

## The effects of plant essential oils on escape response and mortality rate of *Aedes aegypti* and *Anopheles minimus*

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**ABSTRACT:** The High Throughput Screening System (HITSS) has been applied in insecticide behavioral response studies with various mosquito species. In general, chemical or natural compounds can produce a range of insect responses: contact irritancy, spatial repellency, knock-down, and toxicity. This study characterized these actions in essential oils derived from citronella, hairy basil, catnip, and vetiver in comparison to DEET and picaridin against *Aedes aegypti* and *Anopheles minimus* mosquito populations. Results indicated the two mosquito species exhibited significantly different ( $P < 0.05$ ) contact irritant escape responses between treatment and control for all tested compound concentrations, except with the minimum dose of picaridin ( $P > 0.05$ ) against *Ae. aegypti*. Spatial repellency responses were elicited in both mosquito species when exposed to all compounds, but the strength of the repellent response was dependent on compound and concentration. Data show that higher test concentrations had greatest toxic effects on both mosquito populations, but vetiver had no toxic effect on *Ae. aegypti* and picaridin did not elicit toxicity in either *Ae. aegypti* or *An. minimus* at any test concentration. Ultimately, this study demonstrates the ability of the HITSS assay to guide selection of effective plant essential oils for repelling, irritating, and killing mosquitoes. *Journal of Vector Ecology* 40 (2): 318-326. 2015.

**Keyword Index:** *Aedes aegypti*, *Anopheles minimus*, contact irritant, spatial repellent, toxic.

### INTRODUCTION

Repellents have been used as personal protection against mosquitoes for decades. DEET (*N,N*-diethyl-3-methylbenzamide) was developed by the U.S. Army in 1946 and marketed for public use in 1957. DEET is still considered the most effective and common ingredient in insect topical repellent products but reported side effects including rash, skin irritation, blisters, and eye irritation have occurred (Miller 1982, Amichai et al. 1994, Patel et al. 2012). Picaridin, 2-(2-hydroxyethyl)-1-piperidinecarboxylic acid 1-methylpropylester, also known as KBR3023, was developed by Bayer AG in 1980 as a DEET alternative. Picaridin was found to be as effective as DEET at repelling mosquitoes (Yap et al. 1998). This compound is considered less irritating to skin and does not damage plastics or fabrics like DEET. In 2000, the World Health Organization (WHO) recommended picaridin as a topical repellent for malaria prevention and the Environmental Protection Agency found no toxic effects using animal testing (Katz et al. 2008). In previous studies, Barnard et al. (2002) reported the repellent effect of four synthetic repellents, DEET, picaridin, p-menthane 3,8-diol (PMD), and IR3535 and determined picaridin displayed the highest repellency effect against the black salt marsh mosquito, *Aedes taeniorhynchus*. Furthermore, Frances et al. (2004) revealed that picaridin had similar repellent properties as DEET against *Anopheles* spp.

Plant-derived essential oils are considered non-toxic, alternative insect repellents for humans (Barnard 1999, Trongtokit et al. 2005, Misni et al. 2009). Efficacious,

naturally derived mosquito repellents offer the potential to elicit less offensive side effects to consumers when used properly. Citronella is the most common ingredient used in plant-based mosquito repellents. Phasomkusolsil and Soonwera (2010) reported that citronella had repellent activity against *An. minimus*, *Culex quinquefasciatus*, and *Ae. aegypti* when applied on human skin. Moreover, Bernier et al. (2005) revealed catnip was a good spatial repellent against *Ae. aegypti*, *An. albimanus*, and *An. quadrimaculatus*. Various plant essential oils have been proven to be effective against many mosquito species (Tawatsin et al. 2001, Zhu et al. 2006, Phasomkusolsil and Soonwera 2010). Essential oils obtained from plants can potentially play an important role in repelling vector mosquitoes, therefore potentially reducing pathogen transmission. However, a full characterization of the chemical actions of either synthetic or natural products being considered for use as mosquito repellents must be conducted to select an optimal candidate for product development.

This study used the HITSS assay to investigate contact irritancy, spatial repellency, knock-down, and toxicity responses of *Ae. aegypti* and *An. minimus*, the main dengue fever and malaria vectors in Thailand, respectively, against citronella, hairy basil, catnip, and vetiver oils in comparison with the standard topical repellent DEET.

### MATERIALS AND METHODS

#### Mosquitoes

Susceptible laboratory colonies of *Ae. aegypti* (USDA strain) and *An. minimus* were used for this study. *Aedes*