NEW PYRETHROIDS AS MOSQUITO LARVICIDES AND THEIR EFFECTS ON NONTARGET ORGANISMS

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ABSTRACT. Five new synthetic pyrethroids were evaluated against 6 species of mosquitoes in the laboratory. They were very effective against 4th instar larvae of the various species having an LC_{90} in the range of less than 1 ppb for the most active compound to 50 ppb for the least active. Most of the pyrethroids were highly effective against pupae, having an LC_{90} in the range of 1–10 ppb.

Some of the compounds not previously evaluated were studied in the field against stagnant and flood-water mosquitoes. Permethrin and Sumithrin® [d-(*cis, trans*) phenothrin] were effective in the range of 0.025 lb/A against OP-resistant *Aedes nigromaculis*, with the former being slightly more active.

Against stagnant-water mosquitoes, both Sumithrin and Sumicidin® (α-cyano-m-phenoxybenzyl α-isopropyl-p-chlorophenylacetate) proved effective in the range of 0.025 lb/A, the latter being somewhat more active. In general both compounds controlled mosquito larvae for more than 7 days with 1 treatment.

INTRODUCTION

Recently, substantial advances have been made in improving the larvicidal and adulticidal activity of synthetic pyrethroids against a wide range of mosquitoes. Several of these materials were found to be more active than the most effective and widely used organophosphate larvicides such as Dursban® (chlorpyrifos), Abate® (temephos) and Baytex® (fenthion). At the rate of 0.001 lb/A (1.1 g/ha), decamethrin (FMC-45498) and its chloroanalog FMC-45497 yielded complete control of *Culex tarsalis* Coquillett (Mulla et al. 1978a), thus being 50–100 times as effective as OP larvicides. These pyrethroids were also effective against the resistant and susceptible strains of *Aedes nigromaculis* (Ludlow) larvae in irrigated pastures in Kern and Tulare counties of the southern San Joaquin Valley of California. Permethrin (FMC-33297) at 0.025 lb/A and decamethrin at 0.0025 lb/A produced complete control of *Ae. nigromaculis* larvae (Darwazeh et al. 1978).

Other related pyrethroids were evaluated recently and were found to possess a high level of activity against adults and larvae of several mosquito species, including *Anopheles quadrimaculatus* Say, *Psorophora columbiae* Dyar and Knab, *Cx. peus* Speiser, *Culiseta inornata* Williston, and *An. franciscanus* McCracken (Coombes et al. 1977, Mulla et al. 1975, 1978a, Thompson and Meisch 1977).

At larvicidal rates, the highly active pyrethroids were found to be harmless to 4 species of freshwater fishes. Although moderate reduction in the population of nontarget insects, such as mayfly and dragonfly naiads was observed (Mulla et al. 1978b), the recovery of some of the affected fauna was noted within a week after treatment. The present studies were carried out to obtain information regarding the efficacy of the most effective pyrethroids tested against larvae and pupae of various mosquito species, and to determine the impact of some of these on nontarget organisms in the field.

METHODS AND MATERIALS

LABORATORY. Larvae and pupae of *Cx. quinquefasciatus* (Say) and *Cs. incidens* (Thomson) used in these studies were obtained from laboratory reared colonies at the University of California, Riverside. Larvae and pupae of the other species were collected from field populations and brought into the laboratory for bioassay. These species were: *Cx. tarsalis* (Riverside), *Ae. nigromaculis* (Tulare County), *Ae. taeniorhynchus* Wiedemann (San Diego County) and *Ps. columbiae* Dyar and Knab (Palo Verde Valley).

The pyrethroids evaluated were: decamethrin (FMC-45498 or NRDC-161): (-)-(Cyano)-3--phenoxybenzyl-(+)-*cis*-3-(2, 2-dibromovinyl)-2, 2-dimethylcyclopropane-1-carboxylate; FMC-45497 (NRDC-160): ± *cis* and chloro analog of the former; FMC-35171 (NRDC-148): only contains *cis* isomer of permethrin (NRDC-143): 3-phenoxybenzyl (±) *cis*-*trans*-3-(2, 2-dichlorovinyl)-2, 2-dimethylcyclopropane carboxylate; a formulation of permethrin (SBP-1513); fenvalerate (SD-43775, Pydrin®, Sumicidin®): α-cyano-3-phenoxybenzyl-4-chloro-α-(1-methylethyl) phenylacetate, and Sumithrin®: (3-phenoxybenzyl d-*cis-trans* chrysanthemate (4:1 trans:cis).

Technical grade materials were utilized in preparing 1% stock solutions (W/V) in acetone, and serial dilutions were prepared as needed. The required amount of toxicant was added to 4 oz. waxed paper cups containing 20 4th-stage larvae or 10 pupae in 100 ml of tap water. Each concentration was run in duplicate, and each material was tested 2–3 times on different days. After 24 hr of exposure of the test organisms in a controlled temperature holding room (75°F±1), mortality readings were taken, and the LC_{50} and LC_{90} in ppb were obtained from dosage response lines on probit log paper based on mean mortality values vs. concentrations.

FIELD EVALUATION. Emulsifiable concentrate formulations of permethrin (SBP-1513), and Sumithrin were applied against *Ae. nigromaculis* in a pasture habitat. Two plots per application rate and 2 untreated control plots (1/32 A) were used. Mosquitoes at the time of treatment consisted of 3rd or 4th stage larvae, prevailing in water with dense vegetation over the entire plots. Prior to and 6 and 24 hr after treatment, 10 dips per plot were taken for population assessment. The required amount of toxicant was mixed with 500 ml of tap water and applied with a 1/2 gal stainless steel handsprayer in 4 swaths, covering the entire plot. The % reduction was calculated from the combined average number of larvae and pupae posttreatment as compared to pretreatment populations in the same plots.

Against stagnant water mosquitoes, tests were conducted in ponds at the Aquatic and Vector Control Research Facility in the Coachella Valley of southern California described by Mulla and Darwazeh (1976). These facilities consist of 64 ponds, measuring 18 × 18 ft each. Water to each pond is supplied from an artesian well, through underground pipes. Depth of water in the ponds is kept constant at 12 in by float valves. During these studies (December 1978), mosquito populations consisted of all aquatic stages of *Cx. tarsalis, An. franciscanus* and *Cs. inornata.*

Emulsifiable concentrate formulations of Sumithrin and flowable and encapsulated formulations of fenvalerate (OMS-2000, or Sumicidin) were utilized. The required amount of material was mixed with 100 ml of tap water and applied with an all purpose household (1 qt) sprayer, using 2 ponds per application rate and 2 as checks. Procedures employed in the evaluation of these materials against mosquito larvae and nontarget organisms were described by Mulla et al., 1975. Since efficacy was assessed over a short period of time (1–7 days), % reduction of mosquito larval population was calculated from the posttreatment vs. pretreatment populations in the same ponds.

RESULTS AND DISCUSSION

LABORATORY. Decamethrin was found to be the most effective pyrethroid against the 6 species of mosquitoes (Table 1). It showed a high level of activity against the larvae, possessing an LC_{90} level of about 1 ppb against the least susceptible species. The LC_{90} for the most susceptible species (*Culex* spp) was 0.04–0.08 ppb. The LC_{90} for the most tolerant species was 22 times that of the most susceptible. This material was also highly active against pupae of all 6 species, with an LC_{90} of 0.1 and 1.5 ppb against the most susceptible and most tolerant species respectively.

FMC-45497 (NRDC-160) an analog of decamethrin was also highly active against the various species. The LC_{90} for larvae ranged from 0.08 ppb (most susceptible sp.) to 0.8 ppb (most tolerant sp.), a 10-fold range of concentration. Against pupae, the LC_{90} concentration ranged from 0.3 to 1.6 ppb for the various species. FMC-35171 was somewhat less active than FMC-45497. For the larvae the range of activity (LC_{90}) was in the order of 0.2 to 9.0 ppb (45-fold range of activity). Against pupae FMC-35171 showed activity (LC_{90} level) in the order of 0.8–11 ppb.

Permethrin, an isomer of FMC-35171, was similar in activity to the latter, possessing an LC_{90} of 0.8–5.0 ppb against

Table 1. Susceptibility of larvae and pupae of various mosquito species to synthetic pyrethroids in the laboratory.

Mosquito Species	LC_{50}-LC_{90}(ppb)	
	Larvae[a]	Pupae[b]
	Decamethrin	
Cx. quinquefasciatus	0.02–0.04	0.30–0.5
Cx. tarsalis	0.06–0.08	0.10–0.3
Cs. incidens	0.30–0.90	0.07–0.1
Ae. nigromaculis	0.20–0.55	0.30–0.7
Ae. taeniorhynchus[c]	0.05–0.09	0.55–1.5
Ps. columbiae	0.10–0.30	0.20–0.6
	FMC-45497 (NRDC-160)	
Cx. quinquefasciatus	0.09–0.15	0.60–1.3
Cx. tarsalis	0.10–0.20	0.10–0.3
Cs. incidens	0.30–0.55	0.20–0.5
Ae. nigromaculis	0.35–0.80	0.75–1.6
Ae. taeniorhynchus[c]	0.04–0.08	0.45–1.0
Ps. columbiae	0.20–0.50	0.30–0.7
	FMC-35171 (NRDC-148)	
Cx. quinquefasciatus	0.12–0.20	3.00–11.0
Cx. tarsalis	1.00–2.10	5.00–7.0
Cs. incidens	3.00–9.00	0.35–0.8
Ae. nigromaculis	0.37–0.70	1.50–4.0
Ae. taeniorhynchus[c]	0.40–1.40	3.00–6.0
Ps. columbiae	1.00–2.00	1.00–3.0
	Permethrin	
Cx. quinquefasciatus	1.40–2.50	1.00–5.0
Cx. tarsalis	2.00–4.00	6.00–16.0
Cs. incidens	3.00–5.00	0.70–1.40
Ae. nigromaculis	0.50–0.80	0.90–2.0
Ae. taeniorhynchus[c]	0.50–1.30	1.40–3.8
Ps. columbiae	1.50–3.00	2.00–4.0
	Fenvalerate	
Cx. quinquefasciatus	4.70–8.00	6.00–13.0
Cx. tarsalis	4.00–8.00	12.00–30.0
Cs. incidens	5.50–10.00	1.20–5.8
Ae. nigromaculis	2.80–10.00	1.50–4.0
Ae. taeniorhynchus[c]	0.90–2.00	— —
Ps. columbiae	28.00–50.00	53.00–82.00

[a] 4th stage larvae.
[b] 24 hr. old pupae.
[c] Similar results with salt and tap water.

larvae of the various species. Against pupae its range of activity (LC_{90} level) was in the order of 1.4–16 ppb. Fenvalerate was the least active pyrethroid, having an LC_{90} of 2–10 ppb against larvae and 4–82 ppb against pupae. From these studies it is apparent that the synthetic pyrethroids are some of the most effective mosquito larvicides evaluated. It is also important to note that these compounds have a very high level of activity against pupae and that they are effective at low concentrations.

FIELD. The 5 synthetic pyrethroids (Table 1) which showed a high level of activity in the laboratory have already been studied in the field against various species of mosquitoes (Darwazeh et al. 1978, Mulla and Darwazeh 1976, Mulla et al. 1978a). The gist of the effectiveness of these pyrethroids is presented in Table 2. The trend of field activity is in the same order as found in laboratory; decamethrin and its close analog FMC-45497 being the most effective pyrethroids evaluated. The two currently available pyrethroids (permethrin and fenvalerate) although less effective than decamethrin and its analog, were still effective, showing efficacy in the range of 0.01–0.025 lb/A (permethrin) and 0.025–0.1 lb/A (fenvalerate). Fenvalerate possesses high acute toxicity to most freshwater fishes (Mulla et al. 1978b) and therefore offers low potential as a mosquito larvicide in most situations.

During the current field studies, a new formulation of permethrin (SBP-1513) was evaluated against OP resistant *Ae. nigromaculis* in Tulare County (Table 3). The efficacy of this formulation was essentially the same as that found in previous studies (Mulla et al. 1978a), its activity being in the range of 0.01–0.025 lb/A.

Another synthetic pyrethroid, Sumithrin, when evaluated against *Ae. nigromaculis* gave excellent control at the rate of 0.025 lb/A (Table 3). The effectiveness of this compound against this OP-resistant population is in the range of 0.025–0.05 lb/A.

Against stagnant-water mosquitoes (*An. franciscanus* and *Cs. inornata*), Sumithrin proved quite effective (Table 4). At the rate of 0.05 lb/A it yielded good to complete control of these 2 species for a week or longer. The level of suppression of *Cx. tarsalis* was lower. Two formulations of fenvalerate at 0.025–0.05 lb/A yielded good to complete control of *An. franciscanus* and *Cs. inornata* for more than 7 days. The 10% flowable formulation was more effective than the 5% encapsulated material against *Cx. tarsalis*. It produced complete control of this species at both rates, 7 days after treatment. The delayed effectiveness against some of the species could be due to the very cold water temperature during the course of these field trials.

EFFECTS ON NONTARGET ORGANISMS. During the course of studies on the effi-

Table 2. Field efficacy of synthetic pyrethroids against mosquito larvae in various habitats[a].

Materials and Formulations			Rates (lb/A) needed to produce 90–100% control of	
Code No.	Common Name	Trade Name	Floodwater mosquitoes[b]	Stagnant water mosquitoes[c]
FMC-45498	decamethrin	K'othrin	0.0025–0.005	0.00025–0.0005
FMC-45497	—	—	— —	0.0005–0.001
FMC-35171	—	—	— —	0.005–0.025
FMC-33297	permethrin	Ambush	0.01–0.025	0.010–0.025
SD-43775	fenvalerate	Pydrin®, Sumicidin®	0.025–0.10	0.025–0.10

[a] From Darwazeh et al. (1978), Mulla and Darwazeh (1976), Mulla et al. (1978a).
[b] *Ae. nigromaculis* and *Ps. columbiae*.
[c] Consisting of *Cx. tarsalis, An. franciscanus, Cs. inornata*.

Table 3. Evaluation of synthetic pyrethroids against larvae of *Aedes nigromaculis* in irrigated pasture (Tulare County, 1978).

Material and formulation	Rate lb/A	Avg no of larvae/10 dips pre and post-treat (hr) and % reduction (R)				
		Pretreat	6	(% R)	24	(% R)
SBP-1513						
(permethrin)	0.005	183	16	91	37	80
EC 1	0.010	208	8	96	5	98
	0.025	121	4	97	3	98
Sumithrin	0.005	347	94	73	84	76
EC 2	0.010	112	55	51	26	76
	0.025	110	13	88	8	93
Check	0.	115	134	0	153	0

cacy of new mosquito larvicides in the field, several nektonic and benthic organisms were sampled by the dipping method. Quantitative assessment of the numbers of these organisms sampled prior to and after treatment with the larvicides provide valuable preliminary information on the acute toxicity of the larvicides to these organisms sampled.

Among the aquatic invertebrates, mayfly naiads of the family Baetidae are dominant in our mosquito breeding sources. These insects have been found to be highly susceptible to most mosquito larvicides.

Permethrin (FMC-33297) eliminated mayfly naiads at larvicidal rates (0.01–0.05 lb/A) for stagnant-water mosquitoes (Mulla and Darwazeh 1976, Mulla et al. 1978a). At the 2 higher rates (0.025 and 0.05 lb/A) for stagnant-water mosquitoes dragonfly naiads for more than 7 days after treatment (Mulla and Darwazeh 1976).

Decamethrin, FMC-45497 and fenvalerate also proved highly toxic to mayfly naiads. Fenvalerate was the most toxic while FMC-45497 the least toxic. Decamethrin at larvicidal rates was quite toxic to these highly susceptible organisms (Mulla et al. 1978a).

Similar data on the effects of the new larvicides or formulations studied here were gathered (Table 5). Sumithrin and fenvalerate proved toxic to mayfly naiads at larvicidal rates. There was a great deal of difference in the toxicity of the 2 formulations of fenvalerate. The 10% flowable formulation which proved more effective against mosquitoes was also more toxic to mayfly naiads than the 5% encapsulated formulation.

Dragonfly naiads were affected markedly by both rates of fenvalerate employed. None of the other materials produced very marked reduction of dragonfly naiads. Diving beetle larvae and adults were not seriously affected by any of the compounds except fenvalerate which caused their suppression for a short period. Ostracods and damselfly naiads were not affected markedly by any of the compounds.

From these studies it is apparent that the most susceptible organisms, the mayfly naiads are affected by the test compounds, but none of the other groups (damselfly, dragonfly naiads, diving beetle larvae) are seriously affected at larvicidal rates. With the exception of fenvalerate, the other synthetic pyrethroids do not seem to possess any more toxicity to nontarget organisms than most of the currently used organophosphate larvicides. At mosquito larvicidal rates most of these pyrethroids induced little or no marked, prolonged effects on most of the nontarget biota observed.

References Cited

Coombes, L. E., Baldwin, K. F., Meisch, M. V., Mount, G. A., Pierce, N. W. and Thompson, G. D. 1977. Toxicity of pyrethroid insecticides aerosols to *Anopheles quadrimaculatus*

Table 4. Evaluation of various synthetic pyrethroids against mosquito larvae in experimental ponds (Coachella Valley, 1978).

Material and formulation	Rate lb/A	Avg no of larvae/5 dips and (%) reduction (R) after treatment (days)														
		An. franciscanus					*Cx. tarsalis*					*Cs. inornata*				
		Pre	2	(% R)	7	(% R)	Pre	2	(% R)	7	(% R)	Pre	2	(% R)	7	(% R)
Sumithrin[a]	0.025	4	1	75	1	75	23	11	52	11	52	9	1	89	7	22
EC 2	0.050	17	0	100	0	100	11	4	64	2	82	6	0	100	2	67
Fenvalerate[b]	0.025	10	1	90	0	100	2	2	0	1	50	14	4	71	0	100
(5%) Encap.	0.050	3	1	67	0	100	25	18	28	7	72	39	7	82	2	95
Fenvalerate[b]	0.025	18	1	94	0	100	6	1	83	0	100	11	1	91	0	100
(10%) flowable	0.050	2	1	50	0	100	6	3	50	0	100	50	8	84	0	100
Check	0	13	14	0	7	46	11	9	18	4	64	4	3	25	8	0

[a] Water temp. 50°F min.—60°F max. during the experiment.
[b] Water temp. 42°F min.—52°F max. during the experiment.

Table 5. Effect of various synthetic pyrethroids on various species of nontargets in experimental ponds (Coachella Valley, 1978).

Material and Formation	Rate lb/A	Avg no of nontarget organisms/5 dips pre and post-treat (days)														
		Mayfly naiads			Dragonfly naiads			Diving beetle larvae			Ostracods			Damselfly naiads		
		Pre	2	7	Pre	2	7	Pre	2	7	Pre	2	7	Pre	2	7
Sumithrin	0.025	141	0	0	15	0	4	8	0	3	0	0	0	2	0	1
EC 2	0.050	112	0	0	18	0	0	4	0	3	0	0	0	3	0	0
Fenvalerate	0.025	15	66	12	2	1	1	4	2	3	25	2	21	1	2	1
(5%) Encap.	0.050	31	27	7	8	5	8	1	4	2	389	429	460	1	1	1
Fenvalerate	0.025	90	6	0	3	8	1	6	8	3	1	1	0	1	1	0
(10%) flowable	0.050	27	3	0	7	5	1	1	6	2	10	6	15	0	0	0
Check	0	124	74	64	11	4	7	5	3	4	0	0	1	4	2	2

Say and *Psorophora columbiae* (Dyar and Knab) in Arkansas. Mosq. News 37:268–271.

Darwazeh, H. A., Mulla, M. S. and Whitworth, B. T. 1978. Synthetic pyrethroids for the control of resistant mosquitoes in irrigated pastures. Proc. Calif. Mosq. Cont. Asso. 46: 121–122.

Mulla, M. S. and Darwazeh, H. A. 1976. The IGR Dimilin® and its formulations against mosquitoes. J. Econ. Entomol. 69:309–12.

Mulla, M. S., Darwazeh, H. A. and Majori, G. 1975. Field efficacy of some promising mosquito larvicides and their effects on nontarget organisms. Mosq. News 35:179–185.

Mulla, M. S., Navvab-Gojrati, H. A. and Darwazeh, H. A. 1978a. Biological activity and longevity of new synthetic pyrethroids against mosquitoes and some nontarget insects. Mosq. News 38:90–96.

Mulla, M. S., Navvab-Gojrati, H. A. and Darwazeh, H. A. 1978b. Toxicity of mosquito larvicidal pyrethroids to four species of freshwater fishes. Environ. Entomol. 7: 428–430.

Thompson, G. D. and Meisch, M. V. 1977. Efficacy of permethrin as a larvicide and adulticide against ricefield mosquitoes. J. Econ. Entomol. 70:771–74.

EFFECT OF PASTURE BURNING ON SURVIVAL OF *AEDES* MOSQUITO EGGS

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ABSTRACT. Burning dry dormant pasture grass was tested as a means of controlling the mosquitoes *Aedes nigromaculis* (Ludlow) and *Aedes melanimon* Dyar by destroying their eggs. Test plots containing bermuda grass (*Cynodon dactylon*) were ignited and allowed to burn. The method, however, did not significantly reduce mosquito larval production. Temperature measurements with heat sensitive, lacquered probes showed that lethal temperatures are often not attained near ground level where most eggs are deposited.

INTRODUCTION

The multivoltine *Aedes nigromaculis* (Ludlow) and *Ae. melanimon* Dyar are 2 major species of pest mosquitoes in the central valley of California. Both are found in irrigated pastures and other similar floodwater habitats. Their eggs, which are deposited at the base of vegetation during summer and early autumn, are quiescent during winter.

During the winter, most of the above ground vegetation containing the eggs is killed by frost, creating a flammable material after the moisture content drops in late winter. If the overwintering eggs could be destroyed (i.e. by fire) before irrigations begin the following growing season then initial mosquito control measures could be postponed until reinfestation by immigrating females occurs. In California, the use of fire to destroy mosquito eggs has not been reported. However it could be an inexpensive practical control technique in limited situations, i.e. bermuda grass (*Cynodon dactylon*) pastures where vegetative regrowth occurs in the spring despite winter burning.

In the Don delta, U.S.S.R., Shumkov (1969) conducted tests to ascertain reductions in mosquitoes coincidental with control burning of marshy vegetation during autumn. He concluded that there