



## Vector Control, Pest Management, Resistance, Repellents

# Enhanced Excito-Repellency of Binary Mixtures of Plant-Based Mosquito Repellents Against *Culex quinquefasciatus* Say (Diptera: Culicidae), a Night Biting Mosquito Species

Wasana Boonyuan,<sup>1</sup> Alex Ahebwa,<sup>1</sup> Jiroad Nararak,<sup>1</sup> Sunaiyana Sathantriphop,<sup>2</sup> and Theeraphap Chareonviriyaphap<sup>1,3,✉</sup>

<sup>1</sup>Department of Entomology, Faculty of Agriculture, Kasetsart University, Bangkok 10900, Thailand, <sup>2</sup>National Institute of Health, Department of Medical Sciences, Ministry of Public Health, Nonthaburi 11000, Thailand, and <sup>3</sup>Corresponding author, e-mail: [faasthc@ku.ac.th](mailto:faasthc@ku.ac.th)

Subject Editor: Patricia Scaraffia

Received 21 July 2021; Editorial decision 29 December 2021

### Abstract

Efficacies of essential oils (EOs) of *Vetiveria zizanioides* (L.) Nash. (Poales: Poaceae) (VZ EO), *Cananga odorata* (Lam) Hook. f. & Thomson (Magnoliales: Annonaceae) (CO EO), and crude extract (CE) of *Andrographis paniculata* (Burm.f) Wall ex. Nees (Lamiales: Acanthaceae) (AP CE), against laboratory (lab) and field strains of *Culex quinquefasciatus* Say were investigated. Irritant and repellent activities of individual and binary mixtures of plant extracts were compared with *N,N*-diethyl-*m*-toluamide (DEET) using an excito-repellency system. The irritant activity (direct tarsal contact), the mean percent escape response of VZ EO (91.67%, 83.33%), and CO EO (80%, 88.33%) were not significantly different compared with DEET (88.33%, 95%) against lab and field strains, respectively. Similarly, irritant responses in combinations (1:1 and 1:2, v:v) of either VZ EO or CO EO with AP CE were not significantly different from DEET against both strains ( $P > 0.001$ ). The repellent activity (no tarsal contact), the mean percent escape response of VZ EO (68.33%), CO EO (61.67%), and VZ EO+AP CE (1:1, v:v) (81.67%) against lab strain and CO EO (85%) against field strain were not significantly different from that of DEET ( $P > 0.001$ ). Interestingly, the greatest contact irritancy of VZ EO+AP CE (1:1, v:v) (96.67%) ( $P = 0.0026$ ) and a stronger repellency response of CO EO (85%) ( $P = 0.0055$ ) produced significantly different patterns of escape response compared with DEET against both lab and field strains, respectively. The EOs of VZ EO and CO EO or their mixture with AP CE showed potential as plant-based active ingredients for mosquito repellents. In addition, the major chemical constituents of VZ EO were  $\beta$ -vetivone (6.4%), khusimol (2.96%), and  $\alpha$ -vetivone (2.94%) by gas chromatography–mass spectrometry.

**Key words:** *Vetiveria zizanioides*, *Cananga odorata*, *Andrographis paniculata*, DEET, Excito-Repellency

*Culex quinquefasciatus* Say is the vector of lymphatic filariasis (LF) commonly known as elephantiasis (Sudomo et al. 2010). LF contributes significantly to infectious disease morbidity and associated socioeconomic impacts in the tropic and subtropic countries (Ramaiah et al. 2000, Wynd et al. 2007, WHO 2012). The prevention of mosquito-borne diseases has been achieved through use of tools such as insecticide-treated nets, long-lasting insecticidal nets, insecticide-treated curtains and wall linings, indoor residual spraying, as well as use of topical and spatial repellents (WHO 2013,

Norris et al. 2017). Mosquito repellents currently on the market are mostly synthetic chemicals integrated with DEET (*N,N*-diethyl-3-methylbenzamide) as the active ingredient (Brown and Hebert 1997, Fradin and Day 2002, Katz et al. 2008). Reports have shown that DEET can potentially cause health risks to humans, especially when misapplied at very high concentrations and prolonged usage (Robbins and Cherniack 1986, Qiu et al. 1998). DEET works by modulating olfactory neurons of insects and has been demonstrated to affect all antennae and maxillary palps of *Cx. quinquefasciatus*