

The hourly captures of Tabanidae and mosquitoes in test 2 are summarized as bar graphs in Figure 2. However, several other biting and non-biting families were represented in the collections. The Tabanidae collected included 1881 male and 158 female *T. lineola*, 5 male and 47 female *T. nigrovittatus*, 3 female *T. quinquevittatus*, and 19 male and 58 female *C. atlanticus*. The mosquitoes collected included 78 male and 674 female *Aedes sollicitans*, 3 male and 131 female *A. taeniorhynchus*, 3 male and 103 female *A. cantator*, 87 male and 4 female *A. vexans*, 3 female *Anopheles crucians bradleyi* King, and 9 male and 4 female *Culex* spp. As expected, most captures occurred from dusk to dawn (ca. 2000-0600), the period when the UV lamp is more noticeable. However, an appreciable increase in fly attraction to the UV, especially by males, began 2400 and extended to just before dawn. The total

number of biting flies and mosquitoes trapped during the daylight hours (0600-2000) for the 77-day season was 54 male and 22 female biting flies and 49 male and 235 female mosquitoes.

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FIELD EVALUATION OF REPELLENTS AGAINST MOSQUITOES IN ISRAEL

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ABSTRACT. A number of repellents which were found effective in the laboratory against *Culex pipiens molestus* were tested on humans under natural field conditions against *Culex* mosquitoes (mostly *C. pipiens molestus*) in Israel. Six repellents: 2-ethoxy-N, N-diethylbenzamide (20297), o-chloro-N, N-diethylbenzamide (17586), 1-acetoxy tetrahydrofurfuryl cyclopentanecarboxylate (6496), N,N-diethylbenzene sul-

fonamide (14913-Gb), N,N-o-triethylbenzamide (20690) and N,N-diethyl-m-chlorobenzamide (20701) were similar to deet. Two repellents (4, 5, 6, 7 (or 7a) tetrahydrospiro [cyclohexane-1,3'-indan]-1'-one (12166-B) and N-hexylbutylamide (15130-b) were superior to deet, but not significantly, in one set of field experiments, and significantly superior in another set of field experiments.

Evaluation of promising repellents against various mosquito species under field conditions has been conducted in various parts of the world, (Altman and Smith 1955, Gilbert and Gouck 1955, Gilbert 1957, Gerberg 1966, Gilbert *et al.* 1970). Repellents which were found effective against one mosquito species were not necessarily effective against

other species (Gilbert *et al.* 1957, Bar-Zeev and Ben-Tamar 1971). It is, therefore, necessary to evaluate repellents on each species against which it is intended to be used.

The mosquito *Culex pipiens molestus* Forsk. is the most common domestic species in Israel. It is a fierce biter and is active at sunset and at night throughout the spring and sum-

TABLE 1. Field experiments of repellents in round robin tests against *Culex* mosquitoes

Compound	U.S.D.A. code no.	Conc. (%)	Amt applied (ml)	Protection period (mins.)		
				Range	Adjusted average	Ratio to deet
Deet	22542	5	1	51-270	166.9	1.00
Isopropyl N,N-dipropylsuccinamate	6269	5	1	27-174	59.6	0.36
N-Ethyl-N-(2-butyroxethyl)butyramide	6312	5	1	26-161	80.7	0.48
Dimethyl phthalate	262	5	1	75-178	91.3	0.55
N-Propionyl-N-methylanthranilic acid, methyl ester	5913-a	5	1	25-272	108.4	0.65
Isobutyl ester of N,N-diethylsuccinamic acid	6275-a	5	1	41-260	122.5	0.73
		LSD (5 percent)			43.9	
		LSD (1 percent)			59.4	

TABLE 1 (Continued)
Group b

Compound	U.S.D.A. code no.	Conc. (%)	Amt applied (ml)	Protection period (mins.)		
				Range	Adjusted average	Ratio to deet
Deet	22542	5	1	98-319	222.7	1.00
sec-Butyl N,N-diisopropylsuccinamate	6390-c	5	1	90-253	117.5	0.53
Ethyl N,N-dipropylglutaramate	6365	5	1	73-182	130.4	0.59
2-Ethoxy-N,N-diethylbenzamide	20297	5	1	94-350	198.9	0.89
o-Chloro-N,N-diethylbenzamide	17586	5	1	110-351	251.4	1.13
Spiro [cyclohexane-1,3'-indan]-1'-one, 4,5,6,7 (or 7A)-tetrahydro-	12166-B	5	1	105-325	276.2	1.24
		LSD (5 percent)			52.4	
		LDS (1 percent)			70.9	

TABLE 1 (Continued)
Group c

Compound	U.S.D.A. code no.	Conc. (%)	Amt applied (ml)	Protection period (mins.)		
				Range	Adjusted average	Ratio to deet
Deet	22542	2	2	160-270	212.4	1.00
Phthalic acid, diester with allyl glycolate	329-b	2	2	107-180	149.4	0.70
Cyclopentanecarboxylic acid, 1-acetoxytetrahydrofurfuryl ester	6496	2	2	170-260	208.4	0.98
N,N-Diethylbenzenesulfonamide	14913-Gb	2	2	158-323	211.6	1.00
N-Hexylbutyramide	15130-b	2	2	157-325	288.4	1.36
		(LSD (5 percent)			47.7	
		LSD (1 percent)			65.8	

TABLE I (Continued)
Group d

Compound	U.S.D.A. code no.	Conc. (%)	Amt applied (ml)	Protection period (mins.)		
				Range	Adjusted average	Ratio to deet
Deet	22542	2	2	196-242	217.1	1.00
Propionic acid, <i>alpha</i> -propylpiperonyl ester	20090-n	2	2	61-238	96.3	0.44
Thiocyanic acid, 3 hydroxypropyl ester, propionate	19554-b	2	2	41-173	100.3	0.46
2-Cyclohexene-1-carboxylic acid, 2-methyl-4-oxo-6-propyl-ethyl ester	6515	2	2	32-205	117.4	0.54
Urea, 1,1,3,3-dipentamethylene-	17308-a	2	2	127-238	173.8	0.80
			LSD (5 percent)		43.1	
			LSD (1 percent)		59.4	

TABLE I (Continued)
Group e

Compound	U.S.D.A. code no.	Conc. (%)	Amt applied (ml)	Protection period (mins.)		
				Range	Adjusted average	Ratio to deet
Deet	22542	2	2	178-330	238.8	1.00
3-Buten-1-ol, 1-(<i>o</i> -Methoxyphenyl)-	20034-b	2	2	70-140	115.8	0.49
Piperonyl alcohol, <i>alpha</i> , <i>tert</i> -butyl-	20293-d	2	2	147-278	198.6	0.83
Benzamide, N,N- <i>o</i> -triethyl-	20690	2	2	213-313	253.3	1.06
Benzamide, <i>m</i> -chloro-N,N-diethyl-	20701	2	2	180-302	259.6	1.09
			LSD (5 percent)		39.8	
			LSD (1 percent)		54.9	

mer. About 500 compounds, selected by the U.S. Dept. of Agriculture, out of several thousands tested as repellents against a number of blood-sucking insects, were evaluated in the laboratory for their repellent effect against this mosquito (Bar-Zeev and Ben-Tamar 1971, Bar-Zeev 1972). Compounds which were found effective in the laboratory, and were cleared for use on the skin, were tested on humans in the field under natural conditions. The experiments were conducted in an area of orange groves, about 15 miles southwest of Ness-Ziona. The predominant mosquito was *Culex pipiens molestus*, as can be seen from the following collection of mosquitoes, made by aspirating them from test subjects: *Culex pipiens molestus* 166; *Culex univittatus* 14; *Culiseta (Theobaldia) annulata* 1.

MATERIALS AND METHOD. The method was similar to that described by Alt-

man and Smith (1955) and Gilbert and Gouck (1955). The tests started at sunset when the mosquitoes began to be active. With the onset of darkness, small electric bulbs (12v, 4W) connected to a battery were used. This gave a faint light which enabled visibility of the biting mosquitoes, but did not prevent them from biting. One ml at 5% concentration in ethanol or 2 ml at 1% or 2% concentration in ethanol were spread evenly on one forearm, from wrist to elbow, and a similar aliquot of another repellent on the other forearm. The palms of the hands were covered with gloves and the head and face were covered by a veil of netting (used by beekeepers to protect the face from stings) in order to prevent any bites on the non-treated uncovered parts of the body. The treated arms were exposed continuously to the mosquitoes. The repellents were tested in groups using deet (N,N-

diethyl-*m*-toluamide) as a standard (see Table 1). With each group a round robin series was made. Each repellent was compared twice with every other repellent. Effectiveness was based on complete protection, i.e. the time (min.) between treatment and first confirmed bite (a bite followed by another bite within 30 minutes). A statistical analysis was made according to Kempthorn (1952), as suggested by I.H. Gilbert of the U.S.D.A. From an analysis of variance the least significant difference (LSD) at the 5 percent level and 1 percent level between any two repellents was determined. The relative effectiveness of the repellent to deet was expressed as the ratio of the protection period: When-

ever controls were used, by treating the arms with ethanol, mosquito bites were obtained within a few minutes.

RESULTS AND DISCUSSION Results are given in Table 1. A summary of these results is given in Table 2. Repellents that were superior or similar to deet were further tested in 2 groups. Results are given in Table 3. From this table it can be seen that the 2 compounds 12166-B and 15130-b, which in previous tests (Table 1) were significantly superior to deet, gave again better results than deet, though in these tests it was not significant at the 5% level. It should be noted that these 2 compounds gave in laboratory experiments significantly better

TABLE 2. Summarized results of Table 1. Relative effectiveness of the repellents as compared to deet

Chemicals significantly superior to deet	Chemicals not significantly different from deet	Chemicals significantly inferior to deet	
12166-B	6496	262	6390-c
15130-b	14913-Gb	329-b	6515
	17586	5913-a	17308-a
	20297	6269	19554-b
	20690	6275-a	20034-b
	20701	6312	20090-n
		6365	20293-d

TABLE 3. Field experiments of the best repellents obtained in the previous tests (Table 1 groups a & b) in round robin tests against *Culex* mosquitoes

Compound	U.S.D.A. code no.	Conc. (%)	Amt applied (ml)	Protection period (mins.)		
				Range	Adjusted average	Ratio to deet
Deet	22542	1	2	98-164	134	1.00
o-Chloro-N,N-diethylbenzamide	17586	1	2	113-233	155	1.16
Spiro[cyclohexane-1,3'-indan-1'-one, 4,5,6,7 (or 7A)-tetrahydro]	12166-B	1	2	64-250	163	1.22
2-Ethoxy-N,N-diethylbenzamide	20297	1	2	43-321	195	1.46
	LSD (5 percent)				74.3	
	LSD (1 percent)				106.8	
Deet	22542	2	2	144-275	195	1.00
N,N-Diethylbenzenesulfonamide	14913-Gb	2	2	115-252	185	0.95
Cyclopentanecarboxylic acid, 1-acetoxytetrahydrofurfuryl ester	6496	2	2	170-246	193	0.99
Benzamide, m-chloro-N,N-diethyl-	20701	2	2	155-270	205	1.05
Benzamide, N,N,o-triethyl-	20690	2	2	178-299	217	1.11
N-Hexylbutylramide	15130-b	2	2	165-307	218	1.12
	LSD (5 percent)				27.8	
	LSD (1 percent)				36.5	

results than deet against *Culex pipiens molestus* (Bar-Zeev and Ben-Tamar 1971). Consequently, it may be assumed that these 2 compounds are superior to deet against this mosquito.

ACKNOWLEDGMENT. This research has been financed in part by a grant (No FG-Is-238) made by the United States Department of Agriculture, Agriculture Research Service, authorized by Public Law 480.

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