Evaluations of Repellents for *Hippelates* Eye Gnats[1,2]

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ABSTRACT

Twenty chemicals or combinations of chemicals were evaluated for their repellency toward *Hippelates pusio* Loew with turntables in the field. Some of the materials were also tested against *H. bishoppi* Sabrosky and *H. pallipes* Loew. The most effective repellents for *H. pusio* were: Triple Mix (63.8% dimethyl phthalate + 18.8% Indalone® (butyl 3,4-dihydro-2,2-dimethyl-4-oxo-2*H*-pyran-6-carboxylate) + 17.3% ethyl hexanediol), MGK (McLaughlin Gormley King Co.) Formula 5780 (75% ethyl hexanediol + 4% MGK 264® (*N*-(2-ethylhexyl)-5-norbornene-2,3-dicarboximide) + 1% MGK Repellent 11® (1,5a,6,9,9a,9b-hexahydro-4a (4H)-dibenzofurancarboxaldehyde) + 1% MGK Repellent 326® (di-*n*-propyl 2,5 pyridinedicarboxylate)), butyl acetanilide, and butyl ethyl propanediol. Less repellency was shown by TMPD (2,2,4-trimethyl-1,3-pentanediol) + 8% dimethyl phthalate, TMPD, and ethyl hexanediol. Other materials exhibited little or no repellency.

H. bishoppi was generally repelled by those chemicals which were effective against *H. pusio* but some exceptions indicated definite differences in the sensory responses of these 2 species. Limited tests indicated that a repellent that is effective against *H. pusio* is not necessarily effective against *H. pallipes.*

Four repellents applied to human skin were tested for their effectiveness against caged laboratory-reared gnats. The frequency of gnat landings on the treated skin of the forearms was used as the index of effectiveness. The repellency of deet, Triple Mix, and ethyl hexanediol declined to 50% of the initial level in about 110 minutes and TMPD in about 60 minutes.

Some species of *Hippelates* (Diptera: Chloropidae) eye gnats are readily attracted to man and animals and can be extremely annoying. They have been implicated also in the spread of human conjunctivitus ("sore eyes") by Dow and Hines (1957). Since these gnats breed extensively in disturbed, friable soil (Bigham 1941, Burgess 1951, Mulla 1962, Jay 1963), control is extremely difficult. An ecological approach has been suggested in some situations (Mulla 1963a), and the use of biological control agents has been suggested (Bay and Legner 1963). In the absence of an adequate control program, temporary relief from the annoyance of *Hippelates* gnats may be possible by means of chemical repellents.

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Commercial repellents have been evaluated against *H. collusor* (Townsend) in California (Mulla 1963b, Mulla et al. 1960a). In the Southeastern United States, *H. collusor* does not occur, but a closely related species, *H. pusio* Loew, is pestiferous. In the same localities, *H. pallipes* Loew is often annoying to man and animals while *H. bishoppi* Sabrosky occurs in large numbers but is not a pest of man and animals. *H. bishoppi* is similar to *H. pusio* morphologically and was not distinguished from *H. pusio* in early research in the Southeastern United States. Early reports on *H. pusio* in California probably were referring to *H. collusor*. This species problem has been clarified by Dow et al. (1951) and Sabrosky (1951).

This report presents the results of evaluating the effectiveness of certain commercial repellents against *H. pusio, H. bishoppi,* and *H. pallipes.*

MATERIALS AND METHODS.—Candidate repellents were evaluated for their effectiveness by means of motor-driven turntables operated in the field in North Carolina. The equipment and procedures were modifications of those used by Mulla et al. (1960a) and Mulla (1963b). Each turntable was 4 ft in diam and rotated 7 times/min. The repellents were compared in their ability to prevent gnats from coming to a 5% solution of powdered whole eggs (aged 4 days at 25–30°C), which is an efficient attractant (Mulla et al. 1960b). Equidistant around the circumference of the turntable, 4 gnat traps were placed over dishes of aged egg bait. Preliminary experiments following the suggestions of Dow (1959) indicated that the traps were not significantly different and use of more than 4 traps/turntable resulted in interactions between adjacent treatments. Each trap consisted of an inverted glass filtering funnel (10 cm diam) with a plastic collecting vial (5 cm diam × 9 cm long) inserted over the 6-cm stem. The bait dishes rested on top of a filter-paper disk (5 cm diam) which was soaked in 1 ml of the desired concentration of the candidate repellent (dissolved in isopropyl alcohol). The entire apparatus (trap, bait dish, and filter paper) rested on top of 4-mesh hardware cloth fastened over a circular opening in the turntable. Thus, the gnats could enter the trap only by passing through the hardware cloth and by the repellent-soaked filter paper. The number of gnats collected in the control traps (filter paper soaked in isopropyl alcohol) was compared with the number of gnats collected in the traps over the repellent-treated filter paper. Two or 3 turntables were operated simultaneously for durations of 1–2 hr and replicated 2–4 times. Gnat catches were converted to the values of ($\log X + 1$) prior to analysis of variance (randomized complete block design) and Duncan's multiple range test was used to determine significant differences (5% probability level) for each species *within* each experiment.

Four repellents were evaluated on humans exposed to a mixed population of laboratory-reared *H. pusio* and *H. pallipes* in a screen cage (9×9×7 ft) erected inside a greenhouse (21–27°C and 40–60% RH). The duration of effectiveness of each repellent was evaluated on 3 different persons (similarly dressed males, 20–25 years old). Five evaluations/repellent were conducted. After a count was made of the number of gnats landing on the forearms in a 5-min interval, sufficient volume (ca. 10 ml) of a 25% (wt/wt) solution of the repellent in isopropyl alcohol was applied to cover the forearms. The landing rate was deter-

Table 1.—Responses of *Hippelates* gnats to repellents evaluated on turntables in the field.

Repellent	Concn (%)	Avg no. gnats/test[a] *H. pusio*	*H. bishoppi*
	Experiment A[b]		
MGK 264	50	17 a	125 a
Butyl ethyl propanediol	50	1 b	50 a
Butyl acetanilide	50	2 b	14 b
Control		134 c	151 a
	Experiment B		
Dimethyl phthalate	50	11 a	24 a
Deet	50	31 a	63 b
Dibutyl phthalate	50	112 b	188 c
Control		126 b	170 c
	Experiment C		
MGK Repellent 874	50	12 a	61 b
MGK Repellent 326	50	62 b	112 b
MGK Repellent 11	50	7 a	32 a
Control		188 c	209 c
	Experiment D		
MGK Formula 5520	50	18 b	117 bc
MGK Formula 5731	50	20 b	93 b
MGK Formula 5780	50	0 a	3 a
Control		65 c	172 c
	Experiment E		
Ethyl hexanediol	50	5 a	16 a
Butoxy polypropylene glycol	50	117 c	111 b
Tabatrex	50	40 b	50 b
Control		107 c	105 b
	Experiment F		
Indalone	50	69 b	39 b
Triple Mix	50	5 a	4 a
Kik	25	62 b	64 b
Control		126 b	94 b
	Experiment G		
Dimethyl phthalate	50	18 b	50 b
TMPD + 8% dimethyl phthalate	15	2 a	12 a
Deet	15	49 c	100 b
Control		162 d	187 c
	Experiment H		
TMPD + 8% glycerol	15	6 a	8 a
Deet	15	27 b	27 b
Glycerol	8	104 c	70 c
Control		129 c	91 c
	Experiment I		
TMPD + 8% glycerol	15	7 a	19 a
Deet	15	22 ab	54 b
Deet	50	31 b	51 b
Control		84 c	114 c
	Experiment J		
TMPD + 8% glycerol	15	2 a	52 a
TMPD + 8% glycerol	25	1 a	40 a
Deet	15	33 b	172 b
Control		140 c	421 c
	Experiment K		
TMPD + 8% glycerol	15	3 a	57 b
TMPD + 8% dimethyl phthalate	15	1 a	24 a
Deet	15	29 b	158 c
Control		115 c	314 d

[a] Means for each species followed by the same letter within each experiment are not significantly different at the 5% probability level (Duncan's new multiple range test). The data were transformed to the values ($\log X + 1$) prior to analysis of variance.
[b] Each experiment consisted of 2 turntables (1 trap/treatment per turntable) operated on 4 different occasions.

mined at subsequent 10–20 min intervals until the rate was approximately equal to the initial one.

The chemical designations of proprietary materials are presented at the end of this report.

Results and Discussion.—The responses of *H. pusio* and *H. bishoppi* to relatively high concentrations of the repellents are presented in Table 1. The results of additional comparisons of the responses of *H. pusio* to lower concentrations of the more effective repellents are presented in Table 2. The most effective repellents were each evaluated at 3 different concentrations at 1 time (Table 3).

On the basis of these turntable tests the relative effectiveness of the chemicals as repellents for *H. pusio* may be summarized as follows:

Little or no repellency: Kik®, Indalone®, Tabatrex®, MGK Repellent 326®, MGK 264®, butoxy polypropylene glycol, and dibutyl phthalate.

Moderate repellency: MGK Repellent 874, deet, dimethyl phthalate, MGK Formula 5520, and MGK Formula 5731.

Greater repellency: TMPD + 8% dimethyl phthalate, TMPD, and ethyl hexanediol.

Greatest repellency: Triple Mix, MGK Formula 5780, MGK Repellent 11®, butyl acetanilide, and butyl ethyl propanediol.

Table 2.—Responses of *Hippelates pusio* to repellents evaluated on turntables in the field.

Repellent	Concn (%)	Avg. no. gnats/trap[a]
Experiment L[b]		
Ethyl hexanediol	25	3 a
Triple Mix	25	3 a
MGK Formula 5780	25	2 a
Control		61 b
Experiment M		
MGK Repellent 11	25	4 a
Butyl ethyl propanediol	25	2 a
Butyl acetanilide	25	2 a
Control		72 b
Experiment N		
Dimethyl phthalate	25	40 ab
Deet	25	36 a
MGK Repellent 874	25	33 a
Control		112 b
Experiment O		
TMPD + 8% glycerol	7.5	2 a
TMPD + 8% dimethyl phthalate	7.5	1 a
Deet	7.5	26 b
Control		63 c
Experiment P		
Triple Mix	12.5	7 b
MGK Formula 5780	12.5	1 a
MGK Repellent 11	12.5	6 b
Control		76 c
Experiment Q		
Ethyl hexanediol	12.5	12 a
TMPD + 8% glycerol	3.75	8 a
TMPD + 8% dimethyl phthalate	3.75	7 a
Control		90 b
Experiment R		
Triple Mix	5.0	3 a
MGK Formula 5780	5.0	1 a
MGK Repellent 11	5.0	2 a
Control		41 b
Experiment S		
Ethyl hexanediol	5.0	6 a
TMPD + 8% glycerol	1.5	37 b
TMPD + 8% dimethyl phthalate	1.5	25 b
Control		109 c
Experiment T		
TMPD + 8% glycerol	5.0	34 b
Butyl ethyl propanediol	1.5	1 a
Ethyl acetanilide	1.5	4 a
Control		124 c

[a] Means followed by the same letter within each experiment are not significantly different at the 5% probability level (Duncan's new multiple range test). The data were transformed to the values (log X + 1) prior to analysis of variance.
[b] Each experiment consisted of 2 turntables (1 trap/treatment per turntable) operated on 2 different occasions.

Table 3.—Effect of dilution on the effectiveness of selected repellents against *Hippelates pusio*.

Repellent	Concn (%)	Avg no. gnats/trap[a]
Experiment A[b]		
TMPD + 8% glycerol	10	9 a
	5	5 a
	1	37 b
Control		109 c
Experiment B		
Deet	10	15 a
	5	20 a
	1	36 a
Control		75 b
Experiment C		
Triple Mix	10	3 a
	5	3 a
	1	3 a
Control		86 b
Experiment D		
MGK Formula 5780	10	3 a
	5	2 a
		17 a
Control		141 b
Experiment E		
MGK Repellent 11	10	4 a
	5	5 a
	1	7 a
Control		116 b
Experiment F		
Ethyl hexanediol	10	9 a
	5	11 a
	1	53 b
Control		202 c
Experiment G		
Butyl ethyl propanediol	10	1 a
	5	3 b
	1	2 ab
Control		167 c
Experiment H		
Butyl acetanilide	10	7 a
	5	4 a
	1	6 a
Control		145 b

[a] Means followed by the same letter within each experiment are not significantly different at the 5% probability level (Duncan's new multiple range test). The data were transformed to the values (log X + 1) prior to analysis of variance.
[b] Each experiment consisted of 3 turntabes (1 trap/treatment per turntable) operated on 1 occasion.

In general, *H. bishoppi* was repelled by those chemicals which were effective against *H. pusio* (Table 1). However, the percentage reduction of *H. bishoppi* tended to be lower than for *H. pusio*. MGK 264, butyl ethyl propanediol, and MGK Formula 5520 did not significantly repel *H. bishoppi* but were significantly effective against *H. pusio*. Thus these 2 species, although very similar in ecological and morphological characteristics, exhibit definitive differences in their sensory responses.

The results of repellent evaluations with *H. pallipes* are presented in Table 4. The chemicals included in the experiments were previously shown to be effective for *H. pusio*. At the concentrations used, butyl acetanilide, MGK Repellent 11, ethyl hexanediol, and TMPD + dimethyl phthalate were effective against *H. pallipes*. The other chemicals were not effective. *H. pallipes* apparently differs from *H. pusio* in its response to chemical stimuli. A repellent that is effective for one is not necessarily effective for the other.

The results of testing 4 repellents on humans are presented in Fig. 1. The repellency of deet, Triple Mix, and ethyl hexanediol declined to 50% of the initial level in about 110 min. TMPD was effective for only about half as long. These chemicals exhibited varying degrees of repellency to gnats in the turntable tests. Although the relative effectiveness of the repellents differed in the 2 testing methods, the turntable tests provided a convenient method of selecting chemicals for use in tests on humans.

DESCRIPTION AND SOURCES OF PROPRIETARY CHEMICALS.—

Kik®—*o*-chloro-*N,N*-diethylbenzamide (Geigy Chemical Corp., Yonkers, N. Y.)

Indalone® — butyl 3,4-dihydro-2,2-dimethyl-4-oxo-2*H*-pyran-6-carboxylate (FMC Corp., Niagara Chemicals Div., Middleport, N. Y.)

MGK 264®—*N*-(2-ethylhexyl)-5-norbornene-2,3-dicarboximide (McLaughlin Gormley King Co., Minneapolis, Minn.)

Table 4.—Responses of *Hippelates pallipes* to repellents evaluated on turntables in the field.

Repellent	Concn (%)	Avg no. gnats/test[a]
Experiment A[b]		
TMPD + 8% glycerol	1.5	69 b
Butyl ethyl propanediol	5.0	87 b
Butyl acetanilide	5.0	7 a
Control		184 b
Experiment B		
Triple Mix	5.0	27 ab
MGK Formula 5780	5.0	20 ab
MGK Repellent 11	5.0	6 a
Control		118 b
Experiment C		
Ethyl hexanediol	5.0	14 a
TMPD + 8% dimethyl phthalate	1.5	7 a
Deet	1.5	17 a
Control		134 b

[a] Means followed by the same letter within each experiment are not significantly different at the 5% probability level (Duncan's new multiple range test). The data were transformed to the values (log X + 1) prior to analysis of variance.
[b] Each experiment consisted of 2 turntables (1 trap/treatment per turntable) operated on 4 different occasions.

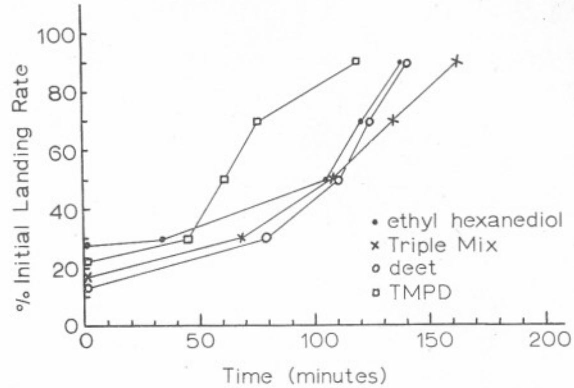

FIG. 1.—Duration of effectiveness against a mixed population of *H. pusio* and *H. pallipes* of 4 repellents applied to humans.

MGK Repellent 11® — 1,5a,6,9,9a,9b-hexahydro-4a-(4*H*)-dibenzofurancarboxaldehyde (MGK Co.)

MGK Repellent 326®—di-*n*-propyl 2,5-pyridinedicarboxylate (MGK Co.)

MGK Repellent 874—2-hydroxyethyl octyl sulfide (MGK Co.)

MGK Formula 5520—5% deet, 5% MGK 264, 1.25% MGK Repellent 11, 1.25% MGK Repellent 326 (MGK Co.)

MGK Formula 5731—17.5% deet, 5% MGK 264, 1.25% MGK Repellent 11, 1.25% MGK Repellent 326 (MGK Co.)

MGK Formula 5780 — 75% ethyl hexanediol, 4% MGK 264, 1% MGK Repellent 11, 1% MGK Repellent 326 (MGK Co.)

Tabatrex®—dibutyl succinate (Glenn Chemical Co., Chicago, Ill.)

TMPD — 2,2,4-trimethyl-1,3-pentanediol (Eastman Chemical Products, Inc., Kingsport, Tenn.)

Triple Mix—63.8% dimethyl phthalate, 18.8% Indalone®, 17.3% ethyl hexanediol (FMC Corp., Niagara Chemicals Div., Middleport, N. Y.)

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