

Laboratory Evaluation of Synthetic Pyrethroid-treated Cotton Fabric Against Mosquitoes and Other Domestic Pests

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Abstract

The bio-efficacy of deltamethrin, lambdacyhalothrin, cyfluthrin, and etofenprox treated cotton fabric was determined against mosquitoes and other domestic pests, viz *Anopheles stephensi* Liston, *Aedes aegypti* Linnaeus, *Culex quinquefasciatus* Say, *Phlebotomus argentipes* Linnaeus, *Musca domestica* Linnaeus, *Periplaneta americana* Linnaeus and *Cimex lectularius* Linnaeus under laboratory conditions. The results revealed that cotton fabric treated with different insecticides had shown variable degrees of impact against different mosquito species and domestic pests. *An. stephensi* was the most susceptible, followed by *Ae. aegypti*, *Cx. quinquefasciatus*, *P. argentipes*, *P. americana*, *M. domestica* and *C. lectularius*. Deltamethrin-treated cotton fabric was most promising, followed by lambdacyhalothrin, cyfluthrin and etofenprox. LD₅₀ values ranged from 5.2-40 mg/m² for *An. stephensi*, *Ae. aegypti* and *Cx. quinquefasciatus* with different synthetic pyrethroids. Similarly, LD₅₀ values for *P. argentipes*, *P. americana*, *M. domestica* and *C. lectularius* varied from 48 to 135 mg/m². LD₉₀ values ranged from 58.8-120 mg/m² for *An. stephensi*, *Ae. aegypti* and *Cx. quinquefasciatus* with different synthetic pyrethroids. LD₉₀ values varied from 85.8 to 180 mg/m² with different pyrethroids for *P. argentipes*, *P. americana*, *M. domestica* and *C. lectularius*. Statistical analysis revealed that deltamethrin is marginally superior to other insecticides (P < 0.5).

Keywords: pyrethroid-treated cotton fabric, mosquitoes, domestic pests, deltamethrin, lambdacyhalothrin, cyfluthrin, etofenprox

Introduction

The strategy of Indoor Residual Spraying (IRS) of insecticide to control malaria has been proved counter-productive due to the inherent problems of resistance, cross-resistance, exophilic and endophilic behavior of vector species, inadequate coverage, lack of collateral benefits, alarming increasing cost of insecticides and spraying and environmental contamination. In view of this, Insecticide Treated Nets (ITN) and Insecticide Treated Curtains (ITC) have been advocated to roll back malaria in endemic countries [1-2]. Effective

control has already been demonstrated in India and elsewhere [3-4]. The strategy is quite appropriate in rural areas, however, the use of nets is cumbersome in urban areas due to inadequate space, socio-cultural differences in living style and sleeping habits. Since plain curtains are used by the majority of inhabitants in urban areas, the use of ITCs would be appropriate, as the Government subsidizes the nominal cost of treatment and also ensures community participation [5]. In view of this, a laboratory study was planned to evaluate the broad-spectrum activity of synthetic pyrethroid-

treated cotton fabric against mosquitoes and domestic pests. Results of this study are reported in this paper.

Materials and methods

Anopheles stephensi Liston, a principal vector of urban malaria, *Aedes aegypti* Linnaeus, a principal vector of dengue hemorrhagic fever and *Culex quinquefasciatus* Say, a principal vector of bancroftian filariasis and a nuisance mosquito, were selected for laboratory evaluation. In domestic pests *Phlebotomus argentipes* Linnaeus, a vector of visceral leishmaniasis, *Musca domestica* *nebulosa*, a mechanical carrier of diarrhea, *Periplaneta americana* Linnaeus, a nuisance pest, and *Cimex lectularius* Linnaeus, a blood-sucking pest, were selected for laboratory evaluation against insecticide-treated cotton fabric. Test insects were reared in the laboratory of the Department of Zoology, University of Delhi, Delhi, as per standard procedures and techniques at a temperature of $28 \pm 1^\circ\text{C}$ and 70 to 80% relative humidity.

tests, which were carried out using WHO kits and standard procedures. Fifteen fed adult female mosquitoes were exposed for three minutes in each replication and the test was repeated at least five times with each insecticide and species. In the case of flies, cockroaches and bugs, 2-3 days old adults of both sexes were tested with similar exposure period. Percent mortality was recorded after 24 hours and corrected by using Abbott's formula [6].

Median lethal dose (LD_{50}) and 90% lethal dose (LD_{90}) values were calculated as described by Finney [7]. Confidence Limits (95%) were also calculated to know the range of LD_{50} and LD_{90} values. A Relative Toxicity Index (RTI) was calculated by finding the ratio of LD_{50} and LD_{90} of different insecticides against *C. lectularius* as it was found to be the most resistant against all insecticides tested, thereby showing the maximum LD_{50} and LD_{90} . Factorial analysis of variance (ANOVA) and t-test were carried out on the corrected mortality using the PROFESSIONAL computer software package.

$$\% \text{ Corrected mortality} = \frac{\% \text{ Observed mortality} - \% \text{ Control mortality}}{100 - \% \text{ Control mortality}} \times 100$$

Emulsifiable concentrate formulations of deltamethrin (2.8%) (Hoechst India Ltd, Maharashtra, India), lambdacyhalothrin (5%) (ICI India Ltd, New Delhi, India), cyfluthrin (5%) (Bayer India Ltd, Bombay, India) and etofenprox (10%) (Mitsui Tohatsu Chemicals Ltd, Japan) were used for the study.

Cotton fabric, of 0.56×0.18 mm hole size with 360 horizontal and 180 vertical threads per sq m weighing 432 g/m^2 , was used for insecticide treatment. The fabric was impregnated with different synthetic pyrethroids at 80, 100, and 150 mg/m^2 of active ingredient of each insecticide as per the procedure described by Ansari *et al* [5]. After treatment, the fabric was fixed on 0.5 m^2 aluminium frame panel and used for bioassay

Results and discussion

The percent corrected mortality of mosquitoes and other domestic pests is depicted in Table 1. It is clear from the table that the bio-efficacy of synthetic pyrethroid-treated curtains varied with different insecticides and pest species. Highest efficacy was observed against mosquitoes, followed by flies, cockroaches and blood-sucking bugs. Of four insecticides tested, deltamethrin showed highest efficacy against mosquitoes and other domestic pests. Cotton fabric treated with deltamethrin @ 100 mg/m^2 produced 100% adult mortality against *An. stephensi*, *Ae. aegypti* and *Cx. quinquefasciatus*. Similar dosages and exposures with lambdacyhalothrin, cyfluthrin and etofenprox produced 93-95%, 89-98% and 90-95%

Table 1 Percent corrected mortality of mosquitoes and domestic pests exposed to cotton fabric treated with different insecticides, under laboratory conditions.

Species	% corrected mortality at dosages (mg/m ²)											
	DM			LC			CY			ET		
	80	100	150	80	100	150	80	100	150	80	100	150
<i>An. stephensi</i> ♀	97.0 ± 2.4	100.0 ± 0.0	100.0 ± 0.0	83.0 ± 4.2	94.0 ± 1.2	100.0 ± 0.0	83.0 ± 2.9	98.0 ± 0.8	100.0 ± 0.0	85.0 ± 3.1	95.0 ± 1.2	100.0 ± 0.0
<i>Ae. aegypti</i> ♀	96.7 ± 1.5	100.0 ± 0.0	100.0 ± 0.0	82.0 ± 3.6	93.3 ± 2.1	100.0 ± 0.0	62.6 ± 3.5	88.6 ± 2.8	100.0 ± 0.0	75.0 ± 4.2	92.0 ± 3.2	100.0 ± 0.0
<i>Cx. quinquefasciatus</i> ♀	90.0 ± 2.8	100.0 ± 0.0	100.0 ± 0.0	83.3 ± 2.7	95.3 ± 1.3	100.0 ± 0.0	64.0 ± 4.5	89.6 ± 3.2	100.0 ± 0.0	75.0 ± 1.3	90.0 ± 2.5	100.0 ± 0.0
<i>Phlebotomus argentipes</i>												
Adults ♂	82.8 ± 4.5	90.2 ± 1.3	100.0 ± 0.0	50.5 ± 2.9	56.2 ± 4.3	100.0 ± 0.5	44.4 ± 2.5	52.5 ± 3.5	100.0 ± 0.2	50.0 ± 2.5	62.6 ± 4.1	92.8 ± 1.2
♀	78.2 ± 4.8	84.3 ± 2.5	100.0 ± 0.0	55.5 ± 1.8	60.5 ± 3.2	100.0 ± 0.2	44.4 ± 4.2	50.5 ± 3.6	100.0 ± 0.5	46.8 ± 3.2	52.8 ± 3.5	90.2 ± 2.2
<i>Periplaneta americana</i>												
Adults ♂	79.8 ± 2.5	85.8 ± 2.5	100.0 ± 0.0	42.5 ± 3.5	52.2 ± 3.7	100.0 ± 0.0	33.3 ± 3.6	40.2 ± 3.5	100.0 ± 0.6	42.5 ± 2.8	50.8 ± 3.4	94.0 ± 2.1
♀	71.1 ± 4.8	74.5 ± 3.2	100.0 ± 0.0	44.4 ± 4.1	50.2 ± 3.5	100.0 ± 0.0	22.0 ± 2.8	28.2 ± 4.5	100.0 ± 0.5	22.8 ± 1.3	28.6 ± 4.5	92.0 ± 3.5
<i>Musca domestica</i>												
Adults ♂	66.5 ± 3.8	72.5 ± 2.5	100.0 ± 0.0	43.8 ± 4.6	48.8 ± 3.5	100.0 ± 0.0	40.0 ± 2.6	50.0 ± 4.2	100.0 ± 0.2	33.2 ± 4.2	42.5 ± 3.5	88.5 ± 4.2
♀	55.8 ± 2.9	62.4 ± 3.9	100.0 ± 0.0	33.3 ± 3.8	35.5 ± 4.3	100.0 ± 0.0	33.2 ± 2.8	39.2 ± 3.8	98.2 ± 2.2	30.2 ± 3.3	40.0 ± 3.2	85.5 ± 3.1
<i>Cimex lectularius</i>												
Adults ♂	32.8 ± 2.4	45.8 ± 4.2	90.8 ± 1.5	25.8 ± 3.5	30.2 ± 2.5	82.5 ± 2.5	21.5 ± 3.5	28.6 ± 4.3	80.8 ± 3.5	16.5 ± 2.8	25.0 ± 2.8	72.8 ± 4.9
♀	32.5 ± 3.4	36.8 ± 3.2	100.0 ± 0.0	16.5 ± 3.5	20.2 ± 4.8	82.0 ± 1.8	13.0 ± 4.2	17.3 ± 3.6	72.0 ± 3.2	8.5 ± 2.7	15.5 ± 4.9	85.0 ± 2.2

DM = Deltamethrin; LC = Lambda cyhalothrin; CY = Cyfluthrin; ET = Etofenprox

mortality, respectively, against these species. However, flies, cockroaches and blood-sucking bugs were less susceptible, and only 15-90% mortality was observed. 100% mortality was obtained when adult *P. americana*, *M. domestica* and female *C. lectularius* were exposed to cotton fabric treated with deltamethrin @ 150 mg/m². More or less similar results were obtained with lambdacyhalothrin and cyfluthrin. Etofenprox at similar dosages could not produce more than 94% mortality in any domestic pest species of either sex. Out of four synthetic pyrethroids, deltamethrin was the most effective against all tested species, followed by lambdacyhalothrin, cyfluthrin and etofenprox. This is in agreement with the earlier findings of Ansari *et al* [5], Baktharatchagan and David [8], and Mutinga *et al* [9].

Tables 2 and 3 depict LD₅₀ and LD₉₀ values with insecticide treated fabrics against different mosquitoes and domestic pests. The calculated LD₅₀ values of deltamethrin on cotton fabric for *An. stephensi*, *Ae. aegypti* and *Cx. quinquefasciatus* were 5.2, 7.8 and 10 mg/m², respectively, suggesting that *An. stephensi* was most susceptible, followed by *Ae. aegypti* and *Cx. quinquefasciatus*. LD₅₀ values for mosquito species varied from 7.8 to 40 mg/m² with lambdacyhalothrin, cyfluthrin and etofenprox. LD₉₀ values for *An. stephensi*, varied from 58.8 to 85 mg/m²; for *Ae. aegypti*, 66.1 to 100 mg/m² and for *Cx. quinquefasciatus*, 80 to 120 mg/m² with these insecticides. These values, in consideration of the Relative Toxicity Index (RTI) further indicate that *An. stephensi* was most susceptible. LD₅₀ values for *P. argentipes*, *P. americana*, *M. domestica* and *C. lectularius* varied from 48 to 99.2, 48.2 to 112.8, 75 to 120 and 110.2 to 135 mg/m², respectively, with different insecticides. Similarly, LD₉₀ values of different insecticides were ranging from 85.8-128, 102.2-140, 122.5-130.2 and 145-180 mg/m², for *P. argentipes*, *P. americana*, *M. domestica* and *C. lectularius*, respectively.

Results of relative efficacy with possible combination of insecticides and pest species were presented in Table 4. Significant difference in efficacy was observed between deltamethrin

Table 2 LD₅₀ values of synthetic pyrethroids on cotton fabric against mosquitoes and domestic pests.

Mosquitoes and domestic species	DM (2.5% EC)			LC (5% EC)			CY (5% EW)			ET (10% EC)		
	LD ₅₀ (mg/m ²)	95% confidence limit	RTI	LD ₅₀ (mg/m ²)	95% confidence limit	RTI	LD ₅₀ (mg/m ²)	95% confidence limit	RTI	LD ₅₀ (mg/m ²)	95% confidence limit	RTI
<i>An. stephensi</i>	5.2	4.7 - 5.7	21.2	7.8	6.6 - 9.0	15.4	10.0	8.6 - 11.6	13.0	8.0	7.5 - 12.4	16.8
<i>Ae. aegypti</i>	7.8	6.6 - 8.9	14.1	30.5	25.1 - 35.4	3.9	35.5	26.3 - 38.0	3.7	20.0	18.8 - 22.5	6.8
<i>Cx. quinquefasciatus</i>	10.0	8.8 - 12.5	11.0	35.3	28.8 - 41.6	3.4	40.0	33.1 - 48.9	3.3	35.0	33.8 - 38.5	3.9
<i>Phlebotomus argentipes</i>	48.0	38.1 - 52.9	2.3	79.5	72.2 - 85.8	1.5	99.2	89.5 - 105.2	1.3	80.0	75.6 - 85.7	1.1
<i>Periplaneta americana</i>	48.2	39.2 - 53.2	2.3	99.8	91.2 - 110.2	1.2	112.8	98.2 - 115.2	1.2	98.9	93.5 - 115.2	1.7
<i>Musca domestica</i>	75.0	65.8 - 85.2	1.5	105.2	100.1 - 110.8	1.1	100.0	98.0 - 104.5	1.3	120.0	110.8 - 130.2	1.4
<i>Cimex lectularius</i>	110.2	98.5 - 115.5	1.0	120.0	115.8 - 125.0	1.0	130.2	125.8 - 135.0	1.0	135.0	130.2 - 140.8	1.0

DM = Deltamethrin; LC = Lambdacyhalothrin; CY = Cyfluthrin; ET= Etofenprox; RTI= Relative Toxicity Index

Table 3 LD₉₀ values of synthetic pyrethroids on cotton fabric against mosquitoes and domestic pests.

Mosquitoes and domestic species	DM (2.5% EC)			LC (5% EC)			CY (5% EW)			ET (10% EC)		
	LD ₅₀ (mg/m ²)	95% confidence limit	RTI	LD ₅₀ (mg/m ²)	95% confidence limit	RTI	LD ₅₀ (mg/m ²)	95% confidence limit	RTI	LD ₅₀ (mg/m ²)	95% confidence limit	RTI
<i>An. stephensi</i>	58.8	47.8 - 69.1	2.5	75.8	57.5 - 95.4	2.4	85.0	63.1 - 100.0	2.0	80.0	70.5 - 92.5	1.8
<i>Ae. aegypti</i>	66.1	54.9 - 80.0	2.2	95.7	80.0 - 110.5	1.9	100.0	80.0 - 120.0	1.7	95.5	85.0 - 105.8	1.5
<i>Cx. quinquefasciatus</i>	80.0	70.5 - 100.0	1.9	98.5	80.8 - 120.0	1.8	120.0	100.0 - 130.0	1.4	98.5	80.0 - 110.0	1.5
<i>Phlebotomus argentipes</i>	99.8	88.2 - 110.2	1.5	110.0	98.3 - 122.5	1.6	128.0	115.3 - 135.2	1.3	85.8	72.5 - 92.3	1.7
<i>Periplaneta americana</i>	110.5	98.2 - 120.2	1.4	120.0	105.0 - 130.5	1.5	140.0	125.8 - 155.0	1.2	102.2	85.8 - 110.2	1.4
<i>Musca domestica</i>	130.2	115.8 - 145.2	1.1	130.0	120.0 - 140.5	1.4	130.0	120.0 - 140.2	1.3	122.5	105.8 - 130.5	1.2
<i>Cimex lectularius</i>	148.6	130.2 - 160.2	1.0	180.0	170.0 - 195.2	1.0	170.0	155.9 - 185.2	1.0	145.0	120.2 - 155.0	1.0

DM = Deltamethrin; LC = Lambdacyhalothrin; CY = Cyfluthrin; ET = Etofenprox; RTI = Relative Toxicity Index

and lambdacyhalothrin, deltamethrin and cyfluthrin, and deltamethrin and etofenprox against all tested species ($P < 0.5$). The difference was insignificant among lambdacyhalothrin, cyfluthrin and etofenprox. However, significant difference was observed between lambdacyhalothrin and cyfluthrin against *Cx. quinquefasciatus* and *P. americana*. Significant difference was also observed against *An. stephensi*, *Cx. quinquefasciatus*, *M. domestica* and *C. lectularius* when efficacy was compared between lambdacyhalothrin and etofenprox ($P < 0.5$). Nevertheless, statistical analysis clearly revealed that deltamethrin-treated fabric is marginally superior to other insecticides.

The Urban Malaria Scheme (UMS) was launched in India in 1971, covering about 131 towns up to the reporting period. The strategy consists of antilarval measures along with focal space spray. In certain towns, fish hatcheries have also been established to control mosquito breeding in ornamental tanks, lakes and ground tanks. However, this strategy could not provide adequate impact due to unplanned developmental activities, inadequate partnership, operational and social constraints. Therefore, the treatment of curtains, particularly in urban populations where the use of ITNs is cumbersome, may be considered most appropriate, as during entry and exit mosquitoes are bound to encounter the treated curtains and get knock-down even with minimal exposure [3]. A composite control of malaria and domestic pests using deltamethrin-treated jute strips in Delhi has already been demonstrated by Ansari *et al* [10]. In view of this, it is suggested that the technology should be incorporated in the national program. The integration of this technology with legislative measures may provide cost-effective composite control of malaria, dengue, DHF and filariasis, along with other collateral benefits.

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Table 4 T-test values of insecticides against different species of mosquitoes and domestic pests.

Insecticides	<i>An. stephensi</i>	<i>Ae. aegypti</i>	<i>Cx. quinquefasciatus</i>	<i>Phlebotomus argentipes</i>	<i>Periplaneta americana</i>	<i>Musca domestica nebulosa</i>	<i>Cimex lectularius</i>
DM & LC	2.11*	2.52*	1.70*	3.42*	4.32*	2.11*	1.82
DM & CY	2.22*	3.40*	2.66*	3.72*	3.85*	2.23*	1.75
DM & ET	2.52*	2.31*	2.10*	3.51*	3.40*	2.32*	2.82*
LC & CY	1.17	0.78	2.11*	1.70	2.10*	0.70	1.02
LC & ET	2.32*	1.12	2.20*	0.40	1.70	2.11*	2.21*
CY & ET	0.44	0.38	0.40	1.11	1.21	0.45	1.14

DM = Deltamethrin; LC = Lambdacyhalothrin; CY = Cyfluthrin; ET = Etofenprox; * $p < 0.5$ (significant)

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