AERIAL APPLICATIONS OF NALED DILUTED IN HAN WITH UC-123K AIRCRAFT FOR ADULT MOSQUITO CONTROL[1]

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ABSTRACT. Aerial application experiments with technical and diluted Dibrom® 14 were conducted at Avon Park Air Force Range, Florida, using caged mosquitoes to bioassay effectiveness and downwind aerosol distribution. A total of 9 tests were conducted with caged *Aedes taeniorhynchus* females placed at 0.1 mi intervals for a distance of ca 2 mi in a line perpendicular to aircraft flight and parallel to wind direction. A dilute formulation of Dibrom14 in heavy aromatic naphtha (HAN), 1:5 ratio, was applied at rates of 0.75 and 1.5 oz/acre (0.125 and 0.25 oz/acre Dibrom14); and undiluted Dibrom14 was applied at rates of 0.25 and 0.75 oz/acre based on a 2000 ft swath width and 150 mph aircraft airspeed. The results indicated that the dilute formulation applied at 1.5 oz/acre (0.25 oz/acre Dibrom14) was more effective than 0.25 oz/acre Dibrom14 undiluted and equal to 0.75 oz/acre Dibrom14 undiluted. These results cannot be considered totally conclusive due to the variability of atmospheric conditions between tests and the lack of replication for some tests. However, the results strongly suggest that dilution substantially improved the application efficiency and that the rate of 1.5 oz/acre of the 1:5 Dibrom 14:HAN mixture gave excellent mosquito control under the environmental conditions existing during these tests. Additional research will be needed to determine the applicability of this technique under other environmental conditions and to verify the effect on natural populations.

Ultra low volume (ULV) aerial applications of Dibrom® 14, an 85% formulation of naled (1,2-dibromo-2,2-dichloroethyl dimethyl phosphate), have been successfully used for large scale control of adult mosquitoes for a number of years (Glancey et al. 1966, Mount and Lofgren 1967, Sutherland et al. 1978). However, recent increases in the cost of insecticides and fuel, as well as environmental concern, have renewed the incentive to improve the efficiency of this technique. To reduce the application rate and cost, the U.S. Air Force Reserve Aerial Spray Branch, Rickenbacker ANGB, Ohio, developed a technique for applying Dibrom 14 diluted in heavy aromatic naphtha (HAN) at a 1:5 ratio (Unpublished Annual Reports for 1973–79). This mixture has been applied at a rate of 1.5 oz/acre (0.25 oz/acre Dibrom14 and 1.25 oz/acre HAN) which represents a 67% reduction in dose of Dibrom14 from the 0.75 oz/acre normally used as a technical ULV application (label recommended rate is 0.5 to 1 oz/acre). The Office of Pest Management, Maryland Department of Agriculture, used this technique in 1978 in an experimental application with good results in controlling *Aedes sollicitans* (Walker) (S. Joseph, personal communication).

The objective of this study was to compare the effectiveness of this mixture with

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applications of undiluted Dibrom14 in field bioassays using caged mosquitoes.

MATERIALS AND METHODS

Field tests with caged mosquitoes were conducted at Avon Park Air Force Range, Florida during April 1980 using procedures similar to those employed by Mount et al. (1970). The test site was predominantly an open area with only low shrubs and scattered trees. Caged *Aedes taeniorhynchus* (Wiedemann) females (25/cage) were placed on 4 ft stakes at 0.1-mi intervals along a roadway that was perpendicular to aircraft flights and ca parallel to wind direction. The test area included 3 intersecting roadways that allowed cages to be set for 3 different wind directions. The number of cages set for each test varied from 15 to 21 (covering a distance of 1.4 to 2.0 mi) and depended on the roadway length and availability of caged mosquitoes.

Laboratory-reared adult mosquitoes (3-6 days old) were used in all tests. The mosquitoes were immobilized in a cold room (ca 2°C) and placed in cylindrical cages (3.5 cm diam x 15 cm long) made of 16 mesh screen wire for exposure to insecticide treatments. The screen wire cage was attached to a plastic cage (3.5 cm diam x 12 cm long) which was used to hold the mosquitoes after exposure (Fig. 1). The cages of mosquitoes were placed in an ice chest with a cotton pad moistened with water and a container of ice for transport to the test site. Mosquitoes were transferred from the screen cage to the plastic holding cage ca 15 min after exposure. A cotton ball moistened with a 10% sugar-water solution was placed on each holding cage and the cages were held in another ice chest for ca 12 hr before mortality readings were made.

Four application treatments were considered in these tests. These included applications of the dilute formulation (1:5 Dibrom 14/HAN) at rates of 0.75 oz/acre (0.125 oz/acre Dibrom14) and 1.5 oz/acre (0.25 oz/acre Dibrom14) and with technical (undiluted) Dibrom14 at rates of 0.25 oz/acre and 0.75 oz/acre. For this paper, a code was developed to reflect the formulation applied and the application rate of Dibrom14 (oz/acre) as follows:

Treatment code	Formulation	Application rate of Dibrom® 14 oz/acre	Total application rate oz/acre
⅛-MIX	1:5 Dibrom 14/HAN mixture	⅛	¾
¼-MIX	1:5 Dibrom 14/HAN mixture	¼	1–1½
¼-TECH	Dibrom 14 undiluted	¼	¼
¾-TECH	Dibrom 14 undiluted	¾	¾

All applications were made with a U.S. Air Force UC-123K aircraft equipped with Spraying Systems Company TeeJet® nozzles on wing booms. The number and size of nozzles, as well as pressure were varied to obtain the proper flowrate for each of the above treatments with a 2000 ft swath width and 150 mph air speed (Table 1). For calibration, the flow was collected and measured from 4 or 8 nozzles for either 30 or 60 sec. The flow was adjusted to within ±1% of the desired rate before each test.

Limited droplet size measurements were made for the dilute formulations at 1.5 oz/acre (1/4-MIX) and the technical application at 0.75 oz/acre (3/4-TECH). Droplet samples were collected on Teflon®-coated slides by impaction with a spinning device. Two spray passes were made over the collection devices at a low altitude (25 to 40 ft). Low altitude was used for these samples in order to maximize the collection of droplets from the entire size distribution. Only 1 collection was made for each of the 2 treat-

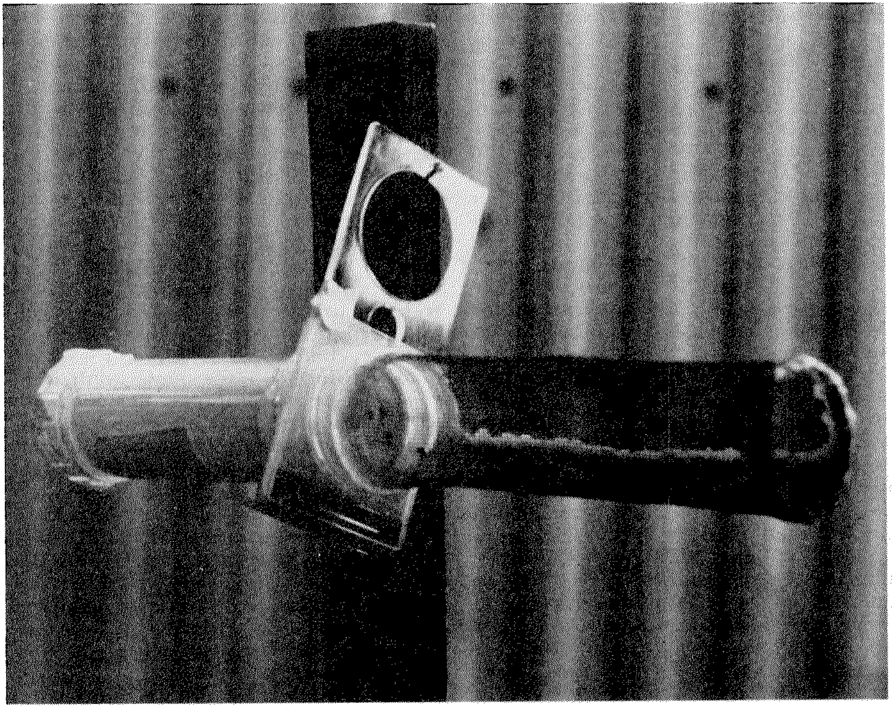

Fig. 1. Screen wire cage for exposure of mosquitoes attached to plastic holding cage.

ments. Each collection resulted in 3 slide samples and 100 droplets from each slide were measured using a microscope equipped with a micrometer (total of 300 droplets for each treatment). These measurements indicated a volume median di-

Table 1. Spray equipment and flow data for aerial application treatments.

Treatment code	Nozzle size[a]	Number of nozzles	Pressure, Psi	Desired flow[b] gal/min
⅛-MIX	8004	18	—[c]	3.55
¼-MIX	8004	18	44	7.11
¼-TECH	8003	4	—[d]	1.19
¾-TECH	8003	12	—[d]	3.56

[a] Spraying Systems Company catalog designation.
[b] Based on 2000 ft swath width and 150 mph air speed. Monitored by a Barton I.T.T. digital flowmeter during spray operation.
[c] No reading.
[d] Pressure gauge defective.

ameter (VMD) of 21 μm for the dilute formulation (1/4-MIX) and 38 μm for the technical formulation (3/4-TECH).

Weather measurements were made during the tests by a meteorological team from McDill Air Force Base, Florida. Wind speed and direction were measured at ground level and at 250-, 500-, 750- and 1000-ft altitude by release of weather balloons. Dry bulb and dew point temperatures were also measured at ground level. Measurements were made every half hour during test periods and those taken closest to the actual application time were used as the ones prevailing during the treatment.

A total of 9 tests were completed under various conditions. A summary of the environmental conditions and application variables is given in Table 2 for each test. Single swath applications were made for the 2 doses of the dilute formulation (Tests 1 and 3), while 3 swaths were applied for the remaining tests. The swaths were applied at 0.4 mi (2112 ft) intervals rather than the theoretical 2000 ft. The spray was released for ca 1.25 mi on either side of the cage line (2.5 mi total spray run/1 min spray time) for each swath. Aircraft speed was constant at 150 mph. Spray altitude varied from ca 200 to 270 ft with the exception of one test at 130 ft during relatively high velocity winds. Four cages of mosquitoes were placed ca 0.5 mi upwind of the treatment area during each test to indicate natural (no treatment) mortalities (Table 2). Natural mortality in these tests was relatively low (overall average 5%, range 2 to 10%) indicating that the laboratory-reared mosquitoes were healthy and handling and transport procedures were adequate.

RESULTS AND DISCUSSION

The mortality of caged mosquitoes at each distance (Figs. 2 and 3) gives an indication of insecticide movement and effectiveness of the different treatments under the particular environmental conditions during each test. Tests 1 and 2 with the 1/8-MIX treatment indicated a low level of kill at this low dose of chemical. The single swath (Test 1) showed evidence of a low level of kill for a distance of ca 1.5 mi downwind from the swath. The multiple swath treatment (Test 2) indicated an average kill of 56% from distances −0.3 to 1.2 mi (1.5 mi total distance). Tests 3 and 4 indicate considerably better kill with the higher dose of the 1/4-MIX treatment. The single swath (Test 3) showed 96–100% kill in the 4 cages immediately downwind (no offset) with the aircraft flying low (130 ft) in relatively high winds (9–11 mph). Again, a lower level of kill was observed for ca 1.5 mi downwind from the single swath. Test 4 indicated an average kill of 84% from −0.3 to 1.2 mi (1.5 mi total) for 3 swaths. This average was reduced by apparent skips in the downwind effects of the insecticide. Ground observations indicated that these skips probably resulted from the wind speed rapidly decreasing and the direction varied to near parallel to the flight path for short periods during the application. This could not be validated by the weather data because measurements were made only at 30 min intervals.

Tests 5 and 6 gave a direct comparison of the 3/4 TECH and the 1/4 MIX treatments under light wind conditions (2-3 mph). Both treatments were highly effective; the average for Test 5 was 93% from the cage at −0.4 mi to the last cage 1 mi downwind of the first swath (1.4 mi total) and the average for Test 6 was 94% from the cage at −0.3 mi to the last downwind cage (1.3 mi total). The high kill probably would have extended for a longer distance, but the number of cages in these 2 tests was limited by the length of road available. A clear indication of swath offsets of 0.4 and 0.5 mi, respectively, is shown in these tests. The approximately equal effect in these 2 tests indicates that dilution improved the insecticidal efficiency of the application since only one-third as much active chemical was applied. Further evidence of this is indicated by Tests 7, 8 and 9, where applica-

Table 2. Weather and application data for 9 aerial application tests.

Test No.	1	2	3	4	5	6	7	8	9
Treatment code	⅛ MIX	⅛ MIX	¼ MIX	¼ MIX	¾ TECH	¼ MIX	¼ TECH	¼ MIX	¼ TECH
Date (1980)	4–14	4–14	4–15	4–15	4–16	4–16	4–17	4–17	4–17
Time of day (hr)	1855	1925	1735	1815	1754	1855	1745	1827	1905
Number of swaths	1	3	1	3	3	3	3	3	3
Altitude (ft)	240	240	130	200	200	200	270	200	200
Temperature (°C)									
Dry bulb			21.1	19.4	22.8	16.7	23.3	20.0	20.0
Dew point			9.4	9.4	11.1	11.1	13.3	11.7	10.6
Wind speed (mph)									
Ground level	5	6	9	5	2	2	8	5	7
250 ft altitude	8	7	12	9	3	3	8	9	12
Wind direction (deg)									
Ground level	290	290	300	290	050	060	100	080	090
250 ft altitude	285	285	275	285	045	055	095	080	085
Cage line (deg)	270	270	270	270	000	000	090	090	090
Check mortality (% avg 4 cages/test)	6	10	3	3	6	5	2	6	—

tions of 0.25 oz/ac Dibrom14 technical (Tests 7 and 9, 1/4 TECH) was compared to 0.25 oz/ac Dibrom14 diluted (Test 8, 1/4 MIX). The 1st test with 1/4 TECH (Test 7) showed a low level of kill (average 55%) for a distance of 1.6 mi (−0.4 to 1.2 mi). The effectiveness in this test was about equivalent to Test 2 with 0.125 oz/ac Dibrom diluted. The 2nd 1/4 TECH test (9) gave considerably more kill (average of 84%) from −0.4 mi to the end of the cage line (14 cages). However, the 1/4 MIX dilute formulation (Test 8) gave an average of 98% kill for a total of 1.6 mi (−0.3 mi to end of the cage line), which was the most effective application in this series.

A possible explanation for the increased insecticidal efficiency of the diluted formulation of Dibrom14 is that increased atomization of this material, as indicated by our size measurement data, produces smaller droplets that are closer to the optimum size range required for

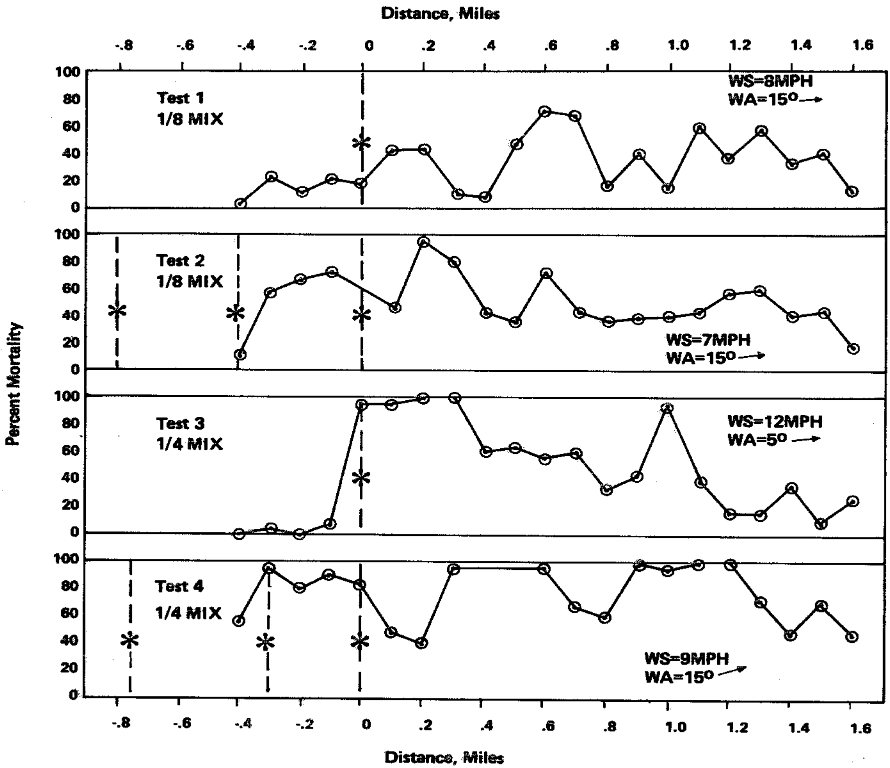

Fig. 2. Percent mortality vs. distance for aerial application tests 1–4 (asterisk indicates aircraft flight line, WS indicates wind speed at 250 ft altitude, and WA indicates the angle between wind direction at 250 ft altitude and the cage line).

effective aerial application. Other possible factors contributing to the increased efficiency may include increased number of droplets and volume of material dispersed.

SUMMARY AND CONCLUSIONS

A series of aerial application experiments were conducted at Avon Park Air Force Range, Florida, to compare the ef-

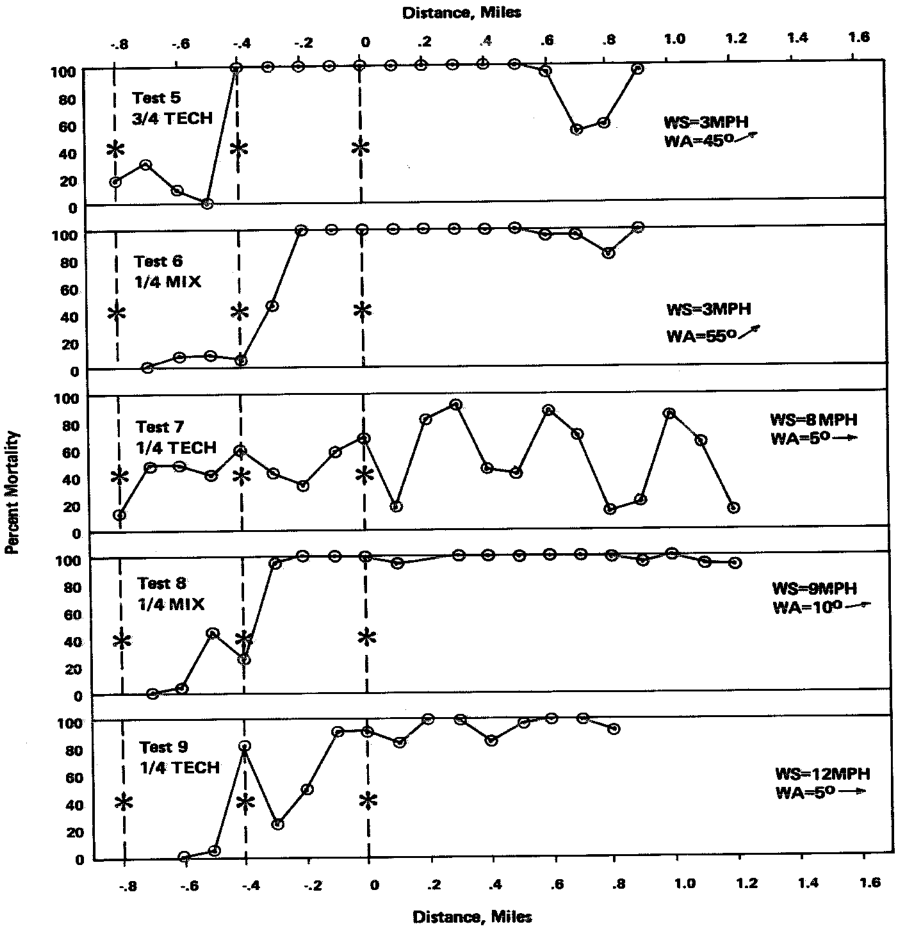

Fig. 3. Percent mortality vs. distance for aerial application tests 5–9 (asterisk indicates aircraft flight line, WS indicates wind speed at 250 ft altitude, and WA indicates the angle between wind direction at 250 ft altitude and the cage line).

fectiveness of Dibrom14 (naled) diluted in heavy aromatic naphtha (HAN), 1:5 ratio, with technical (undiluted) Dibrom 14. All applications were made with an Air Force UC-123K aircraft equipped with TeeJet nozzles (45 degrees forward) on a wing boom and flown at 150 mph. Spray altitude varied from ca 130 to 250 ft. Effectiveness was measured by bioassay with caged *Aedes taeniorhynchus* females (25/cage) placed on 4 ft high stakes at 0.1 mi intervals in a line perpendicular to the aircraft flight and parallel to wind direction. Applications were made with the dilute formulation at rates of 0.75 oz/acre (0.125 oz/acre Dibrom14) and 1.5 oz/acre (0.25 oz/acre Dibrom14) and with technical (undiluted) Dibrom14 at rates of 0.25 oz/acre and 0.75 oz/acre based on a 2000 ft swath width and 150 mph aircraft air speed. Numbers and size of nozzles, as well as pressure, were varied to obtain the desired flow. Results from single and multiple swath applications indicated that insecticide drift was more than adequate to cover 2000 ft. In tests with 3 swaths at 2000 ft intervals, the effectiveness indicated for each of the above treatments were, respectively, 56% (1 test), 92% (average of 3 tests), 70% (average of 2 tests), and 93% (1 test). These results indicate that the dilute formulation applied at 1.5 oz/acre (0.25 oz/acre Dibrom14) was more effective than 0.25 oz/acre of Dibrom14 undiluted and equal to 0.75 oz/acre Dibrom14 undiluted. The low kill with 0.75 oz/acre of the dilute formulation indicates that this dose was too low for effective mosquito control. These results cannot be considered totally conclusive due to the variability of atmospheric conditions between tests and the lack of replication for some tests. However, the results strongly suggest that dilution substantially improved the application efficiency and that the rate of 1.5 oz/acre of the 1:5 mixture will give excellent mosquito control. Use of this technique can result in considerable saving in chemical and application costs, as well as reduced environmental contamination. Additional research will be needed to determine the applicability of this technique under other environmental conditions and to verify the effect on natural populations.

ACKNOWLEDGMENTS

The authors wish to express their sincere appreciation to Lt Col G. Rowcliffe, Chief of Aerial Spray Branch, Rickenbacker ANGB and his spray crews for their assistance; Mr. P. Ebersbach, Avon Park AFR, for his cooperation and onsite support; Mr. A. W. Wooldrige, Chevron Chemical Company, for technical support; Mr. K. F. Baldwin, H. McKeithen, D. Smith, and J. Pinson, Insects Affecting Man and Animals Research Laboratory, for technical assistance; and Sgt M. Ledee, McDill AFB, for weather data collections.

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