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Technical Development Laboratories
Aedes aegypti Eradication Program
National Communicable Disease Center
P. O. Box 769 - Savannah, Ga. 31402

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R. T. TAYLOR, H. F. SCHOOF, AND W. MATHIS

Biology/Chemistry Section, Technology Branch, Communicable Disease Center, Public Health Service, U. S. Department of Health, Education, and Welfare, Savannah, Georgia

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R. T. TAYLOR, H. F. SCHOOF, AND W. MATHIS

Biology/Chemistry Section, Technology Branch, Communicable Disease Center, Public Health Service, U. S. Department of Health, Education, and Welfare, Savannah, Georgia

INTRODUCTION

Experimental huts have provided valuable information on the habits of mosquitoes and their reaction to treated surfaces; they have given information as well on the comparative effectiveness of different compounds.[1] To evaluate further compounds shown to have promise as residual insecticides under conditions in the United States,[2] 12 experimental huts were constructed in Haiti during 1964. The present article reports on the effectiveness of six compounds as residual treatments against *Anopheles albimanus* and includes observations on mosquito activity before and after treatment of the experimental huts.

MATERIALS AND METHODS

Experimental Huts

The 12 huts were constructed in a large rice-growing area in the plain of Arcahaie, approximately 40 miles to the north of Port-au-Prince (Fig. 1). Each hut had a floor of concrete on rock foundation and walls and partitions of woven 2-inch palm slat between 30-inch studs. The palm slats were covered with native mud on the inside and cement on the outside; after drying, the mud was whitewashed with a local mixture of crushed limestone. The roofs were made of dried sugarcane thatch.

Each hut was 8 by 16 feet on the interior and was approximately 10 feet high from floor to roof peak; a partition divided it into two rooms of equal size. The partition extended to a height of 6 feet and had a single central opening (2 by 6 feet). Each structure had four doors (each 2 by 6 feet) and two windows (each 2 by 2½ feet). Two doors were on one 16-foot side wall, and there was a single door on each end wall. Both windows were on the doorless side wall; all openings were in the center of the walls. The walls at the top had a 4-inch eave opening between them and the thatch overhang. The huts were from 50 to 200 feet apart and faced south in a line through the rice fields.

Each hut was fitted with exit traps in one window (Fig. 2), one door (Fig. 3), and in two places under the eaves; there was one entrance cone in the other window (Fig. 4). The other three door openings had tight-fitting doors. The window traps were made up of an outer frame 24 by 24 by 24 inches attached to a 36 by 36-inch base of half-inch plywood bearing an inner pyramidal frame that formed the mosquito-egress cone. The outer frame was covered with 16-mesh plastic screen with a cloth-covered opening in the upper corner of one side for removal of the mosquitoes. The cone, bearing a 1-inch-square apical opening, was covered with polyethylene sheeting, so that escaping mosquitoes resting in the cage would not be subjected to vapors produced by the test insecticides.

The door traps had an outer frame 2 by 2 by 6 feet and an inner entrance way formed by two screened vertical panels projecting into the trap. The entrance way had a 1-inch opening for the full 6-foot height of the trap. Two openings constructed in the bottom corners of the outer frame were used for removal of the mosquitoes, which were knocked down by pyrethrins before collection. The eave traps were similarly constructed of outer and inner frames covered with plastic screen. The dimensions of these traps were 4 by 4 by 30 inches, with ½ inch entrance-way openings. The window-entrance cones were attached to a 36 by 36-inch base of quarter-inch plywood. The cones were fabricated of 8 iron ribs (⅛ inch by 12 inches) welded to 5/32 inch rings at the top (1 inch in diameter) and bottom (12 inches in diameter). The cones were covered with polyethylene sheeting.

Each house could be illuminated by a 10-watt bulb placed on the partition wall between the two rooms. Power was supplied from a 300-watt generator.

Insecticide Treatments and Evaluation

The houses were sprayed approximately 6 months after construction with the following

* These studies were accomplished as part of a contractual agreement between the Communicable Disease Center and the Agency for International Development.

FIGURE 1. Huts in rice fields

insecticides and dosages: folithion—1 and 2 g per m²; SD-8530 (3,4,5-trimethylphenylmethylcarbamate)—1 and 2 g per m²; Mobam—1 and 2 g per m²; Banol—0.25 and 0.5 g per m²; carbaryl—2 g per m²; and DDT—2 g per m². Two unsprayed houses served as controls, the treated and untreated houses being chosen at random. Three-gallon compressed-air sprayers equipped with #8002 nozzles were used to treat the huts. The standard malaria-eradication spraying technique was followed: all surfaces in the huts with the exception of the floors were treated up to the 9-foot level.

Initially the evaluation of the treatments was to include naturally entering mosquitoes and specimens confined under plastic cones. However, the scarcity of mosquitoes necessitated the use of released specimens during the latter part of the study.

To evaluate these insecticides against naturally entering *A. albimanus*, inspections were made 5, 7, 9, and 11 weeks after treatment as follows:

1. One human bait entered each hut at 1800 hours and remained until 0600 hours the next morning; in addition to the entrance cone, two of the four doors were left partially open until 2400 hours, when the doors were closed. The eave openings were sealed.

2. Collectors entered the huts at 0600 hours and collected the dead mosquitoes from the floor and traps.

3. The huts were then "flitted" with pyrethrins and the knocked-down mosquitoes collected both from the floors and the window and door traps.

4. The sex of all mosquitoes was then determined. The females were recorded as killed if collected from the floor or traps before "flitting," as escaped if found in the traps after "flitting," or as survived if collected from the floors after "flitting."

With the released mosquitoes, blood-fed specimens of a colonized local strain of *A. albimanus* were used at 14 up through 19 weeks after treatment. The mosquitoes were allowed to engorge on a rabbit the afternoon preceding the test. Approximately 100 mosquitoes were released in each hut at 1800 hours. At 0600 hours the same procedures were used as in 2, 3, and 4 above.

At weekly intervals after treatment, bio-assay tests were conducted in each hut for 24 to 25

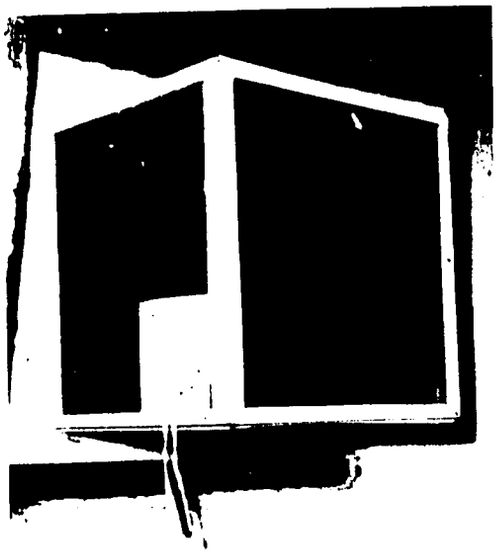

Fig. 2. Window-exit trap

Fig. 3. Door-exit trap

Fig. 4. Entrance cone

weeks. In each test, six cones were placed on whitewashed mud, six on thatch, and six on wood surfaces. Ten 3-day-old sugar-fed *A. albimanus* were introduced into three of the cones on each surface, and ten 3- to 5-day-old blood-fed *A. albimanus* were introduced into the remaining cones. The mosquitoes were exposed for 1 hour, when they were taken out, placed in holding cups with a sugar-water cotton pad on top, and held for 24-hour mortality counts. Mean temperatures during these tests and the holding periods were from 81° to 88° F; mean humidities from 75 to 90 percent.

Three weeks before treatment and 3, 4, 6, 8, 10, and 12 weeks after treatment, indoor-outdoor collections were made in an effort to determine any change in activity patterns that the treatment might have caused. The collections were made between 1800 and 2300 hours, the period of maximum mosquito density.[3] In this collection routine, groups of three huts and outdoor collection sites were used nightly, so that collections were made once weekly in each hut and adjacent outdoor collection site. The latter was from 50 to 100 feet from the hut and consisted of a platform, 2½ by 4 feet, equipped with 1-foot legs. The platform was positioned before the collection period, and it served to keep personnel from working continuously in the water of the rice field. One extra human bait and one collector were available for relief. The baits and collectors were rotated hourly from house to house and from outdoor site to outdoor site on signal from the supervisor.

The numbers of mosquitoes biting during the collection hour and numbers collected resting and their indoor resting heights were recorded.

RESULTS

Unfortunately, the use of naturally entering mosquitoes to evaluate the materials was hampered by the scarcity of adults (maximum per hut, 7 to 21 specimens). This scarcity precluded any valid conclusions, except that none of the treatments was particularly effective.

Data for mosquitoes released in the huts are presented in Table 1. For the period 14 to 19 weeks after treatment, all applications caused approximately 50 percent mortality over a 12-hour exposure period.

In the cone tests, mortality over 90 percent of both sugar- and blood-fed mosquitoes was recorded with all of the insecticides on whitewashed mud, thatch, and wood surfaces tested through week 19 (Table 2). On week 20, tests with blood-fed mosquitoes showed SD-8530 to be the only material over 90 percent effective on all surfaces. DDT gave 70 percent or greater mortality of blood-fed mosquitoes on whitewashed mud for the 25-week test period. The results with DDT were slightly better than those obtained with the experimental compounds.

The break-point in the activity of the residues appeared to be week 20, when most materials showed a sharp drop in effectiveness. There was a slight difference in the mortality of the sugar-fed over that of blood-fed mosquitoes; however, this does not significantly alter the evaluation when based on the 90 and 70 percent mortality criteria. These results were similar to those obtained with free-flying mosquitoes in that all of the compounds had about the same relative residual life.

TABLE 1

Mortality, escape, and survival of released A. albimanus *in experimental huts in Haiti 14 to 19 weeks after treatment with residual insecticides**

	Percent							
	Killed		Escaped		Survived		Mosquito numbers	
	Grams per square meter							
	1	2	1	2	1	2	1	2
Folithion	44	48	34	33	22	19	275	258
SD-8530	58	55	24	27	18	18	248	255
Mobam	42	44	23	34	35	22	222	255
Banol†	48	53	27	33	25	14	335	240
DDT	—	41	—	35	—	24	—	251
Carbaryl	—	58	—	29	—	13	—	243
Control	13	1	38	46	49	53	309	289

* Mosquitoes were exposed for 12 hours, 1800 to 0600 hours.

† Banol was applied at 0.25 and 0.5 g per square meter.

TABLE 2

Weeks of 90-percent mortality of 3- to 5-day-old blood-fed and 3-day-old sugar-fed A. albimanus *on whitewashed mud, thatch, and wood surfaces of experimental huts in Haiti**

	Blood-fed				Sugar-fed			
	White-washed mud		Wood and thatch		White-washed mud		Wood and thatch	
	Grams per square meter							
	1	2	1	2	1	2	1	2
Folithion	19	19	19	21	19	19	19	22
SD-8530	19	21	21	21	21	21	22	23
Mobam	19	19	21	21	19	21	22	23
Banol†	19	19	21	21	21	21	21	24
DDT	—	19	—	21	—	19	—	25+
Carbaryl	—	19	—	21	—	21	—	22

* Plastic cones and 1-hour exposure times were used; three cones with 10 mosquitoes each per surface.

† Banol was applied at 0.25 and 0.5 g per square meter.

Data relative to mosquito activity patterns are summarized in Table 3. Folithion, Mobam, and carbaryl at 2 g per m² appeared to deter *A. albimanus* from entering the houses and biting. SD-8530 and DDT at 2 g per m² appeared to reduce the numbers of engorged resting mosquitoes. The other materials apparently did not alter the relative indoor-outdoor biting behavior or the numbers of mosquitoes resting after their blood-meal.

Table 4 summarizes the resting heights at which the mosquitoes were collected. More than half of the resting mosquitoes were taken below 3 feet. No mosquitoes were collected from cave traps. The presence of insecticidal deposits on the walls did not appear to affect the height at which these mosquitoes normally rest.

DISCUSSION

The construction of experimental huts in a tropical area is done to simulate as closely as

TABLE 3

The effect of insecticide treatment on the activity pattern of A. albimanus *in experimental huts in Haiti before and after spraying**

	Percent biting				Percent resting			
	Grams per square meter							
	1		2		1		2	
	Before	After	Before	After	Before	After	Before	After
Folithion	25	15	16	9	66	73	83	89
SD-8530	12	10	14	15	100	52	100	54
Mobam	13	17	25	9	100	76	92	88
Banol†	34	19	18	12	30	56	100	100
DDT	—	·	27	24	—	—	41	19
Carbaryl	—	—	40	15	—	—	96	85
Control	28	23	17	13	100	77	66	50

* Based on collections 3 weeks before treatment and weeks 4, 6, 8, 10, and 12 after treatment.

† Banol was applied at 0.25 and 0.5 g per square meter.

possible the conditions under which mosquitoes normally enter homes and contact man and the deposits of residual insecticides. While it is possible to introduce changes in construction, baits, and traps that will facilitate the evaluation of insect behavior, the prime requirement is an abundant population of mosquitoes. Unfortunately, this aspect fluctuates with weather and seasonal changes, and entire experiments may be jeopardized or rendered invalid by the scarcity of naturally entering adults. This point was again emphasized in the present studies in which released adults had to be used to obtain some of the desired information.

Despite the meager data from naturally entering mosquitoes, the results for the 12 huts suggest that none of the 1-to-2-month-old treatments was highly effective. That the same residues after 2½ to 4½ months kill higher percentages of the released specimens suggests that the reared adults may tend to rest on the residues longer than do the wild mosquitoes.

In contrast to the free-flying adults, the blood-fed mosquitoes confined under plastic cones for 1 hour were readily killed throughout 19 weeks of testing.

The obvious differences in the results indicated by the cone technique versus those in which the mosquitoes were not confined suggest that with the former, the mosquitoes are exposed for a longer period than is true for free-flying specimens or that confinement of 10 adults in aggregate produces a condition that enhances the effect of the residue upon the mosquito. The relative significance of these factors requires detailed study of the methods involved since, of the procedures used in this study, the cone technique is the one that is best suited for use in occupied houses provided the data obtained can be interpreted in relation to what will occur with naturally entering mosquitoes.

TABLE 4

Resting heights of A. albimanus *collected in all experimental huts in Haiti before and after insecticide treatment*

Resting height (*feet*)	Percent	
	Before	After
0-1	13	11
1-2	20	21
2-3	19	21
3-4	19	17
4-5	13	16
5-6	9	9
+6	7	5
Mosquito numbers	2831	801

The data for all three methods of evaluation indicate that the four experimental chemicals were equal to or superior to carbaryl and DDT as residual applications.

SUMMARY AND CONCLUSIONS

The comparative effect of DDT, carbaryl, Banol, Mobam, SD-8530, and folithion on the

behavior and survival of *A. albimanus* was studied in experimental huts in Haiti.

The average mortality in naturally entering *A. albimanus* at 5 to 9 weeks was generally low with all treatments. At 14 to 19 weeks the average mortality of released *A. albimanus* was approximately 50 percent in all of the treated huts. Mosquitoes in these observations were exposed for 12 hours. Exposure of the mosquitoes under plastic cones rated all materials effective for 19 weeks at the 90 percent level against both sugar-fed and blood-fed *A. albimanus*.

The treatments of the different compounds did not affect the relative indoor resting heights of *A. albimanus*. It was not possible to characterize changes in behavior patterns of this mosquito due to their low density at the time of this study. It did appear, however, that some of the materials may have had either a deterrent or a repellent effect, or both.

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