FIELD TESTS WITH MALATHION FOGS DISPERSED FROM AN AIRPLANE FOR THE CONTROL OF ADULT SALT-MARSH MOSQUITOES

A. NELSON DAVIS,[1] JACK SALMELA,[2] AND C. B. SPENCER, JR.[2]

For a number of years airplanes have been used to disperse insecticidal sprays aimed at controlling mosquito adults. This method has proved to be faster but not so economical as ground-operated thermal aerosol generators. The chief restricting factor is the limited area that can be treated with a single airplane load. In an effort to overcome this limitation, the Brevard Mosquito Control District, Brevard County, Fla., developed a specially constructed exhaust generator for dispersing aerosols from a Stearman (PT–17) airplane. This equipment differs from that previously used for aerial adulticiding insomuch as the aerosol is produced as a "dry fog."

The utilization of the exhaust of an airplane to disperse insecticides for controlling mosquitoes is not new. In a publication prepared by the U. S. Department of Agriculture (1946) the history of the early developments in this field is reviewed. This method was first investigated at the Orlando, Fla., laboratory of the USDA in 1943 by injecting DDT solutions into an extension of the exhaust pipe of a Piper Cub plane. Lindquist *et al.* (1945), in reporting on this equipment, stated that an intense smoke was produced and promising results were obtained against *Aedes taeniorhynchus* (Wied.) adults. The Tennessee Valley Authority also tested this type of equipment on a Stearman plane and reported excellent results against *Anopheles quadrimaculatus* Say larvae. However, subsequent studies by several investigators showed that there was an incomplete conversion of the solution to smoke, and the portion discharged as spray was principally responsible for killing most of the mosquitoes. Metcalf *et al.* (1945) found that by fitting a venturi section to the end of the exhaust pipe a fine spray with only a small amount of screening smoke was produced. This equipment was reported to be highly effective in controlling *A. quadrimaculatus* larvae and adults and also adults of pest species of *Aedes* and *Psorophora*.

The Brevard Mosquito Control District developed a new thermal-aerosol apparatus in 1958 and has been using it in routine control operations since that time. This equipment, described in detail by Salmela *et al.* (1960), consisted of dual exhaust stacks extending 30 inches below the 220 hp. engine. The emission rate was calibrated at 150 gallons per hour. The aerosol used in routine control operations contained 15 percent of a commercial 90 percent malathion solution, 15 percent of heavy aromatic naphtha, 15 percent of Standard Oil No. 1 fog oil, and 55 percent of No. 2 diesel fuel. The naphtha was used as an auxiliary solvent to keep the malathion in solution and the fog oil was added to increase the volume of fog and aid it in falling. This equipment and formulation showed promise in the routine control of adult mosquitoes but the need for an evaluation of effective swath widths and dosage rates was apparent.

Field tests were conducted during 1959 with this new equipment against natural populations of salt-marsh mosquito adults and caged *A. taeniorhynchus* adults from a laboratory strain.

The initial series of tests was conducted to determine the effective swath width for the formulation used in routine control. These tests were conducted on an exten-

[1] Entomology Research Division, Agr. Res. Serv., U.S.D.A.
[2] Brevard Mosquito Control District.

sive impounded salt marsh in north Brevard County which is transected with a series of dikes. Three stations were established on a dike at 200-foot intervals in line with the wind movement. Two screen cages containing about 25 adult females per cage were attached to a stake at each station. The stakes, each 6 feet high with a 3-foot crossarm, were placed upright in the soil and the cages suspended from wires attached to the crossarms (Figure 1). Applications were made between 6:40 and 7:25 a.m., on two days, from an altitude of 25 feet while flying 80 m.p.h., crosswind and at right angles to the line of stakes. Swaths were flown 100 feet upwind from the first station to determine the effectiveness of a single swath. Tests were also run to determine the effect of multiple swaths at intervals of 100 to 300 feet. Within 10 minutes after treatment the mosquitoes were anesthetized with carbon dioxide and transferred to clean cages (Figure 2). Mortalities were recorded after 12 hours. The results are given in Table 1. These tests indicated that effective control of adults could be obtained with an aerosol containing 15 percent of malathion when four swaths were applied at intervals up to 200 feet, but not 300 feet, all upwind of the first station.

A series of four tests was conducted to determine the effectiveness of routine treatments with 200-foot swaths over residential areas with varying degrees of vegetative cover. Prior to treatment cages of *taeniorhynchus* adults were suspended from wires attached to trees and shrubs in semi-open or heavily vegetated locations. Applications were made between 6:30 p.m. and 9:30 p.m. at an altitude of about 50 feet whenever possible, and approximately

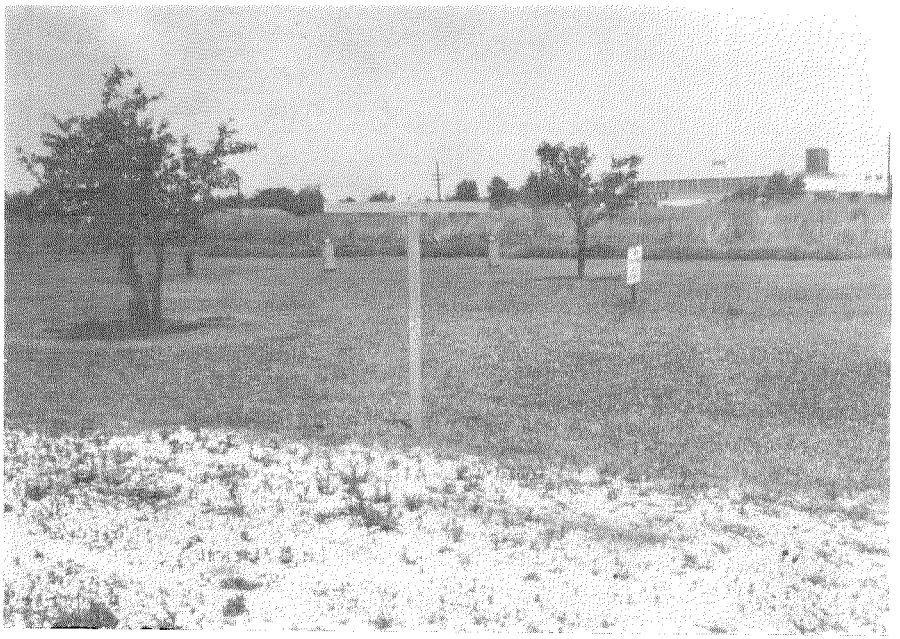

FIG. 1.—Test cages attached to stake.

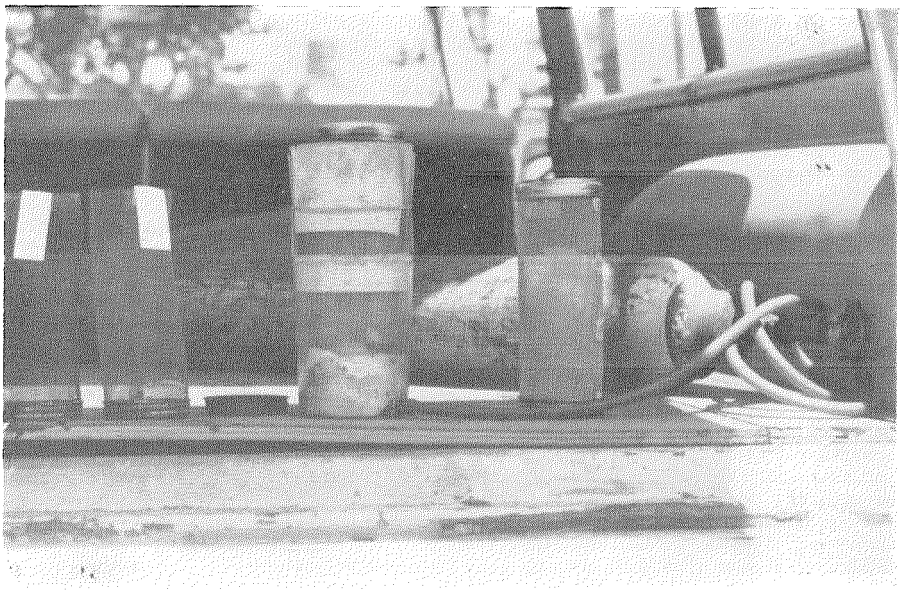

FIG. 2.—Apparatus used to transfer adult mosquitoes from exposure cage on right to holding cages on left. Carbon dioxide from the metal container is used to anesthetize adults in the plastic well in the center.

TABLE 1.—Swath-width studies with an aerosol containing 15% of a 90% malathion concentrate against caged *Aedes taeniorhynchus*. (Stakes 200 feet apart, extending downwind from final swath. 2 replications.)

Swath pattern			Percent mortality after 12 hours—			Wind velocity (m.p.h.)
Total number	Intervals (feet)	Distance upwind from Stake 1 (feet)	Stake 1	Stake 2	Stake 3	
1	——	100	34	20	28	1–2
4	100	400–100	97	94	98	3
4	200	800–200	86	90	90	3–7
4	300	1,200–300	60	75	73	5–8

20 feet above trees and other obstructions, in winds of 3- to 25-m.p.h. velocity. When the wind movement was less than 10 m.p.h. the line of flight of the plane was at right angles to the direction of the wind; whereas, in winds in excess of 10 m.p.h. the line of flight was parallel to the direction of the wind. The size of the areas treated varied from 1,200 to 2,000 acres. A 30- to 60-minute time interval was allowed between treatment and transfer of the adults to clean holding cages. This time lapse was necessary to allow the aerosol cloud to dissipate or drift out of the area in which the cages were exposed. Mortalities were recorded after 12 hours.

The results of these tests are given in Table 2. Average mortalities of 89 to 99

TABLE 2.—Evaluation of routine applications of aerosols containing 15% of malathion (90% concentrate) heavy aromatic naphtha, and fog oil in No. 2 diesel fuel against caged *Aedes taeniorhynchus*

Area	Number of cages	Percent mortality after 12 hours	Wind velocity (m.p.h.)
Residential-wooded	27	98	5–12
	31	99	15–25
	16	99	3
Trailer park-semi-open	12	89	15–20

percent were obtained. The lower kill occurred in a semi-open trailer park. Wind velocities of 15 to 20 m.p.h. prevailed during this test. The absence of vegetation of sufficient density to prevent the rapid passage of the aerosol over the area was the apparent reason for the low kill.

Having shown that formulations containing 15 percent of malathion were highly effective, the next series of tests was conducted at an abandoned airstrip with formulations containing various concentrations of malathion and equal quantities of an auxiliary solvent (heavy aromatic naphtha) in No. 2 diesel fuel. Fog oil (15 percent by volume) was added to each formulation. As in the initial series, three stations were established at 200-foot intervals in line with the wind movement and two screen cages containing about 25 adult females per cage were attached to a stake at each station. Applications were made between 6:30 and 10:30 p.m. from an altitude of 25 to 40 feet while flying 80 m.p.h. crosswind and at right angles to the line of stakes. In these tests swaths were flown 800, 600, 400, and 200 feet upwind from the first station. Within 10 minutes after treatment, the mosquitoes were anesthetized with carbon dioxide and transferred to clean cages. The mortalities were recorded after 12 hours. The results of these tests are given in Table 3. Complete mortalities were obtained consistently with malathion at concentrations as low as 10 percent. Malathion concentrations of 5.0 and 7.5 percent produced 79–100 percent kills.

A fourth series of tests was conducted to evaluate three concentrations of malathion against natural populations of salt-marsh mosquito adults (predominantly *taeniorhynchus*). These studies were made in the Allenhurst-Shiloh area of Brevard County. Test plots of 180 and 900 acres were established in citrus groves. Applications were made during the first 1½ hours of daylight on four mornings from an altitude of 50 to 75 feet in winds of 1 to 7 m.p.h. The plane flew crosswind at swath intervals of 200 feet. The mosquito populations were sampled before and after treatment by two observers at 10 stations in the smaller plots and at 50 stations in the 900-acre plot. Control was determined by comparing the number of mosquitoes

TABLE 3.—Dosage tests with aerosols containing various concentrations (v/v) of malathion (90% concentrate), heavy aromatic naphtha, No. 2 diesel fuel, and 15% of fog oil against caged *Aedes taeniorhynchus*. (Stakes 200 feet apart, extending downwind from final swath. 3 replications.)

Percent of malathion and heavy aromatic naphtha	Percent mortality after 12 hours at indicated distance from final swath			
	200 feet	400 feet	600 feet	Average
15.0	100	100	100	100
12.5	100	100	100	100
10.0	100	100	100	100
7.5	94	99	99	97
5.0	98	100	79	92

that landed on the two observers the day before and 3, 6, and 24 hours after application. These results are shown in Table 4.

TABLE 4.—Effectiveness of malathion aerosols against natural populations of adult salt-marsh mosquitoes. 3 replications

Formulations (percent v/v) [a]			Pretreatment count (average per man per minute)	Percent reduction [b] after—		
Malathion (90% conc.)	Naphtha	Fog oil		3 hours	6 hours	24 hours
15	15	15	46	94	92	+54
10	10	15	40	98	98	+117
5	5	15	37	82	91	61

[a] No. 2 diesel fuel solutions.
[b] Plus sign indicates percent increase.

All formulations gave greater than 90 percent reduction after 6 hours, whereas after 24 hours the control was unsatisfactory owing to rapid reinfestation of the treated areas.

A fifth series of tests was conducted to evaluate two thiocyanate insecticides, Thanite and Lethane 384. Many mosquito control organizations have used these thiocyanates in combination with other insecticides as aerosols produced by ground-operated thermal aerosol generators. The principal combinations have been Thanite (isobornyl thiocyanoacetate, and related compounds) or Lethane 384 (2-(2-butoxyethoxy)ethyl thiocyanate) formulated with DDT, and more recently Lethane 384-malathion formulations. Both Thanite and Lethane 384 were tested alone and in combination with malathion. Each formulation contained an auxiliary solvent (heavy aromatic naphtha) in quantities equal to the insecticides and 15 percent of fog oil in No. 2 diesel fuel.

As in previous tests, three stations were established at 200-foot intervals in line with the wind movement. Two screen cages containing about 25 females per cage were attached to a stake at each station. Applications were made between 5:00 and 6:30 p.m. in wind movements of 3 to 8

TABLE 5.—Effectiveness of thiocyanate insecticides and malathion (90% concentrate) against caged *Aedes taeniorhynchus*. (Stakes 200 feet apart extending downwind from final swath. 3 replications.)

Insecticide and percent concentration (v/v[a])		Percent mortality after 12 hours at indicated distance from final swath			
		200 feet	400 feet	600 feet	Average
Malathion	2.5	56	60	52	56
Plus Lethane 384	5.0	20	19	8	16
Plus Thanite	5.0	32	41	18	30
Lethane 384	15.0	20	6	8	12
	10.0	9	7	7	8
	5.0	17	10	3	10
Thanite	15.0	8	9	13	10
	10.0	5	9	3	6
	5.0	13	22	16	17
None	[b]	0	0	0	0

[a] An equal quantity of heavy aromatic naphtha was also used, plus 15 percent of fog oil, in No. 2 diesel fuel.
[b] Naphtha 15 percent, fog oil 15 percent, No. 2 diesel fuel 70 percent.

m.p.h. from an altitude of 25 feet while flying 80 m.p.h. crosswind and at right angles to the line of stakes. Again all test swaths were flown 800, 600, 400, and 200 feet upwind from the first station. The mosquitoes were transferred to clean cages within 10 minutes after treatment. The results of these tests are given in Table 5. Lethane 384 and Thanite were ineffective at concentrations as high as 15 percent, and, at 5 percent, did not add to the effectiveness of 2.5 percent of malathion. In fact, in these tests mortality with 2.5 percent of malathion alone was actually higher than that with the combinations.

SUMMARY. Field tests were conducted to evaluate a new thermal-aerosol exhaust generator designed to disperse insecticidal fogs from a Stearman airplane. No. 2 diesel fuel formulations containing various concentrations of malathion, an equal amount of heavy aromatic naphtha, and 15 percent of Standard Oil No. 1 fog oil were tested against natural populations of salt-marsh mosquito adults and caged *Aedes taeniorhynchus* (Wied.) from a laboratory strain.

This equipment, calibrated to disperse 150 gallons of solution per hour, was found to have an effective swath of at least 200 feet. Routine control treatments over residential areas with a formulation containing 15 percent of a commercial 90 percent malathion solution were highly effective in killing caged adults. Complete mortality of caged adults was obtained under experimental conditions at 10 percent, and greater than 90 percent mortality at 5 percent. Formulations containing 5 percent, 10 percent, and 15 percent produced satisfactory kills of natural populations.

Lethane 384 and Thanite were ineffective at concentrations as high as 15 percent and at 5 percent did not add to the effectiveness of 2.5 percent of malathion when tested against caged adults.

Literature Cited

LINDQUIST, ARTHUR W., MADDEN, A. H., HUSMAN, C. N., and TRAVIS, B. V. 1945. DDT dispersed from airplanes for control of adult mosquitoes. Jour. Econ. Ent. 38(5):541–4.

METCALF, R. L., HESS, A. D., SMITH, G. E., JEFFERY, G. M., and LUDWIG, G. W. 1945. Observations on the use of DDT for the control of *Anopheles quadrimaculatus*. Public Health Rpts. 60(27):753–4.

ORLANDO, FLA., LABORATORY, BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE. 1946. DDT and other insecticides and repellents developed for the Armed Forces. U. S. Dept. Agr. Misc. Pub. 606, 71 pp.

SALMELA, JACK, SIDLOW, A. J., and DAVIS, A. NELSON. 1960. A new thermal-aerosol generator for dispersing insecticidal fogs from a Stearman airplane. Mosquito News 20(3):275–280.