Simulated field study on the efficacy of the thermal application of a synergized pyrethroid formulation against *Aedes aegypti* (Linn.) and *Culex quinquefasciatus* Say


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**Abstract.** Thermal application of a synergized pyrethroid formulation containing 0.8% w/w s-bioallethrin, 18.7% w/w permethrin and 16.8% w/w piperonyl butoxide was performed to evaluate its efficacy against adult and larva of *Aedes aegypti* and *Culex quinquefasciatus*. Three cages each containing 15 mosquitoes and paper cups each containing 25 larvae in 250 ml of water were deployed at each test point between 3 and 20 feet. The formulation was diluted (formulation:water) 1:33, 1:50 and 1:100, respectively, and applied using a thermal fogger. Sixty minutes post spraying, the adult knock down rate of *Ae. aegypti* and *Cx. quinquefasciatus* at a maximum distance of 15 feet using all dilution ratios ranged from 96.67 – 100% and 43.33 – 100%, respectively. More than 70.00% adult mortalities were recorded for both mosquito species at the distance between 3 feet and 15 feet 24 hours post spraying. In contrast, complete larval mortalities of *Ae. aegypti* were obtained at a maximum distance of 10 feet with dilution ratio of 1:33, while more than 80.00% larval mortalities were observed for *Cx. quinquefasciatus* at similar maximum distance using all dilution ratios. These results showed that thermal application using synergized pyrethroid formulation was effective against both mosquito species tested especially the adult stage.

Among various vector control approaches, chemical control involving the use of adulticides and larvicides appears to be the norm for public health. Adulticides are applied by either space spraying which affects flying mosquitoes or surface residual spraying that aims for resting mosquitoes. Space spraying is performed when source reduction failed to control mosquito populations or during dengue outbreak (Marcombe et al., 2009; Koou et al., 2014a). As such, fogging activities have been conducted in Malaysia during dengue outbreaks since 1970s (Yap et al., 1994).

Space spraying of adulticides can be performed both indoors and outdoors using either cold fogger or thermal fogger. Thermal foggers use heat to vaporize the oil-based or water-based adulticide solutions before being expelled as a dense smoke. Cold foggers such as ultra-low-volume (ULV) and mist blower need high air pressure to break up the
adulticides into minute droplet particles and sprayed out through fine nozzles (Yap et al., 2000).

Malathion, an oil-based organo-phosphorous formulation has been used in both thermal fogging and ultra low volume (ULV) since 1960s (Yap, 1998). However, due to its unfavourable odour, it has slowly being replaced with water-based pyrethroid formulations (Teng & Singh, 2001). Application of pyrethroids in space spraying becomes more popular nowadays as they are odourless, exhibit fast knock down and require only low dosage (Yusin & Vythilingam, 2004). In fact, previous studies have demonstrated that pyrethroids pose very minimal health risks to people (Zaim et al., 2000). Furthermore, the use of synergists including piperonyl butoxide (PBO) in combination with pyrethroids will enhance the effectiveness of these insecticides in controlling mosquito vectors (Koou et al., 2014b). This study was conducted to evaluate the efficacy of thermal application of a synergized pyrethroid formulation containing 0.8% w/w s-bioallethrin, 18.7% w/w permethrin and 16.8% w/w piperonyl butoxide against adult and larva of Aedes aegypti and Culex quinquefasciatus.

The test site was in the vicinity of Institute for Medical Research (IMR), Kuala Lumpur. An area of 184 m² was chosen for the trial due to its proximity and convenience. A thermal fogger (Agrofog® AF35) with a discharge rate of 400 ml/min was used in all tests performed. A formulation of synergized pyrethroid (Mos-Spray®) containing s-bioallethrin (0.8% w/w), permethrin (18.7% w/w) and piperonyl butoxide (16.8% w/w) was tested. The formulation was diluted in water to a ratio of 1:33, 1:50 and 1:100 and applied at an equivalent rate of 1000 ml/ha. The thermal fogging was carried out in the evening after sunset. The weather was fair during the course of application and the wind velocity was <1.0 m/s. Three cages were placed on each point at the distances of 3 feet, 5 feet, 10 feet, 15 feet and 20 feet, respectively. The flow rate was adjusted to affect the output required. The direction of walking was parallel to all points during the course of application.

Caged laboratory-bred and sugar-fed 5-day-old Ae. aegypti (F1010) and Cx. quinquefasciatus (F750) adult females were used to evaluate both adulticidal and larvicidal effects of space spraying. At the test site, 3 cages each containing 15 mosquitoes were placed on each point respectively according to the distances required. One cage each of the mosquito species was kept in the laboratory as control. Paper cups each containing 250 ml of water and 25 larvae of each species were placed near every pole. After the fogging, the knock down rates of adult mosquitoes were recorded every 10 minutes until 60 minutes. After 60 minutes, all the cages and paper cups were collected and brought back to the laboratory. Mosquitoes were transferred into clean paper cups provided with a cotton pad soaked with 10% sugar solution. The mortality of the mosquitoes was recorded after a 24 hours holding period. The larval mortality was also recorded after continuous exposure for 24 hours.

Table 1 illustrates the adulticidal activity of synergized pyrethroid against Ae. aegypti and Cx. quinquefasciatus using the thermal fogger after 60 minutes post spraying. In the trial sprayed with all three different dilution ratios, 96.67 – 100% knock down of Ae. aegypti were recorded at 3, 5, 10 and 15 feet. Meanwhile, for Cx. quinquefasciatus, complete knock down was observed at all points until 15 feet with the dilution ratio of 1:33. At the dilution ratio of 1:50, 100% knock down was achieved at up to 10 feet of distance. Complete knock down was demonstrated only at a maximum of 3 feet of distance when synergized pyrethroid was diluted at the ratio of 1:100.

Figure 1 shows the percentage mortality of adult Ae. aegypti and Cx. quinquefasciatus 24 hours post spraying of synergized pyrethroid using the thermal fogger. For Ae. aegypti adult mosquitoes, high percentage of mortalities which ranged between 96.67% and 100% were observed for all dilution ratios at the maximum distance of 15 feet. However, not more than 50% mortality was recorded at 20 feet using all dilution ratios. Meanwhile, for Cx. quinquefasciatus adult mosquitoes,
Table 1. Adulticidal activity of synergized pyrethroid against *Ae. aegypti* and *Cx. quinquefasciatus* 60 minutes post spraying of thermal fogging

<table>
<thead>
<tr>
<th>Distance</th>
<th>3 ft</th>
<th>5 ft</th>
<th>10 ft</th>
<th>15 ft</th>
<th>20 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dilution of synergized pyrethroid</td>
<td>1:33</td>
<td>1:50</td>
<td>1:100</td>
<td>1:33</td>
<td>1:50</td>
</tr>
<tr>
<td>0</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
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</tr>
<tr>
<td>10</td>
<td>100.00±0.00</td>
<td>100.00±0.00</td>
<td>70.00±15.28</td>
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<td>20</td>
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</table>

**Knockdown rate of adult *Ae. aegypti* (percentage, %)**

**Knockdown rate of adult *Cx. quinquefasciatus* (percentage, %)**
70 – 100% mortalities were observed until 15 feet of distance using all dilution ratios.

Figure 2 shows the larvicidal effect of synergized pyrethroid against larvae of *Ae. aegypti* and *Cx. quinquefasciatus* after 24 hours of continuous exposure. For *Ae. aegypti* larvae, complete mortality was achieved only with the dilution ratio of 1:33 at a maximum distance of 10 feet. Furthermore, percentage mortalities ranged from 0% to 61.33% at all distance points when the dilution ratio of 1:50 and 1:100 were applied. In contrast, for *Cx. quinquefasciatus* larvae, percentage mortalities of more than 50.00% were recorded at all distance points until 20 feet. Complete mortalities of *Cx. quinquefasciatus* larvae were observed at 3 and 5 feet with dilution ratios of 1:33 and 1:50.

No mortality was observed in the control for both adult and larval stages during the course of the trial.

For adulticidal activity, thermal fogging of synergized pyrethroid with dilution ratio of 1:33 was the most effective in producing complete mortalities of both *Ae. aegypti* and *Cx. quinquefasciatus* at a maximum distance of 15 feet, whereas, at larval stage, thermal fogging of synergized pyrethroid was able to produce complete mortalities in both mosquito species only when the dilution ratio of 1:33 was used with a maximum distance of 10 feet for *Ae. aegypti* larvae and 15 feet for *Cx. quinquefasciatus* larvae. These findings showed that thermal fogging of synergized pyrethroid was more effective against *Ae. aegypti* adults than *Cx. quinquefasciatus* adults but the phenomenon was inconsistent at larval stage. Moreover, these results also illustrated that thermal fogging of synergized pyrethroid killed both adult and larval stages of both mosquito species but it was more effective against adult mosquitoes compared to larvae.

Pyrethroids are widely applied in the mosquito control using different approaches including thermal fogging (Kasai et al., 2014). Studies by Karunaratne et al. (2013) indicated that pyrethroids are more effective for space spraying compared to malathion. In fact, it has been found that pyrethroid formulation
sprayed as adulticide using both thermal and cold foggers was more effective when it was diluted in water than in oil (Harburguer et al., 2012a).

Several studies on the use of diverse types of pyrethroids in thermal fogging had been conducted locally. Back in 1990, Lim and Visvalingam found that a commercial pyrethroid formulation; lambdacyhalothrin applied using thermal fogger demonstrated high adulticidal activity against *Aedes aegypti*. Furthermore, Yap et al. (1997) reported that the use of pyrethroids in combination with *Bacillus thuringiensis israelensis* (Bti) showed high mortalities in both larval and adult stages of *Ae. aegypti*, *Ae. albopictus* and *Culex quinquefasciatus*. Later, in 2001, Yap et al. again illustrated through their studies that thermal fogging application of a pyrethroid formulation containing similar active ingredients with synergized pyrethroid was effective as a larvicide and adulticide against *Aedes aegypti, Aedes albopictus, Anopheles sinensis* and *Culex quinquefasciatus* indoors.

Thermal fogging using pyrethroid formulations had also been carried out in other countries. In India, Mani et al. (2005) found that indoor thermal fogging using Deltacide™ (s-bioallethrin 0.71% w/v, deltamethrin 0.5% w/v and piperonyl butoxide 8.9% w/v) showed high adulticidal effect in *Ae. aegypti* adults. In 2009, Marcombe et al. reported that pyrethrins applied by thermal fogger in Martinique caused a high knock down effect in caged *Aedes aegypti* adults. In 2009, Marcombe et al. reported that pyrethrins applied by thermal fogger in Martinique caused a high knock down effect in caged *Aedes aegypti* adults. In 2009, Marcombe et al. reported that pyrethrins applied by thermal fogger in Martinique caused a high knock down effect in caged *Aedes aegypti* adults. In 2009, Marcombe et al. reported that pyrethrins applied by thermal fogger in Martinique caused a high knock down effect in caged *Aedes aegypti* adults. In 2009, Marcombe et al. reported that pyrethrins applied by thermal fogger in Martinique caused a high knock down effect in caged *Aedes aegypti* adults. In 2009, Marcombe et al. reported that pyrethrins applied by thermal fogger in Martinique caused a high knock down effect in caged *Aedes aegypti* adults. In 2009, Marcombe et al. reported that pyrethrins applied by thermal fogger in Martinique caused a high knock down effect in caged *Aedes aegypti* adults. In 2009, Marcombe et al. reported that pyrethrins applied by thermal fogger in Martinique caused a high knock down effect in caged *Aedes aegypti* adults. In 2009, Marcombe et al. reported that pyrethrins applied by thermal fogger in Martinique caused a high knock down effect in caged *Aedes aegypti* adults. In 2009, Marcombe et al. reported that pyrethrins applied by thermal fogger in Martinique caused a high knock down effect in caged *Aedes aegypti* adults. In 2009, Marcombe et al. reported that pyrethrins applied by thermal fogger in Martinique caused a high knock down effect in caged *Aedes aegypti* adults. In 2009, Marcombe et al. reported that pyrethrins applied by thermal fogger in Martinique caused a high knock down effect in caged *Aedes aegypti* adults. In 2009, Marcombe et al. reported that pyrethrins applied by thermal fogger in Martinique caused a high knock down effect in caged *Aedes aegypti* adults. In 2009, Marcombe et al. reported that pyrethrins applied by thermal fogger in Martinique caused a high knock down effect in caged *Aedes aegypti* adults.

In addition, another previous findings by Harburguer et al. (2012b) from Argentina showed that 90% mortality was achieved in caged *Ae. aegypti* adults sprayed with pyrethroids at distances of 3 m and 6 m. Not
only that, a water-based formulation of permethrin 30% and piperonyl butoxide 30% applied by a thermal fogger also showed 99% mortality in caged *Aedes albopictus* (Alimi *et al.*, 2013).

According to Karunaratne *et al.* (2013), both adulticiding by space spraying and larviciding activities are the main control measures in controlling mosquitoes especially during outbreaks. Variety of space spraying methods using numerous types of insecticides demonstrated different efficacy level in the control of each mosquito species. Therefore, it is suggested that more in depth studies on the efficacy of insecticides including pyrethroids used in different space spraying methods to be performed continuously to determine the best method of space spraying for each insecticide and mosquito species.

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**REFERENCES**


