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Further observations on an insecticide-bait-box method for the control of sylvatic plague vectors; effect of prolonged field exposure to DDT powder

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INTRODUCTION

In a previous communication, a field method to control flea vectors of plague was described in which rodents were attracted to bait boxes where they contacted DDT powder (Kartman, 1958). Generally good immediate and residual control of fleas was obtained both on field mice and in their nests when the bait-boxes with 5% or 10% DDT powder were kept in the field for about 1 month. Although two principal sylvatic plague vectors, *Malaraeus telchinum* and *Hystrichopsylla linsdalei*, were adequately controlled in vole nests, control of the latter species on hosts did not have the consistency shown in control of the former. Accordingly, the question remained whether the discrepancy in control of the two flea species was due to insecticide resistance or to other factors. Since adequate control was obtained in rodent nests, the resistance factor seemed remote. This conclusion was especially favoured by the fact that *H. linsdalei* is primarily a nest flea which occurs in very small numbers on its host.

In spite of the above reasoning, it was decided to make further field observations since the greatest hindrance to chemical control of arthropods is the ability of certain species to develop tolerance to an insecticide. In assessing this problem, information on the susceptibility of a species to a given pesticide may be obtained in the field by comparing the effects in treated and untreated areas. 'This detection of resistance under field conditions can be accomplished without detailed laboratory evaluation, as has been shown by studies with mosquitoes and lice in a number of different countries' (World Health Organization, 1958).

The studies reported here were primarily concerned with the detection of possible insecticide resistance in the field. Since flea populations already had been exposed to DDT for short periods, it was decided to maintain the insecticide for at least 6 months in the same area used in the previous tests.

METHODS AND MATERIALS

The work was done in two adjacent field plots (250 ft. × 250 ft. each) in the San Francisco Bay region. Details in regard to exact locality, trapping grids, field plots, all methods and materials used, species of rodents and fleas, and results

of preliminary trials were given in a preceding paper (Kartman, 1958). As noted in the former report, the native meadow vole *Microtus californicus* and the two flea species mentioned above were the predominant fauna encountered and thus constitute the substance of the observations.

The present study was done between July 1958 and February 1959. Empty bait-boxes were placed in the field on 21 July and rodents were observed to enter them soon afterwards. On 24 July rolled barley and about 80 g of 5% DDT powder were placed in each bait-box. The bait and insecticide were maintained continuously in the bait boxes until 4 February. Rodents were trapped throughout the whole period and their flea indices determined. Toward the termination of the experiment, rodent nests and some of the rodents were analysed for the presence of DDT deposits. In these analyses the Schechter–Haller colorimetric method was used and results were calculated as technical DDT (Schechter & Haller, 1944).

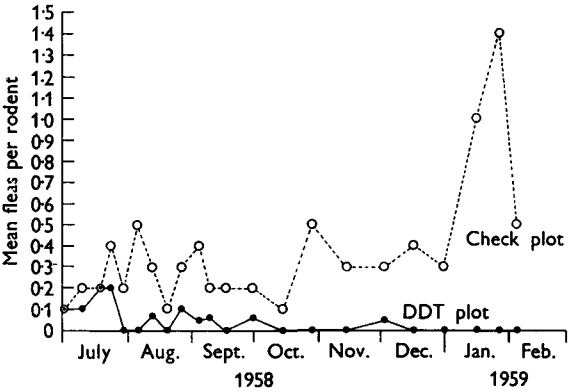

Fig. 1. Effect of 5% DDT powder in bait-boxes on the occurrence of the flea *Hystrichopsylla linsdalei* on the native meadow vole *Microtus californicus*.

DATA AND DISCUSSION

Table 1 summarizes the data showing the effects of 5% DDT powder in the bait-boxes on all flea species parasitizing the vole *Microtus californicus*. It is obvious that maintenance of the bait boxes over a period of 6 months did not allow any significant rise in the flea population on hosts after an initial decline brought about by contact with DDT powder. Both the mean number of fleas and the percentage of hosts infested consistently remained at levels well below those in the untreated check plot 150 ft. distant. In former tests the bait boxes were removed after 4–6 weeks and, after a residual period of several months, flea indices in the treated plot rose to levels encountered in the check plot (Kartman, 1958). However, at that time *Hystrichopsylla linsdalei* did not conform to this general picture. Theoretically, if *H. linsdalei* or any other flea species was capable of developing resistance, it should have persisted and possibly have shown a rise during the 6-month period in which the hosts were exposed to contact with the insecticide. The data in Table 1 suggest that none of the flea species involved exhibited resistance.

Specific evidence in regard to effects upon *H. linsdalei* is shown in Fig. 1. The contrast between data from the treated and check plots suggests that this species

showed no resistance to the effects of DDT. Furthermore, prior to use of DDT from 1 to 23 July, the average percentage of hosts infested with *H. linsdalei* in the treated and untreated plots were 12·5 and 16·7 respectively. After use of DDT, from 29 July to termination of the test, these percentages were 1·9 and 26·3, respectively.

The data on flea populations from hosts during the period 1 to 23 July show some differences as between the two plots (Table 1). This may have been due to carry over of insecticidal effects from former tests when bait-boxes with DDT were last removed during September 1957 and residual effects were noted to December 1957. Nevertheless, Fig. 1 suggests that such possible effects upon *H. linsdalei* were negligible.

Table 1. *Effect of prolonged exposure to 5 % DDT powder in bait-boxes on the incidence of fleas* on the native meadow vole,* Microtus californicus

(Bait-boxes with DDT from 24 July 1958 to 4 February 1959)

	Treated plot			Check plot		
Dates (1958–59)	No. hosts/ no. fleas	Mean fleas	% hosts infested	No. hosts/ no. fleas	Mean fleas	% hosts infested
1 July	22/20	0·8	45	20/26	1·3	55
9 July	16/28	1·7	68	20/61	3·0	55
18 July	24/39	1·6	41	19/54	2·8	52
23 July	18/25	1·3	55	22/69	3·1	50
29 July	17/1	0·05	5	19/37	1·9	73
5 Aug.	19/0	0·0	0	17/78	4·5	70
12 Aug.	13/1	0·07	7	16/77	4·8	75
19 Aug.	15/0	0·0	0	17/119	7·0	94
26 Aug.	16/2	0·1	6	16/105	6·5	93
4 Sept.	17/3	0·1	11	15/104	6·9	86
9 Sept.	15/2	0·1	13	14/101	7·2	85
17 Sept.	16/3	0·1	12	9/76	8·4	88
30 Sept.	16/4	0·2	12	16/103	6·4	100
14 Oct.	19/0	0·0	0	24/223	9·2	91
28 Oct.	13/0	0·0	0	19/169	8·8	100
14 Nov.	15/0	0·0	0	17/99	5·8	100
2 Dec.	20/2	0·1	10	19/83	4·3	78
16 Dec.	18/0	0·0	0	16/97	6·0	87
31 Dec.	12/3	0·2	16	17/129	7·5	94
16 Jan.	5/1	0·2	20	16/108	6·7	87
27 Jan.	1/0	0·0	0	15/219	14·6	93
4 Feb.	2/0	0·0	0	12/97	8·0	100

* Fleas were approximately 75 % *Malaraeus telchinum*, 15 % *Hystrichopsylla linsdalei*, and 10 % comprising the three species *Atyphloceras m. multidentatus*, *Catallagia wymani* and *Opisodasys keeni nesiotus*.

Evidence gathered in the present test confirmed that obtained in previously reported tests (Kartman, 1958) which showed that fleas in host nests were controlled by DDT powder transported from bait-boxes to nests by voles. Table 2 indicates that nest samples collected from the check plot had over 11 times as many fleas in them as did samples from the treated plot. It should be noted in Table 2 that only one nest taken from the treated plot contained fleas. This particular nest was

found close to the border of the check plot and it is possible that the inhabitants carried on much of their activities in the untreated area between the two plots. That visits were made to bait boxes is clear from DDT residues found in this nest, but it is possible that, prior to nest collection, fleas had been deposited by voles who acquired them near the check plot. The transfer of fleas between individual hosts has been definitely established in pilot experiments (Hartwell, Quan, Scott & Kartman, 1958) and in more extensive field tests (unpublished). Another indication that the fleas in this nest may have been introduced from outside was the complete absence of immature stages of fleas. The hypothesis also is favoured by the fact that by 26 January 1959, when the nest was collected, voles in the treated plot had shown a significant decline (Table 1). Under such circumstances it is known that deserted nests often are used by rodents migrating into an area in which the population has declined.

Table 2. *Effect of 6 months' exposure to 5 % DDT powder in bait-boxes on the incidence of fleas in nests of the native meadow vole,* Microtus californicus

(DDT placed in bait-boxes 24 July 1958, and nests collected 26 January 1959.)

Nest sample	Grid site	Larvae	Adults	Total	DDT analysis (mg.)
		Treated plot			
1	A-2	0	0	0	1·08
2	B-3	0	0	0	1·48
3	C-5	0	0	0	*
4	D-4	0	0	0	2·33
5	D-5	0	61	61	0·58
6	E-1	0	0	0	0·84
7	E-5	0	0	0	*
Totals		0	61	61	6·31
Means		0	8·7	8·7	0·90
		Check plot			
8	F-4	0	0	0	*
9	G-1	5	8	13	*
10	H-5	0	0	0	*
11	I-1	44	39	83	*
12	I-3	97	525	622	*
Totals		146	572	718	*
Means		29·2	114·4	143·6	*

* Less than 0·01 mg. DDT present, if any.

The decline in the *Microtus* population can be seen in Table 1 which indicates that the decrease was greatest in the treated plot. In this connexion it should be noted that a general decline in vole and other rodent populations was observed in neighbouring areas and generally throughout California during the 1958–59 season. Some observers attributed the decline to sparse rainfall during that period. Nevertheless, in the specific area used for the field trials rain-gauge records did not

indicate any drastic departure from the usual situation (see Kartman, 1958). From July to December 1958 traces to about 0·5 in. of rain were recorded. The rainfall in inches during the following period was: December, 3·7; January, 6·5; and February, 5·9.

Observations in the treated and check plots after February 1959 showed a population decline in both areas, but by April the voles in the check plot still constituted 75 % of all *Microtus* taken in both plots. Thus it appeared that, in the treated plot, adverse effects of DDT may have been superimposed upon natural factors influencing a general decline of the population. Several *Microtus* from both plots were analysed for DDT and varying amounts were found in individuals from the treated plot as shown in Table 3. All of these voles appeared in good condition except the individual showing 143 μg. of DDT; this animal was found dead. Conclusions cannot be drawn, however, since no information is available on the toxicity of DDT to the particular species involved. Nevertheless, it should be pointed out that many workers have shown that house mice and certain field rodents can be partially controlled with DDT powders (Hayes, 1959).

Table 3. *Evidence of DDT exposure in the native meadow vole,* Microtus californicus, *6 months after 5 % DDT powder had been continuously maintained in bait-boxes*

Plot	Sample no.	Grid site	Sex	Weight (g.)	DDT (μg.)
Treated	1	A-2	♀	23·9	143
	2	B-3	♂	28·6	36
	3	B-4	♂	30·6	35
	4	C-3	♂	25·5	35
	5	C-4	♀	30·5	74
Check	6	I-1	♀	20·0	*
	7	I-3	♂	26·8	*
	8	I-4	♂	27·6	*
	9	J-3	♂	23·9	*

* No detectable DDT within experimental limits (10 μg.).

The most recent compilation of evidence reveals that throughout the world five species of fleas have been reported to have a certain degree of physiological or behaviouristic resistance to DDT (Simmons, 1959). Field and laboratory observations have not demonstrated conclusively that fleas are capable of developing the high order of resistance exhibited by mosquitoes or house flies (Schoof, 1959). Furthermore, no flea vectors of sylvatic plague have ever been noted to be resistant to any insecticide.

The field tests with DDT reported here appear to confirm that fleas are generally quite susceptible to this insecticide. This seems all the more remarkable since of the approximately sixty species of insects known to be resistant to some insecticide, over half involve resistance to DDT and as much as five-sixths to some chlorinated hydrocarbon (Brown, 1958). In the present field tests opportunities for the exhibition of resistance were favourable since flea populations both on hosts and in rodent nests were affected. In the development of resistance, it has been pointed out that larval pressure is more effective than adult, and a combination of pressures

on both stages was the most effective (Brown, 1958). Thus Decker & Bruce (1952) concluded that contamination of larval breeding places was the main factor in the development of DDT resistance in houseflies in the field. Evidence in the present experiments and in former trials (Kartman, 1958) have clearly demonstrated that the DDT affected adult fleas both on hosts and in nests, and that DDT deposits were found in nests where they contaminated the larval medium and killed the larvae.

SUMMARY

A field experiment was conducted from July 1958 to February 1959 in the San Francisco Bay region to test the effect on flea populations of prolonged exposure of the native meadow vole, *Microtus californicus*, to 5 % DDT powder in insecticide-bait-boxes. Previous studies had shown that two important vectors of sylvatic plague, *Malaraeus telchinum* and *Hystrichopsylla linsdalei*, could be controlled both on their hosts and in the host nests by this method. However, the question of possible resistance was postulated since the control of *H. linsdalei* on its host was inferior to control of other flea species.

Bait-boxes with DDT powder were maintained in the field for 6 months. Records of flea populations on *Microtus* during this period showed equally good control of all flea species. Observations on vole nests at termination of the study revealed deposits of DDT and good control of all flea species in them. During the period of study, the evidence suggested that none of the flea species involved exhibited DDT resistance.

The major portion of the field routine was done by Messrs A. R. Kinney and R. L. Martin. Flea identifications were made by Mr H. E. Stark. Analyses of nests and rodents for DDT were performed by Mr C. Cueto, Technical Development Laboratories, CDC, Savannah, Georgia.

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