AERIAL APPLICATION OF 50% MALATHION FOR THE CONTROL OF SYLVATIC VECTORS OF YELLOW FEVER IN A RURAL WOODED COMMUNITY NEAR ENUGU, NIGERIA

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ABSTRACT. Two aerial applications, 6 days apart, of 50% malathion emulsifiable concentrate were made from a single-engined biplane against *Aedes africanus* and other sylvatic vectors of yellow fever (YF) in a densely wooded forest habitat in West Africa. The trial demonstrated that aerial application, at the rate of 1 l/ha, can rapidly suppress populations of the sylvatic vectors of YF for a period of time sufficient to interrupt disease transmission. *Ae. africanus* populations did not recover in the forest around Akpugo village until day 13 after the 2nd application of insecticide and were suppressed until day 35 in compounds (indoors and outdoors). For 2 weeks after the malathion applications no mosquito breeding took place in any of the peri-domestic water containers surveyed. Parity rates showed that there was minimal infiltration from outside the trial area of 200 ha for 20 days. The cost of aerial application is much higher than that of ground application, but it is the only means of successfully treating the inaccessible forest areas of south-eastern Nigeria where there are numerous rural communities and yellow fever outbreaks occur from time to time.

INTRODUCTION

The WHO Arbovirus Vector Research Unit, Enugu, Nigeria, has demonstrated that natural populations of sylvatic vectors of yellow fever (YF) in wooded communities can be controlled by ground application of malathion using Swingfog or Fontan R12 machines (Bang et al. 1980). After 2 applications, 7 days apart, of technical grade malathion from existing foot-paths at a dosage rate of 665 ml/ha in a forested community, the landing rates of all YF vectors were less than 0.5 per man-evening for 10 days, followed by a 100% reduction in oviposition which lasted for 2 weeks. Of the potential vectors of YF, *Aedes africanus* was found to be the most difficult to suppress, as shown by its rapid recovery after treatment especially at canopy level. The suppression and speed of recovery of this species depend largely on the size of the treated area and the distribution of patches of dense vegetation, within or near the treated area, where *Ae. africanus* and other feral species of YF vectors breed (Chippaux et al. 1976). In a series of village-scale trials using Swingfog and Fontan R12 machines, Bang et al. (1980) concluded that ground application of insecticide may not be feasible in a rural area surrounded by dense and inaccessible forest, where success is also hampered by the infiltration of vectors from surrounding untreatable forest habitats.

In south-eastern Nigeria rural communities are frequently situated near secondary or riverine forests where *Ae. africanus* is extremely numerous, with anthrophilic tendencies indoors as well as outdoors in compounds, and with extensive activity extending to the forest proper (Bang et al. 1979). Such rural villages are known to be susceptible to the introduction of YF (Monath et al. 1972) owing to high vector populations and inadequate YF prophylaxis. In such com-

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munities in low rain forest and derived savannah vegetation zones, significant primate reservoirs exist which could act as springboards to introduce virus into the community. The most feasible means of successfully treating such areas is by aerial application, as demonstrated in Angola during a YF epidemic transmitted by *Ae. aegypti* (Ribaro 1973), in a coastal area near Dar es Salaam for the control of *Ae. simpsoni* and *Ae. aegypti* (Parker et al. 1972), in Ethiopia for the control of *Ae. simpsoni* (Brooks et al. 1970) and as shown experimentally in Thailand (Kilpatrick et al. 1970, Lofgren et al., 1970). Outbreaks of dengue haemorrhagic fever (DHF) in Indonesia were successfully controlled by aerial application of 50% malathion emulsifiable concentrate (Pant et al. 1974, WHO, Unpublished Document) and of technical grade ultra-low volume (ULV) malathion (Self et al. 1977).

This paper reports the first aerial applications of 50% malathion emulsifiable concentrate (EC) for the control of *Ae. africanus* in a densely wooded forest habitat in south-eastern Nigeria. The objectives of the trial were to assess: (i) whether aerial application of malathion EC in a community located in high secondary forest could suppress the *Ae. africanus* population for a period of time sufficient to interrupt disease transmission; and (ii) the feasibility of emergency control measures using locally available personnel, aircraft and insecticide. Malathion was selected because of its low toxicity to mammals, its proven effectiveness and its general availability in local markets.

MATERIALS AND METHODS

TEST AREA. The trial was carried out at Akpugo (6°08'N—7°14'E) 68 km south-west of Enugu and 7 km north-east of the Mamu River Forest Reserve. The village covers an area of about 200 ha and has a population of 6,000. It is surrounded by secondary forest (about 100 ha) with many compounds situated along the edge of the forest. Open areas are occupied by schools and the local market. Compounds are made up of mud- or block-walled structures with palm thatch or zinc roofs surrounded by cocoyam and cassava gardens with numerous fruit trees which provide shade and cover around the dwellings. Akpugo is accessible by road from Achi on the Oji River and the Mamu River Forest Reserve.

Abor, a wooded community in the Udi Hills similar to the trial village, was used for comparison.

PRE-TREATMENT MOSQUITO POPULATION. Of 9 *Aedes* and 1 *Eretmapodites* species collected in the year before the trial 84% were *Ae. africanus*, 14% were *Ae. luteocephalus* and 1% was *Ae. aegypti*. The average number of *Ae. africanus* caught per man-evening ranged from 1.3 during the dry season to 47 in the wet season. In a 2-hr crepuscular collection in the forest 1 mosquito scout caught more than 80 *Ae. africanus*. During a 3-month period in the wet season an average of 3.4 *Ae. luteocephalus* were caught in compounds per man-evening (indoors and outdoors), but they were not so abundant in the forest. Before treatment an average of 9.5 *Ae. africanus* were caught per man-evening in a 10-day period (Table 1).

In Akpugo there is no piped water (or electricity) and water is carried from nearby spring-fed streams. An average of 10 domestic water pots were found in 30 compounds (302 inhabitants) along the edge of the forest surveyed during a 1 month period before treatment. Although *Ae. africanus* is predominantly a tree-hole breeder, it will readily use domestic water containers and is therefore considered to be a peri-domestic species (Bang *et al.*, 1979). The house index was 33.3%, the container index was 14.9%, the Breteau index 55.5 and the number of larval positive containers was 68 per 1,000 inhabitants. The ovitrap index was 34.7%. Larval surveys of plant leaf axils before treatment showed 56% of cocoyam, 40% of banana/plantain and 33% of pineapple plants to be positive for either *Ae. simpsoni* or *Malaya* species.

TREATMENT PROCEDURES. Early in

Table 1. Crepuscular landing rates per man-evening of potential vector species at Akpugo before and after aerial application of malathion.

Species	10 days before treatment	0–6 days after first application	0–6 days after second application	7–13 days after second application	15–20 days after second application
Ae. africanus	9.5	2.7	1.2	6.3	5.5
Ae. luteocephalus	1.4	1.0	0.3	1.3	0.8
Ae. aegypti	0.1	0.02	0	0.1	0.04
Ae. simpsoni	0.03	0	0	0	0
No. of man evenings used	36	48	48	36	24

Combined for three collecting sites: compounds, ground and platform.

October 1977 2 applications of 50% malathion EC were made, 6 days apart, from a single-engined bi-plane (Plate 1). The aircraft had a wing span of 18 m and a liquid weight capacity of 1,300 kg and was equipped with 4 micronair AU-3000 atomizers.[4] It flew at an average height of 5–10 m above the tree tops or about 40–60 m above the ground. Locally purchased malathion (50% EC) was applied at a rate of 1.0 l/ha with an emission rate of 9.3 l/min. The aircraft's holding tank was located in the fuselage and the malathion was pumped at 6.5 ats (kg/cm^2) through no. 7 rotary nozzles at 10,000 rpm (160 km/hr) with the rotary pitch set at 15°. The no. 7 micronair atomizer nozzles were set to give the smallest droplet size, estimated to be 50 microns. The total amount of malathion used in the 2 applications was 400 liters or 1 l/ha.

During spraying, flags were posted at the corners of the spray area and large fires were lit. Large white flags between bamboo poles 15 m long were used to mark the 29 swaths on the dirt track along the north side of the village. Swath width averaged 35 m and an average time of 45 sec was required to cover each 2 km long swath. Each run was timed with a stopwatch by the co-pilot and recorded. The aircraft, which tracked north-northeast and then reversed south-southwest, reached an average speed of 167 km/hr. Actual spraying time was 21 min and 41 sec, with a total flight time of 40 min for each application. Flight time from Enugu Airport to Akpugo was about 20 min. Spraying was carried out between 16.15 and 17.00 hr to coincide with the commencement of the biting period for *Ae. africanus*. The mean wind velocity did not exceed 6 kph during either of the 2 treatment days. The relative humidity was about 85% (Fig. 1).

[4] Manufactured by WSK factory, Mislee, Poland. (The mention of specific companies or of certain manufacturers' products does not imply that they are endorsed or recommended by the World Health Organization.)

EVALUATION PROCEDURES

CREPUSCULAR LANDING RATES. Eight catching stations were established: 2 platform sites at a height of 10 m, 1 at the edge and 1 in the center of the forest; 2 ground level sites near the platforms; and 4 compound sites, 2 indoors and 2 outdoors. Peak biting activity of *Ae. africanus* occurs at about sunset. In order to cover the complete biting period 2 scouts at each station collected all mosquitoes landing on their bared feet and legs during a 4-hour period starting 2 hours before sunset.

OVITRAP INDICES. Twenty-four ovitraps (Fay and Eliason 1966) were placed near 12 compounds and 24 in the forest. Ovitrap indices were calculated for each species on the basis of the number of paddles yielding larvae through 3 consecutive soakings (Bang et al. 1980).

LARVAL INDICES. Domestic water containers in 30 compounds in the area and

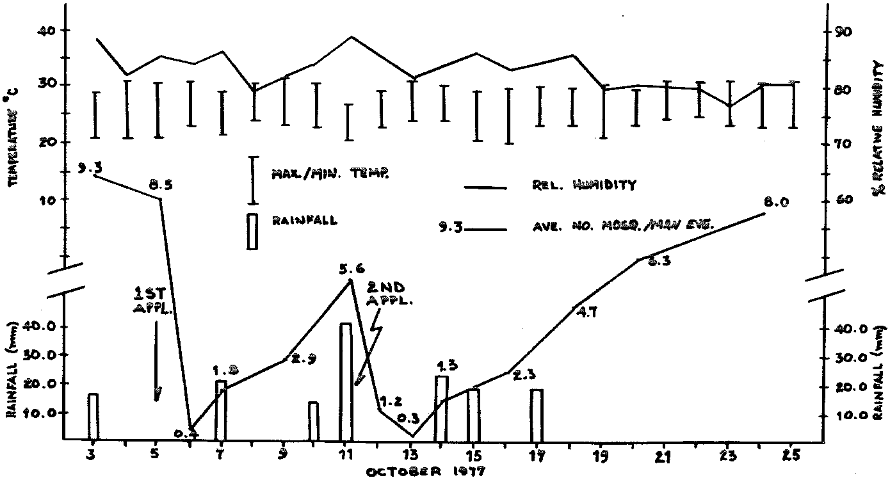

Fig. 1. Daily meterological data and man evening catches of *Aedes africanus* during aerial ULV malathion spray trials, Akpugo Village.

plant leaf axils of 100 cocoyams, 25 banana/plantain and 15 pineapple plants were surveyed before and after each application.

BIOASSAYS. Adult and larval bioassays were carried out during the second application of insecticide. For the adult tests paper cups (236 ml) covered on 3 sides and the top with fine nylon tulle, each containing 10 blood-fed *Ae. aegypti*, were used. Ten cups were placed outdoors on the ground in 10 compounds, 10 were placed on the ground along the edge of the forest, and in a semi-cleared area parallel to a narrow dirt track in the forest 10 were placed on trees at a height of 5 m and 10 at the base of the trees. Ten were placed outside the test area as check cups.

Larval bioassays were carried out at the same time using late 3rd and early 4th instar *Ae. aegypti* larvae. Two glass beakers, each containing 20 larvae in 150 ml of water, were placed in each of the 10 compounds used for adult bioassays. Ten beakers were placed at the edge of the forest and 10 were placed at sites in the forest. Twenty beakers were kept as checks.

In both adult and larval bioassays mortalities were recorded in the field before the mosquitoes were returned to the laboratory where 24-hr mortalities were recorded.

DROPLET DENSITY. To assess the distribution of the mists, malathion droplets were collected on Intek papers (5 × 7 cm). Sets of 15 Intek papers were placed horizontally at ground level at 3 sites in the village (indoors, outdoors, and in cocoyam gardens), at 1 site in a grassy field by the village school, and at 1 site in the forest. At a 2nd site in the forest papers were placed vertically in trees at a height of 5 m.

RESULTS

CREPUSCULAR LANDING RATES. The crepuscular landing rates of vector mosquito species were determined before and after treatment (Table 1). *Ae. africanus* was the most prevalent *Stegomyia* species before and after treatment, followed by *Ae. luteocephalus* and *Ae. aegypti*. Before treatment they comprised 99% of all *Aedes* species. As the *Ae. africanus* population fluctuated in the control area, percentage reduction in the treated area was calculated according to the method used by Bang et al. (1980). The reduction in the combined population of the 3 *Stegomyia* species was 93% on the 1st day after each application and 91% on the 2nd day, rising thereafter to reach pre-treatment levels on day 6 after the 1st application and on day 9 after the 2nd (Table 2). The *Ae. africanus* population at the edge and center of the forest did not recover until day 13 after the 2nd application and not until day 35 in the compounds surveyed. These results are similar to those Lofgren et al. (1970) obtained against *Ae. aegypti* in Thailand where the population was suppressed for 10 days.

Of 57 female *Ae. africanus* examined the week before treatment 86% were parous. In the treated area the rate dropped to below 50% by day 4 or 5 after each application (Table 3). Migration from outside areas appeared to be minimal. In the check area the level remained above 80% (Table 3). The dissection techniques used were those of Beklemishev et al. (1959) and Unguwream (1972).

OVITRAP INDICES. Before treatment the ovitrap index in the compounds was 34.7% for *Ae. aegypti* and 30.6% for *Ae. africanus* (Table 4). The index for *Ae. aegypti* had completely recovered by the 12th day after the 2nd application, while that for *Ae. africanus* remained below 0.5% for 3 weeks; the 1st paddles positive for *Ae. africanus* were collected 19 days after the 2nd application (Table 4).

LARVAL INDICES. Four larval indices (house, container, Breteau and *Stegomyia*) determined from surveys of peridomestic water containers are shown in Table 5. All indices declined after treatment, and it was only 2 months later, well into the dry season, that the container index recovered. Of 3 *Stegomyia* species collected, *Ae. aegypti* was the most common. However, the fact that *Ae. africanus* was frequently found to breed in peridomestic water containers was reflected in the high indices. Larval surveys of plant leaf axils showed a slight decline in

Table 2. Crepuscular landing rates per man evening of *Ae. africanus, Ae. luteocephalus* and *Ae. aegypti* at Akpugo before and after aerial application of malathiom.

Days before or after treatment	Site			All sites combined	
	Compound	Ground	Platform	Rate	% reduction
15 before	10.0	14.7	8.3	11.0 (18.9)*	
After first treatment					
1	0	0.5	1.0	0.5 (20.3)	95.9
2	0.5	2.0	3.5	2.0	83.5
4	1.5	6.5	5.0	4.3	64.6
6	6.8	10.8	6.3	8.0	35.0
After second treatment					
1	0	2.3	1.3	1.4 (20.3)	90.1
2	0.3	0.3	0.3	0.3	98.8
3	0	2.5	1.3	1.3	89.7
5	3.3	3.8	2.5	3.2	73.7
7	4.8	9.3	3.0	5.7 (27.8)	65.7
9	5.8	13.3	7.3	8.8	47.7
13	5.8	13.8	6.3	8.6	48.3
15	6.3	10.3	6.5	7.7	53.7
20	5.5	5.3	4.3	5.0	70.0
35	10.3	9.3	8.0	9.2	—

* The number in parentheses is the landing rate in the control area.

Table 3. Percentage of parous *Aedes africanus* females before and after aerial application of malathion.

Days before or after treatment	Total no. dissected	No. parous	Percentage parous
9 before	57	49	86 (81)[1]
After first treatment			
1	22	17	77
4	36	12	33
6	44	24	55
After second treatment			
1	13	8	62
2	3	2	67
3	13	8	61
5	75	37	49 (86)
9	52	32	62
13	76	61	80
15	40	30	75
20	45	36	80 (89)

[1] The number in parentheses is the percentage parous in the check area.

Ae. simpsoni and *Malaya* species breeding but remained at the pre-treatment levels.

BIOASSAYS. Adult bioassays showed 100% mortality at all sites. Mortality in the control area was 4% (Table 6). Larval bioassays showed 90% mortality in compounds, 80% at the edge of the forest and 94% in the semi-open areas in the forest 12 hr after application. Twenty-four hr after application mortality was 95%, 91% and 97%, respectively. Mortality in the control area was 5%.

DROPLET DENSITY AND SIZE. The mean number of droplets collected on Intek papers is shown in Table 7. Droplet densities ranged from 1.3/cm^2 indoors to 33.4/cm^2 in the open area near the school, and from 5.3/cm^2 at ground level in the forest to 6.1/cm^2 at a height of 5 m, indicating good penetration in the forest. Droplet size (volume median diameter) was 50 microns.

DISCUSSION

This trial at Akpugo demonstrated that aerial application of 50% malathion EC at the rate of 1 l/ha successfully suppressed populations of *Ae. africanus, Ae. aegypti* and *Ae. luteocephalus* for a period of 9 days, which would be a sufficient period of time to interrupt disease transmission

Table 4. Results of ovitrap surveys at Akpugo before and after aerial application of malathion.

Days before or after treatment	% paddles positive for larve of			
	Ae. africanus		*Ae. aegypti*	
	Compound	Forest	Compound	Forest
0–22 before	30.6	16.7	34.7	15.3
After first treatment				
0–2	0	0	0	0
2–4	0	0.04	0.04	0
After second treatment				
0–3	0	0	0	0
3–5	0	0	0	0
5–9	0	0	0	0
10–20	0.01	0.04	48.6	26.4

Table 5. Outdoor peri-domestic water containers at Akpugo positive for known vectors of yellow fever.

Days before or after treatment	Index			
	House	Container[1]	Breteau	*Stegomyia*[2]
21 before first treatment	33.3	14.9 (33.7)	55.5	68.4
2 after first treatment	16.7	7.4 (17.9)	23.3	23.2
2 after second treatment	23.3	13.6 (15.3)	26.7	26.5
9 after second treatment	10.0	4.7 (12.9)	13.3	13.3
15 after second treatment	0	0 (9.2)	0	9.9

[1] The percentage of containers positive for all mosquito species is given in parentheses.
[2] Number of larval positive containers/1,000 inhabitants.

in the event of an outbreak of YF (or other *Aedes*-borne arbovirus disease) in Nigeria's lowland rain forest area. Large inaccessible forested areas and sacred forest zones, where ground application of insecticide is impossible, were successfully treated by aerial application. Effective penetration of ULV droplets through the canopy, which is vital in controlling tree-hole breeders such as *Ae. africanus* which breed and rest primarily in forest, was indicated by an average droplet density at ground level in the forest of 5.3/cm^2. The successful use of locally available insecticide and aircraft was shown to be feasible, a highly important factor when an epidemic occurs and rapid control becomes vital (Self et al. 1977).

The success of the treatment in compounds is seen in: (1) the ovitrap surveys, where the 1st *Ae. africanus*-positive paddles were not collected until 19 days after the 2nd application of insecticide (Table 4); (2) the fact that the adult *Stegomyia* population did not return to pre-treatment levels until day 35 after the 2nd application, thus further restricting virus transmission in and around human habitats. Results from ovarian dissections indicated that there was minimal infiltration from outside the study area (parity dropped to 55% and did not return to pre-treatment levels until day 20 after the 2nd application); and (3) the larval indices which were nil for 2 weeks after treatment.

The reception by the village residents of the trial was overwhelmingly positive. No complaints were made about aircraft noise or the smell of malathion, and no adverse effects on man or animal were reported. A reduction in the number of domestic flies in the market, and in and around compound areas, was a positive side effect mentioned by many villagers.

The results of this trial, together with those of the trials carried out at Ezama-Nike and Awhum (Bang et al. 1980)

Table 6. Adult and larval bioassay mortalities of *Aedes aegypti* during aerial application of malathion at Akpugo.

Stage[1]	Mortality read	Outdoors in compounds	Edge of forest	Ground level in forest	At height of 5 m in forest	Control
Adult	Immediately	0	0	0	0	0
(100)	After 14 hours	100	100	100	100	0
	After 24 hours	100	100	100	100	4
Larvae	Immediately	0	0	0	—	0
(200)	After 14 hours	90	80	94	—	0
	After 24 hours	95	91	97	—	5

[1] The number tested is given in parentheses.

Table 7. Mean droplet density (no./cm^2) of aerially applied malathion at Akpugo as measured on Intek papers.

	Compound			Forest		
	Indoors	Outdoors	Garden	Ground level	At height of 5 m	Open area near school
Mean	1.3	15.1	10.7	5.3	6.1	33.4
Range	0–5	6–28	2–20	1–14	1–11	24–60

demonstrate that either ground or aerial application of insecticide, depending upon the type of habitat and accessibility of the treatment area, can be used successfully to control *Ae. africanus* and/or *Ae. aegypti*. In the event of a mosquito-borne virus disease outbreak in Nigeria, an important factor in controlling the disease would be the availability of insecticide and aircraft for emergency use.

In this trial, the costs of the operation were estimated to be US $0.55/capita or $16.35/ha (about 45% for the 50% malathion EC at $3.70/1 and the rest for the rent of the aircraft) (Table 8). The cost appears to be 7–8 times higher than that of ground application (Bang et al. 1980).

Table 8. Cost analysis of two aerial applications covering 200 ha.

Item	Amount needed	Cost/ha N	Cost/ha Dollars
50% malathion EC*	400 1	4.74	7.41
AN-2 bi-wing	1 hr 20 min	5.72	8.94
Total cost		10.46	16.35
Cost/capita**		.35k	.55¢

* N2.37/1 ($3.70).

** Population estimated at 6,000.

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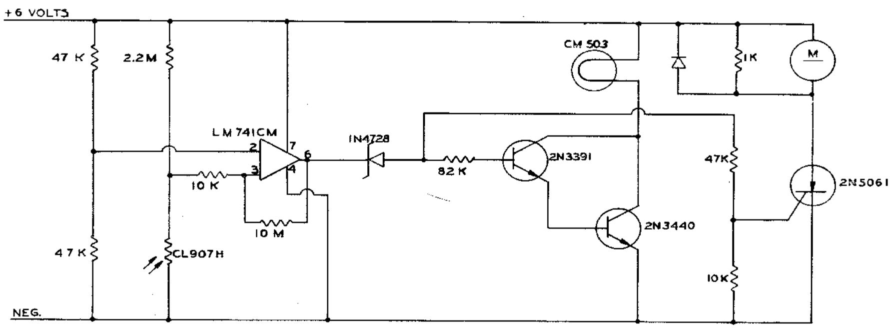
ERRATA

THE US ARMY MINIATURE SOLID STATE MOSQUITO LIGHT TRAP MOSQUITO NEWS, Vol. 40, No. 2, pp. 172–178

Page 172—The name of the fan manufacturer is misspelled. It should be Thorgren.®

Page 175—The drawing of the circuit "B" is reproduced showing the correct symbol for the 2N5061 silicon controlled rectifier, the correct designation of the lamp (CM503) and the power supply connections (pins 4 and 7) of the operational amplifier LM 741 CM.



SCHEMATIC CIRCUIT "B"