COMPARISON OF THREE INSECTICIDES FOR MOSQUITO LARVAL CONTROL ON OKINAWA [1]

R. KENNETH ARMSTRONG

Entomology Branch, U. S. Army Medical Center, Ryukyu Islands [2]

Insecticides have been used extensively on Okinawa since 1947 by the U. S. Army for the control of mosquitoes. DDT was utilized as the insecticide of choice from 1945 to 1959. Gentry (1957) reported that resistance had developed in *Culex quinquefasciatus* Say to DDT and other chlorinated insecticides on Okinawa. Pennington (1968) reported the use of DDT as a mosquito larvicide and adulticidal fog was discontinued in 1959 and replaced by malathion. Malathion was utilized for both larviciding and adult fogging until 1965 when it was replaced by fenthion as an adulticidal fog material (Pennington 1966). Malathion continues to be used for larviciding.

From September, 1966 to December, 1967, Abate® (0,0-dimethyl phosphorothioate, 0,0 diester with 4,4-thiodiphenol); fenthion (Baytex), (0,0-dimethyl o- [4-(methylthio)-m-tolyl] phosphorodithioate); and malathion, (di-ethyl mercaptosuccinate, S-ester with 0,0-dimethyl phosphorodithioate) were compared in laboratory tests and field trails against mosquito larvae on Okinawa. Abate and fenthion commercial emulsifiable concentrates (4 lb/gal) were furnished by the Agriculture Research Service Laboratory, U. S. Department of Agriculture, Gainesville, Florida. Malathion, emulsifiable concentrate (5 lb/gal), a standard insecticide in the Army supply system, was used in the field trials, while a technical grade sample was utilized in the laboratory tests. Granules containing 2 percent fenthion that were obtained from the U. S. Navy supply system were used in the field trials but not in the laboratory tests.

The dominant species of mosquitoes found during the field tests were *Culex tritaeniorhynchus* Giles, *Culex quinquefasciatus* Say, and *Anopheles sinensis* Wiedemann. This corresponds with prevalence studies conducted by the U. S. Army Medical Center, Entomology Branch (unpublished reports). Also noted were *Culex vishnui* Theobald, *Culex vorax* Edwards, *Culex bitaeniorhynchus* Giles, and *Aedes vexans* Theobald.

Because of abundance, year-round breeding and medical importance, *Culex tritaeniorhynchus, Culex quinquefasciatus* and *Anopheles sinensis* were given particular attention during the tests (Tables 2 and 3). *Culex tritaeniorhynchus* is the most common of all the mosquitoes on Okinawa and the most prevalent biter. This mosquito is important not only as a pest but also is the prime suspect as a vector of Japanese B encephalitis. This mosquito breeds year-round in the rice paddies and other sources of clear water on Okinawa. *Culex quinquefasciatus* is the second most common mosquito on the island. Larvae are found in old water containers, and stagnant ditches, as well as rice paddies. This mosquito has also been incriminated as a vector of Japanese B encephalitis. The *Anopheles sinensis* ranks as the third most important mosquito on the island due to its capacity for transmitting malaria in Southeast Asia (Stojanovich 1966) and was the vector of malaria on Okinawa until the disease was eradicated in the 1950's (WHO 1963). It also breeds year round in both stagnant and clear water in rice paddies. Populations are higher when algae or surface

[1] Mention of a proprietary product does not necessarily imply endorsement of this product by the U. S. Army.

[2] Permanent address—Route 3, Box 264, Donalsonville, Georgia 31745.

TABLE 1.—Comparison of abate, fenthion and malathion in field trials.

Insecticide (lb./acre)	Dip Rate Before Treatment		Dip Rate After Treatment		Avg. % of Control	Number of Treatments Below 75% Control	Area Treated (Sq. Feet)		No. of Treatments
	Avg.	Range	Avg.	Range			Total	Range	
Abate .05	13.52	0.89–70.44	0.55	0.0–6.29	95.93	0	60677	187–9520	25
Abate .025	25.26	2.33–268.00	4.77	0.0–125.33	86.47	3	37864	16–7784	25
Fenthion .05	12.13	1.00–67.00	0.62	0.0–2.90	94.88	5	53979	9–7104	25
Malathion .5	23.75	1.25–193.03	2.44	0.0–74.25	89.73	5	42004	24–6148	25
Fenthion 5 lb./acre of 2% gran.	27.14	1.76–1253.33	4.53	0.0–8.33	83.31	6	41074	44–13760	25

vegetation are heavy. These larvae are often associated with *Culex tritaeniorhynchus.*

FIELD TRIALS OF LARVICIDES. Three different locations in the southern half of Okinawa under Army control were used for the larviciding field trials (see Table 1); one area was on the west coast and the other two areas were on the east coast. Plots within the areas receiving treatments were entire rice paddies, standing ditches, night soil pools and/or surface wells with sufficient mosquito larval populations and stationary water.

The mosquito populations were determined by pre-treatment surveys utilizing a long-handled 4-inch enamel water dipper and "ADCAS" (euphonic abbreviation of *Automatic Device* for the *Collection* of *Aquatic Specimens)* (Earle 1956). Dips were taken at six 15-foot intervals on the perimeter of the areas receiving treatment. The larvae collected were taken to the laboratory where they were identified and the number of each species recorded. The total number of mosquitoes per dip was used in determining the population base lines.

The insecticides were applied at the concentrations shown in Table 1, and 25 areas were treated with each concentration. The liquid insecticides were dispersed with a 2-gallon compressed air sprayer utilizing 1 ml of the mixed formulation per square foot (approximately 11.5 gal/acre). The fenthion granules were broadcast by hand.

Post-treatment surveys were conducted 24 hours after treatment, using the same procedures employed in the pre-treatment surveys. The amount of control was figured as percent reduction of the base line population. Table 1 shows the control obtained when all the larvae present were considered and Table 2 demonstrates the mortality of the third and fourth instars of the three most prevalent species.

When all larvae present were considered in the evaluation, Abate and fenthion appeared to be equally toxic and somewhat better than malathion. Abate was slightly more toxic at 0.05 lb/acre than at 0.025 lb/acre. Also, fenthion killed a higher percentage of the larvae as a water emulsion than as a granular application. During the test against third and fourth instar larvae, Abate and fenthion showed approximately the same toxicity to *Culex tritaeniorhynchus* and *Anopheles sinensis,* regardless of the dosage or formulation used. The 0.05 lb/acre dosage of Abate applied as an emulsion, and the fenthion granules, killed approximately the same percentage of all the species, but Abate at 0.025 lb/acre and malathion at 0.5 lb./acre and malathion at 0.5 lb./acre were less toxic to *Culex quinquefasciatus* than to the other species.

LABORATORY TESTING. Susceptibility tests were conducted on mosquito larvae according to the procedures prescribed by the World Health Organization (1960 and 1963) except that 600 ml beakers were substituted for pint jars. Each test con-

TABLE 2.—Percent mortality of 3rd and 4th instar larvae in field trials on Okinawa.

Insecticide	*Culex tritaeniorhynchus*	*Culex quinquefasciatus*	*Anopheles sinensis*
Abate .05 lb/ac AI	99.31	100.00	98.64
Abate .025 lb/ac AI	99.20	85.75	98.21
Fenthion .05 lb/ac AI	97.90	.....*	97.14
Malathion .5 lb/ac AI	96.62	71.58	92.51
Fenthion 5 lb/ac 2% gran.	98.53	98.98	98.80

*No 3rd or 4th instar *C. quinquefasciatus* were present in any areas treated with fenthion .05 lb/ac AI.

sisted of four replicates of 25 fourth instar mosquito larvae for each concentration. Each insecticide was tested at a series of concentrations in distilled water to obtain a range of mortalities that would permit determination of an LC-50 and LC-90 in PPM (see Table 3).

Larvae were collected during 1966 and 1967 from various urban and rural localities on Okinawa. These larvae were transferred to distilled water at the laboratory. On the following day the early 4th instar larvae were separated for testing. The larvae were held at 74° F. during the 24-hour post-treatment period used for determination of mortality. Abbott's formula was applied to correct for mortality in the controls, that ranged from 5 to 20 percent; if this mortality exceeded 20 percent the test was discarded.

Abate was the outstanding material against all three species. It was approximately 4 times as effective against *C. quinquefasciatus* and *A. sinensis* and 14 to 33 times as effective against *C. tritaeniorynchus* as fenthion. It was also 23 to 27 times better against *A. sinensis,* 387 to 525 times better against *C. quinquefasciatus* and 526–4784 times better against *C. tritaeniorhynchus* than malathion. Resistance apparently played some part in the results obtained with malathion as this compound was somewhat less effective against all three species in 1967 than in 1966.

There was little correlation between the amount of vegetation in the water and the degree of control obtained. In some places excellent control occurred on plots containing heavy vegetation, and poor control occurred where no vegetation was present; however, in other places the reverse was true. The density of mosquitoes present before treatment appeared to be of greatest importance, for the control never reached 100 percent in plots with heavy vegetation that averaged over 25 larvae per dip before the sprays were applied.

The fenthion granular insecticide, evaluated by the Navy for residual control over 3-week periods (personal correspondence), did not give any better residual control than did fenthion emulsified con-

TABLE 3.—Comparison of susceptibility of 3 species of mosquito larvae to fenthion, malathion, and Abate- Okinawa-; 1966–1967.

Year	*Culex tritaeniorhynchus* LC 50 (p.p.m.)	*Culex tritaeniorhynchus* LC 90	*Culex quinquefasciatus* LC 50 (p.p.m.)	*Culex quinquefasciatus* LC 90	*Anopheles sinensis* LC 50 (p.p.m.)	*Anopheles sinensis* LC 90	No. of Tests
			Fenthion				
1966	.0029	.0060					5
			.0057	.0103			7
					.0134	.0889	4
1967	.0030	.0065					11
			.0049	.0092			8
					.0115	.0471	2
			Malathion				
1966	.0737	.3622					5
			.335	.9747			12
					.0687	.2011	3
1967	.4306	1.1539					11
			.5190	1.1811			11
					.0846	.2984	5
			Abate				
1966	.00014	.00043					2
			No tests conducted				
					No tests conducted		
1967	.00009	.00032					6
			.00134	.00225			5
					.00308	.01300	3

centrate, but both gave approximately 7 days more residual control than did Abate. None of the applications gave significant control beyond 3 weeks. Plots that were utilized for re-treatment had a sufficient population for testing within 3 to 4 weeks after insecticide application.

Fenthion (.05 lb/ac) gave practically the same control as Abate (.05 lb/ac) in field tests. However, it failed to control at least 75 percent of the pretreatment population in 5 of the 25 treatments, whereas Abate never failed to control at least 75 percent of a pre-treatment population.

ACKNOWLEDGMENT. The author wishes to express his appreciation for the encouragement and support of Mr. James B. Gahan for his critical appraisal and editing of the paper; and to Major Ronald W. Intermill, SFC William E. Gibson, Mr. Tony Silagan Bolinquit, Mr. Ignacio Villanueva, Mr. Gerado Soriano, and other members of the Entomology Branch, Preventive Medicine Activity, U. S. Army Medical Center, Ryukyu Islands, APO San Francisco 96331. Without them, this study would not have been accomplished.

References

ANONYMOUS 1960. Instructions for determining the susceptibility or resistance of mosquito adult-larvae to insecticides. World Health Organization, Tech. Rpt. Ser. No. 191.

ANONYMOUS 1963. Instructions for determining the susceptibility or resistance of mosquito adult-larvae to insecticides. World Health Organization, Tech. Rpt. Ser. No. 265.

EARLE, HILTON H. JR. 1956. Automatic device for the collection of aquatic specimens. Journal of Economic Entomology, Vol. 49, No. 2, pp. 261–262.

GENTRY, JAMES W., and HUBERT, ALEXANDER A. 1957. Resistance of *Culex quinquefasciatus* to chlorinated hydrocarbons on Okinawa. Mosquito News, Vol. 17(2), pp. 92–93.

LOFGREN, C. S., PENNINGTON, NEIL, and YOUNG, WILLIAM. 1966. Evaluation of insecticides against two species of *Culex* mosquitoes on Okinawa. Mosquito News, Vol. 26, No. 1, pp. 52–59.

MULLA, MIR S. 1966. Toxicity of new organic insecticides to mosquito fish and some other aquatic organisms, Mosquito News, Vol. 26, No. 1, pp. 87–90.

PENNINGTON, NEIL E. 1966. Field testing of insecticidal aerosol against two species of *Culex* mosquitoes on Okinawa. Mosquito News, Vol. 26, No. 4, pp. 520–522.

PENNINGTON, NEIL E. 1968. Resistance of *Culex tritaeniorhynchus* Giles and *Culex quinquefasciatus* Say to malathion on Okinawa with notes on susceptibility to other insecticides. Mosquito News, Vol. 28, No. 2; pp. 193–198.

STOJANOVICH, CHESTER J. and SCOTT, HAROLD GEORGE. 1966. Illustrated key to mosquitoes of Vietnam. U. S. Department of Health, Education and Welfare, Public Health Service Communicable Disease Center.

WORLD HEALTH ORGANIZATION. 1963. Report on the Fourth Asian Malaria Conference. WHO/Mal/374.