ISSN: 0976-3031

Available Online at http://www.recentscientific.com

CODEN: IJRSFP (USA)

International Journal of Recent Scientific Research
Vol. 9, Issue, 2(I), pp. 24402-24408, February, 2018

International Journal of Recent Scientific Research

DOI: 10.24327/IJRSR

Research Article

SUSCEPTIBILITY OF *CULEX QUINQUEFASCIATUS* TO THREE COMMONLY USED INSECTICIDES FROM WEST BENGAL, INDIA

Basu, N[1]., Chatterjee, M[2]., Bera, D.K[2]., Maji, A.K[2]., Ballav, S[2] and Saha, P*[3]

[1]Director, Calcutta School of Tropical Medicine, 108, C. R. Avenue, Kolkata-700073, West Bengal, India
[2]Department of Microbiology, Calcutta School of Tropical Medicine, 108, C. R.Avenue, Kolkata - 700073, India
[3]Department of Zoology, A. P. C. Roy Government College, Himachal Bihar, Matigara, Siliguri - 734010, West Bengal, India

DOI: http://dx.doi.org/10.24327/ijrsr.2018.0902.1655

ARTICLE INFO

Article History:
Received 06th November, 2017
Received in revised form 14th December, 2017
Accepted 23rd January, 2018
Published online 28th February, 2018

Key Words:

Filaria vector, Insecticide susceptibility, Knock down rate, Knock down time, India

ABSTRACT

Vector control is a useful tool for elimination of lymphatic filariasis which is severely challenged by the emergence of resistance among the vector mosquitoes against used insecticides. Reports on status of insecticide susceptibility from different parts of the country are important for formulation of vector control strategy. The present study was aimed to assess the larval susceptibility of *Culex quinquefasciatus* to temephos and adult susceptibility to DDT, deltamethrin and malathion. Larvae and adult of F1 generation were used for insecticide bio-assay using standard WHO protocol. It was that the adult *Culex quinquefasciatus* population of the study areas were resistant to all three insecticides tested with corrected mortality well below the 90% (1.25 to 9.38% for DDT, 33.33 to 61.25% for deltamethrin and 13.75 to 50.63 % for malathion). High degree of temephos tolerance was recorded among the larval forms. Such study from other parts of the country is highly suggested.

INTRODUCTION

Lymphatic filariasis (LF), a neglected tropical disease, affects the lymphatic system which leads to the unusual enlargement of body parts, and causes pain, severe disability and social stigma. This disease is commonly known as elephantiasis and found in many regions of the world including the South East Asia, Middle East and Eastern Mediterranean countries (Gyapong *et al,* 2005; Abdel-Hameed *et al,* 2004). World Health Organisation (WHO) estimated that 856 million people in 52 countries worldwide are at risk of LF infection (WHO, 2017). According to WHO, 700 million endemic populations are found in WHO's South Eastern Asian Region (WHO-SEAR) and India contributes about 67% of the endemic populations. In South East Asia, 60 million persons are affected with LF i.e., either harbouring microfilariae (mf) or suffering from clinical manifestations of the disease, of which 82% are found in India (WHO, 2017). India is one of the worst affected countries where 17 states and 6 Union Territories are endemic with about 553 million people are at risk of infection, of which about 146 million live in urban and the remaining in rural areas. About 31 million mf carriers and over 23 million clinical cases are found in India (WHO, 2005). West Bengal is one of the major filarial endemic states of India and 12 districts are endemic for filariasis and mf prevalence ranged from 1.2% to 8.1% (NVBDCP, 2017).

Lymphatic filariasisis amosquito-borne disease caused by helminth parasite *Wuchereria bancrofti* and *Brugia malayi*, *Culex quinquefasciatus* is the major vector throughout all Asian countries (Bhaskar, 2000). In north eastern states of India, this species is considered to be an efficient vector of bancroftian filariasis (Mahanta *et al*, 2001). In India, Elimination Lymphatic Filariasis (ELF) programme was launched in 1997 and it mainly based on annual mass drug administration (MDA) i.e., administration of single dose of diethylcarbamazine and albendazole (NVBDCP, 2017). The current strategy to eliminate lymphatic filariasis is unlikely to achieve complete elimination if MDA is not supplemented by transmission-control interventions in some areas where

Corresponding author:* **Saha, P
Department of Zoology, A. P. C. Roy Government College, Himachal Bihar, Matigara, Siliguri - 734010, West Bengal, India

persistent transmission occurs even after 5 to 6 rounds of MDA (Sabesan, *et al,* 2010).

Chemical Insecticides are considered as the most important components in the global mosquito control efforts (McCarroll and Hemingway, 2002) and has been used for vector and pest control programs for many decades. The vector control strategy formulated by the National Vector Born Disease Control Programme of India (NVBDCP) is mainly based on larval source management by lavicidal agents (temephos, *Bti*), and adult vector control by indoor residual spray (IRS) of organochlorine (DDT) and synthetic pyrethroids, use of insecticide impregnated bed nets with deltamethrin and thermal fogging of malathion. Due to the regular use of these insecticides for vector control measures and in agricultural field for pest management at rural and urban areas, *Culex* mosquitoes, especially *Cx. quinquefasciatus* population are under tremendous pressure of used insecticides. In addition, different physiological mechanisms are also involved for insecticide resistance among vector mosquitoes like reduced sensitivity of sodium channels to insecticides, over-production of detoxifying enzymes which are responsible for detoxification of toxic substances (Brogdon and McAllister, 1998; Feyereisen, 1999; Roberts and Andre, 1994).

Successful implementation of vector control strategies requires definite knowledge on vector distributions, biology and changing trends on susceptibility status to used insecticide. So, regular monitoring of the susceptibility status of vectors mosquitoes against different insecticides is the most important element for vector control programmes (Nauen, 2007) Insecticides susceptibility bioassay is the primary tools for surveillance and monitoring of the insecticide resistance, though it is also monitored by studying the insecticide detoxifying enzyme and molecular markers (WHO, 2011). In spite of huge disease burden and vector abundance, the susceptibility status of *Cx. quinquefasciatus* against different insecticides has not been monitored in a regular basis and very few reports are available from different parts of India (Sarkar *et al,* 2009a; Sarkar *et al,* 2009b., Mukhopadhyay *et al,* 1993; Thavaselvam *et al,* 1993)

The present study was designed to assess the insecticide susceptibility status of adult *Cx. quinquefasciatus* to DDT, deltamethrin, and malathion, in three northern districts of West Bengal, India. This study also assessed the susceptibility of temephos, the major larvicide against *Cx. quinquefasciatus* in the study areas.

MATERIALS AND METHODS

Study sites

The present study was conducted during April, 2017 to October, 2017 in Darjeeling, Jalpaiguri and Uttar Dinajpur districts of West Bengal. These three districts are located at the northern part of West Bengal. In consultation with the respective district health authorities, three blocks of Darjeeling, two blocks of Jalpaiguri and one block of Uttar Dinajpur were selected as study sites. The sites were Phansidewa, Matigara, and Khoribari block of the Darjeeling district; Dhupguri and Malbazar block of the Jalpaiguri district and Chopra block of the Uttar Dinajpur. The study sites of Matigara, Malbazar were sub-urban in nature, whereas study sites of Phansidewa, Khoribari, Dhupguri and Chopra were rural in nature (Fig 1).

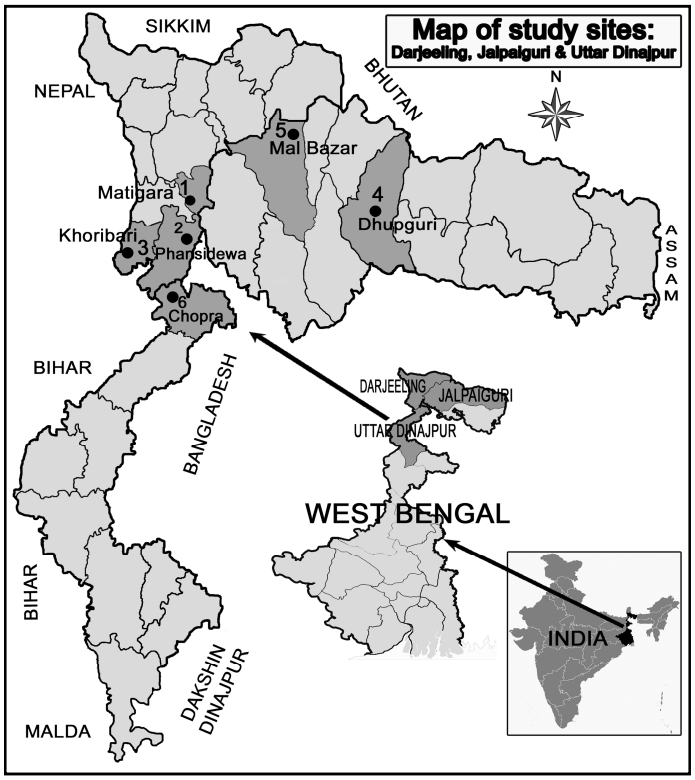

Figure 1 Map showing the study sites

Mosquito collection, rearing and identification

The immature stages of mosquito collected from the natural breeding places such as septic tanks, streams, abandoned buildings, drainages and construction sites. The larvae and pupae were collected with the help of different sized dippers. The larvae and pupae collected from each dip were gathered in a plastic contain. Then the containers were transported to the laboratory on the same day and the larvae and pupae are transferred in the larvae rearing tray along with water collected from the field. The larvae rearing tray was supplied with artificial food such as yeast and fish food. The optimum temperature (25^0C-30^0C) and optimum relative humidity (80%-90%) was maintained in the laboratory. The immature stages were reared to the adult stages and after emergence, the adult mosquitoes were anesthetized with ethyl ether and identified morphologically according to the keys of Rattanarithikul *et al*, 2005 (Rattanarithikul *et al,* 2005) and Tyagi *et al,* 2012 (Tyagi *et al,* 2012). The identified *Cx. quinquefasciatus* were allowed to breed under laboratory conditions. The larvae and adults of the F1 generation were used for larval and adult insecticide bioassays.

Larval susceptibility tests

Larval bioassays were conducted as per the standard WHO bioassay protocol (WHO, 2005) Technical-grade formulations of temephos (50EC; Nitapol Industries Pvt Ltd., Kolkata) was employed for the larval bioassay study. Six different concentrations (0.01, 0.05, 0.1, 0.5, 1.0, and 2.0 ppm) of insecticides were prepared from the stock temephos solution and used in the susceptibility bioassay. Susceptibility tests were performed using 20–25 third instar to early fourth instar larvae

in 200 ml disposable paper cups filled with the required concentration of insecticide solution and double distilled water at room temperature (25°C ± 2°C). Each concentration had four sets of replicates and each set of experiment was accompanied by two sets of controls containing equal concentration of 95% ethanol. After 24 hours of experiment larval mortality was recorded and the larvae that were motionless or convulsive upon a sharp stimulation were counted as dead (WHO, 2005). Larval mortality was determined by dividing the number of dead larvae by the total number tested. A test was considered as invalid if pupation rate was greater than 10%, or mortality rate in the control was greater than 20% (WHO, 2005).

Adult susceptibility bioassay

Adult susceptibility bioassay was performed on 2 to 3-day old laboratory emerged (F1 generation) unfed female *Cx. quinquefasciatus* mosquitoes as per WHO protocol (WHO, 2016). The tests were carried out using 4% DDT, 0.05% deltamethrin, and 5% malathion impregnated papers which were obtained from Universiti Sains Malaysia, Malaysia. Five different holding tubes were used for each set of the experiment of which four were a test and one was a control. In each holding tube, 20-25 adult female mosquitoes were kept for one hour and then mosquitoes from four tubes marked as test were exposed to insecticide-impregnated papers. Silicone oil, olive oil, and risella oil pre-impregnated papers for deltamethrin, malathion, and DDT, respectively were used in control sets. Mosquitoes were allowed in the exposure tube for one hour and cumulative knock down was recorded after 10, 15, 20, 30, 40, 50, and 60 minutes. After that the mosquitoes were transferred to holding tubes and fed on a 5% sucrose solution for the next 24 Hours. Mortality was scored after 24 hours to determine the susceptibility status as per WHO recommendation (WHO, 2016).

Data analysis

The results of larval bioassay were analyzed using Log dose probit (Ldp) Line computer software (Ehabsoft, Cairo Egypt) according to the Finney's method (Finney, 1972). Lethal concentrations (LC_{10}, $LC_{50,}$ and LC_{99}) along with the slope were estimated at 95% confidence intervals (CI) by using the Ldp line software. The resistance ratio (RR_{99}) was calculated by comparing the lethal concentration (LC_{50}/LC_{99}) value for a population with the LC_{50}/LC_{99} value for the insecticide for a laboratory colony. The $RR_{99} \leq 3$ was considered as susceptible, and $3 < RR_{99} \leq 5$ as low resistance, $5 < RR_{99} \leq 10$ as moderate resistance, and $RR_{99} > 10$ as high resistance (Mazzarri and Georghiou, 1995).

In case of adult bioassays, observed mortality was calculated by the formula: observed mortality (%) = (Total no. of dead mosquitoes / Total mosquitoes exposed) x 100. The observed mortality was corrected using Abbott's formula when the mortality rate of control was within 5% - 20%. Corrected Mortality (CM) (%) = [(% of observed mortality - % of control mortality) / (100 - % of control mortality)] x 100. According to WHO, mosquitoes were considered susceptible (S) if the corrected mortality (CM) rate was greater than 98% and resistant (R) if mortality rate was less than 90%. Mortality rate between 90-98% was considered as possible resistance (PR) and needs verification by alternative methods like enzyme bioassay and molecular marker studies (WHO, 2016). The cumulative knock down rates (KDR) were calculated by observing the number of knocked down mosquitoes after 10, 15, 20, 30, 40, 50 and 60 minutes during the hour-long exposure period. Knockdown time (KDT_{10}, $KDT_{50,}$ and KDT_{95}) is the time required for knockdown of a particular proportion of mosquitoes following exposure to any insecticide. KDTs were determined using Ldp Line computer software (Ehabsoft, Cairo Egypt) programme according to the Finney's method (Finney, 1972).

RESULTS

Larval susceptibility status

The LC_{10}, $LC_{50,}$ and LC_{99} values of different study sites did not follow a normal distribution for mortality to the log dose ($\chi^2 \geq 28.57$; $p \leq 0.0001$).

Table 1 Temephos sensitivity status of *Culex quinquefasciatus* in three districts of West Bengal

Values	Study sites					
	Darjeeling			Jalpaiguri		Uttar Dinajpur
	Phansidewa (n = 180)	Matigara (n = 180)	Khoribari (n = 180)	Dhupguri (n = 180)	Malbazar (n = 180)	Chopra (n = 180)
LC_{10} (lower limit - upper limit) [mg/L]	0.044 (0.026-0.059)	0.089 (0.063-0.112)	0.071 (0.04-0.095)	0.057 (0.022-0.077)	0.028 (0.014-0.038)	0.041 (0.019-0.055)
LC_{50} (lower limit - upper limit) [mg/L]	0.159 (0.109-0.228)	0.194 (0.147-0.252)	0.249 (0.168-0.369)	0.255 (0.135-0.446)	0.112 (0.071-0.173)	0.146 (0.089-0.236)
LC_{99} (lower limit - upper limit) [mg/L]	1.639 (1.265-3.109)	0.784 (0.631-1.107)	2.446 (1.907-5.187)	3.914 (3.207-12.593)	1.365 (1.089-3.379)	1.466 (1.212-3.912)
X^2 (p)	46.96 (<0.0001)	28.57 (0.0001)	39.58 (<0.0001)	79.89 (<0.0001)	46.51 (<0.0001)	58.46 (<0.0001)
Slope	2.29 ± 0.11	3.83 ± 0.19	2.35 ± 0.11	1.96 ± 0.09	2.14 ± 0.11	2.32±0.12
R	0.97	0.93	0.97	0.96	0.97	0.96
G	0.08	0.07	0.1	0.16	0.12	0.15
RR_{50}/RR_{99}*	8.93/9.46	10.89/4.53	13.99/14.12	14.33/14.12	6.29/22.59	8.20/8.46
Status#	MR	LR	HR	HR	HR	MR

n = number; **$LC_{10}/LC_{50}/LC_{99}$** = lethal concentration 10%/50%/99%, **RR** = resistance ratio, g = 'g' is a factor used for fiducial limit calculations

* The LC_{50} and LC_{99} values of laboratory strain was 0.0178mg/L and 0.1732mg/L, respectively

#Classification adapted from Mazzari and Georghiou (1995): S = Susceptible ($RR_{99} < 3$), LR = Low Resistance ($3 < RR_{99} < 5$), MR = Moderate Resistance ($5 < RR_{99} < 10$), HR = High Resistance ($RR_{99} > 10$)

The LC_{50} values of Phansidewa, Matigara, Khoribari, Dhupguri, Malbazar and Chopra ranged from 0.112 (0.071-0.173) to 0.255 (0.135-0.446) mg/L, whereas LC_{99} values ranged from 0.784 (0.631-1.107) to 3.914 (3.207-12.593) mg/L. The calculated RR_{50} and RR_{99} values in different study sites were ranged from 6.29 to 14.33 and 4.53 to 22.59, respectively (Table 1). *Cx. quinquefasciatus* larval population of Matigara exhibited low level of resistance to temephos whereas moderate level of temephos resistance was observed among the Phansidewa and Chopra population. The high level of temephos resistance was recorded among the larval population of Khoribari, Dhupguri and Malbazar.

Adult susceptibility status

The adult susceptibility bioassay results *Cx. quinquefasciatus* against three different insecticides are presented in Table 2. After 24 hours of initial exposure, the corrected mortality rates for 4% DDT were ranged from 1.25% to 9.38% in different study sites, which is well below the WHO recommended 90% mortality rate for resistance. So, results suggested that the *Cx. quinquefasciatus* population of the study areas was highly resistant to DDT. The corrected mortality rate for 0.05% deltamethrin and 5% malathion were ranged from 33.33% to 61.25% and 13.75% to 50.63%, respectively in different study sites. Therefore, the adult *Cx. quinquefasciatus* population of all the study sites were also highly resistance to deltamethrin and malathion (Table 2).

The observed KDT_{50} values were 94.97 (75.97-132.36) to 210.93 (124.55-600.38) mins for DDT, 16.52 (15.45-17.56) to 35.55 (32.55-39.18) mins for deltamethrin, and 23.75 (18.27-29.66) to 121.08 (81.91-252.23) mins for malathion. The KDT_{95} values for DDT were 955.09 (514.69-2492.45) to 10214.51 (2283.32-215991.32) mins, for deltamethrin 46.02 (41.91-51.48) to 220.38 (167.08-319.31) mins and for malathion 108.58 (96.12-199.39) to 6814.03 (1753.78-98413.03) mins. The knockdown rate (KDR) of *Cx. quinquefasciatus* against DDT, deltamethrin, and malathion over an exposure time of 1 hour is given in Fig 2(A – C).

During 1 hour of exposure, the knock down rate (KDR) varied from 28.75% - 40.63% for DDT, 74.38% to 93.56% for deltamethrin, and 42.50%% - 78.63% for malathion.

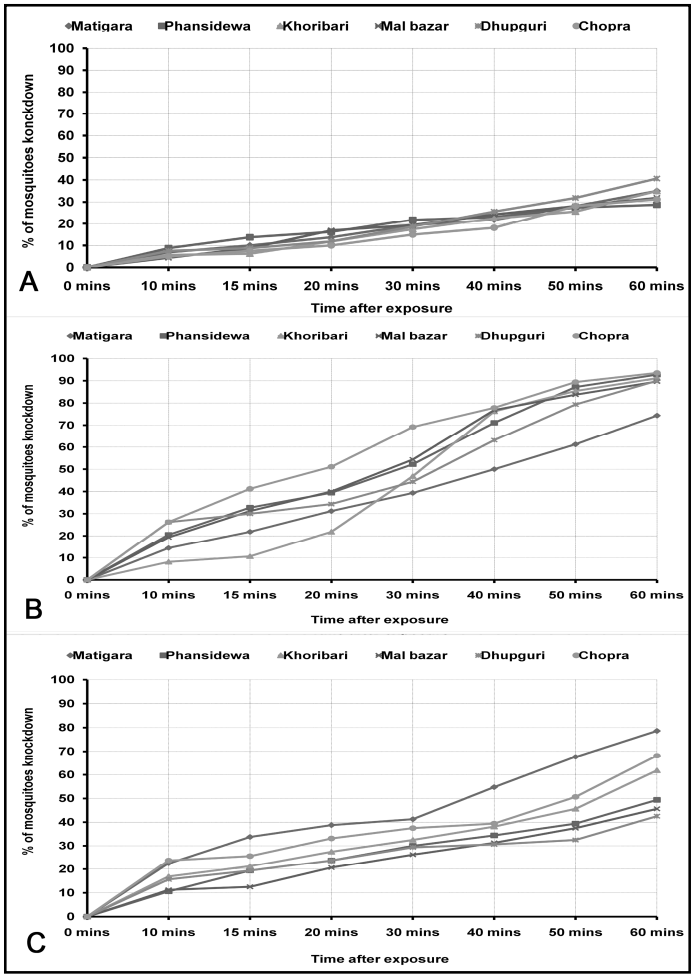

Figure 2 Knock down rate of *Cx. quinquefasciatus* against 4% DDT (A), 0.05% deltamethrin (B), 5% malathion (C) in West Bengal

Table 2 Insecticides susceptibility status of *Culex quinquefasciatus* against 4% DDT, 0.05% deltamethrin and 5% malathion in West Bengal

Insecticides	Districts	Blocks	Mosquito exposed		Mosquito died		Observed Mortality (%)		CM (%)	KDT_{10} [95% CI]	KDT_{50} [95% CI]	KDT_{95} [95% CI]	χ^2 (p)	Slope	Status #
			T*	C*	T*	C*	T*	C*							
4 % DDT	Darjeeling	Phanshidewa	160	40	2	0	1.25	0	1.25	10.26 [5.56-14.22]	210.93 [124.55-600.38]	10214.51 [2283.32-215991.32]	0.65 (0.99)	0.98±0.17	R
		Matigara	160	40	15	0	9.375	0	9.38	14.84 [10.86-18.20]	128.55 [93.62-215.93]	2053.07 [861.88-8900.77]	1.09 (0.96)	1.37±0.18	R
		Khoribari	160	40	10	0	6.25	0	6.25	18.12 [14.33-21.36]	116.92 [89.19-178.24]	1279.72 [628.43-4024.80]	2.08 (0.84)	1.58±0.19	R
	Jalpaiguri	Dhupguri	160	40	14	0	8.75	0	8.75	15.72[12.33-18.65]	94.97 [75.97-132.36]	955.09 [514.69-2492.45]	2.99 (0.70)	1.64±0.18	R
		Malbazar	160	40	15	0	9.375	0	9.38	15.59 [11.71-18.88]	122.08 [90.75-196.34]	1712.69 [765.16-6508.67]	3.13 (0.68)	1.43±0.18	R
	U. Dinajpur	Chopra	160	40	7	0	4.375	0	4.38	19.37 [15.35-22.80]	131.75 [97.41-213.81]	1543.69 [711.36-5548.43]	1.94 (0.86)	1.54±0.19	R
0.05% deltamethrin	Darjeeling	Phanshidewa	180	45	60	0	33.33	0	33.33	8.11 [5.22-9.18]	22.68[18.01-27.49]	84.83 [74.97-132.20]	29.58 (<0.001)	2.87±0.16	R
		Matigara	160	40	71	0	44.38	0	44.38	8.58 [6.77-10.27]	35.55 [32.55-39.18]	220.38 [167.08-319.31]	5.93 (0.31)	2.08±0.16	R
		Khoribari	160	40	63	0	39.38	0	39.38	14.12 [10.59-15.81]	27.48 [22.95-32.51]	64.61 [57.93-87.66]	35.05 (<0.001)	4.43±0.21	R
	Jalpaiguri	Dhupguri	160	40	73	0	45.63	0	45.63	7.02 [3.24-7.55]	25.22 [18.39-33.26]	130.15 [123.51-307.74]	32.91 (<0.001)	2.31±0.16	R
		Malbazar	160	40	78	0	48.75	0	48.75	8.31 [5.86-9.65]	22.58 [18.82-26.44]	81.46 [70.17-115.55]	18.37 (0.003)	2.95±0.17	R
	U. Dinajpur	Chopra	160	40	98	0	61.25	0	61.25	7.44 [6.46-8.35]	16.52 [15.45-17.56]	46.02 [41.91-51.48]	8.79 (0.12)	3.69±0.20	R
5% malathion	Darjeeling	Phanshidewa	160	40	79	0	49.38	0	49.38	8.39 [5.62-10.93]	70.37 [57.68-94.20]	1076.98 [549.19-3117.19]	2.24 (0.82)	1.39±0.16	R
		Matigara	160	38	81	0	50.63	0	50.63	7.27 [4.09-8.24]	23.75 [18.27-29.66]	108.58 [96.12-199.39]	26.68 (0.0001)	2.49±0.16	R
		Khoribari	160	40	78	0	48.75	0	48.75	6.94 [4.62-9.13]	52.71 [45.24-64.82]	710.86 [404.29-1676.95]	8.51 (0.13)	1.46±0.16	R
	Jalpaiguri	Dhupguri	160	40	22	0	13.75	0	13.75	5.24 [2.19-8.27]	121.08 [81.91-252.23]	6814.03 [1753.78-98413.03]	2.16 (0.83)	0.94±0.15	R
		Malbazar	160	40	57	0	35.63	0	35.63	10.29 [7.24-12.99]	80.19 [64.72-110.34]	1118.84 [569.17-3249.18]	2.16 (0.83)	1.44±0.17	R
	U. Dinajpur	Chopra	160	40	56	0	35	0	35.00	4.69 [1.07-5.41]	43.95 [34.57-76.99]	777.57 [664.99-10462.35]	15.64 (0.008)	1.32±0.15	R

***T** = Test, **C** = Control, **CM** = Corrected Mortali **#S** = Susceptible (CM ≥98%), **R** = Confirmed Resistance (CM <90%); **PR** = Possible Resistance (CM = 90 - 97%)

DISCUSSION

During the last few decades, synthetic insecticides were widely used in agricultural field and recently is being used in public health programmes, which has led to the development of resistance among vector mosquitoes in many countries (Kamgang *et al,* 2011; Dusfour *et al*, 2011; Singh *et al,* 2011; Dhiman *et al,* 2013). The susceptibility status of *Cx. quinquefasciatus* population to temephos, DDT, deltamethrin and malathion were investigated in three districts of northern West Bengal. The study revealed low to higher level of resistance to temephos among the larval population of *Cx. quinquefasciatus*. Highest level of temephos resistance was recorded in Malabazar of the Jalpaiguri district and lowest level in Matigara of the Darjeeling district. The RR values at LC_{50} and LC_{99} were greater than 4.53, which indicated that larval population of *Cx. quinquefasciatus* were resistant to temephos. The difference in RR_{50} and RR_{99} values might be due to natural variations in toxicity ratios rather than to resistance selection (Araujo *et al*, 2013). Similar kind of resistance to temephos has been reported from Delhi (Katyal *et al,* 2001), north-western (Suman *et al,* 2010) region and the north-eastern region of India (Sarkar *et al,* 2009; Tikar *et al,* 2009). Conversely, susceptibility to temephos have also been reported in populations of *Cx. quinquefasciatus* and *Aedes aegypti* from Rajahmundry town in Andhra Pradesh, South India (Mukhopadhyay *et al*, 2006) and Karnataka (Shetty *et al,* 2013). Very recently a study from northern part of West Bengal reported susceptible to moderate level of temephos resistance among the *Ae. albopictus* population (Chatterjee *et al,* 2018).
Adult bioassay revealed that adult *Cx. quinquefasciatus* population were highly resistant to DDT, deltamethrin and malathion. Highest level of DDT and deltamethrin resistance was noted in Phansidewa of Darjeeling district, whereas highest level of malathion resistance was recorded in Dhupguri of Jalpaiguri district. The high level of DDT resistance in *Cx. quinquefasciatus* might have been developed over time due to prolonged use in public health programmes for many years. The use of DDT is discontinued in most parts of India due to development of resistance in vector populations. However, it is still being used for control of Kala-azar vector and some parts of north-eastern India for malaria vectors. Nevertheless, persistence of DDT in the environment may have resulted in the continued selection for resistance. Similarly, high level of DDT resistance in *Cx. quinquefasciatus* were also reported from different parts of India such as, north eastern India (Sarkar *et al*, 2009b; Sarkar *et al*, 2009a), Patna (Bihar) (Mukhopadhyay *et al*, 1993) and Panaji (Goa) (Thavaselvam *et al*, 1993). There are many other reports of high levels of DDT resistance in *Cx. quinquefasciatus* in different parts of the world (Duran and Stevenson, 1983; Majori *et al,* 1986; Somboon *et al,* 2003).

In the study areas, pyrethroids were widely used in agricultural fields as well as in public health programmes (for impregnation of bed nets) to reduce the transmission of malaria. A significant level of pyrethroid resistant mosquito was found to be associated with agricultural activity indicating that resistance level increases with increased use of the insecticides in agricultural fields. Two blocks, Khoribari and Phansidewa are endemic for kala-azar. In 2016 the NVBDCP introduced synthetic pyrethroid for IRS to reduce kala-azar transmission. So the vector mosquitoes were under tremendous pressure of pyrethroid for a long period which is reflected by the higher level of resistance among the *Cx. quinquefasciatus* population of the study area. Similarly, reports are available from north eastern part of the country (Kumar *et al,* 2011).

In the study area, malathion fogging was done sporadically to manage the vector borne disease outbreaks during last few years. Malathion was used widely in paddy fields and also in tea gardens for pest control. Insecticide residues used in paddy fields or tea gardens are washed into mosquito breeding sites thus exerting a huge selection pressure on mosquito larval populations, which resulted in the emergence of insecticide resistance. This might be the cause for recording high level of malathion resistance among the *Cx. quinquefasciatus* population of the study area. Similarly malathion resistance was reported from different parts of the country against different species of *Anopheles* (Dhiman *et al,* 2016), *Aedes* (Yadav *et al,* 2015) and *Culex* (Kumar *et al,* 2011; Dhiman *et al,* 2013).

CONCLUSION

The present study showed that the prevailing *Cx. quinquefasciatus* population of the study areas were highly resistant to all three classes of insecticides. The data generated from this study will be useful for the development of future insecticide resistance management strategies and will also help the public health policy makers to select the insecticides for formulation of effective vector control measures. Such study from other parts of the country is highly suggested.

Authors' Contribution

NB, AKM and PS designed the study and supervised all activities; PS, MC, SB, NB, DKB collection and identification of mosquitoes; MC, SB, PS, AKB, TP assessed the insecticide bioassay; NB, AKM, PS, MC, AKB, TP, perform the data analysis and interpretation; NB, AKM, PS, MC, prepare the manuscript

Acknowledgement

This work is supported by the funding from the Department of Science & Technology, Government of West Bengal. We are thankful to the population of study villages for their help during study.

Financial Support

This work was supported by Department of Science and Technology, Government of West Bengal.

Conflicts of Interest

We have no conflicts of interest concerning the work reported in this article.

Reference

Abdel-Hameed, A.A., Dura, W.T. and Alkhalife I.S. 2004. An inguinal mass with local vascular lesions induced by a lymphatic filarial*, Saudi. Med. J,* 25, 1106-1108.

Araujo, A.P., Diniz, D.F.A., Helvecio, E., de Barros, R.A., de Oliveira, C.M.F., Ayres, C.F.J. 2013. The susceptibility of *Aedes aegypti* populations displaying temephos resistance to *Bacillus thuringiensis*

israelensis: a basis for management, Parasit. Vectors, 6, 297.

Bhaskar, C., Harinath, Reddy, M.V.R. 2000. Filariasis in India, *Journal International Medical Science Acadamy*, 13, 8-12.

Brogdon, W.G., and McAllister, J.C. 1998. Insecticide resistance and vector control, Emerg. *Infect. Diseases*, 4(4), 605-613.

Chareonviriyaphap, T., Rongnoparut, P., and Juntarumporn, P. 2002. Selection for pyrethroid resistance in a colony of *Anopheles minimus* species A, malaria vector in Thailand, *J Vector Ecol*, 27, 222–229.

Chatterjee, M., Ballav, S., Maji, A.K., Basu, N., Sarkar, B.C., Saha, P. 2018. Polymorphisms in voltage-gated sodium channel gene and susceptibility of *Aedes albopictus* to insecticides in three districts of northern West Bengal, India, PLoS. Negl. *Trop. Dis,* 12(1), e0006192.

Dhiman, S., Rabha, B., Talukdar, P.K., Das, N.G., Yadav, K., Baruah, I., Singh, L., and Veer, V. 2013. DDT & deltamethrin resistance status of known Japanese encephalitis vectors in Assam, India, *Indian. J. Med. Res,* 138, 988-994.

Dhiman, S., Yadav, K., Rabha, B., Goswami, D., Hazarika, S., Tyagi, V. 2016. Evaluation of Insecticides Susceptibility and Malaria Vector Potential of *Anopheles annulariss. l.* and *Anopheles vagus* in Assam, India, PLoS One, 11(3), e0151786

Duran, M., and Stevenson, H.R. 1983. Insecticide resistance inadult *Culex quinquefasciatus* mosquitoes from Olongapo City, Philippines, *Southeast Asian J. Trop. Med. Public. Health,* 14, 403-406.

Dusfour, I., Thalmensy, V., Gaborit, P., Issaly, J., Carinci, R., Girod, R. 2011. Multiple insecticide resistance in Aedes aegypti (Diptera: Culicidae) populations compromises the effectiveness of dengue vector control in French Guiana, *Mem. Inst. Oswaldo. Cruz,* 106(3), 346-352.

Feyereisen, R. 1999. Insect P450 enzymes, Annu. Rev. Entomol,44, 507-533.

Finney, J. 1972. Probit analysis. 3rd En. London, Cambridge University Press. 68-78.

WHO, 2017. World Health Organisation. 2017. Lymphatic filariasis. http://www.who.int/mediacentre/factsheets/fs102/en

Gyapong, J.O., Kumaraswami, V., Biswas, G., Ottesen, E.A. 2005. Treatment strategies underpinning the global programme to eliminate lymphatic filariasis, Expert. Opin. *Pharmacother*, 6, 179-200.

Kamgang, B., Marcombe, S., Chandre, F., Nchoutpouen, E., Nwane, P., Etang, J., Corbel, V., Paupy. C. 2011. Insecticide susceptibility of Aedes aegypti and Aedes albopictus in Central Africa. Parasit. Vectors. 4, 79.

Katyal, R., Tewari, P., Rahman, S.J., Pajni, H.R., Kumar, K., and Gill, K.S. 2001. Susceptibility status of immature and adult stages of *Aedes aegypti* against conventional insecticides in Delhi, India, *Dengue Bull*, 25:84-87.

Kumar, K., Sharma, A.K., Kumar. S., Patel, S., Sarkar, M.., Chauhan, L.S. 2011. Multiple insecticide resistance/susceptibility status of *Culex quinquefasciatus*, principal vector of bancroftian filariasis fromfilarial endemic areas of northern India, *Asian Pacif J Trop Med,* 4(6), 426-429.

Mahanta, B., Handique, R., Narain, K., Dutta, P., and Mahanta, J. 2001. Transmission of bancroftian filariasis in tea agro-ecosystem of Assam, India, Southeast Asian *J Trop Med Public Health,* 31, 581-584.

Majori, G., Sabatineli, G., Villani, F.,and Petrarca, V. 1986. Studieson insecticide susceptibility of *Anopheles gambiae* s.l. and *Culexquinquefasciatus* in the area of Ouagadougou, Burkina Faso (WestAfrica), *J. Am. Mosq. Control Assoc,* 2,305-309.

Mazzarri, M.B., and Georghiou, G.P. 1995. Characterization of resistance to organophosphate, carbamate, and pyrethroid insecticides in field populations of *Aedes aegypti* from Venezuela, *J. Am. Mosq. Control. Assoc*, 11, 315-322.

McCarroll, L., and Hemingway, J. 2002. Can insecticide resistance status affects parasite transmission in mosqui-toes? *Insect Biochem. Mol. Biol,* 32, 1345-1351.

Mukhopadhyay, A.K., Patnaik, S.K., Sathya, Babu, P. 2006. Susceptibility status of some culicine mosquitoes to insecticides in Rajahmundry town of Andhra Pradesh, *India, J. Vect. Borne. Dis,* 43, 39-41.

Mukhopadhyay, A.K., Sinha, S.N., Yadav, R.L, Narasimham, M.V. 1993. Susceptibility status of *Culex quinquefasciatus* in Patna to insecticides, *Indian J Public Health*, 37, 57-60.

Nauen, R., 2007. Insecticide resistance in disease vectors of public health importance, *Pest. Manag. Sci*, 63(7), 628-33.

NVBDCP, 2017, Lymphatic filariasis endemic districts of India. http://nvbdcp.gov.in/Doc/Lf-Endemic-Districts.pdf

Rattanarithikul, R., Harbach, R.E., Harrison, B.A., Panthusiri, P., Jones, J.W., Coleman, R.E. 2005. Illustrated keys to the mosquitoes of Thailand. II. Genera Culex and Lutzia. *Southeast Asian J. Trop. Med. Public. Health,* 36, 1-97.

Roberts, D.R.,and Andre, R.G. 1994. Insecticide resistant issues in vector-borne disease control, *Am. J. Trop. Med. Hyg*,50, (Suppl. 6), 21-34.

Sabesan, S., Vanamail, P., Raju, K., Jambulingam, P. 2010. Lymphatic filariasis in India: epidemiology and control measures, *J. Postgrad. Med*, 56, 232-238.

Sarkar, M., Bhattacharyya, I.K., Borkotoki, A., Goswami, D., Rabha, B., Baruah, I., Srivastava, R.B. 2009a. Insecticide resistance and detoxifying enzyme activity in the principal bancroftian filariasis vector, *Culex quinquefasciatus* in northeastern India, *Med Vet Entomo*l,23, 122-131.

Sarkar, M., Borkotoki, A., Baruah, I., Bhattacharyya, I.K., Srivastava, R,B. 2009. Molecular analysis of knock down resistance (kdr) mutation and distribution of kdr genotypes in a wild population *of Culex quinquefasciatus* from India, *Trop. Med. Int. Health*, 14 (9), 1097-1104.

Shetty, V., Sanila, D., and Shetty, N.J. 2013. Insecticide susceptibility status in three medically important species ofmosquitoes, *Anopheles stephensi, Aedes aegypti* and *Culex quinquefasciatus*, from Bruhat

Bengaluru Mahanagara Palike, Karnataka, India, Pest. *Manag. Sci*, 69(2):257-67

Singh, R.K., Dhiman, R.C., Mittal, P.K., Dua, V.K. 2011. Susceptibility status of dengue vectors against various insecticides in Koderma (Jharkhand), India*, J. Vector. Borne. Dis***,** 48, 116-118.

Somboon, P., Prapanthadara, L.A and Suwonkerd, W. 2003. Insecticide susceptibility tests of *Anopheles minimus s.l., Aedes aegypti, Aedes albopictus*, and *Culex quinquefasciatus* in northern Thailand, Southeast Asian J. *Trop. Med. Public. Health*,34,87-93.

Suman, D.S., Tikar, S. N., Parashar, B.D.,Prakash, S. 2010. Development of insecticide resistance in *Culex quinquefasciatus* mosquito from different locations in *India, J. Pestic. Sci*, 35 (1), 27-32.

Thavaselvam, D., Kumar, A., and Sumodan, P.K. 1993. Insecticide susceptibility status of *Anopheles stephensi, Culex quinquefasciatus* and *Aedes aegypti* in Panaji, Goa, *Indian Journal of Malariol*,30, 182.

Tikar, S.N., Kumar, A., Prasad, G.B.,Prakash, S. 2009. Temephos-induced resistance in *Aedes aegypti* and its cross-resistance studies to certain insecticides from India, *Parasitol. Res,* 105(1), 57-63.

Tyagi BK, Munirathinam A, Krishnamoorthi R, Venkatesh, A. 2012. A field based hand book of identification keys to mosquitoes of public health importance in India. Centre for research in Medical Entomology, Madurai, India. Pp.25-27.

White, G.B. 1989. Lymphatic filariasis. In: WHO, ed. Geographical distribution of arthropod-borne diseases and their principal vectors. Geneva pp. 23-25.

WHO, 2005. World Health Organisation. Sixth meeting of the Technical Advisory Group on the Global Elimination of Lymphatic Filariasis, Geneva, Switzerland. Wkly Epidemiol Rec. 80, 401-408.

WHO, 2005. World Health Organization, Guidelines for laboratory and field testing of mosquito larvicides. WHO/CDS/WHOPES/GCDPP.13,Geneva, Switzerland.

WHO, 2011, World Health Organization. The technical basis for coordinated action against insecticide resistance: preserving the effectiveness of modern malaria vector control: WHO Geneva, Meeting report. 2011; http://apps.who.int/iris/handle/10665/44526.

WHO, 2016. World Health Organization,Test procedures for insecticide resistance monitoring in malaria vector mosquitoes – 2nd ed.World Health Organization, 20 Avenue Appia, Geneva, Switzerland.http://www.who.int/malaria/areas/vector_control/insecticide_resistance/en/

WHO, 2017. World Health Organisation. 2017. Lymphatic filariasis. http://www.who.int/mediacentre/factsheets/fs102/en

WHO, 2017. World Health Organisation. 2017. Lymphatic filariasis. http://www.who.int/mediacentre/factsheets/fs102/en

Yadav, K., Rabha, B., Dhiman, S., Veer, V. 2015. Multi-insecticide susceptibility evaluation of dengue vectors *Stegomyia albopicta* and *St. aegypti* in Assam, India, Parasit and Vectors, 8, 143.

How to cite this article:

Basu, N *et al*.2018, Susceptibility of Culex Quinquefasciatus To Three Commonly Used Insecticides From West Bengal, India. *Int J Recent Sci Res.* 9(2), pp. 24402-24408. DOI: http://dx.doi.org/10.24327/ijrsr.2018.0902.1655

****