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EFFECTS OF THE AGRICULTURAL INSECTICIDE LAMBDA-CYHALOTHRIN (WARRIOR®) ON MOSQUITOFISH (*GAMBUSIA AFFINIS*)

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ABSTRACT. Because agricultural insecticides have potential to disrupt biological control of mosquitoes, we quantified whether an insecticide used in rice fields causes mortality of mosquitofish. Laboratory studies have shown that lambda-cyhalothrin (Warrior®) is toxic to fish; however, some studies report low field toxicities of pyrethroids to fish because they degrade rapidly and adsorb to soil. We tested whether Warrior kills mosquitofish under field conditions. Replicated enclosures in a rice field were either sprayed with Warrior at 5.8 g active ingredient/ha or were untreated. Mosquitofish were either added before the spray, or 7 days later. Of those added before the spray, none survived. Most fish added 7 days later survived.

KEY WORDS Biological control disruption, lambda cyhalothrin, mosquitofish, rice

INTRODUCTION

Rice fields are often important sources of mosquitoes, and rice cultivation practices can strongly influence the numbers of mosquitoes that rice fields produce (for review, see Lacey and Lacey [1990]). However, few researchers have examined the effects of agricultural pesticide applications on mosquito control. We tested the effects of the pyrethroid insecticide lambda-cyhalothrin (Warrior®; Sygenta Crop Protection, Greensboro, NC) on the mosquitofish (*Gambusia affinis* (Baird and Girard)); mosquitofish are often used to control mosquitoes in rice fields. Warrior is used to control agricultural pests, including pests of rice such as rice water weevil (*Lissorhoptrus oryzophilus* Kuschel) and fall armyworm (*Spodoptera frugiperda* J. E. Smith). Like other pyrethroids, it is toxic to fish. A recent review reports that under field conditions Warrior apparently adsorbs to soil and plant material fast enough to avoid adverse effects on fish (Maund et al. 1998).

In our study area of northern California, Warrior typically is applied for rice water weevil control within 2 wk of rice planting, and it may also be applied at 8–14 wk after planting to control fall armyworms or other later-season pests. The 1st application is unlikely to affect most mosquitofish because mosquito and vector control districts typically wait to add fish until several weeks after rice is planted, and Warrior rapidly disappears from the water column. For example, Hand et al. (2001) found that 90% of the insecticide was degraded after 56 h in an aquatic environment (see also Farmer et al. [1995]). The reason for the delay in adding fish is that many growers drain fields intermittently during the 1st 2–3 wk for herbicide applications. However, later applications could affect fish populations.

MATERIALS AND METHODS

This experiment was performed at the University of California, Davis, Rice Nursery, in a 0.4-ha rice field in July 2002. Rice cultivation in this nursery followed typical area practices for fertilizer and herbicide applications. Insecticides were not used.

Eight weeks after rice was planted, mesocosms were created in the rice fields by sinking sixteen 1-m-tall, 1-m-diameter aluminum rings into the soil at least 10 cm deep, to isolate patches of 5–7 rice plants and water from the rest of the field. The seam in each ring had been sealed watertight with aquarium sealant and aluminum tape. Lambda-cyhalothrin is not expected to diffuse through soil or groundwater (EPA 2001). Rings were embedded rapidly to capture the native invertebrate fauna, which serve as prey for fish. To compensate for any loss of insects during the disturbance of ring embedding, we collected aquatic insects from the field by using two 1-m sweeps of a standard D-ring net, and added these to each enclosure 2 days before the insecticide was sprayed.

Two insecticide treatments were used: no insecticide and Warrior applied at 5.8 g active ingredient (AI)/ha via a hand sprayer. These treatments were crossed with 2 timings of mosquitofish introduction: 5 mosquitofish (4 females and 1 male) added 1 d before the spray and 5 mosquitofish (4 females and 1 male) added 1 wk after the spray. The 4 treatments were replicated in 4 rings each. Mosquitofish females were pregnant adults. The density of mosquitofish in stocked rice fields at season's end was estimated to be 11 fish/m^2 by Stewart and Miura (1985). We chose a density of about half this number to reflect the lower numbers expected in mid-season, and also to avoid overstocking the enclosures so juveniles could survive and grow. The later fish addition was designed to discover whether the insecticide has a lasting effect on fish biocontrol, after direct toxicity became unlikely.

On July 10, 2002, Warrior was applied to designated treatments via a hand sprayer, at a rate of 5.8 g AI/ha, or 4 oz/acre. This rate is within label application rates for armyworm control of 3.2–5.1 oz/acre.

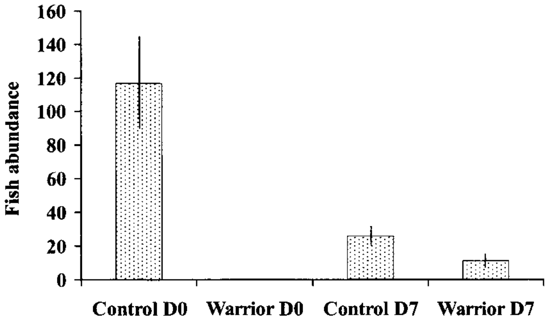

Fig. 1. Mean abundances of mosquitofish in control and treated enclosures (1-m diameter) in a rice field, 1 month after a lambda-cyhalothrin application of 5.8 g active ingredient/ha. D0, fish were added 1 day before enclosures were treated; D7, fish were added 7 days after treatment. Five fish in breeding condition initially were added to all enclosures.

Enclosures where fish were added before the spray were visually inspected for fish survival at 24 h after the spray, and the experiment ended 1 month after the application date. At that time fish were collected from all enclosures by using a standard D-ring aquatic net. We used at least 5 ca. 1-m sweeps in each enclosure, and swept enclosures until no fish had been collected in 5 sweeps. Fish were counted in the field and classified as either juveniles or adults.

To assess experimental conditions, we measured water temperatures every 2–4 days throughout the experiment by using 3 maximum–minimum thermometers placed at the beginning, middle, and end of the linear experimental array. We measured pH and dissolved oxygen in all enclosures on July 24.

RESULTS AND DISCUSSION

In the visual inspection of enclosures at 24 h after the spray, we observed that most fish added before the spray were dead in the water in Warrior-treated enclosures, and no fish were collected from these enclosures at the end of the experiment. In contrast, no dead fish were noted in unsprayed enclosures at 24 h, and at least 4 of the 5 original adult fish were collected alive from each of these unsprayed enclosures at the end of the experiment, in addition to many juveniles. Final fish abundances are shown in Fig. 1. We did not perform a statistical test comparing effects of Warrior on fish added before the spray date, because no variance was found in the Warrior treatment and the result is quite clear. For enclosures where fish were added 7 days after the spray date, no statistically significant differences were found in the numbers of fish collected from treated versus untreated enclosures (analysis of variance, $F = 3.35$, df 1,6, $P = 0.12$).

Field water pH was approximately neutral, ranging from 6.9 to 7.1 among the enclosures. Water temperatures ranged from 20 to 39°C, with mean low of 21°C and a mean high of 34°C. Oxygen levels ranged from 8 to 11 mg/liter. Water depth was approximately 20 cm throughout the study.

Although Maund et al. (1998) reported that under field conditions, no adverse effects of lambda-cyhalothrin have been documented on fish, in our study all fish directly exposed to Warrior® at label rates died. Most studies that Maund et al. (1998) reviewed had studied simulated lighter spray drifts, or runoff conditions where the pyrethroid was already bound to soil particles. However, a paper by Hamer et al. (1994) reported no effects of heavy applications of lambda-cyhalothrin on Nile tilapia (*Tilapia nilotica* L.) in Philippine rice fields. They saw no fish deaths and good population and individual fish growth rates, even when lambda-cyhalothrin was applied at rates from 6.25 to 25 g AI/ha. The application rate in our study was much less, at 5.8 g AI/ha. Water depth was not thoroughly described for the Philippine study, although during some applications of 12.5 g AI/ha, water depth was as low as 10 cm, about half the depth of our study. Fish size may have played a role in the lower susceptibility of tilapia. The tilapia weighed about 10 g each, versus 1–2 g for mosquitofish. Fish species vary in sensitivity to lambda-cyhalothrin; however, data from laboratory studies indicated that all species that have been tested to date should succumb to levels used in the study by Hamer et al. (1994) (see Maund et al. [1998]). Either tilapia are unusually resistant to this pesticide, or the field conditions of the study of Hamer et al. (1994) affected exposure or toxicity.

This study is the 1st to document fish kills from lambda-cyhalothrin applied at label rates under field conditions. The complete loss of mosquitofish indicates a possible need to restock treated fields with mosquitofish if these are the primary method of larval mosquito control. Three other studies also indicated that lambda-cyhalothrin could disrupt biological control of either terrestrial crop pests (Van Den Berg et al. 1998, Tillman and Mulrooney 2000) or mosquito larvae (Dennett et al. 2003). Good communication between rice growers and mosquito abatement districts about pesticide applications may be essential to maintaining biological control of mosquitoes.

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REFERENCES CITED

Dennett JA, Bernhardt JL, Meisch MV. 2003. Effects of fipronil and lambda-cyhalothrin against larval *Anopheles quadrimaculatus* and nontarget aquatic mosquito predators in Arkansas small rice plots. *J Am Mosq Control Assoc* 19:172–174.

EPA [U.S. Environmental Protection Agency]. 2001. Lambda-cyhalothrin general fact sheet. http://npic.orst.edu/factsheets/Lcyhalogen.pdf

Farmer D, Hill IR, Maund SJ. 1995. A comparison of the fate and effects of two pyrethroid insecticides (lambda-cyhalothrin and cypermethrin) in pond mesocosms. *Ecotoxicology* 4:219–244.

Hamer MJ, Hill IR, Rondon L, Caguan A. 1994. The effects of lambda-cyhalothrin in aquatic field studies. In: Hill IR, Heimbach F, Leeuwangh P, Matthiessen P, eds. *Freshwater field tests for hazard assessment of chemicals* Boca Raton, FL: Lewis Publishers. p 331–337.

Hand LH, Kuet SF, Lane MGC, Maund SJ, Warinton JS, Hill IR. 2001. Influences of aquatic plants on the fate of the pyrethroid insecticide lambda-cyhalothrin in aquatic environments. *Environ Toxicol Chem* 20:1740–1745.

Lacey LA, Lacey CM. 1990. The medical importance of riceland mosquitoes and their control using alternatives to chemical insecticides. *J Am Mosq Control Assoc* 2(Suppl):1–93.

Maund SJ, Hamer MJ, Warinton JS, Kedwards TJ. 1998. Aquatic ecotoxicology of the pyrethroid insecticide lambda-cyhalothrin: considerations for higher-tier aquatic risk assessment. *Pestic Sci* 54:408–417.

Stewart RJ, Miura T. 1985. Density estimation and population growth of mosquitofish (*Gambusia affinis*) in rice fields. *J Am Mosq Control Assoc* 1:8–13.

Tillman PG, Mulrooney JE. 2000. Effect of selected insecticides on the natural enemies *Coleomegilla maculata* and *Hippodamia convergens* (Coleoptera: Coccinellidae), *Geocoris punctipes* (Hemiptera: Lygaeidae) and *Bracon mellitor, Cardiochiles nigriceps,* and *Cotesia marginiventris* (Hymenoptera: Braconidae) in cotton. *J Econ Entomol* 93:1638–1643.

Van Den Berg H, Hassan K, Marzuki M. 1998. Evaluation of pesticide effects on arthropod predator populations in soya bean in farmers' fields. *Biocontrol Sci Technol* 125–137.