# SUSCEPTIBILITY OF NEW JERSEY MOSQUITO LARVAE TO DDT, ABATE AND BAYTEX[1]

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In 1960 a program was established in New Jersey to survey the insecticide susceptibility of its mosquito populations, thereby determining base-line data as well as monitoring the development of resistance, on which would be based the choice of insecticide for control (Sutherland and Hagmann, 1962). The program was reviewed after five years (Sutherland, 1966), and the purpose of this communication is to review it again after a similar interval. This program is additionally significant since the usage of DDT has markedly declined, its use in 1970 in the cooperative state airspray program being less than 3 percent of that used in 1968. There is available, then, the opportunity to observe the possible decline of suspected DDT resistance in certain species and populations as well as to predict their susceptibility during future disease outbreaks, at which time the use of DDT for its residual power might become necessary.

MATERIALS AND METHODS. The methods employed were essentially the same as those of the World Health Organization (Brown, 1958), with 95 percent ethanol as insecticide dispersant and the criterion of larval mortality being failure to fully flex head to siphon when stimulated. Transportation of larvae to the laboratory with little or no mortality during the assays was accomplished by stopping the vehicle periodically to allow larvae to surface without disturbance. On the following day, toxicity assays were performed, and subsequently dosage-mortality regression lines were fitted by eye. The few assays involving greater than 8 percent control mortality were excluded. For some species, data are included from studies in 1960–65 (Sutherland, 1966).

RESULTS AND DISCUSSION. The 24 hour $LC_{50}$'s in parts per billion (ppb) of DDT, Abate and Baytex to various species in New Jersey are given as follows: Fig. 1 *Aedes stimulans*, Fig. 2 *A. sollicitans*, Fig. 3 *Culex pipiens*, and Table 1 other species. For the latter, the source of the population is given; such information for the first three species is on file.

Generally, over the ten year period the early season *A. stimulans* has remained highly susceptible to DDT, the $LC_{50}$'s generally falling between 0.4 and 4.0 ppb (Fig. 1). This range is slightly lower than the 1.6–10 ppb reported for extra-state locations (Pal and Kalra, 1965). Abate and Baytex also are highly toxic to this species, the $LC_{50}$ range being 0.2–2 ppb.

*A. sollicitans* larvae have been less susceptible to DDT; generally the range for DDT $LC_{50}$'s to this species in ten years has been 4–40 ppb (Fig. 2). In some years, e.g., early 1961 and 1967–69, a few populations yielded higher $LC_{50}$'s. One population in particular in 1961 (111 ppb), which originated in Cape May in the southern part of the state where DDT usage has been great, was eventually considered pre-resistant. However, among the 10 populations examined in 1966–1969 and found to possess $LC_{50}$'s above 10 ppb (Fig. 2), DDT susceptibilities could not be correlated with histories of DDT treatment. One location, receiving considerable treatment, within 1½ months yielded populations having $LC_{50}$'s ranging be-

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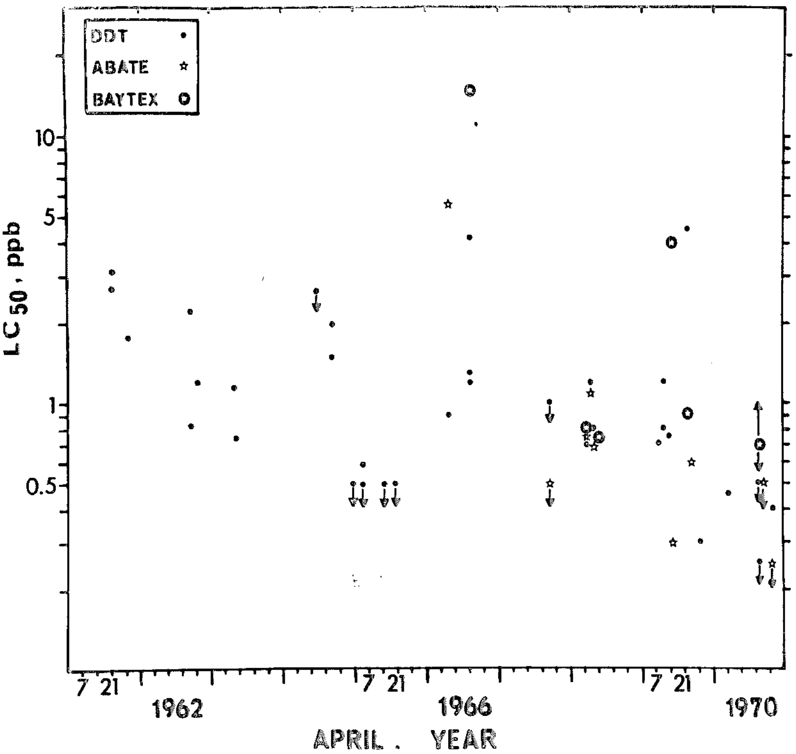


FIG. 1.—Larval $LC_{50}$'s (ppb) of DDT, Abate and Baytex to *Aedes stimulans*, 1961–1970. Single arrows indicate a value less or more than; double arrows indicate interval in which value lies.

tween 6–46 ppb, and one must cautiously, if at all, attribute $LC_{50}$'s above 10 ppb to genetic resistance. It will be of interest to follow the possible increase in DDT susceptibility in future years. Since 1966, with the general safety and efficiency of Abate and Baytex, these compounds have replaced DDT in larval control. To *A. sollicitans* they have been approximately 10 times more toxic than DDT, generally the $LC_{50}$'s falling below 2 ppb. These levels are close to those reported for laboratory-reared and field populations of *A. taeniorhynchus* (Boike and Rathburn, 1969).

DDT has not been widely used in New Jersey for control of *C. pipiens* larvae, because of its inconsistent field performance in polluted waters. The variability of toxicity to the species is evident in Fig. 3, in which the $LC_{50}$'s range from 2 ppb in 1961 to 700 ppb (population indicated at point b in 1967, Fig. 3). The interpretation of the higher level as indicative of resistance must be cautiously made since the sorption of DDT by pollution might be responsible for low susceptibilities. Efforts have been made to clarify this role of pollution by comparing susceptibilities of field populations in habitat and distilled water in the laboratory. However, the effect of transference to laboratory water on the larval susceptibility to DDT may be complex.

Instead, the problem has been investigated by laboratory colonization with DDT selection of field populations having high $LC_{50}$'s. Two such populations (Avalon, A and Turkey Ditch, TD, Fig. 3, point a) were brought into the laboratory in September 1965 from Cape May in southern New Jersey, an area of relatively heavy DDT treatment (Hemmerlein, 1967, 1969). The main objective of his research was to investigate differences in susceptibility to avian plasmodia. Data extracted from his work are presented in Table 1. The parental stock of A and TD exhibited $LC_{50}$'s of 500 and 120 ppb respectively. With DDT selection of subcolonies for 10 or more generations, susceptibility so decreased that $LC_{50}$'s were unattainable, the concentrations of DDT required being so high as to precipitate on dispersion. Concentrations of 10,000–20,000 ppb were necessary to obtain 20–32 percent mortality. However, the amounts of DDT actually available to enter and affect larvae under such conditions may not be proportional to treatment concentration and, therefore, numerical values can not be assigned to the increase in resistance.

With cessation of selection of $TD_R$ in $F_{24}$, susceptibility rapidly reverted in 3 generations to a more normal level ($LC_{50}$ 340 ppb). A slight increase in susceptibility, which could be attributed to laboratory rearing conditions, was also observed in the unselected TD subcolony. This reversion was not observed in 10 generations in the Avalon unselected subcolony. On the basis of these results, i.e., the great potential for DDT resistance in the parent populations, but in the absence of selection no marked increase in susceptibility above the original levels, the original field populations have not been labeled DDT

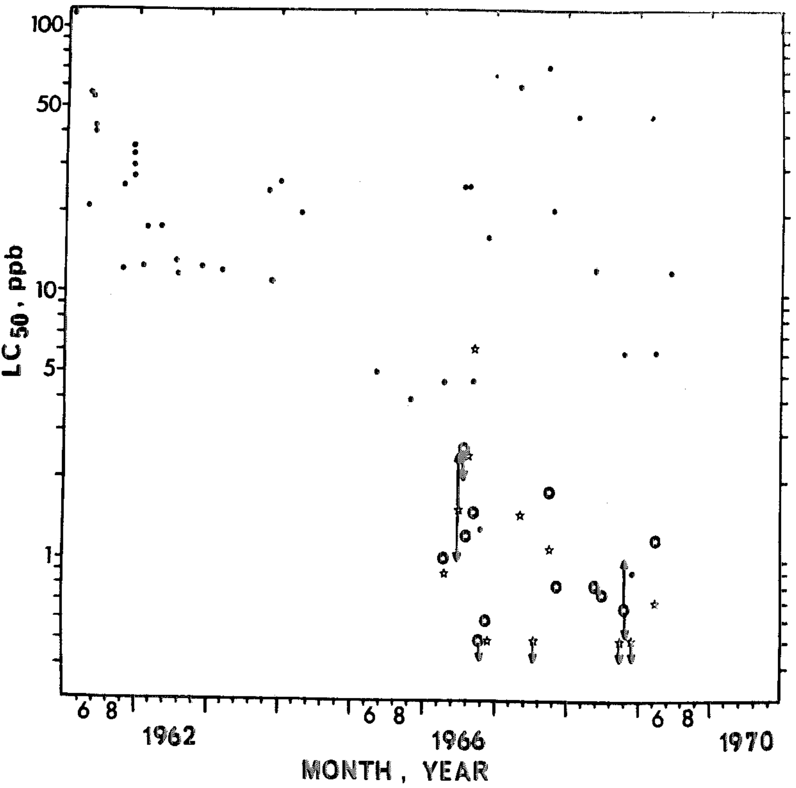


Fig. 2.—Larval $LC_{50}$'s (ppb) of DDT, Abate and Baytex to *Aedes sollicitans*, 1961–1970.

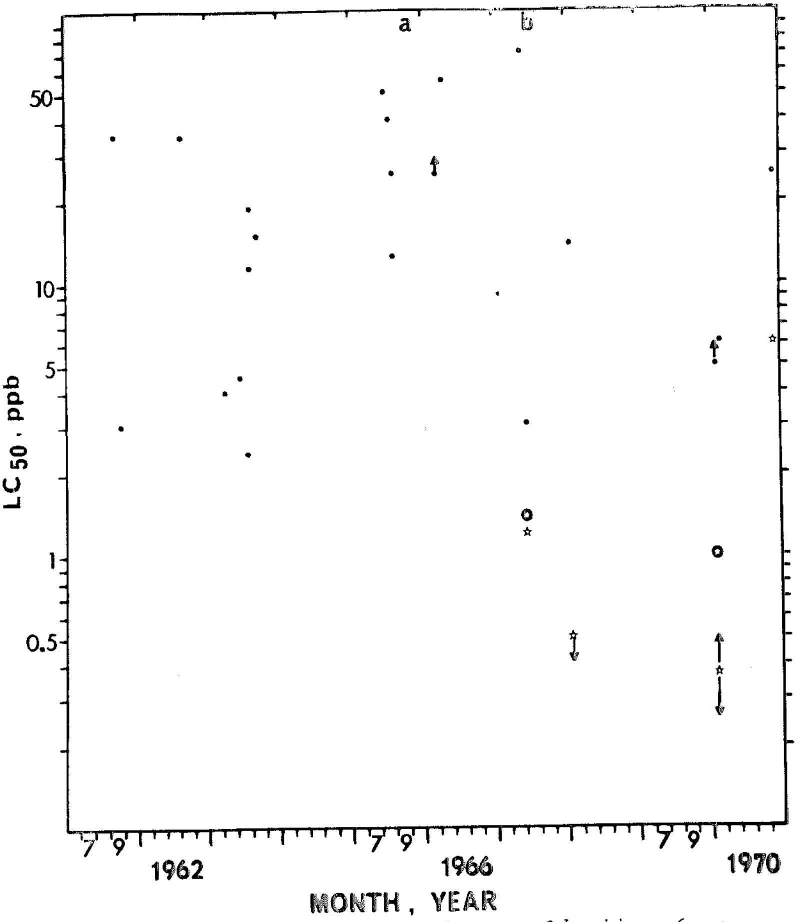


FIG. 3.—Larval $LC_{50}$'s (ppb) of DDT, Abate and Baytex to *Culex pipiens*, 1961–1970.

resistant. It should be noted that this is in some disagreement with Hemmerlein (1967) who felt that an $LC_{50}$ of 100 ppb (0.1 ppm) might be indicative of resistance. While he thought that the two original populations (Avalon and TD) were probably preresistant to DDT, he explained their failure to revert to increased susceptibility as indicative that the resistance in these strains is "stable and may be controlled by a dominant gene or genes."

In the recently revised WHO criteria for *C. pipiens* resistance (Brown, 1971, personal communication), $LC_{50}$'s in excess of 500 ppb would be necessary in order to be classed as DDT-resistant (R), and levels between 80 and 500 ppb would be classed as DDT-tolerant or of intermediate resistance. While one population collected in New Jersey in 1967 (point b, Fig. 3), having an $LC_{50}$ of 700 ppb, could accordingly be classed as resistant, it has not been so labeled, since information on its DDT-resistant potential and habitat pollution level is lacking. While under field conditions such field populations would be difficult or impossible to control with DDT, fortunately no cross resistance to Abate and Baytex has been detected

TABLE 1.—Larval susceptibility to DDT of various laboratory strains of *C. pipiens* (summarized from Hemmerlein, 1967, 1969).

| Strain | Lab DDT Selection Pressure Generation | Conc. ppb. | Generation | Response to DDT, ppb. $LC_{20}$ | $LC_{50}$ | $LC_{80}$ | $LC_{90}$ |
|---|---|---|---|---|---|---|---|
| Avalon | P -$F_{10}$ | none | P | | 500 | | 5,000 |
| | | | $F_{10}$ | 69 | 700 | 10,000 | |
| $Avalon_R$ | $F_1$ -$F_5$ | 500 | | | | | |
| | $F_6$ -$F_{10}$ | 32,000 | $F_{10}$ | 20,000 | ... | ..... | ..... |
| Turkey Ditch | P -$F_{27}$ | none | P | | 120 | | 350 |
| | | | $F_{10}$ | 61 | 140 | 310 | |
| | | | $F_{13}$ | | 50 | | 350 |
| | | | $F_{18}$ | | 41 | | 120 |
| | | | $F_{27}$ | | 39 | | 150 |
| Turkey $Ditch_R$ | $F_1$ -$F_7$ | 100 | | | | | |
| | $F_8$ -$F_{10}$ | 500 | $F_{10}$ | 84 | 350 | 15,000 | |
| | $F_{11}$-$F_{13}$ | 500 | $F_{13}$ | | 680 | | 7,000 |
| | $F_{14}$-$F_{17}$ | 1,000 | | | | | |
| | $F_{18}$-$F_{24}$ | 5,000 | $F_{18}$ | 32% mort. @ 10,000 ppb.* | | | |
| | $F_{25}$-$F_{27}$ | none | $F_{27}$ | | 340 | | 27,000 |

* Highest concentration tested.

in laboratory DDT-resistant colonies. In the limited assays with field populations of *C. pipiens* the $LC_{50}$'s of these latter two compounds have been below 6 ppb (Fig. 2), in the range reported by others (Klassen *et al.*, 1965; Gras and Rioux, 1969).

The susceptibility to DDT of populations of other species (*A. cantator*, *A. canadensis*, *A. vexans*) during 1966–1970 (Table 2) generally is similar to that found in previous years (Sutherland, 1966). Among the exceptions are three populations of *A. cantator* from treated

TABLE 2.—Larval $LC_{50}$'s (ppb) of DDT, Abate and Baytex to various mosquito species, 1966–1970.

| Species | Date | Location | Insecticide $LC_{50}$, ppb. DDT | Abate | Baytex |
|---|---|---|---|---|---|
| *A. cantator* | 3/31/66 | Cape May | >25[a] | | |
| | 4/ 5/66 | Raritan | 62 | | |
| | 4/ 6/66 | Raritan | 15 | | |
| | 4/ 9/66 | Cape May | 65 | | |
| | 4/ 9/69 | Ocean | >10[b] | 0.7 | |
| | 5/ 2/69 | New Gretna | 2 | 0.3 | |
| | 4/21/70 | Eldora | 7 | 0.25 | 0.6 |
| *A. canadensis* | 5/13/68 | S. Brunswick | 2.7 | 1.1 | |
| | 4/10/69 | Cape May | <10[c] | 0.65 | |
| | 4/17/70 | Fishing Creek | 3 | | |
| | 4/21/70 | Fishing Creek | >50[d] | >0.5 | 0.5–1 |
| | 4/29/70 | Ridge Road | 0.5 | 0.25 | |
| *A. vexans* | 7/28/67 | Oxford | 3 | 1.7 | 11 |
| | 5/ 8/68 | Basking Ridge | 33 | 1.3 | <2.5 |
| | 6/ 3/68 | Plainsboro | 4.5 | | |
| | 9/ 9/69 | Great Meadows | 26 | <1 | |

[a] No mortality at 25 ppb.
[b] 14% mortality at 10 ppb, $LC_{50}$ approx. 100 ppb.
[c] 10% mortality at 10 ppb.
[d] 32% mortality at 50 ppb.

areas, whose $LC_{50}$'s to DDT apparently are over 50 ppb. Pal and Kalra (1965) report susceptible ranges of this species to be 4–25 ppb and a resistant level to be more than 2500 ppb. No data are available for New Jersey populations indicating such levels of resistance.

For *A. canadensis* and *A. vexans* $LC_{50}$'s for DDT are generally low and comparable to the range of 3.5–4 ppb and 4–8 ppb respectively reported elsewhere (Pal and Kalra, 1965). These species were highly susceptible to Baytex and Abate.

In summary, the majority of collected populations of New Jersey mosquito species continue to be susceptible to DDT, Abate and Baytex. While a few populations show some tolerance to DDT, there is no evidence of tolerance to Abate and Baytex.

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