EFFECT OF VARIOUS FACTORS ON DROPLET SIZE OF SIMULATED ULTRA-LOW VOLUME AERIAL SPRAYS OF TECHNICAL MALATHION[1]

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A limited amount of data is available concerning the size of droplets deposited by ULV aerial sprays for mosquito control. Rathburn *et al.* reported that the sizes of droplets deposited by various ULV aerial sprays produced by flat-fan tips (No. 800050 to 8003) varied from 53 to 540 μ mass median diameter, although the average diameters varied only from 18 to 41 μ. Kilpatrick (1967) reported that the size range of droplets deposited by ULV aerial sprays should be 50 to 60 μ mass median diameter to achieve the maximum biological effect against mosquitoes but, unfortunately, he did not present any data to support this conclusion. Burgoyne and Akesson (1968) reported that ULV sprays of 70 μ mass median diameter gave good control of mosquito larvae.

In contrast to the results with aerial sprays, Mount *et al.* (1968) reported that ULV ground applications of aerosols for control of adult mosquitoes had increased efficiency when droplet size was reduced; and that good kill (96 to 100 percent) of adult mosquitoes could be obtained with ULV aerosols that had droplet sizes ranging from 6.4 to 10.8 μ mass median diameter when the dose of technical malathion was as little as 0.009 pound (0.12 fluid ounce) per acre. Although ground and aerial application need not have any direct correlation, we felt that the wide differences in rates of application used to obtain good mosquito control with malathion (about 3 fluid ounces for aerial application vs. 0.12 fluid ounce for ground application) indicated that the efficiency of ULV aerial sprays could be increased. Thus, we initiated studies on the relationship of droplet size to kill of adult mosquitoes with aerial sprays at the Insects Affecting Man and Animal Research Laboratory at Gainesville, Fla. However, before droplet size could be correlated with mosquito control, additional data were needed about the factors that affect the production of droplets with conventional equipment. Therefore, this present paper reports research we have conducted on the effect of such factors as nozzle type, orifice size, nozzle position, aircraft speed, and line pressure on the size of the droplets deposited by simulated ULV sprays of technical malathion (95 percent) dispersed with TeeJet nozzle tips.

METHODS AND MATERIALS. Several complications are involved in estimating the size of the droplets delivered by aerial sprays; for example, the error involved in sampling the total spectrum of sizes produced by a nozzle and the difficulty in obtaining a dense sample of droplets to facilitate measurement with a microscope. Furthermore, the collection of droplets after aerial applications is costly and time-consuming. We felt these difficulties could be overcome if aerial sprays were simulated with ground equipment; therefore, we designed a system in which we placed nozzles of various sizes in the air blast of a Buffalo Turbine mist blower. A stainless steel insecticide tank pressurized with carbon dioxide was used to propel the test insecticide, malathion, through a polyethylene line to the nozzle tip. Preliminary tests indicated that the

[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.

droplets produced in this manner were about the same size as those produced by actual aerial application (unpublished data).

In our tests, we evaluated the following variables: (1) wind velocities of 50 and 95 m.p.h., (2) nozzle positions of 45° into and away from the air blast and at 90° downward to the blast, (3) line pressures of 20, 40, and 80 p.s.i., (4) tips made to produce flat fan sprays with spray angles of 15° to 110°, and (5) tips with flow rates ranging from 0.023 gal per minute to 2.0 gal per minute (water at 40 p.s.i.). Except for one test made with D2–13 hollow-cone tips, all tests were made with flat-fan nozzle tips (TeeJet).

The droplets of malathion deposited by the equipment were collected on silicone-treated glass microscope slides by waving the slide through the spray 12 feet from the nozzle tip (except for the tests made at 50 m.p.h. in which case the droplets were collected 6 feet from the nozzle tip). The air velocity was about 26 m.p.h. at the points of collection. During each test, droplets from each spray were collected on four glass slides, and each spray was tested two or three times. Then, since 100 droplets on each slide were measured at 100x magnification, a total of 800 to 1,200 droplets of each spray was sampled.

The diameters of the droplets were measured with an ocular micrometer. Diameters of the original spheres were estimated by correcting for the amount of spread that took place when the droplets impinged on the slides. (The spread factor for malathion was found to be 0.4.) Also, the mass median diameters were then computed by the methods of Yeomans (1949) for droplets impinged on slides.

Results and Discussion. Table 1 presents the data obtained with the nine nozzle tips. The mass median diameters of droplets delivered by flat-fan tip sizes 730023 to 8020 ranged from 30 to only 64 μ despite an increase of almost 100 × in flow rate. Also, the mass median diameters of droplets obtained with the simulated aerial delivery with tips 730077, 80015, and 8003 (30 to 43 μ) compared favorably with those reported (unpublished data) for droplets produced during actual spraying (45 to 54 μ for the same tips when technical malathion was dispersed at 40 p.s.i. from an aircraft flying 95 m.p.h.). The differences undoubtedly resulted from the greater efficiency in collection of small droplets from the simulated sprays rather than from any real differences in droplet sizes delivered by the two methods of application. Rathburn *et al.* (1968) reported an average range of mass median diameters of naled droplets ranging from 53 to 540 μ for flat-fan nozzle tips ranging in size from 800050 to 8003. However, despite this wide variation in mass median diameters,

Table 1.—Sizes of droplets produced by various TeeJet nozzle tips positioned at a 45° angle forward to the air blast (95 m.p.h.) of a Buffalo Turbine mist blower when ultra-low volume sprays of technical malathion were dispersed at 40 p.s.i.

TeeJet nozzle tip no.	Percentage of total volume of droplets in indicated size range (μ)						Maximum diameter (μ)	Average diameter (μ)	Mass median diameter (μ)
	<5–10[a]	11–25	26–50	51–125	126–200	>200			
730023	13	31	29	26	1	0	162	25	32
730039	12	35	34	17	2	0	179	25	32
730077	14	35	24	19	8	0	185	24	30
80015	14	26	25	25	9	1	213	28	36
8003	11	24	27	27	9	2	263	29	43
8006	13	25	25	23	13	1	224	27	41
8010	9	21	30	28	10	2	297	31	47
8020	7	16	23	30	13	11	375	39	64
D2–13	7	17	24	29	21	2	308	36	58

[a] With each of the tips, there were a few droplets as small as 1 to 3 μ.

they reported average droplet diameters ranging from only 18 to 41 μ, which compares favorably with the average diameters of our simulated sprays (24 to 39 μ).

Table 1 also shows the percentage of all droplets in the various size ranges. Kilpatrick (1967) suggested that no more than 10 percent of the droplets delivered as ULV sprays should be smaller than 25 μ and that no more than 10 percent should be larger than 125 μ. Our results showed that ULV sprays can be produced with less than 10 percent of the total volume in droplets larger than 125 μ but that it would be difficult, if not impossible, to produce sprays that had no more than 10 percent of the total volume in droplets smaller than 25 μ. With flat-fan tips, the percentage of droplets of 25 μ or less ranged from 23 to 49 percent of the total volume. The corresponding value for the D2–13 hollow-cone tip was 26 percent. The difference between Kilpatrick's results and those reported in this paper probably occurred because the sampling techniques used by Kilpatrick did not collect a representative sample of the fine droplets in the spray. For example, Mount found that more small droplets were collected when aerial applications were made at an altitude of 25 feet than at an altitude of 75 feet, (unpublished data) and we collected even more small droplets because we were using the Buffalo Turbine mist sprayer.

The D2–13 hollow-cone tip produced droplets with a mass median diameter of 58 μ and was therefore somewhat less efficient in producing small droplets than a flat-fan tip (730077) discharging at a similar rate.

Mass median diameters of the droplets of malathion produced by a nozzle tip positioned at different angles relative to the air blast were as follows (80015 flat-fan; 95 m.p.h.; 40 p.s.i.): 45° forward, 36 μ; 90° downward, 42 μ; 45° backward, 54 μ. Thus, the 45° angle forward to the air blast was slightly more efficient in producing small droplets than the 90° angle downward, and the 45° angle backward gave droplets that were 50 percent larger than the 45° angle forward.

Mass median diameters of droplets of malathion produced by the two air velocities were as follows (80015 flat-fan tip; 45° forward; 40 p.s.i.): 95 m.p.h., 36 μ; 50 m.p.h., 45 μ. Thus, droplet size increased slightly as air velocity decreased from 95 to 50 m.p.h. Mount (unpublished data) also found that droplet size increased as the air speed of the aircraft was reduced from 150 m.p.h. to 110 m.p.h. These results indicate that adequate atomization of the insecticide for satisfactory mosquito control can be obtained even at air speeds as low as 50 m.p.h.

Mass median diameters of droplets of malathion produced by 3 line pressures were as follows (80015 flat-fan tip; 45° forward; 95 m.p.h.): 20 p.s.i., 33 μ; 40 p.s.i., 36 μ; 80 p.s.i., 34 μ. Essentially no differences in droplet size were obtained with line pressure variance of from 20 to 80 p.s.i. Mount (unpublished data) indicated that at an air speed of 95 m.p.h., the droplets produced with a pressure of 80 p.s.i. were 20 percent larger than those produced with 36 p.s.i.; also, at an airspeed of 150 m.p.h., the droplets produced at 60 p.s.i. were 38 percent smaller droplets than those at 40 p.s.i. Therefore, there appears to be no consistent relationship between pressure (from 20 to 80 p.s.i.) and droplet size, and the principal function of pressure is to determine the rate of discharge of the insecticide from the flat-fan nozzle tips.

The effect of the spray angle of the flat-fan tip on droplet size was as follows: 15015, 39 μ; 50015, 37μ; 80015, 36μ; 110015, 42 μ. (The first two numbers of each nozzle tip designation represent the spray angle of water at 40 p.s.i. during a no-wind condition; the spray angle relative to the air blast was 45° forward; the line pressure was 40 p.s.i.; and the air speed was 95 m.p.h.) The results indicate essentially no differences in droplet size were caused by varying the spray-angle.

We concluded from our results that little can be done to make any substantial reduction in the droplet size of ULV aerial sprays dispersed from TeeJet flat-fan nozzle tips. The factors that influence size are nozzle tip size, nozzle position, and aircraft speed. The flat-fan nozzle tips commonly used for ULV sprays range in size from 800050 to 8003. These are about the smallest tips that can be used without consistent plugging. Our data did indicate that slightly larger nozzle tips could be used, especially when high rates of discharge are to be used and/or when plugging occurs. However, the nozzle positions presently used (45° forward to 90° downward) should be maintained. Also, although aircraft speed definitely affected droplet size, it cannot be increased greatly without using very expensive, high-performance planes. We therefore believe that any real reduction in droplet size and, perhaps, increased efficiency of ULV aerial sprays, must await a breakthrough in nozzle development.

SUMMARY. Ultra-low volume (ULV) aerial sprays of technical malathion were simulated by placing TeeJet nozzles in the air blast of a Buffalo Turbine mist blower. This method produced droplets similar in size to those actually applied by aircraft. TeeJet flat-fan nozzle tips ranging in size from 730023 to 8020 yielded spray droplets varying from 30 to only 64 μ mass median diameter. In general, droplet size increased slightly with each increase in the nozzle orifice. A D2-13 hollow-cone nozzle tip was considerably less efficient in producing small droplets than a flat-fan tip tested at a similar rate of discharge (730077). A nozzle angle of 45° forward to the air blast produced droplets slightly smaller than an angle of 90° downward and 50 percent smaller than an angle of 45° backward. Furthermore, an air velocity of 95 m.p.h. gave smaller droplets than an air velocity of 50 m.p.h. No relationship was noted between variations in line pressure (20 to 80 p.s.i.) and droplet size. Also, a variance in the spray angle of the flat-fan tip of from 15° to 110° did not change droplet size.

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