AN INSECTICIDE SUSCEPTIBILITY STUDY OF *CULEX PIPIENS FATIGANS* IN AUSTRALIA

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In many parts of Australia *Culex pipiens fatigans* Wiedemann is a common mosquito in urban areas and this is particularly so in Queensland where its importance now is restricted to that of a nuisance mosquito. Sixty years ago, however, filariasis, of which *C.p. fatigans* was an efficient vector, was a common disease and appeared to be more prevalent in the southern part of the state. In the early part of this century the disease began to decline in the city of Brisbane, virtually disappeared by 1938 and clinical cases are now extremely rare (Mackerras 1958, Anon. 1965). Mackerras (1958) discusses some possible explanations for the decline of the disease but it was certainly not due to the disappearance of *C.p. fatigans*.

Control of *C.p. fatigans* in the Greater Brisbane Area, approximately 375 square miles in extent, has involved both elimination of breeding sites and chemical larvicides. The history of insecticidal usage can be summarised as follows: 1925–1948, petroleum oil; 1948–1951, oils supplemented by DDT; 1951–1959, oil, DDT and BHC with the latter being the material of choice; 1959–1961, dieldrin on a limited scale when replaced by oil; 1961–1962, reintroduction of DDT; 1962–present, oils with products containing synergised pyrethrum together with one of the following at different times, malathion, dimethrin or barthrin (P. J. Sparks, personal communication 22 Mar. 66).

Elsewhere in the world *C.p. fatigans* has shown itself capable of developing resistance to a number of insecticides (Brown, 1963). Marks (1960) and Dowe (1961) conducted susceptibility tests on *C.p. fatigans* larvae from several areas of Brisbane and although their data are incomplete it is possible to deduce the following approximate larval LC_{50} values: in 1960, DDT 0.016, BHC 0.17–0.26, dieldrin 0.17; in 1961, DDT 0.02–0.06, BHC 0.13–0.34. These levels indicate resistance of 1–6 times for DDT and 13 to 34 times for BHC by 1961 and 40 times for dieldrin by 1960.

In 1965 a study was commenced to obtain precise data on the susceptibility of *C.p. fatigans* in the city of Brisbane and this paper reports the results of this study.

MATERALS AND METHODS

Colonies of *C.p. fatigans* were established from egg rafts from a number of sites and the history of larviciding treatment at each site is given below for comparison with the results obtained: Cannon Hill—early treatments of BHC with recent treatment by blended oils; Kedron—treatment over a number of years comprised BHC with intervening periods of oil; Salisbury—treatment with oil only; Chapel Hill—established from four wild engorged females; Q.I.M.R.—a sub-colony obtained from the Queensland Institute for Medical Research, Brisbane. The original colony was colonized from egg rafts obtained locally and had been reared for 22 generations without exposure to insecticides.

Larvae were reared in tap water in enamel or plastic trays and fed twice daily with chicken pellets which had been ground to pass through a 40 mesh sieve. Adults were maintained in 15 x 15 x 15 inch plastic mesh-covered cages and supplied with raisins and water. A blood source was provided in the form of heparinized sheep blood; this was placed in a 2 x 1 inch plastic tube, one end of which was covered with Baudruche membrane. The tube was placed on the screen top of the cage and females fed avidly during and after a simulated dusk period. Females blood-fed about five days after

emergence, oviposited 2–3 days later and the larval period occupied 9–10 days. All rearing took place in a controlled environment room at 75±2° F. and 60±5% relative humidity.

Susceptibility tests were conducted on both larvae and adults according to the procedure advocated by the World Health Organization (1963). Series of concentrations of the insecticides were prepared by dissolving technical grade material in ethanol and de-ionized water was used for the tests. Third instar larvae were used exclusively and were held at 75° F. during the 24-hour post-treatment period employed for determination of mortality. Adult tests employed 3–4 day old sugar-fed females, and were conducted at 75° F. and 60 percent relative humidity. Four replicates, each of 25 individuals, were employed for each dosage level and after the data were plotted on logarithmic-probability paper, regression lines were fitted by eye.

RESULTS AND DISCUSSION

The dosage-mortality relationships for the insecticides used for larvae of the Kedron strain are shown in Figure 1. From this figure, and similar ones for the other strains, the LC_{50} values shown in Table 1 were obtained. The LC_{100} values shown are the concentrations used in the tests at which complete mortality occurred. Since the concentrations ascended by a factor of 2, it is quite possible that the true LC_{100} value is somewhat less than that given. Some limited tests were made with Bromophos (O,O-dimethyl-o-2,5-dichloro-4-bromophenyl) thiono phosphate and Abate (O,O,O^1,O^1—tetramethyl O,O^1-thiodi-p-phenylene phosphorothioate).

Since all of the strains studied showed resistance to DDT, lindane and dieldrin, recourse had to be made to overseas investigations for typical LC_{50}'s for susceptible strains. Burnett and Ash (1961) reported LC_{50} values of 0.012, 0.008 and 0.004 for DDT, lindane and dieldrin respectively in a study of this mosquito in Fiji. Therefore on these figures the level of DDT resistance in our strains ranged from 11 to 46 times and the level of dieldrin resistance from 35 to 245 times. The fact that the highest level of lindane and dieldrin resistance was found in the Q.I.M.R. strain which has been reared in the laboratory for 23 generations without insecticide exposure indicates that resistance to these compounds is quite stable.

On comparison with the data of Marks (1960) and Dowe (1961) it is apparent that the level of DDT resistance has increased from zero in 1960 to 6 times in 1961 and to 46 times in 1965, and this can be correlated with the continued use of DDT as a control larvicide from 1951 to the present. The levels of resistance to lindane and dieldrin have increased in the period 1961–1965, and are evidently due to

TABLE 1.—Susceptibility, in p.p.m., of strains of *C.p. fatigans* from Queensland.

	Cannon Hill		Salisbury		Kedron		Chapel Hill		Q.I.M.R.	
Insecticide	LC_{50}	LC_{100}	LC_{50}	LC_{100}	LC_{50}	LC_{100}	LC_{50}	LC_{100}	LC_{50}	LC_{100}
DDT	0.16	1.25	0.21	2.50	0.46	5.00	0.15	1.25	0.11	1.25
lindane	0.32	1.00	0.39	2.00	0.40	2.00	0.34	1.00	0.41	2.50
dieldrin	0.14	0.50	0.46	2.50	0.76	5.00	0.74	5.00	0.98	5.00
parathion	0.004	0.015	0.0042	0.015	0.0047	0.015	0.0037	0.016	0.0052	0.016
malathion	0.017	0.062	0.030	0.12	0.023	0.06	0.015	0.06	0.026	0.12
diazinon	0.064	0.25	0.060	0.25	0.054	0.25	0.058	0.25	0.060	0.25
fenthion	0.0025	0.008	0.0031	0.015	0.0024	0.008	0.0029	0.016	0.0024	0.008
carbaryl	1.30	4.00	0.70	4.00	0.78	4.00	0.54	2.00	1.10	8.00
Bromophos	...	...	0.0027	0.0078	...	...	...	..	0.0032	0.0078
Abate	...	...	0.001	0.0039	...	...	...	.	0.0009	0.0039

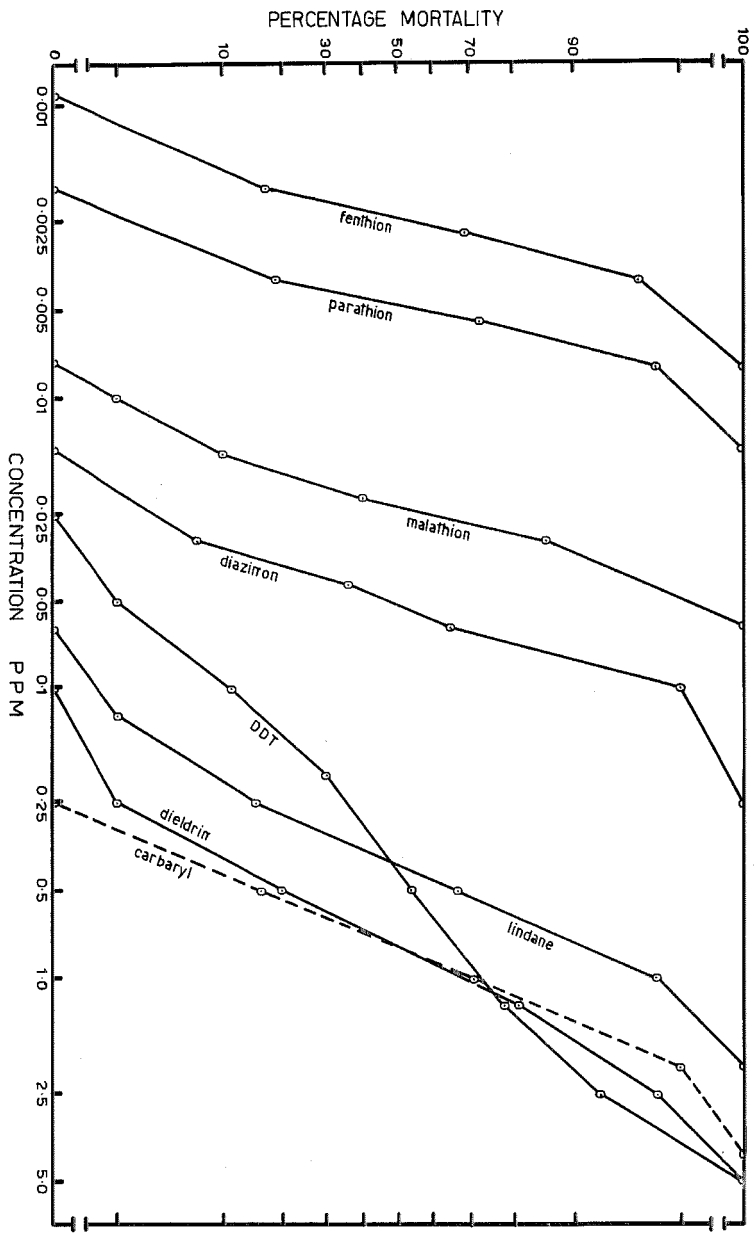

FIG. 1.—Dosage response lines of a number of insecticides against larvae of the Kedron strain of *C.p. fatigans*.

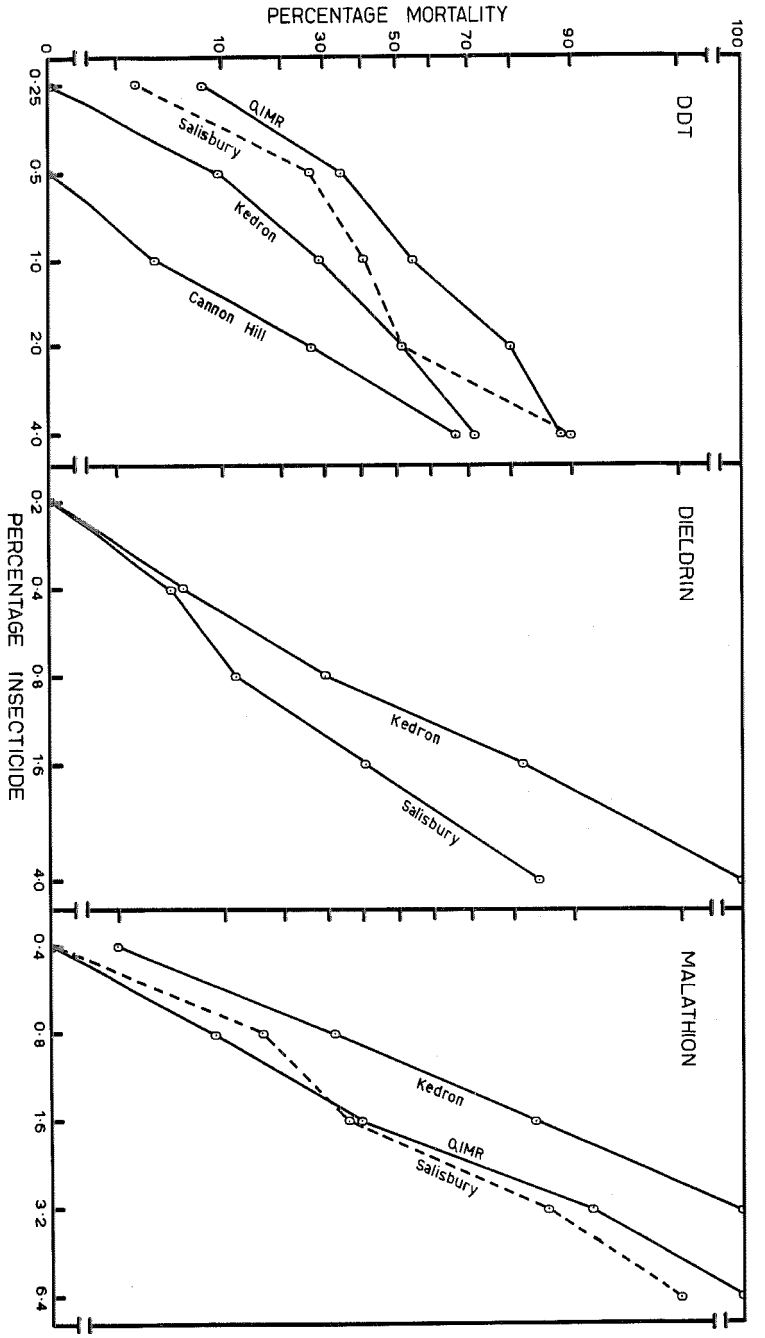

FIG. 2.—Dosage response lines of adults of a number of strains of *C.p. fatigans* to papers impregnated with oil solutions of DDT (24 hr. exposure), dieldrin (24 hr. exposure) and malathion (1 hr. exposure).

the brief use of dieldrin in 1959–1961 and the longer use of BHC in 1951–1959.

After comparison with the results reported by Mulla (1964) on *C.p. quinquefasciatus* and by Thomas (1962) on *C.p. fatigans* it is evident that the susceptibility to organophosphate compounds is normal in these strains, which reflects the very limited usage of these materials in control programmes. The LC_{50}'s for carbaryl are close to the values for susceptible *C.p. fatigans* from Malaya (Thomas, 1962). Both Bromophos and Abate show promise as mosquito larvicides and the organophosphate compounds can be arranged in the following order of decreasing toxicity based on mean LC_{50} values; Abate (0.0009), fenthion (0.0027), Bromophos (0.0029), parathion (0.0044), malathion (0.022) and diazinon (0.059).

Dosage-mortality data for a number of tests on adults are shown in Figure 2. Although the World Health Organization test method specifies a 1-hour exposure period, it was found necessary to utilise a 24-hour exposure period for DDT and dieldrin in order to obtain adequate mortalities. These are the figures which are plotted. It was found that holding the test insects for a further 24 hours on clean paper did not result in any significant change in mortality. The strains were very heterogeneous in their response to the insecticides, particularly to DDT, and therefore the adult $LC_{50}(\%)$ values given below must be considered as approximate only:

	Q.I.M.R.	Salisbury	Kedron	Cannon Hill
DDT (24 hr. exposure)	0.8	1.4	2.4	3.2
dieldrin (24 hr. exposure)	...	1.7	0.9	...
malathion (1 hr. exposure)	1.63	1.8	1.0	...

Smith and Bransby-Williams (1962) reported LC_{50} levels for adults of *C.p. fatigans* in East Africa from untreated areas of 1.9 percent for DDT (1-hour exposure) or 0.9 percent (24-hour exposure), of 0.08–0.17 percent for dieldrin (24 hour exposure) and of 0.3 percent for malathion (1-hour exposure). On the basis of these data the strains tested in our study show a maximum level of resistance to DDT of 3.5 times, to dieldrin of 21 times and to malathion of 5.4 times. It has been stated that since the normal susceptibility of *C.p. fatigans* adults to DDT and dieldrin is low whereas that of the larvae is high, incipient resistance will be more evident in adults than in larvae. This conclusion is not borne out by the results of this study where, in the same strain, the level of DDT resistance in larvae was 16 times compared with 3.5 times in adults (Cannon Hill) and the level of dieldrin resistance in larvae was 115 times compared with 21 times in adults (Salisbury).

The other point which emerges from this study is that there is no correlation between level of resistance and history of insecticidal use at the collecting site. Resistance was found in all strains tested, thus indicating that over the years the population within the city of Brisbane has been well mixed and resistance factors have been well distributed. This is entirely possible since it has been found that individuals of *C.p. fatigans* can travel up to 0.56 mile in urban areas (A. W. Lindquist, personal communication 1965).

Brown (1961, 1963) quoted the occurrence of DDT resistance in *C.p. fatigans* in South Australia in 1958. This arose from a report by Deland (1959) following reports of inefficiency of DDT larval treatment in the field. In 1964 Kerr omitted this resistance from a list of authenticated cases of resistance in Australia but listed a suspected case of DDT resistance in New South Wales. This record was based on an observation that DDT spraying of a polluted stream did not give effective control of larvae (A. D. Lees, personal communication, 1965).

Thus the data in this paper represent the first authentic records of DDT resis-

tance and dieldrin resistance in *C.p. fatigans* in Australia.

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