

EXCITO-REPELLENCY OF DELTAMETHRIN ON THE MALARIA VECTORS, *ANOPHELES MINIMUS*, *ANOPHELES DIRUS*, *ANOPHELES SWADIWONGPORNI*, AND *ANOPHELES MACULATUS*, IN THAILAND

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ABSTRACT. This study compared the behavioral avoidance responses of 4 mosquito malaria vectors, *Anopheles minimus*, *Anopheles dirus*, *Anopheles maculatus* form B, and *Anopheles swadiwongporni*, to deltamethrin, the primary insecticide used for indoor residual spraying for malaria vector control in Thailand. Six test populations, representing 4 laboratory colonies and 2 wild-caught populations, were observed during and after exposure to deltamethrin at the operational dose (0.02 g active ingredient/m²) in excito-repellency escape chambers. The laboratory colonies included a deltamethrin-susceptible colony and a deltamethrin-resistant colony of *An. minimus* species A, 1 colony of *An. dirus* species B, and 1 colony of *An. maculatus* form B. The 2 wild-caught populations included *An. swadiwongporni* and members of the *An. dirus* complex. Times to escape by female mosquitoes during 30 min of exposure to deltamethrin-treated papers were observed in all populations and compared to nontreated paired controls in contact and noncontact test configurations. Strong behavioral avoidance was observed in the deltamethrin-resistant colony of *An. minimus*, followed by *An. swadiwongporni* and *An. maculatus*. The slowest escape response was observed in the colony of *An. dirus* species B. All 6 populations of *Anopheles* showed marked contact irritancy to deltamethrin compared to paired controls and noncontact repellency trials, in both controlled laboratory colonies and field-caught populations. The degree of repellency was less profound than irritancy but, in most cases, produced a significant escape response compared to paired controls. Avoidance behavior appears to be an innate behavior of mosquitoes, as indicated by the general avoidance response detected in all 4 species, regardless of deltamethrin susceptibility status, age, or nutritional and physiological status. Excito-repellency assays of the type described in this study should become an integral part of the overall assessment of an insecticide's ability to control disease transmission in any given area.

KEY WORDS Behavioral avoidance, irritancy, repellency, deltamethrin, *Anopheles minimus*, *Anopheles maculatus*, *Anopheles dirus*, *Anopheles swadiwongporni*, Thailand

INTRODUCTION

In Thailand, malaria remains a major and re-emerging health problem (Chareonviriyaphap et al. 2001). The primary vectors in Thailand include *Anopheles dirus* Peyton and Harrison, *Anopheles minimus* Theobald, *Anopheles maculatus* Theobald, and *Anopheles swadiwongporni* Rattanarithikul and Green, all members of the subgenus *Cellia*. Each species represents a member in broader species complexes, including *An. dirus*, *An. minimus*, and *An. maculatus* (which contains *An. swadiwongporni*), respectively (Rattanarithikul and Green 1986, Subbarao 1998). Many members within these species complexes exhibit both endophagous and exophagous behavioral patterns conducive for efficient malaria transmission (Pinichpongse and Bullner 1967, Suwonkerd et al. 1990, Chareonviriyaphap et al. 2000). *Anopheles dirus* and *An. minimus* are members representing individual species complexes, of which the respective sibling species often are not distinguishable morphologically from one another (Baimai 1989, Rattanarithikul and Panthusiri 1994). *Anopheles maculatus* and *An. swa-*

diwongporni are morphologically distinct members in the *An. maculatus* group (Rattanarithikul and Green 1986). One of the principal methods of malaria abatement in Thailand has been use of various methods of vector control to reduce transmission risk. For many years, DDT was the chemical of choice and was used extensively in malaria-endemic areas. Because of reported adverse impact on the environment and general negative public attitudes, DDT use was gradually phased out between 1995 and 2000 for the control of malaria vectors in Thailand (Chareonviriyaphap et al. 1999).

Deltamethrin, a common synthetic pyrethroid, is frequently and widely used for indoor residual spraying of house surfaces to control anopheline mosquitoes (Patipong 2000). This compound generally is applied in 1 or 2 spray rounds per year in malaria-endemic areas of Thailand (Ministry of Public Health 2000). The true mode of action of deltamethrin on the control of vectors and malaria is still open to investigation in terms of the relative importance of the lethal properties and behavioral responses of vector populations (Roberts et al. 2000). Because most pyrethroids demonstrate a significant and immediate excito-repellency action on exposed mosquitoes, the proposed wide-scale use of deltamethrin for malaria control in Thailand has stimulated the need for well-designed studies on the significance of pyrethroid avoidance behavior and its overall efficacy in reducing human-vector contact. Moreover, the respective roles of irritability and repellency of deltamethrin against the impor-

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