FIELD STUDIES WITH SELECTED SKIN REPELLENTS AGAINST NATURAL INFESTATIONS OF *AEDES TAENIORHYNCHUS* (WIEDEMANN)

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ABSTRACT. Six repellents were highly effective against *Aedes taeniorhynchus* (Wiedemann) when they were applied to human skin in field studies on the east coast of Florida. These compounds were the most promising of 120 repellents tested from 1972 through 1974. The most effective compound, *N,N*-diethyl-5,5-dimethyl-1,3,6-cycloheptatriene-1-carboxamide, was significantly more effective than the *N,N*-diethyl-*m*-toluamide (deet) standard in one series of tests and equal to the deet standard in a second series.

The environmental consequences of controlling insects with insecticidal spray programs have been repeatedly questioned in recent years with the result that some alternate approaches for protecting man against biting insects are being given more emphasis. One of these approaches, personal protection by means of insect repellents, is as old as man's relationship to the blood-sucking mosquito. The use of repellents allows the coexistence of man and biting pests without control measures that may destroy nontarget organisms. Protective clothing such as long-sleeved shirts, head nets, tucked pants cuffs, etc., are useful for persons who are exposed to biting insects; however, not all pests that affect man are deterred by these methods. For example, crawling arthropods such as ticks and mites can get under clothing with relative ease. The logical answer is the use of chemical repellents on both clothing and skin.

The development of personal-use repellents has been relatively slow because of a limited market and limitations on the types of chemicals that can be applied to the human skin. The three most widely used repellents, dimethyl phthalate, ethyl hexanediol (Rutgers 6–12) (Dethier 1956), and deet (*N,N*-diethyl-*m*-toluamide) (Gilbert et al. 1957) were developed in 1929, ca. 1938, and 1957, respectively. Although other lesser known materials are sometimes used, these compounds have world-wide recognition as insect repellents and are the active ingredients in a multitude of commercial formulations. Nevertheless, they have several undesirable characteristics, namely, they are plasticisers, have an oily texture, and resist washing and perspiration poorly. These factors coupled with the uncertainty regarding the availability of petroleum-derived chemicals, have renewed interest in finding better insect repellents.

The Insects Affecting Man Research Laboratory at Gainesville, Florida, has field tested mosquito repellents on the east coast of Florida since the early 1940's. The present paper reports the results of field tests with 6 of the most promising of 120 compounds evaluated against *Aedes taeniorhynchus* Wiedemann during the summers of 1972 through 1974.

MATERIALS AND METHODS. The compounds used in the field test were selected on the basis of performance in the laboratory on cloth screening tests against *Aedes aegypti* (L.) (Smith 1970) and by their toxicological classification in studies by the U.S. Army Environmental Hygiene Agency's Primary Irritation Evaluation Program. The repellent studies were conducted at two wooded sites adjacent to Mosquito Lagoon, located about 8 and 11 miles south of New Smyrna Beach, Florida, on Highway A1A. The experimental compounds were applied as 1-ml aliquots of ethanol solutions and were spread evenly over the forearm of a human subject from wrist to elbow. The solutions were formulated on a weight-volume basis at concentrations of 25 and 50%.

The treated arms were exposed continuously to the natural population of mosquitoes until the first confirmed bite was received (one bite followed by another within 30 min). Head-nets, gloves, and military fatigue jackets and pants were worn by test subjects (up to 6 subjects per test series) to protect against attack on exposed untreated parts of the body.

The experimental design used was a balanced incomplete block where each repellent was paired against each other repellent concurrently on the arms of the subjects. Further discussion of the design of the tests and method of analysis are given by Gilbert et al. (1957) and Schreck (1976).

RESULTS AND DISCUSSION. The statistical analysis showed that one compound of the 120 materials tested was more effective than the deet standard and that 5 others were not significantly different from the deet standard. The names of the 6 compounds, the range of protection times, the statistical averages for these 6 candidate repellents and the deet standard, and the ratio of the protection time of each material to the standard are given in Table 1.

The most effective compound, *N,N*-diethyl-5,5-dimethyl-1,3,6-cycloheptatriene-1-carboxamide (DECC) was tested in 1974 as a 25% ethanol solution. It had a ratio of protection time of 1.42 to the deet standard with an adjusted mean of 456 min of protection compared with 320 min for the standard. Further paired tests were therefore conducted with three subjects (repeated 5 times) with the candidate repellent on one arm (left or right in randomized fashion) and the deet standard on the other. In these supplemental tests, DECC and the deet standard each provided a mean of 313 min of protection. No explanation can be given for the differences in ratios obtained in the round-robin series and the paired tests. However, in 1974 at the time of the second series of tests, the avidity of the mosquito population was greater than it had been at any time during the 8-wk test period, which may have contributed to a reduction in protection time recorded for DECC.

Two ring-substituted benzamides, 2,3-dichloro-*N,N*-diethylbenzamide and *p*-isopropyl-*N,N*-dimethylbenzamide also provided mean protection times of more than 9 h as 50% ethanol solutions and were equal to the deet standard. However, when 2,3-dichloro-*N,N*-diethylbenzamide was tested as a 25% ethanol solution, it was less effective than the standard. 2-Isopropyl-5-methyl-1,3-hexanediol, as a

Table 1. Selected skin repellents equal to or better than a deet standard against *Aedes taeniorhynchus* (balanced incomplete-block design except where noted) (LSD 0.05 level).

			Protection time (min)				
			Candidate		Deet		Ratio
Chemical	No. tests	% Conc.	Range	Adj. mean	Range	Adj. mean	to deet
N,N-diethyl-5,5-dimethyl-1,3,6-cycloheptatrine-1-carboxamide	5	25	357–527	456	270–410	320	1.42[a]
	5[b]	25	235–350	313	287–347	313	1.0
2,3-dichloro-*N,N*-diethylbenzamide	4	50	531–627+[c]	600	385–610+[c]	547	1.1
	3	25	162–282	179	294–300	280	0.64
p-isopropyl-*N,N*-dimethylbenzamide	4	50	486–634	544	459–482	492	1.07
2-isopropyl-5-methyl-1,3-hexanediol	3	50	227–537	438	340–445	442	0.99
3-acetyl-4-ethyl-2-methyl-2-pentyloxazolidine	4	50	416–456	440	385–489	484	.91
hexahydro-1-[(2-methylcyclohexyl) carbonyl]-1*H*-azepine	3	25	163–249	218	294–300	280	.78
	3	25	211–348	334	263–391	373	.89

[a] Significantly different from the deet standard at the 0.05 level.
[b] Paired tests.
[c] Plus indicates repellent on one subject still effective at the end of the test period.

50% ethanol solution, had a mean protection time of 438 min compared with 442 min for the standard.

Likewise a 3-acetyl-4-ethyl-2-methyl-2-pentyloxazolidine in a 50% solution provided a mean protection time of more than 7 h, but this material compared slightly less favorably with the deet standard when tested as a 25% ethanol solution.

Hexahydro-1-[(2-methylcyclohexyl)carbonyl]-1*H*-azepine as a 25% ethanol solution provided a mean of 334 min of protection compared with 373 min for the deet standard.

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