A VERANDAH-TRAP HUT FOR STUDYING THE HOUSE-FREQUENTING HABITS OF MOSQUITOS AND FOR ASSESSING INSECTICIDES. II.—THE EFFECT OF DICHLORVOS (DDVP) ON EGRESS AND MORTALITY OF *ANOPHELES GAMBIAE* GILES AND *MANSONIA UNIFORMIS* (THEO.) ENTERING NATURALLY

By Alec Smith

Tropical Pesticides Research Institute, Arusha, Tanzania

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A verandah-trap hut, designed to enable assessment to be made of the numbers of mosquitos that leave an experimental hut through the open eaves, together with studies on the egress from it of *Anopheles gambiae* Giles and *Mansonia uniformis* (Theo.) have been described by Smith (1965). It was found that, in the Umbugwe area of Tanzania, *A. gambiae* rarely left an untreated hut by the open eaves when window traps were available for egress. *M. uniformis*, on the other hand, left largely by the eaves and was caught in the verandah traps.

Methods

A dichlorvos (DDVP) dispenser was suspended in the middle of one hut, half-way between the ridge and the eaves, in order to study the effects of the insecticide both on the egress and on the mortality of *A. gambiae* and *M. uniformis* entering naturally. A second (untreated) hut was used as a control. The same methods of counting and collection were used as described in Part I, with additional observations to determine mortalities. Dead mosquitos were collected on the floor indoors and in the verandah and window traps. Delayed mortalities over a period of 24 hours were determined for mosquitos caught alive in the window and verandah traps. Experimental-hut assessments of kill inflicted by dichlorvos were complicated by the mode of action of the insecticide; it is brought into contact with the mosquito as a vapour that diffuses from a dispenser, and thus mosquitos confined in window traps are subjected to the fumigant action of the insecticide diffusing through the funnels of cotton netting. Additional studies were therefore made to assess the fumigant effect of dichlorvos in the window traps and in the verandah traps

The results are based on daily counts and collections, from 2nd March to 30th April 1964, from the hut treated with dichlorvos and from the untreated control hut. The dichlorvos was dispensed from a Ciba XI type dispenser opened on 2nd March.

Results

The egress and mortality of mosquitos entering treated and untreated huts

The numbers of living and dead mosquitos counted or collected daily from 2nd March to 30th April 1964, and their distribution within the verandah-trap huts, are shown in Table I, and the egress from the huts, calculated from the data in Table I, is shown in Table II. The numbers of mosquitos caught in the two operational verandah traps, as shown in Table I, are doubled in Table II

TABLE I. *The numbers of* A. gambiae *and* M. uniformis *counted or collected in verandah-trap huts*

	A. gambiae								*M. uniformis*							
	Unfed		Fed		Gravid		Total		Unfed		Fed		Gravid		Total	
	A	D	A	D	A	D	A	D	A	D	A	D	A	D	A	D
Treated hut																
Indoors	8	13	421	164	56	5	485	182	1	1	14	26	0	0	15	27
Window traps	16	2	35	16	76	8	127	26	12	1	71	33	2	4	85	38
Verandah traps	1	1	17	8	13	6	31	15	18	7	43	11	4	5	65	23
Total	25	16	473	188	145	19	643	223	31	9	128	70	6	9	165	88
Untreated hut																
Indoors	13	0	796	0	83	0	892	0	3	0	13	0	0	0	16	0
Window traps	102	13	142	9	500	0	744	22	24	0	72	5	3	0	99	5
Verandah traps	6	0	17	0	14	0	37	0	27	0	50	0	4	0	81	0
Total	121	13	955	9	597	0	1673	22	54	0	135	5	7	0	196	5

A, alive; D, dead.

to give the estimated total number leaving by the eaves. The window-trap catches are not doubled because the windows not leading to the two operational traps were kept closed.

The egress of *A. gambiae* and *M. uniformis* into the window traps, and through the eaves of the hut treated with dichlorvos, is shown in Table II, with results from the untreated control hut for comparison.

The results from the untreated hut show that 48 per cent. of *A. gambiae* in all gonotrophic stages left the hut each night, with 91 per cent. of the egress by the window traps and 9 per cent. by the eaves. With *M. uniformis*, on the other hand, 94 per cent. left the hut each night, with 39 per cent. of the egress through the window traps and 61 per cent. through the eaves. When recently fed mosquitos only were considered, it was found that 19 per cent. of *A. gambiae* left the same night after feeding, with 82 per cent. of the egress by the window traps and 18 per cent. by the eaves; with *M. uniformis*, 94 per cent. left the same night after feeding, with 44 per cent. of the egress occurring by the window traps and 56 per cent. by the eaves.

The results from the dichlorvos-treated hut, however, show that 27 per cent. of *A. gambiae* in all gonotrophic stages left the hut each night, with 62 per cent. of the egress by the window traps and 38 per cent. by the eaves. With *M. uniformis*, on the other hand, 88 per cent. left the hut each night, with 41 per cent. of the egress through the window traps and 59 per cent. through the eaves. When recently fed mosquitos only were considered, it was found that 14 per cent. of *A. gambiae* left the same night after feeding, with 50 per cent. of the egress by the window traps and 50 per cent. by the eaves; with *M. uniformis*, 84 per cent. left the same night after feeding, with 49 per cent. of the egress by the window traps and 51 per cent. by the eaves.

A smaller proportion (27%) of the number of *A. gambiae* present left the treated hut as compared with the untreated one (48%); but of those that did so a higher proportion (38%) left the treated hut by the eaves than left the untreated hut by this route (9%). Although a smaller proportion (88%) of the number of *M. uniformis* present also left the treated hut as compared with the untreated one (94%), about the same proportion (59%) left the treated hut by the eaves as left the untreated hut by this route (61%).

Mortalities were calculated from the basic data in Table I. The equation for assessing ' over-all mortality ' in a window-trap hut is as follows:

$$\text{Over-all mortality} = \frac{100\ (D + F)}{T + F},$$

where D = Number dead in the window trap,
F = Number dead on the floor,
T = Total in the window trap.

When egress from the eaves is taken into account the equation becomes:

$$\text{Over-all mortality} = \frac{100\ (D + 2V + F)}{T + 2M + F},$$

where D = Number dead in the two window traps,
F = Number dead on the floor,
T = Total in the two window traps,
V = Number dead in the two verandah traps,
M = Total in the two verandah traps.

Calculation of the over-all mortality of *A. gambiae* in the treated verandah-trap hut, for example, is as follows:

TABLE II. *The egress of* A. gambiae *and* M. uniformis *into window-traps and through the eaves of a verandah-trap hut treated with dichlorvos (DDVP)*

	A. gambiae								*M. uniformis*							
	Unfed		Fed		Gravid		Total		Unfed		Fed		Gravid		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Treated hut																
Indoors	21	49	585	85	61	33	667	73	2	3	40	16	0	0	42	12
Egress by windows	18	42	51	7	84	46	153	17	13	20	104	41	6	25	123	36
Egress by eaves	4	9	50	7	38	21	92	10	50	77	108	43	18	75	176	52
Total	43	100	686	99	183	100	912	100	65	100	252	100	24	100	341	100
Untreated hut																
Indoors	13	9	796	81	83	14	892	52	3	3	13	6	0	0	16	6
Egress by windows	115	82	151	15	500	82	766	44	24	30	77	41	3	27	104	37
Egress by eaves	12	9	34	4	28	4	74	4	54	67	100	53	8	73	162	57
Total	140	100	981	100	611	100	1732	100	81	100	190	100	11	100	282	100

$$\text{Over-all mortality} = \frac{100\,(26 + (2 \times 15) + 182)}{153 + (2 \times 46) + 182}$$

$$= \frac{23800}{427}$$

$$= 56 \text{ per cent.}$$

It should be noted that the number of mosquitos resting indoors is not brought into the equation. This is because of the cyclical pattern of entry, resting and egress; that is, mosquitos resting in a hut one day are the dead or surviving mosquitos of the next day. The equation assesses kill in a practical way by taking into account mosquitos that have died indoors, or died within 24 hours after leaving the treated hut, and by counting as survivors only those mosquitos that have left the treated hut and survived a further 24 hours.

The over-all mortalities including and excluding the fraction leaving by the eaves are shown in Table III. The results show that over-all mortalities in the treated hut were lower when the fraction leaving the eaves was included, and also that the over-all mortalities of *A. gambiae* were higher than those of *M. uniformis*.

TABLE III. *Over-all mortalities* (%) *of* A. gambiae *and* M. uniformis *in a dichlorvos-treated verandah-trap hut*

	A. gambiae		*M. uniformis*	
	Treated hut	Untreated hut	Treated hut	Untreated hut
Including fraction leaving by the eaves	56	3	34	2
Excluding fraction leaving by the eaves	62	3	43	5

The fumigant effect of dichlorvos on mosquitos confined in the traps

Experimental-hut assessments of kill, where the insecticide has a fumigant as well as a contact action, are complicated by the mortalities inflicted by the fumigant action of the insecticide on mosquitos confined in the window trap. While a polythene funnel fitted to a window trap greatly reduced mortality attributable to the fumigant action of dichlorvos on mosquitos confined in the traps, it seems likely that there may be a higher concentration of dichlorvos in the atmosphere in huts in which ventilation through the window trap has been greatly reduced by the use of a plastic funnel, and that this might account for the higher over-all mortalities in such huts (Smith, 1963*a*).

The fumigant effect of dichlorvos in different parts of a verandah-trap hut was studied by observing the mortalities of caged mosquitos placed in the hut, in the window trap and in the verandah trap. Mortalities 24 hours after exposure were observed in wild-caught blood-fed individuals of *A. gambiae* that were confined in cages of cotton mosquito netting measuring 6 × 3 × 3 in. Twenty mosquitos were placed in a cage, and the results, based on 40 to 480 mosquitos for each test, are summarised in Table IV; it can be seen that mortalities were highest indoors, lower in the window traps and lowest in the verandah traps. There were no mortalities during this period in caged mosquitos placed in similar positions in the untreated hut. The results from the treated hut are of value for comparative purposes, but the mortalities are excessively high compared with those of mosquitos entering naturally. Although close comparisons are not possible, due to wide differences between the two techniques, it seems likely that the higher mortalities in treated huts were partly due to the restricted ventilation in the cages and also to the dichlorvos vapour being absorbed by the cotton netting.

TABLE IV. *Percentage mortality in caged females of* A. gambiae *placed in different parts of a verandah-trap hut*

Age of dispenser in weeks (opened 4.v.64)	Indoors			Window traps			Verandah traps		
	Exposure time (hr.)	Mortality (%)	Number exposed	Exposure time (hr.)	Mortality (%)	Number exposed	Exposure time (hr.)	Mortality (%)	Number exposed
2	12	99	160	12	14	80	—	—	—
3	—	—	—	12	32	80	12	22	320
5	3	25	40	12	80	80	12	25	80
6	3	100	80	12	100	80	12	22	400
7	12	22	80	—	—	—	12	15	320
8	3	66	240	—	—	—	12	26	480

TABLE V. *The average amounts of dichlorvos vapour, in μg. absorbed per minute, on filter papers placed in different parts of a verandah-trap hut*

Experiment	No. of tests	Age of dispenser (weeks)	Indoors μg./min.	Window traps		Verandah traps	
				μg./min.	Percentage of amount absorbed indoors	μg./min.	Percentage of amount absorbed indoors
1	17	3	·0034	·0017	50	·00028	8
2	19	9	·0039	·00178	46	·00024	6
3	6	2	·0050	—	—	·00059	12
4	17	2	·0074	—	—	·00059	8

The concentrations of dichlorvos vapour in different parts of the verandah-trap hut were compared by determining, by an anticholinesterase method (Webley & McKone, 1963), the amount of dichlorvos absorbed by filter papers suspended there for a known length of time. The results of a total of 59 chemical analyses are summarised in Table V, and those of experiments 1 and 2 show that, on average, the verandah traps contained less than a quarter of the concentration of dichlorvos in the window traps.

Discussion

The results show that, over a period of two months, a Ciba XI dispenser gave average over-all mortalities of 56 per cent. for *A. gambiae* and 34 per cent. for *M. uniformis*. Over a period of 24 hours, a greater proportion of *A. gambiae* that entered the dichlorvos-treated hut were killed than left, with a greater proportion (38%) of the egress from the treated hut compared with the untreated hut (9%) occurring through the eaves. This finding may be interpreted as indicating that there was an earlier egress from the treated than from the untreated hut. The explanation offered for the greater use of the eaves for egress from the treated hut is that *A. gambiae*, exposed to a repellent insecticide, prematurely leaves the hut at night and is thus more prone to leave by the open eaves than by the window trap since there is no directional source of light before dawn to guide it towards the window (Smith, 1963*b*).

The effect of dichlorvos on *M. uniformis* was somewhat different, as might be expected from its habits (Smith, 1965). The lower over-all mortality of 34 per cent. may have been due to its short exposure to the insecticide, since it normally left a hut during the same night as it took a blood-meal, unlike *A. gambiae*, most of which normally rest indoors for at least 24 hours after feeding. Any differences in intrinsic susceptibility to the insecticide could also have affected the kill. There was no effect of dichlorvos on the egress of *M. uniformis* through the eaves, which may in some way be related to its normally greater use of the eaves for egress than *A. gambiae* (Table II).

Summary

Assessment of the effects of dichlorvos (DDVP), released from a Ciba XI dispenser, on females of *Anopheles gambiae* Giles and *Mansonia uniformis* (Theo.) entering a verandah-trap hut in the Umbugwe area of Tanzania was made over a period of two months in 1964. Of the numbers of *A. gambiae* that entered one treated and one untreated hut, 27 per cent. of those entering the hut treated with dichlorvos and 48 per cent. of those entering the untreated hut left again. Of the numbers leaving each hut, 38 per cent. left through the eaves of the treated hut as compared with 9 per cent. in the untreated one. In the case of *M. uniformis*, 88 per cent. of those entering the treated hut and 94 per cent. of those entering the untreated hut left again. Of the numbers leaving each hut, 59 per cent. left through the eaves of the treated hut as compared with 61 per cent. in the untreated one.

Over-all mortalities were 56 per cent. for *A. gambiae* and 34 per cent. for *M. uniformis* when the eave-egress fraction from the treated hut was taken into account, compared with 62 per cent. for *A. gambiae* and 43 per cent. for *M. uniformis* when the eave-egress fraction was ignored.

The results of bioassays and of chemical analyses showed that the problem of mortality from fumigation *in situ* was considerably less in verandah traps than indoors or in window traps fitted with funnels of cotton netting.

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