TRAP FOR CAPTURING AND RETAINING *RHYNCHOPHORUS CRUENTATUS* (COLEOPTERA: CURCULIONIDAE) ADULTS USING *SABAL PALMETTO* AS BAIT

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ABSTRACT

Freshly felled cabbage palmettos, *Sabal palmetto* (Walter), were attractive to *Rhynchophorus cruentatus* (Fabricius) adults for at least 35 d. Chopped *S. palmetto* crown tissue placed in 19-liter plastic buckets attracted weevils, but for less than 35 d. Captured weevils did not always remain in the harborage of chopped tissue and were able to escape from uncovered buckets. Baffles constructed from 5 cm long polyvinyl chloride tubes glued together longitudinally and placed over bucket openings effectively prevented escape of *R. cruentatus* adults. Buckets covered by baffles and baited with *S. palmetto* tissue were effective at trapping and preventing escape of weevils. Using this trap design, we determined in laboratory and field assays that *S. palmetto* crown tissue is most attractive to *R. cruentatus* adults within 72 h after harvest from a healthy tree. The optimal time for collection and analysis of volatile compounds from palm tissue which are attractive to weevils appeared to be 24-72 h after palm harvest. The trap described here has several potential applications for the biological study, detection, and management of *Rhynchophorus* spp.

RESUMEN

Palmetos de repollo [*S. palmetto* (Walter)] recientemente tumbados atraían a los adultos de *Rhnychophorus cruentatus* (Fabricius) durante por lo menos 35 días. Tejido picado de hojas colocado en baldes plásticos de 19-litros atraía a los picudos, pero durante menos de 35 días. Picudos capturados no siempre se quedaban en el tejido picado y eran capaces de escapar de los baldes. Deflectores construídos de tubos de polivinilo de 5 cm de longitud pegados a lo largo y puestos sobre las aperturas de los baldes prevenían efectivamente el escape de adultos de *R. cruentatus* y *R. palmarum* (L.). Baldes cubiertos por deflectores y utilizando tejidos de palmas como cebo capturaban y prevenían el escape de *R. cruentatus* en el campo. Utilizando este diseño de trampa, determinamos en ensayos de laboratorio y de campo que el tejido de las hojas de *S. palmetto* es de mayor atracción a los adultos de *R. cruentatus* dentro de 72 horas despues de estar cortado de una palma sana. Los resultados de este estudio indican que el período óptimo para colección y analisis de los compuestos volatiles los cuales emanan de los tejidos de palmas y son atractivos a *R. cruentatus* es de 24-72 horas despues de cortarlos de la palma. El diseño de la trampa descrita tiene varias aplicaciones para el estudio biológico, detección y control de *Rhynchophorus* spp.

The largest weevil in the continental United States is the Palmetto weevil, *Rhynchophorus cruentatus* (Fabricius) (Woodruff 1967). This relatively rare insect breeds in a variety of palms that are stressed or have been recently transplanted (Giblin-Davis

& Howard 1989). *Rhynchophoruscruentatus* is confined to the southeastern U.S. (Wattanapongsiri 1966), sympatric with the native cabbage palmetto [*Sabal palmetto* (Walter)] (Woodruff 1967).

The closely related American palm weevil (*R. palmarum* [L.]) has been reported from southern Texas and California (based on the collection of two specimens), but its distribution extends primarily southward from Mexico and Cuba into South America and the West Indies (Wattanapongsiri 1966). *Rhynchophorus palmarum* is the primary vector of *Bursaphelenchus cocophilus* (Cobb). This nematode is responsible for red ring disease, an important malady of coconut (*Cocos nucifera* L.) and African oil (*Elaeis guineensis* Jacq.) palms in the Neotropics (see Giblin-Davis 1991 for distribution of red ring disease).

It has been suggested that *R. cruentatus* could be a capable vector for the red ring nematode if the nematode were ever introduced into southern Florida (Gerber et al. 1990, Giblin et al. 1987). Esser (1969) noted that red ring disease could easily be imported into Florida from infested areas. Considering the close proximity of this disease to the southeastern U.S. (< 400 km from its closest confirmed point in the Yucatan peninsula of Mexico) it is important to learn as much about the biology, detection, and management of *Rhynchophorus* spp. as possible.

Rhynchophorus adults are strongly attracted to stressed or dying palms (Wattanapongsiri 1966) and also appear to rely on semiochemicals for aggregation (Rochat et al. 1991a, 1991b, Oehlschlager et al. 1991). Trapping with coconut stem tissue as bait has been successful for monitoring the seasonal population dynamics of *R. palmarum* in coconut (Hagley 1963) and oil palm (Schuiling & van Dinther 1981) plantations. Griffith (1987) suggested that traps baited with Lannate-treated coconut palm tissue would effectively control *R. palmarum* adults and red ring disease, although quantitative support of this method is not available. Similarly, Chittenden (1902) suggested that stressed *S. palmetto* and *Phoenix canariensis* Hortorum ex Chabaud tissue is attractive to *R. cruentatus* adults, therefore, tissue-baited traps could be used to monitor this species.

The objectives of this study were to verify that *R. cruentatus* adults are attracted to stressed *S. palmetto* tissue, to develop traps to capture and retain live *R. cruentatus* and *R. palmarum* adults, and to use an optimized trap to temporally quantify attractiveness of cut *S. palmetto* tissue to *R. cruentatus* adults.

Materials and Methods

Attraction to Felled Trees

Five mature *S. palmetto* trees (4-7 m tall) were felled within a grove near West Palm Beach, Palm Beach Co., Florida and periodically observed for *R. cruentatus* adults attracted to cut surfaces. The trees (spaced approximately 10 m apart) were cut on 12 July 1990 at about 0.5 m above the ground. The crown (distal growing portion) was then severed and dragged 0.5 m from the felled stem (trunk), resulting in four exposed tissue cross-sections (stump, basal stem, distal stem, and basal crown). Leaves trimmed from the crown were used to cover cut surfaces and provide shelter for weevils. Adult *R. cruentatus* on each surface were removed, counted, and sexed at 1, 4, 6, 8, 11, 14, 19, and 35 d after felling. Data were subjected to $\sqrt{(X + 0.5)}$ transformation and analyzed by the Statistical Analysis System general linear models procedure (SAS Institute 1985) for differences between surfaces within each collection period. Least significant difference tests (SAS Institute 1985) were used for mean separation where significant ($P \leq 0.05$) effects occurred. Untransformed means are presented.

Trapping Studies

Nineteen-liter black plastic buckets baited with 3.7 kg of chopped *S. palmetto* crown tissue were used to trap *R. cruentatus* adults. Two 5-mm diam. holes drilled in the bottom of each bucket provided drainage. On 23 August 1990, three trap buckets (uncovered) were set on the ground approximately 10 m apart in a *S. palmetto*grove at the West Palm Beach site. All *R. cruentatus* adults in the buckets were collected and sexed 1, 4, 6, 10, and 15 d after installation.

To determine if closures could be used to retain captured weevils, an empty bucket covered with parallel steel wires (3-mm diam.) spaced 2.5 cm apart was compared with an empty, uncovered bucket. In the first test, 10 *R. cruentatus* adults were placed in each bucket and observed for 30 min. for the following responses: successful flight out of trap, successful walking out of trap, attempted but failed flight out of trap, and attempted but failed walking out of trap. This test was repeated except that the inside surface of the top 10 cm of each trap was coated with a thin layer of petroleum jelly, 11 weevils were placed in each bucket, and responses were observed for 1 h. The temperature during both tests was 32°C.

Based on the results of the above experiment, a different trap top was designed to retain captured weevils. Tubes made from polyvinyl chloride (PVC) with inside diameters (ID) of 1.8, 2.4, 2.6, and 2.9 cm were cut into 5 cm lengths (two for each size) and used to determine what diameter could be used to prevent weevils from walking out. For each size, the inside bore of one tube of the pair was coated with a thin layer of a 1:1 mixture of petroleum jelly and mineral oil. Tubes were vertically oriented, placed side by side, and a *R. cruentatus* adult was placed in each, posterior first. Tubes were observed for escaping beetles for 30 min. This test was repeated six times.

Baffles designed to prevent captured weevils from escaping were constructed by gluing PVC tubes (2.4 cm ID) together longitudinally to form 32-cm diam. lids that covered 19-liter buckets (Fig. 1a). The inside bore of each tube of each baffle was treated with the 1:1 grease mixture, described above, and used for all subsequent tests with *R. cruentatus*.

A bucket covered with a baffle was compared with an uncovered bucket for prevention of escape by flight of *R. cruentatus*. A coating of the grease mixture on the top 10 cm of the inside surface of both buckets prevented weevils from walking out. Traps containing 10 field-collected weevils were placed in a room maintained at 32 ± 2 °C with constant light. After 24 h, the number of weevils remaining in each bucket was determined. This test was replicated four times. Differences between percent of weevils escaping from each trap type were analyzed by the Kruskal-Wallis test (X^2 approximation) (SAS Institute 1985).

To determine if the baffle design was effective for capturing *R. cruentatus* adults, four traps baited with 2.5 kg chopped *S. palmetto* crown tissue were placed in the Big Cypress National Preserve (Collier Co.) in an area interspersed with mature *S. palmetto* and saw palmetto [*Serenoa repens* (Bartr.)]. Each baffled trap was treated with the 1:1 grease mixture and suspended from a holder constructed of a 0.95 cm (diam.) metal rod 1.2 m high with a 0.6 m side arm welded to the top. The longer vertical metal rod was cemented into a cinder block (Fig. 1b). Traps were separated by 20 m and baited on 14 May 1991. Weevils in each trap were collected after 7 d and sexed.

Tissue Age Bioassays

Baffled traps baited with *S. palmetto* crown tissue and placed in *S. palmetto* groves at two locations in southern Florida (one in Davie, Broward Co., and one in Big Cypress National Preserve, Collier Co.) were used to quantify weevil response to aging tissue

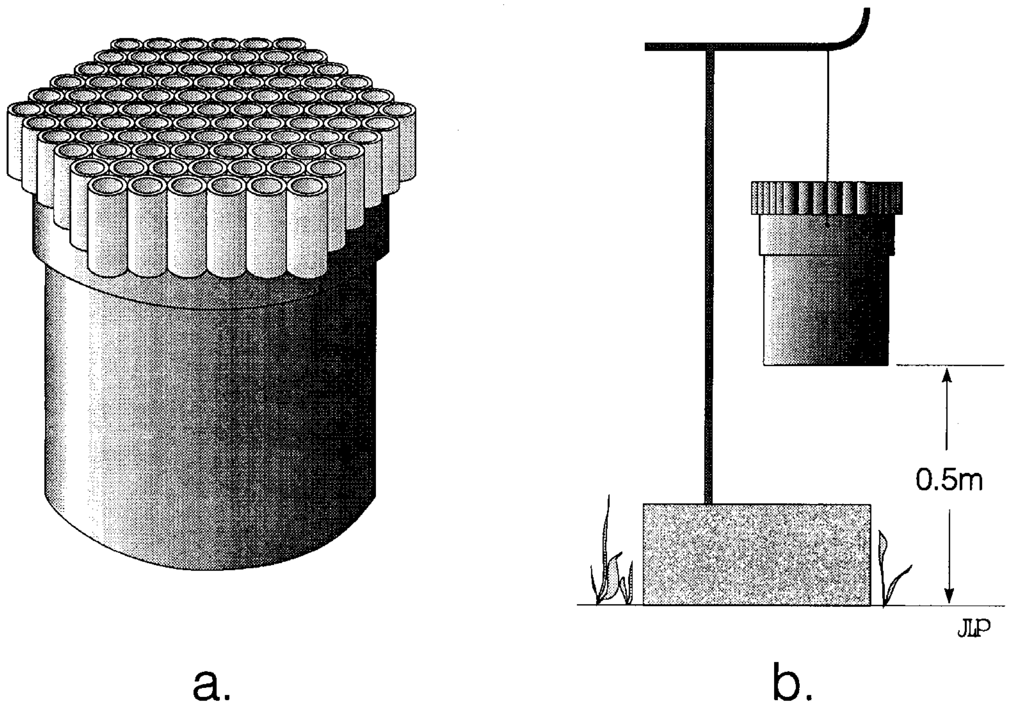

Fig. 1. Baffled lid and bucket used to capture and retain *R. cruentatus* adults attracted to *S. palmetto* tissue (a), and holder to elevate traps above the ground (b).

in the field. Traps were slightly modified by placing a wire mesh barrier (0.6 cm openings) 25 cm above the bottom. Palm tissue (2.5 kg/trap) was placed beneath this barrier, thus preventing weevil contact with, and possible chemical modification of tissue. Moist paper towels were placed above the mesh barrier to provide refugia for trapped beetles. For each replicate (two per location), four traps were suspended from holders (described above) 20 m apart and captured weevils were counted, sexed, and released (50 m from the trap site) daily for 6 days following installation. Tests were conducted in 1991 from 29 May to 4 June and 14 to 20 June in Collier Co., and 7 to 13 June and 23 to 29 June in Broward Co. Data were analyzed by the SAS general linear models procedure for differences in mean weevil capture between days and means were separated by the least significant difference test ($P \leq 0.05$, SAS Institute 1985).

Two bioassay arenas (2.4 × 1.2 × 1.2 m: L × W × H) were constructed and used to quantify *R. cruentatus* adult response to aging palm tissue under controlled conditions. Rigid arena sides and bottoms were painted white and removable tops were constructed of 1-mil clear polyethylene sheeting. In addition, the inside of each arena was lined with 1-mil polyethylene sheeting which was periodically replaced to prevent carry-over desorption from volatile chemicals. Air-flow in each arena (8 cm/sec; measured by movement of smoke) was achieved by placing a 25.4 cm in-line duct fan in a 25.4 cm duct coupled to one 1.2 m^2 outlet. Flexible tubing (10 cm diam.) was used to vent air passing through arenas to the outside of the laboratory. The air-inlet end was covered with 14-mesh fiberglass screen.

One baited and one unbaited (check) baffled trap were placed in each arena at the air inlet end 20 cm from walls and each other. For each of the six replications of the experiment, baited traps received 2.5 kg of fresh shredded *S. palmetto* crown tissue dissected from 7.5 cm above the growing point to 7.5 cm into the woody stem. A mesh barrier and moist paper towel was placed in each trap. The outside surface of the bottom half of each bucket was treated with a thin layer of the grease mixture to prevent weevils from walking up buckets. For each test, either 15 male or 15 female laboratory-reared (Giblin-Davis et al. 1989) or recently field-collected (Hendry Co., Florida) weevils were placed in a clear plastic release container (31 × 23 × 10 cm: L × W × H) located in each arena near the air outlet end. The inside walls of each release container were greased to insure an exit by flight. After 24 h, weevils were removed from each trap and arena and allowed to "recover" for 24 h with an apple slice and moist paper towels, and were then placed back in the arena. During the "recovery" period another group of weevils was placed within each arena as above. Weevils were reused because a limited number were available. Attractancy bioassays were conducted with palm tissue aged 24, 48, 72, 96, 120, and 144 h after dissection from trees. During tests, temperature was maintained at 32 ± 2 °C, and relative humidity ranged from 40-70%. Continual light was provided by fluorescent fixtures (1.0 Lux).

For each 24-h period, mean percent response of weevils to baited and unbaited traps was calculated as the number caught in each trap per total number flying (total number released - number remaining in release container). The *t*-test procedure ($P \leq 0.05$, SAS Institute 1985) was used to compare mean percent response between baited and unbaited traps during each 24-h period.

Results

Attraction to Felled Trees

Rhynchophorus cruentatus adults were collected from one or more cut surfaces of *S. palmetto* trees for at least 35 d after felling (Table 1). There was a significant difference in the number of weevils collected from surfaces on the first ($F = 4.95$; df = 3,12; $P = 0.018$) and fourth ($F = 3.94$; df = 3,12; $P = 0.048$) day after trees were felled. On day one and four, significantly more weevils were collected from the distal stem than any other surface.

TABLE 1. Palmetto weevil (*R. cruentatus*) adults collected from cut surfaces of 5 mature sabal (*S. palmetto*) palms.

Days after cutting	Mean[1] per cut surface ± SEM							
	Stump		Basal Stem		Distal Stem		Basal Crown	
	No.	♀:♂	No.	♀:♂	No.	♀:♂	No.	♀:♂
1	0.0±0.0 b	–	0.0±0.0 b	–	1.2±0.5 a	1:1	0.2±0.2 b	1:0
4[2]	1.0±0.0 b	1:1	1.0±0.5 b	3:2	3.4±0.9 a	9:8	0.6±0.6 b	1:2
6	3.2±1.6 a	1:1	0.0±0.0 a	–	1.0±0.6 a	3:2	1.4±0.6 a	3:4
8	0.0±0.0 a	–	0.2±0.2 a	0:1	0.4±0.2 a	3:1	0.8±0.5 a	3:1
11	0.2±0.2 a	1:0	0.0±0.0 a	–	0.0±0.0 a	–	0.6±0.4 a	1:2
14	0.2±0.2 a	0:1	0.0±0.0 a	–	0.2±0.2 a	0:1	0.0±0.0 a	–
19	0.0±0.0 a	–	0.0±0.0 a	–	0.8±0.6 a	3:1	0.0±0.0 a	–
35	0.0±0.0 a	–	0.0±0.0 a	–	0.6±0.6 a	–[3]	0.0±0.0 a	–

[1]Means within a row followed by the same letter are not significantly different (least significant difference, $P \leq 0.05$).
[2]N = 2 for stump.
[3]Weevils burrowed into tissue and could not be sexed.

Trapping Studies

Rhynchophorus cruentatus adults were caught in uncovered buckets baited with chopped *S. palmetto* crown tissue that were placed in the field for 15 days (mean no. per trap per d ± SEM, females: 0.7 ± 0.2; males: 0.6 ± 0.3).

Observation of weevils placed in an ungreased and uncovered bucket or a similar bucket covered with parallel steel wires spaced 2.5 cm apart demonstrated that weevils could escape from both. Nine of ten weevils escaped from the uncovered bucket within 30 min.; 8 flew out and 1 walked out. Three weevils escaped from the wire-covered bucket within 30 min. by walking out but none flew out despite 24 attempts. Application of the 1:1 petroleum jelly/mineral oil mixture to the inside surface of buckets eliminated escape by walking out. However, within 1 h, seven and five weevils flew out of the uncovered and covered greased buckets, respectively.

Rhynchophorus cruentatus adults were able to walk out of ungreased individual PVC tubes of 1.8, 2.4, and 2.6 cm ID, and greased tubes of 1.8 and 2.6 cm ID. Baffles for subsequent tests were constructed from greased 2.4 cm ID PVC tubes because this size prevented escape by walking while minimizing tube diameter and decreasing the possibility of escape by flight (wing span range 2.1 - 3.4 cm).

After 24 h, no *R. cruentatus* adults escaped from buckets covered by a greased baffle while 85 ± 5 percent of the weevils placed in uncovered buckets escaped. This difference was significant ($X^2 = 6.40$, df = 3, $P = 0.01$).

Rhynchophorus cruentatus adults were caught in baited buckets covered with baffles that were placed in the field for 7 d (mean number per trap per d ± SEM, males = 0.6 ± 0.1, females = 0.8 ± 0.3).

Tissue Age Bioassay

When tested in the field, the number of *R. cruentatus* adults caught in traps baited with chopped *S. palmetto* crown tissue varied through time ($F = 2.46$; df = 5,87; $P = 0.04$). Significantly more weevils were caught in traps on day two than at any other time (Table 2).

In the laboratory, most *R. cruentatus* males and females were caught in baffled traps baited with chopped *S. palmetto* crown tissue from 24 to 72 h after harvesting (Fig. 2). Weevil response to baited traps was significantly greater than to unbaited traps between 24 and 72 h (males, 24 h: $t = 4.00$; df = 5; $P = 0.010$, 48 h: $t = 3.59$; df = 5; $P = 0.016$, 72 h: $t = 5.06$; df = 5; $P = 0.004$, females, 24 h: $t = 2.86$; df = 5; $P = 0.036$, 48 h: $t = 2.76$; df = 5; $P = 0.040$, 72 h: $t = 2.72$; df = 5; $P = 0.042$). In addition, response of females to traps baited with 120 h aged crown tissue was significantly greater than to unbaited traps at 120 hours ($t = 2.61$; df = 5; $P = 0.048$).

TABLE 2. ATTRACTION OF *R. CRUENTATUS* ADULTS TO TRAPS PLACED IN THE FIELD AND BAITED WITH 2.5 KG CHOPPED *S. PALMETTO* CROWN TISSUE.

Days after cutting	Mean[1] No./Trap (n=4) ± SEM	♀:♂
1	0.1 ± 0.1 b	0:1
2	0.6 ± 0.3 a	1:8
3	0.2 ± 0.1 b	2:1
4	0.1 ± 0.1 b	0:1
5	0.1 ± 0.1 b	0:1
6	0.0 ± 0.0 b	–

[1]Means followed by the same letter are not significantly different (least significant difference, $P \le 0.05$).

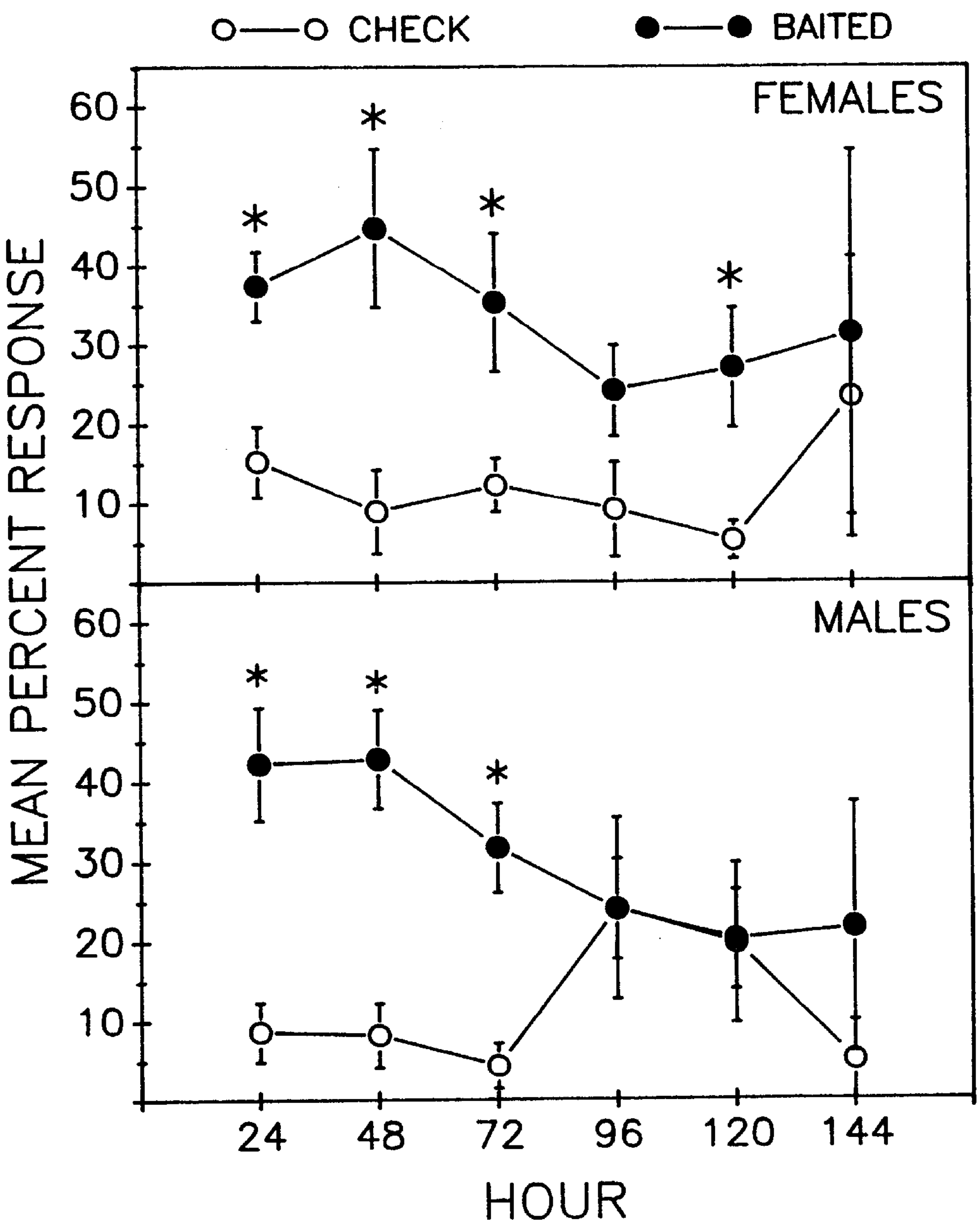

Fig. 2. Percentage of *R. cruentatus* adults flying in arenas and caught in unbaited traps and traps baited with 2.5 kg chopped *S. palmetto* crown tissue aged 24, 48, 72, 96, 120, and 144 h. (*) indicates significant difference between baited and unbaited traps, paired *t*-test, $P \leq 0.05$.

Discussion

Weevils in the genus *Rhynchophorus* attack stressed and damaged palms (Wattanapongsiri 1966). It was suggested by Chittenden (1902) that fermented sap exuding from dead or wounded palms acts as a strong attractant for *R. cruentatus* adults. Results of this study substantiate earlier observations that *R. cruentatus* adults are attracted to volatile compounds emitted by stressed *S. palmetto* trees and suggest that olfaction plays an important role in orientation of adults to their host plants. The chemical ecology of *Rhynchophorus* spp. has, until recently, received little attention. Hagley (1965) empirically tested several organic compounds for their ability to attract *R. palmarum* adults in an olfactometer. He found that malt extract, skatole, and isoamyl acetate were attractive in the laboratory, and that a mixture of these compounds was more attractive in the field than coconut stem tissue. This mixture was, however, an ineffective *R. cruentatus* attractant when tested in the field (unpub. data). Rochat (1987) reported that *R. palmarum* females responded strongly (in an olfactometer) to fermented oil palm sap and that males responded similarly to the palm sap and to a skatole, isoamyl acetate, and ethanol mixture. Furthermore, Moura et al. (1989) and Rochat et al. (1991a) provided evidence that *R. palmarum* males produce an aggregation pheromone attractive to both males and females. Rochat et al. (1991b) identified the major component of the pheromone as (2*E*)-6-methyl-2-hepten-4-ol, however, the chirality of this compound is now known to be 4(*S*) (Oehlschlager et al. 1991). Both the racemic and 4(*S*) chiral isomer of the pheromone are highly attractive in the field when used in conjunction with food sources (Oehlschlager et al. 1991). Preliminary olfactometer results suggest that *R. cruentatus* males also produce an aggregation or arresting pheromone (unpub. data) but at this time, it is not known how or if this compound interacts with palm-produced attractants to influence trap catch.

When placed in traps, chopped *S. palmetto* crown tissue was most attractive to *R. cruentatus* adults within the first 72 h after harvesting. Results of these tests are consistent with studies conducted to determine when most *R. palmarum* adults would be captured at traps after they were baited with palm tissue. Rochat (1990) and Morin et al. (1986) reported that oil palm tissue was most attractive to *R. palmarum* adults in the first two and four days, respectively, after excision from trees. These results suggest that the optimal time to collect volatiles from palm tissues for identification of compounds attractive to *Rhynchophorus* spp. is 24 to 72 h after cutting.

Quantification of *R. cruentatus* attraction to compounds identified from palm tissue will require an effective trap that retains weevils after capture. A number of traps have been described for monitoring and management of *R. palmarum* in the field that have ranged from piles of palm tissue (Morin et al. 1986) and hollowed pieces of sugarcane (Raigosa 1974) to various manufactured devices baited with palm tissue (Maharaj 1965, Mireles 1984, Moura et al. 1989, Raigosa 1974, Rochat 1990, Rochat et al. 1991a). While these systems appear to be effective for attracting weevils, their ability to retain insects after capture was not studied. It has long been assumed that palm tissue used to attract weevils would also provide harborage and dissuade trapped insects from escaping (Chittenden 1902). However, observation of marked *R. cruentatus* adults placed in uncovered buckets baited with chopped *S. palmetto* tissue indicated that weevils are not retained by harborage alone (R.M.G.-D. & R.H.S. pers. obs.). In this study, *R. cruentatus* were able to fly out of uncovered buckets suggesting that escape may be an important element in evaluating trap effectiveness. Insecticides have been used in conjunction with traps to kill weevils before they can escape but this technique may require frequent reapplication of toxin. Maharaj (1965) described a trap designed to physically prevent captured *R. palmarum* adults from flying out by placing wires spaced 2.5 cm apart over the top of the trap. While data indicated that more weevils were caught in wired traps baited with palm tissue than in exposed piles of palm tissue, no data were presented to suggest that weevils did not escape once captured. We have tested several traps in the laboratory and field designed to retain weevils once captured. Using the design similar to that described by Maharaj (1965), we found that *R. cruentatus* adults were able to fly between wires if properly oriented, or were able to grasp wires during flight and pull themselves through. This observation indicated that a more efficient baffle was necessary to interfere with weevil flight out of a trap. Baffles made from 2.4 cm ID PVC tubes did not appear to interfere with *R. cruentatus* entry into buckets (T.J.W. pers. obs.) and when greased, proved to be very effective at retaining captured weevils. In addition, greased baffles constructed from 2.9 cm ID PVC tubes and placed on baited 19-liter buckets were effective for capturing and retaining *R. palmarum* adults in Costa Rica (unpub. data).

The trap design presented in this manuscript has several potential applications as a tool for the biological study, detection, and management of *Rhynchophorus* spp. We have been using this trap to collect live *R. cruentatus* adults for use in laboratory studies, to monitor seasonal population changes, and to quantify weevil attraction to chemicals identified from *S. palmetto* tissues and conspecifics. Traps baited with *C. nucifera* tissue, or identified attractants could be used to detect *R. palmarum* in areas of Florida where introduction is most probable. Because these traps are effective at retaining captured weevils, no toxicants need to be added and weevil health is maintained. This is important if weevil dissections are to be performed to determine the presence or absence of red ring nematodes. This trap design, in conjunction with attractants, may also prove to be an effective alternative to insecticide treated traps for capturing *R. palmarum* adults and subsequently reducing red ring disease incidence.

Acknowledgment

We thank John Cangiamila for technical assistance, Joan Perrier for preparation of Fig. 1, Carlos Chinchilla of United Fruit Company, Coto 47, Costa Rica, for his assistance in collecting *R. palmarum*, A. Duda and Sons for donating *S. palmetto* trees, and A.C. Oehlschlager of Simon Fraser University for sharing his knowledge of *R. palmarum* trapping systems. We are also grateful to Ted Center and Bill Howard for critically reviewing the manuscript and to James Snyder of the Big Cypress National Preserve for his cooperation. This research was supported in part by a USDA Special Grant in Tropical and Subtropical Agriculture CRSR-90-34135-5233 to R.M.G.-D., R.H.S. and J.P. Toth. This manuscript is Florida Agricultural Research Station Journal Series R-01979.

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