Ludlam, K. W., Jachowski, L. A. and Otto, G. F. 1970. Potential vectors of *Dirofilaria immitis*. JAVMA 157(10):1354–1359.

Newton, W. L., Wright, W. H. and Pratt, I. 1945. Experiments to determine potential mosquito vectors of *Wuchereria bancrofti* in the Continental United States. Am. Jour. Trop. Med. 25:253–261.

Phillips, J. H. 1939. Studies on the transmission of *Dirofilaria immitis* in Massachusetts. Amer. Jour. Hyg. 29:121–129.

Pistey, W. R. 1959. Studies on the mortality of mosquitoes infected with *Dirofilaria tenuis* Chandler. 1942. Exptl. Parasit. 8:596–608.

Rosario, F. del. 1936. *Dirofilaria immitis*, Leidy and its culicine hosts in Manila, P. I. Philipp. Jour. Sci. 60:45–47.

Travis, B. V. 1947. Relative efficiency of six species of mosquitoes from Guam, M. I. as supplemental hosts for *Dirofilaria immitis*. Jour. Parasit. 33:142–145:

Weiner, D. and Bradley, R. E. 1970. Ability of some mosquitoes to transmit *Dirofilaria immitis* in Florida. Mosq. News 30:406–410.

Wharton, R. H. 1960. Studies on filariasis in Malaya: Field and laboratory investigation of the vectors of a rural strain of *Wuchereria bancrofti*. Ann. Trop. Med. Parasit. 54:78–91.

Womack, W. L. 1971. The bionomics of *Aedes triseriatus* (Say) larvae in Jackson, Mississippi area. Thesis. University of Mississippi, School of Medicine, Department of Preventive Medicine, Jackson, Mississippi.

Yen, C. H. 1938. Studies of *Dirofilaria immitis* Leidy with special reference to the susceptibility of some Minnesota species of mosquitoes to the infection. Jour. Parasit. 24:189–205.

# COMPARATIVE BEHAVIOUR OF EIGHT SPECIES OF MOSQUITO LARVAE (DIPTERA:CULICIDAE) IN ELECTRIC FIELDS[1]

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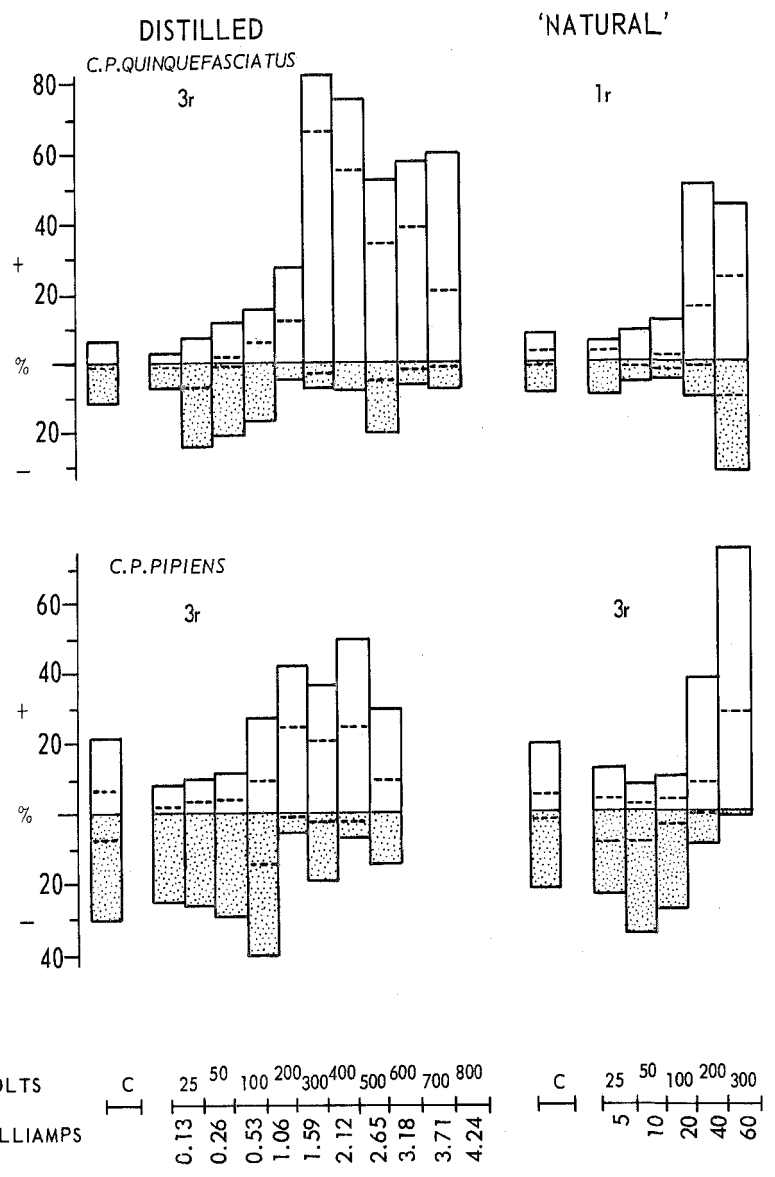
ABSTRACT. The behaviour of late-larval instars of three species of *Aedes*, three of *Culex* and one of *Culiseta* in direct-current electric fields was tested and compared to that of *A. aegypti* (L.). All species showed response to electric current but in none was it as pronounced as in *A. aegypti*. As voltage and current were increased the three *Aedes* species showed the negative—positive—negative reversals in reactions found in *A. aegypti* in earlier work. In the *Culex* and *Culiseta* species, only a negative—positive change was evident before the onset of paralysis. Causes of the reactions remain unknown.

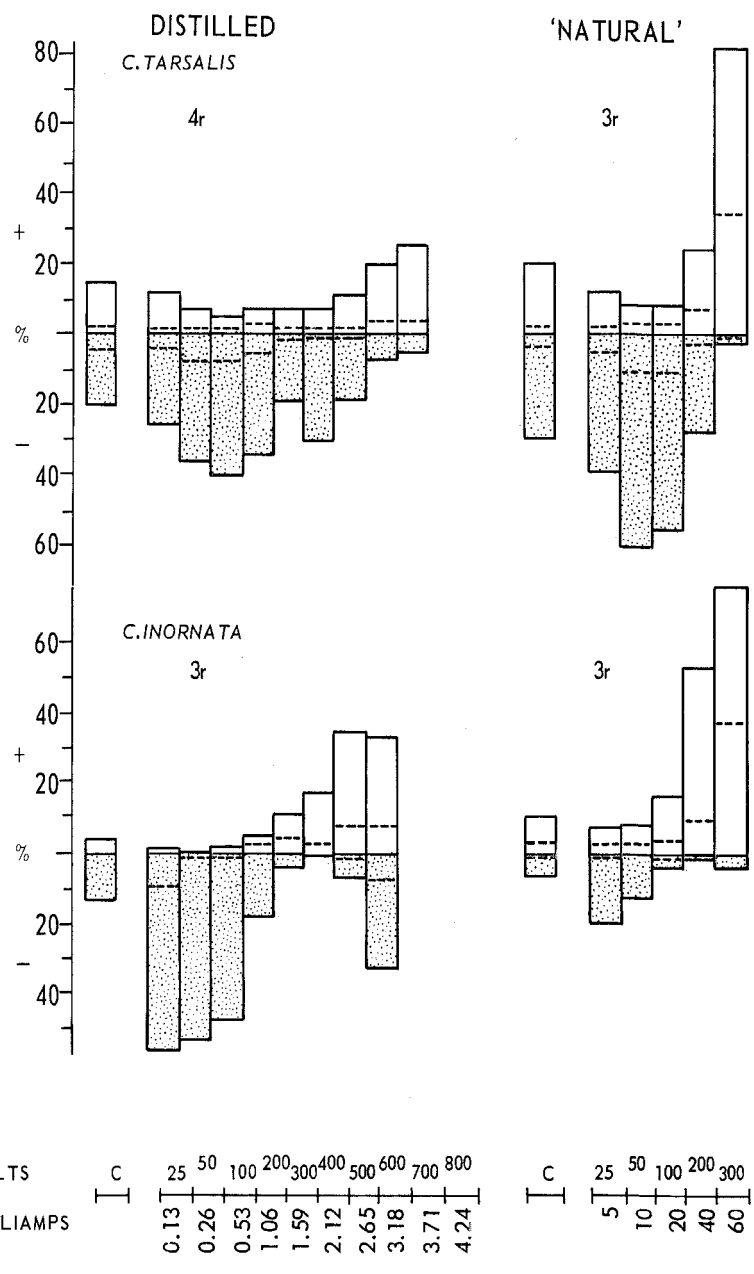
INTRODUCTION. The behaviour of larvae and pupae of *Aedes aegypti* (*L.*) in direct-current electric fields was reported by Riordan (1971). Described here is an extension of this work in which third and fourth instar larvae of *A. stimulans*/ complex, *A. canadensis* (Theobald), *A. atropalpus* (Coq.), *Culex pipiens quinquefasciatus* Say, *C. pipiens pipiens* L., *C. tarsalis* Coq. and *Culiseta inornata* (Williston) were similarly tested and their behaviour compared to that of *A. aegypti*. The work was done at the former Research Institute, Canada Agriculture, Belleville, Ontario.

METHODS. The experimental apparatus and procedures were the same as those described previously (Riordan, 1971). Briefly, the plastic trough in which the tests were conducted is 120 cm long, 12.5 cm wide and is filled with water to a depth of 7.5 cm. Carbon electrodes are situated at each end. Tests were of 20 minutes duration and were conducted in complete darkness. At the end of each test partitions dropped to divide the trough into seven compartments, the centre compartment being twice as long as the others. The larvae were released at

[1] Contribution No. 357 of the Research Station.




Figs. 1a, 1b.—Movement of eight species of mosquito larvae in electric fields in distilled and "natural" water: dimensions of the columns show percentages migrating towards the anode or cathode; broken lines show percentages reaching the electrode compartments.
C=control (no electric field). r=no. of replicates.

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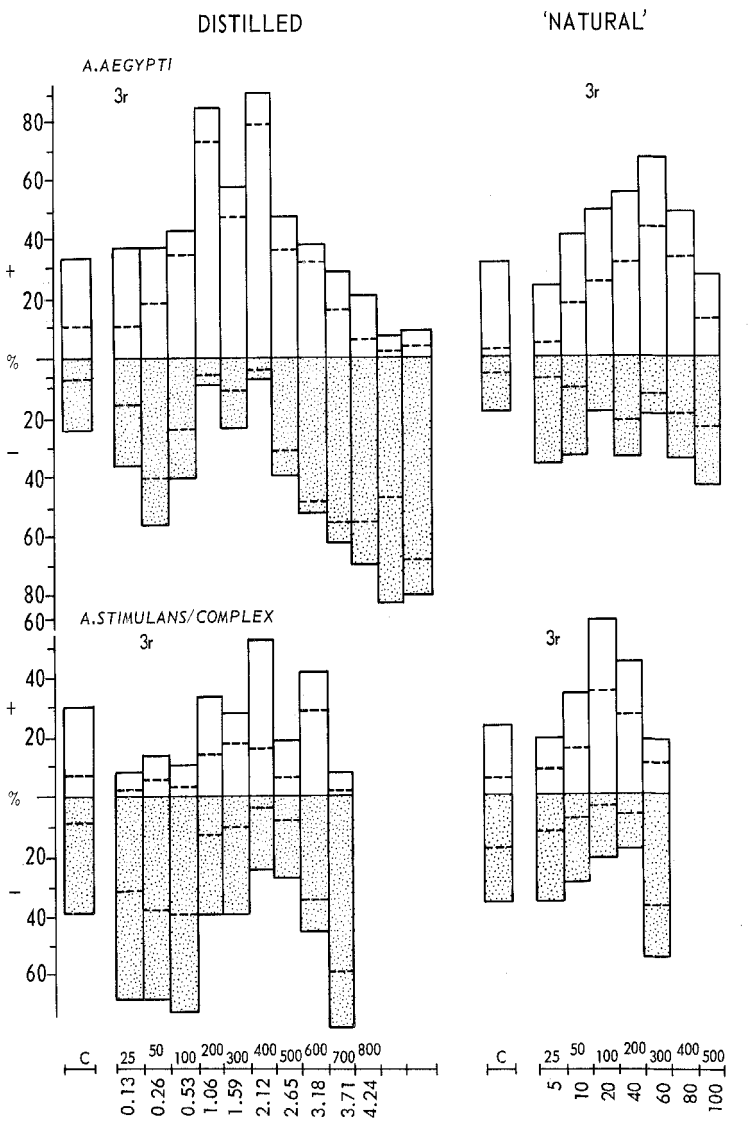
C=control (no electric field). r=no. of replicates.

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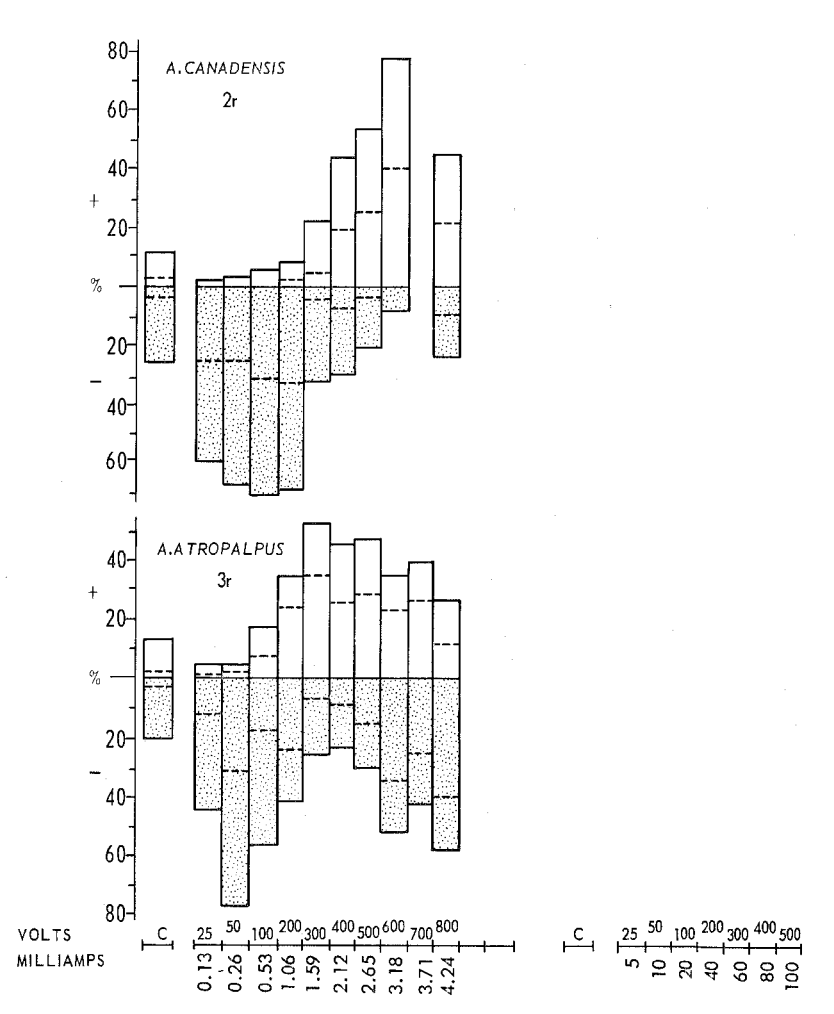


FIGS. 1a, 1b.—Movement of eight species of mosquito larvae in electric fields in distilled and "natural" water: dimensions of the columns show percentages migrating towards the anode or cathode; broken lines show percentages reaching the electrode compartments.
C=control (no electric field). r=no. of replicates.

the centre of the trough and numbers in each compartment counted after the dropping of the partitions.

*A. aegypti*, *C. p. quinquefasciatus*, *C. p. pipiens*, *C. tarsalis* and *C. inornata* larvae were obtained from colonies maintained at the Research Institute, Canada Agriculture, Belleville, Ontario. *A. atropalpus*, *A. canadensis* and *A. stimulans*/complex larvae were collected in the field. The term '*A. stimulans*/complex' is used since while the great majority of the larvae at the collecting site were known to be *A. stimulans* (Walker) small numbers of other species including *A. trichurus* (Dyar) were known to be present and separation was not practical. According to availability, one to four replicated tests were performed with each species. For each replicate one hundred larvae were tested at each field strength. Controls without electric current were similarly replicated. Larvae were only exposed once.

It was not possible to test each species over the wide range of water conductivities used in the earlier study of the behaviour of *A. aegypti* so each was tested in distilled water and in water (henceforth referred to as 'natural') standardized by the addition of sodium chloride to a resistance of 3600 ohms/cm$^3$. This value was derived by averaging the measured resistances of a number of samples of water from a variety of natural habitats. These samples gave a current through the trough of 20 milliamperes at an applied voltage of 100. During the tests the ion content of the distilled water varied to the extent that current through the trough at 100 volts varied between 0.3 and 1.2 ma: mean values are shown in Figures 1a and 1b. Each series of tests was terminated at the field strength where the incidence of larval paralysis reached or exceeded 25 percent.

RESULTS AND DISCUSSION. Figures 1a and 1b display the data obtained in the tests. In the earlier work with *A. aegypti* only the data showing the numbers of larvae reaching the ends of the trough were used. As the work reported here progressed it became evident that these criteria did not properly reveal the behaviour of some of the species since while in several instances only small numbers reached the ends in 20 min., larger numbers were obviously moving in one or the other direction. The overall dimensions of the columns in Figures 1a and 1b therefore indicate the percentages that moved out of the centre compartment towards either the cathode or the anode and the broken lines indicate the percentages that reached the end compartments. The differences between the overall dimensions and the associated broken lines therefore are inversely related to differences between the species in rate of response to the electric fields: observations suggest that these are in fact differences in natural speeds of larval locomotion.

None of the species tested reacted to the same degree as *A. aegypti*. All the species desmonstrated cyclic reversals of direction of movement at certain points as the field strengths were increased. For all the species, numbers of larvae moving towards either the anode or the cathode were still increasing when paralysis reached 25 percent. In the *Aedes* spp. the paralysis occurred while the overall movement was towards the cathode while in the *Culex* spp. movement was towards the anode. *A. aegypti* was considerably more resistant to paralysis than the other species.

During one field collection about thirty anopheline larvae were obtained, probably *A. quadrimaculatus* Say, and these were tested in a variety of electric field strengths. In no case was any appreciable movement observed before paralysis ensued. This was surprising since it had been expected that the horizontal attitude of anopheline larvae would cause them to be especially reactive in electric fields.

These experiments demonstrated some marked variations of behaviour of mosquito larvae in electric fields, especially beteen the behaviour of *Aedes* spp. and *Culex* and *Culiseta* spp. However, it is

still not possible to offer reasons for such behaviour, particularly for the striking reversals in polarity of movement occurring at different field strengths. Further experiments employing pulsed currents would be valuable as it is possible that higher voltages could thereby be used to enhance directional movement producing paralysis. A further advantage of using pulsed currents would be reduction in the bulk and weight of power supplies which would facilitate field experiments in congregating or collecting native populations.

*References cited*

Riordan, D. F. 1971. Behaviour of *Aedes aegypti* (L.) larvae and pupae in direct-current electric fields. Can. J. Zool. 49:581–586.

# AZIRIDINYLPHOSPHINE OXIDES AND SULFIDES AS CHEMOSTERILANTS IN MALE PUPAE OF *ANOPHELES ALBIMANUS* WIEDEMANN[1]

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ABSTRACT. When 19 aziridinylphosphine oxides and sulfides were evaluated as sterilants for pupae of *Anopheles albimanus* Wiedemann, the methyl, ethyl, and propyl alkylamino derivatives of phosphine sulfide were effective: The SC90 concentrations ranged from 0.016 to 0.093 percent. Also, the toxicity of these compounds was relatively low since the safety factors (margin of safety between lethal and sterilizing concentrations—LC15:SC90) ranged from about 5 to 8. A comparison of the homologous series of PS and PO compounds showed that the PS compounds were much more effective sterilants, probably because of greater absorption through the pupal cuticle.

Patterson *et al.* (1971) reviewed the literature concerning sterilization of mosquitoes, investigated methods of sterilizing large numbers as pupae, and concluded that thiotepa administered by the method of White (1966) was a promising procedure for sterilizing *Culex pipiens quinquefasciatus* Say. Also, in our preliminary tests with *Anopheles albimanus* Wiedemann, we found that thiotepa was an effective sterilant; however, the difference between toxic and sterilizing concentrations of the compound was not large enough to insure sterility without excessive mortality. We, therefore, evaluated a series of related bis(1-aziridinyl)phosphine oxides and sulfides in attempts to find compounds that would be less toxic to the mosquitoes. The results are reported here.

METHODS. The procedure used for the test was a modification of that reported by White (1966). Thus, about 200 pupae were removed from water with a small cloth strainer, blotted dry on a paper towel, and transferred from the strainer to filter paper (9 cm, Whatman No. 2) in 9-cm plastic petri dishes. Then 10 ml of aqueous solutions (buffered to pH 9) of the various concentrations of the test chemicals were pipetted over the pupae and filter paper. The petri dish was partly covered with the lid to retard evaporation yet permit emerging males to escape when the dish and pupae were placed in an aluminum screen cage (15.2 x 25.4 x 25.4 cm).

[1] This paper reports the results of research only. Mention of an insecticide in this paper does not constitute recommendation of this product by the U.S. Department of Agriculture.

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