IMPACT OF FENOXYCARB, A CARBAMATE INSECT GROWTH REGULATOR, ON SOME AQUATIC INVERTEBRATES ABUNDANT IN MOSQUITO BREEDING HABITATS

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ABSTRACT. The insect growth regulator, Fenoxycarb, induced various morphogenetic aberrations in *Notonecta unifasciata*, *Anax junius* and *Pantala hymenaea* after treatment of late nymphal stages. Most affected nymphs died while molting from nymphs to adults. Fenoxycarb is also ovicidal to young eggs of *N. unifasciata*. The treatment rate of 0.034 kg AI/ha fenoxycarb induced some reduction in *N. unifasciata* population densities and produced a few morphogenetic abnormalities in some Odonata. However, planktonic organisms and aquatic beetles regularly found in the mosquito breeding habitats showed no deleterious effect.

INTRODUCTION

In recent years, several new carbamates, which have modes of action similar to insect growth regulators, have received much attention as a potential measure for control of various insect pests (Kramer et al. 1981, Robertson 1982, Parrella et al. 1982, Jones 1984). Schaefer et al. (1985, 1986) reported that RO 16-1294, RO 16-1295 and Fenoxycarb were highly effective against immature *Aedes* spp. and *Culex* spp. Mulla et al. (1985, 1986) reported that fenoxycarb showed very high efficacy against mosquito larvae in laboratory and field tests. The objective of this report is to evaluate the impact of fenoxycarb on selected aquatic organisms prevailingly found in mosquito breeding habitats.

MATERIALS AND METHODS

The solubility of Fenoxycarb (Maag Agrochemical Co., Vero Beach, FL) in water is about 6 ppm. It is moderately stable in distilled or clear untreated tap water at temperatures of 10–38°C and a pH range from 6.5–10 (Schaefer et al. 1987). However persistence is reduced, seemingly in decaying exponential form, whereby over 70% is lost in 24 h when as little as ¼ of 1% wt × wt straw is added to treated water (Schaefer et al. 1986). Other tests of the same study indicate that other organic material reduces persistence as well. Therefore application of Fenoxycarb in any body of water containing organic material (eg. leaves, grass, etc.) is likely to persist only for a relatively short time.

For laboratory tests, serial dilutions were made from the technical material in acetone solution using untreated underground tap water as diluent. Six liter glass aquaria and 10 × 8 cm storage dishes were used as test chambers for notonectids and Odonata, respectively. All tests were conducted at 27 ± 1°C under a photoperiod of 14:10 L:D. For field tests, EC formulations (125 g/liter) were used.

Laboratory tests—Odonata. Field collected *Anax junius* (Drury), *Pantala hymenaea* (Say) and *Enallagma civile* (Hagan) were used in these tests. Late instar nymphs (10th and 11th instars) were kept individually in a chamber and exposed to serial dilutions of 1.0 to 0.0001 ppm until emergence of adults, each dosage was replicated 10 times during the test period. Each test animal was provided with a 2 × 15 cm nylon hardware cloth for emergence site and fed daily with mosquito larvae. Tests were held until all nymphs had died or emerged as adults (mean 17 days, SE 0.51).

Hemiptera. Field collected *Notonecta unifasciata* Guerin, nymphs (4th and 5th stadia) and newly deposited eggs (<24 h-old) were used for the tests. Treatment rates used for nymphal stages were 1.0, 0.1, 0.075, 0.05, 0.01, 0.005 and 0.001 ppm and for eggs were 0.1, 0.01, 0.001, 0.0001 and 0.0001 ppm. Ten nymphs or 30 to 150 eggs were used in each test chamber and repeated three times. Post treatment observations were made daily until adult emergence (avg. 6.5 days, SE 0.26) or hatch. Mosquito larvae were provided as a food source.

Field tests. Studies were conducted in experimental rice plots at the University of California Kearney Agricultural Center near Parlier. The facility consists of 12 plots in 4 rows; each plot measures $(6.1\ m)^2$ and 0.5 m deep. Water to each plot was supplied from a reservoir through an underground pipeline and water depth was maintained by float valves. Rice (Cal Pearl) was seeded in early May. Water temperature at 5 cm below the surface and air temperatures were taken with recording thermographs.

Six adjacent plots were used to determine effects of Fenoxycarb on aquatic organisms inhabiting the plots; three of the plots were hand sprayed with a 12 liter stainless steel can sprayer at a rate of 0.034 kg AI/ha (0.03 lb/acre). The required amount of EC formulation was pipetted into the sprayer containing 3 liters of dilution

water, the spray was mixed by shaking and then sprayed from the perimeter toward the center as evenly as possible. The three remaining plots were left untreated and used as controls.

Dipping, trapping and netting, were used to monitor invertebrate population densities in the plots. Twelve dip samples for plankton were taken daily from each plot with a standard 450 ml mosquito dipper. Dip samples from the same plot were concentrated through 70 mesh/cm screens combined in a vial and taken to the laboratory for examination and counting with stereomicroscopes. For monitoring necton, two unbaited modified minnow traps (Miura and Takahashi 1975) were set in each plot during the morning and retrieved the next morning for counting. All trapped organisms were identified, counted and returned to the plots. Net samples were taken with a sweep net (22 cm in diam., 1 mm openings) to monitor notonectid population densities. Four 1-m sweeps were taken at the corners of each plot or wherever the surface water was open to permit making 1-m sweeps; captured bugs were counted and returned at the captured site.

Percentage reduction of densities due to treatment was calculated by the following formula (Henderson 1955):

$$\% \text{ reduction} = 100\left[1 - \frac{Ta \times Cb}{Tb \times Ca}\right]$$

where Tb is the pretreatment mean count and Ta is the posttreatment mean in the treated plots. Cb is the pretreatment mean and Ca is the posttreatment mean in the untreated plots.

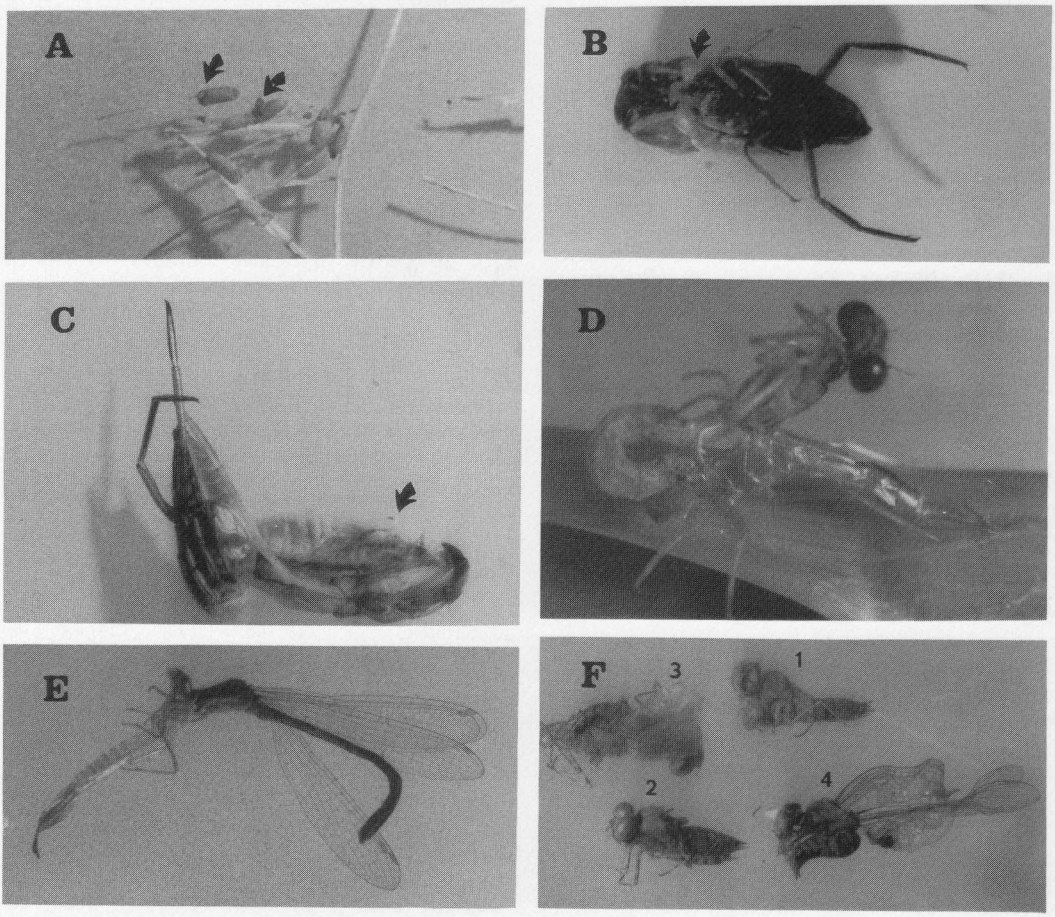

Fig. 1. Morphological aberration induced by Fenoxycarb treatment in the laboratory: A—partially hatched *Notonecta unifasciata* embryos (arrows); B—partially emerged adult *N. unifasciata* (arrow points to nymphal compound eye; C—almost emerged *N. unifasciata* adult (arrow) but hind legs and tip of abdomen restrained within nymphal case; D—adult *Enallagma civile* attached to nymphal case by wings; E—adult *E. civile* attached to nymphal case by head capsule and legs; F—*Pantala hymenaea* (1 and 2) head and partial thorax liberated, (3 and 4) adults with deformed wings.

RESULTS AND DISCUSSION

Laboratory tests. Table 1 shows the toxicity of Fenoxycarb against egg and nymphal stages (4th and 5th) of *N. unifasciata* and late nymphal stages (10th and 11th) of *E. civile*. *Anax junius* and *P. hymeraea* were also exposed to 0.01 ppm solution but the tests were terminated after 40-plus days observation because of a high mortality in controls, but pointed to the fact that no acute mortality occurs with the compound.

Effects of insect growth regulators, in general, appear to be selective towards insects, however, Fenoxycarb has been known to have broad activity against a relatively wide group of insects (Dorn et al. 1981, Kramer et al. 1981, Parrella et al. 1982, Robertson 1982, Masner et al. 1983, Mulla et al. 1985, Schaefer et al. 1985). Ovicidal activity to some species of insects was also reported (Fenoxycarb, Environmental Impact Summary by Maag Agrochemical Co., Jan. 15, 1985).

Fenoxycarb induced varying degrees of morphogenetic aberrations. Treatment of recently oviposited eggs (<24 h-old) of *N. unifasciata* with various concentrations produced dead embryos; apparently Fenoxycarb did not interfere with the development of embryos but treated eggs were unable to hatch, death occurred during hatching (Fig. 1). Treatment of 4th and 5th nymphal stages of *N. unifasciata* produced various degrees of morphogenetic abnormalities, which occurred primarily at the nymph–adult ecdysis; treated 4th stage nymphs usually molted to the 5th stage without any visible abnormalities, but affected 5th stage nymphs were unable to emerge to adult stage (Fig. 1).

Morphogenetic aberrations were also observed in treated Odonata; abnormalities were only visible at the nymph–adult molting; younger nymphs molted to older nymphs without apparent difficulty.

Table 1. Toxicity of Fenoxycarb against egg and nymphal stages of *Notonecta fasciata* and *Enallagma civile* nymphs expressed in percent mortalities.

Rate (ppm)	*N. unifasciata*		*E. civile*
	Egg	Nymph	Nymph
0.00001	6	—	—
0.0001	35.6	—	51.5
0.001	74.7	0	68
0.005	—	71.6	—
0.01	94.2	67.9	94.5
0.05	—	72.0	—
0.075	—	65.9	—
0.1	98.6	91.7	99.5
1.0	—	99.9	100
Duration of test	15 days	13 days	40 days

Typical abnormalities we observed in the laboratory and field tests are as follows:

A. *N. unifasciata* (Fig. 1)
   1. Dead embryos in egg shells.
   2. Dead adults in nymphal skins.
   3. Partly exuviated adults from nymphal skins
B. Odonata (Fig. 1 and 2)
   1. Dead newly formed adults in nymphal skins.
   2. Partly exuviated adults.
   3. Adults with deformed wings.

Field studies. Table 2 shows the results of dipper collections for zooplankton and immature insects captured by the different sampling methods. Planktonic organisms captured in significant numbers by dipping were cladocerans (*Simocephalus* sp., *Ceriodaphnia* sp. and *Alona* sp.); copepods (*Cyclops vernalis* Fisher) and Chironomidae (*Pentaneura* sp., *Chironomus stigmaterus* Say). A few hydra were captured as well. Percent reduction calculations of these sampling data showed little or no difference between treated and control population densities of these organisms during study period.

Table 3 shows the results of trap collections. This method yielded rather low numbers. Necton captured were mayfly nymphs (*Callibaetis* sp.), dragonfly nymphs, *Pantala hymenaea* (Say), *Anax junius* (Drury) and adults and larvae of aquatic beetles *Laccophilus decipiens* Le Conte, *Tropisternus lateralis* (F.). Among the

Table 2. Effects of 0.034 kg AI/ha Fenoxycarb treatments to (6.1 m)^2 rice plots on zooplankton and immature insects. Each number in the table is an average sampled per 12 dips/plot/day.

Organisms	Pre-	Posttreatment (day)				
	1	0	1	2	5	6
	Treated plots					
Daphnidae	218	286	192	214	109	179
Chydoridae	54	127	49	22	27	38
Cyclopidae	453	170	139	51	95	147
Hydra	0.5	0.5	0	0	2	4
Mayfly (N)[a]	4	0.5	0.25	4	2	2
Laccophilus (L)[a]	0	3	1	3	0	3
Tropisternus (L)	3	3	3	3	2	3
Chironomidae (L)	10	39	9	20	55	64
	Control plots					
Daphnidae	444	369	350	310	97	198
Chydoridae	157	110	72	54	67	27
Copepod	436	291	270	171	84	126
Hydra	0	1	1	2	2	8
Mayfly (N)	1	0	0	1	1	2
Laccophilus (L)	5	1	2	3	1	1
Tropisternus (L)	0	2	1	2	3	2
Chironomidae (L)	17	20	11	19	16	30

[a] N = Nymph, L = Larvae.

insects mentioned, there were either no differences between treated and controls and/or not enough specimens were captured to determine percent reduction. However, occasional post-treatment visual inspections after the termination of the initial study period (2 weeks), we have noticed the following phenomena: marked reduction of dragonfly exuvia counts 15–20 days after treatment with reoccurence a few days later, and abnormally high counts of deformed newly emerged adult dragonfly (Fig. 2) in the treated plots.

Table 4 shows the results of sweep net collections of Notonectidae (*N. unifasciata* Guerin, *Buenoa scimitra* Bare). There was ca. 40% density reduction in the number of adults and nymphs for treated plots compared with that of controls, although daily percent reductions, were variable.

In conclusion, the insect growth regulator, Fenoxycarb induced various morphogenetic abnormalities in back swimmers, *N. unifasciata*, dragonfly, *A. junius*, *P. hymenaea* and damselfly *E. civile* after treatment of late nymphal stages. Fenoxycarb is also ovicidal to young *N. unifasciata* eggs. Fenoxycarb appears to be more active

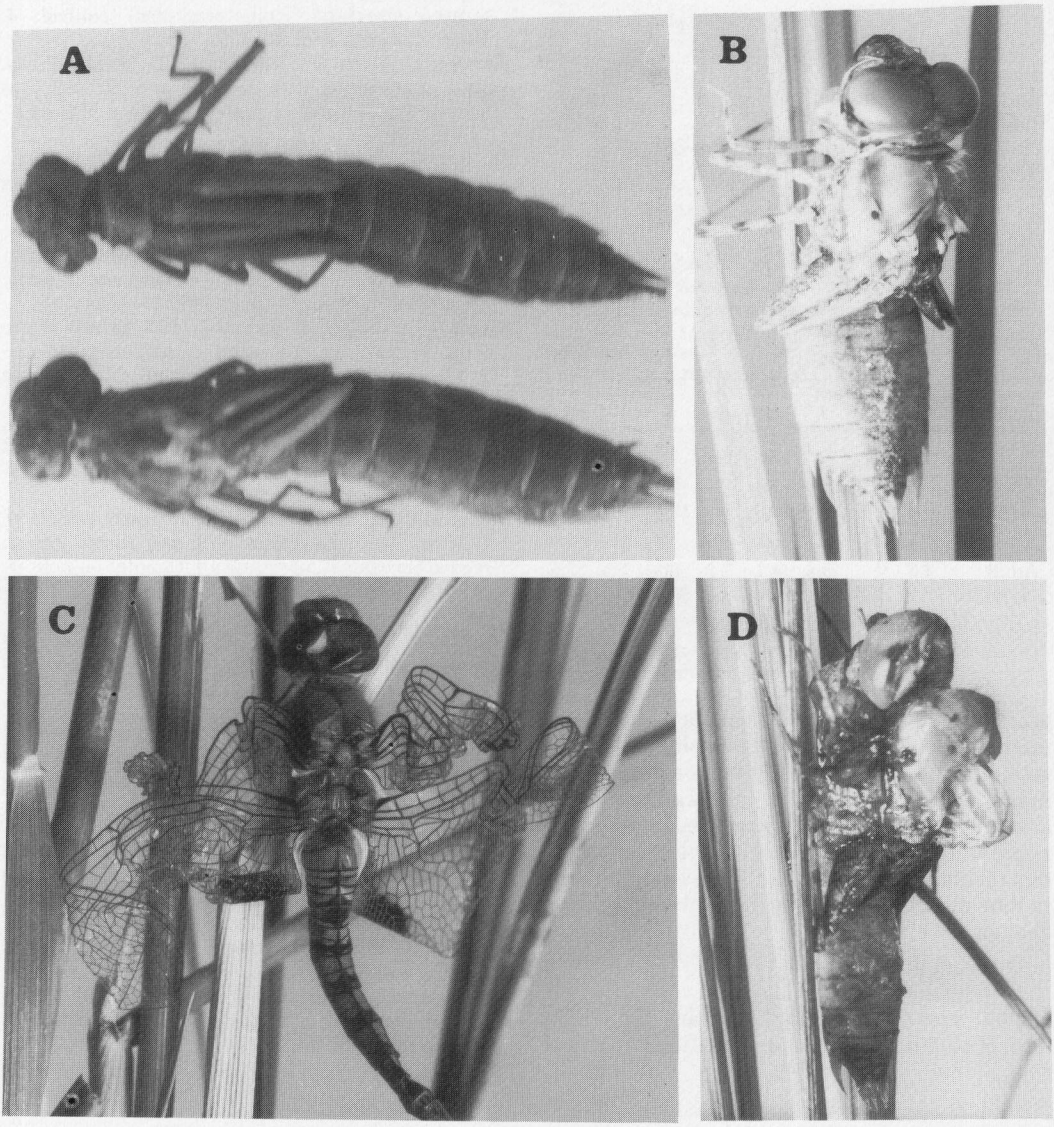

Fig. 2. Morphogenetic aberrations induced by Fenoxycarb treatment (0.034 kg AI/ha) in fields: A—the last nymphal stage of *Anax junius*, dead just before emergence; B and D—partially emerged *P. hymenaea* adults, head capsule and dorsum of thorax are liberated; C—*A. junius*, adult with deformed wings.

Table 3. Effects of 0.034 kg AI/ha Fenoxycarb treatments to (6.1 m)^2 rice plots on aquatic insects. Each number in the table is an average captured per 6 traps/day.

Insect	Pre-	Posttreatment (day)						
	1	0	1	2	5	6	8	14
				Treated plots				
Mayfly (N)[a]	4	1	6	5	5	4	9	51
Dragonfly (N)	6	7	7	15	9	3	13	7
Laccophilus (A)[a]	6	2	1	5	4	6	4	5
Laccophilus (L)[a]	8	2	5	0	1	4	12	2
Tropisternus (A)	24	28	17	27	23	21	7	7
Tropisternus (L)	2	0	0	1	2	1	0	1
				Control plots				
Mayfly (N)	5	3	1	2	2	4	6	8
Dragonfly (N)	14	21	13	11	14	6	13	36
Laccophilus (A)	3	1	2	3	3	6	6	3
Laccophilus (L)	2	1	3	0	1	0	6	2
Tropisternus (A)	39	25	22	23	22	13	13	17
Tropisternus (L)	2	0	1	3	0	1	1	0

[a] N = Nymphs, A = Adults, L = Larvae.

Table 4. Effects of 0.034 kg AI/ha fenoxycarb treatments to (6.1 m)^2 rice plots on *Notonecta unifasciata*. Each number in the table is the mean average per sweep (×10)/plot/day.

Stage	Pre-	Posttreatment (day)						
	1	0	1	2	5	6	8	9
				Treated plots				
Adult	6.6	8.3	5	7.5	2.5	6.7	2.5	3.3
Nymph	9.2	16.6	10.9	10.9	15	10.8	10.9	15.8
				Control plots				
Adult	3.3	5	5.8	4.1	2.5	3.3	7.5	7.5
Nymph	12.5	19.3	29	26.6	31.7	36.6	30	24.2
				% reduction				
		0	54	16	49	56	64	40

against nontarget organisms than the IGR, methoprene (Miura and Takahashi 1973). The rate of 0.034 kg AI/ha induced some reduction in notonectid population densities and produced a few morphogenetic abnormalities in dragonfly nymphs during emergence. However, planktonic organisms and aquatic beetles regularly found in the mosquito breeding habitats showed no deleterious effect.

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