

illustrates that at high concentrations only a relatively small time is needed to give 100 percent control, but that 100 percent control can also be obtained if the concentration is maintained at a low level over a prolonged period. Consequently, this effect should be taken into account when considering the dosage required for control in ponds. The position of this curve is dependent upon some of the environmental factors, principally those related to the rate of metabolism in the

larvae. Increasing the temperature, increasing the food supply, increasing the oxygen supply should effectively raise this curve. Both Figures 4 and 5 illustrate that the environmental factors play an important role in determining the effectiveness of a larvicidal application. The removal curve shown is a hypothetical example. It is not based on any experimental data. There will be a considerable variation in actual removal curves, depending on the environment.

DROPLET SIZE, DENSITY, DISTRIBUTION AND EFFECTIVENESS IN ULTRA-LOW VOLUME AERIAL SPRAYS DISPERSED WITH TEEJET® NOZZLES¹

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TeeJet® flat fan and hollow cone hydraulic nozzles are now the most commonly used devices for dispersing ultra-low volume (ULV) aerial sprays and aerosols of concentrated insecticides. The efficacy of applications made with these nozzles was described by Lofgren (1970) in his review of ULV sprays for use in mosquito control; however, only limited research has been reported on the physical characteristics of these sprays, especially in relation to mosquito control. Also, in a subsequent paper, Mount *et al.* (1970) suggested that increased efficiency might be achieved by improvements in the physical characteristics of the ULV sprays. However, before

improvements can be made, we must have precise information about the physical characteristics of the sprays presently being used. The research reported here was designed to provide additional data on the droplet size, density, distribution and effectiveness of ULV aerial sprays dispersed with TeeJet flat fan and hollow cone nozzles produced by Spraying Systems, Inc.

METHODS AND MATERIALS. The ULV sprays were applied with two Stearman and one Air Force UC-123 aircraft. One Stearman aircraft was equipped with a battery-powered ULV propulsion system for most of the tests. This system consisted of a 12-volt DC motor, a 2000R bronze oberdorfer gear pump, and a B & G stainless steel insecticide tank. The insecticide flowed from the tank to the nozzles through polyethylene tubing. A breaker switch with cables to the battery positioned in the pilot's compartment activated the system. In tests against natu-

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ral populations of salt-marsh mosquitoes, *Aedes taeniorhynchus* (Wiedemann) and *Aedes sollicitans* (Walker), another Stearman aircraft, owned and operated by the Brevard County Mosquito Control District, Titusville, Florida, was equipped with a similar system, except that carbon dioxide was used to pressurize the insecticide.

Four series of tests were made with Stearman aircraft using flat-fan nozzles ranging from 730077 to 8003 that were positioned at a 45-degree angle forward to the thrust line of the aircraft. Line pressures were maintained at about 36 pounds psi, and flow rates were controlled by the size and number of nozzles used. Either 1.5 or 3 fluid ounces (0.14–0.228 pound) of technical malathion or 1 or 2 fluid ounces (0.075–0.15 pound) of fenthion (9.67 pounds per gallon of ULV concentrate) per acre were used. Malathion was used in the first three series and fenthion in the fourth. The aircraft was flown at a speed of 95 miles per hour. Applications were made during early morning when meteorological conditions were favorable. Wind velocities at ground level never exceeded 10 mph.

The first series of tests was made to estimate droplet sizes produced with different sizes of flat-fan nozzles. The aircraft was flown cross-wind at altitudes of either 25 or 75 feet and at swath intervals of 50 or 100 feet, respectively. Eight to ten 1,000-foot-long swaths were made during each collection of droplets. Droplets were collected at two stations 100 feet apart. At each station, two silicone-treated glass microscope slides were positioned vertically facing into the wind at 3 feet above the ground and two additional slides placed horizontally on the ground. Wind velocities at ground level averaged about 5 mph. Between 65 and 400 droplets from each collection were measured at 100 times magnification with the aid of an ocular micrometer. The diameters of the original spheres were estimated by correcting the diameters of the droplets impinging on the slides for the amount

of spread that had taken place. The spread factor for malathion was 0.4 and mass median diameters (mmd's) were computed according to the methods presented by Yeomans (1949) for estimating droplet size from impinging slides.

The second series of tests was conducted to compare mosquito kill and droplet density obtained with the various flat-fan nozzles. The aircraft was flown cross-wind at an altitude of 50–75 feet and 10 swaths, 1,000 feet in length, at 100-foot intervals were flown in the tests. One 16-mesh screen wire cage of adult female *Aedes taeniorhynchus* (25 per cage) was exposed on each of seven 3-foot stakes placed 50 feet apart in a single row in the middle of the plot for 15 minutes after the completion of each application. Mortality counts were made after a 24-hour holding period. Also, two oil-red dye cards were placed at each stake (one vertically at 3 feet above the ground and one horizontally on the ground) and exposed for 15 minutes after each application. Droplet density was determined by examining 4 square inches of each card at 15 times magnification.

The third test series consisted of single swath flights into the wind at an altitude of 50–75 feet to study droplet distribution, droplet density, and mosquito kill at various wind velocities. A minimum of 11 stakes (50 feet apart) were placed in a single row in each plot and one cage of mosquitoes (25 per cage) and one vertically positioned oil-red dye card were placed at a height of 3 feet above the ground on each stake. In some of these tests, an additional oil-red dye card was placed horizontally on the ground by each stake.

The fourth series was made to determine the effectiveness of ULV sprays of fenthion applied with 730077 or 8003 flat-fan nozzles in controlling natural populations of adult salt-marsh mosquitoes, *Aedes taeniorhynchus* and *Aedes sollicitans*. These tests were conducted in citrus groves near Titusville, Florida in plots of about 160 acres located adjacent

to salt-marshes. Counts of mosquitoes were made the day before and 6, 24, and 48 hours posttreatment at 20 locations by two observers standing side by side and facing in opposite directions for 30 seconds. Counting stations were approximately 50 feet apart and were arranged in rows near the center of each plot and at 90-degree angles to the flight swaths.

Another series of tests was made with the twin engine UC-123 aircraft in cooperation with the 4500th Special Aerial Spray Flight, U.S. Air Force, Langley Air Force Base, Virginia. This aircraft was equipped with a system similar to the battery-powered unit of the Stearman. Essentially, it consisted of a 28 volt DC $\frac{3}{4}$ horsepower motor (powered by the aircraft's electrical system) and a 4000R oberdorfer gear pump connected by polyethylene tubing to drums of either malathion or naled. Polyethylene tubing was also used to transfer the insecticide from the pump to the nozzles.

In both series, technical malathion (95 percent) or naled (Dibrom 14) was dispersed from TeeJet nozzles equipped with either D2-13 hollow-cone tips or flat-fan tips ranging in size from 8001 to 8006. The nozzles were positioned at a 45-degree angle forward to the thrust line of the aircraft. Pump pressures were maintained at either 40 or 60 psi during the applications. The aircraft was flown at an airspeed of either 110 or 150 mph. In tests with caged adult mosquitoes, the UC-123 was flown at an altitude of 150 feet and at swath intervals of 500 feet. For droplet collection, the aircraft was flown at an altitude of 50-75 feet and at swath intervals of 50 feet.

The first series of tests was made to evaluate the UC-123 system for dispersal of naled as an ULV spray against adult mosquitoes. The plot (about 320 acres) was an open field adjacent to a small airport near Gainesville. The aircraft was equipped with twelve D2-13 hollow-cone nozzles, and 10 stakes (3 feet high) were placed 100 feet apart in a row perpendicular to the flight swaths near the center

of the plot. One cage of adult female *Aedes taeniorhynchus* (25 per cage) was placed on each stake, and an additional cage of mosquitoes was placed on the ground by each stake. Also, paper cards treated with potassium iodide were placed on the ground at each station to permit an estimate of droplet density. The dose of naled applied was 0.75 fluid ounce (0.082 pound) per acre in both replicates.

The second series of tests with the UC-123 was made in an open field near Waldo, Florida to estimate the size of droplets delivered in ULV sprays dispersed with TeeJet nozzles. For these tests, the droplets of malathion and naled were collected by hand-waving silicone-treated glass microscope slides in the spray during the application. Then, 200 droplets from each collection were measured as before. The spread factor corrections used for malathion and naled were 0.4 and 0.54, respectively.

RESULTS AND DISCUSSION. The results obtained in the series of tests made with the Stearman aircraft are presented in Tables 1 to 5. Table 1 shows droplet size data for 730077, 80015, and 8003 flat-fan tips dispersing malathion. Mmd's ranged from only 45 to 65 microns despite the variations in tip size, but these results are not surprising since Mount *et al.* (1970) indicated that droplet size increased only 2 times though nozzle size increased about 100 times. Also, Rathburn *et al.* (1968) reported no clearcut relationship between nozzle size and droplet size though they felt that smaller nozzles gave somewhat smaller droplets.

Table 1 also compares the data for droplets dispersed at two altitudes. A considerably higher percentage of the total volume of droplets was in the range of 25 microns or less when the plane was flown at an altitude of 25 feet than when it was flown at an altitude of 75 feet.

For example, with 80015 and 8003 flat-fan nozzles and 36 psi, the total volume of droplets of 25 microns or less ranged from 18 to 21 percent at 25 feet and from 2 to 4 percent at 75 feet, prob-

TABLE 1.—Size of droplets collected from Teejet flat-fan nozzles positioned at a 45-degree angle forward to the thrust (95 mph) of a Stearman aircraft when ultra-low volume aerial sprays of technical malathion were applied.

TeeJet nozzle tip No.	Dispersal altitude (feet)	Line pressure (psi)	Percent of total volume of droplets in indicated size range (microns)						Maximum diameter (microns)	Average diameter (microns)	Mass median diameter (microns)
			5-10	11-25	26-50	51-125	126-200	>200			
730077	25	36	4	26	30	28	8	4	211	36	45
80015	25	36	2	16	23	54	5	0	149	45	54
80015	25	80	0	7	32	37	12	12	239	58	65
80015	75	36	0	2	47	43	7	1	203	51	52
8003	25	36	1	20	36	36	7	0	184	40	46
8003	75	36	0	4	45	47	4	0	126	50	51

ably because a portion of the smaller droplets drifted out of the collection area when they were dispersed at the higher altitude. Mount *et al.* (1970) demonstrated that the collection of small droplets was enhanced even more by the use of a Buffalo Turbine mist blower—the total volume of droplets less than 25 microns ranged from 35 to 49 percent with nozzle sizes ranging from 730077 to 8003.

Table 1 also compares droplet sizes obtained when 36- and 80-psi line pressures were used with the 80015 nozzle. The mmd at 80 psi was 20 percent larger than at 36 psi (65 vs. 54 microns); however, this difference may not be significant since Mount *et al.* (1970) found essentially no difference in droplet size due to variance in line pressure (from 20 to 80 psi) in tests with simulated aerial sprays.

The effect of tip size on mosquito kill and number of droplets per square inch on oil-red dye cards is shown in Table 2. The data indicate that nozzle size (730077, 80015, and 8003) had almost no effect on either mosquito kill or droplet density. For example, at a dose of 3 fluid ounces of malathion per acre, the 730077 nozzle gave an average kill of 99 percent compared with 96 percent kill with the 8003 nozzle. Also, at this dose, the average number of droplets per inch square (combined ground and 3-foot high collections) was 12 for the 730077 nozzles and 14 for the 8003 nozzles.

Table 2 also shows that there was less mosquito kill and that there were fewer droplets per square inch at ground level than at 3 feet above ground; the average mosquito kills and deposition rates were 76 percent with 5.5 droplets per square inch and 92 percent with 11 droplets per square inch at the two positions, respectively. Rathburn *et al.* (1968) also obtained less mosquito kill at ground level than at 3 feet above the ground (78.5 percent vs. 93 percent) with aerial sprays applied with Stearman aircraft. They suggested that a portion of their spray was

intercepted by vegetation, resulting in decreased kill at ground level. We do not believe that our differences were caused by vegetation since our test area had recently been burned off. The cause may have been the increasingly horizontal movement of the smaller spray droplets as they approached ground level, which meant that they drifted out of the target area rather than impinging on the caged mosquitoes and dye cards at ground level.

Table 2 also shows that there was no difference in the results obtained with 80015 nozzles when the swaths were 100

per acre, and the average numbers of droplets per square inch were 6 and 13, respectively. Kilpatrick (1967) indicated that at a dose of 3 fluid ounces of technical malathion per acre, impingement of droplets should average at least 10 per square inch.

Table 3 gives the results obtained when single swaths of ULV applications of malathion were made into the wind using 80015 nozzle. With the exception of replication 1, swaths of at least 100 feet, with kills of 95 percent or more, were obtained with single runs. However,

TABLE 2.—Rate of deposition of malathion droplets from ULV sprays dispersed from 3 TeeJet flat-fan nozzles and the effectiveness of the sprays in killing adult female *Aedes taeniorhynchus* (50 to 75-foot altitude; average wind velocity, 5 miles per hour).

TeeJet nozzle tip No.	No. of nozzles used	Swath (ft.)	Dose (fluid ounces per acre)	No. of droplets per square inch on oil- red dye cards at indicated position		Percent mosquito kill ^a at 24 hours after exposure in indicated position	
				On ground (hori- zontal)	3 feet above ground (vertical)	On ground	3 feet above ground
730077	4	100	1.5	4	9	66	87
	8	100	3	9	15	98	100
80015	2	100	1.5	3	8	74	86
	4	200	1.5	4	6	72	91
8003	1	100	1.5	4	10	53	91
	2	100	3	9	19	92	99
Average				5.5	11	76	92

^a Average check mortality was 10%.

feet and 200 feet wide. Average mosquito kill was 80 and 81 percent, and average droplets per square inch were 5.5 and 5, respectively. In ULV aerial spray tests with naled, Rathburn *et al.* (1968) indicated some skips in coverage with 200-foot swaths as evidenced by spotty kills in individual mosquito cages and numbers of droplets on potassium iodide treated cards; however, they did not report comparative data obtained with the same nozzle sizes and doses to show that narrower swaths would have increased mosquito kill.

In Table 2, the average mosquito kill with all nozzle sizes was 78 and 98 percent at doses of 1.5 and 3 fluid ounces

some kill was obtained in all replications except replication 4, over a considerably wider swath. In replications 3 and 4 (winds 4–6 mph), the correlation between kill and droplet density was good; however, in replications 1 and 2 (winds less than 1–2 mph), droplet density was low (average of 1.65 per square inch), even when mosquito kill was high (80–100 percent).

Table 4 compares the results obtained with 3 flat-fan tips when single swaths were flown into the wind. Wider distribution was obtained with nozzles 730077 and 80015 than with 8003; however, kill at the various stations across the swaths varied considerably in each test. Also,

TABLE 3.—Percentage kill of caged female *Aedes taeniorhynchus* and numbers of droplets per square inch on oil-red dye cards produced by single swath, into-the-wind applications of ULV sprays of malathion (application rate 3 fluid ounces per acre based on 100-foot swath; 80015 TeeJet, flat-fan nozzles; mosquito cages and dye cards placed 3 feet above ground).

Distance of cage or center of swath (feet)	Replication No. ^a											
	1 (Wind less than 1 mph)			2 (Wind 1-2 mph)			3 (Wind 4-6 mph)			4 (Wind 4-6 mph)		
	Percent kill	Droplets per square inch		Percent kill	Droplets per square inch		Percent kill	Droplets per square inch		Percent kill	Droplets per square inch	
250	4	0		40	0.5		28	2		0	0.3	
200	12	.5		96	.5		96	8		0	0	
150	16	2.5		100	.3		80	14		0	0	
100	64	6		100	2.3		100	21		0	0	
50	40	5		36	.3		100	48		10	2	
0	80	3.5		48	0		100	27		96	21	
50	68	2.3		20	0		25	5		96	20	
100	12	1.5		12	0		30	1.5		100	16	
150	28	1.5		20	0		15	.3		4	1.3	
200	8	0		16	0		0	1		8	.5	
250	4	0		16	0		0	.3		4	.8	

^a Average check mortality was 3%.

TABLE 4.—Percent kill^a of caged female *Aedes taeniorhynchus* and numbers of droplets per square inch on vertical (3 feet above ground) and horizontal (ground level) oil-red dye cards produced by single swath, into-the-wind applications of ULV aerial sprays of malathion (wind velocities of less than 2 mph; 3 fluid ounces per acre based on 100-foot swaths; 50 to 75-foot altitude).

Distance of cage or card from center of swath (feet)	TeeJet, flat-fan nozzle size									
	730077			80015			8003			
	Percent kill		Droplets per square inch	Percent kill		Droplets per square inch	Percent kill		Droplets per square inch	
250	12	0	0	40	0.5	1	4	0	0	0
200	12	0	0	96	.5	1	8	0	0	0
150	24	0	0	100	.3	1	4	0	0	0
100	28	0	0	100	2.3	3	8	0	0	0
50	20	0	0	36	.3	6	100	7	.3	6
0	4	0	0	48	0	0	16	5	.5	1
50	88	.5	7	20	0	0	100	0	0	4
100	100	0	7	12	0	0	40	0	0	.3
150	32	0	1.5	20	0	0	20	0	0	0
200	56	0	2.5	16	0	0	0	0	0	0
250	48	0	1	16	0	0	8	0	0	0

^a Average check mortality was 12%.

except in the test with nozzle 8003, the oil-red dye cards placed horizontally on the ground collected more droplets than those placed vertically 3 feet above the ground. However, the average droplet density was low compared with that obtained in previous tests made with the same dose of malathion but with higher winds.

The results of the tests with natural populations of salt-marsh mosquitoes (Table 5) confirmed those obtained with caged mosquitoes. With a dose of 0.15 pound per acre of fenthion, the percentage reduction in the natural populations ranged from 82 to 98 percent with nozzle

above the ground than at ground level (87 vs. 94 percent). Rathburn *et al.* (1968) reported an overall average kill of 84 percent for caged adult mosquitoes placed at ground level when they applied doses of naled ranging from 0.05 to 0.11 pound per acre. Also, Mount and Lofgren (1967) obtained reductions of 65 and 88 percent when ULV sprays of naled ranging from 0.05 and 0.1 pound per acre, respectively, were delivered against natural populations of salt-marsh mosquitoes.

Droplet size for the tests with the UC-123 are given in table 6. With malathion, the D2-13 hollow-cone nozzle produced

TABLE 5.—Control of adult salt-marsh mosquitoes, *Aedes taeniorhynchus* and *A. sollicitans*, with ultra-low volume aerial sprays of fenthion.

TeeJet nozzle tip No.	No. of nozzles	Dose (pound per acre)	Pretreat- ment count mosquitoes per man per 30 seconds	Percent reduction at indicated interval after treatment ^a			
				6 hours	24 hours	48 hours	Average
730077	8	0.15	182	82	98	90	90
	4	0.075	121	87	93		90
8003	2	0.15	202	85	91	94	90
Untreated check			180	8	+ 6	+127	+42

^a + indicates percent increase; each treatment replicated 3 times except 0.075 dose which was tested only 1 time.

730077 and from 85 to 94 percent with nozzle 8003. Thus, average reduction with both nozzles was 90 percent; the untreated check plots showed an average increase of 42 percent. Mount and Lofgren (1967) obtained reductions in natural populations ranging from 60 to 89 percent with ULV sprays of fenthion at doses ranging from 0.05 to 0.2 pound per acre on small plots (10-40 acres).

The ULV sprays of naled (0.082 pound per acre) applied with the Air Force UC-123 against caged adult female *Aedes taeniorhynchus* produced an average mortality of 81 percent in the first test and 99.5 percent in the second test. The droplet density at ground level on the potassium iodide cards was 8.6 per square inch in the first test and 14.1 per square inch in the second test. As in the previous tests, mortality was higher at 3 feet

droplets averaging 45 microns mmd. The size was slightly smaller (36 micron mmd) with the 8003 flat-fan nozzle and slightly larger (53 micron mmd) with the 8006 flat-fan nozzle. Glancey *et al.* (1970) also obtained droplet sizes ranging from 34 to 62 microns mmd for malathion sprays dispersed from flat-fan nozzles ranging in size from 8004 to 6515. With naled, the droplet sizes in our test were similar to those obtained with malathion. The D2-13 hollow-cone nozzles produced an average droplet size of 34 microns mmd, and sizes ranged from 23 to 57 microns mmd with the flat-fan nozzles depending on the orifice size of the tip, the speed of the aircraft, and the pump pressure. With 8001 nozzles, a decrease in speed from 150 to 110 mph gave more than a 2-fold increase in droplet size (23 vs. 57 microns mmd); with 8003 nozzles,

TABLE 6.—Size of droplets collected when TeeJet hollow-cone and flat-fan nozzles were positioned at a 45-degree angle forward to the thrust line of an Air Force UC-123 aircraft to apply ultra-low volume aerial sprays of malathion and naled from an altitude of 50 to 75 feet.

TeeJet nozzle tip	Aircraft speed (mph)	Pump pressure (psi)	Percent of total volume of droplets in indicated size range (microns)					Maximum diameter (microns)	Average diameter (microns)	Mass median diameter (microns)		
			<hr/>									
			<5-10 ^a	11-25	26-50	51-125	126-200				>200	
<hr/>												
Malathion (95 percent)												
D2-13 8003 8006	150	40	3	22	41	32	2	0	129	37	45	
				28	43	25	0	0				
				13	39	43	3	0				
Naled: (Dibrom 14)												
D2-13 8001 8001 8003 8003 8003	150	60	30	19	10	37	4	0	151	18	34	
				23	12	28	4	0				
				16	10	41	7	5				
				25	34	28	0	0				
				21	25	43	0	0				
				14	21	52	0	0				
<hr/>												
D2-13 8001 8001 8003 8003 8003	150	60	33	23	12	28	4	0	144	16	23	
				110	60	10	41	212				57
				150	60	34	28	113				26
				110	60	25	43	121				30
				150	40	13	14	121				29
				150	40	13	14	121				29

^a Each nozzle tip produced some droplets as small as 1-3 microns.

lower speed produced slightly larger droplets (40 vs. 47 microns mmd). Mount *et al.* (1970) also obtained an increase in droplet size when air velocity was reduced from 95 to 50 mph (36 vs. 45 microns mmd). Also, in our tests, an increase in pump pressure from 40 to 60 psi gave some decrease in the droplet size for 8003 nozzles (55 vs. 40 microns mmd).

Table 6 also shows the percentage of the total volume of droplets in the various size ranges. Kilpatrick (1967) reported that no more than 10 percent of the droplets should be below 25 microns and no more than 10 percent above 125 microns for satisfactory results with ULV aerial sprays. Our results with the Stearman aircraft (Table 1) flying at an altitude of 75 feet fitted these specifications very well. However, when the same aircraft was flown at an altitude of 25 feet (to enhance collection of the smaller droplets), the total volume of droplets of less than 25 microns ranged from 18 to 30 percent, except when the pump pressure was 80 psi. With the UC-123 (Table 6), the total volume of droplets less than 25 microns ranged from 15 to 32 percent for malathion and from 27 to 56 percent for naled. The total volume of droplets above 125 microns ranged from 0 to 12 percent.

SUMMARY. Field tests were conducted with Stearman and Air Force UC-123 aircraft to accumulate data on droplet size, density, distribution, and effectiveness when ultra-low volume aerial sprays were dispersed with TeeJet nozzles. The tests with the Stearman aircraft showed that ULV sprays produced by 730077, 80015, and 8003 flat-fan TeeJet nozzles have similar physical characteristics and produce similar control of both caged and native populations of adult mosquitoes.

The oil-red dye cards did not necessarily give an accurate indication of droplet density and distribution. When the ULV applications were made in light wind (velocity less than 2 mph), few droplets impinged on the cards, even though mosquito kill was high at the same location. Apparently, the critical

impingement velocity of ULV spray droplets is considerably higher for oil-red dye cards than for the body surface of adult mosquitoes.

With the Air Force UC-123 aircraft, ULV sprays dispersed from various TeeJet nozzles also had similar physical characteristics; however, the differences between nozzles appear to be greater than with the slower flying Stearman. There seemed to be little advantage in using hollow-cone nozzles since flat-fan nozzles having greater discharge rates yielded smaller droplets. Also, flat-fan nozzle size influenced droplet size since each increase produced a small increase in droplet size.

Increased aircraft speed seemed to decrease droplet size, but increased speed can usually be obtained only by substituting larger and/or higher performance aircraft.

We concluded from the results reported here and from those reported by Mount *et al.* (1967) that pump or line pressures within the range of 20 to 80 psi do not necessarily influence droplet size. There may be some reduction in droplet size of naled sprays caused by increases in pressure, but this needs to be confirmed by additional research.

Although most of our tests were not primarily designed to determine the minimum effective doses of the various insecticides, our results seem to confirm those already reported. Satisfactory doses of ULV aerial sprays of malathion, naled, and fenthion dispersed from TeeJet nozzles were 0.228 pound per acre (3 fluid ounces of 95 percent malathion), 0.082 pound per acre ($\frac{3}{4}$ fluid ounce of naled as Dibrom 14), and 0.075 pound per acre (1 fluid ounce of 93 percent fenthion), respectively.

Satisfactory control was achieved with 200- and 500-foot swath intervals with the Stearman and Air Force UC-123 aircraft, respectively, but additional research needs to be done to determine whether greater swath intervals can be used with these ULV aerial sprays.

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Literature Cited

- GLANCEY, B. M., FORD, H. R., AND LOFGREN, C. S. 1970. Evaluation of a fuselage-mounted spray boom for ultra-low volume application of insecticides for mosquito control. *Mosq. News* 30(2):174-180.
- KILPATRICK, J. W. 1967. Performance specifications for ultra-low volume aerial application of insecticides for mosquito control. *Pest Control* 35(5):80-84.
- LOFGREN, C. S., 1970. Ultralow volume applications of concentrated insecticides in medical and veterinary entomology. *Ann. Rev. Entomol.* 15:321-342.
- MOUNT, G. A. AND LOFGREN, C. S. 1967. Ultra-low volume and conventional aerial sprays for control of adult salt marsh mosquitoes, *Aedes sollicitans* (Walker) and *Aedes taeniorhynchus* (Wiedemann), in Florida. *Mosq. News* 27(4):473-477.
- MOUNT, G. A., LOFGREN, C. S., PIERCE, N. W., AND BALDWIN, K. F. 1970. Effect of various factors on droplet size of simulated ultra-low volume aerial sprays of technical malathion. *Mosq. News* 30(1):48-51.
- RATHBURN, C. B., JR., BOIKE, A. H., JR., AND ROGERS, A. J. 1968. Progress report of low volume aerial spray tests against adults of *Aedes taeniorhynchus* (Wied.) and *Culex nigripalpus* Theob. Rept. 39th Ann. Mtg. Fla. Anti-Mosq. Assoc. 26-32.
- YEOMANS, A. H. 1949. Directions for determining particle size of aerosols and fine sprays. USDA Bur. Entomol. Pl. Quar. ET-267.