STUDIES ON WIDE MESH NETTING IMPREGNATED WITH INSECTICIDES AGAINST *CULEX* MOSQUITOES

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ABSTRACT. Seven insecticides, fenitrothion, d-phenothrin, fenvalerate, permethrin, cyphenothrin and fenpropathrin, were each impregnated onto wide-mesh netting and bioassayed for insecticidal activity against *Culex* mosquitoes. After 9 months of aging, cyphenothrin was the most effective chemical. The movement of adult females through untreated nets was recorded. When the size of the opening of the mesh was less than the width of wing expanse, the mosquitoes were found to rest on the netting before they passed through, thus allowing them time to pick up a lethal dose of the insecticide.

INTRODUCTION

A bed net is a very effective physical protection against bites of mosquitoes, but the small mesh prevents fresh air flow through the net and makes it uncomfortable to the user. Large mesh nets provide good ventilation, but allow mosquitoes to pass through them. Schreck and Kline (1983) reported that a net impregnated with diethyltoluamide prevented invasion through the net by *Culicoides* biting midges. Kurihara et al. (1985) evaluated the effect of a wide mesh netting impregnated with d-phenothrin against *Anopheles* mosquitoes and observed "bite and run" behavior (Pampana 1969). These reports suggest it may be possible to use wide mesh netting for mosquito control.

Schreck et al. (1977) assessed a net impregnated with resmethrin. In olfactometer tests, *Aedes aegypti* (Linn.) and *Anopheles quadrimaculatus* Say were not repelled but died from momentary contact with the treated net. Itoh and Hirose (1981) demonstrated that pyrethroids such as permethrin showed locomotory stimulant activity by contact, against *Lyctus brunneus* Stephens (Lyctidae: Coleoptera). This suggests that to be affected, mosquitoes must contact the pyrethroid treated net when passing through it.

In this paper, we report on the observations of *Culex* mosquitoes passing through untreated nets, in darkness, by means of an infra-red camera. An appropriate wide mesh net was selected, on which all the mosquitoes would rest before they passed through the net. The net was then impregnated with various insecticides and assessed for insecticidal activity against mosquitoes.

MATERIALS AND METHODS

MOSQUITO SPECIES TESTED. Three day old unfed females *Culex pipiens pallens* Coq. that were kept under a regimen of 16 hr light and 8 hr darkness.

INSECTICIDES TESTED. Fenitrothion (0, 0-dimethyl 0-4-nitro-m-toryl phosphorothioate, purity 97.6%), a d-phenothrin (3-phenoxybenzyl (1R)-cis, trans-chrysanthemate, purity 92.8%), fenvalerate ((RS)-α-cyano-3-phenoxybenzyl (RS)-2-(4-chloro-phenyl)-3-methylbutyrate, purity 94.6%), permethrin (3-(phenoxyphenol) methyl (1RS)-cis,trans-3-(2-2dichloroethenyl)-2,2-dimethyl cyclopropanecarboxylate, purity 91.0%, cis/trans44/56), prallethrin (Code No. S-4068SF, (S)-2-methyl-4-oxo-3-(2-propynyl) cyclopent-2-enyl (1R)-cis,trans-chrysanthemate, purity 91.8%), cyphenothrin ((RS)-α-cyano-3-phenoxybenzyl (1R)-cis, trans-chrysanthemate, purity 95.8%) and fenpro-pathrin ((RS)-α-cyano-3-phenoxybenzyl 2,2,3,3-tetramethyl-cyclopropanecarboxylate, purity 91.9%). Emulsifiable concentrates of these insecticides were formulated as follows: active ingredient: emulsifier (Sorpol[R] SM100P, Toho Chemical Co. Ltd.) : xylene = 1:2:7 (w/w).

NETTING TESTED. The netting was made of a mixture of cotton and synthetic fiber (vinylon) with mesh sizes of 0.8 × 0.8, 1.6 × 1.6 and 3.2 × 3.2 cm.

EXPERIMENT 1. TESTS TO DETERMINE A NET SIZE THAT MOSQUITOES TOUCH, AND CAN PASS THROUGH. Two glass chambers 70 × 70 × 70 cm, were connected by a plastic tube 10 cm in diameter and 70 cm long, as shown in Fig. 1. The opening of the tube in chamber A was covered with an untreated net 15 × 15 cm. The opening of a cage containing 100 female mosquitoes was inserted into the opening of the tube in chamber B. The infra-red camera (Model AVC-1033S, Sony Co. Ltd.) with a TV Zoom lens)10 × 15 REA 15–150 mm, Canon Co. Ltd.) was set up at the front of the net, outside chamber A, to observe mosquitoes moving from the cage and through the net to the interior of chamber A. The mosquito cage (29 cm upper diameter, 9.5 cm lower diameter and 39 cm height) was exposed to infra-red rays reflected against the room wall, because direct exposure of the ray emitter (Model HUL-1300 IRA, Sony Co. Ltd.) caused hala-

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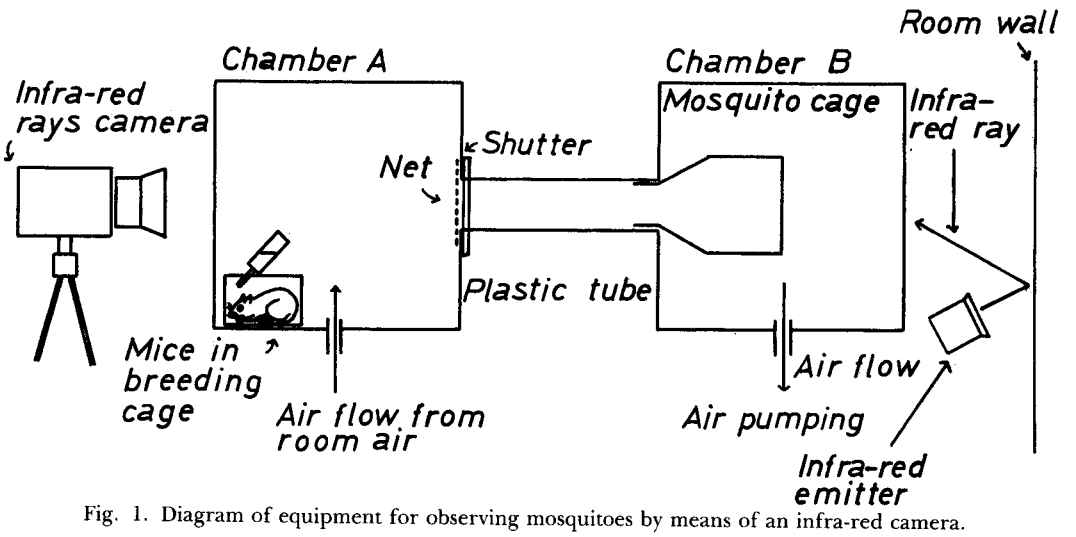

Fig. 1. Diagram of equipment for observing mosquitoes by means of an infra-red camera.

tion. The mosquitoes passing through the net could be seen in silhouette. Caged mice were used in chamber A as an attractant, and air flow from chamber A to chamber B through the tube and mosquito cage was generated by an air pump (Model KP-20-A, Matsushita Electric industrial Co. Ltd.) at the rate of 2 liters/min. The shutter partitioning off the tube from chamber A was opened after the room had been darkened for 1 hr and the mosquitoes passing through the net were monitored by the camera for the next 1 hr period. Information from the camera was recorded by the video cassette recorder (Model TVO-9000, Sony Co. Ltd.) with the video TV monitor (Model PVM-91J, Sony Co. Ltd.), the video timer (Model VTG 33, FOR.A Co. Ltd.) and the controller (Model CC-7T, Canon Co. Ltd.) for focusing the camera. Observations of mosquito behavior were done by the video cassette recorder. Tests with each net were replicated 3 times.

EXPERIMENT 2. RESIDUAL ACTIVITY OF 7 INSECTICIDES APPLIED TO NETTING. The netting (20 × 20 cm) with a mesh of 0.8 × 0.8 cm was immersed for 5 min in a water diluted solution of an insecticide (0.2 or 0.08%). The amount of active ingredient on the netting was calculated by measurement of change of weight before and after treatment. The treated net was air-dried for 24 hr under room conditions and formed into a cylinder 3 cm in diameter and placed into a polyethylene cup (9 cm bottom diameter, 12 cm upper diameter and 7 cm in height) as shown in Fig 2. The upper side of the netting was fastened to the lid by adhesive tape. Five 2 cm holes in the side of the cup were covered with cotton netting (0.2 × 0.2 cm mesh) to provide ventilation. Ten female mosquitoes were then liberated into the cup. Cotton soaked with a 1% sugar solution was placed over a 3 cm hole in the lid as a food source. Mortality was observed 24 hr after liberation. The polyethylene cups were kept in darkness at 35°C and tests were repeated at 1 week, and 1, 2, 6 and 9 months after treatment, to determine duration of activity. Experiments were replicated 2 times.

RESULTS AND DISCUSSION

The manner in which the mosquitoes passed through the 3 kinds of netting is given in Table 1. When the mosquitoes passed through the smallest netting (0.8 × 0.8 cm), all of them rested on it, and entered the chamber by

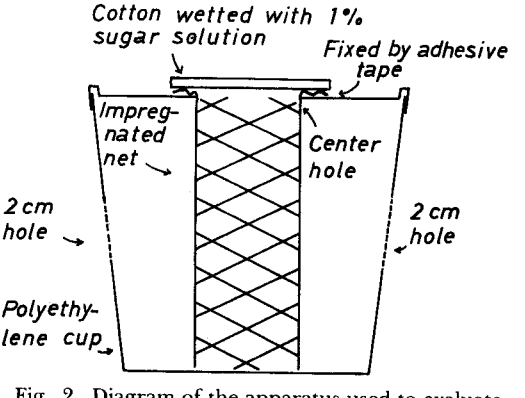

Fig. 2. Diagram of the apparatus used to evaluate residual activity of insecticides impregnated in netting.

Table 1. Observations of female *Culex pipiens pallens* passing through different mesh sizes of netting (Average of 3 replications of 100 in each test).

Mesh width (cm)	No. passing through net	No. resting on net	Percent resting on net*	Av. time resting
0.8 × 0.8	10.7	10.7	100	23 sec
1.6 × 1.6	32.0	2.0	6.3	23 sec
3.2 × 3.2	20.0	0.0	0.0	—

* % of no. resting on net against no. passing through net.

walking. It is reasonable to assume that since the width of wing expanse of flying mosquitoes is larger than 0.8 cm, they cannot fly through the net without touching it. When mosquitoes passed through the mid-sized mesh (1.6 × 1.6 cm), a few rested on the netting, while none rested on the largest (3.2 × 3.2 cm) mesh. These observations indicate that a net mesh size slightly smaller than the unfolded wings of a flying mosquito will cause the mosquito to rest on or contact the net when it attempts to pass through.

Table 2 shows residual activity of 7 insecticides impregnated into nets and tested against *Cx. pipiens pallens*. A measurement of weight change of the netting before and after treatment showed the absorbed amount of water and insecticide to be approximately 62.5 g/m^2. For residual spray applications of insecticides on walls of houses to control malaria mosquitoes, permethrin at 0.5 g/m^2 is recommended (Smith 1982). When the recommended dose of permethrin is used on netting, its concentration is calculated to be 0.8%. Two dose levels were used, one of which was one-fourth that of wall application.

It is obvious that at the 0.2% level of application, cyphenothrin was the most effective at 9 months after treatment, followed by fenvalerate, d-phenothrin and both permethrin and fenpropathrin. These treated nets were kept under darkness in this experiment. Some pyrethroids are unstable in sunlight (Elliott et al. 1978) and since impregnated nets would be expected to be occasionally exposed to sunlight, further tests will be needed to determine residual activity under field conditions.

Schreck et al. (1977) evaluated netting impregnated with resmethrin. They stated that *Ae. aegypti* and *An. quadrimaculatus* were not repelled but died from momentary contact with the treated net. It is also suggested that pyrethroids such as permethrin can be expected to have biological activity only by contact with the treated net, therefore it may be necessary for mosquitoes to contact the treated

Table 2. Residual activity of some insecticide impregnated nets against female *Culex pipiens pallens* (Average of 2 replications).

Insecticides	Concentration (%)	Mortality (%) after a 24 hr exposure at indicated period after treatment				
		1 week	1*	2*	6*	9*
Fenitrothion	0.2	100	100	100	0	0
d-phenothrin	0.2	100	100	100	100	60
	0.08	28**	0	—	—	—
Fenvalerate	0.2	100	100	100	88**	65
	0.08	94**	21**	—	—	—
Permethrin	0.2	100	100	100	100	55
	0.08	95	94**	—	25	—
Prallethrin	0.2	100	100	10	41**	5
	0.08	100	100	10	0	—
Cyphenothrin	0.2	100	100	100	100	100
	0.08	100	100	100	0	0
Fenpropathrin	0.2	100	100	100	100	55
	0.08	100	100	80	0	—
Untreated	—	0	0	5	0	5

* Months after treatment.

** A few mosquitoes escaped when they were transfered into the cup.

net. For this reason, mesh size may be an important consideration. The 0.8 × 0.8 cm mesh used in this experiment provided good ventilation and may be an effective barrier in preventing mosquito borne disease when impregnated with one of the long lasting insecticides such as cyphenothrin.

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