Susceptibility of immature stages of the obliquebanded leafroller, *Choristoneura rosaceana* (Lepidoptera: Tortricidae) to fenoxycarb

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ABSTRACT

In laboratory bioassays, eggs, larvae and pupae of the obliquebanded leafroller, *Choristoneura rosaceana* (Harris), were susceptible to the juvenile hormone analog, fenoxycarb. All eggs treated with 100 ppm failed to hatch; a dose dependent response was noticed at lower concentration (LC_{50}=1.59 ppm, LC_{95}=29.88 ppm). High larval and pupal mortality occurred when fully-grown larvae were exposed to fenoxycarb (LC_{50}=2.33 ppm, LC_{95}=32.67 ppm). Freshly formed pupae were slightly less susceptible (LC_{50}=30.50, LC_{95}=93.00) than eggs or larvae. Abnormal development (both in times required for growth and adult formation) was noted in all treatments.

Key words: *Choristoneura rosaceana*, obliquebanded leafroller, Tortricidae, insect growth regulator, fenoxycarb

INTRODUCTION

The insect growth regulator, fenoxycarb (ethyl [2- (4-phenoxyphenoxy) ethyl] carbamate), is a broad spectrum juvenile hormone analog (JHA) which is effective against a number of insect pests including scale insects, fleas, mosquitoes, houseflies, cockroaches, ants, stored product insects, psyllids, and many species of Lepidoptera (Dorn *et al.* 1981; Masner *et al.* 1981; Charmillot 1989; Reid *et al.* 1990; Williams and Vail 1993; Gordon 1995). Dramatic effects occur when eggs are treated with fenoxycarb (Charmillot 1989); such treatments caused disruption of embryonic development and reduction of egg hatch. Hatching of eggs produced by treated adults was also reduced (Gordon 1995) and the last-instar larvae of lepidopteran insects were susceptible to this compound.

Tortricid leafrollers are among the major pests of tree fruits (Prokopy and Croft 1994). Fenoxycarb has been reported as effective against a number of tree fruit pests including codling moth, *Cydia pomonella* (L.), Oriental fruit moth, *Cydia molesta* (Busck), summer fruit tortrix, *Adoxophyes orana* (Fischer von Röslerstamm), fruit tree tortrix, *Archips podana* (Scopoli), and pear psylla, *Cacopsylla pyricoli* (Förster) (Schmid *et al.* 1978; de Reedè *et al.* 1984; Charmillot 1989; Krysan 1990; Higbee *et al.* 1995). The obliquebanded leafroller, *Choristoneura rosaceana* (Harris) is among the most important leafroller pests of many tree fruit and berry crops throughout North America (Chapman and Lienk 1971). It is widely distributed in the continental United States and Canada and is regarded as a particularly serious pest on red raspberry, apple, and hazelnut (Schuh and Mote 1948; Reissig 1978; AliNiazee 1986). Both foliar and fruit damage may occur, although fruit damage is by far the more troublesome.

Growers with obliquebanded leafroller problems rely on calendar applications of organophosphate insecticides to suppress the infestations. This causes severe disruption of

natural enemies. Fenoxycarb has only recently become available for use in the United States although it has been in use in Europe for nearly a decade. It appears to fit well in a "soft pesticide" program for tree fruit pests. Reported here is a laboratory study evaluating the effects of fenoxycarb on growth and development of eggs, larvae and pupae of the obliquebanded leafroller.

MATERIALS AND METHODS

Insects. Insects needed for this study were obtained from a laboratory culture of the obliquebanded leafroller maintained at 24 ± 1° C on a 16L: 8D photoperiod for 2 years. The culture was initiated by collecting 5th-instar larvae and pupae from hazelnut trees near Corvallis, OR. Upon emergence, the adults were released in 3.75 cylindrical cartons, the inside surface of which was wrapped with wax paper for an oviposition surface. Adults were provided with a 5% sucrose solution for feeding. Eggs were obtained daily by cutting the wax paper and collecting the egg masses, which were placed in 500-mL plastic cups for hatching. Newly hatched larvae were collected and placed in 28 mL creamer cups containing an artificial diet (wheat-germ diet, Nutritional Biochem, Cleveland, OH) for larval development. The larvae were allowed to pupate in the media cups and pupae were collected at frequent intervals and placed in individual cups for emergence for use in bioassays.

Egg bioassays. Fenoxycarb was obtained from the Ciba-Geigy Co. (Greensboro, NC) as 25% wettable powder. Eggs (<12 h old) were dipped in six concentrations (0.1, 1, 5,10, 50, and 100 ppm) of fenoxycarb for 5 seconds and allowed to dry for 30 minutes. After drying, they were placed in 150mL clear plastic cups with hazelnut leaves and covered with lids. Two small holes covered with nylon mesh on the sides of the cups were provided for ventilation. A minimum of 50 eggs were maintained in each replication and treatments were replicated four times. Eclosion was monitored daily. All experiments were conducted in the Percival model growth chambers set at 24 ± 1° C and 70 ± 10% RH with 16L: 8D photoperiod.

Larval bioassays. Larval bioassays were conducted with early fifth instars, by selecting individuals of uniform size and treating them with different concentrations of fenoxycarb. Larvae were anesthetized with carbon dioxide after removal from the artificial diet cups. Immobilized larvae were then placed on filter paper and treated topically using a microapplicator syringe. One microliter of the different concentrations of fenoxycarb dissolved in acetone was applied to the dorsum of prothorax of each larva. Ten larvae were used in each replication and each treatment was replicated four times. After treatment the larvae were returned to their rearing cups with artificial diet, and post-treatment observations on larval mortality and morphological abnormalities were conducted daily at 24 ± 1° C and 16L: 8D photoperiod. Control larvae were treated with acetone. After pupation, pupae were removed from the diet cups, placed into empty cups and covered with plastic lids. The mortality of these pupae was assessed at frequent intervals and their successful development to the adult stage was recorded. Experiments were terminated after 30 days.

Pupal bioassays. The pupal bioassays were conducted with freshly-formed (<24 h old) pupae collected from laboratory cultures. The pupae were topically treated with different concentrations of fenoxycarb. One microliter of insecticide solution was applied to the dorsum of the prothorax of 10 individual pupae. After treatment, each pupa was placed separately in 150 mL clear plastic cups with lids; adult emergence and abnormalities were checked on a daily basis for a period of 30 days, at which time the experiments were

terminated. Control pupae were treated with acetone only. Each treatment was replicated three times.

Statistical analysis. The mortality data were plotted to determine LDP lines using Polo computer program, and LC_{50} and LC_{95} values were estimated through regression lines for each stage tested.

RESULTS AND DISCUSSION

Freshly-oviposited eggs (<24 h old) of the obliquebanded leafroller were highly susceptible to fenoxycarb (Table 1). None of the eggs treated with 100 ppm hatched; effects were noticeable even at 10 ppm which caused about a 90 % reduction in egg hatch, demonstrating the ovicidal activity of this compound. Increasing rates of fenoxycarb resulted in a progressively decreasing egg hatch. Larvae hatched from the treated eggs exhibited no abnormal morphological effects.

Table 1

Regression analysis of fenoxycarb toxicity to different developmental stages of the obliquebanded leafroller showing concentration (ppm) for 50% (LC_{50}) and 95% (LC_{95}) mortality and slope of regression lines.

Stages Tested	LC_{50} (95% confidence limit)	LC_{95} (95% confidence limit)	Slope (±SE)
Egg	1.59 (0.65-2.91)	29.88 (18.11-56.63)	1.01 (0.07)
Larval	2.33 (0.87-4.27)	32.67 (17.13-100.31)	1.12 (0.21)
Pupal	30.50 (12.70-51.00)	93.00 (56.30- 153.30)	2.65 (0.57)

Final-instar larvae were also susceptible to fenoxycarb in a dose-dependent fashion (Table 1). All treated larvae were killed at a rate of 100 ppm. At lower rates of 10 and 50 ppm substantial mortality was recorded. Most of the mortality at the higher doses tested occurred in the larval stage, whereas in the lower rate treatments, most of the treated larvae died in the pupal stage. In other words, at lower doses, a majority of the larvae were capable of molting to the pupal stage, but died soon after. Treated larvae showed prolongation of growth periods and some degree of malformation, including appearance of part pupal and part larval features, remnants of larval characteristics, and reduced adult emergence. These defects were more pronounced at lower doses.

When freshly-formed pupae (<24 h) were treated with fenoxycarb using the lowest dose of 1 ppm, more than 70% reduction in adult eclosion occurred. At higher rates of 100 and 200 ppm, more than 95% pupal mortality was recorded (Table 1). Those few adults that emerged at the higher dose treatments appeared normal, but their survival, longevity and fecundity, were not studied.

Fenoxycarb, in general, has an effect on insects similar to that of the natural juvenile hormone (JH), in that it disrupts metamorphosis. As in many other lepidopterans (Dorn *et al.* 1981; Charmillot 1989; Mulye and Gordon 1989), both eggs and mature larvae of the obliquebanded leafroller were susceptible to topical applications of fenoxycarb. In a related species, *Choristoneura fumiferana*, both adult and egg stages were highly susceptible to this JHA. Approximately 90% of the eggs deposited by treated adults failed to hatch (Gordon 1995). Our data suggest that all three stages tested, eggs, last instar larvae and young pupae were sensitive. Based on the LC_{50} and LC_{95} values (Table 1), the order of susceptibility was eggs > larvae > pupae.

The obliquebanded leafroller is a polyphagous pest of many tree fruit and berry crops in North America. It is generally controlled by the use of broad-spectrum organophosphate compounds. Although insecticide resistance has not been widely noted, development of resistance is nevertheless a serious threat as observed in other leafroller species (Meagher and Hull 1986; Cossentine and Jensen 1991). The results of the present laboratory study establish the toxicity of fenoxycarb to this insect. Further studies should determine the suitability of this compound as a selective control agent in suppressing obliquebanded leafroller populations in the field.

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