Pyrethroid resistance persists in spider mite predator

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Spider mite predators laboratory-selected for pyrethroid resistance successfully overwintered in a northern California apple orchard.

The phytoseiid mite *Metaseiulus* (= *Typhlodromus*) *occidentalis* (Nesbitt), a predator of spider mites, has developed a low to moderate level of resistance to organophosphorus insecticides, such as azinphosmethyl, diazinon, and dimethoate, in the field. Since it can survive low rates of these insecticides applied to control insect pests, the predator is effective against spider mites in many of California's deciduous orchards and vineyards.

Other pesticides are sometimes necessary, because pest insects have developed resistance to many organophosphorus insecticides, and biological control agents are not always available. The pyrethroid insecticides are of potential value for IPM programs, because they have low mammalian toxicity, are very toxic to many insects, and are applied at very low rates. We report here the results of a laboratory project with *M. occidentalis* in which we selected a strain resistant to the pyrethroid permethrin and analyzed the genetic basis of the resistance so that field releases could be conducted most effectively. In addition, we report the successful establishment and overwintering of the permethrin-resistant strain in a Sebastopol apple orchard during 1979-80.

Initially, we tested about 40 populations of *M. occidentalis* from California orchards and vineyards to learn if resistance to permethrin was already present. We screened over 10,000 adult females, using several doses of permethrin during 1977 and 1978. No consistent increase in survival was evident in their progeny. We also screened predator populations from Washington and British Columbia apple orchards. Progeny of three of these populations survived increasing doses of permethrin, and this report concerns our work with one colony sent to us from Washington by S.C. Hoyt.

This colony responded gradually to laboratory selection during the two-year project, yielding a modest level of permethrin resistance (fig. 1). After 18 selections, a genetic analysis of the resistance (fig. 2) indicated that no single dominant or recessive gene was involved. We found no evidence of sex linkage or maternal effects in the F_1 progeny (progeny produced by crossing resistant and susceptible parents), and the F_2 progeny (those produced by intercrossing F_1 individuals) and backcross progeny (produced by crossing the F_1 females to susceptible males) were very susceptible to permethrin. This indicates that this permethrin resistance is inherited as a polygenic character; that is, it is the result of the cumulative action of multiple sets of independently transmitted genes, each of which produces only a small effect. The permethrin-resistant strain thus should be released into orchards or vineyards where native *M. occidentalis* are absent, or are not abundant because of previous permethrin treatments, so that resistance will not be lost through interbreeding with the susceptible natives.

Significantly, this laboratory-selected predator strain retained its original resistance to azinphosmethyl (table 1), even though it was not treated with the insecticide during two years of selection with permethrin. The strain also exhibits some cross-resistance to other pyrethroid insecticides, such as fenvalerate and an experimental pyrethroid (Shell 57706) (table 2), which may increase the predator's usefulness in IPM programs.

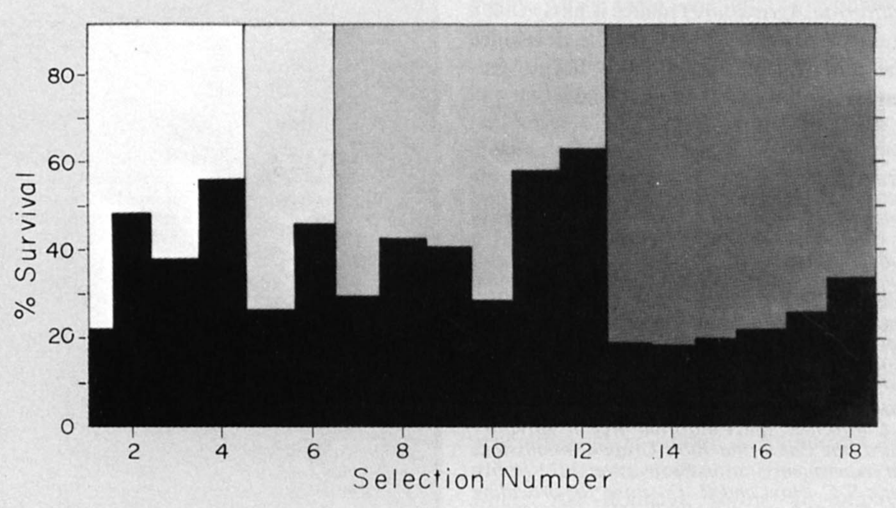

Fig. 1. *M. occidentalis* survival in 18 selections with increasingly higher permethrin rates: four at 0.008 lb active ingredient per 100 gal (unshaded section); two at 0.02 (lightest shading); six at 0.03 (medium); six at 0.07 (darkest).

Field trials with a permethrin-resistant strain selected 18 times are under way during 1980-81 in California almond and apple orchards and in Washington apple and Oregon pear orchards.

A predator colony that had undergone only nine selections with permethrin was field tested during 1979-80 in a California apple orchard and an almond orchard. The predators failed to retain their permethrin resistance in the almond orchard, which had abundant susceptible *M. occidentalis* with which to interbreed. This failure supported our conclusion that permethrin resistance is polygenically inherited.

This predator strain did become established successfully in an apple orchard near Sebastopol where permethrin had been applied before predator releases. Four trees each had been treated on 14 May 1979 at rates of 0.05, 0.1, or 0.2 pound active ingredient permethrin per acre, which had reduced native *M. occidentalis* populations to nil. Predators were released on 11 June, and the first post-release sprays of 0.05, 0.1, or

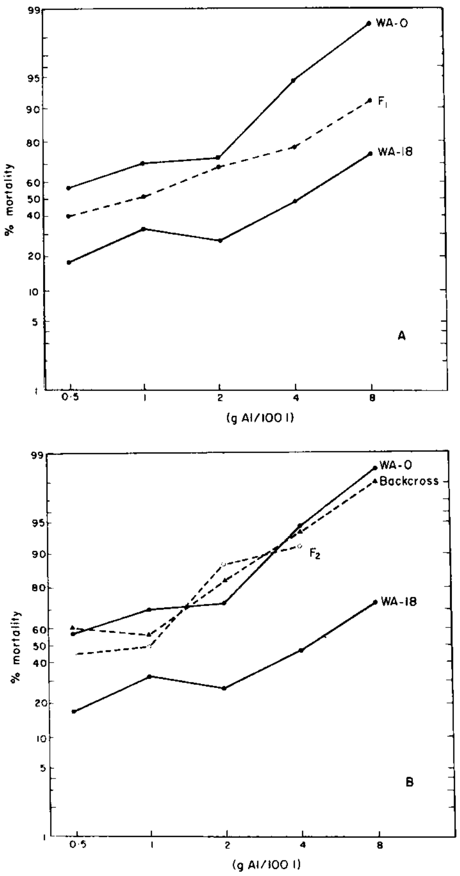

Fig. 2. Genetic analysis: (A) concentration response lines (logit-log scales) for permethrin-resistant (WA-18) and susceptible (WA-0) predators and their F_1 progeny; (B) F_2 and backcross progeny (to susceptible parent) are nearly as susceptible as susceptible colony.

0.2 pound active ingredient per acre were applied on 12 July to each of the four trees. Permethrin-resistant predators were released also into eight unsprayed (check) trees. Predator counts on leaves sampled periodically throughout the season indicated that the permethrin-resistant predators had become established in the twelve sprayed trees and survived the three different rates of permethrin treatment.

Samples of *M. occidentalis* were taken on 25 September 1979 from each of the three permethrin treatments and colonized to determine if they had retained their resistance over the summer. In addition, two colonies of native *M. occidentalis* were initiated from nonrelease trees never treated with permethrin from a different area in the same orchard. Adult females from these five colonies were assayed using 0.02 pound active ingredient per 100 gallons water on bean leaf discs. The native *M. occidentalis* collected from unsprayed trees had survival rates of 25 and 33 percent after 48 hours on treated discs, whereas the three colonies collected from sprayed release trees had survival rates of 79, 82, and 81 percent. This indicated that the resistant strain released in June 1979 had become established in the orchard and survived the three rates of permethrin applied on 12 July.

The trees were sampled again in July 1980 to determine if the permethrin-resistant strain had overwintered. Three colonies of predators were collected from sprayed release trees, and their resistance compared with that of predators collected from the unsprayed release (check) trees and three laboratory colonies (table 3). Predators from unsprayed release trees were susceptible to permethrin; those from the sprayed release trees were resistant. The loss of resistance in the unsprayed release trees probably was due to interbreeding with the susceptible native *M. occidentalis*, as had occurred in the almond orchard. The resistant laboratory colony (WA-18) selected 18 times had a survival rate similar to that of the orchard-collected colonies (table 3), indicating that permethrin resistance was retained in the orchard populations for over 11 months after treatment in July 1979. The moderate level of permethrin resistance developed in this strain of *M. occidentalis* ($LC_{50} = 0.03$ pound active ingredient per 100 gallons water; field rates = 0.05 to 0.2 pound active ingredient per 100 gallons water) means that only low rates of permethrin (or other pyrethroids) will allow this predator strain to persist in orchards or vineyards. However, the use of low application rates of azinphosmethyl to preserve *M. occidentalis* was also necessary in the pear pest management program, thus setting a precedent.

The recent success in selecting this predator for resistance to carbaryl (January 1980, *California Agriculture*) makes it likely that a strain of *M. occidentalis* can be developed that can tolerate organophosphorus, carbamate, and pyrethroid insecticides.

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TABLE 1. Comparison of Azinphosmethyl Resistance in Three Colonies of *M. occidentalis*

	Mortality on leaf discs sprayed with*		
Colony	Water	0.5 lb azinphos-methyl ai/100 gal	1.0 lb azinphos-methyl ai/100 gal
	%	%	%
Berkeley blackberry†	5.1	45.2	48.2
WA-O‡	10.5	4.1	2.0
WA-18§	0	5.5	0

*Forty to 60 adult females on bean leaf discs treated at each dose (ai = active ingredient).
†Susceptible to azinphosmethyl and permethrin.
‡Originally azinphosmethyl-resistant; never selected for permethrin resistance.
§Originally azinphosmethyl-resistant; selected for permethrin resistance.

TABLE 2. Cross-resistance to Other Synthetic Pyrethroids in Permethrin-selected *M. occidentalis* Strain

Colony and date tested	Materials and rates	Survival of females*
	lb ai/100 gal	%
Permethrin-selected WA-9 (1979)	fenvalerate, 0.008	18.8
	fenvalerate, 0.033	3.8
	permethrin, 0.008	67.5
	permethrin, 0.033	43.3
	water	93.3
Unselected California pear (1979)	fenvalerate, 0.008	0
	fenvalerate, 0.033	0
	permethrin, 0.008	15
	permethrin, 0.033	7.5
	water	97.5
Unselected WA-O (1980)	fenvalerate, 0.008	3
	fenvalerate, 0.017	0
	Shell-57706, 0.004	0
	Shell-57706, 0.008	3
	Shell-57706, 0.017	0
	water	88
Permethrin-selected WA-18 (1980)	fenvalerate, 0.008	25
	fenvalerate, 0.017	17
	fenvalerate, 0.033	5
	fenvalerate, 0.067	0
	water	100
	Shell-57706, 0.004	3
	Shell-57706, 0.008	35
	Shell-57706, 0.017	7
	water	100

*Forty to 60 adult females tested at each insecticide dose.

TABLE 3. Permethrin Resistance Retained in Overwintered *M. occidentalis* Collected from Sebastopol Apple Orchard Compared with Resistance Levels of Three Laboratory Colonies

Colony and history	Survival*
	%
Colonies collected in July 1980 from 1979 release trees	
Unsprayed release trees	27
Permethrin treated @ 0.05 lb ai/acre	60
Permethrin treated @ 0.1 lb ai/acre	58
Permethrin treated @ 0.2 lb ai/acre	45
Laboratory colonies tested for comparison	
Unselected original colony	13
Permethrin-resistant colony (WA-18)	48
Permethrin-resistant colony selected 27 times	70

*Sixty to 240 adult females of each colony tested on 2 or 3 days using bean leaf discs sprayed with 0.02 lb permethrin ai/100 gal