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FIELD EXPERIMENTS ON THE BEHAVIOUR OF MALARIA VECTORS IN AN UNSPRAYED HUT AND IN A HUT SPRAYED WITH DDT IN NORTHERN NIGERIA

by

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1. Introduction

House spraying with residual insecticides against adult anophelines is an effective and widely used anti-malaria measure today. In the Mass Control Campaign in Northern Nigeria routine house spraying has been carried out continuously since 1954 (Bruce-Chwatt, Archibald & Haworth, 1958). At first, DDT, dieldrin and BHC were applied against the local malaria vectors Anopheles gambiae Giles and A. funestus Giles. After development of insecticide resistance in A. gambiae against dieldrin (Elliott & Ramakrishna, 1956; Davidson, 1956a) and cross-resistance to BHC (Davidson, 1956b) all the house spraying had to be switched over to DDT. Since October 1957 all the houses in the area have been treated with this insecticide which is applied now at the rate of 1.9 g/m^2 techn DDT w.d.p. twice a year, as a result of which there has been an enormous drop in the numbers of A. gambiae and A. funestus resting indoors. This drop was followed by a marked decrease in the parasite index in the human population. However, the interruption of malaria transmission has not yet been achieved (Archibald, 1959). The vector densities in the huts are still low, the mosquitos are still susceptible to DDT, and there are no indications of secondary vectors so far. This suggests that a number of vectors escape the lethal effect of the DDT, and that the proportion is large

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enough to maintain the life cycle of the malaria parasites. Various reasons, e.g. poor spraying, presence of unsprayed huts, outdoor resting of vectors, etc., could account for the failure to interrupt transmission. Among other investigations those on the behaviour of the local vectors in treated huts were indicated. In particular it appeared that observations to determine whether the mosquitos enter sprayed houses in the same number as the unsprayed ones, and on the fate of those specimens which enter treated houses, would be of interest. Experimental investigations designed to throw some light on these questions were started in Northern Nigeria in August, 1958 and continued over 15 months. Preliminary results obtained with A. funestus have been published elsewhere (Kuhlow, 1959). The present paper deals mainly with observations on A. gambiae.

2. Locality and technique

2.1 Locality

In order to obtain sufficient numbers of mosquitos the experiments were carried out in the unsprayed zone. Therefore, it should be kept in mind, the results obtained do not necessarily reflect the conditions in the neighbouring sprayed area.

The village of Natsini in Western Sokoto was selected for the investigations because of its high mosquito density and because it is accessible by car the whole year round. Natsini is situated in the Sudan Savannah zone of Northern Nigeria. The annual rainfall is about 760 mm, of which 90% falls in the rainy season (June to September). The daily temperatures vary considerably. In the winter months when the cool and dry harmattan wind blows from the Sahara, the relative humidity decreases to 10% and less in the afternoon and at night the temperature at Natsini sometimes drops to 8.9°C. Soon after the harmattan stops the temperature increases sharply and the daily maximum temperature during March, April and May is between 40°C and 45°C and may even be more.

Like most of the people in the Sokoto Province the villagers of Natsini belong to the Hausa ethnic group. The families live in compounds consisting normally of two or more huts enclosed by a high fence of straw mats or mud. Only infants sleep with their mothers in the same hut, while older children have their own.

2.2 Technique

The behaviour of the local malaria vectors in sprayed and unsprayed houses is best studied by means of experimental huts fitted with exit window traps. This technique was introduced by Muirhead-Thomson (1947) and has proved to give a reliable estimate of the fate of mosquitos entering sprayed houses. Our huts and methods have been described before but some repetition may be appropriate.

2.3 Experimental huts

In order to obtain results under conditions as similar to the normal local ones as possible, no special huts were built, but ordinary inhabited huts used for the experiments. The villagers let us have two suitable huts in which older boys slept and which were accessible to us at any time. The two huts were of the local round type, 300 and 340 cm in diameter with the walls 145 and 160 cm high, built of mud only, and conical thatch roofs 310 and 320 cm high at the centre. The only openings in the huts were the entrance and small spaces between the top of the wall and the roof, which were only 1 - 3 cm wide. For the window traps a 30 x 30 cm wide opening facing south-east was made in the wall of both houses. One of the huts ("A") was left unsprayed for control, the other one ("B") was sprayed with DDT. Both huts were free of ants.

2.4 Window traps

The traps constructed were similar to those described by Muirhead-Thomson. A wooden frame, 30 cm cubed, was covered with green mosquito gauze. One side of the trap was inverted to form a funnel, supported by a wire frame and ending in an opening 1.5 cm wide about 3 cm from the opposite wall. The mosquitos caught could be taken out through a sleeve. Strips of plywood, 15 cm wide, were fixed on the front of the trap in order to keep it in position in the window opening and to cover the small space between the wall and trap. The traps were protected against rain by the overhanging roof.

In the initial stage of the work contamination of the traps became obvious from high mortalities among mosquitos obtained from the trap of the control hut. For this reason the figures obtained in that period were discarded when estimating the survival rate. After thoroughly cleaning the traps with acetone, the control mortalities fell to low levels and remained low for the rest of the experiments.

2.5 Methods of collection

Both experimental huts were used in the same way and all the work was done under constant personal supervision. The huts were visited five times per month, usually two or three nights in succession. Before the beginning of each catching period the huts were flitted with a commercial preparation of pyrethrum in the early morning in order to clear them of resting mosquitos. At dusk, the window traps were fixed and a big clean white sheet spread on the floor, properly stretched to the wall. At about 20.00 hours equal numbers of people, usually five, entered the huts. They were instructed not to cover their legs or to kill biting mosquitos.

At 22.00 hours the doorway was closed by a dark blue sheet, after which time the eaves provided the only means of entry for mosquitos. At sunrise the floor sheets were folded up loosely, taken out and the dead mosquitos were collected. Then the traps were removed, the window openings closed, another sheet spread on the floor, the huts flitted and the killed mosquitos picked up from the spray sheet. The dead mosquitos in the traps were taken out and the living specimens transferred into paper cups covered with mosquito netting and provided with cotton wool soaked in sugar solution; they were kept in another suitable hut for a further 24 hours. At the end of this period, the numbers of survivors and of those which had died were recorded. The abdominal condition of all the anophelines obtained in the experiments was noted. Males caught are not included in the tables.

2.6 Spraying

The hut was sprayed for the first time on 8 August, 1958 by an experienced sprayman of the Malaria Scheme in the same way as the routine house sprayings in the Campaign. Using a Hudson X-Pert compression sprayer and a pump charge of 16 oz. technical DDT w.d.p. the total inner surface of the hut was treated at a rate of 1.9 g/m^2 DDT (= 1.4 g/p'p' isomer). However, entomological and chemical findings soon indicated that the insecticide deposit inside the hut was not sufficient. For this reason the hut was resprayed on 12 September, 1958 with a strong dose of 3.8 g/m^2 DDT. The next two sprayings of the hut with 1.9 g/m^2 DDT were carried out in six monthly intervals on 4 March, 1959 and 2 September, 1959. The insecticidal deposit in the hut was checked at intervals using the Alessandrini method. The results have been published elsewhere (Kuhlow, 1960).

3. Results

3.1 General observations

The seasonal abundance of A. gambiae and A. funestus varied considerably. Details of the average densities of the two species per hut and day (females only) obtained from routine spray catches during the period the experiments were carried out are given in Table I. In the day-time most of the mosquitos rest on the upper wall and on the roof of a hut where they are less disturbed by the inhabitants. In the morning, when people cook their meal indoors, the upper part of the hut is full of smoke. The mosquitos descend temporarily to the lowest part of the wall, but rarely leave the hut.

TABLE I. AVERAGE DENSITY OF A. GAMBIAE AND A. FUNESTUS PER HUT AND DAY AT NATSINI (FEMALES ONLY)

	A. gambiae	A. funestus
1958		
August	464	52
September	343	22
October	29	35
November	32	127
December	43	118
1959		
January	4	78
February	2	126
March	2	167
April	20	56
May	44	11
June	28	7
July	308	2
August	878	12
September	550	130
October	46	43

Other anopheline mosquitos found resting in huts quite frequently were A. pharoensis, and more rarely and for a limited season A. wellcomei, A. flavicosta, A. rufipes, A. coustani, A. squamosus, and A. nili.

Pre-experimental spray catches in the huts selected for the behaviour investigations were carried out monthly. From March to August, 1958 we obtained from hut "A": 8, 39, 15, 1, 818 and 537 female A. gambiae and from hut "B": 6, 18, 10, 6, 613 and 637, respectively. This indicates that both huts were suitable as resting places for A. gambiae. They were also suitable for A. funestus as was shown before.

Night catches on human bait were carried out as routine indoors and outdoors and continued from dusk to sunrise. The results obtained show that the main biting activity of A. funestus is between 22.00 and 01.00 hours. A. gambiae feeds predominantly after midnight between 01.00 and 04.00 hours, but continues to bite up to sunrise. The only other anopheline caught biting man readily was A. pharoensis. Its main activity was from dusk to midnight.

The gonotrophic cycle in A. gambiae was found to be two days. Specimens caught are recorded as fed when the blood meal was taken in the previous night, as gravid when taken the night before that, and as unfed.

3.2 Behaviour in the unsprayed hut "A"

The A. gambiae obtained from hut "A" and its trap are consolidated for each month after the last spraying of hut "B" and shown in Table II. The abdominal condition of the mosquitos caught is recorded in Table IV.

A total of 8736 A. gambiae entered hut "A" during the time under observation. More than 95% of them were caught during the rainy season July to September. The very high catches in August and September, 1959 are due to prolific breeding following unusually heavy rains in July and August in that year. However, the figures are smaller than the number obtained by spray catches from normal huts. In the latter the mosquitos also have the opportunity of entering through the entrance. This is mostly open or only closed by a mat, leaving plenty of space for entering.

There were only very few mosquitos dead on the floor sheet. They were obviously squashed by the sleepers, who were worried not only by anophelines but also by culicines, bedbugs, body-lice and Auchmeromyia larvae.

TABLE II. RESULTS OF CATCHES OF A. GAMBIAE FROM UNSPRAYED HUT "A"

	Number of months after last spraying of hut "B"																Total caught	Per cent.
	1958 Aug 1		Sept 1	Oct 2	Nov 3	Dec 4	1959 Jan 5	Feb 6		Mar 1	Apr 2	May 3	June 4	July 5	Aug 6		Sept 1	Oct 2		
Total entering hut	417		313	16	20	23	14	2		9	8	58	40	288	2 002		5 441	85	8 736	
Dead on floor sheet	7 2%		3 1%	- -	- -	2 9%	1 7%	- -		- -	- -	- -	- -	- -	9 <1%		21 <1%	- -	43	0.57
Alive in hut	270 65%		250 80%	8 50%	14 70%	15 65%	10 71%	1 50%		5 56%	8 100%	51 88%	38 95%	264 92%	1 803 91%		4 762 88%	77 81%	7 576	87
Caught in window trap	140 33%		60 19%	8 50%	6 30%	6 26%	3 22%	1 50%		4 44%	- -	7 12%	2 5%	24 8%	190 9%		658 12%	8 9%	1 117	13

TABBE III. RESULTS OF CATCHES OF A. GAMBIAE FROM SPRAYED HUT "B"

	Number of months after last spraying																		Total caught	Per cent.
	1958 Aug 1		Sept 1	Oct 2	Nov 3	Dec 4	1959 Jan 5	Feb 6		Mar 1	Apr 2	May 3	June 4	July 5	Aug 6		Sept 1	Oct 2		
Total entering hut	446		346	18	15	17	-	-		1	3	10	13	193	1 144		3 292	44	5 542	
Dead on floor sheet	117 26%	Resprayed	148 43%	7 39%	8 53%	7 41%	-	-	Resprayed	- -	- -	2 20%	1 8%	13 7%	202 18%	Resprayed	1 908 58%	15 34%	2 428	43
Alive in hut	24 6%		4 1%	1 6%	- -	3 18%	- -	- -		- -	- -	2 20%	1 8%	18 9%	58 5%		46 2%	1 3%	158	3
Caught in window trap	305 68%		194 56%	10 55%	7 47%	7 41%	- -	- -		1 100%	3 100%	6 60%	11 84%	162 84%	884 77%		1 338 40%	28 63%	2 956	54

Most of the A. gambiae entering the unsprayed hut remained resting inside after feeding on the occupants. In the wet season the catch consisted of 11% unfed, 85% fed, and 4% gravid females. In the dry season the specimens caught were 3% unfed, 73% fed and 24% gravid. The proportion of males caught was 9% of the total catch in the wet season and 1.5% in the dry one.

A small proportion of A. gambiae left the hut the same night as they entered. Most of them were unfed. On checking the trap in the morning, an average of 3% were dead, all unfed specimens. During the 24 hours period the mortality increased to a total of 9%, of which 83% were unfed females. Among the males, 55% left the hut at dawn. While it may appear strange at first sight that the gravid females in the trap formed such a small proportion of the total gravid-catch and of the total trap-catch, this is really an expected result in view of the spray-catches made on the days before the trap was operated. Those spray-catches evidently eliminated most of the gravid females which would have reached the trap on the succeeding nights.

For A. funestus the total catch obtained from the unsprayed hut in 15 months was 1547 specimens. Sixteen (1%) mosquitos were collected dead from the floor sheet, 872 (56%) were found alive in the hut, and 659 (43%) were obtained from the window trap.

3.3 Behaviour in the sprayed hut "B"

The behaviour of the mosquitos in hut "B" was watched during the application of the first spray. They immediately showed signs of intense irritation or repellency. In the course of the next hour almost all left the hut.

The A. gambiae obtained from hut "B" and its trap are recorded in Table III and their abdominal condition is shown in Table IV. The total A. gambiae collected in hut "B" was only two thirds of that entering hut "A".

A considerable number of A. gambiae which entered the hut were killed inside by the action of the DDT. Nearly all of them had had a blood meal before. Only a small number of A. gambiae remained alive in the hut and were obtained by spray catches in the early morning. They might have entered not long before or have rested on untreated household effects.

The most striking feature of the results is the considerable number of mosquitos which left the sprayed hut and the high proportion which escaped unharmed. In the first three months after treatment 45% of the A. gambiae left the hut the same night as they entered. This proportion increased in the next three months to 78%.

The average mortality after 24 hours during the first three months after application of the DDT was 75% (Table VI). However, during the following three months up to the next spraying the 24 hours mortality was only 21%. This shows clearly that the lethal effect of the DDT had decreased markedly. The results indicate that the DDT prevented some A. gambiae from feeding, since the proportion of the total catch in hut "B" which were unfed was 24%, compared with only 11% in hut "A". It is also significant that in the sprayed hut only about one in ten of the unfed A. gambiae were found dead on the floor-sheets, whereas the proportion of the bloodfed-catch found on the floor-sheets was more than half.

For A. funestus the total catch obtained from the sprayed hut in the course of 15 months was 483 specimens. One hundred and forty-one (29%) mosquitos were obtained dead from the floor sheet, 20 (4%) were found alive in the hut and 322 (67%) were collected from the window trap. The average proportion of the A. funestus which left the hut in the first three months after spraying was 54%. It increased in the following three months to 80%. The 24 hours mortality for A. funestus during the first three months after spraying was 73% and dropped during the next three months to 30%.

3.4 Observations on other anophelines

Apart from A. gambiae and A. funestus, seven other anopheline species were obtained from the experimental huts. The results are consolidated and shown in Table V. The figures for A. coustani, A. flavicosta, A. nili, A. rufipes, A. squamosus, and A. wellcomei are too small for any conclusions. Only A. pharoensis was caught in reasonable numbers. The most striking feature of the results is the high catch in the sprayed hut, which is 286% of that in the unsprayed hut. Unfortunately, the pre-experimental figures for A. pharoensis, obtained in a season of low density of this species, are too small to show if both huts were equally attractive as resting places. Therefore no conclusion can be drawn on this observation. As a mainly exophilic

TABLE IV. ABDOMINAL CONDITION OF A. GAMBIAE AND A. FUNESTUS FROM BOTH EXPERIMENTAL HUTS
Figures in brackets refer to percentage of total catch. U unfed, F fed, G gravid.

		A. gambiae			A. funestus		
		U	F	G	U	F	G
Unsprayed hut	Total catch	928 (11)	7 377 (84)	431 (5)	320 (22)	981 (66)	187 (12)
	Dead on floor sheet	10 (<1)	32 (<1)	1 (<1)	2 (<1)	12 (<1)	3 (<1)
	Alive in hut	97 (1)	7 102 (81)	377 (4)	15 (1)	699 (48)	123 (8)
	In trap	821 (10)	243 (3)	53 (1)	303 (20)	270 (18)	61 (4)
Sprayed hut	Total catch	1 310 (24)	4 148 (75)	84 (1)	156 (34)	271 (59)	33 (7)
	Dead on floor-sheet	133 (3)	2 292 (41)	3 (<1)	14 (3)	109 (24)	2 (<1)
	Alive in hut	11 (<1)	140 (3)	7 (<1)	3 (1)	9 (2)	8 (2)
	In trap	1 166 (21)	1 716 (31)	74 (1)	139 (30)	153 (33)	23 (5)

TABLE V. OTHER ANOPHELINE MOSQUITOS OBTAINED FROM THE EXPERIMENTAL HUTS

		A. coustani	A. flavicosta	A. nili	A. pharoensis	A. rufipes	A. squamosus	A. wellcomei
Unsprayed hut	Total entering hut	11	14	1	328	16	4	18
	Dead on floor sheet	0	0	0	7	0	0	0
	Alive in hut	0	13	1	113	14	0	1
	Caught in window trap	11	1	0	208	2	4	17
	Dead after 24 hours	0	0	0	11	0	1	1
Sprayed hut	Total entering hut	8	19	2	874	8	8	35
	Dead on floor sheet	0	9	1	249	1	1	11
	Alive in hut	0	4	0	5	3	0	0
	Caught in window trap	8	6	1	620	4	7	24
	Dead after 24 hours	8	5	1	128	1	3	12

species only one third of the A. pharoensis entering hut "A" remained inside. The other two thirds left at dawn. Nevertheless a reference to Table V will show that the over-all mortality among 874 A. pharoensis collected during six months from the sprayed hut was 43%.

4. Discussion

4.1 Previous observations

Observations on the behaviour of malaria vectors in DDT sprayed houses have been reported from many parts of the world - Tarzwell & Fisk (1947); Symes & Hadaway (1947); van Thiel & Metselaar (1953); Reid & Warton (1956); et al. However, it is not clear if the behaviour of all species of anopheline mosquitos in DDT sprayed houses is the same. Therefore observations dealing with A. gambiae and A. funestus are of particular interest.

The important investigations of Muirhead-Thomson (1947, 1950) in West and East Africa indicated that the large decrease of anophelines resting in DDT sprayed houses in day-time may give a completely misleading picture of the reduction of mosquitos achieved. In his experiments large numbers of A. gambiae and A. funestus entered treated houses. But when trying to rest on the wall after feeding, they were irritated by contact with the DDT deposit and left the hut, nearly all of them before having picked up a lethal dose. Hocking (1947) on the contrary could show in his investigations in Kenya, that despite the irritant effect of the DDT a very high kill can be achieved, provided the dose of insecticide applied is strong enough. However, the very discouraging results on the value of DDT in mosquito control given by Muirhead-Thomson have stimulated other investigators in Africa to repeat those experiments. Wilkinson (1951) in Uganda, and Davidson (1953) and Burnett (1957) in Kenya have used huts and methods very similar to those described by Muirhead-Thomson. However, their results did not confirm either the complete failure of DDT in controlling A. gambiae and A. funestus or the promising conclusions of Hocking. The three authors obtained kills between 40% and 80% for the first six months after treatment.

TABLE VI. MORTALITY OF A. GAMBIAE AND A. FUNESTUS FROM THE SPRAYED HUT *

	A. gambiae		A. funestus	
Months after last spraying	1-3	4-6	1-3	4-6
Total catch	3 301 100%	1 273 100%	108 100%	27 100%
Dead inside hut	1 925 58%	216 17%	49 46%	5 19%
Dead in window-trap	548 16%	43 3%	21 19%	3 11%
Died in 24 hours period	21 1%	7 1%	9 8%	0 0%
Total dead after 24 hours	2 494 75%	266 21%	79 73%	8 30%

* Mosquitos caught alive resting in the hut are excluded from calculation because it remains uncertain whether they would have died during the 24 hours period.

4.2 Mortality in present experiments

In the present experiments a considerable drop of the lethal effect of the DDT has been observed in subsequent months after spraying. The mortality achieved was never 100%, not even in the first night after application of the spray. However, in subsequent months the percentages of mosquitos found dead inside the hut, collected dead from the trap, and dying during the following 24 hours decreased markedly (Table VI). Increasing proportions of mosquitos were able to leave the hut. In the first three months after treatment, 25% of the A. gambiae left unharmed, 50% having already fed. During the next three months the proportion leaving unharmed rose to 79% of which 67% had taken a blood meal before.

These observations are in agreement with our chemical estimations which showed a very high loss of the DDT deposit over six months. Further indications are the results of bio-assays carried out in the sprayed area, which showed a notable drop in the lethal effect of the DDT residue after four months (Kuhlow, 1960). However, it has to be remembered that the results obtained from the chemical and bio-assay tests refer to the wall of the hut only. Many mosquitos were found resting in the thatch of the roof, which represents a considerable proportion of the inner surface of a hut. It is possible (Langbridge, 1958) that on the thatch the DDT residue wears off earlier and therefore the loss of its lethal effect in a hut can be noticed earlier as shown by the bio-assays.

However, it can be observed (Table III) that the mortality of the mosquitos which died inside the hut in the first month after the various sprayings, increased from 26% to 43% and to 58%. Probably this effect was due to the cumulative action of the DDT deposit.

4.3 Other observations

4.3.1 Entry

The results obtained in Northern Nigeria show that house spraying with DDT does not prevent A. gambiae and A. funestus from entering houses in large numbers. Several workers have observed this before but they have also noticed a marked reduction in the number of entering mosquitos (Gebert, 1948; Muirhead-Thomson, 1950; Wilkinson, 1951). In our own experiments, a reduced entry is particularly obvious in A. funestus. Only 31% of the number which entered the unsprayed hut were obtained from the sprayed one, while for A. gambiae this proportion was 64%.

The reason for the reduction is not yet clear. Wilkinson (1951), from whose wood and fibre huts unrecorded escapes seemed unlikely, did not observe increased exit. He concluded that a repellent effect of the DDT must have been present or else a masking of the human smell by the insecticide. Davidson (1953) from the results of his cage tests discounted any repellent effect, but was able to demonstrate a particulate effect probably due to the presence of airborne particles of the insecticide. Reid & Wharton (1956) believe this particulate effect to be the cause of reduction of

entering mosquitos. However, this particulate effect is very slight for DDT and does not last long (Davidson, 1953). Our results show a very marked depression of entry even five and six months after the last spraying and make it unlikely to be due to airborne particles of the DDT.

More likely a repellent effect of the DDT will account for the reduced entry. This has been concluded already by Downs & Bordas (1951) from their experiments with A. pseudopunctipennis in Mexico. Recently de Zulueta et al. (1961) reported a marked repellent effect of the DDT in reducing the numbers of A. gambiae coming into their sprayed hut in Uganda.

4.3.2 Biting

Most of the mosquitos entering took a blood meal. However, a certain decrease in the biting rate became obvious from the higher percentage of females which left the hut without feeding. Compared with the unsprayed hut, there was an increase in the proportion of unfed females of 13% for A. gambiae and 12% for A. funestus (Table IV). A similar observation was made by Muirhead-Thomson (1950), who reported an increase of unfed mosquitos of 14% in his treated hut.

4.3.3 Resting

The effect of house spraying with DDT on the resting of A. gambiae and A. funestus is clearly shown by the increased exit of the mosquitos. Compared with the unsprayed hut this rose from 13% to 54% for A. gambiae and from 43% to 67% for A. funestus, due to the irritant effect of the DDT. Unfortunately, this irritant effect is largely independent of the lethal action and is longer lasting. Four to six months after spraying the proportion of A. gambiae, A. funestus and A. pharoensis leaving the hut and being irritated is still very high, even higher than in the first three months (Table III). The irritation becomes particularly obvious when the loss of the lethal effect enables increasing numbers of mosquitos to leave the hut. Davidson (1953) noticed the irritant effect of the DDT in all the nine months of his investigations in Kenya.

4.3.4 Normal behaviour

Catches on successive days have shown that flitting of the hut with pyrethrum in kerosene in the morning does not effect the result of the catch on the following night. It has been shown before by Muirhead-Thomson (1947) that application of kerosene may

have a strong repellent effect. But in his experiments the walls were treated with high pyrethrum concentrations, whereas ours were much lower and the spray fell mainly on the floor sheets which were removed from the hut.

In the house-haunting habits, certain differences between A. gambiae and A. funestus have been observed in our experiments. A high proportion of the A. gambiae entering a hut fed and remained inside. Very few specimens left the house during the same night (Tables II and IV). As shown before (Kuhlow, 1959), there is a noticeable daily movement in the A. funestus population of a hut. Twelve per cent. of the mosquitos entering were gravid and 22% left again without feeding. Of the total A. funestus entering, 43% left the hut during the same night. There was also a marked seasonal variation in the proportion which remained in the hut. Similar observations were made by Davidson (1953) in Kenya, who considered A. funestus as a less house-haunting species than A. gambiae.

However, the resting habits of A. gambiae and A. funestus seem to vary in different parts of Africa. Barber et al. (1932) in Liberia and Hocking & MacInnes (1948) in Kenya conclude from their observations that both species, in all abdominal conditions, show a considerable turnover every night. On the other hand, it has been observed in Transvaal by de Meillon (1934) and in Tanganyika by Muirhead-Thomson (1951) and Gillies (1954) that almost all A. gambiae and A. funestus remain inside the huts after feeding, many of them until they are fully gravid.

The less house-haunting habit of A. funestus observed in Northern Nigeria may account for the fact that this species still occurs in that area despite six years of spraying with residual insecticides. In other parts of Africa A. funestus has vanished after application of house spraying very soon, as in the sprayed areas of Mauritius (Dowling, 1956), Swaziland (Mastbaum, 1957) and Tanganyika (Smith, 1957).

5. Conclusion

The results obtained have shown that a considerable number of local malaria vectors entering DDT sprayed huts do not rest long enough on the treated surface to acquire a lethal dose and are able to leave the hut unharmed. Under the local conditions the DDT residue showed a rapid loss of its lethal action but its irritant property remained effective for a long period. Therefore it seems advisable to spray the houses heavily enough to ensure that resting mosquitos acquire a lethal dose before

they become irritated. The observations made suggest that the dose of 1.9 g/m^2 techn. DDT twice a year may not have been sufficient to interrupt malaria transmission especially if the coverage was not total. Under the special local conditions of Northern Nigeria with holo-endemic malaria, huts built of absorbent mud, and with as efficient malaria vectors as A. gambiae and A. funestus, the application of a heavier dose of DDT seems indicated.

6. Summary

The behaviour of A. gambiae and A. funestus in unsprayed and DDT sprayed houses in Northern Nigeria has been investigated by means of local huts fitted with window exit traps. Some results obtained with other anophelines are reported.

Observations in the unsprayed hut have shown that most of the A. gambiae remain inside the house after feeding. In A. funestus a noticeable movement has been observed. A high proportion left the hut in the same night as they entered it.

The results obtained from the treated hut revealed that the spraying with DDT does not prevent the mosquitos from entering, but a reduction in number was observed. Only 64% of the number of A. gambiae and 31% of the A. funestus, which entered the unsprayed hut, entered the sprayed one. Most of those mosquitos entering fed inside, but a higher proportion of unfed females in the treated hut indicates a certain depression of the biting rate.

The most striking observation was the large number of mosquitos which left the sprayed hut and the considerable proportion which escaped unharmed. Both figures show a very marked increase in subsequent months after the last spraying. In the first three months after treatment, 71% A. gambiae and 73% A. funestus were killed and 19% and 26% respectively in the following three months. This indicates a rapid loss of the lethal action of the DDT residue, whilst its irritant property was seen to be long lasting.

It is concluded that under the particular local conditions in Northern Nigeria the present application of 1.9 g/m^2 DDT twice a year will not be sufficient to interrupt malaria transmission.

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