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FIELD TRIALS OF FENITROTHION, MALATHION, AND DDT DUSTS AGAINST FLEAS ON RATTUS RATTUS DIARDII IN CILOTO, WEST JAVA, INDONESIA

by : Lim Boo Liat, [1] Sustriayu, N., [2] I. Ladera [2] and Y.H. Bang [1]

A B S T R A C T

Sebuah percobaan penanggulangan pinjal Xenopsyll cheopis dari tikus Rattus rattus diardii dilakukan di Ciloto dari bulan Februari sampai Nopember 1978. Racun serangga yang digunakan 50 % malathion wdp, 40 % fenitrothion wdp dan 75 % DDT wdp. dicampur dengan serbuk bedak sehingga terdapat 5 % zat racun aktif (active ingredient). Percobaan dilakukan pada 3 dusun. Pengamatan dilakukan dari bulan Februari sampai Nopember 1978 di daerah percobaan dan daerah kontrol DDT 5 % tidak effektif untuk pemberantasan pinjal, malathion 5 % effektif sampai 15 minggu dan Fenitrothion 5 % sampai 19 minggu sesudah perlakuan pertama. Ketiga racun serangga juga effektif untuk tungau dan kutu, tapi tidak demikian untuk tungau dewasa mesostigmatik (mesostigmatic mites).

INTRODUCTION

Bubonic plague is considered to be endemic in Central Java in an area which lies about 7.5^{O} south of the equator and is bounded on the west by two volcanoes, the still active Mount Merapi (2911 m) and the dormant Mount Merbabu (3142 m). The altitude of the "plague zone" exists mainly between 1000 – 1500 meters in villages concentrated within the high valley that extends between the summits of the two volcanoes (Bahmanyar, 1958; Baltazard & Bahmanyar, 1960; Chamsa, 1970). According to Turner et al. (1975), *Rattus exulans* is probably the primary mammalian reservoir host, *R.r. diardii* functions as a liaison rodents between the reservoir host or amplifying host, and the vectors are the Oriental rat flea *(Xenopsylla cheopis)* and one of the field fleas *(Stivalius cognatus)* (Turner et al., 1974).

A village scale field trial for flea control was carried out from February to November 1978 with three insecticides: malathion, fenitrothion and DDT. The objective of this trial was to assess which of the three insecticides are most suitable for flea control in terms of reduction of flea load and residual activity. The trial was carried out at Ciloto, a non-endemic area, because of the existence of a field station and its proximity to Jakarta (100 km), which afforded better operational facilities and a considerable reduction in expenses (Fig. 1).

TRIAL AREAS

Ciloto (107^{O}E, 06^{O}45'S), lying between southeast of Mount Pangrango (3019 m) and Mount Gede (2988 m) and north of Mount Kencana, has the same elevation as that of the plague zone area (Fig. 1). It also has similar village patterns and the rodent and fleas species are identical to those found in the plague zone area in Central Java.

Three villages about 15 kilometers southeast of Ciloto were chosen for the field trials. Village A has 37 houses, village B 70 and village C 16 houses. Village A lies east of B, and is separated from village B by a large river. Village C lies south of B and they are separated by a hill. Jemprak, a village with 82 houses near the Ciloto Field Station, was used as the untreated control area (Fig. 1).

1) **WHO, Vector Biology and Control Research Unit, P.O. Box. 302, Jakarta, Indonesia.**

2) **National Institute of Health Research and Development, Ministry of Health, P.O. Box. 226, Jakarta, Indonesia.**

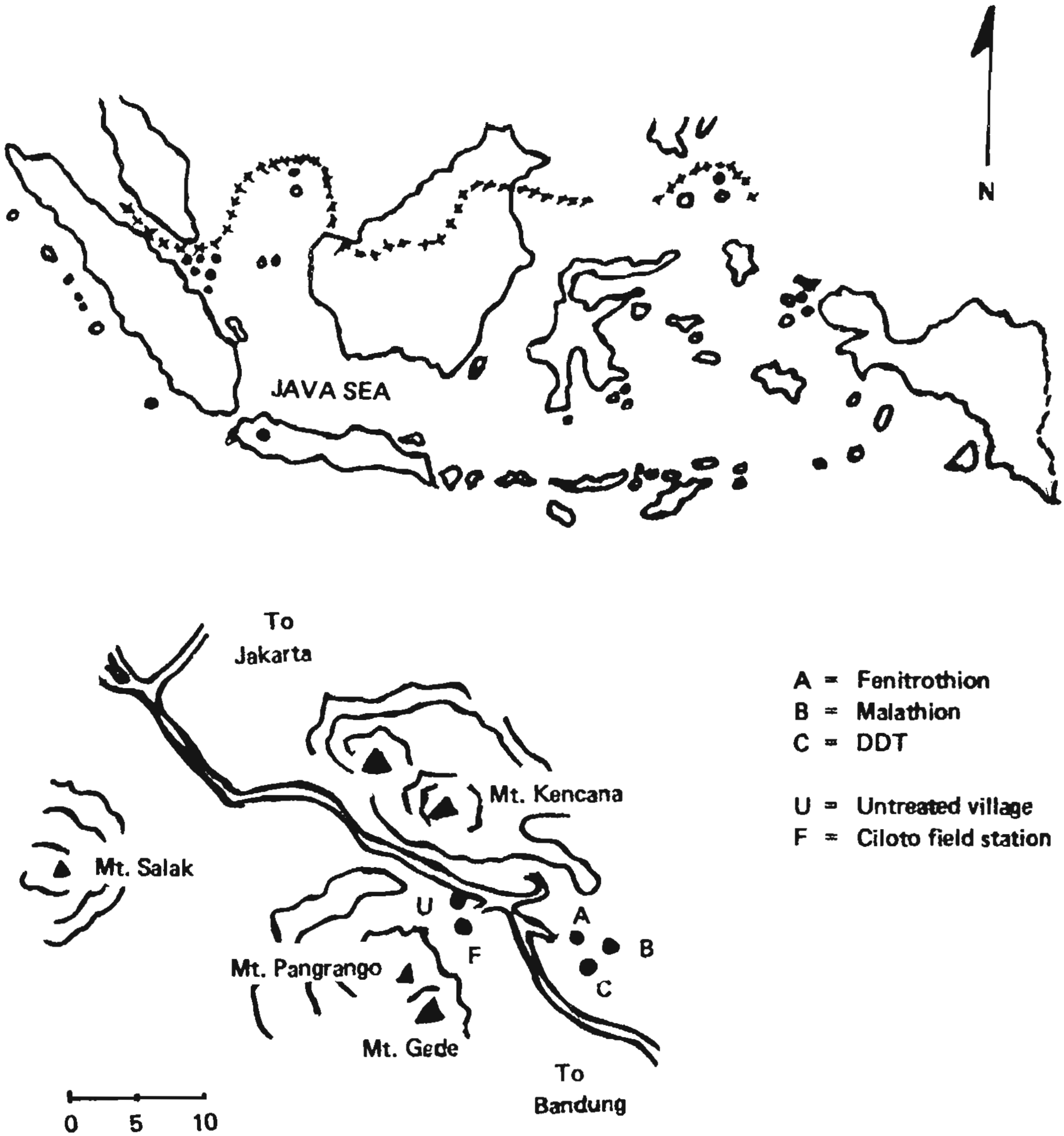

Fig. 1 Map showing four trial villages near Ciloto West Java, Indonesia.

MATERIAL AND METHODS

TRAPPING: Two wire-basket traps baited with toasted coconut meat were placed in the kitchen each house. They were set at 18.00 and checked the following morning at 06.00. Pre-treatment trapping was carried out once a week for four consecutive weeks. Insecticide treatment was made after the trapping in the trial villages. Post-treatment trapping was initiated one week after treatment and continued thereafter at fortnightly intervals. The rats collected during pre-treatment trapping were individually transfered into a cloth bag, labelled and put into a large plastic jar at the trapping sites, brought back to the laboratory and killed by hand following the method used by Sustriayu et al. (1980). The live fleas collected from rats in the pre-treatment period were used for insecticide susceptibility tests. The rats from the post-treatment period were handled in the same manner as above except that they were killed with chloroform at the trapping sites. Pre- and post-treatment trapping of rodents in the control village followed the same procedures as that of the trial villages. Trapping of rats in all the treated and control villages continued for another six weeks after treatment in order to obtain fleas for post-treatment insecticide susceptibility tests.

ECTOPARASITES: The fleas and other ectoparasites from rats killed without any anaesthetizing agents were collected alive with the aid of aspirators in a large enamel basin and transfered to a large glass container. The cloth bag was then searched for any ectoparasites dislodged from the rats. The other ectoparasites collected such as mites, lice and chiggers were preserved in 70 % alcohol for later identification. Ectoparasites collected from anaesthetized rats during the post-treatment periods were sorted into different taxa, and preserved in 70 % alcohol. The dead rats were then identified, measurements taken, and female rats examined for reproductive data.

DUST FORMULATIONS: Three insecticide formulations, malathion 50 % wdp, fenitrothion 40 % wdp and DDT 75 % wdp were reformulated by dilution with talc powder to make 5 % active ingredient (A.I.) dusts. A 77 liter drum was modified as mixing apparatus for the formulation of these dusts (Fig. 2). A maximum of 10 kg being mixed at one time. During the process of mixing, the talc and insecticide were placed at alternate layers in the drum until it reached the required amount for each insecticide mixture. The cover of the drum fixed with a revolving handle, was firmly encased by a metal circular band round the edge. The insecticide was then brought at an average of 110 revolutions per minute for 15 minutes to mix the insecticide and talc throughly and evenly mixed. After that 10 minutes were required to allow the dust in the drum to settle at the bottom. After formulation the 5% dusts were packed in 500 g duster charges in plastic bags which were sealed with two rubber bands. Each bag was numbered and labelled according to the insecticide and the number corresponding to the house where it would be used.

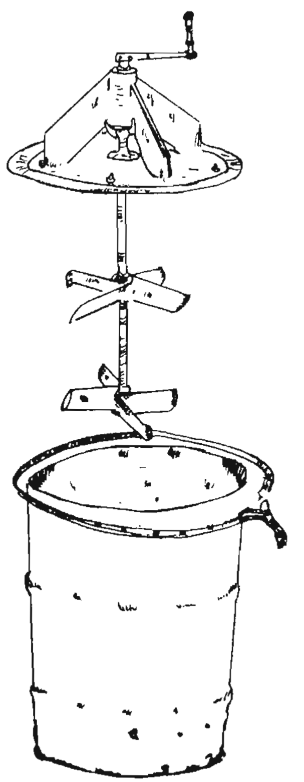

Fig. 2 Diagramtical Drawing Of A Mixing Drum For Insecticides

TREATMENT OPERATION: Two Bellow (R) hand operated dusters were used for applying the insecticides. The container attached to dusters holds 500 g of mixture. There were two teams of two men each under two supervisors, one for each team, and the teams were used in rotation. Each team dusted 10 houses only, after which the other team continued with the dusting. This procedure was necessary because of the very strenuous nature of the work. The whole operation in the different trial villages was carried out by the same teams in order to be consistent.

Dusting was confined to the corners of the floor and all horrizontal beams. Before dusting, furniture and utensils from the houses were moved outside by the house-owners, assisted by the supervisors. The supervisors recorded the time taken for dusting each house, and also checked amount of insecticide dusted in one house before the teams proceeded to the next. The teams worked for 5 hours a day and the whole operation took four days to complete.

The amount of each of these three insecticide dusts used per village, per house, A.I. per house, time taken to dust per house, and number of houses dusted by each team per house is tabulated below.

Villages	Insecticide (5 %)	No. of houses	Amount used (kg)	Amount used per house (gram)	A.I. per house (gram)	Time taken per house (hour)	No. of house per team/ hour
A	fenitrothion	37	17.5	475	23.8	0.20	5.0
B	malathion	70	34.8	497	24.9	0.18	5.6
C	DDT	16	7.5	469	23.4	0.16	6.3

SAFETY PROCEDURES: The safety measures described by Fanara et al. (1979) for the dusters, mixers and supervisors were strictly followed. In addition, a WHO technical officer also assisted in the supervision of such safety precautions during mixing, handling and application of the insecticides.

SUSCEPTIBILITY TEST: Standard exposure to 4 % DDT, 0.5 % malathion, and 1 % fenitrothion impregnated papers in accordance with the procedure described in WHO/VBC/75.588 Rev. 1, was followed. Only fully-fed unsexed adult fleas collected on *R.r. diardii* were used for insecticides susceptibility test. During exposure the tubes were held in darkness at 25°C to 30°C and 65 to 85 % RH. Control mortality was below 5 % in all tests. After the 24 hours holding, all dead fleas were removed, counted and identified by species, surviving fleas were killed and likewise identified. Percent mortality were plotted on logarithmic probability paper on which regression lines were drawn to determine LT_{50} and LT_{95} values.

RESULTS

MAMMALS: The results of the trapping rates of small mammals during pre- and post-treatment are presented in Table 1. The house rat *(R.r. diardii)* was the most common household rodent caught, and only small numbers of *R. exulans* and *Suncus murinus* were found. Chi-square tests showed there was no significant difference in the trapping rates among the four villages selected for trials before insecticide dusting, although the rate for the DDT area was high (28.2 %).

There was also no significant difference of the trapping success rates between pre- and post-treatment periods for each of the 3 most common rat species caught in the four villages. Specifically, however, the trapping rate for the house rat increased in all the 3 insecticide treated villages while that in the untreated village declined from 11.8 % to 9.1 %. The rate for *R. exulans* and *S. murinus* declined in all the four villages after the treatment. Because of increase in the trapping rate, the house rat comprised more than 80 % of total animals trapped after insecticide dusting whereas the other two species declined significantly in all the 3 treated villages (Table 1).

FLEA INFESTATION : here were two flea species, *Xenopsylla cheopis* (the Oriental rat flea) and *Stivalius cognatus* (field flea). The Oriental rat flea was more prevalent than field flea on *R.r. diardii, R. exulans* and *S. murinus* in that order. The number of *S. cognatus* recovered from *S. murinus* was negligible. For comparisons of flea infestation before and after insecticide treatment, two flea indices were calculated, namely crude index (mean number of flea per rat trapped) and specific index (mean number of flea per flea positive rat) (Tabel 2).

Following dusting, no *S. cognatus* was recovered from 28 *R. exulans* and 23 *S. murinus* trapped in treated villages for a period of 29 weeks. The Oriental rat flea was also negative

Table 1. Comparisons of the trap rates and distribution of different rat species before and after insecticide treatment in four study areas near Ciloto, W. Java.

	Control		Fenitrothion		Malathion		DDT	
	before	after	before	after	before	after	before	after
No. trap night	600	2250	296	1110	560	2100	124	480
% trap success	14.8	10.8	15.9	15.1	12.7	10.4	28.2	31.7
Trap rate for (%)								
Rattus r. diardii	11.8	9.1	9.1	14.1	8.9	10.0	20.0	26.0
Rattus exulans	1.2	0.9	4.1	0.5	1.9	0.2	4.8	3.1
Suncus murinus	1.8	0.9	2.7	0.6	1.9	0.1	3.2	2.5
Total rat trapped	89	244	47	168	71	219	35	2152
% distribution for								
Rattus r. diardii	79.8	83.6	57.4	92.9	71.8	96.3	71.4	82.2
Rattus exulans	7.9	8.2	25.5	2.9	14.1	2.3	17.2	9.9
Suncus murinus	12.3	8.2	17.1	4.2	14.1	1.4	11.4	7.9

Table 2. Crude (C) and Specific (S) flea indices by rats before and after insecticide treatments.

Insecticides	Week before or after treatment	*R.r. diardii*				*R. exulans*				*Suncus murinus*			
		X. cheopis		*S. cognatus*		*X. cheopis*		*S. cognatus*		*X. cheopis*		*S. cognatus*	
		C	S	C	S	C	S	C	S	C	S	C	S
Control	Before	4.8	5.7	0.8	2.6	1.9	3.3	2.1	3.8	1.0	3.7	0	0
	1 – 15	3.7	4.6	0.5	2.4	1.6	2.7	1.8	3.6	1.1	3.0	0.1	1.0
	16 – 29	3.8	5.0	0.8	2.5	1.8	2.3	1.9	3.2	1.2	2.8	0	0
Fenitrothion	Before	3.1	4.0	0.7	2.6	1.8	3.5	2.1	3.6	1.9	2.5	0.1	1.0
	1 – 15	0.2	1.5	0.02	1.0	0	0	0	0	0	0	0	0
	16 – 29	1.3	2.5	0.06	1.3	0	0	0	0	0	0	0	0
Malathion	Before	4.1	5.1	0.6	2.8	1.0	1.7	2.2	4.4	1.0	5.0	0	0
	1 – 15	0.5	2.1	0.02	1.5	0	0	0	0	0	0	0	0
	16 – 29	3.1	4.4	0.03	1.5	0	0	0	0	0	0	0	0
DDT	Before	3.7	5.5	0.8	2.5	1.8	3.7	2.3	3.5	1.0	4.0	0	0
	1 – 15	2.3	3.1	0.05	1.5	0	0	0	0	0	0	0	0
	16 – 29	3.2	4.4	0.04	1.5	0.6	1.3	0	0	0.4	3.0	0	0

in the two mammal species but only in villages treated with fenitrothion and malathion. In the untreated village, all the flea indices determined for the Oriental rat flea and the field flea on the three different mammal species fluctuated during the trial period (Tabel 2) but student 't' tests show that the difference between pre- and post-treatment was not significant.

The percentage of *R.r. diardii* infested with Oriental rat fleas in the untreated village also fluctuated during trial period, ranging from 60 to 90 % (Fig. 3). In the fenitrothion treated village, the percentage was reduced drastically from 77 % to 18 % within the first week of the dusting and remained below 25% for about 15 weeks. The flea infestation in the malathion-treated village declined but it took 3 weeks after the dusting and recovery was also faster than with fenitrothion. There was not much difference between the DDT treated and the untreated village.

Figure 4 shows the mean number of the Oriental rat flea per house rat crude index) trapped from the four villages before and after treatment. The index in the fenitrothion treated villages declined to less than 0.3 % after dusting and remained below 1.0 % for a period of 24 weeks compared to 14 weeks in the malathion treated villages. The crude index in the DDT treated village never reached the 1.0 % level.

The reduction of flea infestation was calculated on the basis of numbers of the Oriental rat fleas recovered from the house rats using the formula $100 - 100 \frac{p}{q}$ where P is the difference of the flea infestation in the post-treatment between the treated (t) and untreated (u) areas (t/u) and q is the pre-treatment difference (Table 3). In the fenitrothion treated village there was over 90 % reduction for 5 weeks compared to 3 weeks in the malathion area. For 15 weeks more than 70 % reduction was obtained by fenitrothion dusting, about twice as long as

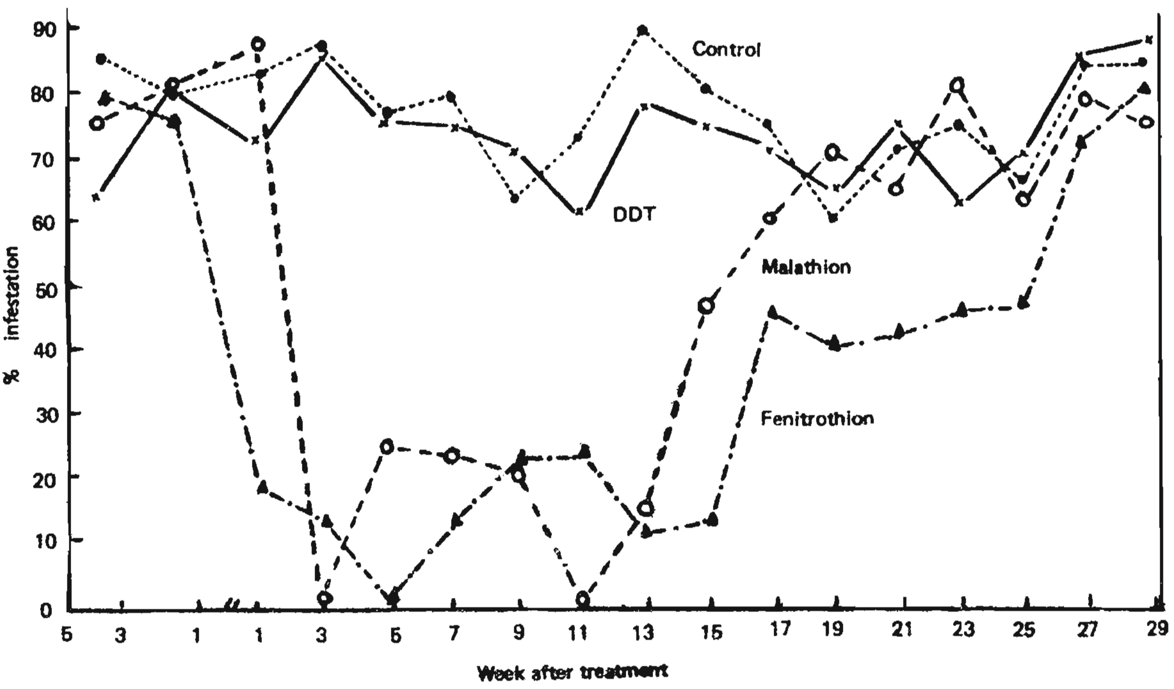

Fig. 3 Percentage of *R.r.diardii* infested with Oriental rat flea in villages treated with different insecticiced near Ciloto, W. Java.

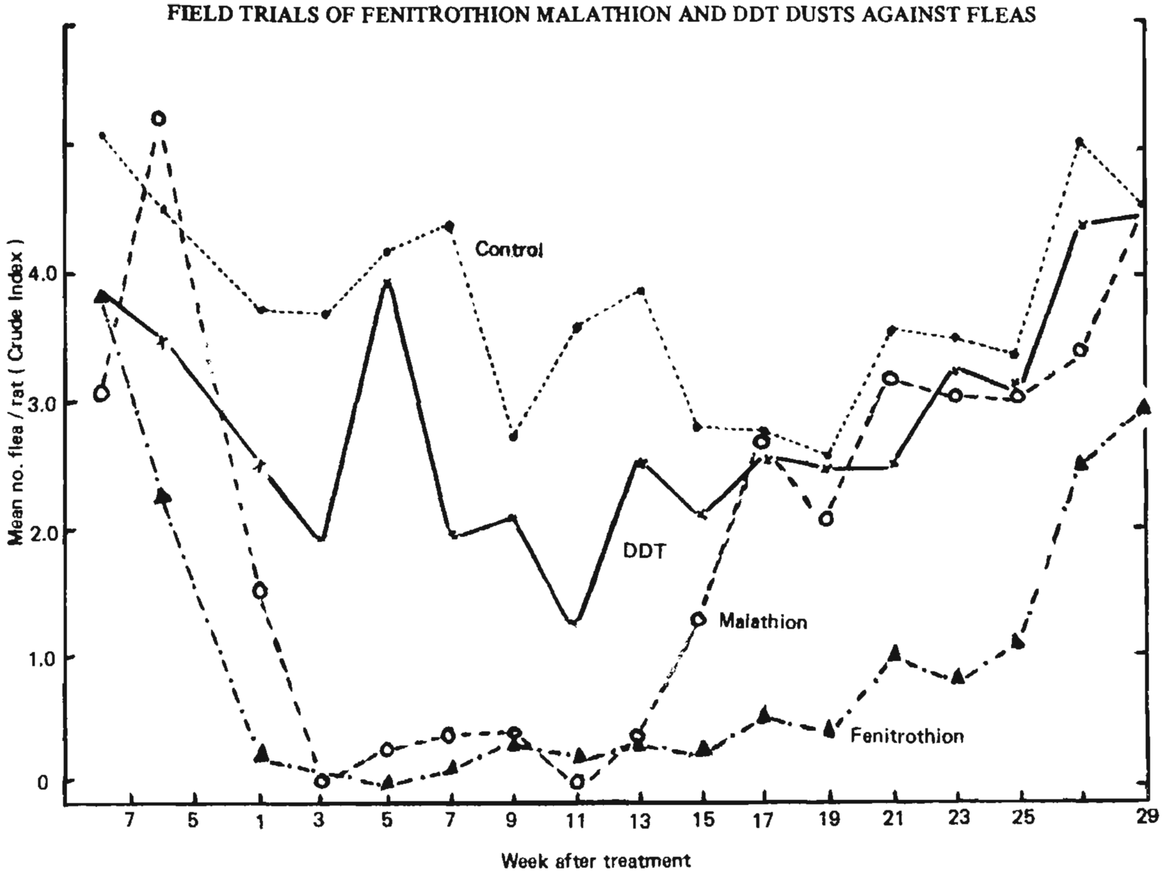

Fig. 4 Number of Oriental rat flea on R.r. diardii trapped in insecticide treated and control villages, near Ciloto, West Java.

for the malathion dusting. In the DDT-treated area, reduction was less than 20 % even during the first few weeks of the treatment.

Using the same formula, % reduction was also calculated with crude indices for the Oriental fleas on the house rat (Table 3). The number of weeks for 90, 70 and 50 % reduction based on the crude indices was longer than that based on the percentage of flea infestation. The difference was reflected mostly by an

Table 3. Number of weeks of 90, 70 and 50 % reduction as determined with % of flea infestation by rat and crude index in three villages treated with insecticides. 1)

Insecticides		No. week for reduction of			
		90 %	70 %	50 %	20 %
Fenitrothion	% infestation	5	15	15	25
	crude index	7	19	23	27
Malathion	% infestation	3	7	13	15
	crude index	7	13	15	15
DDT	% infestation	0	0	0	0
	crude index	0	0	0	3

1) Reduction was calculated by using formula $100 - 100\left(\frac{p}{q}\right)$ where P is % reduction in control area based on the pre-treatment level and q is % reduction in treated area based on the pre-treatment level.

increase in the trapping rates of the house rats after dusting (Table 1).

Other ectoparasites such as lice, mesostigmatic mites and chiggers were also examined from rats during pre- and post-treatments (Table 4). Two species of mesostigmatic mites *(Laelaps nutalli, L. (Echinolaelaps) echidnidus)*, two species of lice *(Hoplopleura pacifica, Polyplax spinulosa)* and a species of chigger *(Ascoshoengastia (Laurentella) indica)* were identified.

Among these ectoparasites, chiggers and lice were completely controlled in all the treated villages after dusting (Table 4). However, the reduction of mesostigmatic mites on the house rats was gradual after treatment and no marked difference between different treatments: 57 % reduction for 15 weeks in the fenitrothion village as compared to 60 % in malathion and 53 % in DDT.

SUSCEPTIBILITY: Table 5 shows lethal time for 50 and 95 % mortalities LT_{50} and LT_{95} of the Oriental rat fleas from house rats trapped in three treated villages before and after dusting (fenitrothion was not tested before dusting as impregnated papers were not available). The susceptibility tests for the fleas from the untreated village were carried out only once after dusting in the treated villages. Lethal-time values determined for 0.5 % malathion before and after dusting were alike and are within a range for the values for the untreated villages. Both the LT_{50} and LT_{95} values for the fenitrothion treated villages were not

Table 4. Percentage of rats infested with ectoparasites before and after insecticide treatment near Ciloto, West Java.

Insecticides	Week before or after treatment	No. of rats examined	*R.r. diardii*			No. of rats examined	*Rattus exulans*			No. of rats examined	*Suncus murinus*		
			Meso 1)	Chigger	Lice		Meso 1)	Chigger	Lice		Meso 1)	Chigger	Lice
Control	Before	71	45.1	16.9	5.6	7	2*	3*	2*	11	36.4	0	9.1
	1 – 15	106	46.2	18.9	16.0	10	40.0	20.0	20.0	11	27.3	0	10
	16 – 29	98	40.8	18.4	20.4	10	30.0	10.0	20.0	9	2*	0	1*
Fenitrothion	Before	27	44.4	25.9	18.5	12	33.3	25.0	41.7	8	2*	0	2*
	1 – 15	78	19.2	0	0	3	0	0	0	4	0	0	0
	16 – 29	78	28.2	0	0	2	0	0	0	3	0	0	0
Malathion	Before	51	29.4	9.8	5.9	10	20.0	30.0	20.0	10	30.0	0	10.0
	1 – 15	104	11.5	0	0	5	0	0	0	3	0	0	0
	16 – 29	107	30.8	0	0	3	0	0	0	1	0	0	0
DDT	Before	25	48.0	12.0	4.0	6	2*	1*	1*	4	2*	0	1*
	1 – 15	62	22.6	0	0	6	1*	0	0	5	1*	0	0
	16 – 29	63	25.4	0	0	9	1*	0	0	7	1*	0	0

1) Mesostigmatic mite * from one rat.

Table 5. Lethal-time (LT) values determined with *X. cheopis* recovered from *R.r. diardii* trapped in treated and control villages before and after dusting. 1)

Insecticides impregnated paper	Before and after dusting	No. fleas tested	Fleas calculated from respective treated village		Fleas collected from untreated village	
			LT-50	LT-95	LT-50	LT-95
DDT 4 %	before	240	5:40	58:20	–	–
	after	240	15:00	–	5:30	60:00
malathion 0.5 %	before	200	1:08	6:10	–	–
	after	200	1:30	7:20	1:22	8:20
fenitrothion 1.0 %	after	200	0:40	5:40	0:35	4:30

1) Mortalities based on 4 replicates with 10 fleas for each exposure time.

significantly different from those for the untreated village. Likewise in the DDT treated village, the LT_{50} and LT_{95} values before dusting were the same as those for the untreated village. However the LT_{50} value was increased from 5 hour 40 minutes to 15 hours after dusting (Table 5), and the LT_{95} was not obtainable due to lower mortality with the 4 % DDT papers.

DISCUSSIONS

The results of the field trials of various insecticides against the Oriental rat flea on house rat showed that 5 % DDT dust was not an effective insecticide in the village tested. Malathion dust at 5 % was effective in reducing the percentage of flea infestation and flea-load for 15 weeks post-treatment after which there was a sudden rise of the infestation and flea-load rates. Fenitrothion dust at 5 % was found every effective up to 15 weeks, and it continued to be effective by keeping the infestation and flea-load down to a gradual rise until 19 weeks after treatment (Fig. 3). All the three insecticides were also found to be effective against the field fleas *(S. Cognatus)* as indicated in Table 2, and equally effective against chiggers and lice (Table 4). There were significantly lower rates of infestation of mesostigmatic mites among the animal species during the first 15 weeks post-treatment in all the treated villages, and the rates increased to the pre-treatment level 16 weeks after treatment. This indicates that all the three insecticides have temporary effects on mesostigmatic mites (Table 4).

In some villages in Ciloto, Fanara et al. (1979) using 5 % malathion dust and 95 % ULV fenitrothion showed that both the chemicals controlled the Oriental rat flea on house rat for two to three months. In the present trials the effectiveness of 5 % malathion dust extended to 15 weeks, while 5 % fenitrothion dust extended the period to 20 weeks before it returned to levels of about 50 % (Table 3). For fenitrothion, it was obvious that the formulation of this chemical as a dust had a greater effect than 95 % ULV solution as it controlled the Oriental rat flea more than twice as long.

In the control village the LT_{50} of the Oriental rat flea with 4 % DDT impregnated papers after post-treatment was nearly 3 times higher than that of the pre-treatment levels in the treated village and the control village (Table 5 & 6). The higher degree of resistance of the Oriental rat flea to DDT post-treatment could be due to elimination of the susceptible portion of the population during the treatment periods. The susceptibility of the Oriental rat flea to 0.5 % malathion and 1.0 % fenitrothion impregnated papers during pre-treatment and in the control village conformed with the susceptibility of these insecticides to the Oriental rat flea from different villages in Ciloto by Fanara et al. (1979) who found an LC_{50} 2.3 % (=LT_{50} 13.8 hours) that of pre-treatment.

The present findings that Oriental rat flea on house rat in the Ciloto area are susceptible to 5 % malathion and fenitrothion dusts confirmed that these two insecticides are effective in the control of Oriental rat flea. There is a difference between the flea fauna in the plague endemic area and that of Ciloto area. In the plague endemic area, both Oriental rat fleas and field fleas are equally abundant, while in the latter area, the Oriental rat flea is dominant. Field fleas in the plague endemic area had been shown to be partially resistance to 0.5 % malathion in the susceptibility test, but highly susceptible to 1.0 % fenitrothion (Sustriayu et al., 1980). With this in mind, it is suggested that if there is any evidence of an outbreak of plague, 5 % fenitrothion dust should be the insecticide of choice to control flea vectors *(X. cheopis and S. cognatus)* in the plague endemic area of Central Java, Indonesia.

SUMMARY

A village-scale field trial with various insecticide dusts against *Xenopsylla cheopis on Rattus rattus diardii* was carried out in Ciloto area from February to November 1978. Three insecticide formulations, 50 % malathion wdp, 40 % fenitrothion wdp and 75 % DDT wdp were formulated by dilution with talc powder to

make 5 % active ingredients applied to three trial villages, and with an untreated control village near Ciloto Field Station. DDT dust at 5 % was not effective in controlling against the Oriental rat flea. Malathion at 5 % dust was found to control the Oriental rat flea up to 15 weeks only, while 5 % fenitrothion dust was effective until 15 weeks, and it continued to be effective until 19 weeks post-treatment. All three insecticide dusts were also found to be effective for chiggers and lice, but less so for mesostigmatic mites.

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