

THE STATUS OF INSECTICIDE RESISTANCE IN SOME MOSQUITO SPECIES OF TEXAS

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INTRODUCTION. Approximately four years after beginning the use of BHC (3 percent gamma isomer) as an adulticide in the Galveston County mosquito control program in 1956, salt-marsh mosquitoes in some parts of the county were noted by field personnel to be less affected by the insecticide than in previous years. It was especially noticeable that "barrier strips" did not provide population centers with as many days protection from flights of *Aedes sollicitans* as at the beginning of the program. More recently, there have been similar indications of increasing BHC-tolerance in *A. sollicitans* and *A. taeniorhynchus* in adjacent Brazoria County where the insecticide has been used intensively for a period of 2 years.

Prior to the above observations and before the organization of mosquito control districts along the Texas Gulf Coast, it was noted by mosquito control personnel engaged in the fogging of DDT in several communities of this area that *Culex fatigans* adults were largely unaffected by this insecticide. Likewise, populations of this species have not been controlled with BHC dust during recent years.

Approximately a year and a half ago, a study designed to determine the status of insecticide-resistance in certain mosquito species of Texas was begun, starting with those mentioned above (Micks, 1960). This work has been extended more recently to include *Culex salinarius*, which appeared in unusually large numbers in coastal areas during the first four months of 1961, replacing *C. fatigans* in

many septic ditches. The results, representing the first report of resistance in mosquitoes of this state, are presented herein.

MATERIALS AND METHODS. A number of different batches or strains of *Culex fatigans*, *Culex salinarius*, *Aedes sollicitans* and *Aedes taeniorhynchus* were collected at widely separated points in Galveston and Brazoria Counties. In most instances, sufficient larvae were collected to permit testing their susceptibility to DDT, gamma-BHC and dieldrin and to determine the susceptibility of the corresponding adults to DDT and dieldrin. In this way, a complete spectrum of resistance to chlorinated hydrocarbon insecticides was obtained.

Tests with larvae of the salt-marsh species were conducted using the water in which they were collected. Larvae of the two *Culex* species were tested in distilled water after it was determined that the use of the polluted water in which they were collected did not produce a significantly different test mortality.

At least two replicates of 25 to 30 fourth-stage larvae each were used for each insecticide concentration (0.004, 0.02, 0.1, 0.5 and 2.5 p.p.m.). Tests with adults utilized from three to five replicates, using 20 to 25 specimens per tube. The standard insecticide susceptibility test method of the World Health Organization was employed in each instance. However, if little or no mortality in adults occurred following 1-hour exposures to the highest insecticide concentrations, the exposure time was extended to 2 or more hours.

RESULTS. The susceptibility to DDT of seven field-collected strains of *C. fatigans* larvae was compared with that of a susceptible strain (UTMB) and a DDT-resistant Okinawa strain (OK),

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both of which have been maintained in this laboratory for a number of years (Table 1). It can be readily seen that

TABLE 1.—Susceptibility of *Culex fatigans* larvae to DDT (p.p.m.)

Strain	Hours exposure				
	1	2	3	24	
CLS	0	19	23	98	
G	10	..	88	100	
A(60)	..	..	16	98	
H	37	..	..	..
CLS	8	..	..	..
UTMB	85	..	..	..
OK	13	..	..	..

all seven strains were susceptible to DDT and that two of them were considerably more so than the UTMB strain. On the other hand, Table 2 shows that two of

TABLE 2.—Susceptibility of *Culex fatigans* larvae to Dieldrin (p.p.m.)

Strain	Hours exposure				
	1	2	3	24	
CLS	0	10	70	100	100
A(59)	0	0	20	82	100
A(60)	0	0	29	100	100
UTMB	0	3	53	100	100
OK	..	0	0	19	57

these same strains, both from Angleton, Texas, were resistant to dieldrin.

All of the five strains of *C. fatigans* tested in the adult stage and which were susceptible to DDT as larvae, were found to be DDT-resistant (Table 3). Even the UTMB strain showed 15 percent survival upon 1-hour exposure. When exposure to 4 percent papers was extended beyond 1 hour, practically all specimens were knocked down; however, a considerable number of them recovered. All strains tested were found to be resistant to dieldrin (Table 4), the maximum mortality obtained in field-collected strains being only 7 percent following the customary 1-hour exposure period. Most

TABLE 3.—Mortality of adult female *Culex fatigans* after exposure to DDT (4%)

Strain	Hours exposure			
	1	2	3	24
EC	0	19	23	98
A(59)	10	..	88	100
A(60)	..	..	16	98
H	37	..	..	..
CLS	8	..	..	..
UTMB	85	..	..	..
OK	13	..	..	..

striking of all was the high level of dieldrin-resistance exhibited by the two strains from Angleton (A59 and A60), wherein 8 days of continuous exposure to 1.6 percent papers produced only 76 percent mortality in the latter.

Three strains each of *A. taeniorhynchus* and *A. sollicitans* larvae showed virtually complete susceptibility to DDT, dieldrin and gamma-BHC as exemplified by the BHC results shown in Table 5. On the other hand, several batches of *A. sollicitans* adults exhibited resistance to dieldrin (Table 6). Likewise, only 75 and 40 percent mortality occurred following 2-hour exposures of *A. taeniorhynchus* from two separate points in one locality.

More recently, *Culex salinarius* larvae from Brazoria and Galveston Counties were found to be completely susceptible to 0.02 p. p. m. of DDT, dieldrin and gamma-BHC. However, adults from these collections were resistant to dieldrin. One-hour exposures of two groups to 4 percent papers resulted in 26 and 27 percent mortality, respectively. In another test, only 30 percent were killed by a 6-hour exposure to 4 percent dieldrin. The mortality in four different strains of adults was 85, 71, 91, and 85 percent, respectively, upon 1-hour exposure to 4 percent DDT papers.

Table 7 summarizes the spectra of chlorinated hydrocarbon resistance in three species used in this study. Whereas all *C. fatigans* larvae were susceptible to DDT, those of the Angleton strains were dieldrin-resistant and the adults were re-

TABLE 4.—Mortality of adult female *Culex fatigans* after exposure to dieldrin

Strain	Hours exposure to 1.6%							
	1	2	3	5	16	18	24	192
EC	0	14	0	..	..	..	31	..
A(59)	7	..	..	80	..	70	..	..
A(60)	..	..	0	..	0	..	0	70
CLS	0	..	..	..	..	..	..	..
UTMB	19	..	..	..	..	..	..	..
OK	10	..	..	..	..	..	..	..

TABLE 5.—Susceptibility of *A. sollicitans* and *A. taeniorhynchus* larvae to BHC (p.p.m.)

Strain	.004	.02	.10	0.5	2.5
AT(Q) 7	100	100	100	100	100
AT(Q) 11	100	100	100	100	100
AT(C)	100	100	100	100	100
AS(C)	87	100	100	100	100
AS(VP)	93	100	100	100	100
AS(VP) 2	91	100	100	100	100

TABLE 6.—Mortality of adult female *Aedes sollicitans* and *A. taeniorhynchus* after exposure to dieldrin (1.6%)

Strain	1-hour	2-hour
AT(Q) 7	95, 92, 96	..
AT(Q) 11	..	75, 90, 40
AT(C)	95, 90, 90	..
AS(C)	50	..
AS(VP)	20	..
AS(SB)	100, 61, 58, 50	..

TABLE 7.—Patterns of susceptibility and resistance in larvae and corresponding adult females of *C. fatigans*, *C. salinarius*, and *A. sollicitans*

Species	Stage	DDT	Dieldrin
<i>C. fatigans</i>	Larvae	S*	R
	Adults	R	R
<i>C. salinarius</i>	Larvae	S	S
	Adults	S	R
<i>A. sollicitans</i>	Larvae	S	S
	Adults	S	R

* S=susceptible, R=resistant.

sistant to both insecticides. On the other hand, both *C. salinarius* and *A. sollicitans* larvae were susceptible to both insecticides, while the adults were DDT-susceptible and dieldrin-resistant.

DISCUSSION. The finding of resistance to both DDT and dieldrin in *C. fatigans* is not surprising since this species has shown insecticide-resistance in various parts of the world. DDT-resistance in *C. fatigans* was recognized in India in 1952 and was followed by Reunion, Taiwan, Okinawa, Venezuela, Puerto Rico, South Australia, Panama, Hawaii and the Congo, during the ensuing seven years. Resistance to BHC and/or dieldrin was reported from California in 1951 and is also present in Malaya, India, Asia, South America, West Africa, Panama, Zanzibar and the Congo. In 1959, malathion resistance in this species at Duala, Cameroun was reported (Brown, 1961).

Whereas in other parts of the world, dieldrin-resistance has been found in adult populations where residual applications of this insecticide have been used for several years, dieldrin-resistance in the United States has frequently occurred in the apparent absence of the use of this insecticide.

The finding of dieldrin-resistant *C. salinarius* in Texas represents the first report of insecticide-resistance in this species.

The development of DDT-resistance in *A. sollicitans* and *A. taeniorhynchus* in Florida in 1947 and 1949, respectively, was followed several years later by resistance to the BHC-dieldrin group and more recently by malathion-resistance (Brown, 1961). *Aedes sollicitans* has also become resistant to DDT (Darsie *et al.*, 1957) and BHC (Darsie and Sutherland, 1959) in Delaware. Dieldrin-resistance was demonstrated in *A. taeniorhynchus*

from a small focus in Chatham County, Georgia, and was accompanied by a degree of cross-resistance to DDT (Schoof, 1959).

It appears likely that the dieldrin-resistance exhibited by the several species used in this study is largely a result of the use of BHC in mosquito control programs. On the other hand, the rapidity of development of dieldrin-resistance in species from Brazoria County might be partly accounted for by the use of aldrin in connection with extensive rice-growing areas.

Since the use of DDT in these two counties has been confined to the infrequent fogging of only a few communities, the agricultural use of the insecticide may have contributed to the widespread DDT-resistance in *C. fatigans*.

One of the important points to emerge from this study is that insecticide susceptibility test results from the larvae alone can be very misleading and should, therefore, be accompanied by data from the corresponding adults. Although the adults of all species studied were resistant to dieldrin, the larvae, with the exception of two strains did not exhibit resistance.

SUMMARY. Adult *Culex fatigans*, *C. salinarius* and *Aedes sollicitans* reared from larvae collected from widely separated localities in Galveston County and Brazoria County, Texas, exhibited resistance to dieldrin. DDT-resistance was also present in *C. fatigans*. Except for two strains of *C. fatigans*, the larvae of this species as well as those of *C. salinarius*, *A. sollicitans* and *A. taeniorhynchus* were susceptible to DDT, dieldrin and BHC.

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DDT-RESISTANCE IN A STRAIN OF *CULEX PIPIENS* FROM NORTHERN ILLINOIS

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The South Cook County Mosquito Abatement District comprises 340 square miles in the south part of Cook County, Illinois. The District includes approximately all of the area south of 87th Street in the City of Chicago to the Cook-Will County line in the south and west and

the Indiana state border to the east. DDT has been the principal insecticide used by the District during the past six years.

During the 1960 mosquito season, several reports were received from field personnel that they could not achieve control of *Culex pipiens* in certain areas of the District with their routine larviciding dosage rate of 0.2 pound of DDT per acre. Formerly, good control had been possible at this rate of application.

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