Appl. Ent. Zool. **25** (1): 59–65 (1990)

Inhibition of Rice Virus Transmission by Esfenvalerate and Its Mechanisms

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(Received May 31, 1989; Accepted September 6, 1989)

Synthetic pyrethroid, esfenvalerate, reduced the incidence of the rice stripe virus disease transmitted by smaller brown planthoppers, *Laodelphax striatellus*, in the greenhouse. To make clear the mechanisms preventing virus infection, the effects of esfenvalerate on vectors were investigated. This compound showed a high repellent activity against smaller brown planthopper which is a stripe disease vector, and green rice leafhopper, *Nephotettix virescens*, which is a tungro vector. Electronic measurement of insect feeding behaviour revealed that 1 ppm of esfenvalerate inhibited the ingestion and salivation of both species. These results suggested that insecticide lethality, repellency and/or activity inhibiting ingestion and salivation behaviour contributes to prevention of virus infection by planthoppers and leafhoppers.

INTRODUCTION

The virus diseases of rice such as tungro and stripe are transmitted by the feeding behaviour of vectors, the green rice leafhopper, *Nephotettix virescens*, and the smaller brown planthopper, *Laodelphax striatelles*, respectively. These diseases cause a serious loss of rice yield. At present, the control of the vector population using appropriate insecticides is the practical procedure for prevention of the propagation of virus diseases. SATAPATHY and ANJANEYULU (1986) showed that carbofuran, isoprocarb and BPMC had high insecticidal activities against tungro vector and reduced virus infection in the field. Synthetic pyrethroids also reduced the incidence of tungro disease in the greenhouse and the field (SATAPATHY and ANJANEYULU, 1984; ANJANEYULU and BHAKTAVATSALAM, 1987). The main reasons for their effectiveness were assumed to be insecticidal, knockdown and repellent activities (SATAPATHY and ANJANEYULU, 1984).

In the greehouse and laboratory, we confirmed that some pyrethroid compounds could control virus diseases and investigated mechanisms preventing virus infection. In this experiment, we mainly used smaller brown planthoppers which carry rice stripe virus.

MATERIALS AND METHODS

Chemicals. Commercially available formulations of the following insecticides, were used: esfenvalerate, alpha cypermethrin, fenitrothion, BPMC, and buprofezin. Deltamethrin (purity: 99.0%) was synthesized at Sumitomo Chemical Co., Ltd. It was formulated to an emulsifiable concentrate with xylene and sorpol 3005x® (Toho Chemical Industry Co., Ltd.) before the experiment.

Insects. Smaller brown planthoppers, which carry rice stripe virus were used. They were reared in the laboratory at 28±1°C, 50–70% RH, 16L–8D. The percentage of viruliferous insects of the reared population was maintained at above 50%. Green rice leafhoppers reared under the same conditions, were also used.

Selection of the viruliferous insects. Females in the reared population were individually put into test tubes with rice seedlings for 4 days to oviposit. Each insect was confirmed to be a carrier by the latex flocculation test (BERCKS and QUERFURTH, 1971; TAKAHASHI, 1988). The seedlings on which the viruliferous females oviposited were cultivated to collect the viruliferous nymphs. The nymphs were reared in the laboratory under the same conditions.

Greenhouse evaluation. The insecticides were applied to ten rice plants (6-day-old) cultivated in plastic cups. The plants were covered with transparent plastic cups. Thirty to 50 viruliferous nymphs of smaller brown planthopper were kept in the cup to inoculate plants with virus for 2 days. Mortality and repellency observations were made 48 hr after inoculation. The plants were transplanted to plastic trays and cultivated in the greenhouse until the observation. The number of infected plants at 28 days after inoculation was recorded. The index of infection was calculated as follows:

$$\text{Infection Index} = \frac{100\times\left(\begin{array}{c}\text{the number of plants which}\\ \text{showed leaning symptoms}\end{array}\right)+50\times\left(\begin{array}{c}\text{the number of plants which}\\ \text{showed stripe symptoms}\end{array}\right)}{\text{the total number of plants}}$$

Symptoms are shown in Fig. 1.

Laboratory assessment of mortality. Rice seedlings were dipped into predetermined concentrations of test chemicals with surfactant for 1 min and then dried. They were put into test tubes and smaller brown planthopper or green rice leafhopper adults were released on the treated plants. Mortality was assessed after 24 hr.

Repellency test. Rice seedlings were dipped in insecticide solution with surfactant for 1 min, dried and then put into glass flasks filled with water. One smaller brown planthopper or green rice leafhopper female adult was released onto each rice seedling. Twenty replications were made at each concentration. After 2 hr the rate of repelled insects was observed and EC_{50} values were calculated.

Electronic measurement of insect feeding behaviour. The feeding activities of leafhoppers and planthoppers were electronically measured according to KAWABE and MCLEAN (1980) and KAWABE et al. (1981). The rice seedlings which were dipped in the insecticide solution for 1 min were used. The waveforms associated with feeding behaviour of a green rice leafhopper on the untreated seedling is shown in Fig. 2. The waveforms of ingestion and salivation behaviour which cause the virus infection were distinguished from other waveforms (KAWABE and MCLEAN, 1980). The observations were continued for at least 60 min in each experiment. Since the responses of planthoppers were much weaker than that of leafhoppers, waveforms obtained from the leafhoppers are shown (Figs. 2 and 3).

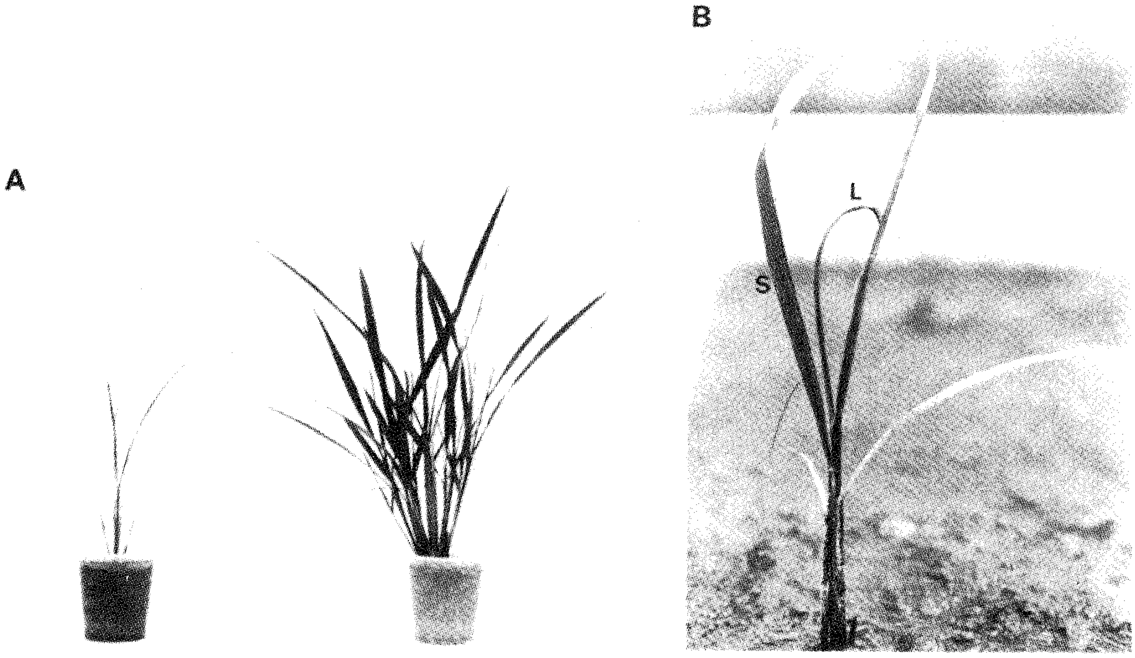

Fig. 1. Symptoms of rice stripe disease. A: Rice plant infected with serious stripe disease (left) and uninfected plant (right). Plants are 34 days old. B: Infected plant. L, leaning sympton; S, stripe symptom. Rice plants which are slightly infected show only stripe symptoms.

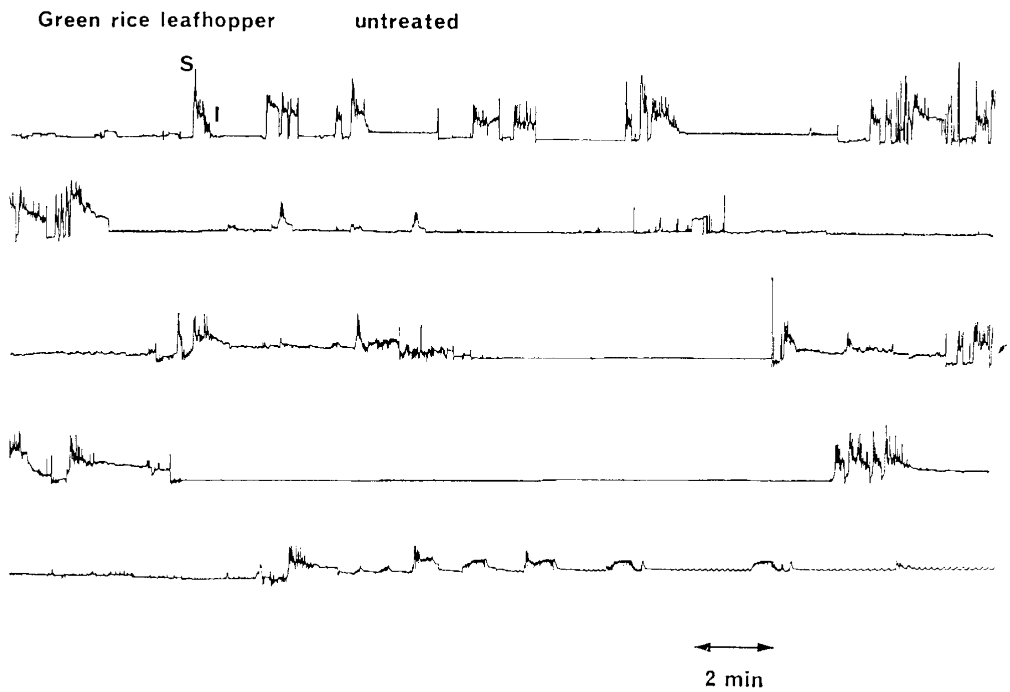

Fig. 2. Waveform obtained from *Nephotettix virescens* on an untreated seedling. These are typical waveforms showing the ingestion (*I*) and salivation (*S*) of insects which cause the virus infection. Discrimination of waveforms was shown in Kawabe and McLean (1980). Charts to be read from left to right and top to bottom.

RESULTS

Greenhouse evaluation

Lethality and repellency of 3 synthetic pyrethroids, and infection index of the rice treated with these insecticides are shown in Table 1. Esfenvalerate was the best compound to kill the insects and to prevent stripe virus infection among 3 insecticides at 10 ppm. Although 1 ppm of esfenvalerate showed lower insecticidal activity than 10 ppm of alpha cypermethrin and deltamethrin, the disease incidence at 1 ppm of esfenvalerate was lower. In this experiment, the percentage of viruliferous insects was 80%, which was much higher than that in the field, and all untreated plants showed serious stripe symptoms.

Laboratory assessment of mortality

LC_{50} values of esfenvalerate and fenitrothion against planthoppers and leafhoppers are shown in Table 2. The values of esfenvalerate against both species were much lower than that of fenitrothion, especially against planthoppers.

Repellency test

Esfenvalerate showed a high repellent activity (Table 3). The EC_{50} values of esfenvalerate against the smaller brown planthopper and the green rice leafhopper were 0.34 and 1.5 ppm, respectively. On the other hand, fenitrothion, BPMC and buprofezin

Table 1. Lethality and repellency of 3 synthetic pyrethroids, and infection index treated with these insecticides, determined in the greenhouse evaluation using viruliferous *Laodelphax striatellus*

Insecticides	Conc. (ppm)	% of insects		Infection index
		repelled	dead	
Esfenvalerate	10	24	60	25
	1	14	22	45
Alpha cypermethrin	10	30	38	85
Deltamethrin	10	6	32	100
Untreated		10	6	100

Eighty percent of insects used were viruliferous.

Table 2. LC_{50} values of esfenvalerate and fenitrothion against *Laodelphax striatellus* and *Nephotettix virescens* by the leaf dipping method

Insecticides	LC_{50} (ppm)			
	L. striatellus		*N. virescens*	
	male	female	male	female
Esfenvalerate	104.2 (58.8–106.6)	208.6 (174.6–272.4)	10.8 (8.5–13.0)	15.1 (12.3–17.9)
Fenitrothion	1.2 (1.0–1.2)	2.0 (1.8–2.3)	3.3 (3.3–3.8)	8.1 (7.8–12.6)

Figures in parentheses are for the 95% confidence limit.

Table 3. Repellency of 4 insecticides against *Laodelphax striatellus* and *Nephotettix virescens*

Insecticides	EC_{50} (ppm)	
	L. striatellus	*N. virescens*
Esfenvalerate	0.34 (0.21–0.48)	1.5 (1.2–2.0)
Fenitrothion	>100	>100
BPMC	>100	N.O.
Buprofezin	>100	>100

Figures in parentheses are for the 95% confidence limit.
N.O.: not observed

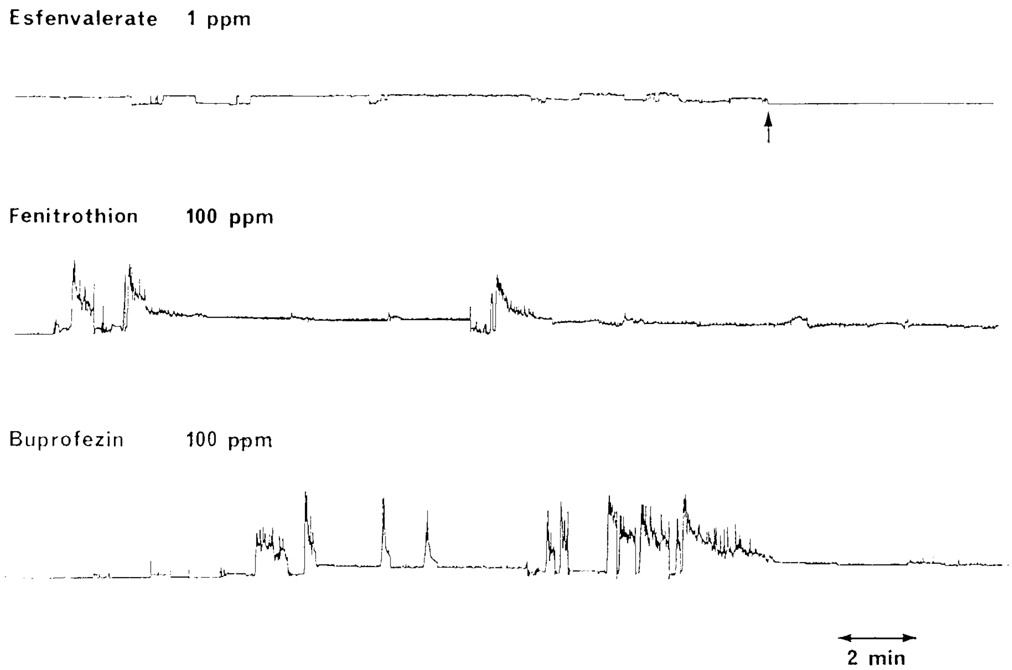

Fig. 3. Wavefrom obtained from *Nephotettix virescens* on a seedling treated with 1 ppm esfenvalerate, 100 ppm fenitrothion and 100 ppm buprofezin. Arrow indicates that insect left the seedling.

did not show remarkable activity. None of the insects left the untreated seedling during observation periods.

Electronic measurement of insect feeding behaviour

The green rice leafhopper frequently showed ingestion and salivation behaviour on an untreated seedling for at least 60 min (Fig. 2). The waveform shown in Fig. 3 was obtained from a leafhopper on a seedling treated with 1 ppm esfenvalerate. There was no typical waveform associated with feeding behaviour, as in Fig. 2. This response indicated that the insect did no ingestion and salivation while on the seedling. Moreover, the insect left the seedling after about 40 min. On the other hand, ingestion

Table 4. Inhibition of ingestion and salivation behaviour by esfenvalerate, fenitrothion and buprofezin

Insecticides	Conc. (ppm)	*L. striatellus*	*N. virescens*
Esfenvalerate	0.1	—	—
	1	±	+
	10	+	+
Fenitrothion	100	—	—
Buprofezin	100	—	—

—: Ingestion and salivation activities were observed.
±: Ingestion and salivation activity was rarely observed.
+: No ingestion or salivation activity was observed.
Results were obtained by electronic measurements.

and salivation waveforms were obtained from a leafhopper on a seedling treated with 100 ppm fenitrothion and 100 ppm buprofezin (Fig. 3). Smaller brown planthoppers also showed ingestion and salivation on seedlings treated with 100 ppm fenitrothion and buprofezin, and rarely on seedlings treated with 1 ppm esfenvalerate. Table 4 shows inhibitory activity at various concentrations.

DISCUSSION

Several experiments have been carried out to find the appropriate insecticides to prevent virus diseases of rice using organophosphate, carbamate and pyrethroid compounds (SATAPATHY and ANJANEYULU, 1984, 1986; ANJANEYULU and BHAKTAVATSALAM, 1987). They made clear that synthetic pyrethroids, especially cypermethrin and deltamethrin, reduced the incidence of tungro disease in the greenhouse and the field. The efficacy of these 2 chemicals was higher than that of fenvalerate. In our experiment, esfenvalerate showed good efficacy to prevent the infection of stripe virus in the greenhouse (Table 1). However, alpha cypermethrin, a mixture of 2 isomers of cypermethrin, and deltamethrin did not show activity as high. Efficacy may be variable among insect species and isomers of chemicals.

It was assumed that the repellency and inhibition of ingestion and salivation contributed to the prevention of virus infection. We, therefore, investigated those activities of esfenvalerate, which was the best compound to reduce the incidence of stripe among 3 chemicals. Although esfenvalerate had lower insecticidal activity than fenitrothion against planthoppers and leafhoppers, it showed higher repellency against both species (Tables 2 and 3). Leafhoppers stayed on seedlings treated with 1 ppm esfenvalerate but did not feed. In the case of planthoppers, ingestion and salivation behaviour was rarely observed during 60 min on the seedling, and occurred for totals less than 3 min. The minimum inoculation period of tungro was 10 min (SATAPATHY and ANJANEYULU, 1986). In the case of stripe, the period was assumed to be a few hours (MUKOO, 1975). These results suggest that 1 ppm esfenvalerate contributes to the prevention of the virus infection. As assumed by SATAPATHY and ANJANEYULU (1984) with regard to cypermethrin and deltamethrin, lethal and repellent activities of esfenvalerate also contribute to the prevention of virus infection. Moreover, sublethal concentrations of esfenvalerate inhibited the ingestion and salivation behaviour of the insects staying on the plants, which is actually the cause for virus infections.

ACKNOWLEDGEMENTS

The authors are indebted to Dr. TSUNEO TSUCHIZAKI of National Agriculture Research Center for a gift of viruliferous *Laodelphax striatellus*. They also wish to thank Miss Kayo MIYAZAKI for conscientious technical assistance.

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