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EFFECTS OF SYNTHETIC PYRETHROIDS ON GROWTH AND DEVELOPMENT OF THE FALL ARMYWORM, *SPODOPTERA FRUGIPERDA*

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ABSTRACT

Nine synthetic pyrethroids were evaluated at 1 ppm in an artificial diet fed to larvae of the fall armyworm, *Spodoptera frugiperda* (J. E. Smith)

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(Lepidoptera: Noctuidae). All compounds were effective insecticides for FAW control at this sublethal concentration because they inhibited growth of larvae, reduced the amount of feeding by larvae, reduced mobility of adults, and in 8 instances reduced fecundity.

RESUMEN

Se evaluaron 9 pyrethroids sintéticos a 1 ppm en una dieta artificial usada para alimentar larvas del cogollero, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae). Todos los compuestos fueron insecticidas efectivos en controlar al cogollero a esta concentración subletal, porque ellos inhibieron el crecimiento de las larvas, reducieron la cantidad comida por las larvas, la mobilidad de los adultos, y en 8 ocasiones la fecundidad.

The photostable synthetic pyrethroids have high acute toxicities as well as chronic effects on the fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith) (Gist and Pless 1985 a,b,c). Chronic effects are evident at concentrations of pyrethroids lower than those causing mortality. Such effects may prevent damage to plants. Use of lower concentrations might reduce the development of resistance in pest populations and minimize detrimental effects to beneficial arthropods (Ross and Brown 1982). Reese and Beck (1976) hypothesized that chronic effects, such as slowing developmental rate, could increase mortality through longer exposure of target species to parasites, predators, pathogens, and adverse physical factors.

Effects of sublethal dietary concentrations of pyrethroids on insects have been investigated only recently. Tan (1981) found that cypermethrin and permethrin induced a significant extension of the larval period of *Pieris brassicae*, with a reduction in the maximal larval and pupal weights. Fecundity of adults in those experiments was also reduced, possibly due to the reduction of pupal weights. Ross and Brown (1982) found that sublethal concentrations of fenvalerate and permethrin inhibited larval growth (decreased overall larval weight) of FAW. NRDC-161 in the diet of *Anthonomus grandis grandis* reduced the fecundity of the females (Moore 1980).

The quantitative nutritional approach to studying insect growth and development consists of measuring the amount of food consumed, digested and assimilated, excreted, metabolized, and converted into biomass (Waldbauer 1968). Analysis of these measurements reveals how organisms respond to different foods and which food components (or additives) exert the greatest effects on growth (Schribner and Slansky 1981). Information on the effects of sublethal dietary concentrations of pyrethroids on feeding indices has not been published.

The purpose of this study was to evaluate the effects of sublethal dietary concentrations of nine synthetic pyrethroids on the growth, development, and subsequent fecundity of a laboratory strain of FAW.

MATERIALS AND METHODS

Insecticide-acetone (wt/vol) solutions were mixed with dry diet components (Bio-Serv Corn Earworm Rearing Media, Bio-Mix #9394, packet A) in a blender for 10 min.

The acetone was allowed to evaporate overnight. The diet was then prepared according to directions and stored in a refrigerator (12°C) until needed. The final concentration of pyrethroid in the diet was 1 ppm. Control diet was treated with acetone only. The synthetic pyrethroids were technical formulations of permethrin and cypermethrin (ICI Americas, Inc.); permethrin, cypermethrin, Pounce®, and Ammo® (FMC Agricultural Chemical Group); Pydrin® (Shell Development Co.); Mavrik® (Zoecon Corp.); and Pay-Off® (American Cyanamide Co.).

Thirty larvae in the 3rd instar from a laboratory culture (Gist and Pless 1985a) were weighed and placed individually onto weighed squares of treated or control diet in 60-mm-dia. petri dishes. All measurements were made during 4th-6th instars because younger FAW (1st-3rd instars) consume $< 2\%$ of the total dietary intake (Luginbill 1928). Thus, by allowing the 3rd instar to acclimate, "loss of appetite" upon initial exposure to a new food, as discussed by Wiklund (1973) and Jermy, et al. (1968), was avoided. Fresh diet was provided as needed to allow the larvae to feed freely. All larvae were kept within environmental chambers at $27 \pm 2°C$, L14:D10 photoperiod, and 60-70% RH. Frass was separated from uneaten diet, and separately they were dried and weighed. The weight and instar of each larva was recorded daily. Thirty aliquots of each experimental diet and the control diet were weighed, dried, and reweighed to determine the initial percentage of dry matter.

Newly emerged adults were placed in 4-liter cylindrical wire cages lined with paper toweling for an ovipositional substrate. Cotton saturated with an ascorbic acid-beer (1.5 g/828 ml) solution was placed into each cage for adult diet. The number of egg masses and eggs for each treatment was recorded. Egg masses were clipped from the paper toweling, surface sterilized with sodium hypochlorite, and placed on control diet within the environmental chambers. The number of eggs that had not hatched after 7 days was recorded.

The nutritional indices (Scribner and Slansky 1981, Waldbauer 1968) calculated were relative growth rate (RGR); relative consumption rate (RCR); approximate digestibility (AD); efficiency of conversion of digested food (ECD); and efficiency of conversion of ingested food (ECI). Statistical analyses were performed where needed and significant differences between means were detected by Dunnett's test (Zar 1974).

Results and Discussion

Larvae fed synthetic pyrethroids required significantly longer to reach their maximum weight than larvae fed the control diet (Table 1). Increases ranged from 2X [permethrin (ICI)] to 3X [cypermethrin (FMC)]. Although the duration of stadia 4-6 was increased, the duration of the prepupal stadia remained approximately the same as for the control. This suggests that pyrethroids at 1 ppm exert a detrimental effect on actively feeding stages.

Larvae fed pyrethroid-treated diet had significantly lower maximum weights than the control group (Table 1). Scriber (1977) stated that larval growth can be reduced by lack of water. Although all diets contained sufficient water (ca. 81%) for normal growth, larvae that fed on treated diet were more flaccid than control larvae, indicating a lack of body

TABLE 1. RATE OF GROWTH, WEIGHT, AND SURVIVAL OF *Spodoptera frugiperda* LARVAE REARED ON ARTIFICIAL DIET IMPREGNATED WITH 1 PPM OF NINE SYNTHETIC PYRETHROIDS.

Compound	Days to Maximum Weight ($\bar{x}$ ± SE)[1]	Maximum Larval Weight (mg ± SE)	Pupal Weight[1]	% Mortality
Control	6/0 (± 0.0)	436.1 (± 14.3)	258.6 (± 26.2)	0.0
permethrin (ICI)	12.3 (± 0.9) *	317.1 (± 30.4)	204.3 (± 47.1) *	16.7
Ammo®	12.7 (± 1.3) *	375.6 (± 30.6)	229.4 (± 34.8) NS	3.3
Mavrik®	13.7 (± 0.5) *	408.0 (± 20.9)	229.8 (± 31.8) NS	0.0
Pydrin®	13.7 (± 0.5) *	393.6 (± 15.6)	230.4 (± 33.9) NS	10.0
Pounce®	14.3 (± 0.5) *	331.5 (± 30.5)	220.4 (± 45.7) NS	3.0
Pay-Off®	15.3 (± 1.7) *	360.1 (± 38.5)	206.7 (± 35.4) *	0.0
cypermethrin (ICI)	16.3 (± 2.1) *	370.3 (± 18.0)	208.2 (± 41.8) *	13.3
permethrin (FMC)	18.3 (± 1.3) *	272.3 (± 22.5)	159.4 (± 24.4) *	53.3
cypermethrin (FMC)	20.3 (± 0.5) *	272.8 (± 27.7)	145.5 (± 26.5) *	60.0

[1] * = Significantly different from control at $p \leq 0.05$. NS = not significantly different from control (Dunnett's procedure).

water. Abnormally low weights of treated larvae were not apparent until the 6th instar. Pupal weights were reduced significantly by 5 of the pyrethroids. The most dramatic reductions of weight were caused by permethrin (FMC) (38% less than the control) and cypermethrin (FMC) (44% less than the control).

All of the pyrethroids tested significantly reduced the RGRs (Table 2). In no case was AD, ECD, or ECI reduced by the pyrethroids, indicating that although these compounds do effect mortality when incorporated into the diet at 1 ppm, there is no metabolic "cost" incurred to detoxify them (Scriber and Slansky 1981). Additives in the food that reduce feeding usually impose a reduced RCR (Scriber and Slansky 1981). A reduction in RCR occurred with all the pyrethroids tested indicating that these compounds deter feeding. This has been further substantiated by Gist and Pless (1985b) who found that these pyrethroids deterred feeding by 3rd instar FAW at 50 ppm and 5 ppm, both in 2-choice and no-choice tests. An imposed reduction in RCR should result in lengthy extension of the larval stadium with final body weight reduced below normal (Mathavan and Muthukrishnan 1976, McGinnis and Kasting 1959, Mukerji and Guppy 1970, Rojas-Rousse and Kalmes 1978). We concluded that reduction in RCR was induced by the pyrethroids because they deter feeding, increase time in the larval stage, and decrease final body weights.

Larvae reared on the treated diets pupated normally, and emergence of the adults was comparable to control adults (Table 3); however, many of the subsequent adults were unable to inflate their wings upon emergence. This might add to population control since adults would be unable to fly when disturbed, thus making them more susceptible to natural mortality factors. Mating and feeding would also be inhibited by their inability to fly.

TABLE 2. EFFECTS OF NINE SYNTHETIC PYRETHROIDS IN ARTIFICIAL DIETS FED TO LARVAE OF *Spodoptera frugiperda* ON NUTRITIONAL INDICES[1] (4TH-6TH INSTARS) OF 1 PPM.

Compound	AD[2]	ECD[2]	ECI[2]	RCR[2]	RGR[2]
Control	67.5	15.8	10.5	3.38	0.35
permethrin (FMC)	55.3 NS	8.9 NS	4.8 NS	2.08 *	0.10 *
Ammo®	48.8 NS	14.1 NS	6.0 NS	2.87 *	0.16 *
Mavrik®	47.0 NS	15.5 NS	7.3 NS	2.03 *	0.15 *
Pounce®	46.4 NS	14.4 NS	6.6 NS	1.83 *	0.12 *
cypermethrin (ICI)	46.0 NS	14.1 NS	5.9 NS	2.08 *	0.13 *
cypermethrin (FMC)	42.3 NS	9.3 NS	3.9 NS	2.94 *	0.12 *
permethrin (ICI)	42.2 NS	16.3 NS	6.8 NS	2.43 *	0.17 *
Pydrin®	42.2 NS	17.6 NS	7.0 NS	1.88 *	0.13 *
Pay-Off®	36.0 NS	16.9 NS	6.0 NS	2.11 *	0.13 *

[1]AD (Approximate digestibility) = (I-F)/I; ECD (Efficiency of conversion of digested food) = B/(I-F); ECI (Efficiency of conversion of ingested food) = AD x ECD; RCR (Relative consumption rate) = I/T/B; RGR (Relative growth rate(= RCR x ECI; where B = biomass gained, I = ingested food, F = feces egested (undigested food + excretory products), I-F = assimilated food, B = mean weight during time period T, and T = time in days to maximum weight.

[2]* = Significantly different from control ($p \leq 0.05$). NS = not significantly different from control (Dunnett's procedure).

TABLE 3. EFFECTS ON FECUNDITY AND PUPAL ECLOSION OF 1 PPM OF NINE SYNTHETIC PYRETHROIDS IN ARTIFICIAL DIETS FED TO LARVAE OF *Spodoptera frugiperda.*

Compound	Adults failing to emerge	% uninflated wings	eggs masses/ ♀	eggs/ ♀	% eggs not hatching
Control	10.0	0.0	9.8	1011.4	0.7
Pydrin®	14.8	13.0	19.8	1982.0	10.7
Pounce®	10.3	0.0	8.2	575.6	10.2
cypermethrin (FMC)	8.3	9.1	8.5	353.6	11.3
permethrin (ICI)	8.0	17.4	5.7	465.7	6.7
permethrin (FMC)	7.1	15.4	4.9	355.7	14.3
cypermethrin (ICI)	3.9	8.0	7.5	454.5	10.0
Ammo®	3.5	21.4	6.2	497.9	4.2
Pay-Off®	3.3	10.3	7.0	571.9	4.5
Mavrik®	0.0	43.3	6.3	407.0	7.4

Treatment reduced the number of eggs/female by ca. 50%; however, there was a 2-fold increase with Pydrin®-treated insects (Table 3). Hormologosis, a phenomenon in which subharmful quantities of stress agents are stimulating (Luckey 1968), is a possible explanation for the increase seen with Pydrin®. Eggs laid by treated females had 6X (Ammo®) to 20X [permethrin (FMC)] greater mortality than eggs laid by control females.

In conclusion, the synthetic pyrethroids can be effective insecticides for FAW control at sublethal concentrations because they inhibit growth of the larvae, reduce the amount of feeding by larvae, reduce mobility of adults and reduce fecundity. These characteristics might help prevent the formation of large FAW populations in the field thus reducing overall economic damage.

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FEEDING DETERRENT EFFECTS OF SYNTHETIC PYRETHROIDS ON THE FALL ARMYWORM, *SPODOPTERA FRUGIPERDA*

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ABSTRACT

Nine synthetic pyrethroids were tested in the laboratory for feeding deterrency to 3rd instar fall armyworm, *Spodoptera frugiperda* (J. E. Smith)

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