0.15
Agat	0.96 ± 1.01	0.53	2	1.14	0.57	0.60	0.06
Dededo	35.12 ± 10.94	3.22	2	303.58	301.79	0.31	0.05
Inarajan WPTRC	0.63 ± 1.01	1.31	2	2.54	1.27	0.30	0.15
Malesso	3.07 ± 2.52	1.98	2	22.57	11.28	0.17	0.22
Mangilao	4.08 ± 3.30	0.29	2	6.82	3.41	0.75	0.03
Tamuning	2.02 ± 1.45	0.26	2	1.20	0.60	0.77	0.03
Yigo	1.34 ± 1.35	0.42	2	1.63	0.81	0.66	0.05
Yigo WPTRC	8.87 ± 3.88	0.66	2	20.67	10.33	0.53	0.08
Yoña	7.45 ± 3.35	0.00	2	0.07	0.03	0.99	0.00

Dependent variable: catch (N = 17). The overall trap catch means adjusted for the variation in the rainfall. WPTRC – Western Pacific Tropical Research Center

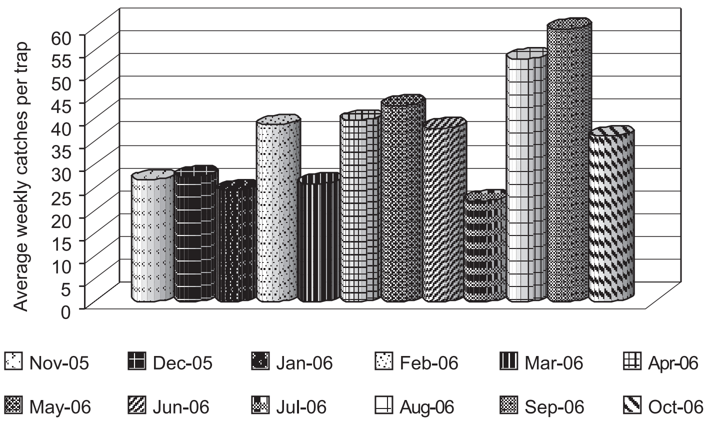
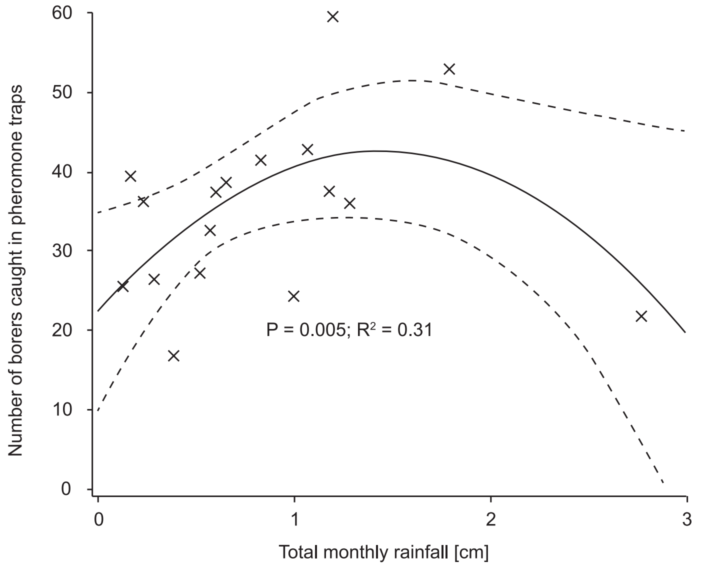


Fig. 5. Mean weekly capture rate of adult *C. sordidus* caught in ramp traps baited with synthetic pheromone at the Dededo location during November 2005–October 2006



Regression Equation:
catch = 22.2532 + 27.92436*total monthly rainfall – 9.579371*total monthly rainfall^2

Fig. 6. A regression relationship (R^2) and the statistical significance of the correlation between the mean number of borers caught and rainfall (cm) at Dededo location

DISCUSSION

In the present study, ramp traps baited with pheromone lures caught significantly higher numbers of *C. sordidus* than unbaited ones. The literature provides many examples of insects that use both visual and olfactory cues to locate mates (Prokopy 1986), but others are known that use only visual cues (Prokopy and Owens 1983; Prokopy 1986) or only olfactory ones (Vet and Dicke 1992; Reddy and Guerrero 2004). In addition, synergetic response has been observed in quite a few insect groups (Raguso and Willis 2002; Reddy and Guerrero 2004). Hidaka (1972) reported the necessity of visual stimuli in addition to pheromones to attract *Hyphantria cunea* (Drury) (*Lepidoptera: Arctiidae*) males, and Carlton and Cardé (1990) noticed that *Lymantria dispar* (L.) (*Lepidoptera: Lymantridae*) males also used visual cues after landing on females. More recently, Fukaya *et al*. (2006) demonstrated the importance of visual stimulus (black and gray sources) in combination with the female sex pheromone anthranilic acid for mate location in the black chafer, *Holotrichia loochooana loochooana* (*Coleoptera: Scarabaeidae*). Our results show that *C. sordidus* relies exclusively on olfactory cues.

We studied the effect of shading on trap catches because placement is one of the important factors governing trap efficacy (Blackmer *et al*. 2008). Although very few reports address the effect of shade on trap catches, our results are consistent with those that have. For example, Arbogast *et al*. (2007) reported a marked preference of the small hive beetle, *Aethina tumida* (Murray) (*Coleoptera: Nitidulidae*), for shaded traps over those placed in sunshine, and Sallam *et al*. (2007) recommended that traps be placed at the edge of the field or under the shade of trees in monitoring of *Rhabdoscelus obscurus* (*Coleoptera: Curculionidae*). We believe that sunlight may have unfavourable reflective effects on trap colour, or it may slightly modify trap colour to the eyes of the insect, but more probably, sunlight affects the chemical stability of the pheromone, decreasing its effectiveness. In addition, the insects may simply avoid sunlight in general because it, e.g., overheats or desiccates them. Another such possible reasons could be *C. sordidus* are nocturnal. They like darkness that could be the reason why they respond to shaded areas

Economic trap-catch thresholds were not available for *C. sordidus* in Guam or the Pacific region in general, but trap catch densities in the present study were very high compared with the trap densities of 15 adults per trap reported by Smith (1982). The threshold for Hawaii was five adults per trap (Mau and Kessing 2005). Similarly, the economic threshold values for *C. sordidus* in South Africa were one to two adults per trap (Govender and Viljoen 2004). According to ChemTica Internacional, S.A. (unpublished data), trap catch threshold levels for *C. sordidus* are low, < 5 adults per week; medium, 5–10 adults per week; high, >10 adults per week. Our results therefore showed that northern sites had medium to high infestation levels, whereas the southern sites had relatively low levels. Guam's close proximity to Hawaii might mean that the threshold levels reported by Mau and Kessing (2005) and ChemTica Internacional, S.A. are an appropriate reference, but this conjecture should be tested in the near future.

Populations of *C. sordidus* clearly differ in different parts of Guam. In the present study, rainfall had a significant effect on the trap catches, particularly at the Dededo site. Our results do not corroborate those of Tinzaara *et al*. (2005), who found that relative humidity was significantly positively correlated with *C. sordidus* catches but that wind speed, temperature and rainfall had no effect. On Guam, temperature, wind speed, and relative humidity vary little, so we did not include these factors in our study.

Further studies will be required to determine whether mass trapping alone can eradicate *C. sordidus* or at least reduce its population below the economic threshold level. Alternatively, pheromone-based trapping could be used as part of an integrated pest management (IPM) program in Guam. Although the present experiments were conducted on a small Pacific island, the results provide basic, applied and practical information on the control of the banana borer that could be transferred to any other region. We expect our results to alert pest management specialists in our area to take the necessary control measures, so as to avoid further spread of the pest to neighbouring islands. However, further studies are needed for example to determine whether pheromone trapping can suppress significantly weevil populations and damage.

ACKNOWLEDGEMENTS

This research was supported by Grant #98-34135-6786 from the Tropical and Subtropical Agricultural Research (TSTAR), Special Grants, CSREES, USDA. We thank Mr. Raymond Gumataotao and Ms. Nakita Braganza for their help during this study.

REFERENCES

Alpizar D., Fallas M., Oehlschlager A.C., Gonzalez L.M., Jayaraman S. 1999. Weevil aggregation pheromones for mass trapping banana weevil in banana and plantain. Abstracts of the XIV International Plant Protection Congress, p. 100. Jerusalem, Israel, July 1999.

Arbogast R.T., Torto B., Van Engelsdorp D., Teal P.E.A. 2007. An effective trap and bait combination for monitoring the small hive beetle, *Aethina tumida* (Coleoptera: Nitidulidae). Florida Entomol. 90: 404–406.

Beauhaire J.P., Ducrot H., Malosse C., Rochat D., Ndiege I.O., Otieno D.O., 1995. Identification and synthesis of sordidin, a male pheromone emitted by *Cosmopolites sordidus*. Tetrahedron Lett. 36: 1043–1046.

Blackmer J.L., Byers J., Rodriguez-Saona C. 2008. Evaluation of colour traps for monitoring *Lygus* spp.: design, placement, height, time of day, and non-target effects. Crop Prot. 27: 171–181.

Budenberg W.J., Ndiege I.O., Karago F.W. 1993. Evidence for volatile male-produced pheromone in banana weevil *Cosmopolites sordidus*. J. Chem. Ecol. 19: 1905–1916.

Carlton R.E., Cardé R.T. 1990. Orientation of male gypsy moths, *Lymantria dispar* (L.), to pheromone sources: the role of olfactory and visual cues. J. Insect Behav. 3: 443–469.

Fletcher T.M., Moore J.C., Kitching W. 1997. Absolute configuration of Sordidin and 7-Episordidin emitted by the banana weevil, *Cosmopolites sordidus*. Tetrahedron Lett. 38: 3475–3476.

Franzmann B.A. 1972. Banana weevil borer in North Queensland. Queensland Agric. J. 319–321.

Fukaya M., Wakamura S., Arakaki N., Yasui H., Yasuda T., Akino T. 2006. Visual 'pinpoint' location associated with pheromonal cue in males of the black chafer *Holotrichia loochooana loochooana* (Coleoptera: Scarabaeidae). Appl. Entomol. Zool. 41: 99–104.

Gold C.S., Pena J.E., Karamura E.B. 2001. Biology and integrated pest management for the banana weevil *Cosmopolites sordidus* (Germar) (Coleoptera: Curculionidae). Integr. Pest Manage. Rev. 6: 79–155.

Govender P.,Viljoen A. 2004. The biology and management of the banana weevil, *Cosmopolites sordidus* in South Africa. Infomusa 11: X.

Gressitt J.L. 1954. Insects of Micronesia. Vol. 1. Bishop Museum, Honolulu.

Hidaka T. 1972. Biology of *Hyphantria cunea* Drury (Lepidoptera: Arctiidae) in Japan. XIV. Mating behavior. Appl. Entomol. Zool. 7: 116–132.

Jayaraman S., Ndiege I.O., Oehlschlager C.A., Gonzales L.M., Alpizar D., Fallas M., Budenburg W.J., Ahuya P. 1997. Synthesis and analysis and field activity of sordidin, a male-produced aggregation pheromone of the banana weevil *Cosmopolites sordidus*. J. Chem. Ecol. 23: 1145–1161.

Koppenhoeffer A.M., Seshu Reddy K.V., Sikora R.A. 1994. Reduction of banana weevil populations with pseudostem traps. Inter. J. Pest Manag. 40: 300–304.

Mau R.F.L., Kessing J.L.M. 2005. *Cosmopolites sordidus* (Germar) (http://www.extento.hawaii.edu/Kbase/crop/type/cosmopol.html).

McIntyre B.D, Gold C.S., Kashaija I.N., Ssali H., Night G., Bwamiki D.P. 2001. Biomass, nutrients, soil water and pest incidence in banana-legume intercrops. Biol. Fert. Soils 34: 342–348.

Mori K., Nakayama S., Takikawa H. 1996. Synthesis and absolute configuration of sordidin, the male-produced aggregation pheromone of the banana weevil, *Cosmopolites sordidus*. Tetrahedron Lett. 37: 3741–3744.

Ndiege I.O., Jayaraman S., Oehlschlager A.C., Gonzalez L.M., Alpizar D., Fallas M. 1996. Convenient synthesis and field activity of a male-produced aggregation pheromone for *Cosmopolites sordidus*. Naturwissenschaften 83: 280–282.

Oehlschlager C.A., Alpizar D., Fallas M., Gonzalez L.M., Jayaraman S. 2000. Pheromone-based mass trapping of the banana weevil *Cosmopolites sordidus* and the West Indian sugarcane weevil, *Metamasius hemipterus* in banana and plantain. Abstracts of the XXI International Congress of Entomology. Iguassu Falls, Brazil, 20–26 August 2000.

Ostmark H.E. 1974. Economic insect pests of bananas. Annu. Rev. Entomol. 19: 161–176.

Prokopy R.J. 1986. Visual and olfactory stimulus interaction in resource finding by insects. p. 81–90. In: "Mechanisms in Insect Olfaction" (T.L. Payne, M.C. Birch, C.E.J. Kennedy eds.) Oxford University Press, Oxford, UK.

Prokopy R.J., Owens E.O. 1983. Visual detection of plants by herbivorous insects. Annu. Rev. Entomol. 28: 337–364.

Raguso R.A., Willis M.A. 2002. Synergy between visual and olfactory cues in nectar feeding by naive hawkmoths. Anim. Behav. 63: 685–695.

Reddy G.V.P. 2007. Improved semiochemical-based trapping method for old-house borer, *Hylotrupes bajulus* (Coleoptera: Cerambycidae). Environ. Entomol. 36: 281–286.

Reddy G.V.P., Guerrero A. 2004. Interactions of insect pheromones and plant semiochemicals. Trends Plant Sci. 9: 253–261.

Rukazambuga N.D., Gold C.S., Gowen S.R. 1998. Yield losses in East African highland banana (*Musa* spp., AAA-EA group) caused by the banana weevil, *Cosmopolites sordidus* Germar. Crop Prot. 17: 581–589.

SAS Institute Inc. 2004. SAS/STAT user's guide, release 9.13. SAS Institute, Cary, NC.

Sallam M.N., Peck D.R., McAvoy C.A., Donald D.A. 2007. Pheromone trapping of the sugarcane weevil borer, *Rhabdoscelus obscures* (Boisduval) (Coleoptera: Curculionidae): an evaluation of trap design and placement in the field. Aust. J. Entomol. 46: 217–223.

Sengooba T. 1986. Survey of banana pest problem complex in Rakai and Masaka districts, August 1986: preliminary trip report. Ministry of Agriculture, Namulonge Research Station, Uganda.

Sikora R.A., Bafokuzara N.D., Mbwana A.S.S., Oloo G.W., Uronu B., Seshu Reddy K.V. 1989. Interrelationship between banana weevil, root lesion nematode and agronomic practices and their importance for banana decline in the United Republic of Tanzania. FAO Plant Protection Bulletin 37: 151–157.

Smith RI. 1982. *Cosmopolites sordidus* Germ. pp. 438–442. In: "Enfermedades, plagas y malezas de cultivos tropicales" (J. Kranz, H. Schmutterer, W. Koch eds.) Paul Parey, Berlin & Hamburg, Germany.

Stover R.H., Simmonds N.W. 1987. Bananas. Tropical Agriculture Series. Scientific and Technical, UK.

Tinzaara W., Tushemiereirwe W.K., Kashija I. 2000. Efficiency of pheromones and trap type in the capture of the banana weevil *Cosmopolites sordidus* Germar in Uganda. Ugandan J. Agric. Sci. 5: 91–97.

Tinzaara W., Dicke M., Van Huis A., Gold C.S. 2002. Use of infochemicals in pest management with special reference to the banana weevil, *Cosmopolites sordidus* (Germar) (Coleoptera: Curculionidae). Insect Sci. Appli. 22: 241–261.

Tinzaara W., Dicke M., Van Huis A., Van Loon J.J.A., Gold C.S. 2003. Different bioassays for investigating orientation responses of the banana weevil, *Cosmopolites sordidus*, show additive effects of host plant volatiles and a synthetic male-produced aggregation pheromone. Entomol. Exp. Applic. 106: 169–175.

Tinzaara W., Gold C.S., Dicke M., Van Huis A., Ragama P.E. 2005. Factors influencing pheromone trap effectiveness in attracting the banana weevil, *Cosmopolites sordidus*. Intern. J. Pest Manag. 51: 281–288.

Vet L.E.M., Dicke M. 1992. Ecology of infochemical use by natural enemies in a tritrophic context. Annu. Rev. Entomol. 37: 141–172.

Waterhouse D.F., Norris K.R. 1987. Biological Control Pacific Prospects. Inkata Press, Melbourne, Australia.

Weddell J.A. 1932. The banana weevil borer. Brief Notes on *Plaesius javanus* Er., the histerid predator. Queensland Agric. J. 38: 24–29.

POLISH SUMMARY

PUŁAPKI FEROMONOWE DO MONITORINGU POPULACJI CHRZĄSZCZA *COSMOPOLITES SORDIDUS* (GERMAN) (COLEOPTERA: CURCULIONIDAE)

Chrząszcz *Cosmopolides sorididus* (Koleoptera: Curculionidae) jest rodzimym gatunkiem szkodnika występującym w Malezji i Indonezji, chociaż spotykany jest niemal we wszystkich rejonach uprawy drzew bananowych. Celem prezentowanych badań było określenie skuteczności pułapek feromonowych, wpływu zacienienia na liczebność odławianych dojrzałych osobników oraz monitoring populacji chrząszcza *C. soridus* z zastosowaniem wabiących pułapek feromonowych na wyspie Guam. Przed przystąpieniem do monitoringu przeprowadzono badania podstawowe, z których wynikało, że wabiące pułapki feromonowi usytuowane w cieniu korony drzewa bananowego odławiały znacznie więcej dorosłych osobników w porównaniu do takich samych pułapek wystawionych na ekspozycję słoneczną, a uzyskane różnice były istotne. Badania podstawowe potwierdziły też, że zastosowanie feromonu jako czynnika wabiącego owady miało istotny wpływ na liczebność odławianych chrząszczy w porównaniu z kontrolą (pułapki bez wabiących przynęt). Pułapki wabiące umiejscowiono w 10 punktach na terenie całej wyspy listopadzie 2005. Każdego tygodnia określano liczebność chrząszczy. Wyniki badań wykazały wyższy poziom populacji chrząszczy (powyżej 10 owadów tygodniowo) w północnej części wyspy oraz od niskiego (poniżej 5) do stanu średniego (5–10), w jej południowej części. Uzyskane różnice w poziomach populacji były wysoce istotne. Współczynniki regresji liniowej i kwadratowej wpływu poziomu opadów na liczebność populacji były też statystycznie istotne.