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Eradication Programs of Two Sweetpotato Pests, *Cylas formicarius* and *Euscepes postfasciatus*, in Japan with Special Reference to their Dispersal Ability

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Abstract

Eradication programs are being implemented for 2 sweetpotato weevil pests, *Cylas formicarius* and *Euscepes postfasciatus*, in the Ryukyu Islands located in the southernmost part of Japan by the application of the sterile insect technique (SIT). As it is essential for the implementation of the programs to assess the dispersal ability of the weevils, recent studies were reviewed. Both the flight and walking ability of *C. formicarius* was much higher in males than in females when determined in the laboratory. Synthesized sex pheromone of *C. formicarius* has been used as a strong lure to capture the males in the field. Results of the mark-recapture experiments suggest that a distance of at least 2 km is needed for the range of the buffer zone to separate the SIT target area from others. Since *E. postfasciatus* is unable to fly, only the walking ability was evaluated in the laboratory, indicating that the females exhibited a fairly higher locomotion activity compared with the males. Since no effective attractant for *E. postfasciatus* has been identified yet, information on the dispersal activity in the field is limited. Fundamental studies should be conducted to determine the dispersal ability of both weevil pests to implement successfully the eradication programs.

Discipline: Insect pest
Additional key words: Okinawa, Kagoshima, sterile insect technique (SIT), sex pheromone

Introduction

Sweetpotato is the third most important root/tuber crop in the world[3]. However, the presence of the sweetpotato weevil, *Cylas formicarius* (Fabricius), and the West Indian sweetpotato weevil, *Euscepes postfasciatus* (Fairmaire) has prevented the growers from expanding the acreage and production of sweetpotato in the developing countries of tropical and subtropical regions, especially in Asia[7]. In Japan, these 2 weevil pests are distributed only in the Ryukyu Islands and Bonin Islands, the southernmost part of the Japanese territory, and movement from infested areas to uninfested areas of host plants of the pests is strictly prohibited, based on Japan's Plant Protection Law. To solve the problems caused by this restriction, eradication programs using the sterile insect technique (SIT) were initiated in Kagoshima and Okinawa Prefectures in 1988 and 1990, respectively[21, 22]. It is essential for the application of the SIT to assess the dispersal ability of the target pests since the results can be used directly in the various phases of the program; namely estimation of the dispersal range of the released sterile adults, planning of trap arrangement design to evaluate the effect of SIT, and determination of the range of the buffer zone to separate the target area from infested and/or uninfested areas[16,25]. We briefly outline the programs and review the dispersal ability of the 2 weevils determined mainly based on the recent research results obtained in the course of the programs. Since the weevils are the major pests of sweetpotato worldwide, this article may contribute to the progress of the eradication programs as well as to the improvement of conventional methods of control.

Outline of the eradication programs

There are 3 steps in the course of the eradication

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programs as in the case of those of the melon fly, *Bactrocera cucurbitae*, that had been successfully eradicated from the same area of the Ryukyu Islands[8,11,13]. The first step was essentially a research phase to develop techniques for the eradication procedures, followed by small pilot eradication experiments, which were started on Kiyama Island (35 ha) near Amami-Ohshima Island (ca. 28°20' N, 129°30' E)[35,36] and on Oh Island (21 ha) near Okinawa Island (ca. 26°20' N, 128°E)[21,22] in 1988 and 1990, respectively. In 1994, as the second step of the programs to confirm their feasibility, experimental eradication projects were initiated on Kikai Island (5,687 ha) located about 20 km east of Amami-Ohshima Island and on Kume Island (6,321 ha) about 80 km west of Okinawa Island. Since the sweetpotato weevil populations were almost eradicated by using SIT in the target areas of both islands[12, 48], the final step of the programs will be put into practice in 2001 to eradicate the pests from all the distribution areas in the Ryukyu Islands, ca. 3,500 km^2 [30].

Dispersal of *Cylas formicarius* by flight and walking

A large number of studies have been conducted on the sweetpotato weevil outside of Japan because of the severe damage on sweetpotatoes. Although some of them dealt with the dispersal ability of *C. formicarius*, qualitative data indicated that: 1) the longest distance covered in any case did not exceed 50 feet and males were much more easily induced to fly by being tossed in the air than the females[33]; 2) marked adults were caught in a light trap at a distance of ca. 1.25 miles maximum from the release point[2]; and 3) the maximum distance of flight observed in the laboratory was about 20 feet[37].

In the USA, when the sex pheromone of the weevil was identified and synthesized artificially[6], a trap was developed for surveying the adult populations using the synthesized pheromone that is highly attractive to males[31]. Field studies were conducted in Florida to determine the effects of the sex pheromone dose and lure age on the movement of male adults, indicating that the distance covered was at least 280 m in 16 h[14].

Although nearly a century has passed since the invasion of the weevil in Japan[28], little information on its dispersal in Japan had been available until recently because of its limited distribution. However, due to the initiation of the eradication programs, many studies have been conducted to directly promote the programs with SIT, as the first trial on this pest in the world[22,25].

Diurnal changes in micro-habitat use by the adults and of their behavior were observed in the laboratory and in field cages[34]. The males were active at night, while the females were less active than the males during the hot season and mating and flying occurred at night.

Spontaneous daily flight patterns in the laboratory were examined by a simple method of counting the number of adults flying out of a cup (Fig. 1)[39]. The flight activity of the males peaked just after the onset of darkness and gradually decreased toward the onset of light under a 14L10D photoregime. Only a small proportion of the insects flew during the photophase. On the other hand, the flight activity of the females was low and more than 75% never flew.

Flight mill systems used for *B. cucurbitae*[26] and *Plautia crossota stali*[18] were modified to meet the specific conditions of *C. formicarius*[20]. Although male weevils flew during a much longer period than the females, the calculated flight distances, far less than 50 m on the average, were very short compared with those of the 2

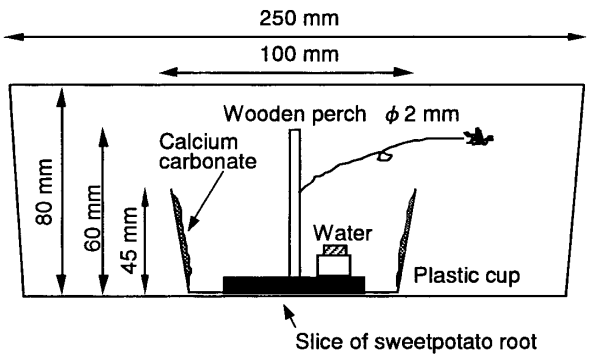

Fig. 1. Container with a cup to measure the flight activity of the weevil
From Ref. 39 ; with permission.

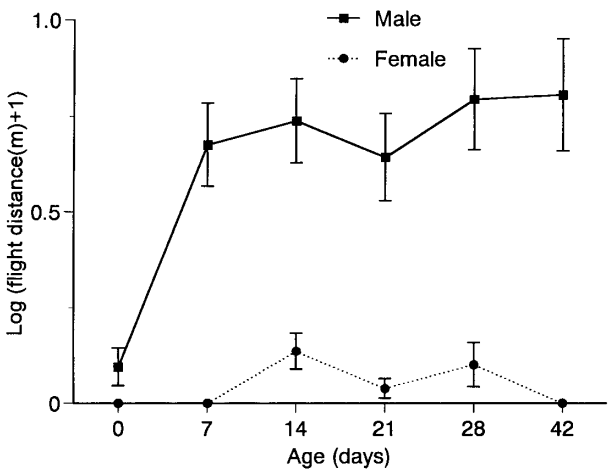

Fig. 2. Flight distance of *C. formicarius* adults measured by the flight mill system during 23 h in relation to their age at 27±1°C and under a photoperiod of 14:10 (L:D) h
Error bars: Standard error of the mean.
From Ref. 24 ; with permission.

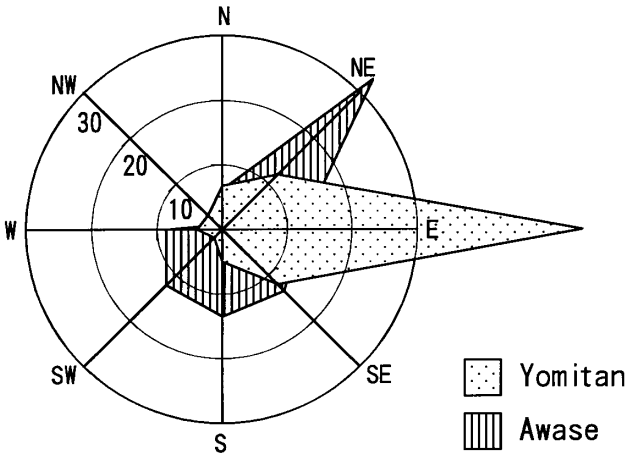

Fig. 3. Percentage of total captured sweetpotato weevil males in 8 trap lines baited with a sex pheromone in Okinawa Isl.[15)]

insects. The flight performance was further evaluated in relation to the adult age, mating status and the degree of starvation[24)]. Males showed a much higher flight ability than the females for all the ages tested between 0 and 42 days old (Fig. 2). Mating status and starvation did not affect appreciably the flight ability and no distinct signs of migratory behavior of adults were detected.

Considering their low flight activity, it is likely that the females disperse mainly by crawling in the field and not by flying[20)]. Therefore, the locomotion activity was measured with an actograph. After the preliminary experiment[19)], the locomotion ability was evaluated for the same 3 parameters, as mentioned above[24)]. Locomotion activity of the male was also higher than that of the female, but the difference was not as pronounced as that in the flight activity. Age and mating status did not affect appreciably the locomotion activity. Although a starvation period of 3 days significantly lowered the locomotion activity of the adults, this phenomenon was probably caused by the lack of food. Starvation did not enhance the locomotion activity. A computer-controlled actograph system was assembled with water and food-supplying devices and the locomotion activity of the adults was continuously recorded for 7 days[40)]. Although the adults walked mostly during the dark period, they also walked during the light period. The tendency for the males to walk over long distances might due to the fact that the males actively seek females in response to the sex pheromone emitted by them.

In the field, the dispersal ability of the sweetpotato weevil was assessed by the mark-and-recapture method using a trap baited with synthesized sex pheromone. Since only males were captured by this trap, little information is available on the dispersal of the females in the field as long as this method was applied.

Sex pheromone of the sweetpotato weevil in USA, which was designated as *C. formicarius elegantulus* at that time, was identified and synthesized in 1986[6)]. It was also synthesized in 1988 for the first time in Japan and it was confirmed that the pheromone was attractive to the males of *C. formicarius* in Okinawa, Japan. More males were captured when they were released downwind of the trap than when they were released from the upwind or other directions. The number of males caught in the pheromone trap showed a distinct peak around sunset. Some of the marked males were recaptured in the trap at a distance of 1 km from the release point after one night[47)]. On the other hand, the adults of both sexes dispersed very little from the host plants in the winter season[43)].

The attraction area of a pheromone trap to the weevil population and dispersal distance were evaluated in sugarcane fields in Amami-Ohshima Island in 1989[41)]. Based on the mark-and-recapture experiments, the effective radius of the attraction area of the pheromone trap was estimated by the Hartstack's area-ratio model[4)] to be about 55 m for 100 μg of pheromone loaded in the trap and about 64 m for 400 μg. From the mark-and-recapture data, the mean dispersal distance of male adults was estimated by Hawke's model[5)] to be about 55 m/day.

Release and recapture of the reared adults were replicated 7 times in different seasons in the same locality of Okinawa Island, mainly in sweetpotato and sugarcane fields[15, 17)]. As about 8,000 males were marked each time, 54,444 males in total were released, and about 27% of them were recaptured by pheromone traps. Percentage of recaptured individuals and dispersal distance were positively correlated with the mean temperature during each experiment. In September, marked adults were captured 4 days after the release on the trap placed at 1,000 m from the release point. The number of males captured was significantly different among 8 trap lines and the largest one was oriented windward during the experimental period (Fig. 3). The dispersal distance in the field without sweetpotato plants was longer than that recorded in the sweetpotato-cultivated area.

Dispersal potential of the pest should be evaluated to determine the size needed for buffer zones in the eradication program. Using the mark-release-capture method, 36,703 marked males were released from 2 islets in the central part of Okinawa Island, Japan (Fig. 4)[16)]. Forty-five pheromone traps were placed on 6 islets near Okinawa Island and 24 on the eastern seashore of Okinawa Island. Of the 71 recaptured males, 34 were caught by 3 traps on the Sea Road (a 5-km bank connecting Okinawa Island and Henza Island) located 2 km northwest of the release point. These results suggest that for *C. formicar-*

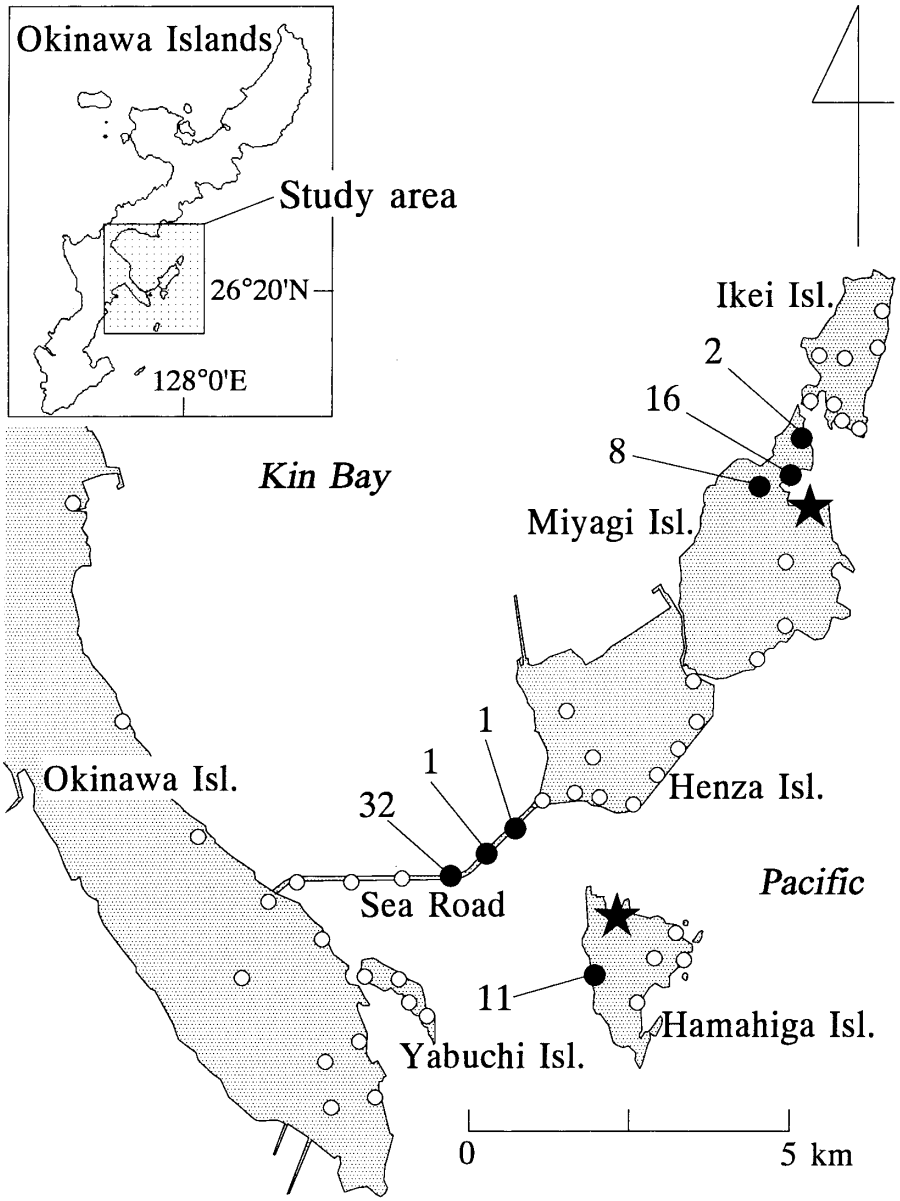

Fig. 4. Distribution of release points of marked sweetpotato weevil males (★) and sex pheromone traps in which marked adults were captured (●) and not captured (○) [16]
Numerals indicate the number of marked adults captured in each trap.

ius eradication programs, a buffer zone with a minimum radius of 2–4 km should surround the area targeted for the control. Since cone type traps[31,47] used for these experiments were found to have some disadvantages, a cylinder type trap was developed (Fig. 5)[10,42] and was mainly used for the program in Okinawa Prefecture.

Dispersal of *Euscepes postfasciatus* by walking

Distribution of the West Indian sweetpotato weevil is somewhat narrower in its range than that of the sweetpotato weevil and the former is not found in the mainland of USA. Therefore, *E. postfasciatus* has not been studied yet, including the method of control[32]. It is considered that *E. postfasciatus* mainly disperses by walking since its flight has not been observed although it has normal hindwings[1,37].

Movement of the weevil could be analyzed in a preliminary experiment with a simple actograph[19]. The locomotion activity of the adults was then continuously recorded for 7 days by using an improved actograph system as in the case of *C. formicarius*[40]. The daily patterns of the locomotion activity were similar to those of *C. formicarius*, i.e. high during the scotophase and relatively

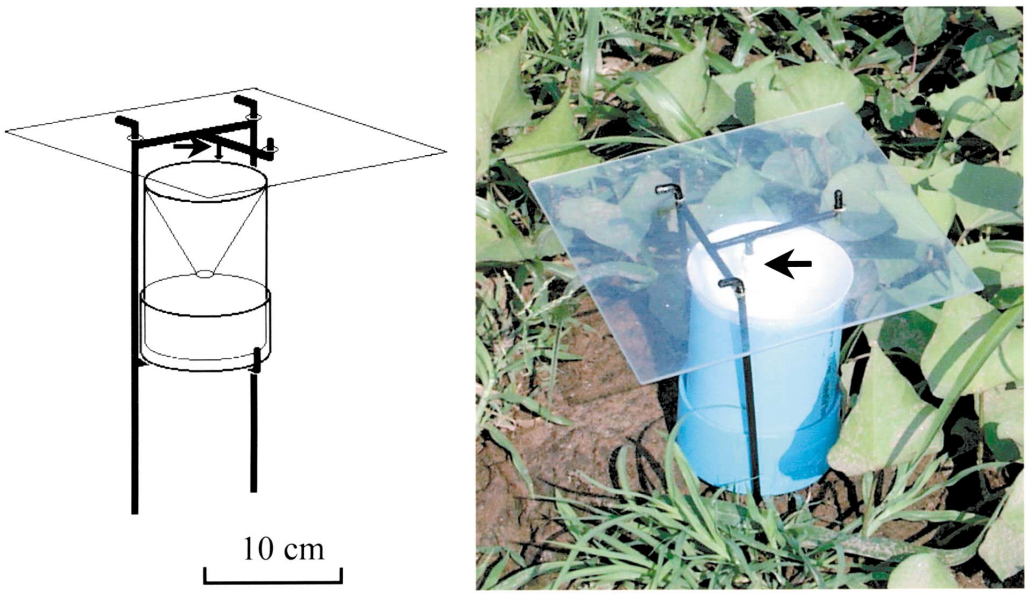

Fig. 5. Cylinder type sex pheromone trap for *C. formicarius*
Arrows indicate where the sex pheromone dispenser was fixed. Left: From Ref. 42 ; with permission.

low during the photophase.

A system for tracking adult locomotion was developed using commercially available electronic devices[38]. Movement of the adults was automatically traced by the system in 16 transparent plastic cases, each containing one adult (Fig. 6). The locations of all the adults were determined to obtain locomotion parameters such as distance walked, walking time and so on. The values of all the parameters were significantly larger for the females than for the males ($p<0.05$). Furthermore, data comparison was made between the tracking system and an actograph system using a simulation procedure. One assumed beam line was drawn through the center of the case just like the infrared beam of the photoelectric switches that detects the movement of an insect in the actograph system. When the number of crosses to the assumed beam was monitored for each adult track, the linear regression of the accumulated distances on the number of crosses fitted to the data remarkably well (r^2 = 0.996). Therefore, the absolute walking distance can be estimated with considerable accuracy from the count obtained with an actograph. Since this relationship was also applicable to *C. formicarius*, the total estimated distances walked for 7 days are shown in Table 1 for the 2 species. According to the results, the width of 200 m[29] might be insufficient for the buffer zone of an emergent control effect on *E. postfasciatus* which had invaded recently in Yaku Island, Kagoshima Prefecture.

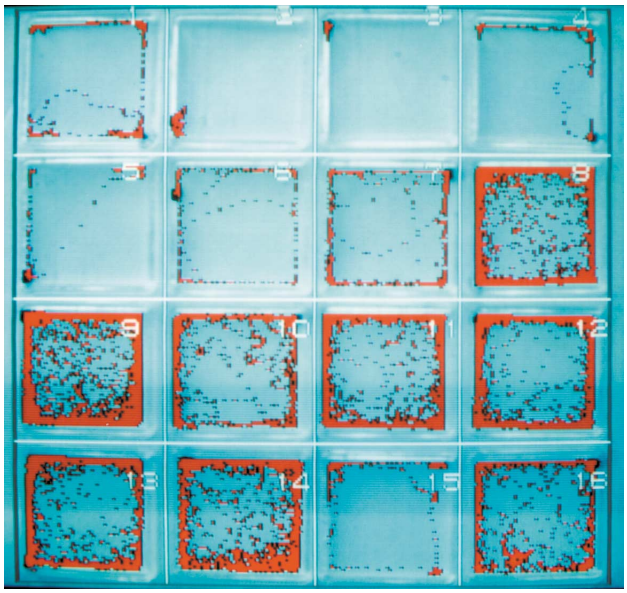

Fig. 6. Walking trajectories of *E. postfasciatus* displayed on CRT screen[23, 38]
Sixteen adults were monitored simultaneously by an automatic tracking system.

Unlike the sweetpotato weevil whose sex pheromone strongly attracts the male, there is no effective field method for collecting both sexes of the West Indian sweetpotato weevil. Thus, a pitfall trap baited with sweetpotato root was developed to collect the adults in the field (Fig. 7)[44–46]. In a fallow field, this trap attracted marked adults from a distance up to 10 m but not at 25 m. In a sweetpotato field, however, the number of captured adults decreased with the days after planting of the sweetpotato plants. Estimation of the dispersal rate of the weevil was attempted in Okinawa Island by using these traps[9]. In a mature sweetpotato field, however, neither

Table 1. Total distance (m) walked for 7 days measured with an actograph*

Species	Sex	*N*	Mean	SD	Min.	Max.	
E. postfasciatus	female	16	217.7	21.6	117.5	426.9	n.s.**
	male	18	177.9	127.0	13.8	487.5	
C. formicarius	female	18	195.5	143.0	14.6	674.7	***
	male	19	568.2	377.4	146.4	1,195.7	

*: Placed at 25±1ºC, under 14L10D photoregime, **: Not significant, ***: $p<0.001$.
From Ref. 40; with permission.

marked nor wild weevils were captured. The dispersal rate could be estimated only for the females at about 33 m during 5 days in an area recently cleared from vegetation.

It has been recently reported that the weevil displays a positive phototactic behavior in the laboratory[27]. This finding may contribute significantly to the progress in studies on the wild weevil populations including their dispersal ability by the use of a newly developed chemiluminescence light trap[27] since the number of captured adults by the trap was significantly larger than that by the trap baited with sweetpotato roots[44] in a sweetpotato field.

Prospect

It appears that remarkable progress has been made in the studies on the 2 weevil pests for the last decade in relation to their dispersal ability as well as other aspects related to the eradication programs. However, except for one male of *C. formicarius*, whose data could be obtained by using the synthesized sex pheromone in the field, our knowledge of the weevils is still insufficient to promote eradication programs. Although time and budget are limited, basic research on ecological and ethological aspects may enable to eradicate the targets eventually.

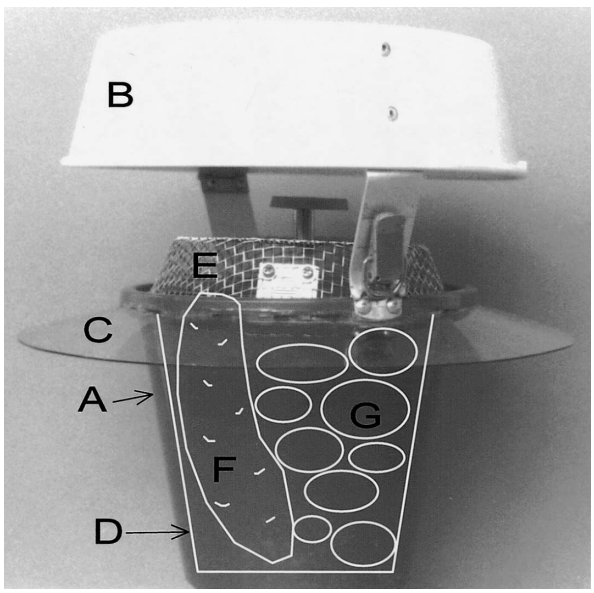

Fig. 7. Field pitfall trap used to capture *E. postfasciatus*
A: base, B: roof, C: brim, D: inside receptacle, E: wire net, F: sweetpotato root, G: styrene foam.
From Ref. 44 ; with permission.

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