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Enhanced mortality in deltamethrin-resistant *Aedes aegypti* in Thailand using a piperonyl butoxide synergist

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ABSTRACT

Aedes aegypti is the primary vector of dengue viruses in Thailand. Control of this mosquito continues to rely heavily on use of insecticides in various forms and applications. The synergistic effect of piperonyl butoxide (PBO), combined with deltamethrin against eight populations of *Ae. aegypti* collected from different regions in Thailand is presented. The standard WHO adult contact bioassays found all populations with low to moderate levels of resistance to deltamethrin alone (using a 0.05% discriminating concentration), with final mortalities ranging from 15.6 to 70%, while a laboratory strain was fully susceptible (100% mortality). Pre-exposure of female mosquitoes to 4% PBO for 1 h, followed immediately by exposure to deltamethrin for 1 h, significantly increased mortality in seven populations (64.8–98.1%) with the exception of mosquitoes derived from Lampang Province. The knockdown time (KDT) synergist ratios between deltamethrin only and PBO + deltamethrin ranged from 1.7 to 2.8 for KDT_{50} and 1.9 to 4.0 for KDT_{95}. Between deltamethrin alone and mosquitoes exposed to PBO + deltamethrin, all resistant populations produced significant differences ($P < 0.05$) in final 24-h mortality, except marginally for Lampang ($P = 0.053$). The synergistic effects of PBO with deltamethrin-resistant *Ae. aegypti* suggest a combination of this synergist with deltamethrin or other pyrethroid compounds can significantly enhance the effectiveness of these insecticides against pyrethroid-resistant *Ae. aegypti* found commonly in Thailand.

1. Introduction

Globally, *Aedes* (*Stegomyia*) *aegypti* (L.) is the primary mosquito vector of dengue and other viruses (yellow fever, chikungunya and Zika) (Gubler, 2002; Bhatt et al., 2013; Higgs and Vanlandingham, 2015; Paixão et al., 2016; Vongpunsawad et al., 2017). Vector control remains the mainstay for transmission control and prevention of *Aedes*-borne pathogen outbreaks. The development of widespread resistance by *Aedes* vectors (including *Aedes albopictus* Skuse) to insecticides used to control adult and immature stages has raised alarm for prevention programs (Hemingway, 2014; Smith et al., 2016). The primary response in Thailand to these findings has been to increase monitoring to better define the distribution and level of insecticide resistance in the country. This would target locations in immediate need of assistance and formulate more comprehensive resistance management recommendations and strategies in the longer term. The second initiative has been to explore and test alternative classes of active ingredients with differing modes of action or to enhance existing insecticides with synergist additives to combat vector populations that show diminishing control responses.

Synthetic pyrethroid insecticides are the most widely used chemical class of insecticidal compounds for controlling insect pests in agriculture and public health vector-borne disease transmission in Thailand (Chareonviriyaphap et al., 2013). Compared to other chemical classes, pyrethroids are relatively inexpensive, have relativevly lower degree of toxicity (mg/kg) to humans and other mammals, and a lower level of persistence in the environment. Deltamethrin is a synthetic pyrethroid that is still commonly used in Thailand to control dengue mosquito

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