CURRENT STATUS ON THE FLORIDA ABATE MONITORING PROGRAM—SUSCEPTIBILITY LEVELS OF THREE SPECIES OF MOSQUITOES DURING 1984

A. H. BOIKE, JR., C. B. RATHBURN, JR., K. L. LANG, H. M. MASTERS AND T. G. FLOORE

Department of Health and Rehabilitative Services, West Florida Arthropod Research Laboratory, Post Office Box 15277, Panama City, FL 32406

ABSTRACT. During 1984, larval susceptibility tests of temephos were performed on *Aedes taeniorhynchus* and *Culex nigripalpus* collected from the same general areas as in 1980–82, and the results compared to the susceptible laboratory strains. No resistance was detected against these two species. When strains of *Culex quinquefasciatus* from some new areas were tested against temephos, malathion, naled, fenthion and chlorpyrifos, their tolerance varied according to the insecticide tested and the origin of the strain. Some strains ranged from 1.6 to 43.0X more tolerant to temephos when compared to the West Florida Arthropod Research Laboratory strain (WFARL strain).

INTRODUCTION

The Florida Abate Monitoring program (Boike et al. 1982) was initiated during 1980–82 and resulted in testing 3 species of mosquitoes from 6 counties in Florida against temephos, malathion, naled, chlorpyrifos and fenthion. Results of tests during this period indicated no resistance of temephos by *Aedes taeniorhynchus* (Wied.) or *Culex nigripalpus* Theobald, but variable resistance of up to 22X by *Culex quinquefasciatus* Say.

The intention of the program is to test populations of these mosquito species against temephos every other year only to determine if any resistance was beginning to appear. If any tolerance to temephos was noted, tests for cross resistance to the other insecticides would be conducted.

MATERIALS AND METHODS

Wild populations of *Ae. taeniorhynchus* and *Cx. nigripalpus* were collected essentially from the same areas as those collected in 1980–81 by using CDC portable light traps baited with dry ice (Newhouse et al. 1966). Adults were shipped to the laboratory in styrofoam chests chilled with plastic freezer containers. Strains of *Cx. quinquefasciatus* (which is easily colonized) were sent to the laboratory either as egg rafts or larvae. Some strains were obtained from the same areas as in 1980; however, some new areas were selected in 1984 due to elimination of the original breeding area or for comparison to the area selected in 1980–81. These new strains were tested against all 5 insecticides. Adults of all species were fed on anesthetized chicks and were offered 10% sugar cotton pads for carbohydrate.

Laboratory bioassays consisted of pipetting 1 ml of an appropriate insecticide dilution into 200 ml of tap water. Twenty-five 3rd instar larvae in 49 ml tap water were then added to the beakers giving a total of 250 ml solution. All insecticide dilutions were in ACS acetone. A replication consisted of a control and 5–7 serial dilutions of the insecticide to be tested and an average of 12 replications were performed on each insecticide for a given species. All tests were performed in water baths at 27± 1°C and mortality counts made at 24 hrs. posttreatment (Rathburn and Boike, 1967, Boike et al. 1978).

The LC_{50} and LC_{90} values were calculated by probit analysis using the SAS program through the facilities of the NE Florida Regional Data Center and were expressed in μg AI/ml (ppm).

RESULTS

Results of larval susceptibility tests of *Ae. taeniorhynchus* are shown in Table 1, and those for *Cx. nigripalpus* are shown in Table 2. Tests of *Cx. quinquefasciatus* against temephos and malathion are shown in Table 3 and against naled, chlorpyrifos and fenthion are shown in Table 4. The resistance ratio was found by dividing the LC_{50} and LC_{90} values of the area strain by the LC_{50} and LC_{90} values of the susceptible strain (not shown in tables).

Aedes taeniorhynchus—Temephos—(Table 1): Of the 4 comparable areas sampled in 1984, all had similar LC_{50} and LC_{90} values compared to 1980, indicating no resistance to temephos. When tested against fenthion, the *Ae. taeniorhynchus* from Marco Island, Collier County, were comparable to the West Florida Arthropod Research Laboratory susceptible strain (WFARL strain).

Culex nigripalpus—Temephos, fenthion, naled—(Table 2): *Culex nigripalpus* from 3 areas in Collier, Lee and Polk counties showed less variation in susceptibility to temephos when compard to the WFARL strain. The two 1984 collections of *Cx. nigripalpus* from the Treesweet and Tropicana Company sites in Fort Pierce, St. Lucie County, showed a slight increase in toler-

Table 1. Susceptibility of *Aedes taeniorhynchus* larvae to temephos and fenthion.

County	Area	Year tested	Lethal concentration in μg AI/ml. (ppm)				Resistance ratio[2]	
			LC_{50}	95% C.L.[1]	LC_{90}	95% C.L.[1]	LC_{50}	LC_{90}
				Temephos				
Collier	Naples	1980	0.00074	0.00071–0.00078	0.00120	0.00114–0.00127	0.9	0.7
	Marcos Is.	1984	0.00148	0.00144–0.00151	0.00189	0.00183–0.00197	1.0	0.7
Lee	Sanibel Is.	1980	0.00072	0.00066–0.00079	0.00144	0.00134–0.00155	0.8	1.0
	Sanibel Is.	1984	0.00126	0.00123–0.00129	0.00180	0.00172–0.00189	0.9	0.8
Manatee	Port Manatee	1980	0.00742	0.00068–0.00081	0.00179	0.00105–0.00196	0.8	1.3
	Manson's Farm	1984	0.00066	0.00046–0.00083	0.00170	0.00127–0.00342	0.5	0.9
St. Lucie	Ft. Pierce Bch.	1980	0.00121	0.00116–0.00126	0.00233	0.00209–0.00261	1.5	1.3
	Ft. Pierce Bch.	1984	0.00199	0.00185–0.00218	0.00280	0.00247–0.00353	0.7	1.4
				Fenthion				
Collier	Marco Is.	1984	0.00181	0.00140–0.00250	0.00436	0.00314–0.00650	0.9	1.0

[1] Confidence limits.

[2] Resistance ratio = $\frac{LC_{50} \text{ or } LC_{90} \text{ of area strain}}{LC_{50} \text{ or } LC_{90} \text{ of susceptible strain}}$

Table 2. Susceptibility of *Culex nigripalpus* larvae to temephos, fenthion and naled.

County	Area	Year tested	Lethal concentration in μg AI/ml. (ppm)				Resistance ratio[6]	
			LC_{50}	95% C.L.[1]	LC_{90}	95% C.L.[1]	LC_{50}	LC_{90}
				Temephos				
Collier	Naples	1980	0.000291	0.000278–0.000304	0.000547	0.000513–0.000583	0.9	0.9
	Marco Is.	1984	0.000792	0.000648–0.000949	0.001252	0.001017–0.002852	1.2	1.3
Hillsborough	Gibsonton	1980	0.000296	0.000283–0.000309	0.000609	0.000564–0.000658	0.9	1.0
	Gibsonton[2]	1984	0.001313	0.001193–0.001460	0.004031	0.003244–0.005493	2.1	4.5
	Gibsonton[3]	1984	0.001115	0.000877–0.001348	0.003402	0.002490–0.006450	1.7	3.9
Lee	Ft. Myers	1980	0.000250	0.000227–0.000275	0.000527	0.000466–0.000596	0.8	0.9
	Ft. Myers	1984	0.000786	0.000721–0.000858	0.001131	0.001003–0.001427	1.1	1.2
Polk	Mulberry	1981	0.000517	0.000494–0.000540	0.000792	0.000728–0.000862	0.9	0.9
	Mulberry	1984	0.000672	0.000648–0.000696	0.000989	0.000931–0.001071	1.0	1.1
St. Lucie	Ft. Pierce	1981	0.000562	0.000546–0.000579	0.000919	0.000863–0.000979	0.9	1.0
	Ft. Pierce[4]	1984	0.001072	0.000947–0.001244	0.002099	0.001704–0.002954	1.6	2.3
	Ft. Pierce[5]	1984	0.001115	0.000914–0.001629	0.001905	0.001396–0.004851	1.7	2.1
				Fenthion				
Hillsborough	Gibsonton	1981	0.00302	0.00295–0.00309	0.00417	0.00402–0.00434	0.9	0.9
	Gibsonton	1984[3]	0.00732	0.00647–0.00828	0.01932	0.01580–0.02582	2.7	5.6
				Naled				
Hillsborough	Gibsonton	1981	0.0528	0.0512–0.0544	0.0895	0.0810–0.0990	1.4	1.7
	Gibsonton	1984[3]	0.0722	0.0659–0.0851	0.1822	0.1337–0.3371	2.0	4.2

[1] Confidence limits.
[2] Collection of July 1984.
[3] Collection of Oct. 1984.
[4] Treesweet Company (Collection of April 3, 1984).
[5] Tropicana Company (Collection of May 21, 1984).
[6] Resistance ratio = $\frac{LC_{50} \text{ or } LC_{90} \text{ of area strain}}{LC_{50} \text{ or } LC_{90} \text{ of susceptible strain}}$

ance to temephos compared to 1981, while the 2 collections of *Cx. nigripalpus* from Gibsonton, Hillsborough County, indicated a substantial increase in tolerance to temephos of approximately 2X at the LC_{50} level and 4–4.5X at the LC_{90} level. When tested against fenthion, the *Cx. nigripalpus* from Gibsonton were 2.7X and 5.6X more tolerant than the WFARL strain. A slight increase in tolerance to naled was also shown. This is the first time a population of *Cx. nigripalpus* in Florida exhibited a substantial tolerance to temephos, fenthion and naled.

Culex quinquefasciatus—Temephos, malathion, naled, chlorpyrifos and fenthion—(Tables 3 and 4): The *Cx. quinquefasciatus* strain from the City of Naples Public Works Department (which is approximately 2–3 miles from the Collier Mosquito Control District Headquarters), Collier County, (1984) was highly resistant to temephos (17.4X at the LC_{50} level and 43.0X at the LC_{90} level). The population was also resistant to fenthion (7.5X at the LC_{50} level and 11.1X at the LC_{90} level) and progressively less resistant to chlorpyrifos, malathion, and naled. The Public Works Department strain was more resistant to all insecticides tested when com-

Table 3. Susceptibility of *Culex quinquefasciatus* larvae to temephos and malathion.

County	Area	Year tested	Lethal concentration in μg AI/ml. (ppm)				Resistance ratio[7]	
			LC_{50}	95% C.L.[1]	LC_{90}	95% C.L.[1]	LC_{50}	LC_{90}
				Temephos				
Collier	Naples	1980	0.00236	0.00220–0.00252	0.00767	0.00670–0.00878	2.1	3.3
	Naples[2]	1982	0.00585	0.00536–0.00638	0.01879	0.01599–0.02203	11.2	22.3
	Naples[3]	1984	0.01056	0.00893–0.01265	0.03921	0.02854–0.06471	17.4	43.0
	Immokalee	1984	0.00119	0.00112–0.00124	0.00188	0.00177–0.00204	1.9	1.6
Hillsborough	Seffner	1980	0.00258	0.00232–0.00287	0.02328	0.01812–0.02991	3.4	12.5
	Seffner	1984	0.00316	0.00252–0.00399	0.01818	0.01169–0.03826	5.2	20.0
Lee	Ft. Myers	1980	0.00287	0.00251–0.00329	0.03459	0.02603–0.04597	2.5	15.0
	Ft. Myers[4]	1984	0.00871	0.00724–0.01069	0.02501	0.01860–0.03965	11.3	23.1
Manatee	Ellenton	1984	0.00522	0.00359–0.00887	0.03517	0.01724–0.13930	7.6	34.9
Polk	Eagle Lake	1980	0.01365	0.01301–0.01432	0.03007	0.02782–0.03198	18.1	16.1
	Lakeland	1984	0.00357	0.00290–0.00434	0.01032	0.00790–0.01560	4.2	8.0
St. Lucie	Ft. Pierce	1980	0.00492	0.00445–0.00544	0.02150	0.01886–0.02450	6.6	11.5
	Ft. Pierce[5]	1984	0.01371	0.01108–0.01689	0.03006	0.02280–0.05318	21.2	32.1
	Ft. Pierce[6]	1984	0.01836	0.01644–0.02092	0.03329	0.02756–0.04633	28.4	35.6
				Malathion				
Collier	Naples	1980	0.310	0.279–0.344	1.534	1.332–1.767	2.2	5.3
	Naples[2]	1982	0.700	0.662–0.740	1.545	1.434–1.667	7.0	10.2
	Naples[3]	1984	0.466	0.434–0.498	1.119	1.020–1.248	4.6	7.8
	Immokalee	1984	0.148	0.144–0.152	0.240	0.229–0.251	1.8	1.6
Lee	Ft. Myers	1980	0.451	0.412–0.494	1.617	1.435–1.823	2.5	4.2
	Ft. Myers[4]	1984	0.293	0.282–0.304	0.555	0.523–0.589	3.5	3.8
Manatee	Ellenton	1984	0.203	0.189–0.216	0.463	0.422–0.521	2.0	3.2
Polk	Eagle Lake	1980	1.133	1.090–1.177	2.716	2.499–2.952	6.4	7.1
	Lakeland	1984	0.323	0.295–0.351	1.141	0.976–1.395	3.2	9.8

[1] Confidence limits.
[2] Collier Mosquito Control District Headquarters.
[3] City of Naples Public Works Department.
[4] River Trails Trailer Park.
[5] Collection of April 3, 1984 (Treesweet Company).
[6] Collection of May 21, 1984 (Tropicana Company).
[7] Resistance ratio = $\frac{LC_{50} \text{ or } LC_{90} \text{ of area strain}}{LC_{50} \text{ or } LC_{90} \text{ of susceptible strain}}$

pared to the strain tested in 1982 from the Collier Mosquito Control District headquarters in Naples.

A strain of *Cx. quinquefasciatus* from Immokalee, Collier County, was tested against all insecticides and was found to have LC_{50} and LC_{90} values of <2X for temephos, malathion and naled. When tested against fenthion and chlorpyrifos, the LC_{50} and LC_{90} values were between 2.6X–2.9X. These results are in agreement with Boike et al. (1984) and Palmisano et al. (1976) who showed that populations of *Cx. quinquefasciatus* collected from areas having little or no mosquito programs are more susceptible to OP insecticides than areas having active mosquito control programs.

The *Cx. quinquefasciatus* strain from the River Trails Trailer Park located on the Caloosahatchee River in Fort Myers, Lee County, tested in 1985 was more tolerant to all insecticides tested when compared to the strain tested in 1980 which was from a shopping center on US 41. The Eagle Lake, Polk County strain tested in 1980 was from a sewage tank which had been treated heavily with temephos, giving an LC_{50} value of 18X compared to the WFARL strain. In 1984, the strain from a school yard in Lakeland, Polk County, was considerably less tolerant than the Eagle Lake strain to all insecticides tested. In Fort Pierce, the *Cx. quinquefasciatus* strains tested for 1980 and 1984 were both from sites at the Treesweet Company. A substantial increase in tolerance to temephos was noted for the 2 collections of 1984 compared to 1980.

DISCUSSION

Aedes taeniorhynchus tested during 1984 were as susceptible to temephos as those tested during the initial phase of the Abate Monitoring Program (Boike et al. 1982). *Culex nigripalpus* from 3 areas in Collier, Lee and Polk counties were as susceptible to temephos in 1984 as in 1980–81 indicating no change in resistance. However, *Cx. nigripalpus* collected from sites at the Treesweet and Tropicana companies in 1984 near Fort Pierce indicate a slight increase in tolerance to temephos compared to results obtained in 1980. In addition, substantial tolerance to temephos was found in 2 collections of *Cx. nigripalpus* from Gibsonton in 1984. Also, these populations of *Cx. nigripalpus* were toler-

Table 4. Susceptibility of *Culex quinquefasciatus* larvae to naled, chlorpyrifos and fenthion.

County	Area	Year tested	Lethal concentration in μg AI/ml. (ppm)				Resistance ratio[6]	
			LC_{50}	95% C.L.[1]	LC_{90}	95% C.L.[1]	LC_{50}	LC_{90}
				Naled				
Collier	Naples[2]	1982	0.356	0.344–0.369	0.644	0.594–0.698	3.7	4.9
	Naples[3]	1984	0.399	0.379–0.418	0.759	0.706–0.829	4.7	6.1
	Immokalee	1984	0.147	0.140–0.156	0.215	0.195–0.250	1.4	1.5
Lee	Ft. Myers	1981	0.142	0.137–0.147	0.240	0.223–0.258	1.1	1.0
	Ft. Myers	1984	0.334	0.306–0.371	0.655	0.552–0.844	4.2	6.1
Manatee	Ellenton	1984	0.338	0.297–0.396	0.777	0.606–1.183	4.2	7.3
Polk	Eagle Lake	1980	0.646	0.620–0.673	1.140	1.060–1.226	5.3	5.6
	Lakeland	1984	0.249	0.221–0.289	0.521	0.416–0.759	2.9	4.4
				Chlorpyrifos				
Collier	Naples	1981	0.00396	0.00368–0.00426	0.00967	0.00851–0.01100	2.2	2.4
	Naples[2]	1982	0.00490	0.00472–0.00509	0.00957	0.00902–0.01020	7.0	4.5
	Naples[3]	1984	0.00893	0.00743–0.01045	0.02085	0.01680–0.02998	8.2	9.2
	Immokalee	1984	0.00234	0.00195–0.00296	0.00423	0.00326–0.00733	2.7	2.9
Lee	Ft. Myers	1981	0.00222	0.00209–0.00235	0.00431	0.00393–0.00472	1.3	1.1
	Ft. Myers[4]	1984	0.00493	0.00398–0.00610	0.00806	0.00642–0.01377	7.2	6.6
Manatee	Ellenton	1984	0.00472	0.00357–0.00583	0.01582	0.01154–0.02884	6.9	12.8
Polk	Eagle Lake	1980	0.00621	0.00587–0.00656	0.02204	0.01944–0.02500	3.5	6.0
	Lakeland	1984	0.00375	0.00346–0.00406	0.00780	0.00693–0.00910	3.4	3.4
				Fenthion				
Collier	Naples[2]	1982	0.0283	0.0270–0.0296	0.0553	0.0525–0.0583	5.9	7.1
	Naples[3]	1984	0.0360	0.0320–0.0400	0.0837	0.0720–0.1029	7.5	11.1
	Immokalee	1984	0.0104	0.0102–0.0106	0.0162	0.0156–0.0170	2.7	2.6
Lee	Ft. Myers	1981	0.0088	0.0084–0.0092	0.0186	0.0170–0.0205	0.9	1.1
	Ft. Myers[4]	1984	0.0278	0.0247–0.0314	0.0451	0.0381–0.0634	6.2	6.4
Manatee	Ellenton	1984	0.0374	0.0272–0.0561	0.1587	0.0899–0.6708	8.7	18.7
Polk	Eagle Lake	1980	0.0413	0.0379–0.0450	0.2439	0.2017–0.2946	5.0	14.8
	Lakeland	1984	0.0328	0.0268–0.0417	0.1099	0.0777–0.1878	3.2	9.8
St. Lucie	Ft. Pierce	1980	0.0157	0.0146–0.0170	0.1004	0.0813–0.1240	1.9	6.1
	Ft. Pierce[5]	1984[5]	0.0320	0.0265–0.0378	0.0810	0.0652–0.1116	6.1	8.9

[1] Confidence limits.
[2] Collier Mosquito Control District Headquarters.
[3] City of Naples Public Works Department.
[4] River Trails Trailer Park.
[5] Treesweet Company (Collection of April 3, 1984).
[6] Resistance ratio = $\frac{LC_{50} \text{ or } LC_{90} \text{ of area strain}}{LC_{50} \text{ or } LC_{90} \text{ of susceptible strain}}$

ant to fenthion and naled. The increase in tolerance to temephos at the citrus canning companies at Fort Pierce was probably due to temephos being used as a larvicide in the effluent ponds prior to June 1980. At Gibsonton, no immediate reason is known for the increase in tolerance to temephos, fenthion and naled. It is postulated that agricultural operations may have influenced the results. Additional collections of *Cx. nigripalpus* from nearby areas this summer (1985) will be made in an attempt to determine how widespread is this increase in tolerance to OP compounds.

ACKNOWLEDGMENTS

Appreciation is expressed to the various mosquito control directors and their staff for supplying samples of adults and eggs. Also, the invaluable assistance of Mr. William J. Callaway is appreciated for collecting, transporting and shipping many of the mosquito collections.

References Cited

Boike, A. H., Jr., C. B. Rathburn, Jr., L. A. Sizemore and M. W. Peters. 1984. Susceptibility of eighteen strains of *Culex quinquefasciatus* Say from Florida to five organophosphate insecticides. J. Fla. Anti-Mosq. Assoc. 55:1–5.

Boike, A. H. Jr., C. B. Rathburn, Jr., L. A. Sizemore and M. W. Peters. 1982. Results of the Florida program for monitoring mosquito susceptibility to temephos, 1980–1982. J. Fla. Anti-Mosq. Assoc. 53:84–92.

Boike, A. H. Jr., C. B. Rathburn, Jr., C. F. Hallmon and S. G. Cotterman. 1978. Insecticide susceptibility tests of *Aedes taeniorhynchus* and *Culex nigripalpus* in Florida 1974–1976. Mosq. News 38:210–217.

Newhouse, V. F., R. W. Chamberlain, J. B. Johnston and W. D. Sudia. 1966. Use of dry ice to increase mosquito catches of the CDC miniature light trap. Mosq. News 26:126–129.

Palmisano, C. T., F. D. Steelman and P. E. Schilling. 1976. Relative effects of insecticide usage in Louisiana mosquito control programs on the susceptibility of adult female *Culex pipiens quinquefasciatus* populations. Mosq. News 36:521–527.

Rathburn, C. B., Jr. and A. H. Boike, Jr. 1967. Studies of insecticide resistance in Florida mosquitoes. Mosq. News 27:377–382.