Laboratory and Field Evaluations of Biorational Insecticides Against the Mexican Rice Borer (Lepidoptera: Pyralidae) and a Parasitoid (Hymenoptera: Braconidae)

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ABSTRACT We compared laboratory and field efficacies of pyrethroid insecticides (Baythroid, 'FCR 4545' [both cyfluthrin], Karate [lambda cyhalothrin]) and insect growth regulators (Confirm [tebufenozide], 'RH-2485' [methoxyfenozide]) against the Mexican rice borer, *Eoreuma loftini* (Dyar), a key pest of sugarcane in south Texas. We also studied treatment effects on longevity and survivorship of its braconid parasitoid, *Allorhogas pyralophagus* Marsh. In the 1996 field season, Baythroid resulted in lower percentages of bored internodes compared with the other treatments. In the 1997 season, less borer damage was found in 'FCR 4545' (an isomer of Baythroid), relative to the other treatments. The differences may be partially attributed to the different application methods (tractor sprayer versus aerial). In both field seasons, no significant treatment effects could be found in any of the yield or juice quality measurements, suggesting that improvements must be made in application technology, or the biorational insecticides must be used in conjunction with other control agents, such as biological controls. Efficacy may be improved if applications can be timed to windows of susceptibility based on either plant phenology or pest lifecycle. Baythroid and FCR 4545 were generally most effective in reducing damage caused by *E. loftini*, although residual toxicity of Baythroid was higher than FCR 4545 against both *E. loftini* and *A. pyralophagus*. Comparisons between similar bioassays showed that Baythroid and tebufenozide were more toxic to *E. loftini* than to *A. pyralophagus*. Therefore, if *A. pyralophagus* or a similar parasitoid were to be used in conjunction with an insecticide, an effective approach may be to use a less toxic biorational, such as the insect growth regulator tebufenozide, or to time the release of the parasitoids after residual toxicity has declined in a biorational such as FCR 4545.

KEY WORDS *Eoreuma loftini*, *Allorhogas pyralophagus*, pyrethroid, insect growth regulator, sugarcane, integrated pest management

BY THE YEAR 2000, 75% of crop acreage in the United States will be under integrated pest management (IPM) if the U.S. Department of Agriculture is successful in implementing its 1994 IPM initiative (Matteson 1995). The use of agricultural pesticides should decline sharply, perhaps on a scale comparable to the 50% reductions mandated in Sweden, Denmark, and the Netherlands, also for the year 2000. The adoption of IPM often requires the integration of biologically based controls with chemical pesticides continuing to play a significant role. The challenge has been one of discovering potential compatibilities between the biological and chemical controls. Many broad-spectrum insecticides, especially organophosphates, are extremely toxic to nontarget organisms including biological control agents. Parasitic Hymenoptera often are far more susceptible to insecticides than their hosts, possibly because of differences between their detoxification processes (Plapp and Vinson 1977). Target host insects often possess detoxification mechanisms adapted to coping with a wide array of plant toxins, whereas parasitoids are adapted only to those of a specific host or limited range of host insects (Baker et al. 1995).

The toxicity of commercial insecticides to natural enemies has been studied by several workers. For example, Bayoun et al. (1995) tested 14 commercial insecticides against the Russian wheat aphid, *Diuraphis noxia* (Kurdjumov) (Homoptera: Aphididae), and selected natural enemies consisting of 3 species of parasitic Hymenoptera and 4 coccinellids. Malathion showed low toxicity to *D. noxia*, but was highly toxic to the natural enemies. In contrast, acephate showed relatively high systemic toxicity to *D. noxia*, but not to the natural enemies. A laboratory strain of *Bracon hebetor* Say (Hymenoptera: Braconidae) was ≈7 times more susceptible to malathion than 2 field strains, which were probably exposed to residual pesticides (Baker et al. 1995). Organophosphates also have been shown to induce sublethal effects on the enzyme systems of predatory lacewings (Neuroptera: Hemero-

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biidae and Chrysopidae). The responses in the activity of enzyme systems ("biomarkers") may be useful in assessing sublethal effects of insecticides on beneficial insects in an IPM program (Rumpf et al. 1997). Beneficial insects have been genetically improved for resistance to insecticides, using artificial selection (e.g., Hoy and Cave 1991) and genetic engineering (Hoy 1993).

Interest has focused on biorational insecticides, which are based on natural products or synthesized analogues of naturally occurring biochemicals (Bentz and Neal 1995). The toxicities of biorational insecticides to natural enemies are often compared with those of conventional chemical insecticides. Examples include studies on insect growth regulators (Biddinger and Hull 1995, Jones et al. 1995), neem (extract from the neem tree, *Azadirachta indica* A. Juss; Spollen and Isman 1996), a derivative of abamectin (produced by the actinomycete *Streptomyces avermitilis;* Kok et al. 1996), and an extract from *Nicotiana gossei* Domain (Bentz and Neal 1995). The biorational insecticides usually are less toxic to natural enemies than conventional insecticides. However, some biorational insecticides also show sufficient toxicity to warrant caution against using them in conjunction with biological agents. Specific IPM programs require research into potential incompatibilities between biorational insecticides and biological control agents (Biddinger and Hull 1995).

We studied the laboratory and field efficacies of pyrethroid insecticides and 2 insect growth regulators against the Mexican rice borer, *Eoreuma loftini* (Dyar), and an exotic parasitoid from Mexico, *Allorhogas pyralophagus* Marsh (Hymenoptera: Braconidae). We also report the effects of the treatments on selected life history traits of the parasitoid progeny.

Materials and Methods

Field Trial (1996). The experimental area (56.4 by 158.6 m) was in a sugarcane field planted with the variety 'TCP 81–3058' near Runn, Hidalgo County, in the Lower Rio Grande Valley of Texas (≈26° N, 98° W). The experimental design used was a 6 × 4 randomized complete block design. The experimental area consisted of 37 rows of sugarcane (158.6 m length) planted in rows 1.5 m apart. The 37 rows of cane were blocked into 6 units (representing 6 treatments) of 5 rows each, with 1 row between units acting as a buffer. Within each block, only the middle 3 rows were treated, leaving a buffer of 1 row on each side. Each block was divided into 4 plots, representing the 4 replicates. Each plot measured 30.5 m in length, with a buffer of 9.2 m between plots. The 6 treatments were as follows: (1) low rate application of Confirm 70W (RH-5992 wettable powder) with Latron CS-7 spray adjuvant (tebufenozide [benzoic acid, 3,5-dimethyl, 1-(1,1-dimethylethyl)-2-(4-ethylbenzoyl) hydrazide]) (both products Rohm & Haas, Philadelphia, PA); (2) high rate application of Confirm with Latron CS-7; (3) Baythroid 2-liter emulsifiable pyrethroid (cyfluthrin [cyano (4-fluoro-3-phenoxyphenyl) methyl-3-(2,2-dichloroethenyl)-2,2-dimethylcyclopropanecarboxylate]) (Bayer, Kansas City, MO); (4) water (control); (5) 'RH-2485' (methoxyfenozide [N'-Tert-butyl N'-(3,5-dimethylbenzyl)-3-methoxy-2-methylbennzaldehyde]) (Rohm & Haas); and (6) Karate (emulsifiable concentrate) (lambda-cyhalothrin [1α(S*), 3α(Z)]-(±)-cyano-(3-phenoxyphenyl) methyl-3-(2-chloro-3,3,3-trifluoro-1-propenyl)-2,2-dimethylcyclopropanecarboxylate) (Zeneca Ag Products, Wilmington, DE). Application rates (kg [AI]/ha) were Confirm (low rate), 0.14; Confirm (high), 0.2; Baythroid, 0.049; RH-2485, 0.17; and Karate, 0.034. Confirm is an insect growth regulator (IGR) that targets most lepidopterous larvae by simulating the action of 20-hydroxyecdysone, the insect hormone responsible for inducing molting and metamorphosis. RH-2485 is an experimental IGR. Baythroid and Karate are pyrethroid insecticides. The treatments were applied in aqueous solutions at the rate of 374.1 liters/ha using TeeJet standard flat spray tip nozzles (Spraying Systems, Wheaton, IL) on a tractor-mounted sprayer (3.2 km/h). Foliar materials were applied with a compressed air-powered ground sprayer with 9 nozzles on a 4.6-m boom at a pressure of 6.3 kg/sq cm. The control received only the water. Spray dates were 12 June, 31 July 1996, and 11 September after the economic threshold level for *E. loftini* was reached. Samples were collected at 12- to 30-d intervals starting the last week of June. Harvest date was 15 November 1996.

Field Trial (1997). The research site was located in a sugarcane field (≈36 ha) planted with the variety 'CP 70–321', also near Runn, Hidalgo County, TX. The experimental area measured 577 by 396 m (22.8 ha), consisting of 384 rows of cane planted 1.5 m apart. Four treatments were tested: Baythroid 2 liter, and 'FCR 4545' (an isomer of Baythroid); Confirm 2 F with Latron CS-7; and a water control. The 384 rows of cane were divided into 4 parallel blocks (representing 4 replicates). Each block consisted of 96 rows of cane (384/4), which were allotted to the 4 treatments (24 rows per treatment), assigned randomly within each block. Of the 24 rows allocated for each treatment, only the middle 8 rows were treated, leaving a buffer of 8 rows on each side. Through a local flying service, treatments were applied aerially (46.8 liters/ha of aqueous solution, at a pressure of 1.76 kg/cm^2) using a boom with a swath width of 12.2 m (hollow-cone nozzles 12.7 cm apart) sufficient to treat 8 rows of cane per pass. Aerial speed was 185.2 kph (115 mph). Application rates (kg [AI]/ha) were Baythroid, 0.049; FCR 4545, 0.018; and Confirm, 0.28 (with Latron CS-7 spray adjuvant). The control was sprayed with water alone at 46.8 liters/ha. Spray dates were 1 May, 2 June, and 25 July 1997. Harvest date was 10 November 1997.

Data Collection (Field Trials). Forty sugarcane stalks were collected for each treatment (10 stalks per plot × 4 replicates) at 5- to 10-d intervals, until harvest. Starting 25 June in the 1996 season, and 19 May in 1997, numbers of internodes were recorded, as well as those showing signs of damage by *E. loftini.* At harvest, 15 stalks per plot were collected to measure sugarcane yield and quality. The terminology and methodology

used in the analysis of sugarcane yield and juice quality are standard to the industry (Chen 1985). Yield was measured as weight of sugarcane stalks and expressed in terms of weight per stalk or stalk weight over a harvest area. For each plot in the 1996 season, a single row of cane measuring 15.2 m was harvested and weighed. In the 1997 field season, all aboveground biomass in each plot (measuring ≈1.4 ha) was harvested destructively and weighed.

To assess juice quality, a hydraulic press was used to extract the juice. The remaining plant material, or bagasse, was composed of water, a low percentage of sugar, impurities, and 'fiber' (expressed as a percentage). Filtration produced a clear juice for analysis with a polarimeter. The polarimeter measured the percentage of sucrose in the juice (pol). Inorganic dissolved minerals consisted primarily of potassium (ash, in mmhos). The ratio of sucrose to all dissolved solids in the juice was termed the 'juice purity' (in percentage). The amount of sucrose extracted was extrapolated to 1 ton of sugarcane ('sugar per ton', pounds of sugar per ton of sugarcane). Extrapolation on an acre basis resulted in 'sugar per acre' (tons sugar per acre of sugarcane field).

Laboratory Bioassays: *E. loftini*. Toxicities of the field treatments were measured in the laboratory against *E. loftini* and *A. pyralophagus*. In 1996, sugarcane leaf blades from plants in each of the 4 treatments were collected 1 d after spray. Plants were selected randomly. Exposed leaf blades close to the whorl were collected and cut into 4-cm segments. Two leaves were placed inside 5-cm-diameter petri dishes. Ten 1st-instar *E. loftini* from a laboratory colony were placed between the leaves inside the petri dish. Each petri dish constituted a replicate, and 4 replicates were used. The insects were maintained under ambient laboratory conditions (25–30°C, 59–93% RH). Mortality was checked daily for 9 d. In 1997, leaves from treated fields were collected 1 d after spray. Five 2nd- and 3rd-instar larvae of *E. loftini* were placed in between 2 leaves inside each petri dish, and 10 replicates were used. Mortality was checked daily for 11 d. The procedure was repeated using plant material collected 4 d after spray, and mortality was checked daily for 9 d.

Laboratory Bioassays: *A. pyralophagus*. The *A. pyralophagus* parasitoids tested were obtained from a colony initially collected from local sugarcane fields, and maintained in the laboratory for ≈2 yr. To measure toxicity against the parasitoid, plant leaf blades from each of the field treatments (collected 1 d after spray) were brought to the laboratory, cut into 7-cm segments and placed inside the 9-cm-diameter petri dishes with honey streaked onto the covers. To ensure air flow, the dishes had a 2-cm hole covered with screen cut into the center of the lid. In addition, each petri dish was fitted with a plastic tubing (0.2 × 1 cm) connected to an air blower to provide ventilation. Air flow was regulated at 0.17 liters/min using an air flow meter (Sierra Instruments, Monterey, CA). The petri dishes were kept under ambient laboratory temperatures. In the 1996 field season, 10 parasitoids were placed inside each of 4 petri dishes. Bioassays were performed after 24-h exposure, 1 d after spray only. Parasitoid survivorship and longevity were measured using plant material collected from the Baythroid, Confirm (low and high rates), and control treatments only. In 1997, 10 parasitoids were placed inside each of 5 petri dishes. Mortality was checked after 4 and 24 h, and the experiment was repeated using plant material collected 4 d after spray.

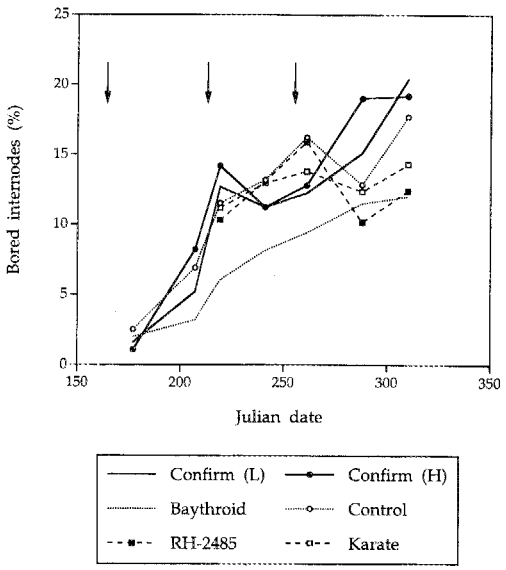

Fig. 1. Percentage of bored internodes (1996 field season). The variety tested was 'TCP 81-3058'. Treatments were applied using a tractor mounted sprayer. Arrows indicate spray dates.

Statistical Analysis. The percentage of damaged internodes was analyzed as a two-way analysis of variance (ANOVA), where time and treatment were independent variables. Yield and juice quality data were analyzed as a one-way ANOVA for the effects of treatment. Laboratory bioassays on *E. loftini* (1996 treatments) were analyzed as a two-way ANOVA (mortality as independent variable, time and treatment as factors). Bioassays for 1997 treatments were analyzed separately for each day and treatment. Percentage mortality and parasitoid longevity in the laboratory bioassays was analyzed daily by ANOVA (SAS Institute 1992), means were separated using least significant difference (LSD) ($P = 0.05$). All percentage data were transformed (square root arcsine) before analysis, but are presented as untransformed means.

Results and Discussion

Field Trials. The damage caused by *E. loftini* is presented in Figs. 1 and 2 as mean percentages of bored internodes, plotted according to treatment. In the 1996 season, the treatment and time effects were highly significant (model: $F = 11.7$; df = 37, 1,482; $P < 0.01$). The significant model is the result of the effect of Baythroid (Fig. 1), which resulted in significantly

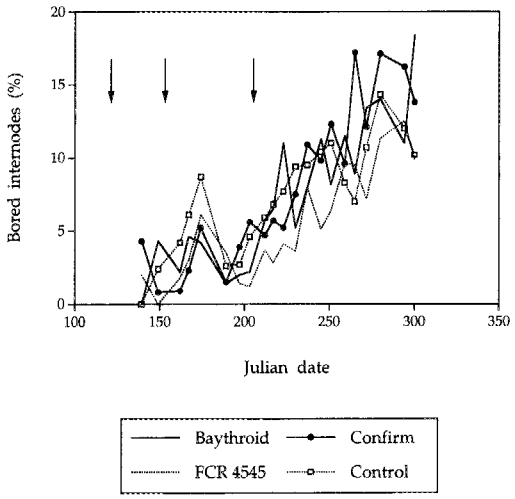

Fig. 2. Percentage of bored internodes (1997 field season). The variety tested was 'CP −70–321'. Treatments were applied aerially. Arrows indicate spray dates.

lower percentages of bored internodes compared with the other treatments (LSD, $P < 0.01$). No other treatment comparisons were significant. In the 1997 season, the treatment and time effects were again significant (treatment, $F = 13.1$; df = 3, 3,244; $P < 0.01$; time, $F = 44.8$; df = 20, 3,244; $P < 0.01$; interaction, $F = 1.7$; df = 60, 3,244; $P < 0.01$). Significantly less borer damage was found in the FCR 4545 treatment ($P < 0.01$); all other treatment comparisons were not significant (Fig. 2). Therefore, Baythroid proved to be the most effective treatment in the 1996 trial, but was relatively ineffective in 1997. The differences between the 2 results may be partially attributed to the different application methods used. The tractor mounted sprayer in the 1996 season may have delivered the insecticide more effectively than the aerial sprayer used in the 1997 season.

The yield and juice quality data collected during the 1996 season revealed no significant treatment effects. Analysis of yield data showed that stalk weight averaged 0.8 ± 0.03 kg (mean ± SE) per stalk and was not significantly affected by treatment ($F = 0.3$; df = 5, 18; $P = 0.9$). Similarly, total weights of 1 row of cane measuring 15.2 m averaged 130.6 ± 7.8 kg and did not differ significantly between treatments ($F = 0.1$; df = 5, 18; $P = 0.9$). Analysis of juice quality showed no treatment differences in ash content (4.8 ± 0.1, mmhos; $F = 0.9$; df = 5, 18; $P = 0.5$), fiber content (15% ± 0.2; $F = 1.0$; df = 5, 18; $P = 0.4$), pol (13.1% ± 0.2; $F = 2.1$; df = 5, 18; $P = 0.1$), juice purity (81.4% ± 0.4; $F = 1.5$; df = 5, 18; $P = 0.2$), sugar per acre (2.4 ± 0.04 t/ac or 5,340.6 ± 78.3 kg/ha; $F = 2.0$; df = 5, 18; $P = 0.1$), and sugar per ton (186.9 ± 2.7 lb/t or 93.4 ± 1.4 g/kg; $F = 2.4$; df = 5, 18; $P = 0.08$).

Similar to the 1996 season, the yield and juice quality data collected during the 1997 season revealed no treatment effects. Yield analysis showed that total sugarcane biomass per plot (each plot ≈1.4 ha) weighed 32,920.1 ± 845.4 kg. ($F = 0.6$; df = 3, 12; $P = 0.6$), and mean weight per stalk was 0.7 ± 0.02 kg, regardless of treatment ($F = 0.7$; df = 3, 12; $P = 0.6$). Other measures of juice quality were not significantly affected by treatment. Percentages of pol averaged 12.7% ± 0.2 ($F = 0.9$; df = 3, 12; $P = 0.5$), juice purity averaged 83.8% ± 0.5 ($F = 1.4$; df = 3, 12; $P = 0.3$), fiber 12.4% ± 0.2 ($F = 1.0$; df = 3, 12; $P = 0.4$), sugar per acre (2.3 ± 0.05 t/ac or 5264.8 ± 111.5 kg/ha; $F = 1.0$; df = 3, 12; $P = 0.4$), and sugar per ton (187.7 ± 4.0 lb/t or 93.8 ± 2.0 g/kg; $F = 1.0$; df = 3, 12; $P = 0.4$).

In both field seasons, no significant treatment effects could be found in any of the yield or juice quality measurements analyzed, despite the large scale harvest performed in the 1997 season. The juice quality measures are largely restatements of sucrose content calibrated to different scales, so insignificant effects on pol content are likely to result in insignificant effects on the derived measures. However, the lack of effects on yield (weight of cane) suggests that the pyrethroids and insect growth regulators tested cannot control *E. loftini* alone. These results are similar to those of Meagher et al. (1994) who concluded that insecticides can often produce statistically significant reductions in percentages of bored internodes, but rarely an increase in sugarcane yield or commercially recoverable sugar. The ineffectiveness of the insecticides is a result of the combined effects of large plant biomass and the cryptic habitat of the pest where later instars tunnel inside stalks and pack the tunnels with frass. The high plant biomass also acts as an impediment to effective scouting and assessment of population densities, which are essential in developing an IPM program (Meagher et al. 1994).

Laboratory Bioassays: *E. loftini*. The 1996 insecticide treatments significantly affected cumulative mortality of *E. loftini* (two-way ANOVA; time, $F = 109.9$; df = 8, 162; $P < 0.01$; treatment, $F = 177.2$; df = 5, 162; $P < 0.01$; interaction, $F = 8.9$; df = 40, 162; $P < 0.01$) (Fig. 3). Highest mean daily mortality was caused by Baythroid, followed by lambda cyhalothrin and methoxyfenozide, the low and high rates of tebufenozide (Fig. 3B) (LSD $P < 0.05$). Mortality in the control was zero.

In 1997, laboratory bioassays on *E. loftini* 1 d after spray showed significant effects beginning after 3 d exposure to leaves with the insecticide treatments ($F = 42.8$; df = 3, 39; $P < 0.01$) (Fig. 4). The Baythroid and FCR 4545 treatments caused significantly higher pest mortality than tebufenozide and the control (LSD, $P < 0.05$). After 7 d exposure, mortalities were lowest in the control, followed by tebufenozide, and highest in the FCR 4545 and Baythroid treatments ($F = 113.7$; df = 3, 39; $P < 0.01$; LSD $P < 0.05$). In summary, 1 d after spray, the highest mortalities of *E. loftini* were found in Baythroid and FCR 4545, followed by tebufenozide, and the lowest in the water control. Interestingly, this trend did not hold when the treatments were tested 4 d after spray (Fig. 4B). After 2 d exposure, Baythroid caused significantly higher mortality in *E. loftini* than the other treatments, which caused zero mortality ($F = 8.5$; df = 3, 39; $P < 0.01$;

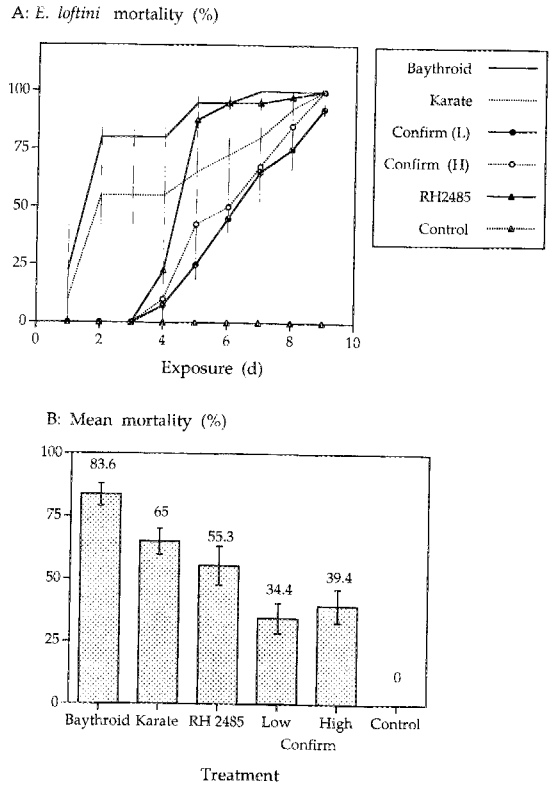

Fig. 3. Laboratory bioassay on *E. loftini* using 1996 field treatments. Ten 1st-instar larvae were placed in each of 4 petri dishes together with plant material collected from the field treatments. (A) Cumulative mortality (means ± SE) was calculated daily for 9 d. (B) Mean mortality was calculated as daily means ± SE.

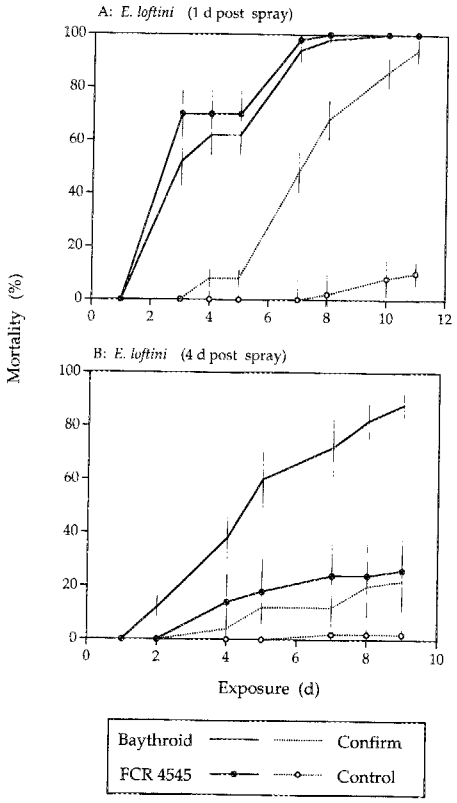

Fig. 4. Laboratory bioassay on *E. loftini* using 1997 field treatments. Five 2nd- to 3rd-instar larvae were placed into each of 10 replicates with plant material from the field treatments. (A) Cumulative mortality (% means ± SE) is shown using plant material collected 1 d after spray. (B) Cumulative mortality is shown using plant material collected 4 d after spray.

LSD $P < 0.05$). For the remainder of the exposure period, the mortalities were significantly higher in Baythroid, whereas the other treatment means could not be separated statistically (day 9, $F = 17.1$; df = 3, 39; $P < 0.01$; LSD $P < 0.05$). A comparison of the 1 and 4 d mortalities after spray shows that the insecticides were less toxic to *E. loftini* after 4 d, which is to be expected. A more interesting result is that FCR 4545 is most toxic 1 d after spray, but apparently does not retain its toxicity after 4 d as well as Baythroid.

Laboratory Bioassays: *A. pyralophagus*. In the 1996 parasitoid bioassays, Baythroid caused 24.5% (SE = 7.1) mortality. All other treatments (tebufenozide [low and high rates], methoxyfenozide, lambda cyhalothrin, and water control) caused zero mortality ($F = 7.4$; df = 5, 23; $P < 0.01$). In 1997, tebufenozide and the control caused no parasitoid mortality at either 4 or 24 h exposure and after 1 or 4 d after spray (Fig. 5). However, after 1 d postspray, significantly higher parasitoid mortality was found in the Baythroid and FCR 4545 treatments 4 h after exposure (Fig. 5B) ($F = 13.7$; df = 3, 19; $P < 0.01$; LSD $P < 0.05$). After 24 h, mortality reached 100% in the FCR 4545 treatment, 84% in Baythroid, and remained zero in tebufenozide and the water control. In the 4-d postspray bioassay, highest mortality was found in the Baythroid treatment ($F = 8.2$; df = 3, 19; $P < 0.01$). The other treatment means could not be separated statistically (LSD, $P > 0.05$). These results suggest that the residual toxicity of Baythroid is higher than that of FCR 4545, which is in agreement with the conclusion obtained from the laboratory bioassays on *E. loftini* (Fig. 4).

Adult survivorship and longevity of *A. pyralophagus* under the tebufenozide (low and high rates), Baythroid and control treatments are shown in Fig. 6. The survivorship curve (Fig. 6A) shows poor survivorship under the Baythroid treatment relative to the others. Analysis of adult longevity (Fig. 6B) showed significant treatment effects ($F = 27.3$; df = 3, 121; $P < 0.01$). Longevity was highest under the control and high rate of tebufenozide treatments (≈20 d), followed by tebufenozide low rate (≈16 d). Parasitoids under the Baythroid treatment showed lowest longevity (≈9 d) (LSD $P < 0.05$). In these tests, the parasitoid *A. pyralophagus* was less adversely affected by the IGR tebufenozide, than the pyrethroid Baythroid.

Effective IPM of sugarcane will most likely require a degree of compatibility between biorational or con-

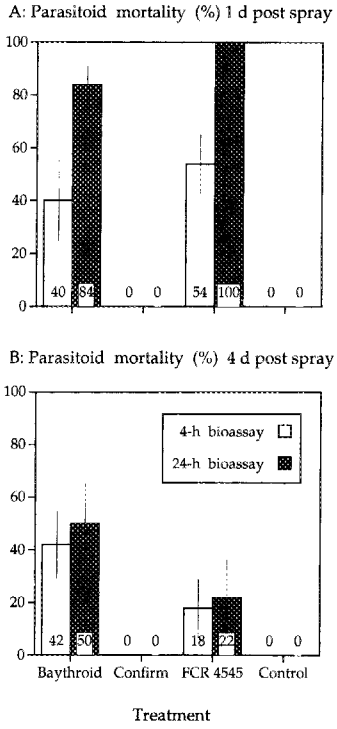

Fig. 5. Effects on parasitoid mortality (%, mean ± SE) using 1997 field treatments. Bioassays were conducted (A) 1 d and (B) 4 d after spray after 4 and 24 h exposure to treatments.

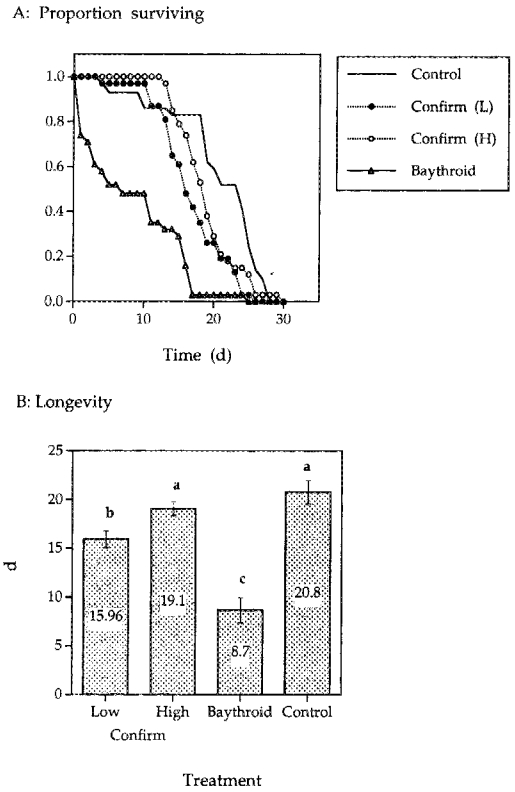

Fig. 6. Effects on parasitoid survivorship and longevity using 1997 field treatments. (A) The survivorship curve is shown for *A. pyralophagus* exposed to plant material collected from the Baythroid, Confirm (low and high rates) and control treatments. (B) Parasitoid longevity (days ± SE) was lowest in Baythroid and highest in the control and Confirm (high rate).

ventional insecticides and biological control agents that may be used in conjunction. Comparisons between field and laboratory bioassays can provide information useful in the design of such IPM programs, especially when the effects of the treatments are evaluated against prospective biological controls. The biorational insecticides we tested showed no significant effects on yield or juice quality, suggesting that improvements must be made in application technology, or they must be used in conjunction with other control agents, such as biological controls. Insecticidal efficacy may be improved if applications can be timed to windows of susceptibility based on either plant phenology or pest lifecycle. The 1st sugarcane internode to develop is the most important to protect, and importance declines with subsequent internodes (Meagher et al. 1994). Insecticidal application may also be timed to synchronize with susceptible lifestages, e.g., ovipositing females, and early 1st instars which migrate on the outer plant surfaces before tunneling into the stalk. The field trials showed that Baythroid was the most effective insecticide treatment to reduce damage caused by *E. loftini*, but was also most toxic to its parasitoid *A. pyralophagus*. FCR 4545 can result in lower percentages of bored internodes than Baythroid, but may have less residual toxicity against both *E. loftini* and *A. pyralophagus*. If *A. pyralophagus* or a similar parasitoid were used in conjunction with an insecticide, an effective approach may be to use a less toxic biorational, such as tebufenozide, or to time the release of the parasitoids after residual toxicity has declined using a biorational such as FCR 4545.

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