COMPARISON OF SUSCEPTIBLE AND DDT-RESISTANT MOSQUITO COLONIES TO INSECTICIDES[1]

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Insecticidal sprays have been applied to the interiors of buildings to kill anopheline mosquitoes so extensively in malaria control campaigns throughout the world that many species have developed degrees of resistance to some insecticides; resistance to DDT is of primary concern. Thus, in looking for alternate compounds, we need to know both the relative effectiveness of insecticides against these strains that are now highly resistant to DDT and the effectiveness of residual deposits against susceptible strains.

We have maintained a susceptible colony of *Anopheles quadrimaculatus* Say in the Insects Affecting Man Laboratory at Gainesville, Florida, for over 30 years; this colony has never been purposely subjected to selection with insecticides. In 1965, we received a strain of this same mosquito (Hartwell Dam strain since it originated from that area in South Carolina) from the Technical Development Laboratory of the U.S. Public Health Service in Savannah, Georgia. At the time we received it, the strain showed moderate resistance to DDT. For the past 2 years, we have increased the level of resistance to DDT in this strain by selection with DDT. Currently, the strain is sufficiently resistant that adults can be maintained in cages with interiors that are coated with technical DDT.

With two strains of *A. quadrimaculatus* available, one susceptible to DDT and the other highly resistant, we had the opportunity to compare the relative effectiveness over time, of promising residual insecticides against both strains. In this way, we could determine any cross-resistance by the decrease in the length of time the compounds were effective in killing mosquitoes. The present paper summarizes the results of laboratory studies with 47 compounds. All test compounds were received from commercial sources. The designation, chemical name, and acute oral LD_{50} in rats (based on information received from the manufacturer) are given in the accompanying list.

MATERIALS AND METHODS. For the tests, acetone solutions of insecticides were sprayed on plywood panels at the rate of 1.0, 0.5, or 0.25 g/m^2. The panels were tested one week after treatment, again after 4 weeks, and every 4 weeks thereafter for 24 weeks or until they became ineffective, whichever occurred first. Panels were considered ineffective when they failed to produce at least 70 percent mortality in two consecutive tests. Sufficient numbers of panels were sprayed with each insecticide so that no surface was used twice.

In each test, twenty 1- to 2-day-old female mosquitoes (*A. quadrimaculatus* Say) from each colony were exposed under half sections of petri dishes on treated panels for 1 hour; then they were transferred to cylindrical screen cages, provided with sugar-water solution on pads of absorbent cotton, and held for 24-hour mortality counts. All tests were replicated 2 to 6 times.

A separate test was made with methoxychlor applied to plywood panels at the rate of 1.0 and 2.0 g/m^2. Mosquitoes were exposed to these panels for 1, 2, 4, and 6 hours after the treatments had aged 1, 3, 4, and 8 weeks, and knockdown

[1] Mention of a pesticide or a proprietary product in this paper does not constitute a recommendation or an endorsement of this product by the U.S. Department of Agriculture.

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Designation	Chemical name	Oral LD_{50} in rats mg/kg
Shell SD-9098	*O*-[2-chloro-1-(2,5-dichlorophenyl)vinyl] *O,O*-diethyl phosphorothioate	109–286
BAY 38799	*o*-cyclopentylphenyl methylcarbamate	>1000
BAY 62862	3-*sec*-butyl-*p*-tolyl methylcarbamate	25
BAY 62863	2,3-dihydro-2-methyl-7-benzofuranyl methylcarbamate	100
Carbanolate		44
Carbaryl		540
Chevron Ortho RE-5305	*m*-*sec*-butylphenyl methylcarbamate	10
Chlorphoxim		>1000
CIBA C-9643	*o*-(4-methyl-1,3-dioxolan-2-yl)phenyl methylcarbamate	110
CIBA C-10015	*o*-(4,5-dimethyl-1,3-dioxolan-2-yl)phenyl methylcarbamate	67
CIBA C-11044	*O*-(2,5-dichloro-4-iodophenyl) *O*-ethyl *O*-methyl phosphorothioate	330
Crotoxyphos		125
DDT		250
Diazinon		100–150
Dicapthon		284–650
Dieldrin		43–47
Chlorpyrifos		145
Endosulfan		30–79
Fenthion		190–310
Fenitrothion		250
Geigy GS-13005	*O,O*-dimethyl phosphorordithioate *S*-ester with 4-(mercaptomethyl)-2-methoxy-Δ^2-1,3,4-thiadiazolin-5-one	50
Hercules 9326	5-*tert*-butyl-2-chlorophenyl methylcarbamate	54
Hercules 9485	*o*-(allyloxy)phenyl methylcarbamate	200
Hercules 9699	*o*-(2-propynloxy)phenyl methylcarbamate	80
Hercules 13462	*O,O*-dimethyl phosphorodithioate *S*-ester with *N*-(1-mercaptoethyl)succinimide	11.6
Hercules 14469	*m*-cumenyl (mercaptoacetyl)methylcarbamate *S*-ester with *O,O*-dimethyl phosphorodithioate	432
Hercules 16806	*m*-*tert*-butylphenyl (chloracetyl)methylcarbamate	491
Hooker HRS-1422	3,5-diisopropylphenyl methylcarbamate	526
Landrin®	mixture of 3,4,5- and 2,3,5-trimethylphenyl methylcarbamate (4:1)	101
Malathion		1650
Methomyl		26
Methoxychlor		5000
Mobam®	benzo[*b*]thien-4-yl methylcarbamate	>234
Niagara NIA-9227	*O,O*-diethyl phosphorothioate *O*-ester with 3-hydroxycoumarin	12.6
Resmethrin	(5-benzyl-3-furyl)methyl *cis-trans*-(±)-2,2-dimethyl-3-(2-methylpropenyl)cyclopropane carboxylate	3500–4500
Phoxim		>1000
Promecarb		35
Propoxur		95–104
Shell SD-8211	2-chloro-1-(2,5-dichlorophenyl)vinyl dimethyl phosphate	>5000
Shell SD-8280	2-chloro-1-(2,4-dichlorophenyl)vinyl dimethyl phosphate	176
Shell SD-15963	*O*-(7-chloro-4-benzofurazanyl) *O*-isopropyl *O*-methyl phosphorothioate	25
Stauffer N-2230	*O*-(2-chloro-4-nitrophenyl) *O*-ethyl ethyl phosphonothioate	23
Stauffer N-2404	*O*-(2-chloro-4-nitrophenyl) *O*-isopropyl ethyl phosphonothioate	32
Stauffer R-14493	*O,O*-diethyl phosphorothioate *O*-ester with *p*-hydrozybenzaldehyde *O*-(butylcarbamoyl)oxime	17
Stauffer R-15552	mercaptoacetic acid 2,2-dimethylhydrazide *O*-ethyl estylphosphonodithioate (ester)	7
Tetramethrin		5200
Upjohn U-18120	*o*-isopropoxyphenyl (methoxyacetyl)methyl carbamate	70

Table 1.—Number of weeks of effectiveness against *A. quadrimaculatus* from the Gainesville regular and Hartwell Dam colonies, after exposure of 1 hour, to residues of insecticides aged various periods. (Treatments applied to plywood panels as acetone solutions at the rate of 1.0, 0.5, or 0.25 g/m^2; average of 2 to 6 replications of 40 females each.)

	Number of weeks effective at indicated dose to					
	Regular colony			Hartwell Dam colony		
Insecticide	1.0	0.5	0.25	1.0	0.5	0.25
Dieldrin	24	24	24	24	24	4
Chlorphoxim	24	24	21	24	23	19
Carbanolate	24	24	8	24	19	16
Geigy GS-13005	24	24	1	24	11	
Carbaryl	24	24	0	18	13	6
Phoxim	24	23	15	24	13	14
Upjohn U-18120	24	22		24	13	
Landrin	24	21	9	24	16	13
BAY 62862	24	19	14	24	20	16
BAY 62863	24	17	13	24	19	19
Chlorpyrifos	24	16	15	22	14	14
Niagara NIA-9227	24	15	1	24	17	1
DDT	24	12	7	0	0	0
Shell SD-8211	24	12	6	19	13	6
BAY 38799	24	11	11	24	14	11
Mobam	24	10	3	24	13	0
Hercules 9326	24	8		16		
Hercules 16806	24	8		14	8	
Hercules 14469	24	7		11		
Stauffer R-14493	24	7		18		
Propoxur	23	17	14	22	14	12
Promecarb	22	16	14	20	13	16
Hercules 13462	22	10	9	24	15	14
Shell SD-8280	22	8		14		
Chevron RE-5305	22	6		16	10	
Fenitrothion	20	16	11	19	17	14
Hercules 9699	20	10	0	20	5	5
Stauffer N-2230	20	10		10		
Stauffer N-2404	20	8		10		
CIBA C-11044	20	8		7		
Hooker HRS-1422	20	6		20	6	
Dicapthon	20	6		12		
CIBA C-10015	20	6		6		
Diazinon	18	14	4	9	10	4
Shell SD-15963	18	11	12	18	14	14
Crotoxyphos	18	4		11	1	
Shell SD-9098	18	4		7		
Malathion	17	9	5	19	6	6
Fenthion	16	14	4	12	4	4
Tetramethrin	16	8		17	2	
Hercules 9485	16	6		5		
Endosulfan	16	2		5		
Methomyl	14	1		13	1	
Stauffer R-15552	14	1		2	1	
CIBA C-9643	13	1		1		
Resmethrin	12	3		1		

TABLE 2.—Exposure time in hours required to knockdown (KDT-50 and KDT-90) and 24 hour mortality (LT-50 and LT-90) of *Anopheles quadrimaculatus* from the regular Hartwell Dam[a] colonies after exposure periods ranging from 1 to 6 hours to residues of methoxychlor aged for various periods of time. (Treatments applied to plywood panels as acetone solutions at the rate of 1.0 or 2.0 g/m^2; average of 2 replications of 20 females each.)

Age of treatment in weeks	After 4 hours		After 6 hours		After 24 hours	
	KDT-50	KDT-90	KDT-50	KDT-90	LT-50	LT-90
			1.0 g/m^2			
1	>4.0	>4.0	<1.0	3.4	1.6	2.6
3	1.9	3.4	2.0	3.4	1.8	4.2
4	3.4	>4.0	2.6	4.5	1.9	2.9
8	1.0	2.9	1.9	3.2	1.4	2.4
12	1.7	3.2	1.3	2.2	1.0	1.9
16	1.6	2.8	1.2	1.6	1.1	1.5
20	1.7	>4.0	1.3	2.2	1.3	2.2
24	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
32	1.1	1.5	1.1	1.5	1.1	1.5
40	<1.0	<1.0	<1.0	<1.0	<1.0	1.0
48	>4.0	>4.0	<1.0	2.1	<1.0	1.2
56	2.0	>4.0	1.5	3.6	1.0	2.9
			2.0 g/m^2			
1	1.6	>4.0	1.4	2.4	1.4	2.4
3	1.8	2.8	1.9	2.8	1.9	2.8
4	4.0	>4.0	3.0	4.7	2.1	3.5
8	1.9	2.8	1.9	2.8	1.3	2.2
12	2.0	4.3	1.1	2.7	1.2	2.5
16	1.3	2.4	0.9	1.8	0.9	1.3
20	1.1	4.2	1.0	2.9	1.1	2.1
24	1.0	1.4	<1.0	1.3	0.5	1.1
32	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
40	<1.0	3.8	<1.0	1.8	<1.0	1.0
48	<1.0	>4.0	<1.0	2.1	<1.0	1.2
56	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0

[a] The Hartwell Dam colony had no knockdown and no mortality.

was recorded after each exposure. Again, mortality was recorded after 24 hours.

RESULTS. The results of tests with all compounds except methoxychlor (listed in descending order of effectiveness) are given in Table 1. All compounds at the highest dose tested were effective for 12 weeks or more against the susceptible strain of mosquitoes. Against the Hartwell Dam strain, 23 of the 46 compounds were less effective since the weeks of effective kill were fewer at one or more doses.

The results with methoxychlor are given in Table 2. The compound was not highly effective against the susceptible colony since it required 4-hour exposures of 1.0 or 2.0 g/m^2 to produce 93 to 100 percent kill. It was completely ineffective against the Hartwell Dam strain at similar doses and exposures.