BIOLOGICAL ACTIVITY AND LONGEVITY OF NEW SYNTHETIC PYRETHROIDS AGAINST MOSQUITOES AND SOME NONTARGET INSECTS

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ABSTRACT. Several synthetic pyrethroids evaluated against 4th stage larvae in the laboratory were found to be highly effective. The LC_{90} range was 0.045-8.0 ppb. Among these, FMC-30980 [(±) (-Cyano-3-phenoxybenzyl) (±)-*cis-trans*-2,2-dimethyl-3-(2,2-dichlorovinyl) cyclopropane - 1 - carboxylate], FMC - 45497 (± *cis* isomer of FMC-30980), and FMC-45498 or decamethrin (+ *cis* and bromo analogue of above) showed the highest activity with the latter being the most active compound.

In the field, FMC-33297 or Pounce® [3-phenoxybenzyl (±) *cis - trans* - 3 - (2, 2 - dichlorovinyl) - 2, 2 - dimethylcyclopropane - 1 - carboxylate] and SD - 43775 or Pydrin® [α - cyano - 3 - phenoxybenzyl - 4 - chloro-α - (1 - methylethyl) - phenylacetate] yielded good to excellent control of multi-resistant strains of *Aedes nigromaculis* Ludlow at 0.01 and 0.025 lb/acre (11 and 28 g/ha), respectively. FMC-45498 was the most effective compound, producing excellent control of *Ae. nigromaculis* and *Psorophora confinnis* (L-A) at 0.001-0.0025 lb/acre (1.1 and 2.8 g/ha).

Against 3 species of stagnant-water mosquitoes, FMC-45498 again was the most effective compound. It produced 80% control of these species for 2 wk at 0.001 lb/acre (1.1 g/ha). Control was more long-lasting in the cooler months than in the warmer months.

All the pyrethroids proved toxic to mayfly populations in the field at larvicidal rates. Recovery of populations occurred 2–3 wk after application in some of the treatments. SD-43775, however, was the most toxic, suppressing mayfly and dragonfly naiads for more than 3 wk. Dragonfly naiads were not adversely affected by larvicidal rates of the other compounds.

INTRODUCTION

Synthetic pyrethroids, as reported earlier by Darwazeh and Mulla (1974), showed high biological activity against mosquito larvae and pupae in the laboratory, but this trend of activity was not carried into the field. Photo-decomposition and hydrolytic degradation were some of the factors probably responsible for their inactivity in the field.

Recently, several highly effective photostable synthetic pyrethroids have become available for experimentation. Among these, SD-43775 or Pydrin® and FMC-33297 or Pounce® (NRDC-143) were subjected to preliminary field trials. These compounds produced excellent control of larvae at practical rates (Mulla et al. 1975, Mulla and Darwazeh 1976). The present studies were initiated to evaluate further these and other newer synthetic pyrethroids against susceptible and resistant strains of flood-water and stagnant-water mosquitoes. The effects of these on mayfly and dragonfly naiads, and chironomid midge and aquatic beetle larvae were also assessed.

MATERIALS AND METHODS

In the laboratory, all experimental compounds were bioassayed against 4th-stage larvae of laboratory reared *Culex quinquefasciatus* Say. The bioassay techniques utilized are described elsewhere (Mulla et al. 1966). One percent stock solutions (w/v) in acetone were prepared from technical grade materials, and serial dilutions were prepared as needed. Aliquots of 1-ml or less of the proper strength solution were added to 100-ml of tap water in 4-oz waxed paper cups containing 20 larvae. Each concentration was run in duplicate, and each material was tested 3–5 times on different days. After 24 hr of exposure, mortality readings were taken.

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In order to determine LC_{50} and LC_{90} values, the mean mortality values were plotted on log probit paper.

The chemicals screened in the laboratory were:

ABG-6070: 3-Chloro-4-phenyl-*trans*-2-butenyl-1-yl-*dl-cis trans*-chrysenthemate.

SD-41706: α-Cyano-3-pheoxybenzyl 2,2,3,3-tetramethyl cyclo-propanecarboxylate.

SD-43775: α-Cyano-3-phenoxybenzyl 4-chloro-α-(1-methylethyl)=phenylacetate.

FMC-30980 (NRDC-149): (±) (-Cyano-3-phenoxybenzyl (±)-*cis-trans*-2,2-dimethyl-3-(2,2-dichlorovinyl)cyclopropane = 1-carboxylate).

FMC-33297 or Pounce® (NRDC-143): 3-Phenoxybenzyl (±)*cis-trans*-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropane = carboxylate. *cis-trans* isomers of FMC-35171.

FMC-35171 (NRDC-148): only containing *cis* isomer of above.

FMC-45497 (NRDC-160): ±*cis* and chloro analog of FMC-45498.

FMC-45498 or decamethrin (NRDC-161):(-)-(Cyano)-3-phenoxybenzyl-(+)*cis*-3-(2,2-dibromovinyl)-2,2-dimethylcyclo = propane-1-carboxylate.

Field studies were conducted against natural populations of larvae in experimental ponds and in plots in alfalfa fields and irrigated pastures. Emulsifiable concentrate (EC) formulations were utilized in all tests. The required amount of the EC was diluted with water and evenly sprayed onto the surface of water.

EXPERIMENTAL PONDS. The ponds (18'x18'x1' or 30 m^2) used are located at the Vector Control and Aquatic Research Facility of the University of California, Riverside, near Oasis in the Coachella Valley of southern California. Detailed description of these aquatic habitats are published elsewhere (Mulla and Darwazeh 1971). At the time of the experiments, mosquito populations in the ponds consisted of all aquatic stages of *Cx. tarsalis* Coquillett (40%), *Culiseta inornata* Williston (50%), and *Anopheles franciscanus* McCracken (10%). The required amount of toxicant formulation for each rate was mixed with 100 ml of water and applied with a 1-qt all purpose household sprayer. Each material was tested at several rates, utilizing 2 ponds per rate, and 2 ponds as an untreated check. Five dips (400 ml ea) per pond were taken prior to, 2 days, and weekly after treatment until the mosquito larval populations re-established and reached the late stages of development (3-4th stage), or pupae occurred in noticeable numbers. The 5 dips per pond on each sampling date were concentrated into 1 composite sample (Mulla et al. 1975) and organisms, including beetle larvae, mayfly, and dragonfly naiads present were identified and counted under a dissecting microscope in the laboratory. Based on the number of 3-4th stage larvae and pupae in the pre- and posttreatment counts, percent reduction (%R) was calculated and thus the longevity of biological activity of the materials was determined.

Chironomid midge larval assessment was made by taking 2 bottom mud samples per pond with a scoop (4×2×1 in). The sample was mixed and stirred with water and washed through a 50 mesh screen sieve; the residue on the screen containing the larvae was transferred to plastic cups. For counting, the midge larvae were floated by adding saturated solution of $MgSO_4$ in water. The larvae were grouped in the subfamilies Chironominae and Tanypodinae.

FIELD PLOTS. The plots were 1/32 acre and were in Rancho Santa Maria or Smith pastures in Kern County and Tosti pasture in Tulare County. Mosquito larval populations consisted of 4th-stage larvae of *Ae. nigromaculis* Ludlow. Susceptibility levels of the larvae to ethyl and methyl parathion, and synthetic pyrethroids in both locations were determined prior to chemical application by establishing dosage mortality lines for each material for the field larvae. The same procedure was also used for the evaluation of the synthetic pyrethroid FMC-45498 against *Psorophora confinnis* (L-A) in a Rio Rancho alfalfa field located in Riverside County in

the Palo Verde Valley of southern California.

The required amount of the EC formulation was diluted with 500 ml of water and applied with a pressurized 2-liter sprayer. Pretreatment and posttreatment larval assessment was made by taking 10 dips/plot. Percent reduction was determined from the pre- and posttreatment means.

RESULTS AND DISCUSSION

MOSQUITOES. The new synthetic pyrethroids showed exceptionally high levels of biological activity against mosquito larvae (Table 1). Their activity, as measured by the LC_{90} values against *Cx. quinquefasciatus* Say were in the range of 0.045 to 15 ppb. Among these compounds, the pyrethroid FMC-45498 was the most active material evaluated. Other highly active pyrethroids were: FMC-30980, FMC-45497, FMC-35171, and FMC-33297, with LC_{90} values of 0.14-2.5 ppb.

These pyrethroids were fast-acting and produced most mortality within 5–10 min after exposure. Most of these compounds were also noted to be active against mosquito pupae, producing complete mortality at 1 ppb. or less. Additional details will be published as a separate paper. This is the first time that compounds with such high biological activity against both larvae and pupae have been evaluated.

It is interesting to note that field populations of the pasture mosquito *Ae. nigromaculis*, from 2 areas showed different susceptibility patterns to the new pyrethroids. Although both strains were highly resistant to methyl parathion, the Kern County strain was more susceptible to ethyl parathion than the Tulare County strain. The former strain, although manifesting high susceptibility to the pyrethroids, was somewhat more tolerant to these compounds than the ethyl parathion-resistant strain from Tulare County. FMC-45498 was the most active compound, followed by FMC-35171, FMC-30980, and FMC-45497. These compounds had an LC_{90} of less than 1 ppb against the Tulare County strain and about 1-2 ppb against the Kern County strain. From these studies, it is clear that multi-resistant strains of this mosquito are highly susceptible to these synthetic pyrethroids.

After determining the biological activity of these pyrethroids against the multi-resistant strains of *Ae. nigromaculis*, the most effective compound, FMC-45498 was evaluated against the same populations in the field. At the same time, field tests against another floodwater mosquito

Table 1. Susceptibility of 4th stage mosquito larvae to new synthetic pyrethroids in the laboratory.

	(LC_{50}–LC_{90}) ppb		
	Cx. p. quinquefasciatus	*Ae. nigromaculis*	
Material	Riverside–Lab.	Kern County	Tulare County
ABG-6070	8.0 –15.00	–[a] –[a]	–[a] –[a]
FMC-30980 (NRDC-149)	0.07–0.14	0.40–0.90	0.30–0.80
FMC-33297 (NRDC-143)	1.40–2.50	– –	– –
FMC-35171 (NRDC-148)	0.12–1.80	0.70–1.40	0.30–0.60
FMC-45497 (NRDC-160)	0.09–0.15	0.65–1.70	0.30–0.80
FMC-45498 (NRDC-161)	0.02–0.045	0.40–0.90	0.20–0.50
SD-41706	3.50–5.00	– –	– –
SD-43775	7.00–8.00	– –	– –
Methyl parathion	– –	210.00–680.00	180.00–680.00
Ethyl parathion	– –	27.00–68.00	68.00–340.00

[a]Not tested.

(*Ps. confinnis*) were undertaken in the Palo Verde Valley in the eastern part of Riverside County. FMC-45498 showed exceptionally high activity against both species (Table 2). The activity trends found in the laboratory were corroborated in the field, as FMC-45498 showed higher activity against the more resistant strain of *Ae. nigromaculis* in Tulare County than the less resistant strain in Kern County. This material produced almost complete control of larvae of the 2 species at the rates of 0.001-0.005 lb/acre.

The synthetic pyrethroid SD-43775 was not as effective as FMC-33297 against these 2 populations of *Ae. nigromaculis*. It proved more effective against the Tulare County strain (more OP-resistant) than against the Kern County strain. Its range of effectiveness seems to lie between 0.01-0.05 lb/acre.

The 4 FMC pyrethroids were evaluated against natural populations of 3 species of stagnant-water mosquitoes, *Cx. tarsalis*, *Cs.*

Table 2. Evaluation of synthetic pyrethroids against 4th stage larvae of *Ae. nigromaculis* in irrigated pastures.

Material and formulation	Rate (a.i.)		Avg. no. of larvae/10 dips					
			Kern County			Tulare County		
	lb/a	g/ha	Pre	Post	(%R) [a]	Pre	Post	(%R) [a]
FMC-45498 [b] EC 0.21	0.001	1.1	87	22	75	29	0.15	99
	0.0025	2.8	85	9	89	35	0.30	99
	0.005	5.6	149	2	99	24	0.0	100
	0.010	11.2	58	0	100	–[c]	–	–
FMC-33297 EC 3.2	0.005	5.6	–	–	–	26	1.4	95
	0.010	11.2	–	–	–	20	0.3	98
	0.025	28.0	49	0	100	–	–	–
	0.050	56.0	161	0	100	–	–	–
SD-43775 EC 2.4	0.005	5.6	108	45	58	–	–	–
	0.010	11.2	112	22	81	–	–	–
	0.025	28.0	133	15	88	23	0.15	99
	0.050	56.0	–	–	–	18	0.45	97
	0.100	112.0	–	–	–	19	0.10	99
Check	–	–	112	158	0	31	41	–

[a] Counts were taken 6 hrs posttreatment. Based on 3–4th stage larvae and pupae.
[b] Similar results were obtained against *Ps. confinnis* larvae in the Palo Verde Valley of River side County. To save space, data omitted.
[c] Not assessed.

Mulla and Darwazeh (1976) evaluated 2 other synthetic pyrethroids, FMC-33297 and SD-43775 against mosquito larvae, but were unable to determine the minimum effective rates. These 2 materials, therefore, were further evaluated here. FMC-33297 yielded almost complete control of larvae of resistant strains of *Ae. nigromaculis* in Kern and Tulare Counties (Table 2) at the rates of 0.005-0.01 lb/acre. It seems that the effective rate of this material against this pasture mosquito will be in the range of 0.01-0.02 lb/acre.

inornata, and *An. franciscanus* in experimental ponds where suppression of 3rd and 4th stage larvae and pupae was assessed during the cool winter months of Nov.–Dec. 1976. The detailed data are not presented. FMC-33297, FMC-35171, FMC-45497, and FMC-45478 produced complete larval control up to 4 weeks at the rates of 0.025, 0.01, 0.005, and 0.001 lb/acre, respectively. When these materials were evaluated further during the warmer

months, May-June 1977, all compounds rendered the same results but for shorter periods of time due to high air and water temperatures which contributed to the rapid degradation of these materials in water.

In these tests, FMC-33297 controlled mosquito larvae and pupae for 1 wk at 0.025 lb/acre, while FMC-35171 eliminated larvae and pupae for 2 days only at the same rate (Table 3). FMC-45497 was more effective than the 2 previous materials, causing drastic reduction of 3rd and 4th stage larvae and pupae for 1 wk at the rate of 0.001 lb/acre. FMC-45498 was the most effective material tested, producing 80% control of larvae and pupae 2 wk posttreatment at the rate of 0.001 lb/acre. At the lower rate, 0.0005 lb/acre, this material was highly active against all stages of mosquitoes, producing complete control 2 days after treatment, and 90% reduction in the population 7 days after treatment (Table 3). From these findings, it is apparent that FMC-45498 is highly effective against flood-water and stagnant-water mosquitoes at rates as low as 0.0005–0.0025 lb/acre (0.6–1.1 g/ha).

SD-43775 proved to be equally effective against both stagnant-water mosquitoes and the floodwater mosquito *Ae. nigromaculis*. This material produced good control of stagnant-water mosquitoes for more than 2 wk at the rate of 0.025 lb/acre (28 g/ha). At the higher rate (0.05 lb/acre), this material yielded complete control of stagnant water mosquitoes for more than 2 wk. It seems that complete larval control could be achieved by SD-43775 at the rates of 0.025–0.05 lb/acre (28–56 g/ha).

ABG-6070 was the least effective material tested, and at the rate of 0.1 lb/acre (110 g/ha), only 94 percent reduction was achieved and for 2 days only (Table 3).

NONTARGET INSECTS. Effects of the pyrethroids evaluated against mosquito larvae were also assessed on mayfly and dragonfly naiads and larvae of aquatic beetles. The mayflies prevailed at high density and only data pertaining to the population trends of these are presented (Table 4). Mayfly naiads (mostly baetids) were adversely affected by all treatments. SD-43775 was the most toxic material, producing complete mortality at a rate (0.01 lb/acre) not considered effective for mosquito control. At this and higher rates, this material completely eliminated mayfly naiads from the treated ponds; no recovery appeared 24 days posttreatment.

FMC-45497 although suppressing mayfly naiads did not annihilate these insects. In the FMC-33297, FMC-35171, FMC-45498 and ABG-6070 treatments, there was a slight recovery within a 1–3 wk posttreatment. Populations in the checks remained high, generally at or above the pretreatment level.

Dragonfly naiads and diving beetle larvae were retrieved in small numbers in the dipping samples and data on their population trends are omitted. However, in general most of the treatments as listed in Table 4, affected these groups of insects only slightly. The diving beetle larvae were noted to be suppressed markedly by all the dosages of SD-43775, the 2 higher rates of FMC-35171 and the highest rate of FMC-45497. It is anticipated that mosquito larvicidal rates of these pyrethroids (excepting SD-43775) will in general not produce marked mortality in the aquatic stages of these 2 groups of insects.

Chironomid midge larvae, considered here as nontarget organisms, were not markedly affected by any of the treatments as listed in Table 4. However, it was noted that the tanypodine larvae were suppressed for a short period of 1 wk or so by the 2 higher rates of FMC-33297. In order to induce higher levels of mortality in both chironomine and tanypodine larvae, higher rates of application will be needed.

From these studies it is apparent that the mayfly naiads are the most susceptible component of the aquatic fauna in mosquito breeding sources. We have often encountered this situation in other studies of mosquito larvicides.

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Table 3. Evaluation of synthetic pyrethroids against mosquito larvae in experimental ponds. (Oasis, Calif., May, 1977)

Material and formulation	Rate (a.i.)		Avg. no. of larvae and pupae/5 dips pre- and posttreatment (days)													
			Pre-treat			2				7				14			
	lb/a	g/ha	1–2	3–4	P	1–2	3–4	P	(%R)	1–2	3–4	P	(%R)	1–2	3–4	P	(%R)
FMC-33297	0.005	5.6	16	12	2	3	13	1	0	29	22	5	0	79	36	4	0
EC 0.8	0.010	11.2	32	9	11	2	2	3	80	29	3	1	80	83	16	2	0
	0.025	28.0	11	6	6	0	0	0	100	2	0	0	100	123	28	1	0
FMC-35171	0.0025	2.8	69	29	1	4	4	0	89	83	30	0	14	–[a]	–	–	–
EC 1.6	0.0050	5.6	85	26	1	4	3	0	90	72	17	0	46	–	–	–	–
	0.010	11.2	61	27	2	0	2	1	91	65	20	0	40	–	–	–	–
	0.025	28.0	71	15	2	0	0	0	100	49	9	0	55	–	–	–	–
FMC-45497	0.00025	0.28	22	23	5	5	20	2	22	21	8	3	79	54	18	3	60
EC 0.8	0.00050	0.56	26	35	7	4	10	3	74	15	6	2	90	54	9	2	86
	0.0010	1.1	29	26	13	1	1	5	97	9	5	2	88	43	21	0	55
FMC-45498	0.00025	0.28	22	15	4	1	1	1	94	8	2	1	92	57	7	0	74
EC 0.21	0.00050	0.56	7	12	3	0	0	0	100	6	2	0	90	59	12	1	44
	0.0010	1.1	20	22	7	0	0	0	100	2	0	0	100	30	8	0	80
SD-43775	0.010	11.2	10	6	4	1	1	0	85	1	3	1	70	84	22	0	0
EC 2.4	0.025	28.0	45	36	11	0	9	8	77	1	3	0	95	27	12	0	81
	0.050	56.0	47	19	12	2	1	5	95	1	0	0	100	30	1	0	97
ABG-6070	0.025	28.0	72	13	3	4	3	3	68	80	14	3	9	–	–	–	–
EC 4	0.050	56.0	138	28	3	7	3	2	86	47	13	1	43	–	–	–	–
	0.100	112.0	31	12	2	3	1	0	94	49	19	1	0	–	–	–	–
Check	–	–	51	15	3	45	19	3	–	72	17	4	–	39	17	4	–

[a] Not assessed.

Table 4. Effect of synthetic pyrethroids against mayfly naiads in experimental ponds. (Oasis, Calif., May, 1977).

Material & formulation	Rate		Avg. no./5 dips pre- and posttreatment (days)				
	lb/a	g/ha	Pre	2	7	14	21
FMC-33297	0.005	5.6	15	0	0	2	4
EC 0.8	0.010	11.2	7	0	0	1	2
	0.025	28.0	41	1	1	0	2
FMC-35171	0.0025	2.8	4	0	5	–[a]	–
EC 1.6	0.005	5.6	5	0	1	–	–
	0.010	11.2	2	0	0	–	–
	0.025	28.0	10	0	0	–	–
FMC-45497	0.00025	0.3	23	33	15	2	2
EC 0.8	0.0005	0.6	35	30	16	2	1
	0.001	1.0	28	25	7	0	2
FMC-45498	0.00025	0.28	30	30	2	0	5
EC 0.21	0.0005	0.56	52	2	0	1	4
	0.001	1.1	22	0	0	0	0
SD-43775	0.010	11.2	16	0	0	0	0
EC 2.4	0.025	28.0	24	0	0	0	0
	0.050	56.0	12	0	0	0	0
	0.050	56.0	12	0	0	0	0
ABG-6070	0.025	28.0	2	0	1	–	–
	0.050	56.0	3	0	5	–	–
	0.100	112.0	2	0	1	–	–
Check	–	–	12	32	32	12	15

[a] Not assessed.

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