Journal of the American Mosquito Control Association, 17(3):190–195, 2001

LABORATORY AND FIELD EVALUATIONS OF THE INSECT REPELLENT 3535 (ETHYL BUTYLACETYLAMINOPROPIONATE) AND DEET AGAINST MOSQUITO VECTORS IN THAILAND

USAVADEE THAVARA,[1] APIWAT TAWATSIN,[1] JAKKRAWARN CHOMPOOSRI,[1] WANNAPA SUWONKERD,[2] U-RUYAKRON CHANSANG[1] AND PREECHA ASAVADACHANUKORN[3]

ABSTRACT. The insect repellents 3535 (ethyl butylacetylaminopropionate or IR3535) and deet (*N,N*-diethyl-3-methylbenzamide) were prepared as 20% solutions in absolute ethanol and evaluated for repellency against many mosquito species in Thailand under laboratory and field conditions using human subjects. In the laboratory, 0.1 ml was applied per 30-cm^2 of exposed area on a volunteer's forearm (0.66–0.67 mg active ingredient [AI]/cm^2), whereas in the field, volunteers' legs (from knee to ankle, with a surface area of about 712–782 cm^2) were treated with 3 ml per exposed area (0.76–0.84 mg AI/cm^2). In the laboratory, both IR3535 and deet showed equal repellency ($P > 0.05$) for 9.8 and 9.7 h against *Aedes aegypti,* for 13.7 and 12.7 h against *Culex quinquefasciatus,* and for 14.8 and 14.5 h against *Cx. tritaeniorhynchus,* respectively. *Anopheles dirus* was significantly less sensitive to IR3535 than to deet ($P < 0.05$), with a mean protection time of 3.8 and 5.8 h, respectively. Under field conditions, both IR3535 and deet provided a high degree of protection against various mosquito vectors ranging from 94 to 100% during the test periods. Both repellents provided a high level of protection for at least 8 h against *Ae. albopictus* and for at least 5 h against *Cx. gelidus, Cx. tritaeniorhynchus, Cx. quinquefasciatus, Mansonia dives, Ma. uniformis, Ma. annulata, Ma. annulifera, Anopheles minimus,* and *An. maculatus.* This study clearly documents the potential of IR3535 for use as a topical treatment against a wide range of mosquito species belonging to several genera.

KEY WORDS Repellents, IR3535, deet, mosquitoes, Thailand

INTRODUCTION

Mosquito-borne diseases, such as malaria, filariasis, dengue fever, dengue hemorrhagic fever, yellow fever, and encephalitis are still some of the major public health problems for people in tropical countries (Service 1993). Up to the present time, no effective vaccine has been available for protection from these diseases, except yellow fever and Japanese encephalitis. Therefore, protection from mosquito bites is 1 of the best strategies to prevent these diseases or reduce their incidence. Since the late 1950s, deet (*N,N*-diethyl-3-methylbenzamide) has been 1 of the most commonly used repellents against a broad range of mosquitoes and other biting insects (Smith 1957, Thavara et al. 1990, Coleman et al. 1993). However, several workers have reported occasional risks resulting from the topical use of deet. Contact urticaria syndrome due to application of deet was reported by Maibach and Johnson (1975). Zadikoff (1979) reported 2 cases and Edwards and Johnson (1987) reported 1 case of toxic encephalopathy in children. Reuveni and Yagupsky (1982) reported skin eruptions in 10 soldiers after application of 50% deet. Recently, Qiu et al. (1998) reviewed the pharmacokinetics, formulations, and safety of deet, and concluded that deet exhibits a good margin of safety, but does manifest some adverse effects in humans. To find safer and more acceptable repellents for topical use, many workers have searched for other chemicals providing repellency equal to or better than that obtained from deet (Schreck and McGovern 1989, Coleman et al. 1993, Frances et al. 1996, Walker et al. 1996, Yap et al. 1998, Debboun et al. 1999). Insect repellent 3535 (ethyl butylacetylaminopropionate or IR3535) is considered to have a high margin of safety to humans, including infants, and lack of toxic effects when recommended usage is followed (U.S. EPA 1999).

This study was designed to evaluate the repellency of IR3535 against mosquito vectors under both laboratory and field conditions. In the laboratory, the tests were conducted against 4 mosquito species. Field evaluations were carried out in 5 provinces of Thailand to cover a broad range of mosquito vectors. The most commonly used repellent, deet, was used as the standard against which the efficacy of IR3535 was evaluated.

MATERIALS AND METHODS

Test materials: Two repellents, IR3535 (purity 99.8%; provided by Merck KgaA, Darmstadt, Germany) and deet (purity 99.3%; purchased on the market), were evaluated. The repellents were prepared as 20% (w/w) solutions in absolute ethanol.

Test mosquitoes in the laboratory: The mosquitoes used in this study were laboratory-reared fe-

[1] National Institute of Health, Department of Medical Sciences, Ministry of Public Health, 88/7 Tiwanon Road, Nonthaburi 11000, Thailand.

[2] Office of Vector-borne Disease Control No. 2, Department of Communicable Disease Control, 18 Boonruangrit Road, Chiang Mai 50200, Thailand.

[3] Department of Statistics, Faculty of Commerce and Accountancy, Chulalongkorn University, Phayathai Road, Pathumwan, Bangkok 10330, Thailand.

male *Aedes aegypti* (L.), *Culex quinquefasciatus* Say, *Culex tritaeniorhynchus* Giles, and *Anopheles dirus* Peyton and Harrison. These mosquitoes were reared according to the standard protocol of the Biology and Ecology Section, National Institute of Health, Ministry of Public Health, Thailand, and maintained in the insectary of the institute. Sugar-fed, 3- to 5-day-old females of these mosquitoes were used in laboratory repellent tests. Before testing, the mosquitoes were starved for 24 h. The tests against *Ae. aegypti* were carried out from 0600 to 1800 h, whereas those against *Cx. quinquefasciatus, Cx. tritaeniorhynchus,* and *An. dirus* were conducted between 1800 and 0600 h. However, because our preliminary study found that both repellents could protect against biting of *Cx. quinquefasciatus* and *Cx. tritaeniorhynchus* for more than 12 h, the treatments were then applied at 1400 h, 4 h before the beginning of each test against the 2 species.

Laboratory repellent test procedure: The tests were conducted at the National Institute of Health, Thailand, in a room maintained at 27 ± 2°C and relative humidity 70 ± 10%. The light intensity was regulated at 300–500 lux for the testing of day-biting mosquitoes and at about 10–50 lux for the night biters. The evaluation method used was similar to that described by Tawatsin et al. (2001). For testing, 0.1 ml of the 20% solution of IR3535 (0.67 mg active ingredient [AI]/cm^2) was applied onto a 3 × 10-cm marked area of 1 forearm of each of 3 human volunteers (25–37 years old) and a similar dose of deet (0.66 mg AI/cm^2) was applied to the other forearm. Each arm was covered by a paper sleeve with a 3 × 10-cm exposed area corresponding to the marked and treated site. After treatment, every 30 min, each volunteer put the arm into a mosquito cage (30 × 30 × 30 cm) containing 250 female mosquitoes and left the arm there for 3 min. Before the start of each exposure period, mosquitoes were tested for their readiness to bite by placing an untreated bare hand of each volunteer into a test mosquito cage for up to 15 sec for *Ae. aegypti,* and for up to 30 sec for *Cx. quinquefasciatus, Cx. tritaeniorhynchus,* and *An. dirus.* The mosquitoes were blown from the hand before any blood was taken. If at least 2 mosquitoes landed or bit (generally many more mosquitoes bit during this period) the hand, the repellency test was carried out, otherwise the test was not conducted. For the actual test, the number of biting mosquitoes on the marked area was recorded at each interval until either 2 bites occurred in a single 3-min exposure period, or 1 bite occurred in each of 2 consecutive exposure periods. At this point the test was terminated. The duration between the application of repellent and the first 2 bites or 2 bites in successive observations was recorded as the protection time.

Field test sites: The field evaluations were carried out in various areas of Thailand during both day and night to include a wide range of mosquito species. First, Surat Thani, a province in southern Thailand, was selected to conduct the tests against day-biting mosquitoes. *Aedes albopictus* (Skuse) was the dominant daytime biter here. Several provinces in other regions of Thailand (Mae Hong Son, Nonthaburi, Nakhon Si Thammarat, Surat Thani, and Satun) were chosen to run the tests against night-biting mosquitoes. Test sites are shown in Fig. 1.

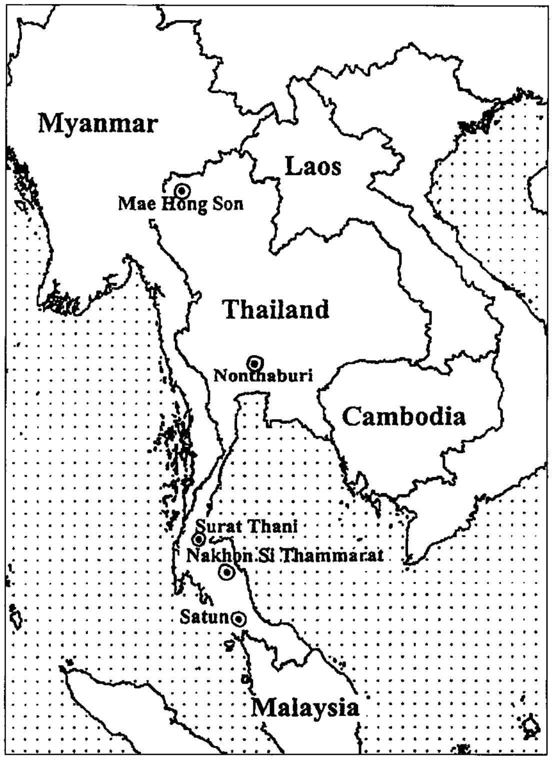

Fig. 1. Map of Thailand showing the study sites.

Field evaluation procedure: The human-bait method was used to evaluate the efficacy of the test repellents (WHO 1996). In the treated group of 6 adult volunteers (18–42 years old), each person was treated with IR3535 on 1 leg and deet on the other leg. The volunteers rolled their pants up to their knees. These 2 repellents were directly applied to lower part of their legs, from the knee to the ankle. Three milliliters of the 20% repellent solutions were applied to each leg (surface area of about 712–782 cm^2), providing dosages of about 0.77–0.84 mg AI/cm^2 for IR3535 and 0.76–0.84 mg AI/cm^2 for deet. Nothing was applied to the legs of 6 other adult volunteers (18–42 years old) assigned as controls. Assessments of the efficacy of the tests were conducted by comparisons between control (untreated) and treated volunteers. The volunteers were seated in pairs, each pair consisting of 1 control and 1 treated volunteer sitting about 1 m apart from each other. The pairs were located at least 5 m away from any other pair. The tests were run in

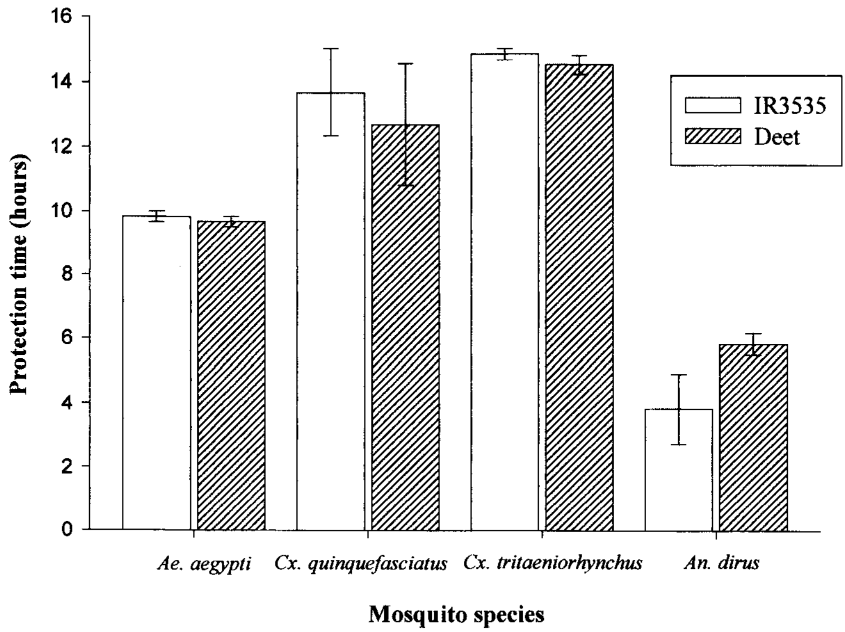

Fig. 2. Relative repellency (mean ± SE) of IR3535 and deet against 4 mosquito species under laboratory conditions.

protected locations with minimal wind disturbance where mosquito landing or biting activity was high. The pairs of volunteers sat on chairs and collected all of the mosquitoes landing on or biting their legs in the specified area for a 10-min period. Each exposure period was followed by a 10-min break before the next mosquito collection was conducted. Each hour of the test included 3 mosquito collections and 3 breaks. The tests were conducted for 8 h (0900–1700 h) against day-biting mosquitoes, whereas tests against night-biting mosquitoes were carried out for 5 h (1900–2400 h). The captured mosquitoes were brought to the laboratory and identified to species under a stereomicroscope. The percentage reduction in landing and bites during every hour of test was calculated according to Mani et al. (1991) and Yap et al. (1998):

$$\text{percentage reduction} = \frac{C - T}{C} \times 100,$$

where C is the number of mosquitoes collected by the control volunteers and T is the number collected by the treated volunteers.

Statistical analysis: The repellency comparisons of IR3535 and deet under laboratory conditions against each mosquito species were analyzed as mean protection time comparisons using Student's t-test. For field evaluations, percentage reduction for each hour was transformed to log $(x + 1)$ for analysis of variance (Yap et al. 1998). The transformed data were analyzed for analysis of variance and mean comparisons using the SPSS program (version 9.0) (SPSS Inc., Chicago, IL).

RESULTS AND DISCUSSION

Laboratory tests

Relative repellency (mean protection time) under laboratory conditions provided by IR3535 and deet against the 4 mosquito species is shown in Fig. 2. Both IR3535 and deet demonstrated equal repellency ($P > 0.05$) for 9.8 and 9.7 h against *Ae. aegypti,* for 13.7 and 12.7 h against *Cx. quinquefasciatus,* and for 14.8 and 14.5 h against *Cx. tritaeniorhynchus,* respectively. Mean (±SE) biting on the control areas (the untreated bare hands) for *Ae. aegypti, Cx. quinquefasciatus,* and *Cx. tritaeniorhynchus* was 4.7 ± 0.2, 4.8 ± 0.3, and 3.7 ± 0.3 bites, respectively. On the other hand, *An. dirus* was significantly less sensitive to IR3535 than to deet ($P < 0.05$), with mean protection time of 3.8 and 5.8 h, respectively. Mean (±SE) biting on the control areas for *An. dirus* was 2.6 ± 0.3 bites. With regard to deet, Frances et al. (1996) found that 20% deet provided protection from *An. dirus* (6–7 days old) bites for an average of 105 min in a test cage containing 200 mosquitoes. This protection time is shorter than that found in our studies using 4- to 5-day-old mosquitoes. This discrepancy between the 2 studies can be explained in terms of different evaluation procedures and different responses in different species or populations of the same species. Such differences in response to chemical repellents have been reported by Rutledge et al. (1978) and Robert et al. (1991), where variable responses in time and location have been noted.

Table 1. The relative efficacy of IR3535 and deet against day-biting mosquitoes (*Aedes albopictus*) over an 8-h exposure period (0900–1700 h) in April and July 1999, at Surat Thani, Thailand.

		Reduction (%) of mosquito bites during 8 h of exposure								
Month	Repellent	1	2	3	4	5	6	7	8	Mean ± SE[1]
April	IR3535	98.6	98.9	97.5	100	94	97.8	100	100	98.4 ± 0.7 a
	Deet	97.3	98.9	97.5	95.9	94	95.7	100	100	97.4 ± 0.8 a
July	IR3535	100	100	100	100	100	100	100	100	100 ± 0 b
	Deet	100	100	100	100	100	100	100	100	100 ± 0 b

[1] Means in this column followed by different letters are significantly different from each other ($P < 0.05$).

Field tests

The relative efficacies of IR3535 and deet against day-biting mosquitoes in the field at Surat Thani, Thailand, studied in April and July 1999, are presented in Table 1. In the April test, IR3535 and deet provided an average reduction of field mosquito bites of 98 and 97%, respectively, during the 8 h of exposure period. In the April test, only 9 and 14 mosquitoes, all *Armigeres subalbatus* (Coquillett) were caught on the volunteers treated with IR3535 and deet, respectively (mosquito collections on the untreated volunteers are presented in Table 3), during the entire 8 h of testing. In the July test, the 2 repellents provided complete repellency against mosquitoes during the test period of 8 h.

The relative repellencies of IR3535 and deet against night-biting mosquitoes at various study sites are shown in Table 2. The 2 repellents yielded equally excellent repellency with almost complete prevention of mosquito landing and biting in the 4 study sites. Note that no significant difference was found in efficacy of both repellents among the test sites and the test months ($P > 0.05$). At Nakhon Si Thammarat (July), deet provided complete reduction of mosquito bites, whereas IR3535 gave an average of 99% protection over the 5-h exposure period. In fact, only 1 *Culex sitiens* Wiedemann bit 1 of the 6 volunteers treated with IR3535. At Mae Hong Son, IR3535 showed an average of 99% biting reduction in July and August, whereas deet gave an average of 98 and 99% reduction, respectively. In the July test, only 3 and 6 mosquitoes were captured on the 6 volunteers treated with IR3535 and deet, whereas in August, 2 and 1 mosquitoes were captured by the treated group, respectively. These very few mosquitoes caught belonged to 2 species, *Anopheles hyrcanus* (Pallas) and *Anopheles minimus* Theobald.

The total number of mosquitoes caught by the volunteers of the control group and predominant species are presented in Table 3. For repellency tests conducted against day-biting mosquitoes in Surat Thani, the mosquitoes captured on controls belonged to 3 species: *Ae. albopictus, Ar. subalbatus,* and *Coquillettidia crassipes* (Van der Wulp). In the April test, both *Ae. albopictus* and *Ar. subalbatus* mosquitoes were caught on the untreated volunteers, whereas in July, *Ar. subalbatus* was replaced by *Cq. crassipes.* Therefore, we conclude that both IR3535 and deet provide complete repellency of *Ae. albopictus* and *Cq. crassipes* for at least 8 h under field conditions. For the tests conducted against night-biting mosquitoes in Nakhon Si Thammarat, Nonthaburi, Satun, and Mae Hong Son, the mosquitoes caught by the control groups included 13 species belonging to 3 genera. These were *Anopheles maculatus* Theobald, *An. hyrcanus, An. minimus, Anopheles pseudowillmori* Theobald,

Table 2. The relative efficacy of IR3535 and deet against night-biting mosquitoes over a 5-h exposure period (1900–2400 h) in tests conducted from April to August 1999, at various locations in Thailand.

			Reduction of mosquito bites (%) during 5 h of exposure					
Study site (province)	Month	Repellent	1	2	3	4	5	Mean ± SE[1]
Nakhon Si Thammarat	April	IR3535	100	100	100	100	100	100 ± 0
		Deet	100	100	100	100	100	100 ± 0
Nakhon Si Thammarat	July	IR3535	100	100	100	94.1	100	98.8 ± 1.2
		Deet	100	100	100	100	100	100 ± 0
Nonthaburi	May	IR3535	100	100	100	100	100	100 ± 0
		Deet	100	100	100	100	100	100 ± 0
Satun	July	IR3535	100	100	100	100	100	100 ± 0
		Deet	100	100	100	100	100	100 ± 0
Mae Hong Son	July	IR3535	100	100	100	97.1	98	99.0 ± 0.6
		Deet	100	97.4	97.4	94.2	100	97.8 ± 1.1
Mae Hong Son	August	IR3535	100	100	100	100	93.8	98.8 ± 1.2
		Deet	100	100	96.4	100	100	99.3 ± 0.7

[1] Means of all treatments at all locations are not significantly different from each other ($P > 0.05$).

Table 3. Total mosquitoes captured, biting rate, and predominant species of mosquitoes collected at various study sites in Thailand, April–August 1999.[1]

	Surat Thani		Nakhon Si Thammarat		Nonthaburi	Satun	Mae Hong Son	
	April	July	April	July	May	July	July	August
Total mosquitoes	541	542	93	55	544	66	230	137
Biting rate (no./person-hour)	22.5[2]	22.6[2]	6.2[3]	3.7[3]	36.3[3]	4.4[3]	15.3[3]	9.1[3]
Predominant species (%)	*Ae. albopictus* (83) *Ar. subalbatus* (16) Other species (1)	*Ae. albopictus* (69) *Ar. subalbatus* (11) *Cq. crassipes* (18) Other species (2)	*Cx. sitiens* (42) *Cx. tritaeniorhynchus* (15) *Ma. annulata* (19) *Ma. annulifera* (10) Other species (5)	*Cx. sitiens* (17) *Cx. tritaeniorhynchus* (55) *Ma. annulifera* (19) *Ma. dives* (6) Other species (3)	*Cx. gelidus* (64) *Cx. quinquefasciatus* (27) *Cx. tritaeniorhynchus* (6) Other species (3)	*Ma. dives* (79) *Cq. crassipes* (17) *Ma. uniformis* (4)	*An. hyrcanus* (38) *An. maculatus* (6) *An. minimus* (45) *An. sawadwongporni* (6) Other species (5)	*An. hyrcanus* (62) *An. minimus* (24) *An. pseudowillmori* (5) *An. sawadwongporni* (4) Other species (5)

[1] *Ae.*, *Aedes*; *Cx.*, *Culex*; *Ma.*, *Mansonia*; *An.*, *Anopheles*; *Ar.*, *Armigeres*; *Cq.*, *Coquillettidia*.
[2] Biting rates were computed according to mosquitoes captured between 0900 and 1700 h.
[3] Biting rates were computed according to mosquitoes captured between 1900 and 2300 h.

Anopheles sawadwongporni Rattanarithikul and Green, *Culex gelidus* Theobald, *Cx. quinquefasciatus, Cx. sitiens, Cx. tritaeniorhynchus, Mansonia annulata* Leicester, *Mansonia annulifera* (Theobald), *Mansonia dives* (Schiner), and *Mansonia uniformis* (Theobald).

It is quite clear that in Nakhon Si Thammarat both in April and July, significant numbers of *Culex* species and 3 *Mansonia* species were landing on and biting the control groups (Table 3). The 2 test repellents provided almost complete protection from the *Culex* species (see Table 3). In Satun, the mosquitoes biting during the test were *Ma. dives* and *Ma. uniformis,* with the repellents again providing complete protection during the test period. In the Mae Hong Son area in July and August, 5 species of *Anopheles* were actively landing and biting the control groups during the test periods (see Table 3). Treatment with IR3535 and deet provided 94–100% protection from landing and biting of these *Anopheles* mosquitoes. No rash, skin irritation, or hot sensation was observed on arms and legs of the test volunteers treated with IR3535 and deet during and after application.

In summary, IR3535 demonstrated excellent repellency (100% protection in most tests) against both day- and night-biting mosquitoes under laboratory and field conditions. A high degree of protection averaging 94–100% was observed under a variety of field conditions for the various biting mosquitoes. Therefore, this study clearly indicates the potential of IR3535 for use as an effective topical repellent against a wide range of mosquito species belonging to various genera.

ACKNOWLEDGMENTS

We are grateful to M. Jalalian (Merck KgaA, Darmstadt, Germany) and Sirikul Samutsakorn and Vithita Prasopakarakit (Merck Ltd., Thailand) for providing the active ingredient of IR3535 and relevant information. We thank Jotika Boon-Long, Wichai Kong-ngamsuk, Sumas Junthamas, Chumpon Chumponrak, Dusit Noree, Nares Junthornnuan, and local volunteers for their assistance in field testing. We also thank Yoshiro Nagao for his contribution to Fig. 1.

REFERENCES CITED

Coleman RE, Robert LL, Roberts LW, Glass JA, Seeley DC, Laughinghouse A, Perkins PV, Wirtz RA. 1993. Laboratory evaluation of repellents against four anopheline mosquitoes (Diptera: Culicidae) and two phlebotomine sand flies (Diptera: Psychodidae). *J Med Entomol* 30:499–502.

Debboun M, Strickman D, Klein TA, Glass JA, Wylie E, Laughinghouse A, Wirtz RA, Gupta RK. 1999. Laboratory evaluation of AI3-35765, CIC-4, and deet repellents against three species of mosquitoes. *J Am Mosq Control Assoc* 15:342–347.

Edwards DL, Johnson CE. 1987. Insect-repellent–induced toxic encephalopathy in a child. *Clin Pharm* 6:496–498.

Frances SP, Klein TA, Hilderbrandt DW, Burge R, Noigamol C, Eikarat N, Sripongsai B, Wirtz RA. 1996. Laboratory and field evaluation of deet, CIC-4, and AI3-37220 against *Anopheles dirus* (Diptera: Culicidae) in Thailand. *J Med Entomol* 33:511–515.

Maibach HI, Johnson HL. 1975. Contact urticaria syndrome. *Arch Dermatol* 111:726–730.

Mani TR, Rueben R, Akiyama J. 1991. Field efficacy of "Mosbar" mosquito repellent soap against vectors of bancroftian filariasis and Japanese encephalitis in southern India. *J Am Mosq Control Assoc* 7:565–568.

Qiu H, Jun HW, McCall JW. 1998. Pharmacokinetics, formulation, and safety of insects repellent *N,N*-diethyl-3-methylbenzamide (deet): a review. *J Am Mosq Control Assoc* 14:12–27.

Reuveni H, Yagupsky P. 1982. Diethyltoluamide-containing insect repellent: adverse effects in worldwide use. *Arch Dermatol* 118:582–583.

Robert LL, Hallam JA, Seeley DC, Roberts LW, Wirtz RA. 1991. Comparative sensitivity of four *Anopheles* (Diptera: Culicidae) to five repellents. *J Med Entomol* 28:417–420.

Rutledge LC, Moussa MA, Lowe CA, Sofield RK. 1978. Comparative sensitivity of mosquito species and strains to the repellent diethyl toluamide. *J Med Entomol* 14: 536–541.

Schreck CE, McGovern TP. 1989. Repellents and other personal protection strategies against *Aedes albopictus*. *J Am Mosq Control Assoc* 5:247–252.

Service MW. 1993. Mosquitoes (Culicidae). In: Lane RP, Crosskey RW, eds. *Medical insects and arachnids* London: Chapman & Hall. p 120–240.

Smith CN. 1957. Insect repellents. *Soap Chem Spec* 34: 105–122, 126–133.

Tawatsin A, Wratten SD, Scott RR, Thavara U, Techadamrongsin Y. 2001. Repellency of volatile oils from plants against three mosquito vectors. *J Vector Ecol* 26: 1–7.

Thavara U, Malainual Y, Chansang C, Phan-Urai P. 1990. Evaluation on the use of repellent soap. *Bull Dept Med Sci* 32:203–207.

U.S. EPA [U.S. Environmental Protection Agency]. 1999. *Biopesticide factsheet* Office of Pesticides Programs, Washington, DC http://www.epa.gov/oppbppd1/biopesticides/factsheets/fs113509t.html [accessed 2001 February 6].

Walker TW, Robert LL, Copeland RA, Gotheko AK, Wirtz RA, Githure JI, Klein TA. 1996. Field evaluation of arthropod repellents, deet and piperidine compound, AI3-37220, against *Anopheles funetus* and *Anopheles arabiensis* in western Kenya. *J Am Mosq Control Assoc* 12:172–176.

WHO [World Health Organization]. 1996. *Report of the WHO informal consultation on the evaluation and testing of insecticides* CTD/WHOPES/IC/96.1. Geneva: Control of Tropical Diseases Division, World Health Organization.

Yap HH, Jahangir K, Chong ASC, Adanan CR, Chong NL, Malik YA, Rohaizat B. 1998. Field efficacy of a new repellent, KBR 3023, against *Aedes albopictus* (Skuse) and *Culex quinquefasciatus* (Say) in a tropical environment. *J Vector Ecol* 23:62–68.

Zadikoff CM. 1979. Toxic encephalopathy associated with use of insect repellent. *J Pediatr* 95:140–142.