ARTICLES

RELATIVE EFFECTIVENESS OF SEVERAL INSECTICIDES AS SPRAYS AND AS FOGS AGAINST SALT-MARSH MOSQUITO ADULTS[1]

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For the last several years most of the mosquito-control districts in Florida have placed greater emphasis on the control of adults than on the control of larvae. Airplanes are widely used in large or inaccessible areas, but most of the districts rely mainly upon ground spray and fog machines for control of adults in towns and rural communities. Such machines are more economical than airplanes for small-scale work, are less limited in use in unfavorable weather, and have the added advantage of being usable day or night. However, little or nothing was known of the relative efficiency of some of the newer types of ground equipment, particularly under different conditions of use. Extensive field tests were therefore conducted in 1951 and 1952 to compare the performance of several types of spray and fog machines when applying different insecticides against the salt-marsh mosquitoes *Aedes taeniorhynchus* (Wied.) and *sollicitans* (Wlkr.). The results obtained in these studies are presented in this paper.

TYPES OF EQUIPMENT.—In 1951 tests were conducted with an old-model Hession Microsol mist sprayer, a Dyna-Fog generator, and a jeep-operated mist sprayer developed by Husman (1953). In 1952 a new-model Hession Microsol, a Lawrence Aero-Mist L-40 sprayer, a small Japanese Kyoritu fog machine, and a skid-mounted adaptation of the jeep sprayer were used.

The Hession Microsol is a self-powered unit which atomizes insecticidal solutions by means of multiple rotating disks and disperses them by an air blast from a turbine. The Lawrence Aero-Mist is a conventional type of hydraulic mist sprayer, in which the solution is forced through nozzles under low pressure and dispersed in a strong air blast. The jeep sprayer atomizes the solution by the shearing action of compressed air on the solution as it is forced through fine pneumatic nozzles. The unit is not equipped with a blower; so dispersal of the spray is dependent upon the wind. Each of these machines was calibrated to disperse 30 gallons of insecticidal solution per hour.

The Kyoritu fog machine is a small, self-powered unit in which the insecticidal solution is sprayed into the hot exhaust pipe and transformed into smoke or fog. A blower attachment on the exhaust disperses the smoke. With the Dyna-Fog the solution is injected into a jet tube, transformed into smoke, and dispersed in the powerful jet exhaust. The Dyna-Fog was calibrated to deliver 30 gallons per hour, but the Kyoritu was capable of dispersing only 6 gallons per hour.

The size of particles produced by the Microsol and jeep sprayers or the Dyna-Fog generator was not determined in 1951, but this information was obtained for all the machines before the field tests were begun in 1952. Data were obtained from measurements on magnesium oxide-coated slides exposed 50 feet downwind from each machine. The results are given in Table 1. Droplets smaller than 5

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TABLE 1.—Size of particles produced by the four types of spray or fog machines.

Machine	Percent of particles of indicated diameter (microns)				Diameter averages (microns)		
	5–40	41–80	81–120	121+	Median	Mass median	D_o [1]
Jeep sprayer	71	29	..	..	39	51	60
Hession Microsol	40	40	18	2	74	104	115
Lawrence Aero-Mist	70	16	6	8	46	160	107
Kyoritu	42	50	8	..	52	72	84

[1] D_o is the diameter in microns of a drop with the same ratio of surface to volume as a representative sample of the drops in the spray.

microns were not included, as they do not produce distinct craters. With the Kyoritu fog machine probably most of the droplets were below this size.

MATERIALS AND DOSAGES.—The following insecticides were tested in fuel oil solution at the concentrations indicated:

1951	1952
Lindane 2.5%	Heptachlor 2.5%
Dieldrin 5%	BHC (40% gamma) 2.5% gamma
DDT 10%	Chlordane 5%
	Dieldrin 5%
	DDT 5%

Cyclohexanone was used as an auxiliary solvent for lindane, BHC, and dieldrin, and a hydrocarbon solvent for DDT.

All the insecticides were applied with each machine at rates of 6, 12, and 24 gallons per mile. Heptachlor and BHC were also tested at 3 gallons per mile. These rates of application were obtained by varying the speed of the vehicles on which the sprayers were mounted, not by altering the rate of dispersal. On the basis of an effective swath of 100 yards, the approximate pounds of insecticide per acre for different concentrations and rates of dispersal may be calculated as follows:

Gallons per mile	10%	5%	2.5%
3	0.07	0.04	0.02
6	.14	.07	.04
12	.28	.14	.07
24	.56	.28	.14

TEST PROCEDURES.—All the tests in 1951 and about half those in 1952 were conducted in orange groves near salt marshes in the Mims and Shiloh districts of Brevard County, Fla. The remainder of the tests in 1952 were made in typical wooded areas in northern Volusia and southern Flagler Counties. Test plots were selected where mosquitoes occurred in annoying numbers and where roads were suitable for slow travel. Test plots for three of the machines were ¼ mile in length, but for the small Kyoritu they were only 100 yards long because of its low rate of dispersal.

Spraying and fogging operations were begun before sunrise and continued as long as inversion conditions persisted. The 1951 tests were conducted in winds ranging from 1 to 15 miles per hour, but in 1952 all tests were run in winds of less than 1½ miles per hour. After the machines were set in operation, the carrying vehicles were driven at a predetermined speed along the upwind side of the test plot so that the spray drifted into the area.

Mosquito populations were determined

by counting those landing on each of two men in 1 minute at ten stations in each plot. The stations were arranged in two lines of five each, 50 feet apart, perpendicular to the line of dispersal and near the center of the plot. Only five stations along a single line were set up in the Kyoritu plots. Counts were made on the afternoon before treatment and again 6 or 10 hours after treatment. Counts were also made regularly in untreated areas to determine whether any change in the treated plots was due to the treatments or to natural factors.

RESULTS. *Tests in 1951.*—In 1951 the 2- and 10-hour posttreatment counts were so nearly alike that either one could be used in evaluating the effectiveness of the different treatments and machines. In most of the tests slightly greater reductions were indicated by the 2-hour counts, but the difference was never more than 13 percent and seldom more than 10 percent. Since the counts were so closely comparable, only those made 2 hours after treatment are considered in the discussion. Results based on these counts are given in table 2.

The effectiveness of the insecticides varied somewhat with the rate of application, the type of machine, and the wind velocity. However, on the basis of the actual amount of insecticide applied, lindane was slightly more effective than dieldrin, and both were more effective than DDT. Specifically, applications of 2.5 percent of lindane solution gave equal or slightly better reductions in adult populations than applications of 5 percent of dieldrin, and both gave greater reductions than 10 percent of DDT.

With the Microsol mist sprayer 2.5 percent of lindane and 5 percent of dieldrin gave similar results at each rate of application. Lindane and dieldrin also gave comparable reductions at medium and high rates of application with the jeep sprayer, but lindane was superior at the lowest test dosage. With the Dyna-Fog generator lindane was more effective than dieldrin or DDT, which were about equal. No differences in the effectiveness of high, medium, and low dosages of lindane and DDT were indicated in the tests with the jeep sprayer, but with the

TABLE 2.—Effect of type of machine, wind velocity, and rate of application on the reduction of mosquitoes obtained with lindane, dieldrin, and DDT in oil solutions.

Wind velocity (m.p.h.)	Percent reduction with indicated gallons per mile								
	Lindane (2.5%)			Dieldrin (5%)			DDT (10%)		
	6	12	24	6	12	24	6	12	24
	Microsol sprayer								
1–5	55	82	83	68	86	78	57	55	69
5–10	91	95	100	89	90	97	79	90	88
10–15	89	87	89	88	88	91	71	90	86
Average	78	88	91	82	88	89	69	78	81
	Dyna-Fog generator								
1–5	95	95	96	80	69	88	88	87	91
5–10	75	66	80	72	64	58	50	30	62
10–15	28	25	54	12	24	56	28	37	51
Average	66	62	77	55	52	67	55	51	68
	Jeep sprayer								
1–5	57	47	58	51	68	71	22	26	23
5–10	84	88	92	60	79	93	83	92	85
10–15	96	97	100	72	86	95	88	91	93
Average	79	77	83	61	78	86	64	70	67

other two machines the highest dosage caused the greatest reduction.

The best results with the Microsol sprayer were obtained when the wind velocity was 5 to 10 miles per hour, and the poorest at 1 to 5 miles. The jeep sprayer gave the best results at 10 to 15 miles per hour, and poor results at 1 to 5 miles, presumably because light breezes failed to disperse the spray particles. On the other hand, the Dyna-Fog generator was very effective at 1 to 5 miles per hour, and relatively ineffective at 10 to 15 miles. These results suggest that the fine particles of insecticidal fogs are of little value if dispersal is swift. This confirms the results obtained in Alaska in 1950, which indicated that fogs were most effective when they dispersed slowly and near the ground.

Tests in 1952.—Results of the tests in 1952 are presented in table 3. BHC was the most effective insecticide followed in order by heptachlor, DDT, dieldrin, and chlordane. With few exceptions a BH solution at 6 gallons or more per mil showed excellent control at both the and 6-hour counts. Heptachlor ga rather poor immediate control except the highest dosage, but showed exceller results after 6 hours. In most of the tes the highest dosage of DDT caused 90 pe cent or higher reductions within 2 hour but lower dosages gave erratic and ge erally unsatisfactory control. Dieldri was generally slightly less effective tha DDT at corresponding dosages, but goo control was indicated after 6 hours i plots treated at a rate of 24 gallons pe mile with the Aero-Mist and Micros sprayers. Chlordane was the least effe tive insecticide tested, the highest dosage giving only fair control.

There was little consistent difference i effectiveness between the various machine at wind speeds of less than 1½ miles pe hour, which prevailed throughout th tests. All gave about equally good r

TABLE 3.—Percent reduction of mosquitoes 2 and 6 hours after dispersal of various insecticides with four types of machines, 1952. (2 to 5 tests.)

Insecticide and gallons per mile	Aero-Mist		Microsol		Jeep sprayer		Kyoritu	
	2 hours	6 hours	2 hours	6 hours	2 hours	6 hours	2 hours	6 hours
Heptachlor 2.5%								
3	58	36	16	44	..	..	71	82
6	22	77	78	92	72	96	49	74
12	48	99	60	100	56	99	30	85
24	61	99	94	100	86	100	89	98
BHC 2.5% gamma								
3	38	50	45	77	..	..	32	32
6	92	99	88	98	0	..	83	98
12	98	99	95	100	0	..	78	99
24	98	100	100	99	57	100	97	99
Dieldrin 5%								
6	39	55	18	71	27	45	70	68
12	45	55	29	66	60	73	71	90
24	51	90	43	93	76	82	71	62
DDT 5%								
6	80	73	40	66	59	56	79	78
12	80	80	17	75	63	64	96	85
24	93	95	82	93	90	91	98	82
Chlordane 5%								
6	41	60	18	78	31	78	13	55
12	48	62	48	98	5	35	26	68
24	60	82	57	85	58	64	28	70

[resu]lts with heptachlor and BHC. There [w]ere slight differences with the other in[se]cticides, but these are not considered [si]gnificant.

SUMMARY.—Extensive field tests were [co]nducted in 1951 and 1952 to compare [th]e performance of several types of spray [an]d fog machines when applying different [in]secticides against adults of the salt-[m]arsh mosquitoes *Aedes taeniorhynchus* ([W]ied.) and *sollicitans* (Wlkr.).

In 1951 lindane was slightly more effec[ti]ve than dieldrin and both were superior [to] DDT regardless of the type of equip[m]ent used. A fog machine (Dyna-Fog) [g]ave the best results when winds were [le]ss than 5 miles per hour and the poorest [at] wind speeds over 10 miles, whereas the [re]verse was true with a jeep-operated mist sprayer. A Hession Microsol sprayer was most effective at wind speeds of 5 to 10 miles per hour.

In 1952 BHC (40% gamma) was slightly more effective than heptachlor, and both were considerably better than DDT, dieldrin, and chlordane. There was little consistent difference in effectiveness between the Lawrence Aero-Mist, Hession Microsol, and jeep sprayers and a Kyoritu fog machine at wind speeds of less than 1½ miles per hour, which prevailed throughout the tests.

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TESTS WITH GRANULATED INSECTICIDES FOR THE CONTROL OF SALT-MARSH MOSQUITO LARVAE [1, 2]

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Aerial spraying of insecticides fre[q]uently fails to give satisfactory control of [t]he larvae of *Aedes taeniorhynchus* (Wied.) and *sollicitans* (Wlkr.) in salt-[m]arsh breeding areas in Florida. Such [t]reatments are ineffective largely because [o]nly a small proportion of the spray pene[t]rates the vegetative cover and reaches [t]he larvae in the water. The development [o]f increased resistance in these species to [t]he chlorinated hydrocarbon insecticides [h]as further emphasized the need for get[t]ing adequate quantities of larvicide into [t]he water.

In tests on the control of *Psorophora [c]onfinnis* (L.-Arr.) and *discolor* (Coq.) in rice fields in Arkansas, Whitehead (1951) found that better penetration of thick stands of rice could be obtained by applying bentonite pellets coated with the larvicides. In view of the results, tests were made on salt marshes in Brevard County, Florida, to determine whether greater efficiency could be obtained with insecticides on granular carriers.

HAND APPLICATIONS.—Preliminary tests were conducted on small plots (100 to 7,000 square feet) with lindane, dieldrin, heptachlor, chlordane, TEPP, and parathion on granular bentonite, in comparison with emulsions of the same materials. All emulsions were applied at a concentration of 1 percent with a small hand atomizer. The granular bentonite containing 0.5, 1.5, and 5 percent of toxicant was broadcast by hand. The emulsions and granulated insecticides were applied in various amounts to give dosages of 0.01, 0.025, 0.05, and 0.1 pound of toxicant

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