Effects of indoor residual spraying using bifenthrin on *Anopheles* species composition, abundance, feeding behaviors, and susceptibility to pyrethroids in malaria ecosystems of East and South Thailand

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Research Focus

• There exist diverse malaria ecotopes to which local Anopheles vectors adapted to receptive environments and outdoor malaria transmission are related.

• Indoor residual spraying (IRS) using bifenthrin currently used for vector control as part of the National Malaria Control Program (NMCP) in Thailand is tested in order to assess its effects on species composition, abundance, feeding behaviors of Anopheles vectors, as well as susceptibility of Anopheles vectors to pyrethroids.
Malaria-associated rubber plantation (MRP) ecotope

Malaria outbreak occurring within 1.5 km² MRP ecotope at Khlong Khak, Borai, Trat

Khlong Khak malaria ecotope, East Thailand

A 1-km² malaria ecotope is covered by rain forest, the patches of rubber plantations, mixed fruit orchards, brooks, and stream.
Khlong Khak malaria ecotope, East Thailand

- IRS using bifenthrin at a concentration of 25 mg/m²
- It has potency of as long as 3-6 months
Effects of IRS using bifenthrin on *Anopheles* species composition, abundance and feeding behaviors in Khlong Khak malaria ecotope

*Figures not shown.*

Effects of IRS using bifenthrin on *Anopheles* vector abundances in Khlong Khak malaria ecotope

Susceptibility of *An. campestris* to pyrethroids

<table>
<thead>
<tr>
<th></th>
<th>Total number of samples</th>
<th>Mortality (%)</th>
<th>95% CI for observed mortality in test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Test</td>
<td>Control</td>
<td>Test</td>
</tr>
<tr>
<td><em>An. campestris</em>&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deltamethrin, 0.05%</td>
<td>140</td>
<td>32</td>
<td>87.2</td>
</tr>
<tr>
<td>Bifenthrin, 0.9%</td>
<td>88</td>
<td>30</td>
<td>95.0&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup>Population samples obtained at 3- and 6-month post IRS from the study MRP ecotope.

<sup>b</sup>Abbot’s formula applied to correct observed mortality in test.
Susceptibility of *An. dirus* to pyrethroids

<table>
<thead>
<tr>
<th></th>
<th>Total number of samples</th>
<th>Mortality (%)</th>
<th>95% CI for observed mortality in test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Test</td>
<td>Control</td>
<td>Test</td>
</tr>
<tr>
<td><strong>An. dirus</strong>&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deltamethrin, 0.05%</td>
<td>32</td>
<td>10</td>
<td>100.0</td>
</tr>
<tr>
<td>Bifenthrin, 0.9%</td>
<td>10</td>
<td>10</td>
<td>100.0</td>
</tr>
<tr>
<td><strong>An. dirus</strong>&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deltamethrin, 0.05%</td>
<td>60</td>
<td>10</td>
<td>100.0</td>
</tr>
</tbody>
</table>

NA – not applicable.

<sup>a</sup>Population samples obtained at 3- and 6-month post IRS from the study MRP ecotope.

<sup>b</sup>Population samples obtained between pre-IRS and during IRS from the study MRP ecotope as *Anopheles* sampling site II<sup>b</sup>, and additionally, other *Anopheles* sampling site of Borai district<sup>c</sup>.
Malaria ecotopes in South Thailand

Malaria ecotope B is 6.28 km southeast apart from malaria ecotope A.
Malaria ecotope B, South Thailand

A 1-km² malaria ecotope B is covered by rain forest, the patches of oil palm plantations, mixed fruit orchards, brooks, and stream.
IRS using bifenthrin

- IRS using bifenthrin at a concentration of 25 mg/m²
- It has potency of as long as 3-6 months
Effects of IRS using bifenthrin on species diversity of night biters in malaria ecotope B

<table>
<thead>
<tr>
<th>Diversity index</th>
<th>Pre-IRS</th>
<th>During IRS</th>
<th>1-month post-IRS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total no. of wild-caught mosquitoes*</td>
<td>129</td>
<td>98</td>
<td>222</td>
</tr>
<tr>
<td>Species no.</td>
<td>10</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>Shannon Index (H)</td>
<td>1.6992</td>
<td>1.3914</td>
<td>0.5337</td>
</tr>
<tr>
<td></td>
<td>(1.5727 – 1.8257)</td>
<td>(1.3657 – 1.4171)</td>
<td>(0.5278 – 0.5396)</td>
</tr>
<tr>
<td>Simpson Index (D)</td>
<td>4.2161</td>
<td>2.9994</td>
<td>1.3036</td>
</tr>
<tr>
<td>Evenness (E)</td>
<td>0.7379</td>
<td>0.6691</td>
<td>0.27426</td>
</tr>
</tbody>
</table>

Periodic assessment: Pre-IRS (June 2018), During (July 2018), and 1-month post-IRS (August 2018)

*For two consecutive nights at each time of mosquito collection
Effects of IRS using bifenthrin on *Anopheles* species composition, abundance and feeding behaviors in malaria ecotope B

*for two consecutive nights at each time of mosquito collection*
Effects of IRS using bifenthrin on *Anopheles* species composition, abundance and feeding behaviors in malaria ecotope B

Mean density of adult female *Anopheles* vectors (mosquitoes per night)

- **Primary vectors**
  - Pre-IRS
    - HLC-Indoors
    - CBT-Indoors
    - P < 0.001*
    - HLC-Outdoors
    - CBT-Outdoors
    - P < 0.001*
  - During IRS
    - HLC-Indoors
    - P < 0.001*
    - CBT-Indoors
    - P < 0.001*
    - HLC-Outdoors
    - P = 0.001*
    - CBT-Outdoors
    - P < 0.001*
  - 1-month post-IRS
    - HLC-Indoors
    - P < 0.001*
    - CBT-Indoors
    - P < 0.001*
    - HLC-Outdoors
    - P = 0.043*
    - CBT-Outdoors
    - P = 0.043*

- **Secondary/suspected vectors**
  - Pre-IRS
    - HLC-Indoors
    - CBT-Indoors
    - P < 0.001*
    - HLC-Outdoors
    - CBT-Outdoors
    - P < 0.001*
  - During IRS
    - HLC-Indoors
    - P < 0.001*
    - CBT-Indoors
    - P < 0.001*
    - HLC-Outdoors
    - P = 0.001*
    - CBT-Outdoors
    - P < 0.001*
  - 1-month post-IRS
    - HLC-Indoors
    - P < 0.001*
    - CBT-Indoors
    - P < 0.001*
    - HLC-Outdoors
    - P = 0.043*
    - CBT-Outdoors
    - P = 0.043*

*Statistically significant with Mann-Whitney *U* test for two-independent samples

Mean human landing rate (or cow biting rate) (mosquitoes per person per hour per night)

- **Primary vectors**
  - Pre-IRS
    - HLC-Indoors
    - CBT-Indoors
    - P = 0.05*
    - HLC-Outdoors
    - CBT-Outdoors
    - P = 0.022*
  - During IRS
    - HLC-Indoors
    - P = 0.007*
    - CBT-Indoors
    - P = 0.046*
    - HLC-Outdoors
    - CBT-Outdoors
    - P = 0.022*
  - 1-month post-IRS
    - HLC-Indoors
    - CBT-Indoors
    - HLC-Outdoors
    - CBT-Outdoors
    - P = 0.022*

- **Secondary/suspected vectors**
  - Pre-IRS
    - HLC-Indoors
    - CBT-Indoors
    - P = 0.022*
    - HLC-Outdoors
    - CBT-Outdoors
    - P = 0.022*
  - During IRS
    - HLC-Indoors
    - P = 0.007*
    - CBT-Indoors
    - P = 0.046*
    - HLC-Outdoors
    - CBT-Outdoors
    - P = 0.022*
  - 1-month post-IRS
    - HLC-Indoors
    - CBT-Indoors
    - HLC-Outdoors
    - CBT-Outdoors
    - P = 0.022*
Key messages

- IRS using bifenthrin has the effects on
  - Reduction of species diversity of night biters
  - Reduction of species composition and abundance, especially indoor density of primary vectors such as *An. dirus*, *An. minimus*, and *An. maculatus*
  - Changes in feeding behaviors of *Anopheles* vectors; hence avoiding feeding indoors but likely to feed outdoors
Key messages

• Susceptibility of *Anopheles* vectors to pyrethroids in treated malaria ecotope
  – Primary vectors such as *An. dirus* and *An. maculatus* are highly susceptible to 0.05% deltamethrin as well as 0.09% bifenthrin
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https://doi.org/10.1155/2018/9853409

Research Article
Adaptation of Anopheles Vectors to Anthropogenic Malaria-Associated Rubber Plantations and Indoor Residual Spraying: Establishing Population Dynamics and Insecticide Susceptibility
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