

ARTICLES

DDT-RESISTANCE HAZARD IN NORTH AMERICAN POPULATIONS OF *Aedes aegypti*

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Larvae of *Aedes aegypti* (L.) have developed resistance to the DDT used in treatment of breeding foci in certain localities in Trinidad, Haiti, Dominican Republic, Guadeloupe, Puerto Rico, Jamaica, Colombia, Venezuela, French Guiana and Surinam (Blazquez, 1957; Fay, 1959; Fontan and Fauran, 1959; Fox, 1960; Fox *et al.*, 1960; Gilkes *et al.*, 1956; Kerr, 1960; Pan American Sanitary Bureau, 1956, 1957; Sautet and Vuillet, 1956). Many of the Caribbean strains became so DDT-resistant that the LC_{50} approximated 5 p.p.m. DDT (Fay, 1956). Increased DDT-tolerance has also been observed in the field in South Viet Nam (Sautet *et al.*, 1959) and has been developed by laboratory selection in strains from Nigeria (Surtees, 1958) and Malaya (Shidrawi, 1957; Abedi and Brown, 1960). The genetic origin of DDT-resistance in Malayan population (Coker, 1958) has been considered to differ from that in larvae from Haiti or Trinidad (Qutubuddin, 1958).

In view of the interest in eliminating *Aedes aegypti* in parts of the continental United States, studies of DDT-susceptibility levels were made by Evans *et al.* (1960) on larvae collected at New Orleans, La. and Miami, Fla. and tested either immediately or after a generation of laboratory culture. The New Orleans sample showed no resistance, the LC_{50} being 0.013 p.p.m. DDT. On the other hand, the Miami sample was significantly DDT-tolerant, the LC_{50} being 0.07 p.p.m. and 7 percent of the larvae surviving 0.5 p.p.m. DDT.

In order to ascertain whether North American populations of *A. aegypti* were

capable of developing the decisive DDT-resistance characteristic of certain Caribbean localities, the New Orleans strain was submitted to five generations of DDT selection pressure in our laboratory. A strain was also obtained from Key West, Fla. and submitted to similar laboratory pressure with DDT. The selection was made on larvae in the 3rd and early 4th stadia, lots of 25 being exposed in 250-ml. glass jars so that the percent mortality could be observed. The selecting levels of DDT were adjusted in each generation so that more than 95 percent mortality was obtained in the first selections and over 90 percent mortality in the later generations. The resulting resistance levels obtained in each succeeding generation were tested by the standard method for mosquito larvae (World Health Organization, 1960).

NEW ORLEANS STRAIN. Eggs of the 10th generation of the laboratory colony maintained at the U. S. Quarantine Station, New Orleans, were supplied by Mr. B. R. Evans in April, 1960; when tested in June they showed an LC_{50} of 0.017 p.p.m. DDT. Selection pressure was then applied for five generations (Table 1), and it was found that the LC_{50} increased to 4.5 p.p.m., the rise being particularly marked between the F_3 and F_4 generations. This decisive increase in resistance was accompanied by a considerable decrease in slope of the dosage-mortality regression line (Fig. 1), indicating that susceptible phenotypes still persisted. Such a situation would allow reversion to occur on relaxation of selection pressure, as was

TABLE 1.—Increase in larval LC₅₀ levels (in p.p.m. DDT) of the New Orleans and Key West strains exposed in every generation to selecting doses causing more than 90 percent mortality

Generation	New Orleans		Key West	
	Selecting dose	LC ₅₀	Selecting dose	LC ₅₀
P		0.017		0.30
F ₁	0.04	Not Det.	0.5	0.61
F ₂	0.04	0.06	1.0	0.80
F ₃	0.32	0.16	2.5	1.3
F ₄	1.0	1.4	5.0	2.1
F ₅	1.0	4.6		

found with the Malayan strain by Abedi and Brown (1960); but these authors found that even in such a case resistance would eventually stabilize on resumption of selection.

KEY WEST STRAIN. Eggs were supplied in April 1960 by Dr. G. B. Craig, University of Notre Dame, from a culture originally established by A. O. Lea at the Florida Entomological Research Center, Vero Beach, from adults collected at Key West in November, 1959. When tested in June this strain proved to be already somewhat DDT-tolerant, showing an LC₅₀ of 0.30 p.p.m.; it was also tolerant to dieldrin (LC₅₀ 0.073 p.p.m.) and to gamma-BHC (LC₅₀ 0.60 p.p.m.). Selection pressure was then applied with DDT for four generations (Table 1), and it was found that the LC₅₀ steadily increased to 2.1 p.p.m. DDT. The development of this decisive DDT-resistance was accompanied by a gradual flattening of the dosage-mortality regression line (Fig. 1).

CUCUTA STRAIN. Parallel studies were made with a strain from Cucuta, north-eastern Colombia, where DDT-resistance had been reported in 1957. The strain under study originated from a larval collection made in November 1959 and was colonized in the Instituto Carlos Finlay, Bogota, by Mr. A. Morales, who found it to be DDT-susceptible (LC₅₀ approximately 0.05 p.p.m.). Eggs of this strain were provided by Dr. J. Austin Kerr in May 1960; when reared in our laboratory,

it showed a very low oviposition rate. Susceptibility tests performed in August and September showed the strain to be (a) variable, with LC₅₀ levels ranging from 0.19 to 0.84 p.p.m., and (b) extremely heterogeneous, the dosage-mortality regression lines having a very low slope and two inflections. It was also somewhat tolerant of dieldrin (LC₅₀ 0.09 p.p.m.) and of gamma-BHC (LC₅₀ 0.12 p.p.m.). When sufficient parental stock had been obtained in two generations of laboratory culture, selection pressure was applied with 1 p.p.m. DDT. The LC₅₀ of the F₁ from selected parents was found to have increased to 4.5 p.p.m. DDT, with a slight further decrease in slope of the d-m line. Similar pressure raised the LC₅₀ of the F₂ to 5.1 p.p.m.; subsequent relaxation of pressure left the LC₅₀ of the F₃ at 2.2 p.p.m. DDT, the slopes of the d-m lines remaining very low.

SUMMARY. By means of selection pressure in the laboratory, it has been shown that strains of *Aedes aegypti* from New Orleans, La. and Key West, Fla. are capable of developing high DDT-resistance in the larvae, the results paralleling those obtained from a strain from Cucuta, Colombia. It is therefore concluded that the DDT-resistance hazard in populations in the southern U.S.A. is just as high as in Central American regions.

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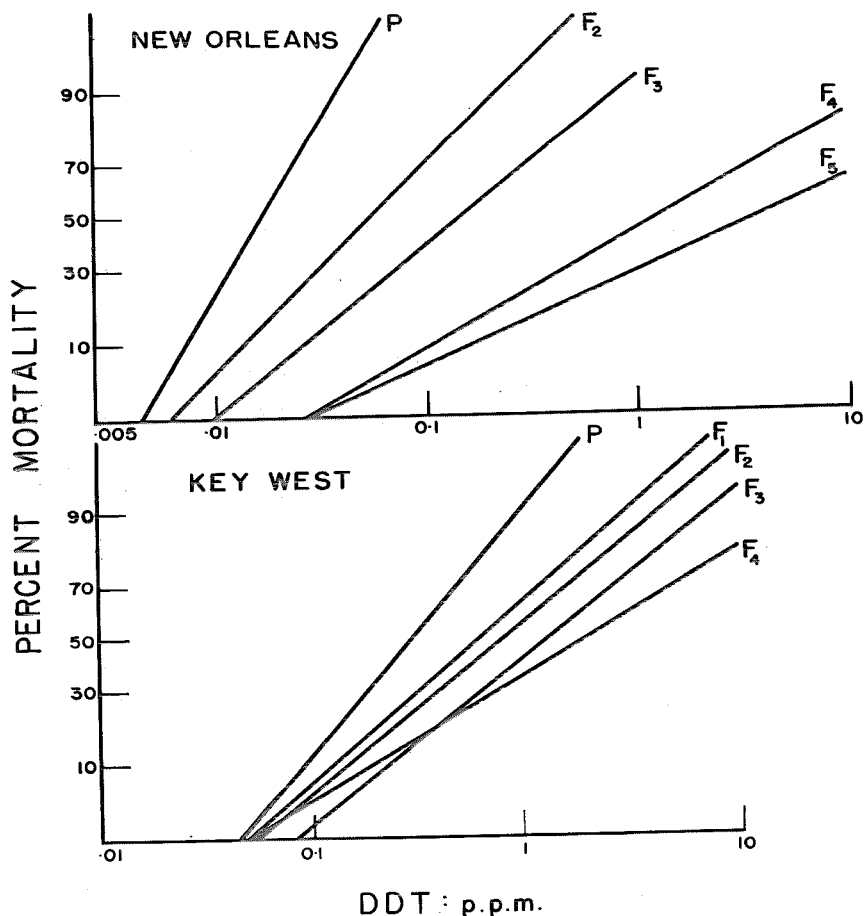


FIG. 1.—Dosage-mortality regression lines for the increasing DDT-resistance of strains of *A. aegypti* from the southern U. S. A. submitted to 4-5 generations of selection pressure.

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FURTHER COMMENTS ON THE SUSCEPTIBILITY OF *Aedes aegypti* TO DDT IN THE MIAMI, FLORIDA, AREA

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An earlier paper by Evans *et al.* (1960) presented evidence suggesting that *Aedes aegypti* (Linn.) from the Miami, Florida, area are somewhat tolerant or resistant to DDT. The tests reported therein showed that 7.0 percent of the *aegypti* larval mosquito population survived 0.5 p.p.m. of DDT.

More recent tests, performed in the same manner, using the WHO test kit and method of testing, show a broad range of reaction to DDT as is indicated in Table 1. The larvae tested are the F₁ generation of field-collected larvae and adults from four different areas of Miami. These are des-

ignated as area "A" for the Miami River front; area "B" for larvae found in a coconut stump in a residential section of the city nearly two and one half miles from the river; area "C" for specimens from the Miami International Airport; and area "D" for specimens recovered from tree-holes in the southeastern section of the city.

Larvae of *aegypti* from these four areas show a significant degree of natural variation in their reaction when exposed to DDT. They range from areas "A" and "D" which are relatively susceptible to DDT with an LD-50 of .029 and .028, respectively, to larvae from area "B" which show indications of resistance to DDT with an LD-50 of .22. Populations showing intermediate degrees of susceptibility were those from area "C" having an LD-50 of .138.

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