39007 (*o*-isopropoxyphenyl methylcarbamate) and Schering 34615 (*m*-cym-5-yl methylcarbamate) were about equal to naled and twice as effective as malathion. Dursban (*O,O*-diethyl *O*-3,5,6-trichloro-2-pyridyl phosphorothioate) and Shell SD-8211 (2-chloro-1-(2,5-dichlorophenyl)= vinyl dimethyl phosphate) were less effective than fenthion or naled but were more effective than malathion. Barthrin, Abate (*O,O*-dimethyl phosphorothioate *O,O*-diester with 4,4'-thiodiphenol), and Shell SD-8447 (2-chloro-1-(2,4,5-trichlorophenyl) vinyl dimethyl phosphate) were generally less effective than malathion, but barthrin was more effective against *A. quadrimaculatus*.

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ULTRA-LOW VOLUME AND CONVENTIONAL AERIAL SPRAYS FOR CONTROL OF ADULT SALT-MARSH MOSQUITOES, *AEDES SOLLICITANS* (WALKER) AND *AEDES TAENIORHYNCHUS* (WIEDEMANN), IN FLORIDA[1]

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The past few years the concept of low volume spraying, that is, the use of undiluted or concentrated insecticide, for area control of insects has captured the imagination of many engaged in insect control. In large-scale insect control programs, the savings in cost, time, and labor that this technique offers are enormous. Credit for the modern-day interest in this method goes to the Methods Improvement Section of the Plant Pest Control Division (PPCD), ARS, USDA. The first experiments with this method (in grasshopper control) were reported by Messenger (1963, 1964).

Before proceeding, it is necessary to clarify terminology in this field. It is quickly obvious in talking to people involved in other aspects of insect control that the term "low volume" is not very descriptive. Researchers on cotton insects consider as "low volume" applications of technical or concentrated insecticide between ½ to 15 gallons per acre. One-half gallon or less is called "ultra-low volume." From this definition it is apparent that ultra-low and low volume sprays have been used for mosquito control for many years. In fact over 15 years ago Blanton *et al.* (1950) reported on tests in Alaska where

[1] The mention of a proprietary product does not necessarily imply endorsement of this product by the USDA.

application rates of DDT in oil as low as ¼ pint or 4 fl. oz. were evaluated against mosquitoes.

To avoid confusion in this paper, "ultra-low volume" will be used to designate any spray in which total volume applied is less than ½ gallon per acre. This will also be done when referring to the work of other authors even though they used different terminology. Applications greater than ½ gallon will be referred to as "conventional" sprays.

At the Gainesville laboratory, we became interested in ultra-low volume spraying through our contacts with PPCD, and in 1964, we obtained the Mini-Spin® nozzles recommended by them. In late summer and fall of that year, the first tests were made in Florida (Glancey *et al.*, 1965). The results showed clearly that rates of application of technical malathion as low as 2 fl. oz. per acre could give good control of salt-marsh mosquitoes, *Aedes sollicitans* (Walker) and *A. taeniorhynchus* (Wiedemann) (over 90 percent in 24 hours). Also, Knapp and Roberts (1965) reported good control of *A. sollicitans* in preliminary tests in Kentucky with ultra-low volume applications of malathion.

Further tests in 1966 (Glancey *et al.*, 1966a) showed that ultra-low volume applications could be used successfully with other insecticides; they obtained excellent control with naled and various combinations of naled and malathion. Fenthion was also tested. Although the doses applied (0.016–0.03 lb. per acre) were below the rates required for optimum control, the results again appeared promising. For these tests, they used a self-contained spraying system which circumvented the conventional system. It consisted essentially of a small stainless-steel spray tank pressurized by CO_2 gas from a cylinder located in the baggage compartment behind the pilot. A Tygon® insecticide line extended from the baggage compartment through the pilot's compartment, where a control valve was located, and out along the standard spray boom. The insecticide was dispersed through two or four Mini-Spin nozzles attached to the metal boom and the Tygon tubing. This system eliminated the continual problem of blockages of lines and nozzles of the conventional system so volumes of liquid as low as ¼ fl. oz. per acre could be used.

In all the tests at the Gainesville laboratory, and in all those of other investigators, no direct comparison has been made of the effectiveness of ultra-low volume sprays with conventional sprays. Obviously, such information is necessary before judgments can be made of the true effectiveness of ultra-low volume treatments. In Florida, the conventional spray rate recommended by the State Board of Health is 1 to 6 quarts per acre, and 3 quarts per acre has been our standard rate of application in tests for many years. This paper presents results of tests conducted this past year in which the effectiveness of ultra-low and conventional sprays (3 quarts per acre) of malathion, naled, and fenthion was compared against mixed populations of the two salt-marsh mosquitoes, *A. taeniorhynchus* and *A. sollicitans*.

METHODS AND MATERIALS. The tests were conducted between July and September 1966 in 10- to 40-acre citrus groves adjacent to salt marshes on the north end of Merritt Island near Titusville, Florida. Large numbers of the two species of salt-marsh mosquitoes were in the citrus groves throughout the tests; pretreatment counts for the individual plots ranged from 7 to 741 per man per 30 seconds, and the average for all tests was 72 mosquitoes per man per 30 seconds.

The sprays were applied from a Stearman airplane owned and operated by the Brevard Mosquito Control District, Merritt Island, Florida. In all the tests, the airplane was flown at a speed of 85 m.p.h., at an altitude of 50 to 75 feet, and at 100-foot swath intervals.

A self-contained system similar to that described by Glancey *et al.* (1966b) was mounted on the plane and used for all ultra-low volume treatments. Differences were the three-eighths inch polyethylene tubing used throughout the unit to com-

pensate for the high degree of solvency of some components of the formulations and the four flat fan Tee Jet® nozzles (Spraying Systems Co.) used instead of Mini-Spin nozzles. These nozzles were spaced 6 and 12 feet from each side of the fuselage and under the lower wings of the airplane. The desired rate of application of each formulation was obtained by varying the nozzle size (No. 800067 to No. 8003) and line pressure (24 to 42 p.s.i.). The volume of spray applied per acre ranged from 1.6 to 6.4 fl. oz., depending on the dose desired and the concentration of insecticide in the formulation.

Conventional spraying was done with a typical metal spray boom equipped with 17 flat fan Tee Jet (#6510) nozzles operated at a pressure of 20 p.s.i. In all tests the orifices of the nozzles were oriented straight downward at a 90° angle to the wings of the airplane.

The insecticides tested were naled, fenthion, and malathion. Although we wished to apply undiluted insecticides for all the ultra-low volume tests, such a procedure was impossible for some rates of application with the nozzle sizes we had available. Therefore, it was necessary to dilute the insecticides to obtain some of the desired flow rates. The 0.05 and 0.1 lb. per acre applications of naled and fenthion and the 0.1 and 0.2 lb. per acre applications of malathion were achieved by making a 4 lb. per gallon solution of the insecticide in methylene chloride; this solvent was chosen because of its high solvency and low flammability. Naled and fenthion (0.2 lb. per acre) and malathion (0.4 lb. per acre) were applied as undiluted concentrates (naled, 14 lb. per gallon; fenthion, 8 lb. per gallon; malathion, 95 percent technical).

Conventional spraying was done with water emulsions formulated from the following emulsifiable concentrates: naled (8 lb. per gallon), fenthion (4 lb. per gallon), and malathion (5 lb. per gallon).

Counts of mosquitoes were made the day before and 6, 24, and 48 hours after treatment to evaluate the effectiveness of the treatments. Counts were made at 10 locations by two observers after standing side by side and facing opposite directions for 30 seconds. Counting stations were about 50 feet apart and were arranged in one, two, or three rows (depending on the width of the grove) near the center of each plot at 90° angles to the flight swaths.

The tests were conducted on 10 different mornings at times ranging from 5:30 to 10:30 a.m. Wind speeds during the applications never exceeded 10 m.p.h. and were usually less than 5 m.p.h. From 2 to 10 replications were made with each treatment.

RESULTS AND DISCUSSION. Data for the ultra-low volume spray tests are presented in Table 1. Naled was the most effective compound after 6 hours; it produced 88 and 94 percent reductions at rates of 0.1 and 0.2 lb. per acre, respectively; however, the degree of control decreased appreciably after 24 hours. Fenthion, which gave only fair control after 6 hours at all three doses, gave better control after 24 to 48 hours at the two higher doses (75 and 89 percent). Malathion gave poor control, regardless of doses or interval after treatment; this result reflects the resistance to this insecticide that is developing in Florida. Recent tests have indicated a 15-fold tolerance to malathion in mosquitoes collected from this area compared with that of our standard laboratory colony. Recent papers by Glancey *et al.* (1966b) and Gahan *et al.* (1966) discuss this problem further.

In the conventional spray tests (Table 2), fenthion gave good immediate control (95 to 98 percent in 6 hours) at all three test doses. At the highest rate, good control was maintained for 48 hours, but only fair control was obtained at 24 and 48 hours at the two lower rates. Naled was less effective than fenthion at the two lower rates of application. Control at a rate of 0.2 lb. per acre was excellent after 6 hours but declined considerably after 24 hours. Again, malathion was less effective; however, at 0.2 lb. per acre, it maintained from 74 to 88 percent control

TABLE 1.—Control of adult salt-marsh mosquitoes with ultra-low volume aerial sprays of various insecticides.

Insecticide	Lb./acre	Oz. of spray per acre	Nozzle size	p.s.i.[a]	No. of replics.	Pretreatment count (mosq./man/1/2 min.)	Percentage reduction at indicated hour after treatment[b] 6	24	48
Naled	0.05	1.6	800067	42	10	46	65	17	..
	.1	3.2	80015	38	6	69	88	36	..
	.2	1.8	8001	28	5	169	94	78	33
Fenthion	.05	1.6	800067	34	6	49	79	60	..
	.1	3.2	80015	34	6	50	72	75	84
	.2	3.2	730116	42	5	53	75	89	77
Malathion	.1	3.2	80015	34	4	127	54	30	..
	.2	6.4	8003	42	6	81	63	53	53
	.4	5.3	8002	38	5	233	46	66	55
None (untreated)	..	..	..	..	19	56	+10	4	+10

[a] Pressure between insecticide tank and nozzles while system was operating.
[b] + indicates percentage increase.

throughout the 48-hour test. Both naled and malathion were less effective than reported by Davis *et al.* (1960). As indicated previously, the poor results with malathion are attributable to resistance; however, cross-resistance to naled could not be demonstrated in preliminary laboratory tests, and the poorer results are therefore unexplained.

A comparison of the results obtained with the ultra-low volume and conventional sprays indicates that naled was the only compound that gave essentially the same control with both methods of application. Fenthion produced about 20 percent less control at 6 hours when it was used as an ultra-low volume than as a conventional spray, but both methods gave about the same control at 24 and 48 hours. Ultra-low volume spraying with malathion was slightly less effective than conventional spraying, regardless of the time after treatment.

Thus differences do exist in the effectiveness of an insecticide applied by the two methods. The comparable results obtained by the two methods with naled may have been caused by its fumigating effect which could nullify differences in effectiveness caused by particle size and

TABLE 2.—Control of adult salt-marsh mosquitoes with conventional (3 quarts per acre) aerial sprays of various insecticides.

Insecticide	Lb./acre	No. of replications	Pretreatment count (mosq./man/1/2 min.)	Percentage reduction at indicated hour after treatment[a] 6	24	48
Naled	0.05	4	18	79	24	..
	.1	2	25	82	44	..
	.2	2	381	99	73	..
Fenthion	.05	2	26	97	57	..
	.1	2	33	98	64	74
	.2	2	38	95	96	80
Malathion	.2	2	35	74	88	77
	.4	2	187	84	70	..
None (untreated)	..	10	56	+18	4	34

[a] + indicates percentage increase.

distribution. Those differences obtained with fenthion or malathion might be attributable to particle size or distribution. Investigations into the effects these factors might have on mosquito control would certainly be worthwhile.

SUMMARY. A comparison of the effectiveness of ultra-low volume and conventional sprays of malathion, naled, and fenthion were made with adult salt-marsh mosquitoes, *A. taeniorhynchus* and *A. sollicitans*. Naled gave essentially the same control with both methods of application: a dose of 0.2 lb. per acre was necessary to obtain over 90 percent control within 6 hours and no application gave good residual control. Fenthion gave excellent control as a conventional spray (95 to 98 percent) at doses of 0.05 to 0.2 lb. per acre for 6 hours, but only the higher rate gave residual control (80 percent after 48 hours). The ultra-low volume treatments that gave only fair control (72 to 79 percent) at the same doses at 6 hours gave as good or better control after 24 to 48 hours at the two higher rates (75 to 89 percent). Malathion gave poor control regardless of dose, undoubtedly because of resistance; however, slightly better control was obtained with conventional spray applications.

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