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RELATIVE EFFICACY OF SYNTHETIC PYRETHROID-IMPREGNATED FABRICS AGAINST MOSQUITOES UNDER LABORATORY CONDITIONS

MUSHARRAF ALI ANSARI,[1] NEERA KAPOOR[2] AND V. P. SHARMA[1]

ABSTRACT. The efficacy of synthetic pyrethroid-impregnated fabrics was evaluated against *Anopheles stephensi, Aedes aegypti,* and *Culex quinquefasciatus,* under laboratory conditions. Results revealed that deltamethrin was significantly superior in comparison to lambdacyhalothrin and cyfluthrin. Results of bioassay tests revealed that deltamethrin was 1.5 and 1.9 times more effective than lambdacyhalothrin and cyfluthrin, respectively, against *An. stephensi* exposed to cotton fabric treated at 100 g/m^2. Deltamethrin was 3.9 and 4.6 times more effective against *Ae. aegypti* and 3.53 and 4.0 times more effective against *Cx. quinquefasciatus.* Of cotton, nylon, polyethylene, and jute fabrics, the cotton was the best on the basis of median lethal dose (LD_{50}) and 95% lethal dose (LD_{90}) values and persistence of insecticide.

KEY WORDS Insecticide-impregnated curtains, mosquitoes, malaria control, bioassy, relative toxicity index, deltamethrin, cyfluthrin, lambdacyhalothrin, cotton, nylon, polyethylene, jute, fabrics

INTRODUCTION

Recently, much emphasis has been placed on personal protection measures against mosquitoes. The advent of synthetic pyrethroids with a quick knockdown effect has revived interest in using mosquito bednets. Trials carried out in India and China with various synthetic pyrethroids provided encouraging results, particularly in rural areas (Rozendaal 1989). The use of impregnated bednets is cumbersome in urban areas because of the lack of space, sociocultural differences in life style, and differences in sleeping habits of the people. Social acceptability of bednet use is also quite low (Majori et al. 1989). Plain curtains are normally used in the majority of houses in the city and if they are impregnated with synthetic pyrethroid, the entries of mosquitoes can be prevented to a great extent. Mosquitoes normally rest on hanging objects such as curtains in urban areas and if a small proportion of mosquitoes enter into the house, they will pick up a lethal dose of pyrethroid while resting on curtains before and after the entry and be killed. Therefore, impregnated curtains may play an important role in controlling vector-borne diseases in urban areas. Thus, this study was undertaken to develop procedures and techniques for impregnation of different types of fabrics and to evaluate pyrethroid efficacy and persistence on different fabrics.

MATERIALS AND METHODS

Anopheles stephensi Liston, a principal vector of urban malaria, *Aedes aegypti* (Linnaeus), a principal vector of dengue and dengue hemorrhagic fever, and *Culex quinquefasciatus* Say, a principal vector of bancroftian filariasis and a nuisance mosquito were selected for laboratory evaluation.

Emulsifiable concentrate formulations of deltamethrin (2.8%) (Hoechst India Ltd., Maharashtra, India), lambdacyhalothrin (5%) (I.C.I. India Ltd., New Delhi, India), and cyhalothrin (5%) (Bayer India Ltd., Bombay, India) were used during the study.

The following new fabrics were used: cotton, 0.56 × 0.18-mm hole size with 560 horizontal and 180 vertical threads per m^2 weighing 432 g/m^2; nylon, 4 × 3-mm hole size with 400 horizontal and 320 vertical threads per m^2 weighing 45 g/m^2; jute, 5.5 × 5.5-mm mesh hole size with 322 horizontal and 288 vertical threads per m^2 weighing 160 g/m^2; and polyethylene, 0.38 × 0.46-mm mesh hole size with 390 horizontal and 470 vertical threads per m^2 weighing 132 g/m^2. All fabrics were impregnated with the different synthetic pyrethroids at 20, 40, 80, and 100 mg/m^2. Mosquito colonies were maintained in the insectary at 28 ± 1°C and 70–80% relative humidity as described earlier by Ansari et al. (1978).

Impregnation technique

The absorption rate was determined by dipping a measured piece of each fabric into water. After calculating the surface area of the fabric, the target dose was calculated using the following formula:

$$\text{volume required} = \frac{\text{weight (g)} \times 100}{\%\ \text{solution of insecticide}}.$$

The appropriate quantity of water to soak the fabric was measured and the volume of insecticide required to give the target dosage (g/m^2) was added. The curtain was soaked in a nonabsorbent container such as a plastic tub with this solution and rubbed and squeezed to obtain uniform distribution of the insecticide over the entire piece of fabric. The cur-

[1] Malaria Research Centre, 20, Madhuban, Delhi-110092, India
[2] School of Life Sciences, Indira Gandhi Open University, New Delhi, India.

Table 1. Relative efficacy of synthetic pyrethroids on different fabrics against mosquitoes.[1]

Species	Fabric	Deltamethrin (2.8% EC)			Lambdacyhalothrin (5% EC)			Cyfluthrin (5% EC)		
		LD_{50} (mg/m²)	LD_{90} (mg/m²)	Fiducial limits	LD_{50} (mg/m²)	LD_{90} (mg/m²)	Fiducial limits	LD_{50} (mg/m²)	LD_{90} (mg/m²)	Fiducial limits
Anopheles stephensi	C	5.2	58.8	4.7–5.7	7.76	75.8	6.9–9.0	10.0	85.0	8.62–11.64
	N	9.95	83.72	8.5–11.2	13.8	95.2	10.2–18.6	22.07	100.0	18.1–26.3
	J	5.12	70.79	4.4–5.8	10.0	93.75	8.7–11.4	20.0	95.0	17.3–22.9
	P	6.31	78.26	5.5–7.3	11.36	90.0	9.7–12.8	20.4	97.82	16.9–23.4
Aedes aegypti	C	7.8	60.06	6.6–8.9	30.5	95.75	25.1–35.4	35.5	100.0	26.3–38.01
	N	10.7	85.0	9.3–12.3	24.1	103.09	20.8–27.5	42.73	110.7	38.01–47.08
	J	5.24	78.2	4.6–5.8	21.73	97.18	18.1–25.1	40.0	104.65	33.8–46.7
	P	6.60	85.62	5.75–7.58	23.8	95.0	33.8–46.7	41.6	102.27	35.4–48.9
Culex quinquefasciatus	C	10.0	80.0	8.8–12.5	35.3	98.55	28.8–41.6	40.0	120.0	33.1–48.9
	N	21.2	92.8	19.5–24.8	24.2	108.43	21.3–26.9	42.78	110.58	36.3–47.8
	J	10.5	80.71	9.5–12.8	24.2	100.0	20.4–28.1	41.0	110.58	33.8–47.1
	P	13.8	100.36	11.4–15.5	40.0	100.0	20.4–26.9	42.5	104.65	36.3–50.1

[1] EC, emulsifiable concentrate; LD_{50}, median lethal dose; LD_{90}, 90% lethal dose; C, cotton; N, nylon; J, jute; P, polyethylene.

Table 2. Relative toxicity indexes on different fabrics.[1]

Species	Fabric	D and L	D and C	L and C
Anopheles stephensi	C	1.5	1.9	1.28
	N	1.38	2.21	1.19
	J	1.95	3.9	2.0
	P	1.8	3.23	1.8
Aedes aegypti	C	3.92	4.6	1.16
	N	2.09	3.98	1.77
	J	4.14	7.6	1.84
	P	3.6	6.3	1.75
Culex quinquefasciatus	C	3.53	4.0	1.13
	N	1.14	2.01	1.77
	J	2.3	3.9	1.7
	P	2.94	3.12	1.06

[1] D, deltamethrin; L, lambdacyhalothrin; C, cyfluthrin; C, cotton; N, nylon; J, jute; P, polyethylene.

tain was then spread on a polyethylene sheet and allowed to dry in the shade. The fabric was turned several times during the process of drying so that the insecticide was uniformly distributed on both surfaces.

Bioassay tests were carried out with susceptibility test kits for both relative efficacy and persistence of insecticides on different fabrics. Median lethal dose (LD_{50}) and 90% lethal dose (LD_{90}) values were calculated as described by Finney (1938). Relative toxicity index was calculated by comparing LD_{50} and LD_{90} values.

RESULTS AND DISCUSSION

The efficacy of insecticide varied from fabric to fabric (Table 1). Deltamethrin was most effective on cotton whereas cyfluthrin was most effective on jute fabric. Lambdacyhalothrin was equally effective on all fabrics. Of the different fabrics tested, cotton fabric provided consistent results with different dosages. Calculated LD_{50} values on cotton fabric for deltamethrin, lambdacyhalothrin, and cyfluthrin were 5.2, 7.8, and 10 mg/m², respectively, for *An. stephensi*; 7.8, 30.5, and 35.5 mg/m², respectively, for *Ae. aegypti*; and 10, 35.3, and 40 mg/m², respectively, for *Cx. quinquefasciatus*. Similarly, LD_{90} values for cotton fabric with deltamethrin, lambdacyhalothrin, and cyfluthrin were 58.8, 75.8, and 85 mg/m², respectively, for *An. stephensi*; 60.06, 95.7, and 100 mg/m², respectively, for *Ae. aegypti*; and 80, 98.5, and 120 mg/m², respectively, for *Cx. quinquefasciatus*. These values substantiate earlier observations that *An. stephensi* is the most susceptible species, and *Cx. quinquefasciatus* is the least susceptible (Table 1).

Relative toxicity index

Relative toxicity indexes based on LD_{50} values revealed that deltamethrin was 1.5 and 1.9 times

Table 3. Persistence of different insecticides at a dosage of 80 mg/m² against different mosquito species on various fabrics.

Insecticide	% corrected mortality at different intervals											
	0 wk				4 wk				8 wk			
	C	N	J	P	C	N	J	P	C	N	J	P
	Anopheles stephensi											
D	97.0	88.0	92.0	89.3	97.0	80.0	90.4	82.0	96.0	76.0	87.0	74.0
L	83.0	78.0	80.0	82.0	80.0	70.0	77.0	71.0	74.5	60.0	73.0	60.0
C	83.3	70.0	80.0	80.0	78.5	61.0	77.0	71.0	72.0	53.6	72.0	62.0
	Aedes aegypti											
D	96.7	86.0	94.0	92.0	94.2	82.5	89.8	86.8	91.4	79.0	87.0	75.0
L	82.0	72.5	78.0	76.0	78.2	62.4	74.0	68.2	74.6	53.0	70.0	55.0
C	62.6	59.3	61.3	60.0	60.6	53.0	55.9	54.0	57.8	45.0	53.0	45.0
	Culex quinquefasciatus											
D	90.0	84.0	89.2	85.3	82.8	80.0	76.0	78.0	78.0	73.4	65.6	72.0
L	83.3	79.3	82.8	80.0	77.0	75.2	74.0	73.0	72.6	70.0	64.0	63.0
C	64.0	70.0	62.0	60.0	57.0	61.0	55.3	50.0	53.0	53.6	48.2	40.0

[1] C, cotton; N, nylon; J, jute; P, polyethylene; D, deltamethrin; L, lambdacyhalothrin; C, cyfluthrin.

more toxic than lambdacyhalothrin and cyfluthrin, respectively, for *An. stephensi,* 3.9 and 4.6 times more toxic for *Ae. aegypti,* and 3.5 and 4 times more toxic for *Cx. quinquefasciatus* on cotton fabric. Lambdacyhalothrin was about 1.2 times more toxic than cyfluthrin. Similar results were obtained with other fabrics (Table 2). These results infer that deltamethrin is marginally superior to other insecticides in terms of toxicity.

Persistence

Further observations on persistence of different insecticides against mosquito species on different fabrics were made to confirm that the efficacy of the insecticide is directly proportional to the dosage used (Table 3). Persistence was 4 wk against *An. stephensi* when cotton curtains were impregnated at 20 mg/m² of deltamethrin. Persistence was increased to 16 wk when the dosage was increased to 80 mg/m². For *Ae. aegypti* and *Cx. quinquefasciatus,* persistence was 13 and 8 wk respectively, at a similar dosage. Similarly, persistence of lambdacyhalothrin was only 3 wk against *An. stephensi* when the dosage was 20 mg/m². Persistence increased to 12 wk when the dosage was increased to 80 mg/m². For *Ae. aegypti* and *Cx. quinquefasciatus,* persistence was reduced from 10 to 7 wk, respectively. Persistence was observed only for 2 wk against *An. stephensi* when cotton curtains were impregnated with cyfluthrin at 20 mg/m². Persistence increased to 6 wk when the dosage was increased to 80 mg/m². For *Ae. aegypti* and *Cx. quinquefasciatus,* persistence was reduced from 5 to 4 wk, respectively.

The efficacy of insecticide-impregnated curtains has been evaluated by several workers in the field. Curtains impregnated with 1% permethrin provided a considerable reduction in indoor densities of *Anopheles gambiae* (Giles) and *Anopheles funestus* (Giles) for a period of 11 months (Majori et al. 1989). A similar reduction in mosquito entry was observed in experimental huts in Tanzania where impregnated window curtains were used. However, the same degree of reduction was not achieved when a strip of treated fabric was fixed around the eaves of the house, because of the presence of several other objects on which mosquitoes could rest within the house (Lines et al. 1987). Thus, curtains seem to act more as insecticide-treated resting places rather than as barriers to entry. However, in another experiment in Kenya, cotton cloth impregnated with permethrin provided protection for 6, 4, and 10 months against *An. gambiae, Cx. quinquefasciatus,* and *Ae. aegypti,* respectively (Mutinga et al. 1992). These studies clearly showed that populations of malaria vectors can be effectively controlled by the use of pyrethroid-impregnated curtains in urban and slum settlements.

In view of these encouraging results, further studies are indicated to evaluate the operational feasibility and efficacy of impregnated curtains in reducing mosquitoes and malaria incidence. This technology in combination with legislative measures may prove to be cost effective and appropriate for controlling vector-borne diseases, particularly malaria in metropolitan areas.

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Table 3. Extended.

% corrected mortality at different intervals											
12 wk				16 wk				20 wk			
C	N	J	P	C	N	J	P	C	N	J	P
Anopheles stephensi											
95.0	71.2	83.0	62.0	91.4	64.5	81.0	47.0	85.0	57.7	78.0	35.0
66.0	48.0	68.0	46.0	56.0	38.2	60.0	30.2	46.3	29.0	50.0	10.0
62.0	44.0	67.0	50.0	55.0	36.0	60.0	40.0	45.0	27.5	51.0	25.0
Aedes aegypti											
89.4	71.0	84.5	65.5	87.0	64.0	82.0	57.0	85.0	54.0	73.0	36.0
72.0	42.5	66.4	45.0	65.0	31.1	62.0	28.0	57.2	22.0	52.0	8.0
55.0	37.3	47.5	33.0	51.2	26.2	40.0	18.0	45.0	16.0	33.0	4.0
Culex quinquefasciatus											
73.0	63.0	55.0	57.0	65.9	56.5	48.0	46.0	55.0	48.0	40.0	31.0
65.6	57.0	55.0	52.0	60.0	46.4	40.0	43.0	56.0	40.0	30.0	30.0
48.0	44.0	48.0	29.0	44.0	36.0	34.0	17.0	35.0	27.5	28.0	3.0

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