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EVALUATION OF SELECTIVE SPRAYING OF BENDIOCARB (FICAM VC®) FOR THE CONTROL OF *ANOPHELES FLAVIROSTRIS* IN THE PHILIPPINES

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ABSTRACT. The effectiveness of selective and complete spray applications of bendiocarb for the control of the major malaria vector, *Anopheles flavirostris*, was compared in an experimental hut trial in the Philippines. Selective spraying involved treatment of the vector's preferred indoor resting sites, namely, the lower wall areas, wall areas immediately surrounding the doors and windows, and eaves. Complete spraying involved treatment of all internal wall and ceiling areas, and the eaves. At intervals over a 6-month period, mosquitoes were released into the huts and recaptured within 13 h, either inside the huts, or within the interior of net traps placed over the huts. Mortality levels differed by <8% between the spray regimes over the posttreatment period, with both regimes giving 75–100% kill of *An. flavirostris* during the initial 3 months. The time spent spraying and spray volume used during treatment of village houses were respectively 36 and 49% less under the selective spraying regime. Selective application of bendiocarb therefore shows considerable promise, both in terms of efficacy and cost effectiveness, for the control of *An. flavirostris* in the Philippines.

INTRODUCTION

Malaria continues to be a leading public health problem in the Philippines and current efforts at reducing incidence of the disease are mainly directed toward vector control (Salazar et al. 1988). A number of organophosphate, carbamate, and pyrethroid insecticides are now being used as alternatives to DDT for the control of mosquitoes. The more modern insecticides are generally, however, more expensive than DDT in terms of cost per area treated. This has led to a search for strategies in which these insecticides can be used in the most cost-effective manner.

In control programs based on house spraying, one of the means by which insecticide use may be reduced is by the selective application of the product to the preferred indoor resting sites of the vector. Selective spraying of DDT has been shown to provide effective control of the malaria vector *Anopheles maculipennis* Meigen in Italy (Logan 1953) and Yugoslavia (Pampana 1969). Selective spraying was successful against *Anopheles aconitus* Dönitz in Indonesia (Bang et al. 1981) and has been proposed for use against *Anopheles darlingi* Root and *Anopheles marajora* Galvão and Damasceno in Colombia (Quiñones and Suarez 1990). Arrendondo-Jiménez et al. (1992) also recently reported selective application of bendiocarb to be as effective as complete spraying for the control of *Anopheles albimanus* Wied. in Mexico.

Successful implementation of selective spraying relies on obtaining detailed and accurate data on the indoor resting behavior of the vector. In the Philippines, the indoor resting behavior of the principal malaria vector, *Anopheles flavirostris* Ludlow, has been intensively studied (Urbino et al. 1961). This species has a strong preference for resting on interior house walls at a height <2.1 m above the floor. Locations within 2.4 m of windows and where light intensity is less than 54 lux (e.g., room corners) are also preferred.

The present study assessed whether selective spraying with an insecticide could provide effective control of *An. flavirostris*. Bendiocarb was considered especially suitable for use in this approach because of its extremely low irritancy to mosquitoes (Evans 1993). It would therefore be unlikely that mosquitoes might avoid contact with the insecticide in partially treated buildings. Previous laboratory and field evaluations in the Philippines have shown bendiocarb to be highly active against *An. flavirostris* (Del Rosario and Del Rosario 1984).

MATERIALS AND METHODS

Trial location: The trial was carried out in Kaybanban, San Jose del Monte, Bulacan, an area lying approximately 45 km northeast of Manila. The region contains many foothill streams and tributaries that are used as breeding sites by *An. flavirostris.* Malaria transmission typically begins towards the end of the rainy season in November. The trial was conducted over the period January 1991–June 1992.

Entomological observations: The resting height preference of *An. flavirostris* in a village in the trial area was studied by a one-night observation of mosquitoes resting on walls inside houses

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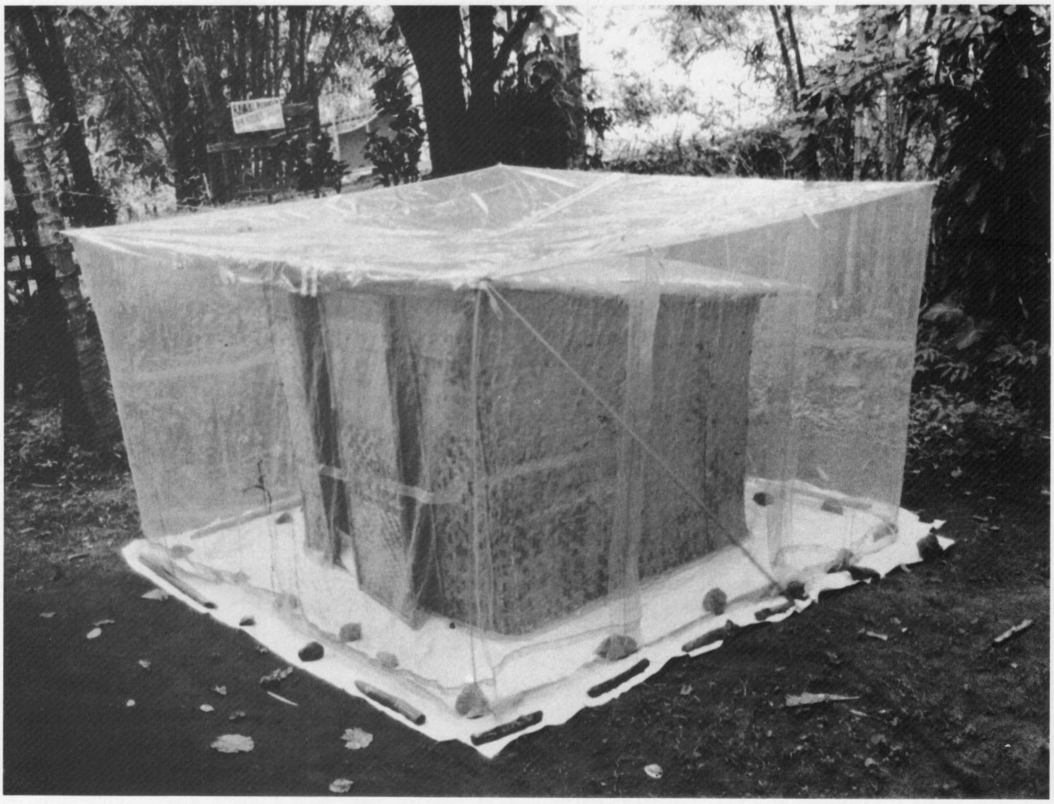

Fig. 1. Experimental hut and mosquito net used to study the mortality of released *Anopheles flavirostris* exposed to selective or complete spray applications of bendiocarb.

between 1800 and 0600 h. Also, 244 freshly bloodfed mosquitoes, which had been collected using cattle-baited traps, were released into a woven bamboo experimental cabin (8 × 4 × 4 m) and their resting locations noted at regular intervals up to 4 h later.

Construction of experimental huts: Three experimental huts (Fig. 1) were built using bamboo as walling material nailed onto wooden posts. The roofs were made of mat and cogon grass fixed onto bamboo slats. The huts were situated approximately 16 m apart and measured 2 × 2 m, with a height of 1.8 m at the front and 1.5 m at the rear. Each hut consisted of a single unpartitioned room. A door (1.7 × 0.5 m) and window (0.8 × 0.6 m) were constructed in each hut.

Pretreatment recapture assessment: Using cattle-baited traps, additional freshly bloodfed mosquitoes were collected to compare the recapture rates of mosquitoes released into the 3 experimental huts. These mosquitoes were placed in groups of 20 into paper cups (8.5 cm diam × 9 cm height), covered with water-moistened towelling. Any injured or dead individuals were removed at the end of a 30-min holding period. During the holding period, the roof and the ground inside and immediately outside (to a distance of 0.3 m) each hut, were covered with white plastic sheeting for the later location of mosquitoes. Each hut was then enclosed with a mosquito net (3.5 m^2) for the trapping of exiting mosquitoes.

Immediately after the holding period, the cups containing the mosquitoes were taken to the huts and placed on the ground, and mosquitoes were given 15 min to acclimatize before their release. At 1900 h, the towelling covering the cups was removed and the mosquitoes were then able to move freely inside the huts. Between 75 and 150 mosquitoes were released inside each hut. At 3-h intervals until 0400 h mosquitoes located on the exterior of the huts or interior of the net traps were collected using mouth aspirators. Between 0700 and 0800 h, all mosquitoes remaining either inside or outside the huts (but within the nets), were collected.

Treatment of experimental huts: One hut was

Table 1. Resting heights of *Anopheles flavirostris* observed inside houses in Kaybanban.

Height above floor (m)	Mosquitoes observed No.	%
0–0.30	6	18.8
0.31–0.60	10	31.2
0.61–0.90	15	46.9
0.91–1.20	1	3.1
1.21–1.50	0	0
>1.50	0	0

allocated to each of 3 treatments (untreated, selective spraying, and complete spraying). Selective spraying mainly involved treatment of the internal wall area below a height of 0.7 m from the floor. Areas of wall within 0.1 m of the door and window, and the internal and external eaves, were also treated giving a total area sprayed per hut of approximately 6 m^2. Complete spraying involved treatment of the entire internal wall area (including the door and window surrounds), plus the ceiling and internal and external eaves. The total area sprayed per hut was approximately 16 m^2. For both treatments, application was carried out using a Hudson X-Pert® sprayer fitted with a Tee-jet® 8002-E nozzle to give an even spray deposition across the swath. Ficam VC® (80% bendiocarb water-dispersible powder) was applied at an application rate of 40 ml/m^2, giving a dosage of 400 mg AI/m^2.

Posttreatment recapture assessments: On the day after spraying, mosquitoes were obtained and released inside the huts in the same manner as previously described. As mosquitoes were recaptured, they were assessed as alive or dead, placed inside paper cups, and provided with cotton wool moistened in 10% glucose solution. Water-moistened towelling was used to cover the cups and a mortality count made 24 h later. The release–recapture assessment was repeated at intervals over a 6-month period using the same experimental huts.

Treatment of village houses: To provide an indication of the time taken and volume of spray used to treat village houses, 6 typical houses in a village in the trial area were randomly selected and 3 each treated under the selective and complete spraying regimes.

RESULTS

Entomological observations and pretreatment recapture assessment: Observations of mosquitoes resting inside houses in the trial area and inside the experimental cabin confirmed the strong tendency of *An. flavirostris* to rest on the lower wall areas. Half of the mosquitoes observed inside the houses were seen resting <0.61 m above the floor (Table 1), and 53% of mosquitoes inside the cabin were observed resting below 0.61 m (Table 2). Between 89 and 100% of the mosquitoes released inside each of the 3 experimental huts during the pretreatment assessment were recaptured. This indicated that mosquitoes could be retrieved with a high degree of success, and that there was no major difference between the huts in this respect.

Posttreatment recapture assessments: More than 75% of the mosquitoes released inside the treated huts were recaptured inside, indicating that mosquitoes had not been strongly irritated and stimulated to exit by exposure to bendiocarb. The mortality of mosquitoes occurring under the 3 treatments was calculated using the formula from the World Health Organization (1975) and corrected using Abbott's (1925) formula (Table 3). Both spray regimes gave 100% mortality of *An. flavirostris* in the initial assessment completed 3 days after spraying, and maintained >75% mortality for more than 3 months. Thereafter, mortality decreased steadily, dropping to <50% between 4 and 6 months after spraying. Over the entire posttreatment period, mortality under the 2 regimes differed by <8%, indicating both to have had similar effectiveness at controlling released *An. flavirostris.*

Treatment of village houses: The mean time spent spraying village houses was significantly (36%) less under the selective spraying regime than under the complete spraying regime (7.4 vs. 11.7 min per house; $P < 0.01$, related means t-test). The mean volume of spray applied was also significantly (49%) less under the selective spraying regime (2.9 vs. 5.7 liters per house; $P < 0.001$).

DISCUSSION

Selective spraying of bendiocarb on the interior lower wall areas, door and window surrounds, and eaves of experimental huts proved to be as effective for controlling released *An. flavirostris* as complete spraying of all interior wall, ceiling, and eaves areas. Some mosquito mortality in the initial posttreatment assessments may have been due to the airborne effect of bendiocarb (Eshghy et al. 1979), but as the level of ventilation occurring in the huts was high, this effect was unlikely to have been important. The similar levels of mortality occurring under both spray regimes over the entire 6-month posttreatment period provided strong evidence that mosquitoes in the selectively sprayed huts were dying

Table 2. Resting heights of *Anopheles flavirostris* observed following release of mosquitoes into an experimental cabin in Kaybanban.

Time post-release	No. (and %) of mosquitoes observed at height above floor indicated (m)				
	0–0.60	0.61–1.20	1.21–1.80	1.81–2.40	>2.40
15 min	154	31	12	22	25
30 min	139	29	11	24	41
1 h	128	29	17	23	47
2 h	116	25	13	26	64
4 h	109	33	16	31	55
Total	646(53)	147(12)	69(5.7)	126(10.3)	232(19)

due to direct contact with bendiocarb-treated surfaces, and confirmed the accuracy of the pretreatment observations of the vector's preferred resting height.

In an analysis of the costs of using different residual insecticides in malaria control programs, Phillips and Mills (1991) concluded that operational cost differences were relatively small in relation to the costs of the insecticides themselves and external transport costs. In the present study, the 49% reduction in bendiocarb use when treating village houses under the selective spraying regime would therefore constitute a highly significant cost saving at an operational level. The 36% reduction in spraying time, although valuable, would be less important given that spraying time is generally a small proportion of total operator working time. Both Bang et al. (1981) and Arredondo-Jiménez et al. (1992) similarly have reported highly significant savings in insecticide use or manpower during evaluations of selective spraying. Bang et al. (1981) also proposed 2 other important advantages of selective insecticide application against mosquitoes. First, the avoidance of spraying at heights above operator level may substantially reduce operator contamination from spray fallout. Second, because not all the vector's resting areas are treated, a small proportion of the population may survive and this may delay or reduce the development of insecticide resistance.

Before selective spraying can be considered for implementation throughout the Philippines, the resting site preference and extent of exophily of *An. flavriostris* in each locality should be determined. Roberts et al. (1987), following a comparison of their observations with those from a previous study conducted in a different region of the country, proposed that *An. darlingi* populations in Brazil might display regional differences in preferred resting sites. Adoption of a selective spraying program against *An. flavirostris* should also involve long-term observations of mosquito behavior following insecticide use. Although there has been no evidence as yet that selective spraying may induce changes in mosquito resting site preference, the possibility that this may occur cannot be discounted. Byford et al. (1987) reported that intensive selection with pyrethroids could lead to a change in resting site preference of the horn fly, *Haematobia irritans* (Linn.). Flies feeding on cattle fitted with pyrethroid-impregnated ear tags had developed a preference for resting on the largely toxicant-free, ventral and posterior regions of their hosts.

Although selective spraying of insecticides was first shown to be a cost-effective means of achieving mosquito control more than 40 years ago, this methodology has not been widely adopted. Damar et al. (1981) believed the major reasons for this to be the relatively low cost of DDT, the lack of data on resting sites of the principal vector species, and the emphasis on malaria eradication. However, DDT is now almost a speciality

Table 3. Mortality of *Anopheles flavirostris* following release of mosquitoes into experimental huts either selectively or completely sprayed with bendiocarb.

Treatment	Mortality (%) at postspray time indicated						
	3 days	5 days	7 days	1 month	3 months	4 months	6 months
Selective spraying	100	97.7	92	88.3	77.1	63.2	35.4
Complete spraying	100	96.4	98.9	90	76.9	70	43.5
n[1]	130	115	125	150	125	100	75

[1] Number of mosquitoes released per treatment.

chemical, knowledge of vector behavior has improved, and control, not eradication, is the current aim of most antimalaria campaigns. Given these changes and the current emphasis of the World Health Organization on optimum targeting and cost-effectiveness in vector control, the selective application of insecticides may become increasingly important as a means of controlling mosquitoes that show marked preferences in indoor resting sites.

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