MAP OF CALIFORNIA INDICATING THE AREAS SAMPLED FOR FLY RESISTANCE

The Present Status of . . .

HOUSEFLY RESISTA

G. P. GEORGHIOU · W. R. BOWE

Resistance to insecticides varies with dif used, but flies have been able to survive lations despite any insecticide used to dat to develop even more rapidly where the used compound. Well known fly control m ment and general farm sanitation remai need for frequent insecticide application resistance.

THE CONTINUOUS POPULATION growth in California and accompanying expansion of the livestock and poultry industries, have focused increasing attention on the age-old problem of control of houseflies. This problem is particularly serious near poultry ranches, dairies, and cattle feedlots, all of which provide breeding sites for flies. Some of these operations were originally established several miles away from residential areas, but have eventually become practically surrounded by new housing developments. Increasingly strict city and county ordinances concerning the production of flies have caused ranch operators to resort to frequent use of insecticides as a means of suppressing fly production. On many poultry ranches insecticides are used weekly during most of the year, and in a few cases as many as 120 applications in a single year have been reported. Such intensive use of insecticides leads to the rapid development of insect resistance to the chemicals. Difficulties in the control of resistant flies are among the most serious operational problems confronting the animal industries today.

Selective agents

It is now well established that the development of increased ability in insects to survive exposure to certain insecticides is not induced directly by the insecticides themselves. These chemicals do not cause genetic changes in insects; they only serve as selective agents, eliminating the susceptible insects and enabling the more tolerant survivors to increase and fill the void created by the destruction of the susceptible individuals. Repetition of this process over several generations eventually gives rise to strains which are capable of surviving the maximal economic or safe dosages of the insecticide.

The most common of several species of flies which frequent livestock operations are listed in the table. Although it is hoped to eventually investigate the resistance status of several of these species, the present study is concerned only with the housefly because of its common occurrence and its importance as a vector of human and animal diseases. The housefly is the first insect species to have developed resistance to DDT. In California, this was observed in 1948 and was soon followed by resistance to lindane and dieldrin which were used as replacements for DDT. Organophosphorus insecticides were introduced for fly control in the early 1950's. Outstanding field performance and the early results of laboratory studies raised hopes that resistance to these chemicals might be minimal and have little effect on their sustained usefulness. Some of the first organophosphorus compounds used have partly justified this expectation by performing well for four to five years. However, resistance even to these materials has gradually appeared in some areas.

DOMESTIC FLIES COMMONLY FOUND ON LIVESTOCK AND POULTRY PREMISES IN CALIFORNIA

Name	Poultry	Dairy	Cattle feedlot
Black blowfly, *Phormia regina* (Meigen)	+	+	+
Black garbage fly, *Ophyra leucostoma* Wiedemann	+		
Ophyra aenescens Wiedemann	+		
Blue bottle or blowfly, *Calliphora* species	+		
False stable fly, *Muscina stabulans* (Fallén)	+	+	+
Muscina assimilis (Fallén)	+	+	+
Flesh fly, *Sarcophaga* species	+	+	
Green bottle or blowfly, *Phaenicia sericata* Meigen	+	+	
Phaenicia cuprina Wiedemann	+	+	
Common housefly, *Musca domestica* L.	+	+	+
Little housefly, *Fannia canicularis* (L.)	+	+	
..............(*), *Fannia femoralis* Stein	+	+	
Latrine fly, *Fannia scalaris* (Fab.)	+	+	
Stable fly, *Stomoxys calcitrans* (L.)	+	+	+

(*) No common name.

Where organophosphate resistance has occurred, it was also found that substitute organophosphates did not last as long as the earlier-used organophosphates. This group of compounds is extremely large, however, and experience has shown that several of these materials are highly toxic to the present resistant strains of insects. The problem requires continued vigilance so that a change to a new insecticide can

NCE TO INSECTICIDES

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N · E. C. LOOMIS · A. S. DEAL

ferent fly species, areas, and materials and eventually build up resistant popu-e. Resistance to new compounds appears flies are already resistant to an earlier ethods including good manure manage-n essential as a means of reducing the s and thus delaying the development of

be made when the currently used compound fails to give effective control. The present investigation was aimed at characterizing the types of resistance occurring in California, as a guide to the more advantageous use of available insecticides.

Areas sampled

Housefly larvae were collected from animal droppings in the field and were reared in the laboratory for one or two generations until adequate numbers of adult flies were produced for testing. Six areas of the state were sampled. In four of these areas — Sebastopol, Sonoma County; Gilroy, Santa Clara County; Moorpark, Ventura County; and Anaheim, Orange County (see map)—the samples were collected from poultry ranches located near residential areas where difficulties had been experienced due to resistance. A cattle feedlot at Brawley, Imperial County, and a poultry ranch at Blythe, Riverside County, were also sampled. These latter operations had experienced little use of insecticides, but agricultural crops in the vicinity had been treated regularly. The Moorpark area was studied more extensively with nine ranches sampled to assess the effect of distance between ranches on the distribution of resistant flies.

Resistance status

The resistance status of each strain was determined by a standard laboratory method involving the application of one drop of insecticide solution measuring 1/1000 milliliter to the thorax of each test insect. By the use of a series of insecticide concentrations, it is possible to obtain an accurate measurement of the resistance level of each strain. Parallel tests were performed on a susceptible strain which had been kept in the laboratory for over 20 years without exposure to insecticides. For the purpose of comparison, the susceptibility levels of the laboratory and field strains were calculated in terms of the amount of insecticide required to produce 90% mortality. The accompanying composite graph shows the number of times the field strains are more resistant than the laboratory strain to each insecticide.

The tests with organophosphorus insecticides indicate the existence of distinct interstrain differences, which are a function of the differing histories of past use of these compounds on the various farms. The graph shows that in the Blythe strain, resistance to all organophosphates and carbamates tested is at an extremely low level (two to three times greater than normal), confirming that these compounds had not been used in this area for fly control. In contrast, flies from the four coastal locations (Anaheim, Sebastopol, Moorpark, and Gilroy) show moderate or high levels of resistance to malathion, diazinon and Korlan (ronnel), while they are still susceptible to Cygon (dimethoate), Dimetilan (active ingredient in "Snip" fly bands) and an experimental compound Hercules 8717E.

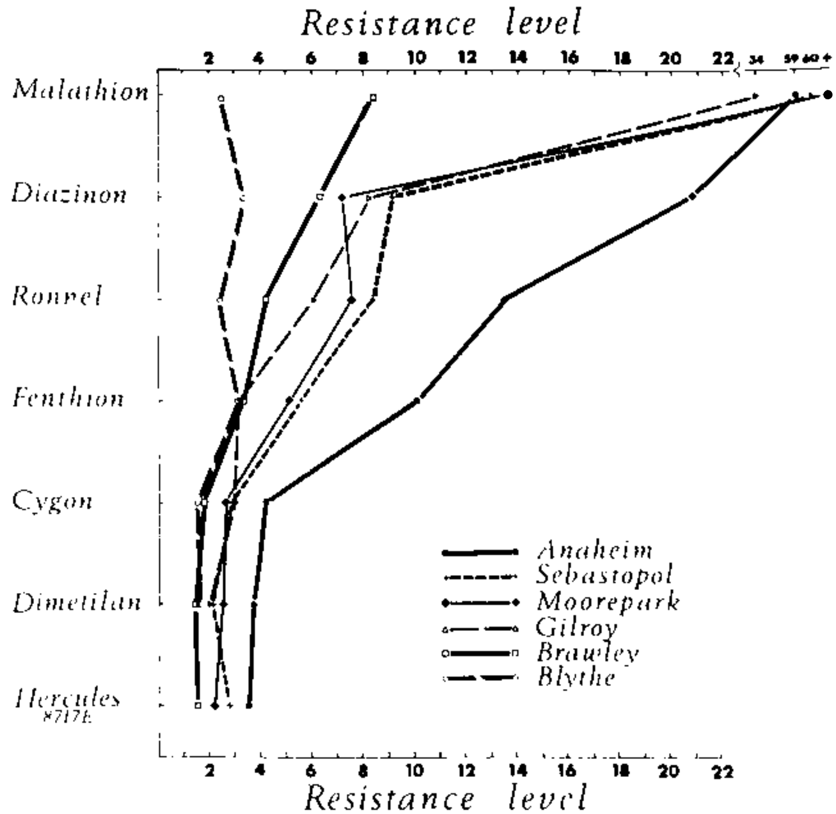
Examination of case histories of each individual ranch aids further in the interpretation of these results. Malathion, which has been used widely since the early 1950's is now ineffective against the resistant flies. The highest resistance (more than 60 times normal) is in the Moorpark area, where this compound has been used most extensively. Flies here are also moderately resistant to diazinon, Korlan and Baytex. Resistance to diazinon is the highest (20.7 times) in the Anaheim area which has experienced the most intensive use of this compound. Flies in this area are also resistant to malathion but less so than the Moorpark flies. Resistance to diazinon in Anaheim carries also high levels of resistance to Korlan (13.5 times) and Baytex (10.1 times).

Lasting effects

The results obtained with DDT and dieldrin indicate that resistance to these compounds continues at a very high level (greater than 100 times the normal) in spite of their not having been used for fly control for over 10 years. Resistance to DDT is evidently bolstered by the use of organophosphorus compounds since its level is in proportion to the level of diazinon resistance. On the contrary, resistance to dieldrin shows no correlation with organophosphorus resistance.

Since certain insecticides are often used for fly control in combination with

DEGREE OF RESISTANCE TO INSECTICIDES IN HOUSEFLIES FROM VARIOUS CALIFORNIA LOCALITIES



Numbers indicate degree of resistance × "normal" or non-resistant flies. Ronnel = Korlan; fenthion = Baytex.

sugar, the levels of resistance of the Anaheim strain were also assayed by exposing flies to sugar-insecticide baits. Resistance determined by this means was roughly in the same relative order as obtained for this strain by the previous method (DDT > dieldrin > malathion > diazinon > Korlan). However, the degree of resistance to Baytex and Cygon, as well as to the two carbamates (Dimetilan and Hercules 8717E) was greater in the bait tests, suggesting that these compounds would perform better as contact than as stomach poisons. In contrast, relatively high concentrations of diazinon in sugar bait (1%) were very toxic to the Anaheim flies in spite of the high resistance in this strain to the contact action of diazinon.

Age of resistance

The tests on various ranches in the Moorpark area revealed that the extent of dispersal of resistance from a given ranch is, in general, positively correlated with the "age" of such resistance. Old resistances (DDT, dieldrin and malathion) are now generally distributed throughout the area, while relatively recently developed resistance (diazinon, Korlan) is still found in proportion to the extent of use of these compounds on each ranch. A multitude of factors, particularly the constant availability of adequate breeding media, are known to affect fly dispersal. Although dispersal was evidently slow in this area, the movement to a given ranch of even a small number of flies resistant to a certain insecticide, would undoubtedly constitute the nucleus for the rapid development of resistance when this insecticide is used on the latter ranch.

While answering a number of questions, this study also raises many others that emphasize the complexity of the resistance problem. It is obvious that resistance to DDT and dieldrin in all the areas sampled is still high, a fact which precludes the resumption of their use for fly control in the foreseeable future. Resistance to the organophosphates presents a mosaic pattern characteristic of the history of use of these compounds in each area. For this reason it is possible to offer only guidelines as to which compound might be best used in each situation. For example, resistance to malathion, although high in most areas, is low in others; in the latter it would be desirable to use malathion in preference to other organophosphates, since resistance to this compound is specific, imparting only low cross resistance to diazinon. In areas where malathion is ineffective, diazinon and Korlan may be used instead, and the addition of sugar to the spray may be expected to enhance their effectiveness. Cygon should prove effective for some time where resistance to diazinon and Korlan has occurred.

Certain other organophosphates, such as Dibrom and DDVP, and the carbamate Dimetilan, have also shown high toxicity to diazinon and malathion-resistant flies. However, past experience indicates that resistance to new compounds may develop more rapidly where the flies are already resistant to an earlier used compound. New compounds and new approaches to insect control are constantly being explored, but this research, unfortunately, is costly and requires prolonged and tedious experimentation. Therefore, well known measures of fly control, such as manure management and general farm sanitation, should be observed as a means of reducing the frequency of insecticide applications and thus delaying the development of resistance.

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