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STUDIES ON THE UTILIZATION OF A FEMALE SEX PHEROMONE FOR THE MANAGEMENT OF SWEETPOTATO WEEVIL, *CYLAS FORMICARIUS FORMICARIUS* (F.) (COLEOPTERA: CURCULIONIDAE)

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N. S. Talekar and S. T. Lee (1989) Studies on the utilization of a female sex pheromone for the management of sweetpotato weevil, *Cylas formicarius formicarius* (F.) (Coleoptera: Curculinonidae). *Bull. Inst. Zool., Academia Sinica* **28**(4): 281-288. A female sex pheromone, (Z)-3-dodecen-1-ol(E)-2-butenoate, identified in *Cylas formicarius elegantulus* (Summers) was also active with *C. formicarius formicarius* (F.). A trap baited with 0.1 μg sex pheromone attracted significantly more male sweetpotato weevils than a trap baited with five virgin females. A linear dose response was observed between sex pheromone concentration of 0.001 to 1 mg/trap and the number of insects captured over four weeks. A water trough with openings on all sides proved to be suitable and an economical trap for weevils. A highly significant negative correlation was observed between the distance from pheromone source (up to 100 m) and the number of male sweetpotato weevils recaptured. A 1 mg sex pheromone sample could capture over 94.7% marked males from 10 m and 11.4% ones from 100 m in 24 hours. Preliminary studies indicated a potential of this chemical in mass trapping and communication disruption. A 10 μg sex pheromone sample was uniformly active for at least one month in the field.

Key words: Sweetpotato weevil, Sex pheromone, Trap design, Mass trapping.

A sweetpotato weevil (SPW), *Cylas formicarius formicarius* (F.) (Coleoptera: Curculionidae), is a destructive pest of sweet potato (*Ipomoea batatas* (L.) Lam) in tropical to subtropical Asia, Africa, and the Oceania. Major damage to the roots results from larval feeding through torturous tunnels which are filled with frass. This damage gives the roots terpene odor which makes even slightly damaged roots unfit for human consumption. At the Asian Vegetable Research and Development Center (AVRDC) considerable research has been carried out during the past 15 years to develop suitable control measures to reduce this insect's damage (Talekar, 1987). Several years ago, in our initial studies, we demonstrated the presence of sex pheromone in virgin females of SPW (AVRDC, 1976). Later, presence of similar sex pheromone activity in *C. formicarius elegantulus* (Summers) was demonstrated by Coffelt *et al.* (1978), and recently, a research group in the United States Department of Agriculture (USDA) isolated and synthesized the sex pheromone of *C. formicarius elegantulus* (Heath *et al.*, 1986). To find out whether the same pheromone is effective on *C. formicarius formicarius*, we tested this chemical and worked out various parameters for the utilization of pheromone to control SPW in the field.

MATERIALS AND METHODS

The sex pheromone, (Z)-3-dodecen-1-ol (E)-2-butenoate (99+% pure) was purchased from Bedoukian Research Inc., Danbury, Connecticut, USA. The insects used were either natural population in the field or were reared in laboratory on sweet potato roots and released in the field. For an initial study, a trap similar to one designed by Proshold *et al.* (1986) was used.

Comparison of synthetic pheromone and virgin females

A total of 8 traps; 4 baited with 0.1 μg pheromone each and 4 with five 1–2 day old virgin females were placed randomly in a SPW-infested field. A distance of 30 m was maintained between two adjacent traps. After 24 hours, the number of SPW males caught in the trap was recorded.

Pheromone concentration study

A total of 20 traps, in which each batch of four was baited with 0, 0.001, 0.01, 0.1 or 1.0 mg of synthetic pheromone were placed randomly in SPW-infested field for four successive weeks. A distance of at least 20 m was maintained between two adjacent traps, and the location of traps was changed randomly every day. The number of SPW males captured in each trap was recorded every week.

Trap design study

Traps of the following five designs (Fig. 1) and each baited with 10 μg sex pheromone were placed in a SPW-infested field: (1) sticky paper trap commonly used for monitoring of most lepidopterous insects (Fig. 1A) with pheromone source placed under the top cover; (2) rectangular water trough trap with openings on only two directions (Fig. 1B) and the pheromone source attached to the top cover 2–3 cm above water level; (3) round water trough trap with cover and openings on all directions (Fig. 1C) and the pheromone source hung from the top about 2–3 cm above water level; (4) an ordinary polyethylene bottle with perforation in the upper one third portion and with pheromone coated septum hanging inside (Fig. 1D); and (5) stainless steel funnel trap similar to that used by Proshold *et al.* (1986) (Fig. 1E) wherein the pheromone source was hung 1–2 cm above the top of the funnel. A distance of at least 20 m was maintained between any two adjacent traps. The traps were placed in the field in such a way that the pheromone source will be 10–15 cm above the plant canopy.

In the first experiment, all five traps were tested for three consecutive weeks and the number of insects trapped in each trap per week was recorded. Each week's insect catch was considered as one replicate. In the second experiment in a separate field, only three traps; water trough with openings on all directions, polyethylene bottle and stainless steel funnel traps, were utilized. The traps were placed in the field for four consecutive days. Their location within the field was changed once every day. The number of insects caught in each trap for four consecutive days was recorded. Each day's capture was considered as one replicate. In the third experiment in another field, the test was conducted in a similar fashion as the second experiment except that the insect count was recorded only in three consecutive days and each day's insect count was considered as one replicate.

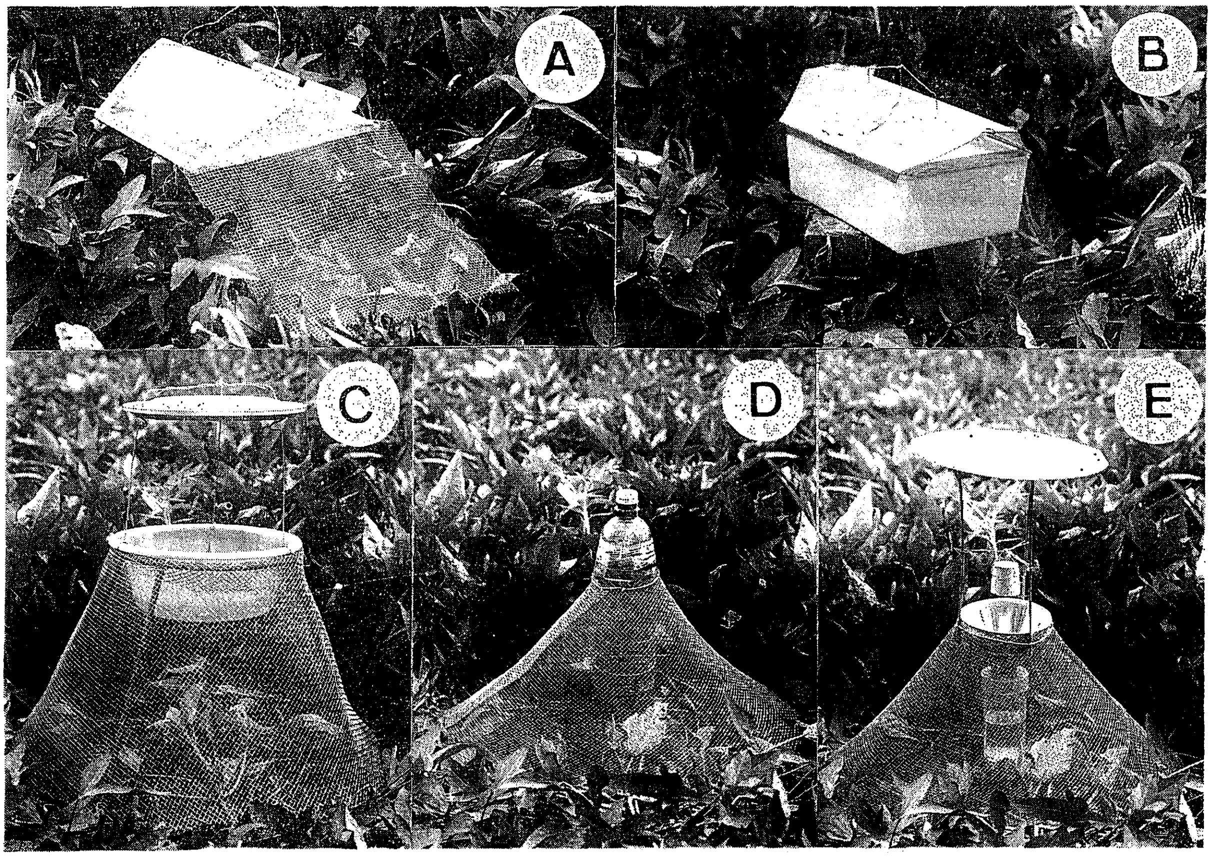

Fig. 1. The five different trap designs: (A) sticky paper, (B) water trough with openings on two directions, (C) water trough with openings on all directions, (D) polyethylene bottle and (E) stainless steel trap.

Insect capture efficiency

Every day for five consecutive days, one water trough trap, one polyethylene bottle trap and one stainless steel trap, each baited with 10 μg sex pheromone, were placed wide apart in an open field. One hundred SPW males marked with paint on their elytra, were released along the circumference one meter away from each trap. The number of marked insects captured in the following day was recorded every day and each day's insect count was regarded as one replicate. The insect capture efficiency was calculated by dividing the number insects trapped by the number of insects released and the product multiplied by 100.

Effective distance study

One water trough trap baited with 1.0 mg synthetic pheromone was placed in an open field, and at distances of 5, 10, 20, 40, 50, 60, 80 and 100 m from the trap, along the wind direction, 100 marked males were released. The number of marked insects captured within 24 hours was recorded. This experiment was repeated for 10 days and the mean number of insects captured from each distance every day were computed. The data were analyzed by simple linear regression and correlation to determine the correlation between the distance of the insects from the trap and the percent of insects captured from each distance.

Mass trapping study

The potential of sex pheromone in reducing the SPW population was studied at AVRDC and Penghu island in the Taiwan Strait. At each location, 2 to 3 traps, each baited with 10 μg pheromone, were placed in one field (0.05 to 0.1 ha) with a distance of 10 to 15 m between two adjacent traps. The number of SPW males captured was recorded every day. The traps were moved within the field every day until the number of insects trapped was reduced substantially. The traps were then moved to the next field and the procedure was repeated until male weevil capture was reduced substantially. This procedure was repeated in six fields at AVRDC and four fields at Penghu island.

Communication distruption study

Rubber septa, each coated with 1.0 mg synthetic sex pheromone were tied to wooden stakes and hung at the height of just above the plant canopy in a SPW-infested field. A plastic petri dish was placed in an inverted position over each septum to protect the pheromone from rain. The septa were placed at the junction of 2 m grid in one location, 5 m grid at the next, and at 10 m grid of the third. A trap baited with 0.1 μg pheromone was placed in the center of each grid and the number of insects captured was recorded once a week for three consecutive weeks. Simultaneously, in the same field but far from the pheromone use area, a 0.1 μg pheromone baited trap was placed and the number of weevils trapped was monitored.

In comparison of effectiveness of synthetic sex pheromone and virgin female, differences between the treatments were compared by Students' *t* test. In remaining studies insect capture data were analyzed by analysis of variance and means among the treatments were separated using Duncan's (1955) multiple range test at $P=0.05$.

RESULTS AND DISCUSSION

Comparison between synthetic pheromone and virgin females

The results of comparison between SPW males captured in pheromone-baited and virgin female-baited traps are summarized in Table 1. The 0.1 μg pheromone baited trap attracted significantly more males than 5 virgin female-baited trap. Proshold *et al.* (1988) reported a greater number of *C. formicarius elegantulus* males captured in 10 or 100 μg baited traps than 1 or 3 virgin female baited traps. They also reported SPW male response at the concentration of 0.01 μg pheromone but they did not use virgin female for comparison. Our results show that the phermone is very active against *C. formicarius formicarius* and can serve as an important tool for monitoring the presence of this insect pest.

Pheromone concentration study

As the pheromone concentration increased from 0.001 to 1 mg per trap, the number of SPW males captured increased proportionately. This pattern remained

Table 1
Comparison of effectiveness between sex pheromone and virgin females in trapping SPW males

Bait	No. males trapped	*t* value[a]
0.1 μg pheromone	69.8	11.5**
5 virgin females	11.5	

[a] Astrisk indicates difference in SPW males captured in two treatments significant at $P=0.01$.

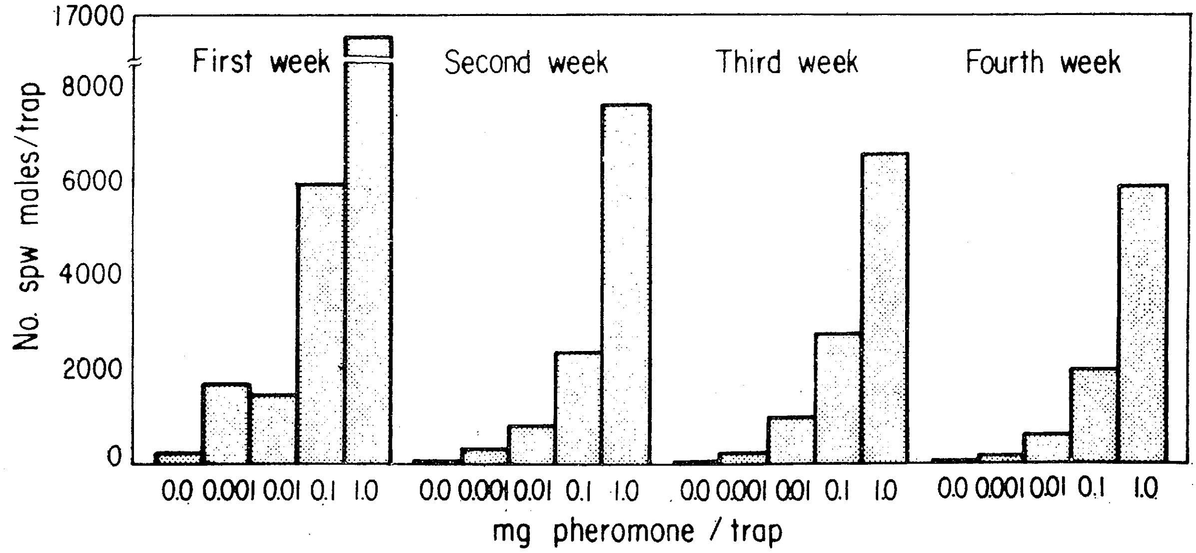

Fig. 2. Dose response of SPW males to various concentrations of sex pheromone durig four weeks.

unchanged during each of the four successive weeks (Fig. 2). A dose-response of SPW male captured was obvious in each week's test. At every succeeding week, however, the number of insects trapped decreased gradually. This could be attributed to the reduction in population of males due to their capture in the pheromone-baited trap in the preceding week. The possibility that this could be due to reduced concentration of pheromone cannot be ruled out but such effect is expected to be insignificant (see later discussion on mass trapping).

Trap design study

In the first experiment in which all five types of traps were included, the sticky paper trap and water trough trap with openings on all directions attracted the greatest number of SPW males (Table 2). The sticky paper trap is not convenient because it needs to be replaced frequently due to

Table 2
Effectiveness of various trap designs in capturing SPW males in pheromone-baited traps

Trap types	No. males captured/trap/week[a]		
	Expt. 1[b]	Expt. 2[c]	Expt. 3[b]
Stiky paper trap	4,138a	—[d]	—[d]
Water trough trap (openings on 2 directions)	3,685abc	—[d]	—[d]
Water trough trop (openings on all directions)	4,023ab	1,901a	873a
Polyethyle bottle trap	2,000bc	2,081a	303a
Stainless steel funnel trap	1,713c	1,436a	797a

[a] Means in vertical columns followed by the same letter are not significantly different (P=0.05, Duncan's [1955] multiple range test).
[b] Mean of three replicates.
[c] Mean of four replicates.
[d] These traps were not utilized in the two experiments.

the sticky surface getting covered by the captured male weevils. The water trough trap with opening on only two opposite directions captured less insects than the water trough trap with opening on all directions. The sticky paper trap and water trough trap with openings on two directions were, therefore, discarded from the subsequent tests. No significant difference in insect capture was observed among the three remaining traps in subsequent tests. However, since the water trough trap with openings in all directions captured greater numbers of SPW males, and its construction entails lower cost than the stainless steel funnel trap, and it is more convenient and durable than the polyethylene bottle traps, this trap was used in subsequent tests.

Insect capture efficiency

No significant difference was observed among three traps in recapturing SPW males placed 1 m away from the pheromone source. Water trough trap captured 92.2%, polyethylene bottle trap, 92.3%, and stainless steel funnel trap, 96.7% of the marked males. This trapping efficiency is quite high and makes all three traps acceptable for practical use.

Effective distance study

The percentage of marked males captured varied from 94.7% at a distance of 5 m to 11.4% at 100 m from the pheromone source. There was a gradual and proportional reduction in the percentage of insects recaptured from the distance of 5 m to up to 100 m from the pheromone baited trap (Fig. 3). At a distance of 10 m, over 90% of the marked males were recaptured within less than 24 h. A distance of 20 m between two adjacent traps will, therefore, be adequate to cotinuously trap the males from the field. This amounts to 25 traps/hectare assuming that the traps are kept stationary throughout the season.

Since the response of *C. formicarius formicarius* to the pheromone was similar to that of *C. formicarius elegantulus*, we

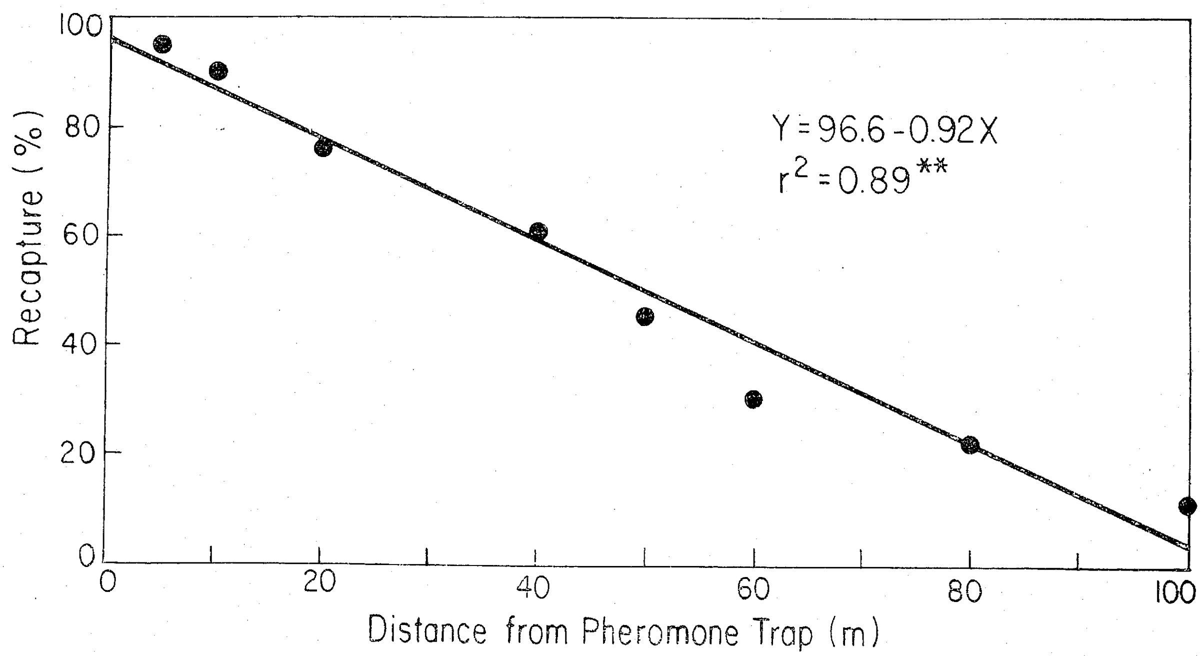

Fig. 3. Male SPW recapture in pheromone baited trap as influenced by the distance of marked males from the pheromone source.

Table 3
Pattern of capturing of sweetpotato weevil males in sex pheromone-baited traps at two locations

Field No.	No. weevils/trap/day								
Day:	1	2	3	4	5	6	7	8	9
				Penghu Island					
1	65	27	72	7	13	31	33	20	5
2	92	92	61	67	126	122	3	12	
3	93	32	41	34	38	24	25	18	5
4	731	328	91	375	101	298	98	109	32
				AVRDC					
1	984	157	75	63	43	9			
2	251	37	43	33					
3	61	42	33						
4	480	6	109	89					
5	234	238	231	1,392	307	74			
6	1,195	1,315	505	455	61				

did not perform trap height study, and instead used the findings of Proshold *et al.* (1986) in our experiments.

Mass trapping study

The results of the mass trapping study, both at AVRDC and Penghu island are presented in Table 3. At each location, the insect capture from the initial field reduced gradually with time. This was initially attributed to the reduction of pheromone concentration due to evaporation. However, when the same trap was placed in a new field, the number of SPW males captured increased dramatically and decreased gradually thereafter. This indicated that the insect population is gradually reduced due to the continuous trapping of SPW males. A 10 μg pheromone was active throughout 35 days at Penghu island and 27 days at AVRDC when the experiment was discontinued. This suggests a potential for the use of this pheromone in mass trapping

Table 4
Influence of exposure to high concentration of sex pheromone on traping weevil males in pheromone-baited traps

Distance between pheromone points[a] (m)	No. males captured (% CD efficiency)[b] during		
	18-21 Sept. 1987	21-24 Sept. 1987	25-30 Sept. 1987
2	54.0 (82.3)b	28.0 (58.5)a	—[c]
5	12.5 (95.4)b	6.3 (90.7)a	6.3 (86.3)b
10	—[c]	—[c]	7.8 (83.0)b
Control	305.5 (0.0)a	67.5 (0.0)a	46.0 (0.0)a

[a] 1 mg pheromone was placed at the junction of 2, 5, or 10 m grid.
[b] Data are means of four replicates. Means in each vertical column followed by the same letter are not significantly different (P=0.05, Duncan's [1955]) % CD efficiency=

$$\frac{\text{No. insects in control} - \text{No. insect in treatment}}{\text{No. insects in control}} \times 100$$

[c] These treatments were not included in respective tests.

for the control of SPW in the farmers' field.

Communication disruption study

The results of the communication disruption are summarized in Table 4. The communication disruption effect was judged by the number of SPW males trapped in 0.1 μg pheromone baited trap. Since in the previous study, 0.1 μg pheromone-baited trap captured a greater number of males than 5 virgin female-baited trap, we opted for the use of more convenient synthetic pheromone to monitor the weevil. The greater the confusion, caused by the high concentration of the pheromone in the surroundings, the lesser was the number of insects trapped in the pheromone baited trap. Substantial reduction in the number of males captured in the pheromone-baited trap was achieved in the treated area compared to the control area in all three tests. In two of the three tests the difference was statistically significant. Statistically, there was no significant difference in communication disruption between 2 m and 5 m or 5 m and 10 m grids. These results indicate the potential of using this pheromone for communication disruption to control SPW in the field.

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利用性費洛蒙管理甘藷蟻象之研究

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Cylas formicarius elegantulus (Summers) 雌蟲分泌之性費洛蒙，(Z)-3-dodecen-1-ol(E)-2-butenoate，對 *Cylas formicarius formicarius* (F.) 雄蟲具活性反應。0.1 微克性費洛蒙之誘蟲效果顯著的比 5 隻處女雌蟲之誘蟲效果佳。在 4 週之誘蟲試驗中，性費洛蒙之濃度從 0.001 毫克到 1 毫克時，與所誘蟲數成線性關係。圓形開口之水盤誘蟲器具實用及經濟性。在 100 公尺內誘引距離與誘引蟲數顯著的呈負線性關係。釋放標幟雄蟲24小時後，1 毫克的性費洛蒙可誘得90%以上距性費洛蒙10公尺處之雄蟲，距性費洛蒙 100 公尺遠之雄蟲亦有 11.4%被誘得。初步試驗結果顯示此性費洛蒙極具大量誘殺及交尾擾亂之潛能。在田間 10 微克之性費洛蒙可穩定的使用至少 1 個月以上。