# Technical Papers

## Cross Tolerances in Resistant Houseflies

**John J. Pratt, Jr. and Frank H. Babers**

*Bureau of Entomology and Plant Quarantine,*
*U. S. Department of Agriculture,*
*Beltsville, Maryland*

Strains of houseflies (*Musca domestica* L.) that have developed resistance to a given insecticidal chemical may or may not exhibit some resistance to other chemically unrelated insecticides. There are no reported instances of the specific resistance of *M. domestica* to an insecticide, but some strains do show cross tolerance only to analogues of the compound to which they have developed resistance (*1, 5, 6*). Other strains exhibit various degrees of cross tolerance for a few to several unrelated compounds (*3, 4, 6–8*). Barber and Schmitt (*2*) reported that a strain selected for resistance to methoxychlor was not resistant to DDT.

The work reported was undertaken to determine whether resistance could be developed in *M. domestica* toward several insecticidal compounds simultaneously. The research was carried on incidental to physiological studies of resistance, and the method used for evaluating resistance was not as accurate as more time-consuming ones would be. However, the results are thought to be of sufficient interest to report, in the hope that they may aid others working on the problem of resistance.

The two strains used in these experiments were derived from the 55th generation of a strain of *M. domestica* in which resistance to DDT was developed by Wilson and Gahan (*8*). Selection of the strain for resistance to DDT was continued in this laboratory for 20 generations, and adults of the 21st generation were tested for resistance to the individual components of an insecticidal mixture containing the following compounds dissolved in cyclohexanone: DDT, methoxychlor, chlordane, lindane, toxaphene, and pyrethrins (proportions as indicated in Table 3). Selection was accomplished by exposing the adults to sprays or deposits of DDT that would cause approximately 90% mortality. All exposures were done prior to mating so that offspring would derive only from parents that had survived exposure to DDT. This DDT-resistant strain is herein designated as strain R.

Selection for resistance to the mixture of insecticides was begun with adults of the 9th generation of strain R, and was accomplished as described except that the mixture of insecticides was used instead of DDT alone. Concentration of the mixture was adjusted so that approximately 90% of the adults of each generation were killed. Selection was carried out for 11 generations, and tests for resistance to the individual components of the insecticidal mixture were made with adults of the 12th generation. This strain is herein designated as strain RX. The normal laboratory strain, which was not selected for resistance or otherwise exposed to insecticides, is designated as strain N.

In the tests for resistance, flies were confined in wire cages suspended from the top of a 36-cu ft chamber, and the cages were continuously swung during exposure. One milliliter of the desired solution was sprayed into the chamber by means of a small atomizer, and the spray was allowed to settle for 20 sec. The flies were then introduced and exposed for 2 min. They were then transferred to clean cages, supplied with food, and held at a temperature of approximately 27° C and 60% relative humidity for 24 hr, at the end of which period mortality counts were taken. Single tests were made using 200–600 flies 24–32 hr old, all three strains being sprayed simultaneously.

TABLE 1

MORTALITIES IN SUCCESSIVE GENERATIONS OF HOUSEFLY STRAINS N AND R EXPOSED TO DDT SPRAY

| Strain N | | Strain R | | |
|---|---|---|---|---|
| Generation | Percent mortality | Generation | Percent mortality | |
| | | *2% DDT* | | |
| A | 92 | 13 | 33 | |
| B | 84 | 14 | 41 | |
| C | 83 | 15 | 25 | |
| D | 83 | 16 | 2 | |
| E | 87 | 17 | 5 | |
| F | 74 | 18 | 3 | ($RX_9 = 2\%$) |
| | | *4% DDT* | | |
| G | 97 | 19 | 2 | ($RX_{10} = 3\%$) |
| H | 90 | 20 | 0.2 | |
| I | 91 | 21 | 0 | |

Table 1 shows that strain R developed increasing resistance to DDT during the period of selection for resistance to this insecticide. Table 2 indicates a simultaneous increase in resistance of strain R to the insecticide mixture.

An increase in the resistance of strain RX to the insecticide mixture during the period of selection is apparent in Table 2. Further evidence that strain RX developed resistance to the mixture may be seen in the fact that the concentration of the mixture required to kill approximately 90% of the adults of generation 11 was 12 times that required to kill approximately 90% of the adults of generation 1.

The results of comparing the susceptibilities of strains N, R, and RX to the individual components of the insecticide mixture are presented in Table 3. Strains R and RX are more resistant than strain N to all the com-

TABLE 2

MORTALITIES IN SUCCESSIVE GENERATIONS OF HOUSEFLY STRAINS N, R, AND RX SPRAYED WITH A SOLUTION CONTAINING DDT, METHOXYCHLOR, CHLORDANE, LINDANE, TOXAPHENE, AND PYRETHRINS*

| Strain N | | Strain R | | Strain RX | |
|---|---|---|---|---|---|
| Generation | Percent mortality | Generation | Percent mortality | Generation | Percent mortality |
| C | 99 | 15 | 76 | 6 | 65 |
| D | 90 | 16 | .. | 7 | 40 |
| E | 95 | 17 | 18 | 8 | 23 |
| F | 96 | 18 | 7 | 9 | 6 |
| G | 96 | 19 | .. | 10 | 8 |
| H | 96 | 20 | 0 | 11 | .. |
| I | 98 | 21 | 12 | 12 | 17 |

* Proportions as indicated in Table 3.

pounds. Strain RX shows no greater resistance than strain R to the mixture or to its components. It is also apparent (Tables 1 and 3) that strains R and RX show a similar degree of resistance to DDT, although the latter strain was not selected for resistance to DDT alone. Strain RX was tested for resistance to parathion and, on an $LD_{50}$ basis, was found to be twice as resistant as strain N.

It appears, then, that strains R and RX show no specific resistance to the compounds for which they were selected, but rather show some degree of resistance to other compounds. Another point of interest is that the resistance of strains R and RX is practically the same for all of the six compounds tested. If resistance were strictly specific, strain R should be considerably more resistant to DDT than strain RX, and strain RX should be more resistant than strain R to the components of the insecticide mixture other than DDT and methoxychlor.

The question arises whether a portion of this general resistance may be due to increased vigor of the flies, resulting from several generations of selection for ability to withstand adverse conditions, i.e., poisoning by a toxic substance. Wilson and Gahan (*8*) concluded that their DDT-resistant laboratory strain was an unusually strong stock of flies, since the resistance was not specific for DDT but extended to several other insecticides. March and Metcalf (*7*), after studying three resistant wild strains and one resistant laboratory strain, concluded that the levels of resistance of each strain were specific for different insecticides and not general for all the insecticides tested. It is obvious that if a general level of resistance to several insecticides existed, all the resistance would probably be due to an increased vigor of the strain, rather than to the development of some protective mechanism against a specific poison. In strains that exhibit cross tolerance for several compounds, it may be that all of the resistance exhibited to chemicals other than the one for which the strain was selected is due to increased vigor and not to the functioning of a protective mechanism.

Experiments are being planned to determine to what extent, if any, increased vigor functions in the cross tolerances of resistant houseflies to other insecticides and in the selection for resistance to a given insecticide.

It is interesting to note that all strains showing cross tolerance only to analogues of the insecticide to which resistance was developed are wild strains (*1, 5, 6*) which obviously are not selected for resistance so severely, or interbred so strongly, as are laboratory strains. Resistance of a strain of *M. domestica* to several unrelated compounds seems to be related to a high level of resistance to the compound for which the strain was selected.

TABLE 3

MORTALITIES OF STRAINS N, R, AND RX WHEN SPRAYED WITH THE INDIVIDUAL COMPONENTS OF A MIXTURE OF INSECTICIDES

| Insecticide | Quantity sprayed (g/1,000 cu ft) | Strain and percent mortality | | |
|---|---|---|---|---|
| | | N | R | RX |
| DDT ..... | 5.555 | 99 | 0.3 | 1 |
| Methoxychlor .... | 2.222 | 97 | 4 | 1 |
| Chlordane ..... | 0.556 | 98 | 8 | 7 |
| Lindane ..... | 0.167 | 100 | 72 | 61 |
| Toxaphene ..... | 0.556 | 100 | 69 | 68 |
| Pyrethrins ..... | 5.555 | 70 | 3 | 1 |
| Mixture ..... | Each component in above quantity | 100 | 99 | 91 |

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## A Semiautomatic Injection Apparatus for Use with Radioactive Solutions[1]


**Margaret W. Holt**[2]

***Brookhaven National Laboratory, Upton, New York***


In connection with the handling of highly radioactive or other dangerous materials, it is sometimes desirable to inject solutions into test animals by remote control. The apparatus described here affords a means of holding the skin of the animal in position while a hypodermic needle is automatically inserted. The apparatus is suitable for use with remote-control devices, and it has the


[1] Research carried out at Brookhaven National Laboratory under the auspices of the Atomic Energy Commission.


[2] Atomic Energy Commission Postdoctoral Fellow in the Biological Sciences.