Cooper, R. and A. W. Sweeney. 1982. The comparative activity of the Australian and United States strains of *Culicinomyces clavosporus* bioassayed in mosquito larvae of three different genera. J. Invertebr. Pathol. 40:383–387.
Finney, D. J. 1971. Probit analysis, 3rd ed. Cambridge Univ. Press, London.
Merriam, T. L. and R. C. Axtell. 1982. Evaluation of the entomogenous fungi *Culicinomyces clavosporus* and *Lagenidium giganteum* for control of the salt marsh mosquito, *Aedes taeniorhynchus*. Mosq. News 42:594–602.
Sweeney, A. W. 1975. The mode of infection of the insect pathogenic fungus *Culicinomyces* in larvae of the mosquito *Culex fatigans*. Aust. J. Zool. 23:49–57.
Sweeney, A. W. 1978. The effects of temperature on the mosquito pathogenic fungus *Culicinomyces*. Aust. J. Zool. 26:47–53.
Sweeney, A. W. 1981a. Preliminary field tests of the fungus *Culicinomyces* against mosquito larvae in Australia. Mosq. News 41:470–476.
Sweeney, A. W. 1981b. The effects of low temperature storage on the infectivity of *Culicinomyces* conidia for mosquito larvae. J. Invertebr. Pathol. 38:294–296.
Sweeney, A. W. 1983. The time-mortality response of mosquito larvae infected with the fungus *Culicinomyces*. J. Invertebr. Pathol. 42 (in press).
Sweeney, A. W. and C. Panter. 1977. The pathogenicity of the fungus *Culicinomyces* to mosquito larvae in a natural field habitat. J. Med. Entomol. 14:495–496.

AN EXPERIMENTAL EVALUATION OF SIX DIFFERENT SUCTION TRAPS FOR ATTRACTING AND CAPTURING *AEDES AEGYPTI*

K. O. KLOTER[1], J. R. KALTENBACH[1],
G. T. CARMICHAEL[1] AND D. D. BOWMAN[2]

ABSTRACT. Common types of portable suction traps were evaluated to determine their efficacy for attracting and capturing *Aedes aegypti*. Six different traps were equally spaced around the circumference of a circle (radius = 5 m). At the beginning of each trial, mosquitoes were released at the center of the circle and recaptured over a 2 hr period. Before the next trial, traps were rotated clockwise to the next position. Six trials were done for each experiment. Experiments were conducted day or night during which traps were or were not baited with dry ice. A Fay-Prince trap captured significantly more male mosquitoes under all conditions and more female mosquitoes in trials without dry ice. The efficacy and practicality of several trap types is discussed regarding their potential for use in *Ae. aegypti* surveillance. A UV Fay-Prince trap is recommended for *Ae. aegypti* adult surveillance.

INTRODUCTION

Giglioli (1979) described the methods currently used for *Aedes aegypti* (Linn.) surveillance, particularly those applied to adult sampling, as inadequate. Adult sampling methods which include landing/biting rates, space spray collections and house searches for resting adults were considered labor intensive, low yield and often statistically insignificant. An alternative to these methods is to use a suction trap for adult surveillance. Sampling *Ae. aegypti* adults by a suction device was first explored by Fay (1968) and Fay and Prince (1970), but the portable trap developed was not widely used for surveillance. A New Orleans Mosquito Control Board report[3] indicates the Fay-Prince trap was a superior *Ae. aegypti* collecting device when compard with the CDC miniature light trap (Sudia and Chamberlain 1962). Other traps developed for *Ae. aegypti* include a CDC miniature trap equipped with near-infrared diodes (Mangum and Callihan 1968), a modified New Jersey trap (Eliason 1979) and a small black cylinder suction trap (Giglioli 1979). The effectiveness of these traps was not adequately tested. In some cases trap performance was measured in a very confined space and in no instance were comparative trials conducted to simultaneously test the attractiveness of the various traps. The purpose of the present study was to compare the efficacy of each of 6 different portable suction traps for capturing *Ae. aegypti*.

[1] New Orleans Mosquito Control Board, 6601 Lakeshore Drive, New Orleans, LA 70126.
[2] Department of Tropical Medicine,Tulane Medical Center, 1430 Tulane Avenue, New Orleans, LA 70112.

[3] Brody, M. S. 1977. Annual Report: *Aedes aegypti*, New Orleans Mosquito Control Board, pp. 13–15.

MATERIALS AND METHODS

The following suction traps were compared: CDC miniature light trap (bulb No. EM 47-General Electric), ultraviolet light trap (bulb No. F4T5-General Electric), near-infrared light trap (10 diodes No. T1L32-Texas Instruments), black cylinder trap (no light source), Fay-Prince trap (no light source) and blank trap (CDC miniature trap without bulb). Collection cylinder housings were the same inside diameter (8.5 cm) and fans were of identical size powered by 6 volt DC motors (Pitman–P8512C375) operating at 1250 rpm. Catch bags were made of light grey nylon netting.

The comparisons were conducted in an empty greenhouse 11 m wide, 30 m long and 8 m high. Temperature was maintained between 26.5–32.2°C and relative humidity remained between 70–90%. House vents were closed to minimize draft and windows were frosted providing subdued light for daylight trials. No competitive light was visible through the glass during night trials.

The 6 traps were arranged at points 5 m apart around the circumference of a circle with a radius of 5 m from a central release point. Traps were suspended 2 m from ground level, 1 m above screened tables which uniformly covered the greenhouse floor.

For each trial mosquitoes were released and recaptured for a 2 hour period. Each trap was assigned to one of the 6 trapping sites for the first trial. The trap sequence was Fay-Prince trap, CDC trap, UV trap, blank trap, infrared trap, and black cylinder trap. On the next day, traps were rotated clockwise one site, but remained in sequence so after 6 trials each trap was eventually tested at each of the 6 sites in the trapping circumference. An experiment was completed after 6 trials, each for the same duration on consecutive days. Four different experiments were conducted. The trap sequence remained the same for each experiment. For two experiments 300 g of dry ice were placed in a cloth sock and hung above each trap during the 6 trial periods. Two experiments were conducted at night and two during daylight. Conditions for each experiment were as follows:

Experiment 1—daylight, no dry ice, 2–8 June 1982.
Experiment 2—daylight, dry ice, 17–22 June 1982.
Experiment 3—night, no dry ice, 1–6 July 1982.
Experiment 4—night, dry ice, 22–27 July 1982.

Daylight releases were made 1800–2000 hr. and night releases 2230–2430 hr.

At the beginning of each of the 6 trials in any experiment, approximately 500 male and 1500 nulliparous female *Ae. aegypti* (New Orleans Mosquito Control colonized isolate) were set free from a cage placed on a table 1 m high at the central release point. The suction traps were operated for 2 hr after which catch bags were collected. Any uncaptured mosquitoes were evacuated from the greenhouse with several heavy duty exhaust fans. Captured mosquitoes were killed, sexed and counted.

Analyses of variance using arcsine transformations of the square root of the percentages of trap captures per trial were computed for male and female mosquitoes for the 6 trials of each experiment. Using Duncan's multiple range test, these transformations were analysed to determine significant differences between means for male or female mosquitoes captured by each trap during the 6 trials of each experiment.

RESULTS

Analyses of variance of the arcsine transformations of percentages of males or females captured by individual traps in each of the 4 experiments showed there was at least one trap that caught a significantly different ($P<.05$) number of mosquitoes than did other traps. Capture results and their analyses by Duncan's multiple range test, which was used to segregate significantly different ($P<.05$) means for male or female captures in the 4 experiments, are shown in Tables 1–4. The Fay-Prince trap captured significantly more male *Ae. aegypti* with or without dry ice, day or night in all 4 experiments (Tables 1, 2). The Fay-Prince trap was significantly superior to the other trap types in capturing females in Experiment 1 trials conducted during daylight without dry ice (Table 3). Results of Experiment 3 night trials without dry ice showed the Fay-Prince and ultraviolet traps captured significantly more females than the other traps (Table 4). Experiments 2 and 4, for which traps were baited with dry ice during all trials, produced results indicating that no singular trap was significantly outstanding in capturing females (Tables 3, 4). Overall, the mean number or mean percentage of *Ae. aegypti* females captured were highest for the Fay-Prince trap in each experiment.

DISCUSSION AND CONCLUSIONS

The portable suction traps which were compared were of two basic types: visual attraction and light traps. The Fay-Prince trap was engineered as a visual attraction device based

Table 1. Capture results for daylight releases of male *Aedes aegypti.*

	Experiment 1—without dry ice			Experiment 2—with dry ice		
Trap type	x̄ and s.d. for captures[1]	x̄ % and s.d. for captures[1]	Duncan's grouping[2]	x̄ and s.d. for captures	x̄ % and s.d. for captures	Duncan's grouping
Fay-Prince trap	51.2 ± 12.4	45.6 ± 14.7	A	59.2 ± 85.8	35.7 ± 18.2	A
CDC miniature light trap	9.3 ± 6.9	8.1 ± 6.9	C	24.0 ± 42.8	10.0 ± 8.9	B
Ultraviolet light trap	13.3 ± 12.0	11.6 ± 9.7	BC	8.8 ± 7.9	8.2 ± 7.2	B
CDC miniature trap without light	10.7 ± 11.1	8.8 ± 8.1	C	16.2 ± 12.8	15.1 ± 16.9	B
Infrared light trap	14.5 ± 18.8	9.8 ± 9.2	BC	35.3 ± 38.2	16.2 ± 16.8	B
Black cylinder trap	22.8 ± 23.9	16.1 ± 13.5	B	31.2 ± 57.7	14.8 ± 18.1	B
All Traps	121.8 ± 47.4	100		174.7 ± 184.1	100	

[1] Six trials.
[2] Means with same letter are not significantly different (P = 0.05, DF = 20).

Table 2. Capture results for night releases of male *Aedes aegypti.*

	Experiment 3—without dry ice			Experiment 4—with dry ice		
Trap type	x̄ and s.d. for captures[1]	x̄ % and s.d. for captures[1]	Duncan's grouping[2]	x̄ and s.d. for captures	x̄ % and s.d. for captures	Duncan's grouping
Fay-Prince trap	39.8 ± 57.5	32.5 ± 13.6	A	102.7 ± 63.9	35.1 ± 9.4	A
CDC miniature light trap	18.7 ± 18.4	18.5 ± 5.9	B	45.0 ± 41.3	15.1 ± 8.9	BC
Ultraviolet light trap	13.2 ± 9.2	16.8 ± 8.7	B	19.2 ± 7.9	6.9 ± 1.8	CD
CDC miniature trap without light	15.0 ± 13.6	15.0 ± 7.2	B	68.7 ± 73.0	23.0 ± 15.3	B
Infrared light trap	11.0 ± 8.0	11.6 ± 3.0	B	36.3 ± 29.9	14.0 ± 10.5	BCD
Black cylinder trap	6.0 ± 6.5	5.9 ± 5.9	C	17.2 ± 12.8	6.0 ± 3.3	D
All Traps	103.7 ± 103.6	100		289.1 ± 136.5	100	

[1] Six trials.
[2] Means with same letter are not significantly different (P = 0.05, DF = 20).

upon the contrast provided by a black suction tube panel against a white cover (Fay and Prince 1970). This trap and its predecessor, the black trap (Fay 1968), were designed to capture *Ae. aegypti* insectary escapees as well as for use in field surveillance. The application of this concept for field sampling was successfully tried with dispersal studies in which Fay and Craig (1969) recaptured *Ae. aegypti* with the black trap. The visual attraction concept was more recently applied to *Ae. aegypti* sampling by using a lightless, topless black New Jersey trap (Eliason 1979). The modified New Jersey trap was not evaluated in this study because it was not portable. A portable miniature version of this trap mentioned by Giglioli (1979) was developed by Wilton (personal communication) on the grounds that the Fay-Prince and modified New Jersey traps were cumbersome. While the black cylinder suction trap did not produce good results in our study, the potential of this prototype trap needs further evaluation in the field. Despite the awkward appearance of the Fay-Prince trap, it was not unmanageable and our data indicate it was the best visual attraction device for collecting *Ae. aegypti.*

A surprising result of our study showed the Fay-Prince trap collected comparatively more *Ae. aegypti* than other traps during night experiments. With the exception of the ultraviolet trap, the Fay-Prince trap outperformed the other light traps day or night. Studies by New Orleans Mosquito Control (unpublished data) showed that the Fay-Prince trap collected more *Ae. aegypti* day or night when compared with the CDC miniature light trap in urban field trials. Results concerning night captures are interesting because *Ae. aegypti* biting activity is generally characterized as a daylight phenomenon (Strauss et al. 1965, Trpis et al. 1973, Corbet and Smith 1974, Soman 1978, Nelson et al. 1978). Studies in which night captures were made do not suggest much biting activity occurs at that time, but they indicate night movement by *Ae. aegypti* does occur naturally or may be elicited by visual attraction or light traps. In either case, suction traps, not just landing/biting collections, can sample night activity.

Table 3. Capture results for daylight releases of female *Aedes aegypti.*

	Experiment 1—without dry ice			Experiment 2—with dry ice		
Trap type	$\bar{x}$ and s.d. for captures[1]	$\bar{x}$ % and s.d. for captures[1]	Duncan's grouping[2]	$\bar{x}$ and s.d. for captures	$\bar{x}$ % and s.d. for captures	Duncan's grouping
Fay-Prince trap	196.7 ± 72.3	39.6 ± 9.0	A	171.7 ± 47.9	22.8 ± 8.9	A
CDC miniature light trap	54.3 ± 53.3	11.0 ± 10.9	CD	122.2 ± 111.7	14.8 ± 11.8	B
Ultraviolet light trap	83.3 ± 54.7	18.4 ± 13.3	B	106.0 ± 91.6	12.9 ± 9.6	B
CDC miniature trap without light	36.0 ± 36.2	6.5 ± 4.7	C	123.3 ± 118.0	15.6 ± 14.1	B
Infrared light trap	58.3 ± 54.7	10.3 ± 5.5	CD	149.4 ± 107.4	19.1 ± 12.4	AB
Black cylinder trap	72.7 ± 58.4	14.2 ± 9.2	BC	109.5 ± 69.7	14.8 ± 11.1	B
All Traps	501.3 ± 192.1	100		782.2 ± 126.0	100	

[1] Six trials.
[2] Means with same letter are not significantly different (P = 0.05, DF = 20).

Table 4. Capture results for night releases of female *Aedes aegypti.*

	Experiment 3—without dry ice			Experiment 4—with dry ice		
Trap type	$\bar{x}$ and s.d. for captures[1]	$\bar{x}$ % and s.d. for captures[1]	Duncan's grouping[2]	$\bar{x}$ and s.d. for captures	$\bar{x}$ % and s.d. for captures	Duncan's grouping
Fay-Prince trap	204.2 ± 72.2	35.3 ± 10.5	A	224.3 ± 75.6	25.4 ± 4.2	A
CDC miniature light trap	82.2 ± 39.8	14.2 ± 6.0	B	167.7 ± 73.7	18.7 ± 5.9	AB
Ultraviolet light trap	183.4 ± 113.6	29.7 ± 12.7	A	118.2 ± 74.6	12.9 ± 5.0	BC
CDC miniature trap without light	34.8 ± 15.2	6.5 ± 3.6	B	185.5 ± 105.6	19.9 ± 6.3	AB
Infrared light trap	38.3 ± 15.2	6.6 ± 2.9	B	116.4 ± 45.3	13.5 ± 4.1	BC
Black cylinder trap	41.8 ± 13.3	7.7 ± 3.3	B	84.3 ± 55.8	9.6 ± 5.4	C
All Traps	584.7 ± 139.9	100		896.4 ± 316.9	100	

[1] Six trials.
[2] Means with same letter are not significantly different (P = 0.05, DF = 20).

The trap equipped with near-infrared light was not an effective or practical sampling device. Our data confirm that IR light was only effective in attracting *Ae. aegypti* in conjunction with emissions of CO_2, but results for the other traps generally indicated that baiting with CO_2 enhanced captures. Dry ice-baited or CO_2 emitting traps were effective devices for collecting *Ae. aegypti* as shown by Morlan and Hayes (1958) and Nayar (1981). However, CO_2 baited traps are expensive to maintain and logistically unmanageable for an operational surveillance program.

When comparing the efficacy of the traps there is the possibility that there was an interaction between neighboring traps. The manner of trap placement was such that it was impossible to quantify the effect of any trap on each of its neighboring traps in the circle. Therefore, if a trap was exceedingly good it may have made its neighbors appear less effective than if each were tested alone. Conversely if a trap performed poorly in this design, its neighbors may have captured more mosquitoes. However, the results clearly indicate no matter what the sampling conditions, the Fay-Prince trap outperformed the other traps in capturing mosquitoes.

In conclusion, this study shows the Fay-Prince trap was most attractive to *Ae. aegypti* adults and that ultraviolet light was attractive to *Ae. aegypti* at night. The UV Fay-Prince trap may provide the best combination of visual and light cues for attracting *Ae. aegypti.* Such a suction trap appears to be the most practical device for *Ae. aegypti* surveillance because it is portable and functional without CO_2 bait. Field studies during the summer of 1983 in New Orleans with the UV Fay-Prince trap confirmed its effectiveness as a surveillance tool for both *Ae. aegypti* and *Culex quinquefasciatus* Say.

ACKNOWLEDGMENTS

The authors are grateful to Dr. Dana C. Focks of the USDA Insects Affecting Man and Animals Laboratory, Gainesville, Florida and Dr. D. P. Wilton of the CDC Laboratory in Fort

Collins, Colorado for their advice and encouragement. Thanks go to Dr. B. Good and R. Dominick for aid with the field work. Help with preparation of the manuscript by P.A. Schultz is appreciated. The cooperation of the New Orleans Parks and Parkways Commission during the use of their greenhouse is gratefully acknowledged.

References Cited

Corbet, D. S. and S. M. Smith. 1974. Diel periodicity of landing of nulliparous and parous *Aedes aegypti* (L.) at Dar es Salaam, Tanzania (Diptera, Culicidae). Bull. Entomol. Res. 64:111–121.

Eliason, D. 1979. Vector Topics No. 4: Biology and control of *Aedes aegypti*. CDC, PHS, DHREW, Atlanta, GA., 68 pp.

Fay, R. W. 1968. A trap based on visual responses of adult mosquitoes. Mosq. News 28:1–7.

Fay, R. W. and G. B. Craig. 1969. Genetically marked *Aedes aegypti* in studies of field populations. Mosq. News 29:121–127.

Fay, R. W. and W. H. Prince. 1970. A modified visual trap for *Aedes aegypti*. Mosq. News 30:20–23.

Giglioli, M. E. C. 1979. *Aedes aegypti* programs in the Caribbean and emergency measures against the dengue pandemic of 1977–1978: A critical review. Dengue in the Caribbean, 1977, Pan Amer. Hlth. Orgn., Sci. Pub. No. 375, pp. 133–152.

Mangum, C. L. and P. S. Callihan. 1968. Attraction of near-infrared radiation to *Aedes aegypti*. J. Econ. Entomol. 61:36–37.

Morlan, H. B. and R. O. Hayes. 1958. Urban dispersal and activity of *Aedes aegypti*. Mosq. News 58:137–144.

Nayar, J. K. 1981. *Aedes aegypti* (L.) (Diptera: Culicidae): Observations on dispersal, survival, insemination, ovarian development and ovipositional characteristics in a Florida population. J. Fla. Anti-Mosq. Assoc. 52:24–40.

Nelson, M. J., J. S. Self, C. P. Pant and S. Usman. 1978. Diurnal periodicity of attraction to human bait of *Aedes aegypti* (Diptera: Culicidae) in Jakarta, Indonesia. J. Med. Entomol. 14:504–510.

Soman, R. S. 1978. Studies on diel periodicity in the landing of *Aedes aegypti* on man in Bangalore City. Indian J. Med. Res. 67:937–941.

Strauss, W. G., H. I. Maibach, A. A. Khan and T. R. Pearson. 1965. Observations on biting behavior of *Aedes aegypti* (L.). Mosq. News 25:272–276.

Sudia, W. D. and R. W. Chamberlain. 1962. Battery-operated light traps, an improved model. Mosq. News 22:126–129.

Trpis, M., G. A. H. McClelland, J. D. Gillett, C. Teesdale and T. R. Rao. 1973. Diel periodicity in the landing of *Aedes aegypti* on man. Bull. W.H.O. 48:623–629.