# ARTICLES

## PRESENT STATUS OF MOSQUITO RESISTANCE TO INSECTICIDES IN THE SAN JOAQUIN VALLEY IN CALIFORNIA

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The resistance of mosquito larvae to DDT in California was first reported by Smith (1949) in Kern County. The following year Bohart & Murray (1950) showed that larvae of *Aedes nigromaculis* (Lud.) were resistant to this insecticide in Tulare County. More comprehensive studies by Gjullin & Peters (1952) showed that resistance to chlorinated hydrocarbon insecticides was present in larvae of *A. nigromaculis, Culex tarsalis* Coq., and *C. quinquefasciatus* Say throughout the treated areas of the San Joaquin Valley from Merced County in the north through Kern County in the south. Moderate resistance was present in the northern portion and high resistance in the southern portion of this 200-mile-long area. The complete failure of these insecticides in the southern portion in 1951 made it necessary for the control districts to use organic-phosphorus compounds. EPN, parathion, or malathion have been used by these districts since that time. Higher resistance has also developed in the northern end of the area, and all districts in this section have changed to the organic-phosphorus compounds in the last two or three years.

A partial resurvey of the San Joaquin Valley by the authors (Isaak 1956, Gjullin 1956) showed that resistance to DDT had increased in the areas that were sampled. Larvae taken outside the boundaries of the districts, where no resistance had been present in 1951, are now as resistant as larvae taken inside the districts. This paper reports further tests on the resistance of mosquitoes to organic-phosphorus insecticides and DDT in Fresno and Kern Counties in 1956.

TESTS WITH LARVAE.—Early fourth-instar larvae were collected from breeding places inside and outside the abatement-district boundaries. The test procedures were similar to those described by Gjullin & Peters (1952). Sufficient insecticide in acetone was added to 200 ml. of tap water to give the desired concentration. The tap water used in different areas had shown no significant variation in percentage of kill. Two containers with 20 larvae in each were used per test.

Data obtained with *tarsalis* (Table 1) show that this species had developed resistance to malathion in a number of locations in the Fresno abatement district during the 2½ years that this insecticide has been used. The amounts of malathion required for 50 and 90 percent kills are now 21 and 33 times greater, respectively, than are required for larvae taken from untreated areas outside the district. No parathion has been used in the Fresno district. Malathion or various other agricultural insecticides have not produced cross-resistance to parathion in this species.

Untreated *nigromaculis* larvae could not be found in sufficient numbers for adequate comparison with malathion-treated larvae of this species from the Fresno district. However, no resistance to malathion or cross-resistance to parathion was indicated in the results that were obtained (Table 2).

In the Fresno district DDT resistance

TABLE 1.—Percent mortality of *Culex tarsalis* mosquito larvae from treated and untreated areas when exposed to various concentrations of malathion, parathion, or DDT

| Insecticides (p.p.m.) | Fresno County | | Kern County | |
|---|---|---|---|---|
| | Treated Areas | Untreated Areas | Treated Areas | Untreated Areas |
| Malathion | 5 areas | 4 areas | 6 areas | 5 areas |
| 3 | 94 | .. | .. | .. |
| 2.5 | 92 | .. | .. | .. |
| 1.4 | 69 | .. | .. | .. |
| 1.0 | 57 | .. | .. | .. |
| 0.2 | 30 | .. | .. | .. |
| .1 | 33 | .. | .. | .. |
| .08 | .. | 94 | 76 | .. |
| .06 | 23 | 84 | 72 | 93 |
| .03 | 8 | 29 | 42 | 68 |
| .01 | .. | 3 | 10 | 20 |
| LD-50 | 0.73 p.p.m. | 0.035 p.p.m. | 0.035 p.p.m. | 0.2 p.p.m. |
| LD-90 | 2.44 | .73 | .135 | .058 |
| Parathion | 3 areas[a] | 4 areas | 6 areas | 4 areas |
| 0.01 | 93 | 89 | .. | .. |
| .008 | .. | .. | 98 | .. |
| .005 | 54 | 63 | 52 | 91 |
| .004 | 20 | .. | .. | .. |
| .003 | 4 | 28 | 34 | 73 |
| .002 | .. | .. | 28 | 48 |
| LD-50 | 0.0043 p.p.m. | 0.0052 p.p.m. | 0.0035 p.p.m. | 0.0032 p.p.m. |
| LD-90 | .0083 | .0092 | .006 | .0048 |
| DDT | 5 areas | .. | .. | .. |
| 1.2 | 91 | .. | .. | .. |
| 1.0 | 87 | .. | .. | .. |
| 0.5 | 81 | .. | .. | .. |
| .2 | 50 | .. | .. | .. |
| .1 | 26 | .. | .. | .. |
| LD-50 | 0.2 p.p.m. | .. | .. | .. |
| LD-90 | 1.0 | .. | .. | .. |

[a] Treated with malathion. Parathion was tested against these larvae to determine if cross-resistance had developed.

in both *tarsalis* and *nigromaculis* was indicated to be two or three times greater than in 1951. This compares with results obtained in Merced, Tulare, and Kern Counties. Meltzer (1956) obtained high resistance to Diazinon, DDT, dieldrin, and toxaphene in house flies through selection pressure with Diazinon. March *et al.* (1956) also found that selection with parathion and Diazinon induced high levels of resistance in house flies to DDT, methoxychlor, and dieldrin. This suggests that increased resistance to DDT in mosquito-abatement districts may have been brought on by the use of organic-phosphorus compounds as well as the chlorinated hydrocarbon insecticides for agricultural purposes.

In the Kern Mosquito Abatement District, which had been routinely sprayed with EPN and parathion since 1951, neither *tarsalis* nor *nigromaculis* showed any resistance to parathion or cross-resistance to malathion.

TESTS WITH ADULTS.—*C. tarsalis* females from the Fresno Mosquito Abatement District and from untreated portions of Kern County were exposed to malathion residues to determine resistance. All females were obtained from larvae and pupae collected in these areas. Those from the Fresno district were taken in pastures

TABLE 2.—Percent mortality of *Aedes nigromaculis* mosquito larvae from treated and untreated areas when exposed to various concentrations of malathion, parathion, or DDT

| Insecticides (p.p.m.) | Fresno County | | Kern County | |
|---|---|---|---|---|
| | Treated Areas | Untreated Areas | Treated Areas | Untreated Areas |
| Malathion | 3 areas | 1 area | 5 areas | 2 areas |
| 0.08 | .. | .. | .. | 91 |
| .06 | 82 | 83 | 81 | 75 |
| .04 | 72 | 30 | .. | .. |
| .02 | 34 | 0 | 81 | 64 |
| .01 | 20 | 10 | 27 | 4 |
| .005 | 8 | .. | .. | .. |
| LD-50 | 0.022 p.p.m. | .. | 0.016 p.p.m. | 0.015 p.p.m. |
| LD-90 | .07 | .. | .068 | .065 |
| Parathion | 3 areas[a] | 1 area | 5 areas | 3 areas |
| 0.01 | 94 | 63 | .. | .. |
| .005 | 69 | 35 | 92 | 98 |
| .003 | 33 | 10 | 73 | 72 |
| .001 | 2 | 8 | 20 | 25 |
| LD-50 | 0.0038 p.p.m. | .. | 0.019 p.p.m. | 0.017 p.p.m. |
| LD-90 | .0084 | .. | .047 | .036 |
| DDT | 3 areas | .. | 2 areas | 2 areas |
| 0.8 | 79 | .. | .. | .. |
| .6 | 74 | .. | .. | .. |
| .4 | 69 | .. | 90 | 89 |
| .2 | 63 | .. | 69 | 71 |
| .1 | 41 | .. | 48 | 29 |
| .08 | .. | .. | 31 | 26 |
| LD-50 | 0.22 p.p.m. | .. | 0.125 p.p.m. | 0.145 p.p.m. |
| LD-90 | .85 | .. | .38 | .42 |

[a] See footnote to Table 1.

where previous tests had indicated high resistance to malathion. Untreated females for comparison were obtained from Kern County, because this species was not available in sufficient numbers from untreated portions of Fresno County.

Acetone solutions of malathion were placed in petri dishes and allowed to dry for 24 hours. Deposits of the insecticide ranging from 0.25 to 14 mg./sq. ft. were made on the dishes by using different amounts of solution. Ten to 15 females were exposed in each dish for 90 minutes, and then transferred to clean cages. The mortality was determined after 24 hours. All tests were made at 80° F.

The results of these tests are given in Table 3. The amounts of malathion residue required for LD-50 and LD-90 against *tarsalis* females from the Fresno District were 93 and 100 times greater, respectively, than for females collected from untreated areas.

CONCLUSION.—Application of malathion emulsion in the Fresno Mosquito Abate-

TABLE 3.—Percent mortality of *Culex tarsalis* females after 90 minutes' exposure to malathion residues. (Average of 7 replications.)

| From Treated Areas | | From Untreated Areas | |
|---|---|---|---|
| Mg./sq. ft. | Percent Kill | Mg./sq. ft. | Percent Kill |
| 14 | 88 | 0.15 | 70 |
| 10 | 55 | .1 | 66 |
| 8 | 50 | .07 | 50 |
| 6 | 39 | .05 | 25 |
| 5 | 31 | .025 | 9 |
| 4 | 18 | .. | .. |
| 3 | 12 | .. | .. |
| 2 | 13 | .. | .. |
| LD-50 | 7.3 p.p.m. | .. | 0.078 p.p.m. |
| LD-90 | 21.0 | .. | .21 |

ment District of California during 1954–56 caused resistance to develop in both larvae and adults of *tarsalis*. A 90 percent larval kill now requires 33 times more malathion, and use of this larvicide is no longer practical against this species. Malathion is still effective against *nigromaculis*, and parathion is effective against both species. The absence of any resistance to parathion in either species in the Kern district after continued use of EPN and parathion since 1951 indicates that resistance to parathion may develop more slowly or not at all. *C. tarsalis* adults from the Fresno district were about 100 times more resistant to malathion than larvae from untreated areas.

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