EVALUATION OF THE EFFECTIVENESS OF THE ULTRA LOW VOLUME AERIAL APPLICATION OF INSECTICIDES AGAINST *AEDES AEGYPTI* (L.) IN FLORIDA

DONALD A. ELIASON,[1, 2] JOHN W. KILPATRICK [1, 3] AND M. F. BABBITT [1, 4]

INTRODUCTION. In 1963, the United States Public Health Service was charged with the responsibility of eradicating *Aedes aegypti* from the United States, Puerto Rico, the Virgin Islands, and Hawaii. During the first 2 years of operational efforts, it became apparent that *Ae. aegypti* infestations were more widespread and intense than originally anticipated. In addition, von Windeguth *et al.* (1969) observed that in a low socioeconomic area the human population further complicated eradication efforts by continually providing new *Ae. aegypti* larval habitats. During a 3-month period following an insecticidal spray operation approximately 50 percent of the treated containers had been removed from the premises but, more importantly, had been replaced with about an equal number of new and presumably untreated containers. At the end of the 3-month period, *Ae. aegypti* larvae were found in an average of 0.7 percent of the new containers per block. After 2 years of insecticidal pressure in selected operational areas, it was obvious that the ground-applied larvicidal approach of chemical control was a slow and expensive procedure for eradicating *Ae. aegypti*. In many instances, reinfestations occurred in the treated area before the next cycle of treatment was scheduled. Many of the new infestations probably occurred in untreated containers brought into the area since the last insecticide treatment.

In an effort to develop additional tools to supplement the established ground application method, studies were initiated in Florida to evaluate the usefulness of ultra low volume (ULV) aerial applications of insecticides in the eradication effort. Kilpatrick *et al.* (1970) showed that an immediate reduction (but little if any residual effect) could be obtained with aerial application of malathion, Abate,[5] and Dursban. An extensive evaluation was undertaken in a selected area of Dade County, Florida, to determine the effects of various toxicants and treatment cycles on *Ae. aegypti* populations.

PROCEDURE. Aerial applications of technical malathion (3 ounces/acre) and of Abate (1 ounce of active ingredient/acre) were applied to four areas of 1,280 acres each as shown below:

Area A—Abate applied at 14-day intervals. Eight applications.
Area B—Malathion applied at 7-day intervals. Fourteen applications.
Area C—Malathion or Abate applied on alternate weeks with treatments being applied at 7-day intervals. Fourteen applications.
Area D—Malathion applied at 3- to 4-day intervals. Twenty-five applications.
Area E—Untreated control.

[1] From the Biology Section, Technical Development Laboratories, Laboratory Division, Center for Disease Control, Health Services and Mental Health Administration, Public Health Service, U.S. Department of Health, Education, and Welfare, Savannah, Georgia 31402.

[2] Present address: Laboratory Division, Center for Disease Control, Atlanta, Ga. 30333.

[3] Present address: Foreign Quarantine Program, Center for Disease Control, Atlanta, Ga. 30333.

[4] Present address: National Cancer Institute, National Institutes of Health, Bethesda, Maryland 20014.

[5] Use of trade names is for identification purposes only and does not constitute endorsement by the Public Health Service or the U.S. Department of Health, Education, and Welfare.

The first application was made on April 19 and the last on July 14. Insecticides were applied with a twin-engine C18S Beechcraft specifically equipped for ULV aerial application of pesticides (Kilpatrick, 1967). The system included an electrically driven pump, four Teejet nozzles, internal booms, and diaphragm check valves to insure positive cutoff. The nozzles were mounted so as to discharge insecticide at a 45 degree angle downward and into the air stream. The system was operated at 90 to 95 pounds pressure. Applications were made with the aircraft flying at an altitude of 150 feet and at an air speed of 150 miles per hour. Under these conditions, with the aircraft flying crosswind, an effective swath width of 300 feet was obtained as determined from biological data and deposition of droplets on dye cards.

Supplemental ground treatments were applied in all (except control) areas with power sprayers, using 1.25 percent DDT suspension to eliminate residual *Ae. aegypti* foci not destroyed by the aerial applications. Such treatments were made only on those premises (less than 5 percent of the total number) found positive for larvae during an inspection conducted midway through the treatment period.

Evaluation tools included larval inspections, oviposition traps to detect changes in oviposition rates (Fay and Eliason, 1966), and oil red dye cards to determine the quality and distribution of the treatment. In addition, detailed observations were made to evaluate the effects, if any, that might accrue from the treatments to tropical fish in 57 backyard pools. Efforts were made to obtain and investigate all complaints related to the insecticidal applications.

RESULTS AND DISCUSSION. Table 1 shows the insecticide usage for each area for the entire period of treatment. The calculated quantities are based on the dosages and acreages shown. The quantity of insecticide actually used varied slightly because of the following:

1. Variations in the number of swaths flown per treatment of an area because of changes in wind direction and velocity during flight.
2. Mechanical aberrations such as nozzle clogging and pressure fluctuation.
3. Differences in pilot reaction time and judgment in starting and stopping insecticide flow at the beginning and end of each swath.

The result of such variations is seen in comparing the range of quantities per application with the calculated quantities shown for each area.

Table 2 lists the average number of droplets per square inch each area received by treatment and date. The average number of droplets per square inch varied considerably, ranging from 6.2 to 66.0.

Treatments during the first 3-week period were often applied when winds were borderline or excessive. (Ten miles per hour had been chosen as the cutoff point.) Since the public had been prepared for treatments at this time, it was thought advisable to apply the treatments even though weather conditions were not ideal. On a number of these early appli-

TABLE 1.—Insecticide usage in ULV treatment of four areas of 1,280 acres each in Dade County, Florida.

	A Abate	B Malathion	C Abate	C Malathion	D Malathion
Calculated gallonage for one treatment	23.3	31.2	23.3	31.2	31.2
Number of treatments	8	14	7	7	25
Mean gallonage used	23.6	32.8	23.7	31.8	32.9
Range	22.5–25.5	28.3–35.5	22.5–25.5	28.4–34.4	25.0–38.0

TABLE 2.—The number of insecticide droplets per square inch that impinged on oil red dye cards from treatments with either malathion or Abate at 3 and 1 oz./acre, respectively.

Date	Droplets per Square Inch			
	Section A	Section B	Section C	Section D
4/19		8.1		8.05
4/20	11.5		16.0	
4/25	18.3	25.1	19.5	6.2
4/29		21.6		21.6
5/2	29.0		41.7	13.6
5/5		8.5	9.9	6.3
5/9				12.7
5/12	13.8		8.5	
5/13		55.0		25.0
5/16				35.4
5/19		25.0	38.0	42.0
5/23				42.5
5/26	32.0	29.0	17.0	45.4
5/31				26.0
6/2		36.0	21.0	24.0
6/6				26.0
6/10	25.0	15.0	13.0	19.0
6/13				51.0
6/16		29.0	27.0	35.0
6/20				35.0
6/24	29.0	39.0	20.0	40.0
6/27				36.0
6/30		16.0	15.0	10.0
7/5				38.0
7/7	58.0	55.0	39.0	66.0
7/11				14.0
7/14		31.0	34.0	54.0
Range	11.5–58.0	8.1–55.0	8.5–41.7	6.2–66.0

cations, drift was recorded in excess of 1 mile. This may have affected the original control area located downwind of the target area. Subsequently, a new control area (E) that was more distant from the study area was chosen.

Penetration of the droplets through vegetation appeared to be good. Table 3 shows the locations of dye cards placed around a church in relation to wind direction and velocity and the resulting droplets per square inch obtained during several treatments. Insecticide drift which occurred during these applications was considered desirable because it caused overlap of swaths and thus produced more uniform coverage of the area.

Table 4 shows the results of larval inspections carried out before, during, and after aerial applications were made. Infestations in all treated sections showed a continuous and substantial decline when compared with the pretreatment levels or with the control indices. The most dramatic decline in larval infestations was noted in Area D which received 25 treatments with 3 ounces of malathion at 3–4 day intervals. The premises index prior to treatment was 20.1 percent. The midtreatment inspection showed larval infestations were down to 3.5 percent, and at the end of the treatments, the index was 1.3 percent. Indices in the control area at mid- and posttreatment periods were 29.7 and 17.9 percent, respectively.

Oviposition traps were used throughout the evaluation period to determine the effects the treatments had on the adult *Ae. aegypti* population and, more specifically, whether oviposition patterns were altered. In each of the four treatment areas and in the control area, a test plot was selected for evaluating the effects of each type treatment. These evaluation

TABLE 3.—The number of insecticide droplets per square inch that impinged on individual dye cards under varying conditions of wind velocity and direction.

Date	5–16	5–19	5–23	5–26	5–31	6–2	6–6	6–10	
Wind velocity (mph)	1	2	4	6	7	5	7	7	
Wind direction	WSW	W	SSE	W	S	N	E	S	
Card No.									Exposure
1	10	45	17	12	35	25	41	12	N
2	21	34	28	31	29	15	35	12	N
3	22	10	3	8	21	8	18	17	N&W
4	16	12	9	13	4	11	3	14	N
5	1	2	4	10	11	23	13	16	N
6	31	4	5	3	7	50	4	17	NE
7	1	33	7	9	14	39	14	24	NW
8	30	15	9	14	20	16	9	26	N&W
9	19	4	16	22	18	32	27	33	E
10	61	22	17	34	29	40	10	22	S&E
11	68	45	22	46	59	27	30	32	S
12	48	43	20	48	51	31	33	26	S&W
13	0	3	3	11	3	24	10	24	S&W
14	4	5	4	28	16	5	9	3	N&W
15	48	33	42	28	26	25	25	23	N, W&E
Range L	0	2	3	3	3	5	3	3	
Range H	68	45	42	48	59	50	41	33	

sites represented approximately 1/2 square mile each. Approximately 50 oviposition traps were located on a 500-foot grid throughout the evaluation sites and were serviced on a weekly basis. Data, expressed as percent positive oviposition traps, are shown in Table 5. The probable influence of rainfall is also shown in data collected at a weather station located in the area. Approximately 45 inches of rain occurred during the period of April 1—August 6. Weekly rainfall data are given in Table 5.

Considering the fact that little insecticidal pressure other than ULV aerial treatment was applied to these areas, results on oviposition rates were rather spectacular. In Area D, treated with 3 ounces of malathion per acre on a twice weekly basis, oviposition was completely disrupted from week 3 until treatments were terminated, except for week 10, which had 2.2 percent of the oviposition traps positive. All treatments, regardless of toxicants or treatment cycle, resulted in good reductions in oviposition when compared with the pretreatment levels and with the oviposition rates in the control area. By week 8, the oviposition rate in the control area was up to approximately 50 percent, and by week 10 had exceeded 80 percent.

Oviposition rates decreased in the area treated on alternate weeks with Abate and malathion (Area C); however, they did not remain at zero as consistently throughout the treatment and evaluation period as did rates in the area treated twice weekly with malathion (Area D). Reductions in oviposition in the area treated weekly with malathion (Area B) were comparable to those obtained with the alternate weekly treatments with Abate: malathion (Area C). In general, the treatment with Abate applied once every 2 weeks gave the least consistent results (Area A).

The number of complaints received during the first 11 weeks of treatment were considerably lower than expected (approximately 30). Several complaints of honey bee mortality were received; however, the utilization of water sprinklers over the hives before daylight on the

TABLE 4.—Results of premises inspections before, during, and after ULV aerial applications of malathion and/or Abate showing number and percent of premises positive with *Aedes aegypti* larvae.

Area *	Pretreatment Inspected	Pretreatment Pos.	Pretreatment % Pos.	Midtreatment Inspected	Midtreatment Pos.	Midtreatment % Pos.	Posttreatment Inspected	Posttreatment Pos.	Posttreatment % Pos.	Percent Reduction **
A	3507	539	15.4	3537	158	4.5	3518	116	3.3	79
B	4029	555	13.8	4099	210	5.1	4058	161	4.0	71
C	4544	624	13.7	4564	110	2.4	4490	71	1.6	89
D	3536	712	20.1	3572	125	3.5	3514	46	1.3	94
E Control	442	85	19.2	442	132	29.9	442	79	17.87	
Dates	March 29–April 14			June 6–July 6			July 14–July 25			

* A — 1 oz./acre Abate every other week—8 treatments.
B — 3 oz./acre malathion weekly—14 treatments.
C — 1 oz./acre Abate:3 oz./acre malathion on alternate weeks—14 treatments.
D — 3 oz./acre malathion twice weekly—25 treatments.
** Percent reduction in the number of positive premises from pretreatment to posttreatment inspections.

TABLE 5.—The percent of oviposition traps positive by week after treatment of the area with ULV aerial applications of malathion and/or Abate. Data based on approximately 50 traps per area.

Week No.	Area*					Rainfall (inches)
	A	B	C	D	Control	
Pretreatment	14.3	13.6	10.3	20.0	....	0.09
2	11.9	4.5	0	11.9	....	2.72
3	11.9	9.8	0	0	15.2	0.07
4	2.4	3.3	7.1	0	....	0.56
5	0	0	0	0	24.4	0.01
6	0	1.6	1.7	....	26.7	2.85
7	0	4.8	0	....	6.7	1.69
8	9.7	25.2	6.7	0	48.9	8.32
9	4.1	8.5	5.9	0	....	1.34
10	9.5	12.2	1.1	2.2	81.8	4.45
11	20.4	0	0	0	....	8.37
12	4.1	0	8.2	0	71.8	0.54
13 **	18.0	6.1	10.4	0	32.5	2.22
14	27.1	0	2.1	4.2	85.0	1.60
15	14.3	28.0	8.2	14.3	47.5	3.04
16	14.0	16.0	12.5	10.0	52.5	5.58
			Total Rainfall April 1–Aug. 6, 1966—43.45			

* A — Treated 1 oz./acre Abate every other week—8 treatments.
B — Treated 3 oz./acre malathion weekly—14 treatments.
C — Treated 1 oz./acre Abate:3 oz./acre malathion on alternate weeks—14 treatments.
D — Treated 3 oz./acre malathion twice weekly—25 treatments.
** Treatments terminated week 13 (July 14).

morning of treatment eliminated further calls. With the sprinklers on the hives, the bees remained inside and thus were not exposed to the spray. The majority of the complaints involved allergies, headache, eye irritation, and odor. One complaint was received from a woman who claimed two canaries in her house were killed by the airplane spray in the area treated with malathion. One complaint of paint damage to a newly painted car was received, but when the car was examined, the reported damage was found to be caused by road tar.

A total of 57 backyard fish pools in the area were kept under weekly observation to detect any adverse effects. Mortality of gold fish was observed in one pool. However, in this case, it is very doubtful that this mortality resulted from the ULV treatments. The fish pool in question had a surface area of approximately 50 square feet with a water depth of from 5–6 inches in the center to only 1–2 inches near the edges. The pool was located in an open area with no protection from direct sunlight. The owner stated that no fish mortality had been observed prior to the aerial applications of insecticides. A tropical fish hatchery located in the area had no fish killed by the ULV applications over their exposed tanks.

SUMMARY. Four areas (1,280 acres each) in an urban location were treated by aerial ULV applications as follows:

A. Abate, 1 fluid ounce/acre every other week (eight applications).
B. Malathion, 3 fluid ounces/acre weekly (14 applications).
C. Malathion, 3 fluid ounces/acre every other week (seven applications). Abate, 1 fluid ounce/acre on alternate week (seven applications).
D. Malathion, 3 fluid ounces/acre twice per week (25 applications).

An additional area was left untreated for a check area. Inspection for *Ae. aegypti* larvae revealed a significant de-

cline in premises positivity for each treated area as compared to the control area. Data from oviposition traps in the area treated twice weekly with malathion showed that oviposition by *Ae. aegypti* was totally interrupted for 10 weeks during the 11-week treatment period, whereas in the untreated control area during the same period, oviposition rates ranged from 50–80 percent each week. Reductions in oviposition rates in areas treated weekly with malathion or with Abate:malathion combinations were comparable, but these rates were lower than those obtained in the area treated twice weekly with malathion. The biweekly treatments with Abate alone gave the least consistent reductions in oviposition of the toxicants and formulations tested.

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THE USE OF PARASITIC WATER-MITES FOR AGE-GRADING FEMALE MOSQUITOES

PHILIP S. CORBET
Research Institute, Canada Department of Agriculture, Belleville, Ontario

In a recent note to this journal, Graham (1969) recorded the presence of parasitic mites on female adults of 9 or 10 species of mosquito, classifying the hosts according to whether they were nulliparous or parous. His aim was to determine whether or not such mites would provide a useful means of age-grading for Alberta mosquitoes. Because he found them on relatively few individuals, and on parous, as well as on nulliparous females, Graham concluded that "mites would appear to be ruled out as indicators of nulliparity in Alberta." He qualified this conclusion with the observation that the work of Corbet (1963) in Africa "shows that they might be useful in certain areas."

When external characters, such as parasitic water-mites, are to be used for age-grading mosquitoes, it is essential that a clear distinction be made between two concepts: the *reliability* of such characters as indicators of physiological age; and their *practical usefulness* for age-grading. Because Graham fails to make this distinction consistently, his note could create an erroneous impression among entomologists unfamiliar with the rationale of this method of age-grading. The purpose of the present communication is to prevent this, because the critical use of external characters can make an important contribution to the logistics of age-grading programs.

RATIONALE. For an external character to be of any use at all it must be a reliable indicator of the nulliparous (or parous) condition. However, such a correlation need not be reciprocal. Thus, although all mite-bearing females might be nulliparous, it need not follow that all nullipars bear mites. If there is a reliable correlation one way (i.e., mites are found only on nullipars), this has immediate value in so far as every mite-bearing female can be classified without dissection. This operation alone will not of course tell the investigator what the *proportion* of nulli-