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INSECT RESIS IN HOUS IN CALI

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Precise measurement of insecticide toxicity against house flies from various poultry ranches, dairies and cattle feed lots provided evidence of the presence of resistance roughly in proportion to the extent of insecticide use in each situation. The data indicate where changes to new insecticides are advisable, and illustrate how heavy reliance on insecticides over several years for fly control leads to gradual depletion of available insecticide resources.

TABLE 1. INSECTICIDE USE ON RANCHES TESTED FOR RESISTANCE, 1970, 1971

Location	Operation	Collection dates	Insecticides in common use*
Moorpark (Ventura Co.)	Poultry (Ranch #5)	June 4, 1970 August 6, 1971	1970–71, clean-up at 10-day intervals. 1962–69, weekly applications of insecticides: Naled 1964–69; dichlorvos 1963–69; Gardona 1968–69; ronnel 1962–64; diazinon 1964.
Moorpark (Ventura Co.)	Poultry (Ranch #20)	June 4, 1970 August 6, 1971	1971, clean-up at 15-day intervals. Weekly applications of insecticides: Naled 1968–71; diazinon 1965–70; dichlorvos 1965–68.
Sebastopol (Sonoma Co.)	Poultry	August 10, 1970	Ronnel 1969 (5), 1970 (2); naled 1969 (1), 1970 (2); diazinon 1969 (3), 1970 (2); dichlorvos 1969–70.
Yucaipa (San B/dino Co.)	Poultry	July 8, 1970	Weekly applications of insecticides: Diazinon, ronnel 1965–66; naled, dichlorvos, Zytron 1967–70.
Gilroy (Santa Clara Co.)	Poultry	August 10, 1970	Ronnel 1969 (16), 1970 (8); naled 1970 (2); dichlorvos bait (weekly); clean-up at 15-day intervals.
Norco (Riverside Co.)	Dairy	August 6, 1971	Monthly applications of insecticides: Dimethoate, naled 1966–69; dimethoate, naled, malathion, methoxychlor 1970–71.
Riverside (Riverside Co.)	Dairy	August 6, 1971	As at Norco dairy.
Chino (San B/dino Co.)	Dairy	August 6, 1971	Naled (7–14-day intervals) 1970–71.
Camarillo (Ventura Co.)	Dairy	August 6, 1971	Naled, dimethoate 1970 (36), 1971 (36).
Blythe (Riverside Co.)	Cattle feedlot	July 8, 1970	Dichlorvos 1968 (15), 1969 (5).
Brawley (Imperial Co.)	Cattle feedlot	July 30, 1970	On surrounding crops: Parathion 1968 (6), 1969 (3), 1970 (11); malathion 1968 (2), 1970 (6), 1971 (2); mevinphos 1968 (3), 1969 (3), 1970 (10), 1971 (5).

* In parentheses, number of applications during year.

THE CONTROL OF HOUSE FLIES and related insects continues to be one of the principal preoccupations of poultry, dairy, beef feedlot and horse ranch operators, especially in the coastal zone and intermediate valleys of the state. In these areas, favorable climatic conditions for fly production in animal manure, and the encroachment of urbanization, impose the need for a strict program of fly control. Despite improvements in control efficiency achieved through frequent disposal of fly-producing wastes, it often becomes necessary to resort to insecticides in cases where either the source reduction measures are not regularly adhered to, or local ordinances require a very high standard of fly control.

Although progress is being made in the development of alternative or supplementary measures, such as the preservation and encouragement of natural enemies, use of attractants, juvenile hormones, and sterilization, the application of insecticides continues to be the main weapon available for quick abatement of an existing fly infestation. However, frequent use of insecticides is known to generate a number of problems, the principal one being that of resistance to insecticides. Because this is a genetic phenomenon transmitted to subsequent generations, resistance becomes more intense with each successive insecticide treatment. The fly population eventually comes to contain a large proportion of individuals able to survive the maximum permissible dosage of the insecticide. It is evident that any measure which reduces the need for frequent applications of an insecticide, such as proper manure management (see U.C. Agricultural Extension Leaflets AXT-72; AXT-n32), would also tend to prevent or

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TABLE 2. HOUSE FLY RESISTANCE TO INSECTICIDES IN VARIOUS CALIFORNIA LOCALITIES, 1970

	Resistance levels* (at LD_{95})							
	Poultry ranches					Dairies	Cattle feedlots	
Insecticide	Moorpark No. 20	Moorpark No. 5	Sebastopol	Yucaipa	Gilroy	Norco	Blythe	Brawley
DDT	>100.0	>100.0	>100.0	>100.0	>100.0	>100.0	>100.0	>100.0
Malathion	>100.0	>100.0	>100.0	>100.0	>100.0	>100.0	11.7	8.5
Diazinon	580.0	160.0	58.2	39.8	11.8	25.8	4.7	6.1
Ronnel	737.3	168.2	30.2	35.5	11.6	18.6	4.0	5.6
Fenthion	43.1	26.3	10.8	12.3	5.8	7.6	3.1	4.4
Naled	26.2	17.9	6.0	5.8	2.4	3.3	1.4	1.9
Dimethoate	15.1	6.6	5.0	3.9	4.1	15.3	1.7	2.0
Zytron	12.1	9.6	1.8	5.3	1.6	3.8	1.4	1.4
Dichlorvos	6.5	7.9	1.6	2.6	1.0	1.3	1.0	0.8
Gardona	4.2	4.3	1.6	1.6	1.6	1.4	1.6	1.9
Pyrethrins + p.b.	0.8	0.8	1.4	1.1	0.8	0.8	0.9	1.0

* Numbers indicate degree of resistance. Level of nonresistant flies = 1.
† Dotted line separates resistance levels exceeding 10-fold.

delay the onset of resistance and thus prolong the "useful life" of the insecticide.

Two earlier studies reported in 1967 indicated that resistance in flies varies widely throughout the state, depending on the past and present fly control practices in each area. It was also reported that the duration of effectiveness of a new insecticide is shorter the more varied the "resistance load" of a given population. This is especially evident where the insecticides involved are chemically related. Thus, while treatments by "compound X" may provide satisfactory control over 50 successive generations of flies, a chemically related insecticide introduced subsequently may be expected to yield control over a small number of generations.

Aside from the increased costs of more frequent applications, an important implication of resistance is the reduction in the number of effective insecticides available for fly control. This is especially serious because the greatly increased costs of developing new insecticides, the multitude of safety tests required for their registration, and the specter of resistance, have slowed down the commercial introduction of new materials.

This situation dictates the need for extending the useful life of presently available insecticides. It is hoped that this progress report of the results of long term studies on resistance will serve the dual purpose (a) of providing information on the present status of resistance in selected localities and suggesting guidelines for modification of chemical control practices as necessary and (b) of causing greater awareness of the problem of resistance and the need for avoiding or delaying its development.

Resistance was investigated on seven ranches in 1970 and on six ranches in 1971. In selecting these ranches for study, an attempt was made to include those representative of a variety of operations and approaches to fly control. It is believed that the ranches studied typify a large proportion of the situations encountered in this state.

The location of each ranch, the type of operation, and the insecticides used for fly control are summarized in table 1. Flies were collected on the dates indicated and were cultured in the laboratory for further study. Offspring of the subsequent three or four generations were tested by a microdrop technique for resistance to the insecticides used in fly control. The performance of several new compounds was also examined.

The levels of resistance determined in the 1970 studies are given in table 2. It should be pointed out that there is no generally accepted level of resistance above which every insecticide is considered to be no longer effective. Insecticidal effectiveness is a relative term involving both potency at the time of application and duration of residual action. These properties are affected by biological as well as physical factors. In general, it is considered that for most insecticides a 10-fold level of resistance, as determined in the laboratory, signifies the beginning of detectable control difficulties. This, however, varies with different insecticides, and in the case of dimethoate "satisfactory" control was reported even when resistance had exceeded the 10-fold level. On the basis of this criterion it becomes apparent that the extent of resistance varies considerably among the different cases investigated. It is obviously of high level and more inclusive in poultry ranches, less so in dairies, and still less in cattle feedlots, thus reflecting the differences in the extent and variety of insecticide use in each type of operation.

Resistance to malathion, diazinon and ronnel was found at relatively high levels on all five ranches studied (table 2). These materials have been extensively used in fly control for several years, and it may be expected that high and relatively stable resistance is now well established. In recent years the insecticide naled has been used at increasingly higher frequency as a surface spray in place of the earlier-used organophosphates, and it is obvious that on certain ranches, such as Moorpark 5 and 20, resistance to it has appeared. However, resistance is only moderate or low in other areas where its use has been minimal. The same situation is also evident in the results obtained with dimethoate and Zytron. Gardona has been introduced more recently and resistance has not yet developed except on a low level at Moorpark; but high resistance has been reported from Denmark where use of this insecticide has been more extensive.

The results in table 2 clearly illustrate the gradual depletion of available insecticides where chemical control measures have been heavily relied upon. In the most critical case studied in 1970, namely the Moorpark ranch 20, the level of resistance is below the 10-fold level for only three registered insecticides. Among these, pyrethrins are useful for a quick kill as space sprays but possess no residual activity, and dichlorvos is used mainly in sugar baits and also as a nonresidual space spray. Thus, the need for conservation of available insecticides is abundantly evident.

TABLE 3. HOUSE FLY RESISTANCE TO DIMETHOATE AND NALED IN VARIOUS CALIFORNIA LOCALITIES, 1971

Establishment and locality	Resistance levels (at LC_{95})	
	Dimethoate	Naled
Poultry Ranches		
Moorpark		
Ranch 5	4.8	16.0
Ranch 20	8.4	26.3
Dairies		
Riverside	38.4	-
Camarillo	41.6	14.0
Norco	57.9	-
Chino	105.3	10.7

DAIRIES

The results of the 1970 study on the Norco dairy (table 2) indicated that, as in the case of poultry ranches, resistance was high toward malathion, diazinon and ronnel. In addition, resistance to dimethoate was higher than found on poultry ranches, apparently due to the more extensive use of this material on dairies. Resistance to dimethoate and naled was examined further in 1971 when three more dairies were studied. It is apparent from the results in table 3 that a significant level of resistance to dimethoate is present at all four dairies and that future trends must be monitored closely.

Additional evidence of resistance comes from the Sacramento Valley where fly control studies have been conducted on dairies over a period of several years. Field tests in this area in 1970 did not produce the high level of fly control obtained in 1965 and 1967. Dimethoate sprays which normally resulted in excellent fly control (90 to 100%) for periods of 5 to 6 weeks, gave only good to fair control (59 to 92%) for up to 3 weeks on the same dairies in 1970.

CATTLE FEEDLOTS

With the exception of high resistance to DDT and moderate resistance to malathion, results show that the fly populations on the two cattle feedlots examined continue to remain generally susceptible to the insecticides tested (table 2). The lack of high resistance in these cases can be attributed to minimal fly production and fewer generations per year due to the desert environment, and the remoteness of the feedlots from densely populated areas—factors alleviating the need for dependence on chemical control.

Long term studies

A long term study concerned with the evolution of resistance in relation to insecticide usage has been under way at Moorpark (Ranch 5) since 1964. The results given in table 4 illustrate clearly the year-by-year increase in resistance, both in intensity and breadth, as new insecticides were introduced in control operations (see insecticide usage data for Ranch 5 in table 1). By 1970 resistance involved seven insecticides including malathion, coumaphos, crotoxyphos, diazinon, ronnel, fenthion and naled.

More important is the fact that resistance to each compound continued to rise even after the compound was replaced by another. Thus, resistance to ronnel continued to increase after the compound was replaced by diazinon, and resistance to the latter rose further after this was replaced by naled and other organophosphates. These results suggest that it is unlikely that significant regression of resistance to organophosphates may occur, as long as the fly population continues to be under selection pressure by a member of this class of compounds.

Other studies indicate that regression may be expected where the population is no longer under chemical control, or is treated only rarely, preferably with insecticides unrelated to those against which resistance has developed. Such regression, especially where it involves long-standing resistance, is too slow to be of practical significance. An indication of this fact is evident in the very small drop in resistance observed on Moorpark ranch 5 between 1970 and 1971 (table 4). Since June 1970, the routine application of insecticides on this ranch was replaced by a program of manure removal at 10-day intervals and infrequent use of dichlorvos-sugar baits. This practice has evidently arrested the further increase in resistance, and it will be of interest to observe further developments in future years.

New insecticides

In view of the pressing need for new insecticides for fly control in certain critical areas, especially for materials of distinctly novel structure, tests were carried out with five insecticides of recent origin, against flies from two poultry ranches (Moorpark 5 and 20) and two dairies (Norco and Camarillo). The results (table 5) showed that only limited cross-resistance toward these insecticides exists in field flies. These materials show lower toxicity against susceptible flies than most other insecticides presently used for fly control. However, one recent compound, NIA 24110 (not listed in table 5), was found to be more toxic to flies (LD_{50} 0.39 $\mu g/g$) than any other compound in current use. These new insecticides are reported to have only limited persistence and may, after further testing, be found useful in situations where quick knockdown of flies is a primary consideration.

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TABLE 4. YEARLY CHANGES IN INSECTICIDE RESISTANCE IN HOUSE FLIES AT MOORPARK (RANCH NO. 5), 1964–1971

Insecticides	Resistance levels* (at LD_{95}) 1964	1965	1966	1968	1969	1970	1971
Malathion	>100.0	>100.0	>100.0	>100.0	>100.0	>100.0	>100.0
Coumaphos	-	>100.0	>100.0	-	-	-	-
Crotoxyphos	-	17.7	>100.0	-	-	-	-
Diazinon	7.0	17.3	66.4	136.4	162.9	160.0	-
Ronnel	8.1	13.6	26.4	46.0	114.0	168.2	90.9
Fenthion	5.4	6.6	10.3	13.9	18.1	26.3	-
Naled	-	4.7	-	8.3	9.3	17.9	16.0
Dimethoate	2.7	3.6	3.1	7.9	8.2	6.6	4.8
Dichlorvos	1.8	2.1	4.2	4.2	2.7	7.9	-
Gardona	-	-	-	2.3	3.5	4.3	3.6
Zytron	-	-	1.8	-	-	9.6	-
Pyrethrins + p.b.	-	-	-	-	-	0.8	-

* Numbers indicate degree of resistance. Level of nonresistant flies = 1.
† Dotted line separates resistance levels exceeding 10-fold.

TABLE 5. EVALUATION OF NEW INSECTICIDES AGAINST RESISTANT HOUSE FLIES FROM VARIOUS CALIFORNIA LOCALITIES

Insecticide	Resistance levels (at LD_{95}) Poultry ranches: Moorpark #5	Poultry ranches: Moorpark #20	Dairies: Norco	Dairies: Camarillo	LD_{95} ($\mu g/g$) Susceptible WHO strain[1]
Bioresmethrin (NRDC 107)	3.8	3.1	5.5	3.8	2.1
cis-Bioresmethrin (NRDC 119)	4.4	1.8	3.4	3.3	13.5
Bioneopynamin	3.9	6.3	2.4	5.0	47.0
Bioallethrin	1.4	2.3	2.0	0.9	100.0
Neopynamin	3.0	3.1	4.6	2.1	115.0

* Comparative activity of some other insecticides (in $\mu g/g$ are: dimethoate 0.6; naled 1.3; DDT 1.9; diazinon 2.9; malathion 27.5.