

# DDT RESISTANCE IN *ANOPHELES QUADRIMACULATUS* FROM THE U. S. ARMY CHEMICAL CENTER, MARYLAND\*

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DDT-tolerance has been reported in *Anopheles quadrimaculatus* Say larvae by Kruse *et al.* (1952), Love and Kartman (1953), Gartrell and Ludvik (1954), and Hawkins (1956). Adult resistance to dieldrin, BHC and chlordane was reported by Mathis (1956). Martinez (1959) found *Anopheles quadrimaculatus* resistant to both dieldrin and DDT in areas that were intensively treated with insecticide for the control of cotton insects.

Results of tests conducted in 1958 and in 1959 indicate that a strain of *Anopheles quadrimaculatus* at Army Chemical Center, Maryland, is DDT-resistant. Test results were compared with those obtained

with a DDT-susceptible strain from the United States Department of Agriculture's laboratory at Orlando, Florida.

The Army Chemical Center anopheline population was subjected to intensive treatments from 1946 to 1958 with aerial and ground applications of DDT for the control of mosquitoes and other insects of medical importance. During 1959 the Army Chemical Center was treated five times with aerial sprays of malathion at 0.5 lb. per acre and received numerous ground treatments with DDT and malathion. The area adjacent to the Center is mostly agricultural land and is frequently treated with both chlorinated-hydrocarbon and phosphorus-containing insecticides for the control of insect pests of the various crops, possibly further exposing the anopheline population to insecticides. The Orlando *Anopheles* have been reared under laboratory conditions for seventeen years at Orlando and have not been treated with insecticides.

**METHODS AND MATERIALS.** Adult females of the Army Chemical Center (ACC) strain of unknown age were collected with aspirators from a donkey barn located in

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a woods adjacent to the main part of the cantonment area. Most of the females were recently engorged and either used for testing on the day of collection or confined in cages for oviposition or testing at a later date. Adult females of the Orlando strain were maintained in the laboratory at 83° F. and 60 percent relative humidity and were tested at 3 to 5 days of age after engorgement. Larvae of both strains were reared without temperature control, in temperatures which varied from 80° to 97° F., and were tested in the late third or early fourth instar. They were fed a powdered mixture of 60 percent whole wheat flour, 25 percent powdered yeast, 10 percent dried beef blood and 5 percent dried skimmed milk. World Health Organization test kits were used for all tests except for one series against larvae. The larvae were subjected to 250 ml. of an alcohol-water suspension of the insecticides, and the adults were exposed to filter papers impregnated with Risella oil solutions of the insecticide. During the 24-hour test periods, 80° F. ± .5° F. temperature and 75 percent ± 2 percent relative humidity were maintained in a constant temperature and humidity cabinet (Aminco Aire). Adult mortality was recorded 24 hours after the exposure period except in tests where exposures were continuous for more than 24 hours. Larval mortality was

recorded 24 hours after continual exposure to insecticide suspensions. Mortality in the controls throughout the tests ranged between zero and 10 percent and in most of the tests was 5 percent or less.

DISCUSSION. Against the larvae of the ACC strain, DDT at 2.5 parts per million failed to cause kills greater than 90 percent in any test. Against larvae of the Orlando strain, DDT at 0.004 parts per million caused 87 to 94 percent kills, agreeing favorably with results of previous tests reported by Deonier *et al.* (1946), and by Keller *et al.* (1951), who reported an LC<sub>50</sub> of 0.0021 p.p.m. These results demonstrate that the larvae of the ACC strain are highly resistant (about 600-fold) to DDT. The results of these tests are summarized in Table 1.

Against the adult females of the ACC strain, exposures of 1 to 54 hours to 4 percent or 8 percent DDT residues failed to cause greater than 90 percent kill. Females of the Orlando strain exposed 1 hour to 2 percent DDT produced between 85 percent and 90 percent kills and similar exposure of the ACC strain produced 10 percent to 25 percent kills. The results of these tests which are shown in table 2 demonstrate that there is a very high degree of DDT resistance in the adults of the ACC strain.

In very limited tests female *Anopheles*

TABLE 1.—Susceptibility of *Anopheles quadrimaculatus* larvae to DDT (Averages of duplicate tests of 20 or 25 late third or early fourth instar larvae each)

Date of test	Percent kill at indicated concentration in p.p.m.					LC <sub>50</sub> p.p.m.
	0.004	0.02	0.1	0.5	2.5	
ACC strain						
22 July 1959	0	15	40	90	90	0.11
22 July 1959	0	0	55	75	90	0.09 <sup>4</sup>
22 July 1959	0	5	40	55	70	0.30
31 Aug. 1959	5	10	15	75	87.5	0.25
2 Sept. 1959 <sup>1</sup>	—	—	4	88	78	—
Orlando strain						
17 Sept. 1959 <sup>2, 3</sup>	87	100	100	100	100	<0.004
	94	94	100	100	100	<0.004

<sup>1</sup> Progeny from survivors of field-collected females subjected to 4 percent DDT for 1 hour.

<sup>2</sup> Average of 4 tests of 25 larvae each.

<sup>3</sup> Laboratory-prepared ethanolic solution.

<sup>4</sup> Determined by extrapolation.

TABLE 2.—Susceptibility of *A. quadrimaculatus* females to residues of DDT (20 females per test) except as otherwise noted

Date of test	Exposure period (hrs.)	Percent kill at indicated percent concentration						LC50
		0.25	0.5	1.0	2.0	4.0	8.0	
ACC strain								
8 Sept. 1958 <sup>1, 2</sup>	1	0	—	—	—	—	0	—
8 Sept. 1958 <sup>1, 2</sup>	2	20	—	—	—	—	20	—
9 Sept. 1958 <sup>1</sup>	54	—	—	—	—	50	50	—
10 Sept. 1958 <sup>1, 2</sup>	30	—	—	—	—	—	60	—
10 Sept. 1958 <sup>1, 2</sup>	24	—	—	—	—	—	60	—
15 Sept. 1958 <sup>2</sup>	42	50	70	60	80	90	80	—
18 Sept. 1958 <sup>1</sup>	30	—	30	30	30	40	62	>4.0
22 Sept. 1958 <sup>1</sup>	30	—	—	45	35	50	—	4.0
22 Sept. 1958 <sup>1</sup>	30	—	—	45	35	50	50	—
25 Sept. 1958 <sup>1</sup>	30	—	—	45	45	70	70	>2.0
25 Sept. 1958 <sup>1</sup>	30	—	—	45	37	89	80	—
19 Dec. 1958 <sup>1</sup>	30	—	—	—	—	—	45	>8.0
9 June 1959 <sup>2</sup>	1	—	—	—	—	10	—	—
13 July 1959	1	20	25	25	35	45	—	>4.0
27 July 1959	1	0	5	10	25	25	—	>4.0
3 Aug. 1959	1	0	15	15	15	55	—	—
17 Aug. 1959	1	5	0	5	10	30	—	>4.0
20 Aug. 1959	16	—	—	—	—	80	—	<4.0
27 Aug. 1959	1	—	—	—	10	30	—	>4.0
1 Sept. 1959 <sup>1</sup>	1	—	—	5	5	15	—	>4.0
Orlando strain								
25 Sept. 1959	1	—	—	—	90	100	—	<2.0
28 Sept. 1959	1	0	10	40	85	95	—	2.2
29 Sept. 1959	1	5	15	55	90	95	—	0.9

<sup>1</sup> Part of this high resistance might be attributed to accumulation of internal fat required for successful hibernation.

<sup>2</sup> Ten insects per test.

*punctipennis* (Say) and *Anopheles crucians* (Wied.) collected among the *Anopheles quadrimaculatus* were all killed by dosages of DDT that killed less than half of the *A. quadrimaculatus* indicating that these two species are considerably more susceptible to DDT, although they were probably subjected to the same treatments.

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