REPELLENCY AND ANTIFEEDANT ACTIVITY OF PYRETHROIDS TO DIAMONDBACK MOTH

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SUMMARY

The repellency and antifeedant effects of permethrin and fenvalerate against third instar diamondback moth *(Plutella xylostella)* larvae were investigated in laboratory and field experiments. Strong repellency and antifeedant effects were observed at LC_1 and LC_{50} in laboratory experiments, but these effects were not as marked with field weathered residues. The significance of these effects under field conditions cannot yet be fully stated.

INTRODUCTION

Diamondback moth (DBM) is a ubiquitous pest of brassica crops in New Zealand. The larvae may cause extensive foliar injury and, because processors and consumers demand practically no damage, horticultural crops require protection from transplanting to harvest. A spray programme of organophosphate or carbamate insecticides applied at 7-14 day intervals has commonly been used. Recently, several pyrethroid insecticides have been registered for use against pests on these crops. They are good contact insecticides (Elliot *et al* 1978) but they are also claimed to possess a number of unique properties (Ruscoe 1977; Highwood 1979). In particular, the effects of sublethal doses of these insecticides apparently induce antifeedant and repellency actions which, according to Ruscoe (1977), may significantly extend the period of crop protection afforded by a single spray. Until recently, much of the information on these and other sublethal effects was of an observational nature and so a study was initiated to quantify some of these responses using larvae of DBM as the test species. The repellency and antifeedant actions of two pyrethroids, permethrin and fenvalerate, were investigated in laboratory and field experiments.

METHODS

Toxicity data for permethrin (Ambush 50 EC) and fenvalerate (Sumicidin 10 EC) against third instar larvae and adults have been determined (Kumar and Chapman 1983). The sublethal concentrations selected for the following laboratory experiments were the LC_1 and LC_{50} values which appear in Table 1.

Repellency and antifeedant action to larvae

The repellency action was tested by placing 20 third instar larvae on six-week-old broccoli plants *(Brassica oleracea italica* cv De Cicco*)* of uniform size and leaf number which had been sprayed on all surfaces with 10 ml of each insecticide at the LC_1 and LC_{50}. Water was sprayed on to control plants and each treatment was replicated four times. To trap larvae that were repelled from the plants, a cardboard arena, coated on the upper surface with "Tack-Trap" was placed at the base of each plant. Percentage repellency was calculated as:-

$$\frac{\text{No. of larvae on control plants - No. larvae on treated plants}}{\text{No. larvae on control plants}} \times 100$$

The antifeedant action was determined by presenting 200 mm diam. leaf discs treated with the insecticides at the LC_1 and LC_{50} to third instar larvae. Treated discs were arranged randomly with water sprayed control discs on the base of a petri dish.

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Four replicates of each set of discs were prepared and 20 third instar larvae, which had been starved for 24 h prior to the experiment, were released into each dish. After 12 h, the leaf area damaged was measured by passing the discs through a leaf area machine (Lambda: Model LI-3100).

Bioassay of field-weathered insecticide residues

Young broccoli plants (cv De Cicco) were transplanted into 6 x 2 m plots at 0.5 m intervals on 26.1.81 at the Horticultural Research Centre, Lincoln College. Each insecticide was applied by precision plot sprayer (D-24 cone nozzles; 350 kPa) at rates equivalent to 50 and 150 g ai/ha in 200 litres water. These application rates covered the then recommended label rates for the two insecticides. All treatments and a water sprayed control were replicated four times in a randomised block design.

Ten, 20 mm diam. discs were punched from leaves selected at random in each plot at zero (3 h after spraying), 2, 4, 7, 12, 19, 26 and 33 days after treatment. On each occasion the discs were brought into the laboratory where five third instar larvae were released onto each disc. Mortality and percentage leaf area damage was assessed after 48 h as previously described.

TABLE 1: Repellency and antifeedant action of sub-lethal rates of permethrin and fenvalerate to DBM third instar larvae in laboratory experiments.

Insecticide	Conc. % ai	Larvae repelled		Leaf area consumed[1]	
		Mean No. ±S.E.	%	Mean ±S.E. (cm^{-2})	%
untreated		0	0	5.8 a	100
permethrin LC_1	0.0006	11.8 ± 1.8 c	59	0.6 ± 0.17 b	10
LC_{50}	0.002	18.5 ± 1.0 a	93	0	0
fenvalerate LC_1	0.0005	14.5 ± 1.0 b	73	0.4 ± 0.13 b	7
LC_{50}	0.003	19.8 ± 0.3 a	99	0	0

LC_1 and LC_{50} are the median lethal concentrations required to kill 1 and 50% of the test population, respectively.

[1] Area of leaf disc = 5.8 cm^2

RESULTS

Table 1 records the antifeedant and repellency actions of permethrin and fenvalerate to third instar larvae. Larvae placed on pyrethroid treated leaves escaped the residues by spinning down from the leaf edges. Both insecticides were highly repellent with significantly more ($p < 0.05$) being repelled at LC_{50} than the LC_1. Fenvalerate was superior to permethrin at LC_1 but no difference was observed at LC_{50}. No larvae were recorded leaving the untreated plants.

Treated leaf discs were apparently a non preferred food source for third instar larvae as both insecticides provided complete (LC_{50}) or nearly complete (LC_1) protection from feeding injury over the 12 h test period. By comparison, the untreated discs were completely eaten.

Figure 1 presents an example of the results achieved when field-weathered residues were used in bioassay tests to determine mortality and antifeedant activity (Kumar 1982). During the trial period the mean daily temperature was 16 °C and there were 4 days of rain totalling 27 mm. This rainfall should not markedly reduce residue levels on the leaves because these pyrethroids are highly lipophilic and exhibit a degree of rainfastness (Ruscoe 1977). Percentage mortalities were converted to probits and the relationship between time and probits described by linear regression equations (Table 2). The rate at which mortality decreases from 100 to 0% was comparable for both insecticides and rates, but the period over which mortality occurred was longer at the higher rate. This is because 150 g/ha resulted in 100% mortality at 4-7 days with fenvalerate and permethrin respectively (Fig. 1). By contrast, 100% mortality at 50 g ai/ha for both insecticides occurred only on the day of spraying (time 0). The quantities of leaf damage at 50 and 1% mortality levels are also presented in Table 2. The area of leaf eaten were considerably higher than the laboratory treated discs (Table 1) and there was no major difference between the two LC levels.

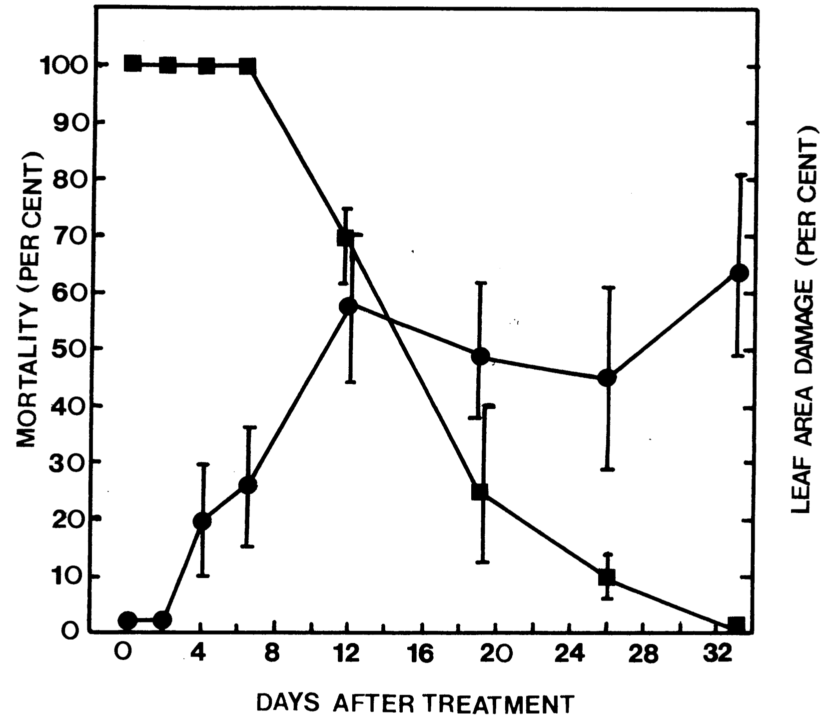

Fig. 1: **Effect of permethrin (150 g/ha) on the leaf area damage and mortality of *P. xylostella* larvae in laboratory bioassay**

TABLE 2: **The effect of field weathered residues of permethrin and fenvalerate on mortality and feeding of DBM third instar larvae.**

Insecticide	Rate g ai/ha	Time-probit regression	R^2	% leaf damage at mortality 50%	1%
permethrin	50	y = 5.53 - 0.127x	74.9	38	53
	150	y = 7.00 - 0.129x	98.4	50	62
fenvalerate	50	y = 5.69 - 0.102x	85.4	40	54
	150	y = 6.09 - 0.086x	99.1	46	55

1% mortality transformed to probits
R^2 = coefficient of determination

DISCUSSION AND CONCLUSIONS

When third instar DBM were exposed to pyrethroid residues and had the freedom to move over the plant, a high percentage of larvae spun down off the plant. Whether spinning down contributes significantly to mortality in the field has not been determined. Larvae could be permanently 'lost' from the crop or they may be able to regain themselves on leaves lower down the plant which could have little or no insecticide residue. Recent observations on spider mites show they rapidly redistribute to unsprayed portions of the plant (Penman and Chapman 1983). It is also possible the spin down percentages are exaggerated under laboratory conditions because larvae were placed directly onto residues on treated plants and were therefore assurred of coming into contact with the insecticide. Furthermore, spray coverage on laboratory treated plants would probably have been more uniform and therefore fewer unsprayed refugia would have existed.

Under laboratory conditions, leaf protection from feeding injury was also exhibited at sublethal concentrations. Conditions in these experiments allowed larvae a choice of variously treated leaf discs demonstrating that third instar larvae can discriminate between treated and untreated foliage, preferring to feed on the latter. One practical implication of this result is the requirement to achieve thorough coverage of crop foliage to ensure near-complete leaf protection. Greatest difficulty in achieving this is with young, emerging leaves in the centre of the plant which are also the favoured feeding sites of DBM on some brassicas (A.M. Ferguson, pers comm).

Ruscoe (1977) suggested the period of crop protection against DBM by a single spray would be a combination of larvicidal and antifeedant activity of pyrethroids. From laboratory and field experiments in the United Kingdom up to 12 days larvicidal activity plus a further seven days of antifeedant activity were demonstrated, but unfortunately the rates of application, levels of larval mortality and antifeeding were not quoted. In the trial described here, high larval mortality (>95%) occurred for up to 7 days with 150 g/ha of permethrin, but protection of leaves from feeding by antifeedant effects was much lower than expected from laboratory results. A number of explanations may account for this. Firstly, the insecticide residues on field sprayed plants are unlikely to be as uniform as laboratory sprayed deposits, particularly on the undersides of leaves. The laboratory experiments demonstrated that larvae discriminated between treated and untreated foliage (Table 1). The densities of insecticide deposit may well differ between laboratory and field leaf discs. If residues were less dense on field collected discs, a proportionately larger area of leaf would have to be eaten to result in a comparable level of antifeedant activity or mortality. Residue analyses would be needed to resolve this point.

In conclusion, the antifeedant and repellency activity of these pyrethroids at sublethal concentrations have been shown to be quite marked with third instar DBM larvae under laboratory conditions and are similar in many respects to those recorded for white butterfly larvae (Tan 1981). The responses to field-weathered residues were, however, not as marked and further field experiments are required to fully assess their effects on field populations of DBM.

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