PUBLICATIONS
MODE OF INHERITANCE OF FENITROTHION RESISTANCE IN ANOPHELES STEPHENSI LISTON

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SUMMARY

The genetic mode of fenitrothion resistance was studied using a diagnostic dosage of 0.125 ppm to late third instar larvae of Anopheles stephensi in various genetic crosses which include homozygous fenitrothion resistant (FNr) and susceptible (FNs), F1 hybrids, back crosses and F2 generations. The data of genetic crosses between resistant and susceptible individuals revealed that the gene FNr is incomplete dominant and autosomal as the resistance was shown in both sexes for both F1 hybrids and back crosses. The log-dosage probit lines for resistant and susceptible, F1, and F2 hybrids clearly showed the characteristics imparted by a single incomplete dominant gene.

Key Words: Anopheles stephensi, genetic crosses, fenitrothion resistance.

INTRODUCTION

A special attention has been paid to the genetic basis of resistance, because genetic techniques can serve as analytical tools by which the separation of the different resistant mechanisms occurring simultaneously in a single strain can be effected. Such a separation can be of great help in the discovery of the cause of the resistance since it enables us to establish relationship of resistance with physiological or biochemical characters. Genetic studies of vector mosquitoes continue to be an important strategy in the field of genetic control.

Rapid development of resistance to insecticide by insect vectors of human diseases during the past 50 years has jeopardised vector control programmes. More than 160 species of vectors have now become resistant to major groups of insecticides. The control of mosquito vectors specially in India mainly depends upon the application of insecticides.

Resistance to insecticides has been extensively reviewed by Brown (1958, 1960), while in mosquitoes by Davidson & Mason (1963). Changes in protein and esterase isozyme pattern during developmental stages of a few insecticide resistance and susceptible strain and effect of insecticide resistance on reproductive potential have also been studied (Rao & Shetty 1996). The organophosphorus (OP) insecticide resistance has been reported in Culex pipiens (Stone & Brown 1969), Aedes aegypti (Hemingway et al. 1989). The genetic studies of malathion, fenthion, methyl-parathion and deltamethrin have been studied (Rao & Shetty 1994, Rajashree & Shetty 1998a). Mode of inheritance of malathion resistance in An. stephensi was studied by Rathor & Toquir(1981). Use of fenitrothion microcapsules as a new residual spraying formulation for mosquito control was also studied (Kawada et al. 1994). Shoukry & Hamed (1990, 1991) studied the mode of inheritance of fenitrothion resistance in Cx. pipiens larvae. Mechanisms of resistance to organophosphorus insecticides in Cx. tarsalis was studied by Apperson & George (1975). We report in this paper on the establishment of resistant and susceptible strains of An. stephensi for diagnostic dosage of 0.125 ppm of fenitrothion, an OP compound and its mode of inheritance.
MATERIALS AND METHODS

An. stephensi used for the present study was collected from a cemented tank from West of Chord Road (WCR) in Bangalore. Larvae of this mosquito were reared and maintained in the laboratory at the temperature of 25 ± 1°C, relative humidity of 75 ± 5% and photoperiod of 16 h. The pupae were collected in wide mouthed bottles and released in 8" x 8" x 8" cages. The adults were fed on 10% sucrose. Females were provided with blood meal of mice. Emerged larvae containing tap water were lined with strips of filter paper and placed inside the cages for oviposition. The larvae were provided with synthetic yeast. Fenitrothion was obtained as technical grade concentration (95%) from Rallis (India) Ltd., Bangalore. Susceptibility status of this strain was carried out using a diagnostic dosage of 0.125 ppm of fenitrothion (WHO 1986). Susceptible and resistant stocks were selected in the laboratory. The larvae derived from iso-female or F$_1$ strain were treated with the above dosage. The larvae survived from this treatment were maintained as separate stocks. Process was repeated for 20 more generations, in order to establish a homozygous resistant stock of fenitrothion strains (Table 1). The untreated portion of above WCR strain was used to establish the corresponding susceptible strains. The latter were synthesized after 11 generations (Table 1). Genetic males of F$_1$ hybrids with that of corresponding F$_n$ strains in order to establish the part of F$_1$ individuals were mated to get F$_2$ generation and the remaining mosquitoes were back-crossed to parental type. Resistance / susceptibility tests were carried out on late third instar larvae using diagnostic dosage as recommen to anophelines larvae (WHO 1981). The mortality (susceptible) and survivability (resistant) were considered after 24 h period for all genetic crosses. The number of males and females were also considered individually for resistance / survivability. The chi-square ($\chi^2$) values were calculated (Table 2). The dosage mortality relationship of fenitrothion resistance and susceptibility strains were recorded for third instar larvae for various genetic crosses (Fig. 1).

OBSERVATIONS

The data of the genetic crosses between the resistant and susceptible individuals are given in Table 2. In the crosses 3 and 4 (Table 2), the F$_1$ hybrids showed 59.35% and 60.58% resistance and 40.64% and 39.41% susceptibility to fenitrothion. The dosage mortality (d-m) line for F$_1$ hybrids were found to be closer to that of resistant strains (Fig. 1). The F$_1$ is significantly more resistant than susceptible parental strains, but less resistant than the resistant parental strain. The results of the crosses of F$_1$ hybrids to parental individual showed 52.17%, 48.41%, 51.58% and 51.12% respectively (Table 2). Similarly, susceptibility was found to be 47.82%, 48.35%, 48.41% and 48.85% respectively. The d-m lines of back crosses were found to be in between susceptible and F$_1$ hybrids (Fig. 1). The ratio of resistant and susceptible individuals was found to be almost 1:1. The F$_2$ hybrids showed 68.54% and 66.72% resistance and 31.45% and 33.28% susceptibility when treated 0.125 ppm of fenitrothion. The d-m line is found to be in between susceptible F$_1$ hybrids and resistant individuals (Fig. 1).

The data of genetic crosses between resistant and susceptible individuals revealed that the gene for the fenitrothion resistant (F$\text{nR}$) is incompletely dominant and autosomal. The logistic probit (LD-P) line for F$_1$ was in between the LD-P lines of susceptible and resistant strains. LD lines for back cross progeny showed a clear plateau between the LD-P lines of the susceptible and resistant individuals across a range of doses. It indicates that the resistance is controlled by a single gene. The data of the genetic crosses between resistant and susceptible individuals revealed that the gene for F$\text{nR}$ is completely dominant and autosomal as the resistance was shown in both sexes in both F$_1$ hybrids and back crosses by 1:1. The LD-P line of F$_2$ progeny was slightly irregular and no segregation was noticed. The presence of resistant and susceptible individuals was in a ratio of 3:1 per Mendelian monohybrid cross.

The LC$_{50}$ values of susceptible and resistant and F$_1$ hybrids were analysed for the degree of dominance D (Stone 1968). The value of D was found to be less than 1 indicating incomplete dominance.
Fig. 1: Dosage-mortality relationships of the fenitrothion resistant and susceptible strains of *An. stephani*. 
### DISCUSSION

Organophosphate compounds are excellent inhibitors of choline esterase and are used as fumigants and as systemic insecticides for nearly every type of control. The mode of action in mosquito roughly follows the general pattern of nerve which includes restlessness, hyper-excitability, tremor, convulsions and paralysis.

The fenitrothion has been extensively used for the control of mosquitoes (Kawada et al.). The present study indicated that *An. stephensi* has gradually developed resistance for fenitrothion. The fenitrothion resistance gene *FNR* reported here is an excellent genetic marker for *An. stephensi*. Such genes are extremely useful in conducting basic and applied genetic research including size of genetic sexing strains as conditional lethal for the preferential elimination of females early developmental stages (Shetty 1987). The resistant strains reported here are excellent for biochemical studies. Such studies have been carried out extensively in our laboratory (Shetty 1996, 1997, Rajashree & Shetty 1998b, Ghosh & Shetty 1997).

<table>
<thead>
<tr>
<th>Generation</th>
<th>Treated dose (ppm)</th>
<th>Mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parental</td>
<td>0.001</td>
<td>74.22</td>
</tr>
<tr>
<td>F₁</td>
<td>0.002</td>
<td>72.05</td>
</tr>
<tr>
<td>F₂</td>
<td>0.003</td>
<td>70.00</td>
</tr>
<tr>
<td>F₃</td>
<td>0.004</td>
<td>68.12</td>
</tr>
<tr>
<td>F₄</td>
<td>0.005</td>
<td>64.20</td>
</tr>
<tr>
<td>F₅</td>
<td>0.006</td>
<td>60.00</td>
</tr>
<tr>
<td>F₆</td>
<td>0.007</td>
<td>57.5</td>
</tr>
<tr>
<td>F₇</td>
<td>0.008</td>
<td>55.3</td>
</tr>
<tr>
<td>F₈</td>
<td>0.009</td>
<td>52.62</td>
</tr>
<tr>
<td>F₉</td>
<td>0.01</td>
<td>48.3</td>
</tr>
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<td>F₁₀</td>
<td>0.02</td>
<td>42.9</td>
</tr>
<tr>
<td>F₁₁</td>
<td>0.03</td>
<td>40.00</td>
</tr>
<tr>
<td>F₁₂</td>
<td>0.04</td>
<td>36.16</td>
</tr>
<tr>
<td>F₁₃</td>
<td>0.05</td>
<td>28.15</td>
</tr>
<tr>
<td>F₁₄</td>
<td>0.06</td>
<td>23.19</td>
</tr>
<tr>
<td>F₁₅</td>
<td>0.07</td>
<td>21.33</td>
</tr>
<tr>
<td>F₁₆</td>
<td>0.08</td>
<td>18.22</td>
</tr>
<tr>
<td>F₁₇</td>
<td>0.09</td>
<td>10.5</td>
</tr>
<tr>
<td>F₁₈</td>
<td>0.1</td>
<td>07.01</td>
</tr>
<tr>
<td>F₁₉</td>
<td>0.125</td>
<td>03.12</td>
</tr>
<tr>
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<td>0.125</td>
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</tr>
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<td>F₂₁</td>
<td>0.125</td>
<td>00.00</td>
</tr>
<tr>
<td>Genetic Crosses</td>
<td>No. of Females</td>
<td>Total No. of Larvae Tested*</td>
</tr>
<tr>
<td>----------------</td>
<td>---------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>Parental</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Resistant x Resistant</td>
<td>20</td>
<td>777</td>
</tr>
<tr>
<td>2. Susceptible x Susceptible</td>
<td>20</td>
<td>1272</td>
</tr>
<tr>
<td>F₁ Hybrid</td>
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<tr>
<td>3. Resistant x Susceptible</td>
<td>20</td>
<td>1058</td>
</tr>
<tr>
<td>4. Susceptible x Resistant</td>
<td>20</td>
<td>1162</td>
</tr>
<tr>
<td>Back Crosses</td>
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<td></td>
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<tr>
<td>5. Susceptible $\sigma^r \times F₁ \varphi$ (Resistant x Susceptible)</td>
<td>20</td>
<td>1472</td>
</tr>
<tr>
<td>6. Susceptible $\varphi \times F₁ \sigma^r$ (Susceptible x Resistant)</td>
<td>20</td>
<td>1398</td>
</tr>
<tr>
<td>7. $F₁\sigma^r \times (Susceptible \varphi \times Resistant \sigma^r) \times Susceptible \varphi$</td>
<td>20</td>
<td>1450</td>
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<tr>
<td>8. $F₁\varphi (Resistant \varphi \times Susceptible \sigma^r) \times Susceptible \sigma^r$</td>
<td>20</td>
<td>1424</td>
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<tr>
<td>F₂ Generation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. $F₂ (Resistant \sigma^r \times Susceptible \varphi)$</td>
<td>20</td>
<td>1274</td>
</tr>
<tr>
<td>10. $F₂ (Susceptible \sigma^r \times Resistant \varphi)$</td>
<td>20</td>
<td>1250</td>
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</table>

*Late third instar larvae exposed to 0.125 ppm fenitrothion for 24 h; ** Statistically insignificant (p>0.05).
ACKNOWLEDGEMENT

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Egg-Float Ridge Number in *Anopheles stephensi*: Ecological Variation

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The strategy of vector control varies according to the vector species and depends upon the fundamental knowledge of their biology, ecology and ethology. Specific ridge numbers on the egg float of *Anopheles* can now be made to possi bile to classify the mosquito strains. In the present study, the type form (9-15 ridges) and intermediate (12-17 ridges) were noted for their egg float ridge number. Most of the regions that were surveyed consisted of urban and semi-urban localities. It is interesting to note that in the present study the type form has been traced from the urban dwellings. This is in contrast to the earlier observations where, the type-form, an efficient strain, was reported to be prevalent in urban areas. The strains with different ridge numbers are as “ecological variants”.

Keywords: *Anopheles stephensi*, egg floats mosquito eggs, ecological variants

*n. stephensi* belongs to the sub-genus Celia of the order Diptera. It is considered to be one of the urban malaria vectors and are distributed in Indian tinent including India, Pakistan, Iran and Iraq. Our laboratory is working on the basic genetic isolation and characterization of mutant markers, etc. studies, genetic basis of insecticide resistance, etc. studies on the resistant strains which are try to formulate genetic control mechanisms (Shetty 1988, 1992a, Rao and Shetty 1992, ajsaree and Shetty 1998, Ghosh and Shetty 1999, dha and Shetty 1999, Shetty et. al 1994,1995). Some translocations and naturally occurring as have also been established in the said species. number of chromosomal translocations including sex autosomal and multiple translocations have been in *An. stephensi* (Shetty and Gayathri 1989, Gayathri ty 1992 b). Research is in progress to produce resistant strains, refractory strains and transgenic mosquitoes control of *An. stephensi*.

*stephensi* was classified as two geographical races in the number of ridges on the egg float (Sweet and 7, Rao et. al 1938). Urban *An. stephensi* was regarded as-form and the rural variety as *myorensis*. Later on the presence of several *An. stephensi* strains in the laboratory the presence of three variants viz. type-form, *myorensis* and intermediate form (Sweet and Rao, 1937; Rao 18). *Myorensis* and intermediate forms were found in 18, but in semi urban areas all these forms were detected 10, et. al 1987).

This paper reports the observations on the ridge numbers on the egg floats in 28 strains of *An. stephensi*, which were collected from semi-urban and urban localities of India.

MATERIALS AND METHODS

In the present study, 28 strains of *An. stephensi*, were originally collected in the form of gravid females/larvae, from different geographical areas of India and were successfully colonized in our laboratory (Table I). Adults and larvae were maintained in the insectary at 25 ± 10 °C, relative humidity of 75 ± 5% and photoperiod of 16 hours. The adults were fed on 10% sucrose solution. Females were provided with restrained mice for the blood meal. Enamel bowls or individual vials containing tap water were lined with strips of filter paper placed for oviposition. The adults and larvae were reared according to the procedure of Shetty (1983).

Eggs from individual females from laboratory maintained strains were counted and the distributions of ridge number were plotted. To establish the ridge number, eggs were placed on a drop of water on a microscope slide and the number of ridges on one side of the egg float was counted, at 100 X magnification using LABO (Bioplan XL) microscope. Depending on the number of ridges on the egg float, the strains were grouped into type, intermediate and *myorensis* with 14-22, 12-17 and 9-15 respectively. The percentage distribution of ridge numbers in each strain was also calculated.

RESULTS

The data regarding the egg-float ridge number of 28 strains of *An. stephensi* maintained in our insectary is presented (Table I). The percentage distribution of eggs with specific ridge numbers was calculated and these are shown for each strain.


<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Strains</th>
<th>Total No. of eggs examined</th>
<th>No. of Ridges on the Egg Float</th>
<th>Range</th>
<th>Variety</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>10</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>1</td>
<td>Kengeri (KNG)</td>
<td>232</td>
<td>14.6</td>
<td>2.2</td>
<td>12.9</td>
</tr>
<tr>
<td>2</td>
<td>Cambridge Layout (CLO)</td>
<td>149</td>
<td>2.7</td>
<td>12.1</td>
<td>16.8</td>
</tr>
<tr>
<td>3</td>
<td>Gorungutepalya (GRP)</td>
<td>501</td>
<td>38.9</td>
<td>44.5</td>
<td>16.6</td>
</tr>
<tr>
<td>4</td>
<td>Mahalakshmipuram (MSK)</td>
<td>161</td>
<td>11.2</td>
<td>29.8</td>
<td>37.9</td>
</tr>
<tr>
<td>5</td>
<td>Mangalore a (MGN a)</td>
<td>228</td>
<td>2.2</td>
<td>6.6</td>
<td>28.5</td>
</tr>
<tr>
<td>6</td>
<td>Mangalore b (MGN b)</td>
<td>471</td>
<td>14.2</td>
<td>20.2</td>
<td>21.4</td>
</tr>
<tr>
<td>7</td>
<td>Delhi a (DEL a)</td>
<td>150</td>
<td>5.3</td>
<td>16.7</td>
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</tr>
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<td>8</td>
<td>Delhi b (DEL b)</td>
<td>157</td>
<td>25.5</td>
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<td>9</td>
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<td>19.6</td>
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<td>Aurangabad (AGB)</td>
<td>181</td>
<td>1.7</td>
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<tr>
<td>11</td>
<td>Punjab OW</td>
<td>127</td>
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<td>7.9</td>
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<td>12</td>
<td>Pondicherry (PDY)</td>
<td>342</td>
<td>9.6</td>
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<td>13</td>
<td>Chunali b (CHN b)</td>
<td>175</td>
<td>2.3</td>
<td>6.9</td>
<td>48.0</td>
</tr>
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<td>14</td>
<td>Rajajinagar (RJN)</td>
<td>135</td>
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<td>15</td>
<td>Thalagattipura (TGP)</td>
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<td>17</td>
<td>West of Chord Road (WCR)</td>
<td>300</td>
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<td>19</td>
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<td>21</td>
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<td>Mysoore d (MSM d)</td>
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<td>40.2</td>
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<td>13.3</td>
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<td>411</td>
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</tbody>
</table>

(The Table I). The strains of Kengeri (KNG), Gorungutepalya (GRP), Cambridge Layout (CLO), Mahalakshmipuram (MSK), Mangalore a (MGN a), Mangalore b (MGN b), Delhi a (DEL a), Delhi b (DEL b), Delhi c (DEL c), Aurangabad (AGB), Punjab (RJN), Chunali b (CHN b), and Pondicherry (PDY) were grouped under type-form with 16-22, 17-19, 14-20, 14-19, 16-21, 16-20, 15-21, 16-20, 17-22, 15-20, 17-21, 18-21 and 16-21 ridges respectively. The strains of Rajajinagar (RJN), Thalagattipura (TGP), Yelahanka (YEL), West of Chord Road (WCR), Chunali a (CHN a), Mysoore a (MSG a), Mysoore b (MSG b), Mysoore c (MSG c), Goa a (GOL), Goa b (GOF), Pune (PUN) and Shimoga (SHM) were grouped under intermediate with 13-18, 11-18, 12-17, 12-19, 13-18, 12-16, 13-17, 15-18, 14-18, 13-17, 13-18 and 14-19 respectively. The strains derived from Cubbonpet a (CUB a), Cubbonpet b (CUB b), and Mysoore d (MSM d) had mysoorensis forms with 10-18, 11-15, and 10-14 ridges respectively.

The strains KNG and HRN showed the highest 14 ridges; CLO with 19 ridges, GRP, DEL b, AGB and PDY with 18 ridges, GOL and GOF with 17 ridges, MSK and MBS with 15 ridges, WCR, CHN a and MSG with 13 ridges, TGP, YEL, PUN, SHM, CUB a and b, showed the percentage of eggs 14 ridges; RJN with 13 and MSM with II ridges.

DISCUSSION

The marked difference in the habits of An. stephensi many parts of India noted by early observers led to postulation of the existence of biological races. Two race An. stephensi were given sub-species status by Pur (1949) and this was accepted by Stone et al. (1959) in their “A Syn Catalog of Mosquitoes of the World”. Later, Rutledge (1970) found the two forms sympatric and interbreeding.
considered them as variants and not sub-species. It is
premature to note that in the present study the type form has
been traced from the semi-urban areas populated by high
census groups. Similarly, mysoensis variety was traced from
urban localities surrounded by slum dwellings. This is in
contrast to the earlier observations where, the type form, an
insect vector of malaria was reported to be prevalent in the
urban areas, and the mysoensis variety, a poor vector was
sent in rural areas (Sweet and Rao 1937, Rao et al. 1938,
a, 1984). In the present study, the type form which is
dominantly found in the urban areas like Delhi and Chennai,
are in consistent with earlier report and it was observed
that the strains of CUB a, b (Bangalore) and MSN, consisted
of mysoensis variety, which was traced from the urban areas was
not consistent with earlier report (Sweet and Rao, 1937).
In the present study, all the three forms were traced from the semi-urban
areas is also in consistent with earlier findings (Subbarno et al.17).
The present investigation revealed that all the three
forms could be traced from even urban localities with different
logical niches. Siddiqui and Aslamkhan (1973), reported
breeding experiments between different forms indicated
the presence of inversion in the polytene chromosomes of An.
shenzi, mysoensis. Coluzzi et al. (1972, 1973) reported
breeding experiments between the varous forms controlled by genetic factors (Curts et al. 1985 and Subbarno et al.17).
Mahmood and Sakai (1984) found rural and urban An.
shenzi populations to differ in chromosome inversion
quencies, eight autosomal paracentric inversions were
found in the populations. Of these three inversions t 12Rb inversion was found in the females of all the three
forms (Subbarno et al. 1987).

Breeding experiments between different forms indicated
the presence of inversion in the polytene chromosomes of An.
shenzi, mysoensis. Coluzzi et al. (1972, 1973) reported
inversion homoygotes had "mysoensis type" of eggs.
However, no such correlation was found with Suguna (1981)
and Rajive et al. (1980) in which the inversions were found in the females of all the three
forms (Subbarno et al. 1987).

Although no sub-species have been found in An.
shenzi, in urban population there is marked distinction
among the population with different ecological niches.
Currently our laboratory is engaged in working on the
susceptibility status of various An. parasites, cytology, genetics and biochemical studies
the above said variants.

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Effect of Fenitrothion, Deltamethrin and Cypermethrin on Reproductive Potential and Longevity of Life Cycle in *Anopheles stephensi* Liston, a Malaria Mosquito

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The effect of sublethal concentrations of Fenitrothion (OP Insecticide), Deltamethrin and Cypermethrin (synthetic pyrethroids) on fecundity, egg hatchability, sex ratio and longevity of life cycle was studied in the malaria vector *Anopheles stephensi*. A sublethal concentration of 0.01 ppm Fenitrothion, 0.0005 ppm Deltamethrin and 0.00175 ppm Cypermethrin was used for the present study. Treatment with the above with "control". The decrease in these parameters was observed even in F1 and F2 generations. However, a tendency to gain normalcy in F2 generation was noticed. The treated strains and their F1 and F2 progeny showed a prolonged life cycle when compared with their corresponding "control" strains.

Keywords: *Anopheles stephensi*, Insecticide, Fenitrothion, Deltamethrin, Cypermethrin, fecundity, egg hatchability, sex ratio, life cycle, reproductive potential.

Among the best known groups of Dipteran insects, mosquitoes are of very great importance to man, as vectors and vectors of the most dreaded human diseases such as malaria, filaria, leishmaniasis, dengue haemorrhagic fever (*Anopheles stephensi*) belongs to the sub-genus Cellia and is one of the important vectors of malaria in Indian sub-continent.

Development of resistance to various types of insecticides such as Organochlorides, Organophosphates and Carbamates, as a serious threat to the conventional control measures vectors, especially mosquitoes. Currently, synthetic pyrethroids are being used because of their biodegradability low mammalian toxicity, to control insect vectors. However, vector control measures using insecticides poses another advantage, that of adverse environmental pollution. Yet, developing countries including India, control of tropical diseases such as malaria, filaria, dengue etc. is solely dependent upon chemical control (Shetty, 1997). This paper reports the effect of Fenitrothion, Deltamethrin and Cypermethrin resistance on fecundity, egg hatchability, sex distortion and longevity of life cycle in *Anopheles stephensi*.

**MATERIALS AND METHODS**

*Anopheles stephensi* were collected as gravid females from 1 of Chord Road, Thalaghattapura (Bangalore) and Dhekari from cattle sheds, huts and human dwellings by aspirator while the larvae were collected from overhead wells and curving water. The strains were separately maintained in 8"x 8"x 8" iron cages covered with cotton net cloth and fed on 10% sucrose solution. Females were provided with blood meal of mice for oviposition. Eggs were collected into enamel bowls containing tap water and lined with strips of filter paper, 72 h after blood meal. Larvae were reared in separate pans and provided with synthetic yeast (Cymo Pharma). The maintenance and rearing was done according to the procedure of Shetty (1983). Currently, 28 strains of *An. stephensi* derived from different geographical areas of India are maintained in our laboratory.

Fenitrothion (O, O-dimethyl-O-nitro-m-tolyl-phosphorothionate) an organophosphorus compound and Deltamethrin (a-cyano-3-phenoxy benzyl-d-cis-3-(2, 2-dibromovinyl)-2.2-dimethyl cyclopropane-1-carboxylate) and Cypermethrin (RS)-O-cyano-3-phenoxy benzyl (1RS)-cis-, trans-3-(2, 2-dichlorovinyl)-2, 2-dimethyl cyclopropane carboxylate), both synthetic pyrethroids were obtained as technical grade from Rallis (India) Pvt. Ltd. Bangalore. The strains from West of Chord Road, Thalaghattapura and Dhekari exposed to Fenitrothion, Deltamethrin and Cypermethrin have been designated as FT, DL and CP strains respectively.

The LC50 values of above insecticides for the respective strains were obtained from log-dosage probit mortality linear regression relationship (Finney, 1971). If control mortality exceeded 10%, corrected mortality was obtained using the formula of Abbott (1925).

Batches of 100 third instar larvae were exposed to sublethal concentrations of Fenitrothion (0.01 ppm), Deltamethrin (0.0005 ppm) and Cypermethrin (0.00175 ppm) for 14 h according to the standard W.H.O. procedure (1981). The exposed larvae were washed with tap water and reared in separate enamel pans. The larvae were fed with yeast. The pupae were collected...
in wide mouthed bottles and upon emergence released into respective cages. After 5 days, adult females were allowed to feed on mice blood and 72 h later, about 20–25 gravid females were randomly selected from each cage and individually released into vials containing tap water and lined with a strip of filter paper for oviposition. Each vial was covered with a net cloth firmly held in place by a rubber band.

The egg production ratio was noted by counting the number of eggs laid by each female. The egg hatchability was calculated for each generation using the formula

\[
\text{Hatchability} = \frac{\text{No. of larvae}}{\text{No. of eggs}} \times 100
\]

The larvae of each female were reared as a single family. Care was taken to avoid selective mortality as a source of bias in obtaining data for sex ratio. The number of freshly emerged males and females were scored at each generation for each female. The sex ratio as well as the number of female offsprings, produced by each female was calculated for each generation.

**RESULTS AND DISCUSSION**

The data on the fecundity, percentage egg hatchability, sex ratio distortion and longevity of life cycle in *An. stephensi* for three generations (Parental, F₁, and F₂) using sublethal concentrations of each insecticide (Fenitrothion, Deltamethrin and Cypermethrin) have been illustrated in Tables I, II and III respectively.

A sublethal concentration of 0.01 ppm Fenitrothion, 0.0005 ppm Deltamethrin and 0.00175 ppm Cypermethrin was used for the present study. Treatment with the above mentioned insecticides showed decreased fecundity, egg hatchability and sex ratio distortion towards males when compared with “control”. The decrease in these parameters was observed even in F₁ and F₂ generations. However, a tendency to gain normalcy in F₂ generation was noticed. The treated strain and their F₁ and F₂ progeny required longer duration to complete their life cycle when compared with their corresponding “control” strains. The present investigation revealed that the decrease in fecundity in FT strain was by 32%, 24% and 20%; in DL strain by 23%, 40% and 32% and in CP strain by 27%, 29% and 32% in the parental, F₁ and F₂ generations respectively when compared with their corresponding control strains.

A reduced egg hatchability of 35%, 31% and 38% in FT strain; 18%, 23% and 24% in DL strain and 26%, 27% and 29% in CP strain was observed for parental, F₁ and F₂ generations respectively against their corresponding control.

The sex-ratio distortion (males:females) of FT strain was found to be 0.82:1, 0.62:1 and 0.83:1; DL strain was 0.86:1, 0.84:1 and 0.93:1 and CP was 0.79:1, 1.03:1 and 0.92:1 for parental F₁ and F₂ generations respectively against control.

The duration of life cycle was prolonged by 4, 4 and 5 days in FT strain, 2, 3 and 2 days in DL strain and 3, 4 and 2 days in CP strain for parental, F₁ and F₂ generations respectively when compared with their control.

Studies on the effect of insecticides on reduced fecundity and egg hatchability have been reported in a few species of mosquitoes. Rao and Shetty (1992) have reported, reduced fecundity, egg hatchability and sex ratio distortion towards males in Malathion, Fenthion and Parathion treated larvae of *An. stephensi* at sublethal doses. Gasbou and Darwood (1973) reported that DDT and malathion showed 40% and 50% decrease in fecundity respectively, but did not reduce the egg hatchability in *C. pipiens*. Similarly, the resistant strain was less fecund to temephos in *Cx. quinquefasciatus* (Ferrari and Georgiou, 1981). The fecundity showed a decrease of 67.20% in *Cx. quinquefasciatus*, 43.30% in *Aedes aegypti* and 40.60% in

---

**Table 1**

<table>
<thead>
<tr>
<th>West of Chord Road</th>
<th>No. of Females</th>
<th>Fecundity</th>
<th>Egg Hatchability</th>
<th>Sex Ratio</th>
<th>Longevity of Life Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>Treated</td>
<td></td>
<td>No. of Larvae</td>
<td>Total Males</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Hatchability</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>55</td>
<td>6724</td>
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<td>1.00</td>
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</tr>
<tr>
<td></td>
<td>39</td>
<td>3259</td>
<td>83.56</td>
<td>0.68</td>
<td>2053</td>
</tr>
<tr>
<td>F₁ Generation</td>
<td></td>
<td></td>
<td></td>
<td>No. of Larvae</td>
<td>Total Males</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Hatchability</td>
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<td>5426</td>
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<td>4125</td>
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<td>0.76</td>
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<tr>
<td>F₂ Generation</td>
<td></td>
<td></td>
<td></td>
<td>No. of Larvae</td>
<td>Total Males</td>
</tr>
<tr>
<td>Control</td>
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<td>6015</td>
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<tr>
<td></td>
<td>47</td>
<td>4092</td>
<td>87.06</td>
<td>0.80</td>
<td>3985</td>
</tr>
</tbody>
</table>

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Table II

Effect of sublethal dose (0.0005 ppm) of Deltamethrin on the reproductive potential of Anopheles stephensi

<table>
<thead>
<tr>
<th>Strain</th>
<th>No. of</th>
<th>FECUNDITY</th>
<th>EGG HATCHABILITY</th>
<th>SEX RATIO</th>
<th>Longevity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Females</td>
<td>Total Eggs</td>
<td>Eggs Female</td>
<td>Ratio</td>
<td>Total Larvae</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rol 101</td>
<td>69</td>
<td>7854</td>
<td>113.82</td>
<td>1.00</td>
<td>7465</td>
</tr>
<tr>
<td>rol 100</td>
<td>60</td>
<td>5251</td>
<td>87.52</td>
<td>0.77</td>
<td>4072</td>
</tr>
<tr>
<td>isolation</td>
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<td>5944</td>
<td>149.60</td>
<td>1.00</td>
<td>5718</td>
</tr>
<tr>
<td>rol 100</td>
<td>42</td>
<td>3738</td>
<td>89.00</td>
<td>0.60</td>
<td>2784</td>
</tr>
<tr>
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<td>51</td>
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<td>132.00</td>
<td>1.00</td>
<td>6449</td>
</tr>
<tr>
<td>rol 101</td>
<td>43</td>
<td>3913</td>
<td>91.00</td>
<td>0.68</td>
<td>2849</td>
</tr>
</tbody>
</table>

Table III

Effect of sublethal dose (0.00175 ppm) of Cypermethrin on reproductive potential of Anopheles stephensi.

<table>
<thead>
<tr>
<th>Strain</th>
<th>No. of</th>
<th>FECUNDITY</th>
<th>EGG HATCHABILITY</th>
<th>SEX RATIO</th>
<th>Longevity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Females</td>
<td>Total Eggs</td>
<td>Eggs Female</td>
<td>Ratio</td>
<td>Total Larvae</td>
</tr>
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<td>rol 101</td>
<td>72</td>
<td>8200</td>
<td>113.89</td>
<td>1.00</td>
<td>7954</td>
</tr>
<tr>
<td>rol 100</td>
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<td>5435</td>
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<td>0.73</td>
<td>3920</td>
</tr>
<tr>
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<td>120.00</td>
<td>1.00</td>
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</tr>
<tr>
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<td>5016</td>
<td>85.02</td>
<td>0.71</td>
<td>3560</td>
</tr>
<tr>
<td>rol 101</td>
<td>53</td>
<td>6925</td>
<td>130.66</td>
<td>1.00</td>
<td>6733</td>
</tr>
<tr>
<td>rol 101</td>
<td>42</td>
<td>3769</td>
<td>89.74</td>
<td>0.68</td>
<td>2615</td>
</tr>
</tbody>
</table>

in stephensi for pyrethroids (Verma, 1986). Similar mortality was reported on reduced fecundity of malathion x. p. pallens (Zhang and Tang, 1990). However, Giliota et al. (1985) found no significant difference in either fecundity or fertility in An. stephensi, to dieldrin. Besides the insecticides, in inhibitors such as perfuron and fural triazine resulted in reduction of fecundity by 78.30% and 23.5% respectively in stephensi (Saxena and Kasuahil, 1986). There was also a significant dependent reduction in average number of eggs per female. Further, it has been reported that d-allethrin reduced fecundity by 69% and 45% in low and high dosages, whereas d-phenthothrin increased the fecundity by 33% at low age, in Ae. aegypti but F2 generation showed reverse to total fecundity (Weide Liu et al., 1986).

Mortality of eggs, followed by delayed toxic effect of temephrin in larvae, pupae and adults has been reported in stephensi (Sahgal and Pillai, 1993). Penetration of the nico into the eggs was believed to be responsible for the failure of eggs during embryogenesis (Grosscatt, 1977; Albert and Pre, 1984). Prolongation of the life cycles of the treated individuals may be attributed to the selection pressure due to insecticides.

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SUSCEPTIBILITY STATUS OF DIFFERENT STRAINS OF Anopheles stephensi, LISTON TO FENITROTHION, DELTAMETHRIN AND CYPERMETHRIN

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ABSTRACT
The use of chemical insecticides continues to be the main component of malaria control in India. The present study deals with the comparative susceptibility status of different strains of Anopheles stephensi, Liston to Fenitrothion (O, O-dimethyl-O-nitro-m-tolylphosphothonate), Deltamethrin ([α-cyano-3-phenoxy benzyl-d-cis-3-(2,2-dibromovinyl)-2,2-dimethylcyclopropone-1-carboxylate] and Cypermethrin [(RS)-α-cyano-3-phenoxy benzyl (1RS)-cis-trans-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropene carboxylate].

A total of eighteen strains of An. stephensi were collected from different parts of India and reared under laboratory conditions. Eight were from Bangalore, two each from Delhi, Chennai and Mangalore and the rest one each from Haryana, Aurangabad, Poona and Pondicherry. Late third instar larvae were used for this study. LC₅₀ and LC₉₀ at 95% confidence limit were calculated using probit analysis for all the strains, which indicated that all the above strains of An. stephensi were susceptible to Fenitrothion, Deltamethrin and Cypermethrin.

KEY WORDS: Fenitrothion, Deltamethrin and Cypermethrin, Susceptibility, An. stephensi.

INTRODUCTION

Since mosquitoes play an important role in transmitting dreadful diseases such as malaria, filaria, dengue haemorrhage, Japanese encephalitis, it became a global priority to control them. Mosquitoes develop resistance to virtually all types of insecticides. Introduction of new insecticides for mosquito control will most likely face the same fate unless integrated resistance management plans are implemented.

The development of resistance in the Anopheles mosquitoes, vectors of malaria has disrupted the WHO global malaria eradication programme. It was found that in a span of nearly 30 years, out of 60 important species of Anopheles mosquitoes, 58 had developed resistance to the organochlorines, viz., DDT, Lindane, Dieldrin. The widespread employment of agricultural insecticides in malarial areas is considered an important factor in selection for multiple resistance in Anophecline vectors.

Insecticide resistance is believed to develop largely, if not entirely, because of the natural selection of preadaptive mutants that possess genetically controlled mechanisms for detoxification, target-site insensitivity or other means of survival in the presence of the insecticide.

Currently, control of mosquitoes is performed mainly through the application of insecticides. Genetic studies of mosquitoes especially of species and strains that are vectors continue to be an essential component of genetic control strategies aimed at disrupting the transmission of diseases. In our laboratory, the genetic basis of insecticide resistance in Anopheles stephensi...
have been established to Malathion; Fenthion and Methyl paraathion; Deltamethrin; Cypermethrin; Fenitrothion.

Biochemical studies between resistant and susceptible strains of An. stephensi to various insecticides have also been carried out. Since the control of malaria solely depends on chemical control of vectors, the present investigation aims to different insecticides.

**MATERIAL AND METHODS**

Eighteen strains of An. stephensi used in these experiments were collected from the field in the form of larvae and gravid females. Adults were reared in cages of iron frames covered by mosquito nets, measuring 12" x 12" x 12" and 8" x 8" x 6" to accommodate 300 and 150 adults respectively.

The adults were fed on 10% glucose solution and adult females were fed on the blood of mice for oviposition. Enamel water bowls lined with filter paper were placed in the cage for oviposition. Temperature was maintained at 25 ± 1°C, the relative humidity at 75 ± 5% and photoperiod of 16 hours.

Fenitrothion (O.O-dimethyl-O-nitro-m-tolylphosphothionate), Deltamethrin (α-cyano-3-phenoxy benzyl-d-cis-3-(2,2-dibromovinyl-2,2-dimethylcyclopropane-1-carboxylate), Cypermethrin [(RS)-α-cyano-3-phenoxy benzyl (1RS)-cis-trans-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropane carboxylate) were used in the present study to find out the base line susceptibility status of different strains of An. stephensi following the methods of WHO.

Different concentrations in ppm (mg/litre) of each insecticide were prepared in ethanol denatured with 2% butanone. Stock solution of 250 ppm was prepared and serially diluted using ethanol. Late third instar larvae were selected for the test. Test concentrations were prepared by adding 1 ml of the insecticide of different insecticides of different grades to 249 ml of water in 500 ml glass beakers and stirred vigorously. 1 ml of ethanol was added to the control set. Larvae were tipped on a flat strainer and the traces of water were blotted before transferring them to test concentrations. Mortality was observed after 24 hours of exposure. The larvae which pupated during exposure time were discarded.

LC₉₀ and LC₅₀ values for the respective strains to each insecticide were calculated by subjecting dosage-mortality data to probit analysis. Probit analysis at 95% confidence limit and Slope ± SEM were calculated using Microstat software (EcoSoft Inc., USA) to compare the different strains for each insecticide.

**RESULTS AND DISCUSSION**

Larval susceptibility status of An. stephensi to different insecticides, viz., Fenitrothion, Deltamethrin and Cypermethrin are presented in Tables 1, 2 and 3. The mortality rate of larvae of the above strains for the above insecticides is presented as the data on LC₉₀ and LC₅₀ values. No significant variation in susceptibility existed among strains for each insecticide.

Among the 15 strains studied for Fenitrothion, LC₉₀ values ranged from 0.0023 ppm to 0.0041 ppm (Table 1). KNG showed the highest LC₉₀ value (0.0041 ppm) while CHN showed the lowest LC₉₀ value (0.0023 ppm). Response slopes ranged from 1.4 to 2.6. Among 6 strains tested for Deltamethrin, LC₉₀ values ranged between 0.0008 ppm and 0.002 ppm (Table 2). GRP showed the highest LC₉₀ value (0.002 ppm) and KNG showed the lowest LC₉₀ value (0.0008 ppm) for the same insecticide.

Response slopes ranged from 0.85 to 1.73. Among 6 strains tested for Cypermethrin, LC₉₀ values ranged from 0.0006 ppm to 0.0035 ppm (Table 3). KNG showed the lowest LC₉₀ values (0.0006 ppm) while PDY showed the highest LC₉₀ values (0.0035 ppm). The response slope ranged from 0.94 to 3.89.

The present study revealed that there were no significant differences between the least and most
### Base line susceptibility status of *An. stephensi* to Fenitrothion

<table>
<thead>
<tr>
<th>Area</th>
<th>Total larvae tested</th>
<th>LC&lt;sub&gt;50&lt;/sub&gt; ppm</th>
<th>95% CL</th>
<th>Slope ± SEM</th>
<th>LC&lt;sub&gt;90&lt;/sub&gt; ppm</th>
<th>X²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haryana (HRN)</td>
<td>725</td>
<td>0.0041</td>
<td>0.0038-0.0043</td>
<td>1.70 ± 0.13</td>
<td>0.0084</td>
<td>20.38</td>
</tr>
<tr>
<td>Delhi-B (DNP)</td>
<td>1000</td>
<td>0.0039</td>
<td>0.0037-0.0041</td>
<td>2.25 ± 0.13</td>
<td>0.0069</td>
<td>20.79</td>
</tr>
<tr>
<td>Delhi-A (DLH)</td>
<td>560</td>
<td>0.0028</td>
<td>0.0026-0.0030</td>
<td>1.65 ± 0.12</td>
<td>0.0061</td>
<td>43.44</td>
</tr>
<tr>
<td>Aurangabad (AGB)</td>
<td>700</td>
<td>0.0039</td>
<td>0.0037-0.0042</td>
<td>1.9 ± 0.14</td>
<td>0.0078</td>
<td>52.67</td>
</tr>
<tr>
<td>Pondicherry (PDY)</td>
<td>350</td>
<td>0.0036</td>
<td>0.0033-0.0038</td>
<td>2.3 ± 0.22</td>
<td>0.0063</td>
<td>11.86</td>
</tr>
<tr>
<td>Chennai-B (CHN)</td>
<td>650</td>
<td>0.0023</td>
<td>0.0021-0.0025</td>
<td>1.7 ± 0.11</td>
<td>0.0049</td>
<td>49.13</td>
</tr>
<tr>
<td>Mangalore-A (MGN)</td>
<td>760</td>
<td>0.0027</td>
<td>0.0026-0.0028</td>
<td>2.5 ± 0.16</td>
<td>0.0045</td>
<td>28.52</td>
</tr>
<tr>
<td>Mangalore-B (MAN)</td>
<td>900</td>
<td>0.0027</td>
<td>0.0026-0.0028</td>
<td>2.2 ± 0.13</td>
<td>0.0049</td>
<td>39.61</td>
</tr>
<tr>
<td>Chennai-A (CHE)</td>
<td>1000</td>
<td>0.004</td>
<td>0.0038-0.0043</td>
<td>1.4 ± 0.09</td>
<td>0.0101</td>
<td>53.86</td>
</tr>
<tr>
<td>West of Chord Road (WCR)</td>
<td>560</td>
<td>0.0037</td>
<td>0.0034-0.0039</td>
<td>2.2 ± 0.17</td>
<td>0.0086</td>
<td>34.29</td>
</tr>
<tr>
<td>Cambridge Layout (CLO)</td>
<td>700</td>
<td>0.0026</td>
<td>0.0024-0.0027</td>
<td>1.9 ± 0.12</td>
<td>0.0050</td>
<td>28.91</td>
</tr>
<tr>
<td>Yelahanka (YLH)</td>
<td>700</td>
<td>0.0038</td>
<td>0.0036-0.0041</td>
<td>1.5 ± 0.12</td>
<td>0.0089</td>
<td>35.79</td>
</tr>
<tr>
<td>Cubbonpet (CUB)</td>
<td>799</td>
<td>0.004</td>
<td>0.0038-0.0042</td>
<td>2.6 ± 0.16</td>
<td>0.0068</td>
<td>31.25</td>
</tr>
<tr>
<td>Rajajinagar (RJN)</td>
<td>600</td>
<td>0.0033</td>
<td>0.0031-0.0035</td>
<td>2.2 ± 0.17</td>
<td>0.0058</td>
<td>22.07</td>
</tr>
<tr>
<td>Kengeri (KNG)</td>
<td>700</td>
<td>0.0041</td>
<td>0.0039-0.0044</td>
<td>1.7 ± 0.09</td>
<td>0.0086</td>
<td>34.17</td>
</tr>
</tbody>
</table>

### Base line susceptibility status of *An. stephensi* to Cypermethrin

<table>
<thead>
<tr>
<th>Area</th>
<th>Total larvae tested</th>
<th>LC&lt;sub&gt;50&lt;/sub&gt; ppm</th>
<th>95% CL</th>
<th>Slope ± SEM</th>
<th>LC&lt;sub&gt;90&lt;/sub&gt; ppm</th>
<th>X²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cubbonpet (CUB)</td>
<td>600</td>
<td>0.001</td>
<td>0.0009-0.0011</td>
<td>1.49 ± 0.11</td>
<td>0.0024</td>
<td>0.18</td>
</tr>
<tr>
<td>Gorguntepalya (GRP)</td>
<td>800</td>
<td>0.002</td>
<td>0.0018-0.0023</td>
<td>0.85 ± 0.06</td>
<td>0.0083</td>
<td>15.67</td>
</tr>
<tr>
<td>Delhi-A (DLH)</td>
<td>700</td>
<td>0.0015</td>
<td>0.0014-0.0016</td>
<td>1.42 ± 0.10</td>
<td>0.0037</td>
<td>0.97</td>
</tr>
<tr>
<td>Kengeri (KNG)</td>
<td>400</td>
<td>0.0008</td>
<td>0.0007-0.0009</td>
<td>1.14 ± 0.13</td>
<td>0.0025</td>
<td>1.61</td>
</tr>
<tr>
<td>Thalaghattapura (TGP)</td>
<td>500</td>
<td>0.001</td>
<td>0.0001-0.0011</td>
<td>1.73 ± 0.13</td>
<td>0.0022</td>
<td>2.53</td>
</tr>
<tr>
<td>Yelahanka (YLH)</td>
<td>600</td>
<td>0.0009</td>
<td>0.0008-0.0011</td>
<td>1.17 ± 0.10</td>
<td>0.0026</td>
<td>1.01</td>
</tr>
</tbody>
</table>

### Base line susceptibility status of *An. stephensi* to Cypermethrin

<table>
<thead>
<tr>
<th>Area</th>
<th>Total larvae tested</th>
<th>LC&lt;sub&gt;50&lt;/sub&gt; ppm</th>
<th>95% CL</th>
<th>Slope ± SEM</th>
<th>LC&lt;sub&gt;90&lt;/sub&gt; ppm</th>
<th>X²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delhi-A (DLH)</td>
<td>800</td>
<td>0.0019</td>
<td>0.0017-0.0021</td>
<td>0.94 ± 0.08</td>
<td>0.0076</td>
<td>13.72</td>
</tr>
<tr>
<td>Yelahanka (YLH)</td>
<td>700</td>
<td>0.0011</td>
<td>0.001-0.0012</td>
<td>1.63 ± 0.11</td>
<td>0.0024</td>
<td>5.15</td>
</tr>
<tr>
<td>Chennai-A (CHE)</td>
<td>700</td>
<td>0.0015</td>
<td>0.0014-0.0016</td>
<td>1.29 ± 0.09</td>
<td>0.004</td>
<td>4.41</td>
</tr>
<tr>
<td>Poona (PON)</td>
<td>900</td>
<td>0.0016</td>
<td>0.0015-0.0017</td>
<td>1.29 ± 0.08</td>
<td>0.004</td>
<td>16.93</td>
</tr>
<tr>
<td>Kengeri (KNG)</td>
<td>900</td>
<td>0.0008</td>
<td>0.0008-0.0007</td>
<td>3.89 ± 0.25</td>
<td>0.009</td>
<td>14.99</td>
</tr>
<tr>
<td>Aurangabad (AGB)</td>
<td>800</td>
<td>0.0015</td>
<td>0.0014-0.0016</td>
<td>2.2 ± 0.15</td>
<td>0.0027</td>
<td>18.68</td>
</tr>
<tr>
<td>Pondicherry (PDY)</td>
<td>700</td>
<td>0.0035</td>
<td>0.0033-0.0038</td>
<td>1.56 ± 0.11</td>
<td>0.008</td>
<td>40.92</td>
</tr>
<tr>
<td>Mangalore-A (MGN)</td>
<td>800</td>
<td>0.0014</td>
<td>0.0013-0.0015</td>
<td>1.51 ± 0.11</td>
<td>0.003</td>
<td>27.85</td>
</tr>
</tbody>
</table>
sensitive strains which were tested for the above
said three insecticides. It is obvious that almost
all the strains of mosquitoes reared in our
laboratory were susceptible to Fenitrothion,
Deltamethrin and Cypermethrin.

The mosquito strains used in the present study
have not shown the tendency of developing
resistance for those three insecticides. Hence all
the insecticides could be used in the control of
An. stephensi in India. All the insecticides included
in the present study are extensively used in the
mosquito control programme(s) in different
countries.

The use of Fenitrothion microcapsules as a
new residual spraying formulation for mosquito
control was also studied in Japan15. Susceptibility
status of Anopheles stephensi and two species of
Japanese encephalitis vectors (Culex pseudovishnui and Cx. tritaeniorhynchus) to
Fenitrothion has been studied in the Thar desert,
Bikaner district of Rajasthan16,17; five species of
Japanese encephalitis vectors (Cx. tritaeniorhynchus, Cx. vishnui, Cx.
pseudovishnui, Cx. gelidus and Cx. luscocephala) were studied for the same insecticide from Kolar
district of Karnataka16.

Susceptibility tests of Culex gelidus to
Fenitrothion were reported from Bangalore city of
Karnataka16. Evaluation of Fenitrothion for malaria
control has been reported from Senegal20-22. The
use of Fenitrothion for controlling mosquito vectors
in different countries has been reported23-27. Evaluation of susceptibility status of Culex
quiquefasciatus larvae to Fenitrothion was carried
out at Pune28. Susceptibility tests for adults of An.
stephensi were also reported from our
laboratory29.

In several trials, Deltamethrin has been used
in the malaria control programme as adulticide30-33. The efficacy of synthetic
pyrethroids has been evaluated elsewhere as
larvicide against various vector species based on
their susceptibility status34.

Synthetic pyrethroids control of a wide range
of insects at much lower rate than established
insecticides, being biodegradable, rapid knock-
down effect, heat stability and volatility of some of
these compounds are the advantageous
properties in mosquito cools35. Deltamethrin are
found valuable in large-scale treatments such as
A range of dosage that gives a low to complete
mortality in susceptible strains will provide the
base line with which the responses of any other
population may be compared36. In view of the
existing differences and the increasing resistance
level under varied circumstances, in vector
species, it is rather essential to undertake
susceptibility tests especially in disease prone
areas.

It is believed that the use of larvicides is an
appropriate adjunct to source reduction and offers
the advantages of killing mosquitoes in the
innocuous larval stage before the adults develop
and disperse. This also provides a quick and
relatively inexpensive method of preventing and
incipient attack by the adults1. In view of the fact
that larval tests are more sensitive than adults.

ACKNOWLEDGEMENT

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   1980: 455.


28. Ganguly SS, Dutta-Gupta KK and Dutta PK. Evaluation of susceptibility status of Culex quinquefasciatus larvae to few organophorous insecticides based on logistic regression
An epidemiologist researching infectious diseases at Atlanta’s Centers for Disease Control and Prevention recently scared Americans by announcing that yellow fever, a disease endemic to Africa, will be the next global epidemic. In the next five years, yellow fever, which is carried by mosquitoes, will reach epidemic proportions in the Americas, Asia and the South Pacific. "It will get here by plane," said the epidemiologist. Too many frequent fliers on too many international flights? No doubt, a fallout of globalisation. Increased air travel has been one of the consequences of the global market for labour, leisure and education.

Globalisation, or the metaphorical shrinking of the world, has fostered a sharing of ideas among nations and a swift exchange of scientific developments. "With this, however, are some scourges as well. One of them, as the epidemiologist’s yellow fever prophecy illustrates, is the threat of global communicable in the form of pandemics.

Take the case of dengue fever. Before 1980, dengue was not a problem in the Americas, but scientists now term it a major global threat, especially in its haemorrhagic form, affecting nearly 100 million a year. Brazil is in the throes of a roaring dengue epidemic, while Hawaii had its first such outbreak in 56 years last year.

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