Selective Toxicity of Three Synthetic Pyrethroids to Eight Coccinellids, A Eulophid Parasitoid, and Two Pest Chrysomelids[1]

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ABSTRACT

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The toxicities of 3 synthetic pyrethroids (permethrin, cypermethrin, and fenvalerate) were determined for 8 species of predaceous coccinellids, 2 pest chrysomelids (northern corn rootworm and cereal leaf beetle) and a hymenopteran parasitoid of the cereal leaf beetle, as topical LD_{50}'s or contact LC_{50}'s. All species were collected from corn or oat fields. Two of the pyrethroids, permethrin and fenvalerate, demonstrated selectivity in favor of most of the coccinellid species, while cypermethrin was more active against the ladybird beetles than the pest chrysomelids. All 3 pyrethroids were considerably more toxic to the parasitoid than to its chrysomelid host.

Pyrethrins, cinerins, and jasmolins, collectively called pyrethrum, are naturally-occurring chemicals, extractable from African chrysanthemums. They have been known for over a century to be very potent insecticides.

Pyrethrum has several attributes which make it an ideal insecticide. It is highly toxic in small amounts to a wide range of insect pests while being relatively safe to mammals (Elliott 1976); it is quickly degraded by light and air to inactive products leaving no harmful or persistent residues (Chen and Casida 1969); and biological systems can readily metabolize it by oxidative and hydrolytic reactions (Casida et al. 1971, Miyamoto 1976). However, the susceptibility to rapid breakdown that makes pyrethrum a non-persistent, biodegradable insecticide makes it economically impractical for wide use in agriculture. Several synthetic variations of pyrethrum (e.g., allethrin, resmethrin) have experienced some commercial success, but only recent analogs containing chlorine or other halogens have demonstrated substantial residual activity in the field.

The increased potency of these halogenated synthetic pyrethroids, their residual properties, and their activity against a broad spectrum of insect pests, raises the question of potential hazards to nontarget species. If these compounds are to be widely used in agriculture by 1980 (Elliott 1976), their effects on the balance of predators and prey in agricultural ecosystems must by analyzed. With the exception of the work by Plapp and Vinson (1977) and Plapp and Bull (1978) with the tobacco budworm, *Heliothis virescens* (F.), its parasitoid, *Campoletis sonorensis* (Carlson), and a predator, the green lacewing, *Chrysopa carnea* (Stephens), little research has been conducted on the toxicity of new synthetic pyrethroids to nontarget insects.

The present study evaluated the toxicity of 3 synthetic pyrethroids, permethrin, cypermethrin, and fenvalerate, against several species of beneficial insects by determining LD_{50} and LC_{50} values. Two chrysomelid pests, the northern corn rootworm and the cereal leaf beetle, that coexist with the beneficial species in corn or oat fields were also treated for comparison. Eight species of predaceous coccinellids were utilized in the following genera: *Adalia* (1 sp.), *Coccinella* (2 spp.), *Coleomegilla* (1sp.), and *Hippodamia* (4 spp.). A hymenopteran parasitoid of the cereal leaf beetle also was tested.

Materials and Methods

Technical grade permethrin, cypermethrin, and fenvalerate were used in all bioassays. Permethrin samples were provided by FMC Corp., Middleport, NY and Shell Canada, Ltd., Toronto, Ontario; Shell also supplied the cypermethrin and fenvalerate samples. The insecticides were applied topically in one μl of acetone solution with a 50-μl microsyringe in a Unimetrics repeating dispenser. For contact toxicity trials, one ml of an acetone solution was applied to a 9-cm filter paper, dried, rolled, and inserted as a liner in an open-mouth 2×8-cm vial, sealed with paraffin wrap. Insects were confined to a paper-lined vial for 24 h. Carbon dioxide was used as an anesthetic while the insects were being handled. Beetles were maintained prior to and after dosing on 20% sugar solution. For each dose, groups of 10 or 20 insects were treated, on at least 3 different days. Insects were held at 27°±1°C, on a 16:8 photoperiod. Mortality readings were taken after 24 h. LD_{50} and LC_{50} values and 95% confidence limits were obtained by using a probit analysis computer program, utilizing at least 4 points (doses) of partial mortality. The minimum number of insects used for computing any regression line was 180. Control groups were maintained (untreated as well as treated with acetone). Control mortality was very low and was corrected for in the probit analysis computations.

The species tested included: 8 predaceous coccinellids *Adalia bipunctata* (L.) (the twospotted lady beetle), *Coccinella transversoguttata richardsoni* Brown (the transverse lady beetle), *Coccinella trifasciata* Mulsant, *Coleomegilla maculata lengi* De Geer, *Hippodamia convergens* Guérin-Méneville (the convergent lady beetle), *Hippodamia glacialis* (F.), *Hippodamia parenthesis* (Say), and *Hippodamia tredecimpunctata tibialis* (Say) (thirteen-spotted lady beetle); 2 chrysomelids *Diabrotica longicornis* (Say), (northern corn rootworm) and *Oulema melanopus* (L.) (cereal leaf beetle); a eulophid parasitoid, *Tetrastichus julis* (Walker), a principle parasite of the cereal leaf beetle in Michigan and Ontario (Harcourt et al. 1977). The insects were all collected from wild populations near Guelph, Ontario. The beetles

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were all collected as adults and the parasitoids were used one day after emergence from overwintering pupae of the cereal leaf beetle. Sexes were not separated.

Results and Discussion

Topical application tests revealed all 3 pyrethroids to be potent insecticides with LD_{50}'s ranging from 0.003 to 5.1 μg/g for the 10 species of beetles treated (Table 1). *A. bipunctata* was the most susceptible species of ladybird beetle, while *C. transversoguttata* and *H. glacialis* were the most tolerant to these insecticides. The most numerous coccinellids in the fields, *H. tredecimpunctata tibialis* and *C. maculata lengi*, demonstrated moderate susceptibilities.

Comparison of LD_{50}'s for the coccinellids and the pest chrysomelids indicated that 2 pyrethroids, permethrin and fenvalerate, were somewhat selective in favor of the coccinellids. Permethrin was less toxic to 6 coccinellids than it was to both pest species; fenvalerate was less toxic to 5 coccinellids than to both pests (and less toxic to 7 coccinellids than to the northern corn rootworm). Conversely, cypermethrin demonstrated selectivity against more of the ladybird beetles, as it was more toxic to 5 of the 8 coccinellids than it was to either pest.

The contact toxicity studies determined the LC_{50} of deposited residues of each chemical against adult *O. melanopus* and the eulophid *T. julis*. The parasitoid was extremely susceptible to all the pyrethroids while the cereal leaf beetle was 2–3 orders of magnitude less susceptible. Permethrin was 1000× more toxic to the parasitoid than its host beetle, fenvalerate was 850× more toxic, and cypermethrin was 150× more toxic. Cypermethrin was considerably more toxic to the host than the other 2 compounds (Table 2).

In all toxicity trials, cypermethrin generally emerged as the most active insecticide; permethrin and fenvalerate were less toxic in most cases, but were still far more potent than many organochlorine, organophosphorus, or carbamate insecticides (Plapp and Vinson 1977, Plapp and Bull 1978). The synthetic pyrethroids thus probably will be applied at quite low doses for many pests. However, even at low doses, the question of selectivity, i.e., relative toxicity to harmful versus beneficial species, remains important. An investigation of permethrin toxicity to mites has determined that this compound is 20–40× more toxic to the predaceous phytoseiid *Metaseiulus occidentalis* (Nesbitt) than to its prey, the twospotted spider mite, *Tetranychus urticae* Koch (Roush and Hoy, 1978). A study comparing the toxicities of several classes of insecticides found both fenvalerate and permethrin to be less toxic (1/27 and 1/2, respectively) to the predaceous green lacewing, *Chrysopa carnea* than to the tobacco budworm (Plapp and Vinson 1978). A comparison of those 2 chemicals against the ichneumonid parasitoid *Campoletis sonorensis* and its host, the tobacco budworm, indicated that fenvalerate and permethrin were, respectively, 1.5 and 18× more toxic to the parasitoid than to the host, while several other types of insecticides were even more selective against the ichneumonid (Plapp and Bull 1978). While our study found fenvalerate and permethrin to be 850 and 1000× more toxic to a parasitoid than its host, it must be recognized that species vary widely in susceptibility to toxicants. The differences observed in the 2 parasitoid studies were not large when consideration is given to the fact that the ichneumonid-tobacco budworm study derived selectivity ratios from LD_{50}'s resulting from one-day exposures for the parasitoid and 4-day exposures for the host, while the present eulophid-cereal leaf beetle study utilized one-day exposures for both the parasitoid and the host.

Table 1.—Toxicity of 3 pyrethroids by topical application to 8 species of coccinellids and 2 chrysomelid pests.

Insect	Avg wt (mg/beetle)	Topical LD_{50} - μg/g (with 95% confidence limits)		
		Permethrin	Cypermethrin	Fenvalerate
Coleoptera: Coccinellidae				
Adalia bipunctata	11	0.10(0.073–0.15)	0.0026(0.0011–0.0047)	0.022(0.008–0.041)
Coccinella transversoguttata	34	1.4 (1.0–2.1)	0.84 (0.58–1.2)	1.1 (0.12–1.6)
C. trifasciata	13	0.37(0.21–0.60)	0.39 (0.19–0.55)	3.1 (1.7–4.4)
Coleomegilla maculata lengi	15	0.14(0.06–0.21)	0.048 (0.031–0.063)	0.58 (0.20–0.95)
Hippodamia convergens	12	1.0 (0.67–1.6)	0.042 (0.017–0.066)	1.5 (0.70–2.8)
H. glacialis	22	1.2 (0.97–1.4)	0.75 (0.44–1.1)	5.2 (4.3–6.8)
H. parenthesis	8.2	0.40(0.26–0.61)	0.092 (0.051–0.12)	2.1 (1.7–2.6)
H. tredecimpunctata tibialis	12	0.87(0.46–1.3)	0.072 (0.037–0.12)	0.39 (0.26–0.55)
Coleoptera: Chrysomelidae				
Diabrotica longicornis	7.0	0.24(0.10–0.38)	0.17 (0.10–0.32	0.33 (0.21–0.53)
Oulema melanopus	7.3	0.22(0.14–0.34)	0.28 (0.09–0.55)	0.69 (0.47–0.87)

Table 2.—Contact toxicity of 3 pyrethroids to the cereal leaf beetle *Oulema melanopus* and the hymenopteran parasitoid *Tetrastichus julis*.

Insect	LC_{50} - μg/cm^2 (with confidence limits)		
	Permethrin	Cypermethrin	Fenvalerate
Oulema melanopus	3.5(2.3–4.2)	0.69(0.41–0.83)	5.0(3.8–5.9)
Tetrastichus julis	0.0034(0.0011–0.0051)	0.0046(0.0027–0.0061)	0.0059(0.0042–0.0069)

Comparisons of toxicities of insecticides to pests and their principle natural enemies have been conducted for a limited number of other pests and other insecticides, both in the laboratory (e.g., Abu and Ellis 1977, Roush and Hoy 1978) and in the field (Rock and Yeargan 1971, Surgeoner and Ellis 1976). Such studies can be of considerable predictive value in the development of integrated pest management programs by providing information on the most selective insecticides, the most susceptible stage, and the best time of application with respect to control, with minimal effects on beneficial species. Unfortunately, there are very few systems for which the entire crop-pest-natural enemies-insecticides complex has been thoroughly investigated.

Our study indicates that selectivity in favor of coccinellids is possible within the newest class of agricultural insecticides, the synthetic pyrethroids. It also suggests that a cereal leaf beetle outbreak possibly could occur if barley or oats were sprayed with one of these chemicals, due to a release from parasitism by *T. julis*, which can attack up to 90% of the *O. melanopus* larvae in some fields (Ellis, unpublished data).

Although field trials are necessary to substantiate the possibilities of selectivity in favor of coccinellids or to the disadvantage of parasitoids, preliminary selectivity data from the laboratory provide a starting point for the study of an insecticide's conceivable effects on natural enemies in the field. Entomologists must take advantage of favorable selectivity at every opportunity if the synthetic pyrethroids are to be utilized to their fullest potential.

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