FIELD EVALUATION OF SOME MOSQUITO ADULTICIDES WITH OBSERVATIONS ON TOXICITY TO HONEY BEES AND HOUSE FLIES[1]

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INTRODUCTION. Using mist blowers and caged *Culex pipiens pipiens* L., *Apis mellifera* L., and susceptible and DDT-resistant *Musca domestica* L., tests were conducted in the summers of 1966 and 1967 to determine the relative effects of three insecticides at dosage levels used for mosquito control in the State of Maryland. The three insecticides were malathion, naled, and pyrethrum.

Numerous papers have been written on the results of tests using the mist blower to control mosquitoes. The literature indicates that only limited studies have been conducted to evaluate the effect of organophosphates and pyrethrins on the honey bee and house fly.

Shepard (1951) reported pyrethrum powder was used to control adult mosquitoes as early as 1880. Joseph *et al.* (1961) reported excellent control of mosquitoes with both malathion and naled. Mallack *et al.* (1961) reported similar results using naled.

Ginsburg (1929) found pyrethrum to be highly toxic, as a stomach poison, to honey bees. Bottcher (1938) also found pyrethrum to be a powerful stomach poison to honey bees. Anderson and Atkins (1967) reported pyrethrum to have a low toxicity to honey bees while naled and malathion were moderately to highly toxic.

Davis *et al.* (1961) obtained 71 to 100 percent reduction of adult house flies with aerially dispersed sprays of naled. Kilpatrick and Schoof (1963) reported good control of house flies with malathion and excellent control with naled. Bodenstein and Fales (1962), using a modification of the residue jar method, found that the DDT-resistant fly showed only partial resistance to naled.

These studies had a three-fold purpose. The first was to evaluate the effectiveness of malathion, naled, and pyrethrum individually and in combination with one another for the control of mosquitoes. Second, mortality studies were made with honey bees with hopes of finding a safe formulation for use in areas with heavy bee populations. Third, evaluations of the effectiveness of the insecticides were made in the interest of fly control.

METHODS AND MATERIALS. The toxicants were dispersed as mist sprays with John Bean Rotomist 100E sprayers which were mounted on flat bed, one-ton trucks. The sprayers were calibrated to deliver 100 gallons per hour at 400 psi from a quadruple nozzle composed of two 19.5 and two 21.5 orifice plates. The trucks were operated between 3 and 5 miles per hour with the sprayer being angled from horizontal to 30 degrees from the horizontal throughout each test run.

The following insecticides were evaluated for toxicity to adult mosquitoes, honey bees, and two strains of house flies: malathion (EC, 57%; American Cyanamid Chemical Co.); naled (EC, 26%; Chevron Chemical Co.); Pyrenone® (EC, 40%; piperonyl butoxide plus pyrethrins; FMC Corp.).

The mosquitoes used for all tests were *Culex pipiens pipiens* L. They were col-

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lected with a dipper and placed in gallon jars as larvae and pupae from several natural sources. The larvae and pupae were brought into the laboratory and reared as described by Rogers *et al.* (1957). The adults were allowed to emerge directly into the test cages which were 3 inches in diameter, 7 inches long and made from Mason jar lids and 16-mesh screen wire.

No attempt was made to separate the sexes of the mosquitoes when stocking the cages but only the females were counted when mortalities were recorded. The number of female mosquitoes per test cage ranged from 14 to 84 with a mean of 41 per test cage.

The honey bees used for all tests were donated by the Bee Pathology Apiary, Beltsville, Maryland. The honey bees tested were all adult female workers of the Italian race. They ranged in age from 10 to 30 days. The bees were placed directly from the hive into the test cages and held overnight in the laboratory where they were fed a 10 percent sugar water solution. There were from 37 to 132 bees in a cage with a mean of 73.

House flies, both susceptible (Chemical Specialties Manufacturers Association 1948 strain) and DDT-resistant (Fales' 1960 wild fly strain) were donated, as adults, by the Pesticide Chemical Research Branch of the Entomological Research Division, Beltsville, Maryland. Both strains were laboratory reared with the DDT-resistant strain being from generation 97 to 117.

The flies were put directly into the test cages and returned to the laboratory where they were fed a 10 percent sugar solution and held over night. The test cages with susceptible flies contained from 43 to 127 flies with a mean of 75. The test cages with the DDT-resistant flies held from 48 to 133 flies with a mean of 78.

Stocked cages were numbered in the laboratory with a pen and placed in a cardboard box covered with a damp towel and transported to the test area. The test area consisted of an open field free of obstructions.

Before each test was run the sprayers were flushed with water in an area some distance from the test site, thus assuring an uncontaminated system. The insecticide and clean water were then mixed in the appropriate amounts and the emulsifiable solution was mixed thoroughly. Once again the sprayer was run before the actual test to assure proper operation of the unit.

Once in the field, the temperature, relative humidity, wind velocity, and wind direction were recorded. When the wind direction had been determined, the metal stakes for the cages were placed in the field, and the cages suspended 4 feet from ground-level, one each at 50 feet, 100 feet, and 200 feet downwind and at a 90 degree angle to the path of the sprayer.

Two check cages containing untreated insects of each species to be tested, were transported to the field in the same manner as the test cages on each test day. These cages were placed in the same general area where the test was conducted but upwind of the sprayer. They were picked up and returned to the laboratory at the same time as the test cages and observed for the duration of the test period.

With the cages in position the sprayer was turned on 150 feet before reaching the cages and shut off 150 feet after passing the cages, producing a swath of 300 feet. The insects were allowed to remain suspended in the cages and on the stakes for ten minutes to allow for all particles to settle. Then they were collected and returned to the laboratory. Mortality counts were made at intervals of one, two, four, and eight hours after treatment.

At the end of eight hours the insects were removed from the cages and the cages were washed with acetone, water, and acetone in preparation for future testing.

RESULTS. A total of 81 tests were conducted on 18 different days at times ranging from 7:00 to 8:00 a.m. Air temperatures ranged from 61° F. to 83° F. with an average of 74° F. Relative humidity ranged from a low of 59 percent to a high of 93 percent with a mean of 78 percent. Wind velocity ranged from 0 to 5 m.p.h. with an average of 3 m.p.h.

Table 1 summarizes the results obtained. This summary is based on the average of all tests at 8 hours at the given distances. In an attempt to find an index to relate the effectiveness of the different formulations one to another, the average of the mean for all distances at 8 hours of exposure follows. This standard seems to offer a satisfactory index of toxicity.

For the control of mosquitoes, the most effective to least effective were the combination of malathion plus naled, naled, naled plus pyrethrins, and malathion. The percent mortalities were 100, 100, 100, and 90.5 respectively. These results coincide closely with the results of previous years' testing.

Non-resistant or susceptible house flies were best controlled by the combination of naled plus pyrethrins. Malathion plus naled was the second most toxic with naled third and malathion the least toxic. Percent mortalities were 97, 92, 77, and 59 respectively.

The most effective formulation for controlling DDT-resistant house flies was the combination of naled plus pyrethrins with naled alone second. Malathion plus naled was third and malathion alone was the least toxic. Percent mortalities were 85, 79, 71, and 61 respectively.

The most toxic formulation to honey bees was the naled plus pyrethrins combination. Naled was a close second followed by the malathion plus naled combination. Malathion alone appeared to kill the least number of bees. Percentage-wise the order of mortality for the several formulations was 86, 85, 79, and 72 respectively.

From these results it could be concluded that the formulation that kills the most mosquitoes and house flies and is the least toxic to the honey bee population is the malathion plus naled combination. Naled was a close second but killed a higher percent of the honey bees. The combination of naled plus pyrethrins was very toxic to all the insects. Malathion was the least effective against all insects.

Thus, in general it may be concluded that any formulation containing naled was effective for the control of mosquitoes and house flies and especially so when combined with malathion. However, malathion, while toxic to all of the insects, was consistently the least effective of the formulations tested.

No mortality resulted in the *C. pipiens* check cages. At the end of eight hours there was an average of 4.4 percent mortality in the *A. mellifera* check cages. The average check mortality for *M. domestica* (DDT-resistant) at the end of eight hours was 3.9 percent. Finally the check mortality for *M. domestica* (non-resistant) at the end of eight hours was 2.5 percent. The figure used in Table 1 footnote 1 is an average of these mortality figures.

Discussion. In these studies there were variations in the results obtained. There were differences in the percentage kill at the same and at all distances. There were numerous variables such as temperature, relative humidity, and wind direction that could have and, in fact, did have an effect on the results of these tests. Other variables that existed in the field included five different sprayers and crews.

Since these tests were conducted in the early morning hours, temperature and relative humidity remained relatively constant but the wind often changed velocity and direction during a test run. A higher wind velocity obviously gave a greater mortality at 200 feet, provided it was downwind. When the wind shifted from downwind during a test run, the 200 foot cage was often observed not to receive its usual dosage of spray, thus causing a lower mortality. This was also observed by Horsfall (1950) who found mists are much more effective when borne by winds with a velocity of 3 m.p.h. near the ground than they are when borne by winds of 0.7 m.p.h.

The spray trucks were driven and the

TABLE 1.—Percent mortality of caged adult mosquitoes, house flies and honey bees in mist spray tests, 1966 and 1967.[1]

Insecticide	lbs.AT/ 100 gal.	Test runs	*C. pipiens*			*M. domestica*[2]			*M. domestica*[3]			*A. mellifera*		
			50′	100′	200′	50′	100′	200′	50′	100′	200′	50′	100′	200′
Malathion	10.0	5	100	91	80	92	54	29	85	75	23	100	70	47
Naled	4.7	5	100	100	100	100	86	46	99	95	44	100	100	54
Malathion + Naled	7.35	5	100	100	100	100	94	81	99	65	51	100	100	38
Naled + Pyrethrin	2.385	5	100	100	100	100	94	78	99	99	57	100	100	57

[1] Average mortality after 8 hours; average check mortality was 2.7 percent.
[2] Susceptible strain (Chemical Specialities Manufacturers Association 1948 strain).
[3] DDT-resistant strain (Fales' 1960 wild fly strain).

sprayers operated, during the tests, as close to the identical manner as when operated during community spraying. With five different sprayers and seven different crews operating the equipment, it was difficult to duplicate with exactness the results, since this procedure introduced so many sources of variability.

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