

Effects of Synergists on the Toxicity of Fenvalerate to Pyrethroid-Resistant Diamondback Moth

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Abstract

Synergism of fenvalerate with piperonyl butoxide (PB), NIA-16388 (NIA), S-421, and MGK-264 on both susceptible (S) and fenvalerate-selected (FS) strains of diamondback moth, *Plutella xylostella* L., were determined in laboratory tests. Further, combinations of fenvalerate and these synergists were tested for their efficacies against resistant strain under field conditions in the Cameron Highlands, Malaysia. Fenvalerate/PB showed higher synergism and efficacy than combinations of fenvalerate with other synergists against FS and pyrethroids-resistant strains in the field. A 1:3 ratio for fenvalerate and PB seemed to be optimal for the control of resistant diamondback moth. Combinations of fenvalerate with NIA, S-421 or MGK-264 showed slight synergism on the FS strain in the laboratory tests, whereas combinations with NIA and S-421 showed efficacy similar to that of combination with PB in the field test. S-strain of diamondback moth was selected by fenvalerate alone and in combination with PB. Selection by fenvalerate alone developed resistance, whereas selection by fenvalerate/PB resulted in a somewhat lower level of resistance. This suggests that fenvalerate/PB may be effective in preventing or retarding the diamondback moth from developing resistance.

Introduction

The diamondback moth (DBM), *Plutella xylostella* (L.) (Lepidoptera: Yponomeutidae), is an important pest of cruciferous crops in many parts of the world. This insect pest has been exposed mainly to organophosphorus insecticides over many years, and lately to pyrethroid insecticides. Recently, DBM strains resistant to pyrethroids have been found in some parts of the world, such as Malaysia (Ho et al 1983) and Taiwan (Liu et al 1981). As one of the countermeasures against the insecticide resistance problem, the use of synergists has been studied by Liu et al (1982, 1984) and Ho et al (1983). High efficacies of combinations of insecticides with synergists have been reported for the control of several insect species which have developed resistance to insecticides, such as *Musca domestica* (Farnham 1973), *Culex pipiens fatigans* (Ranasinghe and Georghiou 1979), *Heliothis virescens* (Plapp 1979) and *Spodoptera litralis* (EI-Sebae 1978, Riskallah 1984). *Heliothis virescens* (Plapp 1979) and *Spodoptera litralis* (EI-Sebae et al 1978, Riskallah 1984).

The purpose of our studies was to evaluate the toxicity of fenvalerate with synergists to a susceptible strain, a fenvalerate-selected strain, and a multiple resistant strain of DBM which occurs in the field in Malaysia. Furthermore, the extent of resistance development was compared between selections using fenvalerate alone and in combination with piperonyl butoxide.

Materials and Methods

Insects

Laboratory tests A susceptible (S) DBM strain reared in the laboratories of the Sumitomo Chemical Co Ltd was used. A fenvalerate-selected (FS) strain was obtained from the S-strain by selection at the 50% level of mortality with fenvalerate treatment over 30 consecutive generations. Insects were raised on radish seedlings. Third instar larvae were used for bioassay.

Field tests Testing was conducted in the field in the Cameron Highlands in Malaysia, where DBM has developed multiple resistance to organophosphorus and pyrethroid insecticides.

Fenvalerate and synergists Fenvalerate 10% EC was formulated by the Sumitomo Chemical Co Ltd. Technical grades of four synergists used were: piperonyl butoxide (PB), NIA-16388 (NIA) (propylprop-2ynyl phenylphosphonate), MGK-264 (N-octyl bicycloheptene dicarboximide), and S-421 (octachlorodipropyl ether).

Bioassay

Laboratory tests Thirty 3rd instar larvae were dipped into a water solution of fenvalerate, alone or with a synergist (five times the amount of fenvalerate) for 20 seconds. After treatment the larvae were kept at $26 \pm 1^\circ\text{C}$ in a plastic cup containing fresh radish seedlings. Mortality was recorded after 48 h. The results were analyzed by the probit method (Finney 1971) from the mortality adjusted by Abbott's formula (1925). LC_{50} values were obtained with a computer program.

Field tests Insecticide application: The tests were conducted at a cabbage farm in the Cameron Highlands in Malaysia in August 1984. Each plot consisted of 20 plants (10 sq m) and each treatment was duplicated. Sprays were made at the rate of 1000 l/ha with a knapsack sprayer. Insecticides were sprayed on 14, 16, and 18 August 1984.

Observations Five plants per plot were selected for the observation, and the numbers of living larvae were counted. Observations were recorded at two days after each spray.

The efficacy was calculated by the following equation

$$\% \text{ Efficacy} = \left(1 - \frac{C_b \times T_a}{T_b \times C_a} \right) \times 100$$

where C_b = number of larvae on untreated check before treatment, C_a = number of larvae on untreated check after treatment, T_b = number of larvae on treated plot before treatment, T_a = number of larvae on treated plot after treatment.

Selections Comparative development of insecticide resistance of DBM between selections made by fenvalerate alone and by fenvalerate in combination with PB were made during 40 consecutive generations. Each time, 1000 3rd instar larvae held in net sacks with radish seedlings were dipped into a 100 ppm concentration of PB for 20 seconds one hour prior to the application of the prescribed concentrations of fenvalerate. Concentrations of fenvalerate for each generation were determined by aiming at approximately 50% larval mortality. Bioassays were carried out once every two or three generations.

Results and Discussion

For the fenvalerate selected (FS) strain of DBM obvious synergistic effects were observed except with S-421 at a ratio of 1:5 (fenvalerate:synergist) (Table 1). PB was the most effective synergist. However, fenvalerate was poorly synergised by PB with the susceptible (S) strain.

Table 1. The effects of synergists on the toxicity of fenvalerate to susceptible (S) and fenvalerate-selected (FS) strains of DBM

Insecticide	LC ₅₀ (ppm)	S.R. ^a
S-strain		
fenvalerate alone	0.68	
+ PB (1:5)	0.09	7.6
FS-strain		
fenvalerate alone	26.6	
+ PB (1:5)	0.77	34.5
+ NIA (1:5)	2.8	9.5
+ S-421 (1:5)	12.4	2.1
+ MGK-264 (1:5)	4.8	5.5

^a Synergistic ratio = LC₅₀ value of fenvalerate alone/LC₅₀ value of fenvalerate + synergist.

It is generally recognized that PB produces its synergistic effect by inhibition of mixed-function oxidases enzymes in the insect body (Casida 1970). Therefore, it is assumed that on increase of the enzyme may be a key factor as the mechanism of resistance in the FS-strain.

Further experiments were conducted to observe the efficacies of fenvalerate combined with each of four synergists for the field strain of DBM in the Cameron Highlands, Malaysia. In this area, vegetables are grown throughout the year, and insecticides have been applied extensively over the past several years. The insect has developed high levels of resistance to several insecticides. A 200 ppm fenvalerate spray gave only 54% control in the field test. However, a fenvalerate/PB combination (1:3) gave 90% control (Figure 1). Combinations of fenvalerate and each of NIA, S-421 or MGK-264, which had provided slight synergism to the FS-strain in laboratory tests (Table 1), showed greater efficacy in field tests, especially NIA and S-421 which gave nearly the same level of control as PB did. The fenvalerate/NIA combination was phytotoxic at a concentration of 200/600 ppm in this test. The high synergism of fenvalerate with S-421 may be caused by S-421 alone, because S-421 itself is toxic to insects. From the above results, PB and S-421 appear to be suitable for combination with fenvalerate for the control of pyrethroid-resistant DBM.

Figure 2 shows the prograession of development of resistance in DBM strains selected by fenvalerate alone and by fenvalerate/PB. Up to 10th generation of both selections, the mean LC₅₀ values of fenvalerate were stable at levels of 0.7 ± 0.2 ppm in both strains. A 17-fold increase in fenvalerate resistance occurred in the strain selected by fenvalerate/PB after the 25th generation, whereas in the strain selected by fenvalerate alone the increase was 63-fold. From the 30th to 40th generation, the resistance levels in both strains did not change significantly, which indicated that the resistance had reached a maximum plateau. The strain selected by fenvalerate/PB attained a lower level of resistance compared to the strain selected by fenvalerate only. PB, which inhibits mixed-function oxidases enzymes, leads to the development of resistance at a much lower level than could be accomplished by fenvalerate alone.

Acknowledgement The authors wish to thank Mr T. Abe of this laboratory for advice. This report was published with permission of the Sumitomo Chemical Co Ltd.

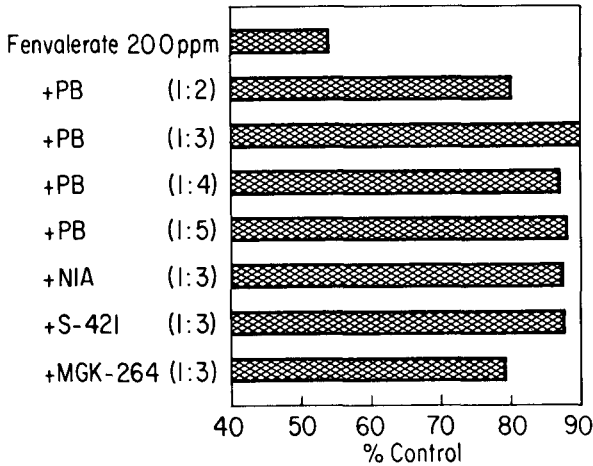


Figure 1.
The efficacies of fenvalerate alone and in combination with synergists to diamondback moth. (Cameron Highlands, Malaysia, 1984)

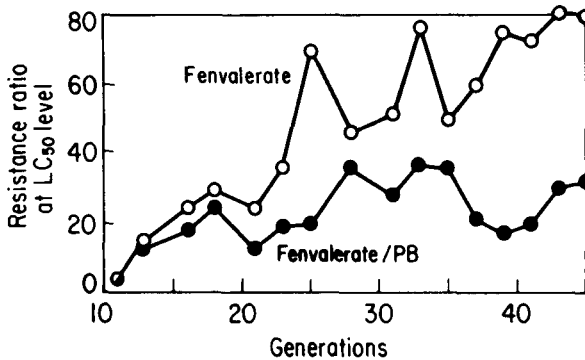


Figure 2.
Development of fenvalerate resistance to selected strains of diamondback moth by fenvalerate alone and in combination with PB

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