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Mathis,Willis; St.Cloud,Arlen; Eyraud,M.; Miller,Steve; Hamon,J.

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Initial Field Studies in Upper Volta with Dichlorvos Residual Fumigant as a Malaria Eradication Technique*

2. Entomological Evaluation

W. MATHIS,[1] ARLEN ST. CLOUD,[1] M. EYRAUD,[2] STEVE MILLER[3] & J. HAMON[4]

In mud houses in Wakara, Upper Volta, dichlorvos dispensers installed at the rate of one dispenser per approximately 500 cubic feet (14 m³) produced 70% or higher average kills of adult Aëdes aegypti, *exposed overnight in screen wire cages suspended at levels of 6 feet (1.8 m) and 2 feet (0.6 m), for approximately three months during the wet season and four months during the dry season. Average kills of 96% and 80% were obtained in the dry season at the 6-foot and 2-foot levels, respectively, with 6-hour daytime exposures 17-22 weeks after treatment.*

The general plan of work and the over-all experiment with dichlorvos as a residual fumigant for malaria control in the test village of Wakara, Upper Volta, have been described in the preceding paper.[5]

The entomological studies consisted of preliminary tests to determine the numbers of dispensers necessary per unit-volume of space and post-treatment evaluation of the effectiveness of each of the three applications.

PROCEDURE

The preliminary tests were conducted during the last week in May 1961, when maximum daily temperatures ranged from 86°F to 94°F (30°C-34.5°C) and the relative humidity averaged approximately 30%. The dispensers used were prepared in February 1961 at Savannah, Ga., and transported by air to Bobo-Dioulasso in May. One dispenser in a room of 840 cubic feet (23.7 m³) was found to provide an average concentration of 0.115 μg of dichlorvos per litre of air during the 3-day period sampled. With one dispenser per 420 cubic feet (11.9 m³), the average air concentration was 0.219 μg for the same period.

Since 0.115 μg of dichlorvos per litre of air was well above the dosage previously found[6] to produce complete mortality of *Anopheles quadrimaculatus* in overnight exposures, an attempt was made to treat all houses in the village at a similar rate. With the initial treatment, begun on 26 June and completed on 6 July, the general rate was one dispenser per 500-1000 cubic feet (approximately 14-28 m³). Before treatment, each room was measured and the volume calculated. The required numbers of dispensers were suspended from the ceiling of each room, usually within a few inches of the 7- to 9-foot (2.1-2.7 m) ceiling. Each dispenser was encased in a

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[1] Entomologist (Medical), Biology Section, Technical Development Laboratories, Technology Branch, Communicable Disease Center, Public Health Service, US Department of Health, Education, and Welfare, Savannah, Ga., USA.

[2] Research Assistant, Office de la Recherche scientifique et technique outre mer, Centre Muraz, Organisation de coopération et de coordination pour la lutte contre les grandes endémies, Bobo-Dioulasso, Upper Volta.

[3] Biochemist, Chemistry Section, Technical Development Laboratories, Technology Branch, Communicable Disease Center, Public Health Service, US Department of Health, Education, and Welfare, Savannah, Ga., USA.

[4] Medical Entomologist, Office de la Recherche scientifique et technique outre mer, and Chief of the Entomology Laboratory, Centre Muraz, Organisation de coopération et de coordination pour la lutte contre les grandes endémies, Bobo-Dioulasso, Upper Volta.

[5] See the article by Quarterman et al. on page 231 of this issue.

[6] Mathis, W., Miles J. W. & Schoof, H. F. (1961) *Bull. Wld Hlth Org.*, 24, 646.

cylinder of 4 × 4 mesh galvanized hardware cloth. These dispensers were from the same batch as that used in the preliminary test but had been shipped by boat to Abidjan, Ivory Coast, and by rail to Bobo-Dioulasso, arriving there on 13 June.

The second treatment was made during the period 8-22 August, when dispensers from a new shipment were installed in all sleeping-rooms of the village at the rate of one dispenser per 500 cubic feet of space. These dispensers had been made in Savannah during July and shipped immediately to Bobo-Dioulasso by air freight. An assumption was made that the dispensers used during the first treatment were still performing at 50% of the capacity of the new ones. Consequently, the old dispensers were placed in rooms not used for sleeping at the rate of one " used " dispenser per 250 cubic feet (7 m^3). A third treatment was made between 23 October and 1 November following the pattern used in the August treatment. In addition, all rooms were treated with new dispensers in 25 houses selected for special biological tests. These 25 houses represented different types of construction (see below).

The initial plan for obtaining test mosquitos for evaluation purposes was to rear adults from eggs obtained from captured wild *Anopheles gambiae* females. This method was abandoned because of the scarcity of *Anopheles gambiae* and rearing difficulties. As a substitute, 3-day-old adult *Aëdes aegypti*, reared at Wakara, were used.

In the biological evaluation, the adult mosquitos were placed in screen cages 3 inches (7.5 cm) in diameter and 6 inches (15 cm) tall that were attached to the walls of the houses at 2- and 6-foot (0.6 and 1.8 m) levels. There were approximately 30-70 females per cage. The exposure period was 12 hours, from 7:00 p.m. to 7:00 a.m. Any mosquitos still alive after the exposure period were held for an additional 24 hours and the mortality determined. When possible, wild-caught *Anopheles gambiae* were also exposed, but the numbers were insufficient to make a direct comparison of their susceptibility level with that of *Aëdes aegypti*.

Owing to the necessity of completing the initial treatment as rapidly as possible, and to the limited numbers of test insects during the first two weeks after the July treatment, only a few tests were made of that treatment. The houses in which tests were conducted represented the extremes of the range in volume per dispenser.

In August, 25 houses were selected for weekly biological tests: (1) five with single rooms, (2) five with two rooms, (3) five with a single large room with partial partitions, (4) five with more than two rooms, and (5) five with more than two rooms and with one or more windows. The latter were the only ones that contained windows; however, all had a circular vent in the ceiling of at least one room. In any single group, the five houses were as similar as it was possible to select. One unoccupied house was left untreated and caged mosquitos were placed in this house each night a test was made.

Inspections were made in houses at Wakara proper and Camp Peulh, the cattle-traders' village at Wakara, for the presence of mosquitos. The number of houses inspected was limited until August. From August through October most of the houses were inspected every week or two.

RESULTS

In 15 houses tested at the 2- and 6-foot (0.8 and 1.6 m) levels during the first two weeks after the July treatment, satisfactory kills (70% or greater) were obtained in nine houses. During the following two weeks (weeks 3 and 4) tests were made in 28 houses and satisfactory mortalities were obtained in 22. The range in the volume in these houses was from 441 to 1008 cubic feet (12.48-28.54 m^3). Dichlorvos concentrations in the air at the 6-foot level ranged from 0.01 μg to 0.046 μg per litre of air in the houses sampled. No pattern was established which would indicate that the difference in volume was the determining factor in relation to mortality. When the mortality fell below 70% in any house tested, the number of dispensers was doubled. After this was done, satisfactory mortalities were obtained in all houses tested except one.

The temperatures prevailing during July and the remainder of the rainy season were 6°F-8°F (3.3°C-4.4°C) lower than those during May, when the preliminary tests to determine dosage rates were performed. After the August treatment, when new dispensers were placed in all sleeping-rooms and in all rooms of the 25 houses selected for biological testing, weekly tests were made in the latter group. Air concentrations of dichlorvos in the 13 houses of this group in which air samples were taken ranged from 0.031 μg to 0.208 μg per litre. The average was approximately 0.1 μg per litre of air. The time of air sampling was from 1 to 10 days after treatment, but there was no correlation between the time element and the vapour concentrations. Table 1 gives results of the biological tests of the treatments applied in August and in October.

TABLE 1

MORTALITY OF CAGED ADULT FEMALE *AËDES AEGYPTI* IN SELECTED HOUSES DURING WEEKS 5-12 AFTER INSTALLATION OF DISPENSERS IN AUGUST 1961 AND DURING WEEKS 17-18 AFTER THE 23 OCTOBER TO 1 NOVEMBER 1961 TREATMENT (12-HOUR EXPOSURE)

House No.	Cubic feet [a] per dispenser	Average female mortality (%) at week:								
		5	6	7	8	9	10	11	12	17-18 [b]
511	448	100	100	52	100	73	48	82	76	53
364	448	100	100	100	57	30	49	21	31	9
536	448	100	81	95	96	100	66	100	100	100
239	448	100	75	73	48	45	61	50	39	51
122	448	100	100	100	52	100	83	62	63	100
77	431	100	98	91	63	86	88	61	91	93
160	411	100	46	70	55	68	46	53	58	61
380	470	Roof fell at week 4								
460	426	100	99	75	61	71	52	88	95	51
383	435	100	86	100	38	40	34	92	25	1
562	462	100	80	100	92	100	92	100	—	100
109	436	100	84	82	43	78	89	48	15	67
554	427	100	100	100	100	100	100	100	100	100
555	448	71	100	85	100	69	100	100	100	57
611	456	100	78	73	100	94	100	80	—	82
589	413	100	74	92	100	86	87	46	61	89
155	487	100	100	—	76	54	69	72	93	58
304	457	100	64	76	73	53	79	71	87	55
590	525	100	83	97	100	82	87	58	76	95
430	460	100	100	100	54	100	84	100	92	51
16	540	100	100	100	52	100	100	100	100	100
163	471	100	100	100	90	99	91	88	61	100
537	549	100	54	62	20	0	21	31	59	14
421	461	100	100	51	59	73	51	91	52	2
349	432	100	100	100	100	100	71	69	78	73
Average for all houses [c]		98	86	84	71	77	74	73	69	63

[a] 100 cubic feet = 2.83 m³.
[b] Weeks after 1 November 1961.
[c] Average mortalities in untreated (control) houses were not above 5% except during weeks 11 and 12.

With the exception of houses 364 and 537, mortalities were 100% for the first four weeks after the August treatment. The first loss of efficiency occurred at the sixth week after treatment, when the average for the 24 houses was 86%. At week 7, the mortality was essentially the same. At both weeks 6 and 7 the average mortality in three houses was below 70%. Eight weeks after treatment, the average mortality for the 24 houses was 71%, but 12 houses had an average mortality below 70%. Mortality levels were essentially the same or slightly higher at weeks 9-12.

At the 6-foot (1.8-m) level, the average mortalities obtained for weeks 5-12 were 100%, 100%, 99%, 94%, 93%, 94%, 92%, and 87%, respectively. At the 2-foot (0.6 m) level, the average mortalities for

TABLE 2
AVERAGE MORTALITY OF CAGED ADULT FEMALE *AËDES AEGYPTI* OBTAINED FOR WEEKS 5-12 IN HOUSES ACCORDING TO TYPE OF CONSTRUCTION

Type of house	Average female mortality (%) at week:							
	5	6	7	8	9	10	11	12
Single room	100	91	84	71	70	61	63	62
Double room	100	82	84	54	66	55	74	67
Partial partition	94	88	88	87	88	96	86	72
Multiple room, no window	100	84	91	81	75	81	69	82
Multiple room, window	100	91	83	64	74	67	78	70

the same periods were 92%, 74%, 72%, 49%, 61%, 56%, 57%, and 49%.

Table 2 gives results of tests according to the type of house. The best and most consistent results were obtained in the houses with partial partitions. These houses were usually a large room with high ceilings (8-9 feet; 2.4-2.7 m). The least effective results were in the double-room houses.

Evaluation of the October treatment after 17-18 weeks indicated only slightly lower average kills than those obtained at week 12 following the August installation. Generally the same houses had the lowest average mortalities for both evaluation periods. Average kill at the 2-foot (0.6-m) position was 43%, that at the 6-foot (1.8-m) level was 84%. However, daytime tests during weeks 17-22 using a 6-hour exposure interval (12 noon to 6:00 p.m.) showed essentially complete kills at the 6-foot level (except for 40% and 70% mortalities in houses 537 and 590 respectively). At the 2-foot level, mortalities were 90% or better in 18 of the 23 houses tested. Houses 511, 239, 590, 430 and 537 gave mortalities of less than 30%. Average kills were 96% and 80% at the 6- and 2-foot levels, respectively.

Insufficient tests were made in the circular houses with adobe walls and thatched roof or all-thatch houses to determine the dosage necessary to give satisfactory kills. However, the data indicated that for effective kills the dosage required would be approximately double that used in the all-adobe houses.

House inspections in Wakara were less than 300 in number prior to August, when inspections of all homes every two weeks were begun. The April-June periods showed the average number of *Anopheles gambiae* and *Anopheles funestus* to be 0.10-1.14 and 0.01-0.17 specimen per house, respectively. During the August-November period, counts of *Anopheles gambiae* ranged from 0.02 to 0.2, and of *Anopheles funestus* from 0.04 to 0.15 specimen per house.

DISCUSSION

As the data (Table 1) show, complete kills of the caged mosquitos were obtained in all houses except one through week 5. Subsequent data reflect high kills in certain houses (No. 562 and 554); in others (No. 537 and 421) low kills ensued. Thus, at week 8, 50% of the houses were showing kills below 70%; at week 10 the percentage was 41; and at week 12 the same level prevailed. Some dwellings (No. 239 and 160) consistently gave kills below 70% during weeks 8-12, whereas others (No. 536 and 460) were characterized by an intermingling of low and high kills on successive weeks. Unfortunately, the manpower, time, and insects available did not permit any exploration into the reasons for these variable results.

One possible explanation of the variable results after week 5 concerns the range of dichlorvos concentrations in the treated houses. Initially, the dichlorvos concentrations in all houses are far enough above the threshold level that produces complete mortalities to overcome the daily influences of temperature changes, ventilation, and other factors. However, as the dispensers age their efficiency declines and the dichlorvos concentrations in the houses at the lower end of the dosage range fall to the threshold level of biological effectiveness. Under these conditions, the biological effectiveness may readily be influenced by temperature and other factors. At the same time, those houses originally in the upper part of the dosage range still have adequate dichlorvos concentrations to overcome the influence of the ecological factors.

As indicated in the results, the kills at the 6-foot (1.8-m) level never fell below 87% during the 12 weeks, but for those at the 2-foot (0.6-m) level the kills dropped below 70% at week 8. In many of the house inspections, the resting-sites of the captured mosquitos were recorded. These data show that 94.6% of the 820 captured specimens of *Anopheles gambiae* and *Anopheles funestus* were resting on the ceiling. This tendency of the mosquitos to rest at ceiling level should enhance the potential of the technique for interrupting malaria transmission in this area.

RÉSUMÉ

Dans des cases de boue séchée de Wakara, en Haute Volta, des évaporateurs de DDVP disposés à raison d'un évaporateur pour environ 14 m³ ont tué 70% ou plus d'*Aëdes aegypti* adultes placées pendant une nuit dans des cages grillagées suspendues à 60 cm et à 2 m de haut. Cet effet a persisté pendant environ 3 mois durant la saison des pluies et 4 mois durant la saison sèche. Des taux de mortalité de 96% et 80% ont été obtenus pendant la saison sèche, lorsque les cages étaient suspendues respectivement à 2 m et à 60 cm et exposées pendant 6 heures de jour, ceci 17 à 22 semaines après l'installation des évaporateurs.