CONTROL OF ANOPHELINE SPECIES IN THE CANAL ZONE WITH ULTRA-LOW VOLUME SPRAYS OF MALATHION AND FENTHION[1]

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INTRODUCTION. Control of anopheline species to interrupt the cycle of transmission of malaria has centered around the spraying of residual insecticide in houses. With this method, developed through the pioneering efforts of Gahan *et al.* (1945) and Gahan and Lindquist (1945), endophilic female mosquitoes are exposed to the insecticide while they rest on treated walls. This effective technique is now used throughout the world in areas where malaria is endemic. There are, however, exophilic anopheline species that do not habitually rest in buildings during daytime. The importance of these species in the spread of malaria is now receiving increased attention, particularly in Southeast Asia. Holway *et al.* (1967) concluded that the exophilic species *A. aconitus* Dönitz, *A. maculatus* Theobold, *A. jeyporiensis candidiensis* Koizumi, and, in limited areas, *A. balabacensis* were the most important vectors of the malaria affecting military personnel in Vietnam.

Because of the outdoor resting habits of exophilic anophelines, the standard residual spray technique of control is not completely effective; also, present day military operations are so mobile that residual sprays cannot protect military personnel in combat. Thus, control of the exophilic species must rely partly on outdoor control procedures. Holway *et al.* (1967) reported on the ground and aerial dispersal of insecticides for this purpose in South Vietnam. Ultra-low volume (ULV) sprays of 57 percent malathion (8–13 oz./acre) are being applied from UH–1 helicopters and C–123 aircraft; however, their overall effectiveness of the sprays in controlling anophelines is unknown. In a limited study on Con Son Island, (located off the coast of Vietnam) they reported a "very good reduction of both larvae and adults over a 10-day period" with a malathion dose of 0.5 lb./acre.

Insecticides used generally against *Culex* and *Aedes* mosquitoes in the United States are also very effective against anophelines (Mount and Lofgren, 1967). The primary concern, therefore, is not with toxicity of the insecticide but with the ability of aerial spray droplets of insecticides to penetrate ground cover and reach the sites where the mosquitoes are located. In jungle areas, the problem is particularly severe because of double or even triple canopies of foliage.

During the fall of 1967, we made preliminary investigations of the effectiveness of two insecticides applied as ULV sprays to jungle areas of the Panama Canal Zone for control of *Anopheles albimanus* Wiedemann and *Anopheles triannulatus* (Neiva and Pinto). Our primary objective was to determine the rates of application necessary to control anophelines when we used standard methods of delivering ULV aerial sprays. This paper presents the results of these tests; they should not be construed as recommendations.

METHODS AND PROCEDURES. The test plots were located adjacent to the right-of-way of the Canal Zone railroad near Darien and Frijoles stations and all bordered on or were within several hundred feet of Gatun Lake where larval breeding was known to occur along the lake margins in heavy growths of *Elodea*. Each plot was about 2,400 feet wide and 1,800 or

[1] Mention of a proprietary product does not necessarily imply endorsement of this product by the USDA. The research was supported in part by U. S. Army Medical Research and Development Command Grant No. 8977.

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2,400 feet deep (about 100–130 acres). Only the boundary along the railroad was measured; the depth was estimated when the insecticide was applied by operating the sprayer for 15 or 20 seconds during the pass over each swath: 15 seconds × 120 feet per second (speed of the plane) = 1,800 feet. All flights were made perpendicular to the tracks. The swaths were marked by smoke delivered from a Dyna-Fog® '150' aerosol generator or by a flag placed on a 24-foot telescoping pole.

Two systems of spray rigs were used in applying the insecticides. One system was supplied by the Medical Equipment Research and Development Laboratories (MERDL) of Ft. Totten, New York and was built to fit helicopters of the UH–1 series; it was originally designed to deliver high volume sprays but can be used for ULV sprays also. The second system, supplied by the Entomology Research Division Laboratory at Gainesville, Florida, is small and portable; it consists of a pump, 12-volt motor, and insecticide tank and utilizes flexible polyethylene tubing for conveying the insecticide to the nozzles. The tubing is clamped to the fixed boom of a conventional spray rig. The nozzles are connected to this line and also taped to the fixed boom. TeeJet® No. 80015 flat fan tips were used with both systems.

The helicopter and pilot were supplied by the 193rd Aviation Company, Headquarters, USARSO. The helicopter was operated at 80 m.p.h., and swaths were 200 feet wide. Since the test area was hilly, the helicopter could not be maintained at a uniform height above the canopy, but the average height was 100 feet with a range of 50–175 feet. All applications were made between 6 and 10 a.m.

Because of the denseness of the vegetative growth on the plots, it was necessary to have special trails cut for men to follow while assaying the mosquito populations. At the midpoint on the railroad side of each plot, a trail 800 feet long and perpendicular to the railroad track was cut. At the end of this trail two more trails, each 900 feet long, were cut at right angles and in opposite directions thus making a trail 1,800 feet long and parallel to the railroad tracks. Each parallel trail ended about 300 feet from the edges of the plots. All pre- and posttreatment mosquito collections were made along this trail except for a few made along the railroad in the last test. Population estimates were made by collecting with a mechanical aspirator the mosquitoes that landed on the collector. These collections were made along the trails for an hour at 24 locations in the daytime or at nine to ten locations at night.

In the first test, both malathion and fenthion were used, and all except a few collections were made from 1 to 3 p.m.; these few were made from 7:45 to 10 a.m. In the second test, only fenthion was applied, and collections were made after dark from 6 to 7:30 p.m. All mosquitoes were returned to the Entomology Laboratory of the Environmental Health Division for identification. (Two species of *Anopheles, albimanus* and *triannulatus,* were collected.) Also, in the second test caged *A. albimanus* (20/cage) were placed along the counting trail of two plots and left there 2 hours after application of the insecticide; these mosquitoes had been transported to the field from the laboratory in styrofoam boxes cooled with refrigerant. In addition, on one plot, oil-red-dye cards were placed on the railroad track and on the ground by the cages to determine the number of droplets deposited per unit area.

RESULTS. The results of the first test (Table 1) showed that applications of 0.1 lb./acre of fenthion and 0.225 lb./acre of malathion did not give satisfactory control of anophelines in the jungle. These rates are within the range generally used for mosquito control in the United States. When the dose of each insecticide was increased about threefold, good control was obtained (85 percent and 90–95 percent, respectively, with malathion and fenthion for as long as 25–30 hours).

In the second test, fenthion was applied

TABLE 1.—Control of anophelines obtained with ULV sprays of malathion and fenthion in jungles in the Panama Canal Zone (averages for duplicate plots).

Insecticide	Rate of application (lb./acre)	Rate of application (fl. oz./acre)	Pretreatment count (mosquito/man/hour)	% Control after indicated hours 6	25–30	49–52	72
Malathion	0.225	3	62	63	0	..	..
(95% technical)	.62	8	87	78	85	75	..
Fenthion	.1	1.6	131	59	62	..	..
	.25	4	72	80	90	..	..
	.32	4.8	33	38	95	[a]	0
(Check)	...	...	172	0	0	0	0

[a] Collections of mosquitoes could not be made because of rain.

at the rate of 0.27 lb./acre to three plots, but heavy rain fell on two 4–5 hours after treatment and on the third immediately after treatment. The results were as follows (the 36-hour counts are based on the results from two plots):

Location of collector	Pretreatment count (mosquito/man/hour)	% Control after— 12 hours	36 hours
In jungle	365	46	69
On railroad	533	49	34

The poorer control in this test can definitely be attributed to the rain on the basis of our experience with aerial sprays in Florida. Presumably this is due to "washing out" of airborne droplets or foliage residues that could kill mosquitoes that do not contact the insecticide immediately or ones that migrate into the area. All caged mosquitoes in one plot died, and 97.5 percent died in the other. The average number of droplets per square inch was 1.4 in the jungle and 10 on the railroad tracks.

CONCLUSIONS. The results showed that control of anophelines can be obtained in moderate to dense jungles with fenthion and malathion though the necessary dose is about three times that required normally. However, this study obviously provided only a limited approach to the problem of mosquito control in jungles, and other methods besides increased doses should be investigated. A study on the relationship between droplet size and penetration through the canopy would be of particular interest.

ACKNOWLEDGMENTS. The cooperation and assistance of the staffs of the Chief Surgeon, the Environmental Health Division and the Post Engineer Division, HQ United States Army Southern Command, the Preventive Medicine Division, U. S. Army Medical Research and Development Command, and the U. S. Army Medical Equipment Research and Development Laboratory, Ft. Totten, New York are gratefully acknowledged. The following personnel from these agencies were especially helpful: Lt.C. Robert T. Cuttings, Cpt. Gerald K. Hicks, Sgt. John A. Wilder, SP5 William C. Langston and Mr. William R. Gaylord.

Literature Cited

GAHAN, J. B., and LINDQUIST, A. W. 1945. DDT residual sprays applied in buildings to control *Anopheles quadrimacultus*. J. Econ. Entomol. 38(2):223–230.

GAHAN, J. B., TRAVIS, B. V., MORTON, F. A., and LINDQUIST, A. W. 1945. DDT as a residual-type treatment to control *Anopheles quadrimaculatus*: Practical tests. J. Econ. Entomol. 38(2):231–235.

HOLWAY, R. T., MORRILL, A. W., and SANTANA, F. J. 1967. Mosquito control activities of the U. S. Armed Forces in the Republic of Vietnam. Mosq. News 27(3):297–307.

MOUNT, G. A., and LOFGREN, C. S. 1967. New insecticides as nonthermal aerosols for control of adult mosquitoes. Mosq. News 27(4):470–473.