Bull. Environm. Contam. Toxicol. 26, 689-695 (1981)

Impact and Joint Action of Decamethrin and Permethrin and Freshwater Fishes on Mosquitoes

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In studies on the efficacy of mosquito larvicides, several new pyrethroids demonstrated excellent biological activity against several species of mosquitoes in the laboratory and under field conditions (MULLA et al. 1978a). Many of these materials proved more effective than the widely-used organophosphorus larvicides such as temephos and chlorpyrifos (MULLA & DARWAZEH 1980). At the rate of 0.001 and 0.025 lb/A (1.1 and 28 g/ha) decamethrin and permethrin, respectively, produced excellent control of various species of stagnant- and floodwater-breeding mosquitoes, including the multi-resistant strain of *Aedes nigromaculis* Ludlow in irrigated pastures of Tulare County in the San Joaquin Valley of California (DARWAZEH et al. 1978).

To facilitate registration of some of these promising pyrethroids for vector control programs, studies are needed to gather information on their impact on the macroinvertebrates which coexist with the immature stages of mosquitoes. In addition, the toxic hazards of these materials have to be assessed on predatory and food fish species which may prevail in mosquito-breeding sources or found in sites subjected to water inflow from treated areas, which may induce chronic or acute effects in resident fish populations.

As reported earlier (MULLA et al. 1978b), some of these pyrethroids were found to possess a good margin of safety against four species of freshwater fishes, namely the mosquitofish *Gambusia affinis* (Baird and Girard), *Tilapia mossambica* (Peters), rainbow trout *Salmo gairdneri*, and the desert pupfish *Cyprinodon macularius* (Baird and Girard).

Solvents utilized in the formulations of the pyrethroids could contribute to the toxicity of the pyrethroids against fish and some aquatic organisms. COATS & O'DONNELL (1979) obtained lower mortality with technical grade materials against rainbow trout *S. gairdneri*, while the same material in emulsifiable concentrate formulation resulted in higher mortality at the same rate. Pyrenone tossits containing 1% pyrethrins as emulsifiable formulation also caused some mortality in caged mosquitofish *G. affinis*, while free swimming fish were not affected at the effective larvicidal rate of 1 tossit/100 ft^2 (44 g/ha). At the same rate, mayfly naiads were drastically affected, but recovered 2 weeks later, while no effect was observed against dragonfly naiads, ostracoda, copepods, and dixa midge larvae (DARWAZEH & MULLA 1981).

0007-4861/81/0026-0689 $01.40

The current studies were initiated to determine the impact of repeated applications of emulsifiable concentrate formulations of the most promising pyrethroids on the survival and reproduction of the mosquitofish *G. affinis* and the desert pupfish *C. macularius*.

METHODS AND MATERIALS

Three separate tests were conducted on three different occasions, and were conducted as follows:

Test A. Decamethrin and permethrin emulsifiable concentrates were applied weekly for 8 successive weeks (Sept. 5--Oct. 23, 1978) against 2 fish species, utilizing 2 replicates per application rate, and 2 ponds of each fish species were left untreated with the insecticides as checks.

Test B. Decamethrin emulsifiable concentrate formulation was applied weekly for 6 successive weeks (July 16--Aug. 20, 1979) against *G. affinis*, utilizing 4 replicates per application rate and 4 checks.

Test C. Permethrin emulsifiable concentrate formulation was applied weekly for 6 successive weeks (Sept. 17--Oct. 22, 1979) against *G. affinis*, utilizing 4 replicates per application rate and 4 checks.

All three tests were conducted in experimental ponds at the Aquatic and Vector Control Research Facility at the University of California, Riverside. These ponds were specially designed for biological control studies, and consist of 12 ponds, constructed in 3 rows, 4 ponds per row (LEGNER & MEDVED 1973, DARWAZEH & MULLA 1981). Each pond measured 5.5 x 7.6 m, and water level (supplied from irrigation reservoirs) was maintained constant at 30 cm by the use of float valves. The ponds are provided with a drainage system through 10-cm pipe placed in the bottom of each pond, leading into 2 m^3 concrete weir structure. Each pond could be drained separately within 15-20 min by removing a screw cap at the end of the drain pipe, and organisms in each pond could be drained and retrieved in a 1 m^3 window screened cage. After each test, the ponds were allowed to dry for 2-3 weeks, then were cleaned and reflooded.

Ten days after the flooding, when mosquito larvae and other aquatic organisms became abundant, 20 individuals with an average length of 2.5-3.0 cm of *G. affinis* or *C. macularius* were transferred from the culture ponds into the test ponds. Treatment began after allowing the fish to acclimate in the test ponds for 2-5 days.

Emulsifiable concentrate formulation of the pyrethroids tested were provided by FMC Corp., Agricultural Chemical Div., Middleport, NY, 14105, and were applied at the effective mosquito larvicidal rate and 5 times that rate. Permethrin (FMC-33297) EC 3.2 was tested at 0.025 and 0.125 lb/A (28 and 140 g/ha), while decamethrin (FMC-45498) EC 0.21 was tested at 0.001 and 0.005 lb/A (1.1 and 5.5 g/ha). The required amount of toxicant was mixed with 120 mL of water, and applied with an all purpose 1-L household sprayer. Water temperature was monitored with a Mini-Max recording thermometer (Markson Science Inc.), and the mean minimum and mean maximum temperatures are shown in the tables. Water pH in the ponds was in the range of 8.0-8.2, and mosquito larval populations consisted mostly of Culex tarsalis Coquillett.

One week after the last scheduled treatment of each test, the ponds were drained, and all the fish present were recovered and counted. To determine the impact of the pyrethroid and the predatory fishes on mosquito larval populations, 5 dips per pond were taken prior to and 2, and 7 days after each treatment.

RESULTS AND DISCUSSION

At the mosquito larvicidal rate, and 5 times the required larvicidal rate, both decamethrin and permethrin produced no adverse effects in the two species of fish tested. Successive weekly applications (6-8) of the pyrethroids did not lower productivity of these fishes when subjected to treatments at the rate of 0.001 and 0.005 lb/A of decamethrin (FMC-45498), and 0.025 and 0.125 lb/A of permethrin (FMC-33297). Even under the weekly treatment regimen, the number of fish in all the ponds increased markedly during the duration of the experiments. Fish harvested from treated ponds were equal to or more than those harvested from the untreated ponds (checks) with chemicals. High number of fish obtained in test (B) is attributed to optimum climatic conditions rather than to the influence of the materials applied. Test A and C were conducted during the months of September-October when temperatures are cooler, while test B was conducted during the warm summer months of July and August (Tables 1-2).

Mosquito larval population during the summer, when water temperature was in the range of 71-80°F, was immediately eliminated after the first treatment with the high rate of 0.005 lb/A of decamethrin. At the lower rate of 0.001 lb/A, this material produced complete control of all the larval stages 2 days after each treatment, but a few young larvae (1-2 stages) were retrieved 7 days after each treatment for a period of 3 weeks after start of the chemical treatments. One week after the third treatment, mosquito larval breeding also was eliminated in the untreated ponds as well, 25 days after stocking the ponds with the fish. By this time the fish reproduced to sufficient numbers to decimate mosquito larvae. These findings indicate that reduction in mosquito larval population due to predation of the fish will require about 3 weeks without the integration of chemical and biological control measures.

TABLE 1. Impact of successive weekly treatments with pyrethroids on the productivity of the mosquitofish *G. affinis* in experimental ponds stocked with 20 fish.

Material and Formulation	Application Rate ppb	g/ha	lb/A	Avg. no. of fish/pond on termination
	Test (A) Sept.-Oct. 1978			
FMC-45498 EC 0.21 (decamethrin)	0.4	1.1	0.001	127[a/]
	2.0	5.5	0.005	320[a/]
FMC-33297 EC 3.2 (permethrin)	9.0	28	0.025	345[a/]
	45	140	0.125	127[a/]
Check	-	-	-	125
	Test (B) July-Aug. 1979			
FMC-45498 EC 0.21 (decamethrin)	0.4	1.1	0.001	719[b/]
	2.0	5.5	0.005	886[a/]
Check	-	-	-	705[b/]
	Test (C) Sept.-Oct. 1979			
FMC-33297 EC 3.2 (permethrin)	9.0	28	0.025	209
	45	140	0.125	57
Check	-	-	-	66

Test A. Water temp. mean min. 65°F (18.3°C) mean max. 75°F (23.8°C).
Test B. Water temp. mean min. 71°F (21.6°C) mean max. 80°F (26.6°C).
Test C. Water temp. mean min. 66°F (18.8°C) mean max. 77°F (25°C).
a/Heavy alga growth in all replicates.
b/Light alga growth in one replicate only.

TABLE 2. Impact of successive weekly treatments of pyrethroids on productivity of the desert pupfish *C. macularius* in experimental ponds stocked with 20 fish[a/].

Material and Formulation	Application Rate ppb	g/ha	lb/A	Avg. no. of fish/pond on termination[b/]
FMC-45498 EC 0.21	0.4	1.1	0.001	278
	2.0	5.5	0.005	325
FMC-33297 EC 3.2	9.0	28	0.025	1012
	45	140	0.125	145
Check	-	-	-	120

a/Algae present on water surface in all treatments except check.
b/Temperatures the same as in Test A, Table 1.

TABLE 3. Joint action of the mosquitofish and the pyrethroid decamethrin against larvae of Cx. tarsalis in experimental ponds stocked with 20 fish and treated weekly with the pyrethroid[a/].

Wkly treat. no.	Avg. no. larvae/5 dips pre- and posttreatment (days)								
	0.001 lb/A			0.005 lb/A			Check[b/]		
	Pre[b/]	2[c/]	7	Pre	2	7	Pre	2	7
1	187	0	18	210	0	0	195	177	202
2	18	4	15	0	0	0	202	247	243
3	15	2	0	0	0	0	243	125	0
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0

[a/] Test B (July-Aug. 1979), water temp mean min. 71°F, mean max. 80°F and each pond was stocked with 20 fish prior to the first treatment.

[b/] All stages of larvae present.

[c/] 1-2 stage larvae present.

Permethrin at the low rate of 0.025 lb/A also produced similar results against mosquito larvae. Reduction in larval density, however, was gradual, and they were completely eliminated in all the ponds, receiving the treatments as well as the ponds with fish alone after the sixth and final treatment. Only (1-2) stage larvae persisted after the first treatment in treated ponds, while all stages were present in the check (fish only) for 5 weeks, but these began to decline drastically after the sixth and final week of the experiment. At the high rate of 0.125 lb/A, permethrin controlled mosquito larvae completely after each treatment, but breeding of a few young larval stages persisted for 3 weeks after start of treatments, and then were completely eliminated after the third treatment (Table 4). The larval population in check ponds (fish alone) persisted in fairly good numbers through the end of the experiment. This clearly shows that under cooler conditions, it takes much longer for the mosquitofish to affect high level of regulation over mosquito larvae. Elimination of larvae by the fish occurred after 3 weeks of stocking in July (see Table 3) as compared to 6 weeks in an experiment initiated in September.

These findings indicate that the predation rate of the mosquitofish on mosquito larvae was negligible initially, but increased as the number of fish increased in the ponds. Mosquito larval breeding was eliminated within 3 wk in the summer, while requiring more than 6 wk in the fall when fish growth and reproduction were slow. An average of 705 individuals were recovered from untreated ponds in the summer (Test B), compared to 100 fish/pond from the untreated ponds in the fall (Tests A and C). In other studies CHALLET et al.

(1974) have reported that G. affinis growth and production was at its peak during the month of July.

TABLE 4. Joint action of mosquitofish and permethrin against larvae of Cx. tarsalis in experimental ponds stocked with 20 fish and treated weekly with the pyrethroid[a/].

Wkly treat. no.	Avg. no. of larvae/5 dips pre- and posttreatment (days)								
	0.025 lb/A			0.125 lb/A[b/]			Check[b/]		
	Pre[b/]	2[c/]	7[b/]	Pre	2	7	Pre	2	7
1	113	19	340	81	0	20	90	23	594
2	340	46	121	20	0	10	594	593	471
3	121	6	65	10	0	0	471	475	412
4	65	6	29	0	0	0	412	360	268
5	29	0	3	0	0	0	268	199	88
6	3	0	0	0	0	0	88	57	3

[a/] Test C (Sept.-Oct. 1979), water temp mean min. 66°F, mean max. 77°F, and each pond was stocked with 20 fish prior to the first treatment.

[b/] All stages of larvae present.

[c/] 1-2 stage larvae present.

In conclusion, permethrin and decamethrin, at the rates applied, showed no acute direct effects on the productivity of G. affinis and C. macularius. Mats of algae (Cladophora sp.) were formed in treated ponds, especially at the higher rates, providing shelter for the young fry to escape cannibalism by the older fish (JOHNSON 1978), resulting in optimum survival rate for the young. Therefore, more fish were recovered from the treated ponds than the untreated (checks), which were free of algal growth (Tables 1-2). The pyrethroids stimulated algal blooms and mats by probably eliminating herbivorous arthropods.

Permethrin and decamethrin displayed no residual activity against mosquito larvae at all rates applied. These materials break down within a week in water, and weekly treatments, therefore, are essential for the control of mosquito larvae in stagnant water habitats, where mosquito larval breeding is continuous.

REFERENCES

CHALLET, G. L., G. T. REYNOLDS and D. L. ROHE: Proc. and Papers Calif. Mosq. & Vector Contr. Assoc. 42: 55 (1974).

COATS, J. R., and J. O'DONNELL: Bull. Environ. Contam. Toxicol. 23: 250 (1979).

DARWAZEH, H. A., and M. S. MULLA: Pyrethrin tossits against mosquito larvae and their effects on mosquitofish and non-target organisms. Mosq. News. In press, (1981).

DARWAZEH, H. A., M. S. MULLA, and B. T. WHITWORTH: Proc. and Papers Calif. Mosq. & Vector Contr. Assoc. 46: 121 (1978).

JOHNSON, C. R.: Proc. and Papers Mosq. & Vector Contr. Assoc. 44: 48 (1976).

LEGNER, E. F., and R. A. MEDVED: Proc. and Papers Calif. Mosq. & Vector Contr. Assoc. 41: 119 (1973).

MULLA, M. S., and H. A. DARWAZEH. Mosq. News 40: 6 (1980).

MULLA, M. S., H. A. NAVVAB-GOJRATI, and H. A. DARWAZEH: Environ. Entomol. 7: 428 (1978b).

Accepted February 24, 1981