Control of *Anopheles albimanus* mosquitos in southern Mexico by spraying their preferred indoor resting sites

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The traditional indoor spraying technique to control Anopheles albimanus *mosquitos was compared with a selective method that targets their preferred resting sites in coastal villages of southern Mexico. We also determined whether mosquitos changed their preferred resting sites following insecticide applications. In the selective spraying approach, two 1-m wide horizontal swaths of bendiocarb insecticide were applied 0.75–1.75 m from the base of the walls and at 1-m upwards from the base of the inner roof at a target dose of 0.4 g/m². A 2-year follow-up (1988–90), which included four insecticide treatments, showed that the selective spraying was as effective as full spraying for controlling* A. albimanus. *Also the mosquitos preferred resting sites that were not modified by the insecticide applications. Finally, the use of this technique required 46% less time and cost 67% less than conventional spraying.*

Introduction

Beginning with the worldwide eradication programmes in the 1950s and 1960s using DDT, residual indoor spraying of insecticides has been the basis of malaria vector control (*1*). Owing to physiological and behavioural resistance to DDT (*2*), as well as environmental concerns, its use has been severely cut back, resulting in a search for safer insecticides, along with the exploration of alternatives to current application techniques in an effort to optimize insecticide use.

Mosquito behaviour provides important information on the role of anophelines as malaria vectors and could serve as the basis for their control. By evaluating their indoor resting patterns it can be verified whether mosquitos prefer specific surfaces, and the potential effect of insecticides on the mosquito population can be estimated (*3*). Studies of the post-feeding indoor resting behaviour of *Anopheles albimanus* Wiedemann, the principal malaria vector on the Pacific coast of Chiapas, Mexico, showed that although mosquitos landed more frequently on interior surfaces other than walls and roofs, they rested longer on walls and roofs (mean resting height: on walls, 1.25 m; on roofs, 0.5 m from base) (*3*).

The objectives of the present study were to determine whether the indoor resting preferences of *A. albimanus* can be used to target and reduce vector populations by selectively spraying insecticide on the preferred resting sites, and to evaluate whether the latter sites change as a result of the residual effect of insecticide applications.

Materials and methods

Study area and experimental design

Two villages were selected in Pijijiapan County on the coastal plain of southern Chiapas State, Mexico, and randomly assigned as treated or untreated using a split-block experimental design (*4*). The study villages were Tutuán (population, 305) consisting of 75 houses (15° 26' 19" N, 93° 05' 40"W), and Alambrado (population, 320) consisting of 80 houses (15° 26' 53" N, 93° 08' 19"W). The villages were treated as follows: Tutuán was divided into two halves, the first was sprayed with conventionally applied bendiocarb (OMS 1394) water-dispersible powder (WP), and the second was selectively sprayed with the same WP compound; and Alambrado remained untreated. Each study village served as the "main plots" and a single main treatment (insecticide or untreated) was assigned to each (*4*).

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No intradomiciliary insecticide spraying had occurred in the area since 1981, and during a preliminary survey both villages had high densities of *A. albimanus*. The malaria incidence, traditionally high in the area, had an estimated annual parasite index (API) of 38 cases per 1000 people in Alambrado and 92 per 1000 in Tutuán during 1987.

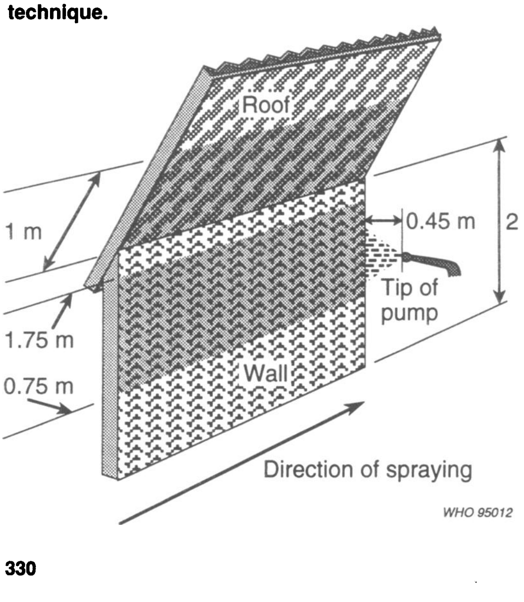
Spraying procedure

Conventional full and selective application techniques were carried out using Hudson X-Pert® hand-compression pumps (HSS 8002E nozzle, with a regulated discharge of 760 ml per minute at a pressure of 40 psi) to spray bendiocarb (80% WP), at a rate of 0.4 g of active ingredient per m^2. Four spray rounds were carried out between July and September 1988 and July and October 1989, respectively.

Conventional spraying. Using the WHO standard technique, operators, while holding the hose tip 0.45 m from the wall, sprayed 0.8-m wide vertical swaths, each having an overlap not greater than 5%, starting at roof level (up to 3 m high) and continuing to the floor. Insecticide discharge, applied to all indoor sprayable surfaces and exterior eaves, took an average of 15 minutes per house.

Selective spraying. The WHO standard technique was modified by applying two 1-m-wide horizontal swaths of insecticide, the first starting at 0.75 m from the base of the walls and extenting up to 1.75 m in height and the second starting at the base of inner roofs and extending 1 m upwards (Fig. 1). Exterior eaves were not treated. The treatment with insecticide took an average of 10 minutes per house.

Fig. 1. **Illustration of the two-swath partial spraying technique.**



Safety measures. Prior to the application of insecticide to their houses, inhabitants were asked to remove light domestic articles (e.g., cooking utensils) as well as food, whereupon plastic sheets were used to cover furniture and appliances. Inhabitants were also advised not to reoccupy their houses until at least 2 hours after spraying had been completed. The spray-men followed the recommendations of safe insecticide handling as outlined by WHO and by the manufacturers (*5*).

Entomological evaluation

Susceptibility tests. Tests were carried out once during pre-treatment, using impregnated papers and following WHO standard protocols.[a] Freshly engorged 2-day old *A. albimanus* adult mosquitos, reared from wild-caught larvae, were exposed (60 minutes) to papers impregnated with standard concentrations of 0.1% bendiocarb. Mortality was recorded 24 hours following exposure.

Insecticide residual effect. To facilitate ventilation, houses are commonly constructed of palm–thatch roofs and walls are made of pole or split bamboo, wood and occasionally, cement block. Standard wall bioassays were conducted to determine the residual effect of insecticides on these surfaces (*6*). *A. albimanus* mosquitos, which were used for each test, were collected from neighbouring non-sprayed areas and assigned randomly for treatment. Tests were carried out on each surface every other week, including pre-treatment, in the untreated and treated villages. Surfaces were tested using four cones, each containing 10 bloodfed mosquitos (exposed for 60 minutes). An additional cone, containing also 60 mosquitos, was placed on untreated surfaces as a control. The mosquitos were kept for 24 hours to determine mortality levels.

Human bait collections. Mosquitos were captured in the experimental villages to determine intra- and peridomiciliary biting rates. Two field technicians working indoors and outdoors collected anopheline mosquitos for 6 hours (18:00–24:00) on 4 days every 2 weeks. Since selective and conventional spraying with bendiocarb was being carried out in the same village, collections of mosquitos were made in houses located at both extremes of the village in order to minimize cross-infiltration of mosquitos from either area. Pre- and post-treatment abundance levels were

[a] *Instructions for determining the susceptibility or resistance of adult mosquitos to organochlorine, organophosphate and carbamate insecticides: establishment of the baseline.* Unpublished document WHO/VBC/81.805, 1981.

estimated (number per man/per hour) and mosquitos were kept for 24 hours to determine mortality rates. Collectors were offered weekly prophylactic treatment with chloroquine.

Indoor resting behaviour. To study indoor mosquito landing and resting behaviour, two technicians carried out pre- and post-treatment mark–recapture of mosquitos once every 2 weeks between 19:00 and 23:00. One technician acted as human bait by sitting inside a house near the open front door. When an *A. albimanus* mosquito landed and engorged itself on him, the second technician applied fluorescent powder to the mosquito and followed its movements with an ultraviolet lamp for 1 hour. The number of landings, total resting time, resting height, and types of resting surfaces were recorded for each marked mosquito. In partially sprayed houses, landing times and the frequency of landing on sprayed or unsprayed sectors of walls and roofs were recorded. If mosquitos attempted to leave the house before 1 hour had elapsed, they were captured, or if they remained inside the house, they were collected at the end of 1 hour. In either case, the mosquitos were kept for 24 hours to determine mortality levels.

House curtain. These experiments, carried out every 2 weeks, were designed to determine the degree of insecticide repellency, mosquito feeding success, and mortality within sprayed houses. The exterior of a house was encircled with a mosquito curtain extending from the roof to the ground (*7*). White sheets were placed on the floor near walls, in corridors and under the eaves of the roof to facilitate collection of mosquitos. During the experiments (18:00–06:30), the curtain remained down. At 17:45 the interior of the house was cleared, and all live and dead mosquitos were collected. From 18:30 to 20:30 four people collected a minimum of 150 nonengorged mosquitos from inside other houses of an untreated village, and released them at 21:00 inside the curtained house. In order to maintain a constant number of hosts, two individuals were stationed inside experimental houses and served as human baits. Between 22:00 and 06:00 at 1-hour intervals, mosquitos resting on the interior of the curtain were recaptured (the assumption being they were leaving the house) and classified as either bloodfed or unfed. These mosquitos were placed in plastic cups according to the hour of recapture and kept to evaluate 24-hour mortality rates. Dead mosquitos found in the corridor between the curtain and the house walls were recovered and included in mortality calculations. At 06:15, prior to raising the curtain, the inside of the house, including the floor and the area between the curtain and house, was checked for live, intoxicated, or dead mosquitos and the mortality rates recorded. To evaluate house exiting patterns, we separated the mosquitos into two groups: those leaving the house "early" (22:00–01:00) or "late" (01:00–06:00). Feeding success and mortality were evaluated, including the mosquitos that left the house during the night.

Data analysis. An ANOVA test for split-blocks with randomized complete block design was used (*4*). Data were either log(x+1)- or arcsin-transformed depending on whether they were numbers or proportions, respectively. Student's t-tests were used for two sample analyses, while χ^2_{MH} tests were used to compare proportions and Scheffé F-tests were used for multiple comparisons among experimental areas (*8, 9*).

Finally, the application costs were calculated to compare conventional and selective spraying techniques, including insecticide and operational expenses.

Results

Susceptibility tests

A. albimanus mortality as a result of exposure to bendiocarb-impregnated papers remained at 100% (n = 200) in both 1988 and 1989.

Insecticide residual effect

Mortalities varied little according to surface type or time (Table 1). Mortalities following the first spraying round in 1988 in both partially and fully sprayed sectors remained ≥75% on all sprayed surfaces (wood, cement, palm–thatch, and pole) for up to 8 weeks and ≥75% for 11–14 weeks following the

Table 1: **Number of weeks after spraying when the mortality of *Anopheles albimanus*, determined using standard wall bioassays, was acceptable**[a, b]

	No. of weeks:			
Treatment	Wood	Cement	Palm–thatch	Pole
Post-partial-spraying				
1st spraying	8	7	7	7
2nd spraying	12	13	13	11
3rd spraying	8	8	8	8
4th spraying	15	15	15	15
Post-full-spraying				
1st spraying	7	8	7	7
2nd spraying	14	14	14	14
3rd spraying	10	6	10	7
4th spraying	14	14	15	15

[a] Walls were treated with bendiocarb at a rate of 0.4 g active ingredient/m^2.

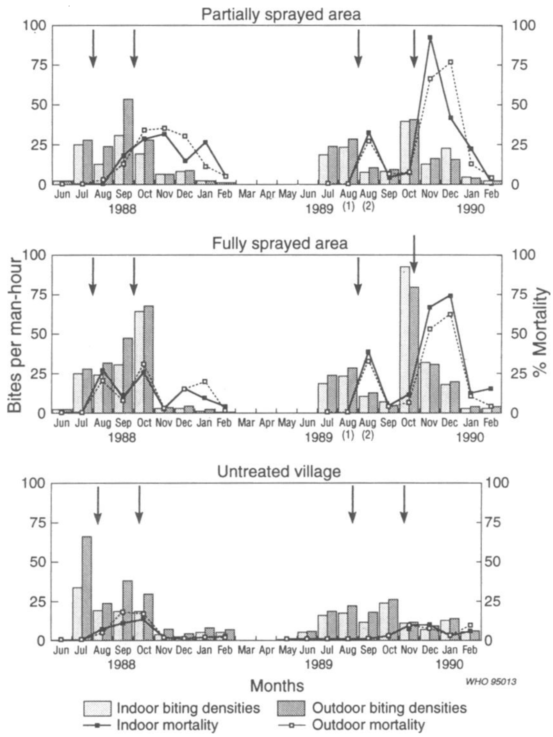
[b] Acceptable was taken to be mortality level ≥75%.

second spraying round. Slightly longer residual activity of ≥75% mortality was noted on all surfaces following the third (6–10 weeks) and fourth spraying rounds (14–15 weeks) in both partially and fully sprayed sectors. The insecticide did not appear to produce a cumulative effect following successive treatments. Mortalities remained <10% on unsprayed surfaces in the untreated village.

Human bait collections

Indoor/outdoor man-biting rates in the partially and fully sprayed sectors of the treated village increased (20–60 bites per man per hour (bmh)) over the period July–October 1988, although to a lesser extent than in the untreated village (20–70 bmh in 1988–89). Similar increases were observed beginning in July 1989 (>20 bmh), which were followed, however, by decreases to <10 bmh in both partially and fully sprayed sectors and again followed by increases in man-biting rates in October (Fig. 2).

Fig. 2. **Indoor and outdoor biting densities and mortality of *Anopheles albimanus* mosquitos, 1988–90, following four partial and full spray applications of bendiocarb (indicated by arows).** For August 1989 in the partially and fully sprayed areas, (1) and (2) refer, respectively, to pre- and post-spraying.



Mean indoor biting densities of 13.01 bmh, 19.57 bmh, and 11.68 bmh for the partially sprayed, fully sprayed and untreated houses, respectively, and of 16.39 bmh, 21.47 bmh, and 17.13 bmh outdoors, were not significantly greater in any of the experimental areas (Scheffé F-tests = 0.053, 0.001, and 0.072, resp., $P > 0.05$, intradomiciliary; and 0.067, 0.35, and 0.111, resp. $P > 0.05$, peridomiciliary). Biting rates decreased to <8 bmh between November and June in both treated and untreated villages, corresponding to the dry season. Peridomiciliary were significantly greater than intradomiciliary biting densities in treated and untreated villages (Student's t test = 2.516, $P = 0.0111$; $t = -4.102$, $P = 0.0003$; $t = -5.097$, $P = 0.0001$, in the partially sprayed, fully sprayed and untreated areas, resp.).

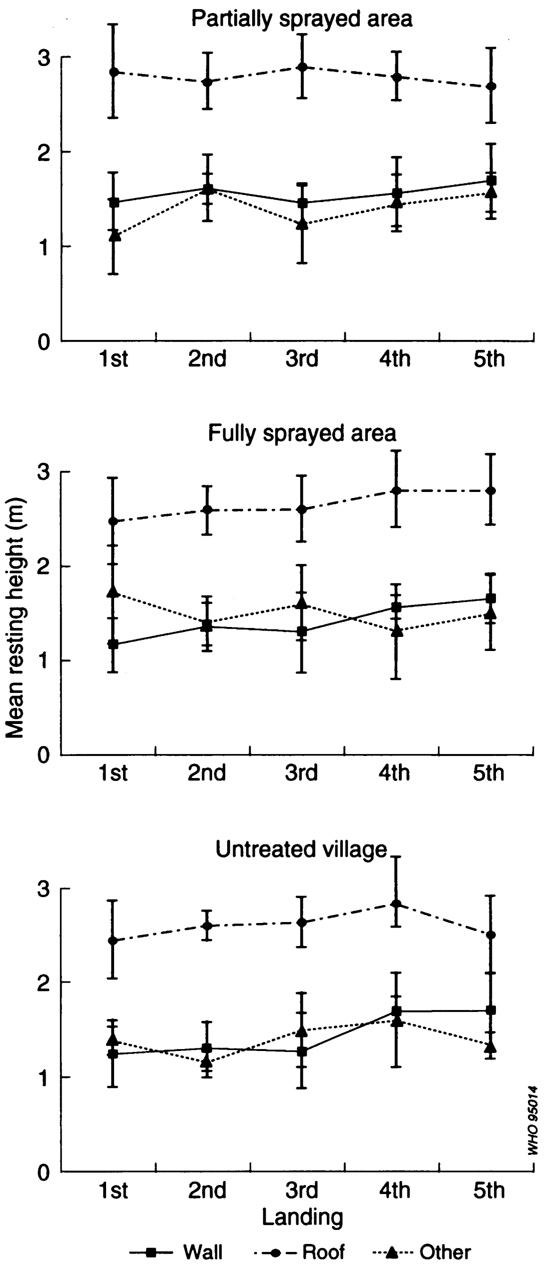
Human bait mortalities were in the range 0–95% in both the partially and fully sprayed sections of the treated village. Highest mortalities generally occurred during the wet season, which corresponded to those periods of highest relative abundance of mosquitos. Mortalities in experimental areas (means 18.01%, 17.56%, and 3.49% (intradomiciliary); 17.93%, 14.71% and 3.93% (peridomiciliary) for the partially sprayed, fully sprayed, and untreated areas, resp.) were significantly greater in treated houses than in the untreated ($F = 4.536$, $P < 0.01$; $F = 3.932$, $P < 0.05$, partially sprayed versus untreated and fully sprayed versus untreated, resp. (intradomiciliary); and $F = 5.77$, $P < 0.01$; $F = 3.251$, $P < 0.05$, partially sprayed versus untreated and fully sprayed versus untreated, resp. (peridomiciliary)).

Indoor resting behaviour

During the 2-year study period, a total of 95, 88, and 103 post-feed *A. albimanus* were followed up in the partially sprayed, fully sprayed and untreated areas, respectively. A mean landing frequency of 3.25 (total landings: 309) and 3.84 (total landings: 338) was observed on wall and roof surfaces of the partially and fully sprayed areas, respectively, with as many as 11 landings per mosquito. Mosquitos collected from the untreated village had a mean landing frequency of 3.39 (total landings: 349) and up to 16 landings. Of all mosquitos followed, only 5, 7, and 4, respectively, left the experimental hut without landing on indoor surfaces at least once, in the partially sprayed, fully sprayed, and control areas.

From the wall landing patterns observed for mosquitos collected from partially and fully sprayed areas of the treated village the mean landing heights calculated for five landings were as follows: 1.63 m (SE, ±0.32 m) and 1.29 m (SE, ±0.27 m) for the partially and fully sprayed areas, respectively (Fig. 3). Contact with roof surfaces varied less, the mean landing

Fig. 3. **Mean resting heights per landing (including standard errors) of *Anopheles albimanus* mosquitos in untreated and bendiocarb-sprayed walls.**



heights being 2.83 m (SE, ±0.36 m) and 2.62 m (SE, ±0.36 m) for partially and fully sprayed houses, respectively. The mean landing height for five landings on other interior surfaces of the partially and fully sprayed areas was 1.03 m (SE, ±0.29) and 1.7 m (SE, ±0.41 m) respectively. In the untreated village, the mean landing height of mosquitos was 1.31 m (SE, ±0.31 m) on walls and 2.78 (SE, ±0.31 m) on roof surfaces. In the partially sprayed houses, 92% of landings were on the insecticide-treated areas.

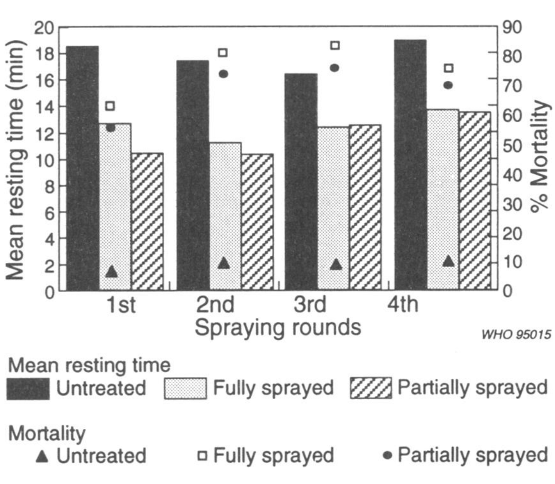
The longest contact (16.3–18.6 minutes; over 5 landings) during spray rounds occurred in the untreated village (Fig. 4). The duration of contact of mosquitos resting on partially (only treated surfaces) and fully sprayed surfaces (10.4–13.6 minutes) was significantly lower ($F = 32.66$, $P < 0.001$; and $F = 23.604$, $P < 0.01$, resp.). There were no significant differences in contact time between the partially and fully sprayed sectors ($F = 0.734$, $P > 0.05$).

The mortality rates for mosquitos collected on partially sprayed surfaces were 56–75%, compared with 63–83% for those collected in the fully sprayed sectors, the difference being not statistically significant ($F = 2.524$, $P > 0.05$). However, the mean mortalities on unsprayed surfaces (7.25%) in the untreated village were significantly lower than those in the partially sprayed (mean = 68.25%; $F = 110.035$, $P < 0.0001$) and fully sprayed areas (mean = 75.25%; $F = 145.889$, $P < 0.0001$).

House curtain

After being released in curtained houses, mosquitos tended to exit the house significantly "earlier" (i.e, in the first 3 hours' post-release) in those areas that were partially sprayed (68–83% of mosquitos,

Fig. 4. **Mean resting times and mortality levels of *Anopheles albimanus* mosquitos in treated and untreated villages during indoor mark–recapture experiments.**



χ^2_{MH} = 177.25, P <0.0001; χ^2_{MH} = 18.09, P <0.0001; χ^2_{MH} = 19.16, P <0.0001; χ^2_{MH} = 8.96, P <0,003; and χ^2_{MH} = 40.95, P = 0.0001, following the 1st, 2nd, 3rd and 4th spraying rounds, resp.) or fully sprayed (70–87% of mosquitos χ^2_{MH} = 495.71, P <0.0001; χ^2_{MH} = 8.78, P <0.05; χ^2_{MH} = 19.16, P <0.0001; χ^2_{MH} = 75.72, P <0.0001; and χ^2_{MH} = 36.23, P <0.0001, following the 1st, 2nd, 3rd and 4th spraying rounds, resp.). In the untreated village, only 41–63% of mosquitos left the houses early (Table 2).

Mosquito feeding success was significantly lower in the partially sprayed area (18%, 16% and 19%, χ^2_{MH} = 7.91, P <0.005; χ^2_{MH} = 5.39, P <0.05; and χ^2_{MH} = 35.53, P <0.0001, following the 1st, 2nd, and 4th spraying rounds, resp.) than in the untreated area, except before and after the 3rd insecticide treatment (41% and 18% feeding success; χ^2_{MH} = 0.03, P = 0.859; and χ^2_{MH} = 3.51, P = 0.061, resp.) (Table 2). Similarly, the fully sprayed area had a negative significant impact on the mosquito feeding success (19%, 12%, 13% and 20%; χ^2_{MH} = 4.58, P <0.05; and χ^2_{MH} = 23.30, P < 0.0001, following the 1st, 2nd, 3rd and 4th spraying rounds, resp.), compared with the untreated area (24%, 26%, 24% and 39% feeding success, resp.), except before the 3rd spraying round.

The mortality of mosquitos exiting the experimental curtained houses was significantly higher in the partially sprayed (35%, 83%, 62% and 71%, χ^2_{MH} = 161.47, P <0.0001; χ^2_{MH} = 253.07, P <0.0001; χ^2_{MH} = 309.03, P <0.0001; and χ^2_{MH} = 342.63, P <0.0001, following the 1st, 2nd, 3rd, and 4th spraying rounds, resp.) and fully sprayed areas (47%, 79%, 69% and 66%, χ^2_{MH} = 221.46, P <0.0001; χ^2_{MH} = 251.73, P <0.0001; χ^2_{MH} = 357.25, P <0.0001; and χ^2_{MH} = 253.69, P <0.0001, following the 1st, 2nd, 3rd and 4th spraying rounds, resp.). In the untreated area mortalities were 6%, 4%, 7% and 7%, resp., except prior to the 3rd spraying round, when mortalities were 5–7% in all areas (Table 2).

No significant differences were found between the treated areas, except following the 3rd spraying round, when mosquitos left the houses earlier (χ^2_{MH} = 5.09, P <0.05), fed less (χ^2_{MH} = 36.85, P <0.0001), and had a higher mortality level (χ^2_{MH} = 4.30, P <0.05) in the fully sprayed than in the partially sprayed area (Table 2).

Table 2: **Exiting and feeding patterns and mortalities of *Anopheles albimanus* mosquitos from the curtained houses in partially, fully and untreated areas after each spraying round**[a]

	Mosquitos:			
	n	% exiting early[b]	% blood-fed	Mortality (%)
Untreated				
Post 1st spraying	616	41	24	6
Post 2nd spraying	208	63	26	4
Pre 3rd spraying	163	46	42	7
Post 3rd spraying	395	59	24	4
Post 4th spraying	452	44	39	7
Partially sprayed				
Post 1st spraying	653	78[c]	18[c]	35[c]
Post 2nd spraying	184	83[c]	16[c]	83[c]
Pre 3rd spraying	73	77[c]	41	6
Post 3rd spraying	438	69[c]	18	62[c]
Post 4th spraying	318	68[c]	19[c]	71[c]
Fully sprayed				
Post 1st spraying	562	77[c]	19[c]	47[c]
Post 2nd spraying	233	76[c]	12[c]	79[c]
Pre 3rd spraying	73	77[c]	41	5
Post 3rd spraying	390	87[c]	13[d]	69[c]
Post 4th spraying	199	70[c]	20[c]	66[c]

[a] 1st Spraying, July 1988; 2nd spraying, late September–early October, 1988; 3rd spraying, July 1989; 4th spraying, October 1989.
[b] Exited the experimental hut during the first 3 hours.
[c] Significantly different exiting, feeding, or mortality relative to the untreated area.
[d] Significantly different exiting, feeding or mortality, for fully sprayed relative to the partially sprayed area.

Cost-effectiveness analysis

In the fully sprayed sector, insecticide was applied at a rate of 8 houses per man per day, while in the partially sprayed area, horizontal spraying permitted treatment of 12 houses per man per day, yielding a net time saving of ca. 50% (Table 3). In terms of costs, the conventional full spraying technique was 67% more expensive than the partial spraying (US$ 8.20 versus US$ 4.90, per house, resp.).

Discussion

As host-seeking mosquitos enter houses, their indoor resting tendencies are determined by two separate components— pre- and post-feeding—selection of pre-feeding resting sites is limited by time and host orientation since feeding has not been completed. Post-feeding behaviour, being motivated primarily by the need to escape from the host and to rest, permits a second opportunity for contact with indoor surfaces (*10*). Identification of these behaviours in malaria vectors is of paramount importance for designing appropriate control tactics. In mosquito control programmes it is not only important to know whether mosquitos rest indoors, but also to determine whether they prefer any particular type of surface or height. Targeting "preferred" indoor resting

Table 3: **Comparison of the costs of the partial and full spraying techniques with bendiocarb in all four spraying cycles**

	Full spraying	Partial spraying
Labour costs (US$):		
Total houses treated[a]	148	152
Personnel (man-days)	19	13
Total per diem (US$ 15/day)	285	195
Insecticide:		
Cost per kilo (US$)[b]	50	50
No. of kg per house (kg)	0.125	0.073
Total insecticide used (kg)	18.5	11.01
Total insecticide costs (US$)	925	550.5
Operational costs (US$):		
Per house	8.2	4.9
Total	1213.6	745.5
Optimization of time and money:		
Partial spraying technique time savings	146%	100%
Partial versus full spraying cost savings	167%	100%

[a] Of the 75 total houses in the treated village, 37 were fully sprayed and 38 were partially sprayed.
[b] Approximate 1993 wholesale price.

sites and applying insecticide there could provide a more cost-effective and rational way of controlling mosquito vectors.

Our results and those of other workers (*11*)[b] show that it is possible to use behavioural indicators as a basis for targeting vector populations and that treatment of indoor preferred resting sites with insecticide may be as effective as spraying all indoor surfaces. In an early mark–release study carried out in Indonesia to determine how control measures can be more effectively used against vector populations, *A. aconitus* Döenitz was found to rest at a constant height on walls in the same way as *A. albimanus* did in the present study, but at a lower height (<1 m) (*11*). The indoor/outdoor landing and resting rates of *A. aconitus* were reduced by spraying a single horizontal swath along the lower portion of indoor walls.[b]

The bioassay results indicated that bendiocarb elicited a sustained adequate residual effect (≥75% mortality) (*12*) on all the surfaces tested (wood, cement, palm–thatch, pole) for at least 3 months following four successive spraying rounds in 1988–90. Therefore, in view of the local coastal plain conditions in southern Chiapas, where mosquito densities are negligible over the period January–June, two spraying rounds at 3-month intervals of an insecticide to which mosquitos are susceptible, e.g., bendiocarb), one in July and another in October, should be sufficient to control *A. albimanus* populations.

As we and other workers have found (*13, 15*) the abundance of both intra- and peridomiciliary mosquitos was apparently not affected by insecticide treatments. Population fluctuations were perhaps more strongly determined by rainfall and the availability of breeding sites, adult resting places, and potential hosts. As in previous studies on *A. albimanus* in Mexico (*13*), mosquitos collected in intra- and peridomiciliary areas first entered houses, and after resting on treated surfaces almost equal proportions returned indoors and outdoors to bite human hosts. The high mortality rates from human bait collections in both partially and fully sprayed areas indicated that similar proportions of mosquitos collected in both intra- and peridomiciliary areas (pre- and post-feed) during periods of high abundance had sufficient contact with sprayed surfaces in both sectors to produce almost equal mortality levels (Fig. 2). Furthermore, the similar mortality rates for mosquitos captured resting on the inside of the curtain net and the mortality rates and resting times for mosquitos settling indoors suggest that mosquitos had almost equal levels of insecticide contact in both partially and fully sprayed sectors.

The preferred resting sites of the mosquitos did not change, even on insecticide-treated surfaces, despite four successive spraying rounds (Fig. 3). One probable reason was the low repellent effect elicited by bendiocarb (*16*), which was not sufficient to prevent mosquitos from coming into contact with insecticide but which made them feed less and increased their mortality rate (Fig. 4, Table 2).

The partial spraying technique was ca. 50% faster and was 67% of the cost of the full spraying approach because application time and the volume of insecticide used were lower. Since the partial spraying technique is faster and cheaper than the full spraying technique, fewer sprayers are needed, providing additional savings. This is especially important in Latin America, where malaria is still prevalent; and because spraymen and equipment are limited, savings made through optimizing insecticide application would allow increased coverage.

A. albimanus typically rests on indoor surfaces. By determining their resting preferences, we showed that after their preferred resting sites had been selectively sprayed the mosquitos maintained their resting preferences even after a long period of insecticide residual activity. Furthermore, mosquitos collected in both intra- and peridomiciliary areas during periods of high abundance had almost the same levels of

[b] **Bang YH et al.** *Selective application of fenitrothion for control of the malaria vector* Anopheles aconitus *in central Java, Indonesia.* Unpublished document WHO/VBC 81:822, 1981.

insecticide contact in both partially and fully sprayed sectors to produce similar mortality levels. It should be possible to apply indoor or outdoor control measures to areas where vectors are most commonly found and reduce excessive use of such measures, while still maintaining the objective of ultimately reducing vector/human contact and malaria.

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Résumé

Lutte contre *Anopheles albimanus* dans le sud du Mexique par pulvérisation d'insecticide sur les surfaces de repos préférentielles de ces moustiques à l'intérieur des habitations

La connaissance du comportement des vecteurs du paludisme en matière de repos à l'intérieur des habitations est d'une importance primordiale lors de la conception des tactiques de lutte appropriées. Pour les programmes de lutte contre les moustiques, il importe non seulement de savoir si les insectes se reposent à l'intérieur des habitations, mais également de déterminer s'ils préfèrent se poser sur un type particulier de surface ou à une hauteur particulière. L'application sélective d'insecticide sur les surfaces de repos préférentielles à l'intérieur des habitations pourrait constituer un moyen plus économique et rationnel de lutte contre les moustiques vecteurs. En 1988–1990, nous avons comparé la technique traditionnelle de pulvérisation à l'intérieur des habitations à une méthode visant les zones de repos préférentielles d'*Anopheles albimanus,* en utilisant un insecticide non répulsif de la famille des carbamates (bendiocarbe), dans des villages côtiers du sud du Mexique. Nous avons également recherché si les moustiques changeaient de zones de repos après l'application d'insecticide. La pulvérisation sélective consistait en l'application de deux bandes horizontales d'insecticide, de 1 m de large, l'uneà une hauteur de 0,75–1,75 m sur les murs et l'autre sur une hauteur de 1 m à partir de la base du toit, à la dose de 0,4 g/m^2. Une étude de suivi de deux ans (1988–1990) qui comportait quatre traitements, a montré que la pulvérisation sélective était aussi efficace que la pulvérisation générale contre *A. albimanus.* Les applications d'insecticide ne modifiaient pas la hauteur à laquelle les moustiques se posaient. Enfin, l'emploi de cette technique économisait 46% du temps et 67% des coûts par rapport à la pulvérisation classique. Cette méthode est donc avantageuse et constitue une approche rationnelle, rapide et économique de la lutte contre les moustiques vecteurs du paludisme.

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