ALTITUDE AND DRIFT OF ULTRALOW VOLUME AERIAL SPRAYS OF TECHNICAL MALATHION FOR MOSQUITO CONTROL [1]

G. A. MOUNT,[2] C. T. ADAMS,[3] C. S. LOFGREN [2] AND D. E. WEIDHAAS [2]

Successful dispersal of ultralow volume (ULV; technical or highly concentrated) aerial sprays against mosquitoes, from higher altitudes than normal (300 to 2,000 feet), (Mulhern 1968; Akesson *et al.* 1968; Shepard and Gorman 1969, and Machado *et al.* 1969) has increased interest in this method of application. Some possible advantages of dispersal at these altitudes are: (1) wider swath intervals, (2) greater safety for aircraft and crew, and (3) the possibility of operating the aircraft at night so that the time of application can coincide with the peak activity of most species of mosquitoes. However, before higher altitudes can be recommended, additional data are needed on performance; therefore, a cooperative project was initiated between the Insects Affecting Man Laboratory, Gainesville, Florida, and the Headquarters Special Operations Center (Tactical Air Command), Eglin Air Force Base, Florida to determine the drift of ULV aerial sprays of technical malathion dispersed from altitudes of 500, 1000, and 3000 feet. Sprays were also delivered at the conventional altitude of 150 feet for comparison.

METHODS AND MATERIALS. A rectangular site (about 4 x 6 miles) at Camp Blanding, Florida National Guard Military Reservation was selected for the tests of altitude. Weather conditions at this site were determined at ground level and at the chosen altitudes by a combat weather team from Detachment 75, 5th Weather Wing, Hurlburt Air Force Base, Florida. Observations were made before, during, and about 30 minutes after each application.

An Air Force C-47 aircraft equipped with a fuselage-mounted spray boom system described previously by Glancey *et al.* (1970) and Lofgren *et al.* (1970) was used to apply the insecticide. Twelve 8008 TeeJet® flat-fan nozzles were positioned at a 45° angle forward to the thrust line of the aircraft and were calibrated to deliver 7.4 gallons per minute at an operating pressure of 29 pounds per square inch. The aircraft was flown at a speed of 150 miles per hour. Swath intervals were 0.2 and 0.4 mile which gave thoretical doses of 3 and 1.5 fluid ounces per acre, respectively. Each swath was 4 miles long. The number flown per test varied from one to nine.

Effectiveness and distribution of the ULV sprays were determined by bioassay with adult female *Aedes taeniorhynchus* (Wiedemann) (2-5 days old) exposed in 16-mesh screen wire cages (25 per cage). The cages were suspended on 3.5-foot stakes spaced at 0.1-mile intervals for 6 miles along a dirt road that transected the test area. We were limited to one test per evening because in all but three tests the mosquitoes were left overnight to insure adequate exposure to the small droplets. However, in two tests in which the spray was delivered from an altitude of 150 feet, the mosquitoes were exposed for only 2 hours, and in one made at 500 feet, they were exposed for 4 hours. Except during the exposures, the mosquitoes were held in cages in insulated chests containing ice in cans and a moist cotton pad

[1] Mention of a pesticide or a proprietary product in this paper does not constitute a recommendation or an endorsement of this product by the U. S. Department of Agriculture or the Department of Defense.

[2] Entomology Research Division, Agr. Res. Serv., U.S.D.A., Gainesville, Florida 32601.

[3] Major, Biomedical Science Corps, U.S. Air Force, Armed Forces Pest Control Board, Liaison Officer, Entomology Research Division, Agr. Res. Serv., U.S.D.A., Gainesville, Florida 32601.

to maintain high humidity. Absorbent cotton pads moistened with 10 percent sugar-water solution were placed on the holding tubes when they were returned to the air-conditioned laboratory. Mortality was recorded at 18 hours after the beginning of the initial exposure.

The sizes of droplets produced with the spray equipment were determined in a separate study done in cooperation with T. Wayne Miller, Director of the Lee County Mosquito Control District at Fort Myers, Florida, who provided a DC-3 for the tests. This aircraft was flown at a speed of 150 miles per hour at an altitude of 50 feet. Three swaths at 50-foot intervals were made over the droplet collection devices to insure that a large and representative sample of all sizes of droplets was collected. The samples were collected on silicone-treated glass microscope slides which rotated in a vertical plane at an average speed of 5 miles per hour by a battery-driven spinning device. This technique increased the chances of impingement of small spray droplets on the slides. The test was replicated four times, and 300 droplets per test were sampled. The analysis of the droplet data was done by the method of Yeomans (1949) for impinged droplets.

Results and Discussion. At 150-feet altitude and wind velocities of 3 to 7 miles per hour, offsets (first indication of mosquito kill) were recorded 0.1 to 0.2 mile from the swath that was made farthest upwind, and maximum mosquito kills occurred 0.2 to 3 miles downwind (Table 1, tests 1-3). Actually, mosquitoes might have been killed at distances farther downwind; however, in test 1, the caged mosquitoes extended only for a distance of 3 miles, and in tests 2 and 3, poor wind angles undoubtedly drifted a portion of the insecticide out of the target area before it reached the mosquitoes 3-5 miles downwind.

At 500-feet altitude (tests 4, 5, and 6), the offsets ranged from 0 to 0.5 mile, and maximum kills occurred from 1 to 5 miles downwind. However, in test 4, relatively high winds were blowing at both ground level (7 mph) and at 500 feet (12 mph) therefore, the high mosquito kills (86-100 percent) obtained at 1 to 5 miles show the drift potential associated with high winds. The extremely poor wind angle in test 6 explains the lack of spray offset and drift in that test (the spray was drifting at almost right angles to the mosquito cages instead of parallel with them).

In tests 7 and 8, 1000-feet altitude, the high winds (13 to 15 mph) gave offsets of 1 to 2 miles (tests 7 and 8), but in test 9 at the same altitude, a moderate wind (7 mph) produced an offset of only 0.5 mile. At this altitude, maximum mosquito kills occurred from 1 to 5 miles downwind.

In tests 10 and 11, made at 3000 feet altitude, the offset was from 2 to 4 miles. In test 11, the wind was at right angles to the mosquito cages, but the spray could have come in contact with the mosquitoes if it had settled to the ground within 3.5 miles. Our results indicated that maximum mosquito kills would occur more than 5 miles downwind with the wind velocities prevailing during these tests.

The size of droplets in the spray and the theoretical drift values (based on terminal velocities and laminar horizontal wind) of various sizes of droplets of technical malathion carried by a 4 miles per hour wind are reported in Tables 2 and 3, respectively. The mass median diameter of the spray droplets averaged 34 microns (μ) and 71 percent of the spray volume was in droplets of 10 to 50 μ. A comparison of the mosquito kills reported in Table 1 and the theoretical miles of drift in Table 3 suggests a possible correlation. For example, the offsets for the altitudes ranged from 0.1 to 4 miles compared with theoretical distances of drift of 0.13 to 2.7 miles for 100-μ spray and 0.6 to 11 miles for 50-μ droplets. With spray altitudes of 500 and 1000 feet, the maximum mosquito kills occurred at distances somewhat less than those indicated theoretically. However, a close comparison is difficult because of wind velocity variations which occurred from ground level to spray altitudes.

Summary and Conclusions. Aerial

TABLE 1.—Effect of altitude on drift of ultralow volume aerial sprays of technical malathion indicated by kill of caged adult female *Aedes taeniorhynchus*. Sprays applied with an Air Force C-47 aircraft equipped with 8008 TeeJet nozzles flying a speed of 150 miles per hour.[a]

Test No.	Dispersal altitude (ft.)	No. of swaths	Swath interval (miles)	Wind velocity (mph)		Wind direction (degrees)[b]		Percentage mosquito kill at indicated intervals (miles) downwind from swath farthest upwind							
				Sur-face	Dispersal altitude	Surface	Dispersal altitude	(—)1–0[c]	0–0.1	0.2–0.5	0.5–1	1–2	2–3	3–4	4–5
1	150	9	0.2	3	5	100	105	1	64	85	87	97	98		
2	150	3	.4	2	7	30	40	1	2	30	53	54	62	16	2
3	150	6	.2	0	3	0	150	7	16	87	94	91	42	2	1
4	500	6	.2	7	12	75	70		28	48	59	86	100	100	100
5	500	3	.4	0	10	0	290	10	26	15	33	74	33	6	5
6	500	6	.2	0	8	0	160	4	92	60	98	100	98	36	4
7	1000	6	.2	2	13	270	270	1	2	0	6	34	82	97	82
8	1000	1		7	15	85	80	1	2	0	2	12	55	26	41
9	1000	6	.2	0	7	0	270	1	0	1	46	81	93	78	23
10	3000	6	.2	0	21	0	270	3	2	3	6	4	15	39	21
11	3000	4	.2	0	9	0	360	6	6	26	3	10	0	1	0

[a] Flow rate was 7.4 gallons per minute.
[b] Since flights were made north and south, a crosswind was one that came from the east (90°) or west (270°).
[c] Upwind from swaths, which would be a "check" area.

Table 2.—Size of droplets in ULV malathion spray produced by 8008 TeeJet nozzle tips positioned at a 45° angle forward to the thrust (150 miles per hour) of a DC-3 aircraft.[a]

Percentage of total mass of droplets in indicated size range (μ)					Maximum diameter (μ)	Average diameter (μ)	Mass median diameter (μ)
<5–10	11–25	26–50	51–100	>100			
7	33	38	19	3	157	32	34

[a] Line pressure was 42 pounds per square inch.

Table 3.—Theoretical drift of droplets of technical malathion released into a wind blowing at a rate of 4 miles per hour.

Altitude (ft.)	Miles of drift for droplets of indicated diameter (μ)			
	10	25	50	100
150	13	2.3	0.6	0.13
500	45	7.7	1.9	.45
1000	89	15	3.8	.9
3000	268	46	11	2.7

sprays of technical malathion were dispersed from altitudes of 150, 500, 1000, and 3000 feet from an Air Force C-47 aircraft equipped with a fuselage-boom spray system. Maximum kills of caged adult female *Aedes taeniorhynchus* (Wiedemann) occurred from 0.5 to 3 miles downwind at 150-feet altitude and from 1 to 5 miles downwind at 500- and 1000-feet altitude. At 3000-feet altitude, little or no mosquito kill occurred within the target area, which was 5 miles long. Some correlation was noted between the theoretical distance of drift and the actual drift of the malathion spray droplets indicated by the mosquito kill.

We concluded that aerial spraying from altitudes higher than 150 feet would not be efficient unless large areas were to be treated or wind velocities were less than those encountered in these tests (10 mph at 500 feet and 12 miles per hour at 1000 feet). However, with very calm weather conditions between ground level and 150 feet, it may be desirable to use a higher altitude to obtain good dispersal of the insecticide. Spraying from an altitude of 3000 feet would not be feasible unless the velocity of the wind was very low.

In general, wind velocity increased with each increase in altitude. This increase and the greater distance spray droplets must fall increase the drift of insecticides dispersed from high altitudes. As mentioned, this drift potential could be used to an advantage by substantially increasing swath intervals when large areas are being treated. Also, our results suggest that if efficient use is made of drift of spray droplets, insecticide doses might be reduced in large-scale treatments.

Acknowledgment. We gratefully acknowledge the assistance of N. W. Pierce and K. F. Baldwin of the Division's staff at Gainesville, Florida in conducting the tests.

Literature Cited

Akesson, N. B., W. E. Burgoyne, and W. E. Yates. 1968. Technical volume formulations and aerial spray application. Proc. Amer. Soc. Agr. Eng., Chicago, Ill., December 10–13, 1968.

Glancey, M. B., H. R. Ford, and C. S. Lofgren. 1970. Evaluation of a fuselage-mounted spray boom for ultra-low volume application of insecticides for mosquito control. Mosquito News 30(2):174–180.

Lofgren, C. S., H. R. Ford, R. J. Tonn, and S. Jatanasen. 1970. Equipping a multi-engine aircraft with a fuselage-mounted spray system for the ultra-low-volume application of malathion. Bull. Wld. Hlth. Org. 42:157–163.

Machado, W. C., E. S. Bordes, Jr., A. J. Blake, AND G. T. CARMICHAEL. 1969. A technique for ULV insecticide application from high altitudes. Mosquito News 29(3):353-60.

MULHERN, T. D. 1968. Recent experiences with low volume spraying for the control of mosquitoes in California. Proc. 8th Intern. Congr. Trop. Med. Malaria, Teheran, Iran, September 8-15, 1968.

SHEPARD, M., AND J. D. GORMAN. 1969. The effects of ultra-low volume Dibrom from a C-47 aircraft on adult mosquitoes. Rept. 40th Ann. Mtg. Fla. Anti-Mosquito Assn., p. 31-6.

YEOMANS, A. H. 1949. Directions for determining particle size of aerosols and fine sprays. USDA Bur. Entomol. Plant Quar. ET-267.

SLOW-RELEASE POLYMERIC COMPOSITIONS FOR MOSQUITO LARVICIDING[1]

CHARLES H. STOCKMAN, EDWARD H. BOLLINGER AND RUDOLPH N. NARANCH, JR.

The B.F. Goodrich Company, 500 South Main Street, Akron, Ohio 44318

Considerable interest has developed in the use of slow-release polymeric formulations of larvicides since the concept was introduced a few years ago. The authors have been cooperating with a number of interested agencies in the evaluation of these materials for public health applications.

Slow-release polymers are solutions of pesticide in solid polymer formulations of both rubber and plastics. Examples of materials which have been used are SBR rubber and polyvinylchloride plastic. When the slow-release formulation is placed in water, the larvicide is slowly dissolved from the surface. As the concentration of larvicide in the surface is depleted, additional larvicide diffuses from within the polymer to the surface so that release of active agent continues. By appropriate research slow-release polymer formulations can be produced for almost all organic larvicides.

Slow-release polymers are a new tool for mosquito control workers. Although they are not yet commercially available, it is desirable that the directors of mosquito abatement districts understand the potential for these new products as an aid to their future planning.

By using slow-release polymers, it may be possible under some conditions to obtain mosquito larval control for an entire season with a single application. Indeed, it might even be possible to obtain two or more seasons' control by a sufficiently heavy dosage. In the use of slow-release polymers to prevent marine fouling an active lifetime of five years has been indicated. However, mosquito abatement districts are normally budgeted on a one-year basis, and from a practical point of view, single-season control is probably most desirable.

Advantages to the use of larvicidal slow-release polymers include: lower labor costs for application since less frequent applications are required; better localization of application; greater safety in handling and application; and the possibility of preflood application. The dry pellets are inactive. If they are scattered over a dry pasture, they will not release larvicide until the pasture is irrigated.

There are, of course, some disadvantages as well. These include: a higher cost for the material; and larvicidal pellets which remain in the environment for a long time.

In discussing slow-release polymers

[1] Presented at the 26th annual meeting of the American Mosquito Control Association, February 22-25, 1970, Portland, Oregon.