EFFECTS OF FENVALERATE INSECTICIDE ON POLLINATORS[1]

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Abstract

Susceptibility to fenvalerate sprays was greatest for the alfalfa leafcutting bee, *Megachile rotundata* (Fabr.); least for the honey bee, *Apis mellifera* L.; and intermediate for the alkali bee, *Nomia melanderi* Cock. Low temperatures increased the residual toxic effects of fenvalerate to honey bees. Fenvalerate at 0.22 kg AI/ha had low residual hazard to bees after one day under Pacific Northwest conditions. Field tests of fenvalerate on blooming alfalfa, pollen shedding corn, and blooming red raspberry resulted in reduced bee visitation and low to moderate adult bee mortality.

Introduction

Fenvalerate (Pydrin) (cyano (3-phenoxyphenyl) methyl 4-choloro-alpha-(1-methyl ethyl) benzeneacetate) is a synthetic pyrethroid available as an emulsifiable concentrate. It kills as a contact or stomach poison, and is registered for insect control on a relatively large number of agricultural crops.

This paper reports results of our research conerning the effects of fenvalerate insecticide on honey bees (*Apis mellifera* L.), alkali bees (*Nomia melanderia* Cock.), and alfalfa leafcutting bees (*Megachile rotundata* (Fabr.)). Also, we report results of field tests of fenvalerate effects on honey bees when applied to blooming alfalfa and pollen shedding corn and effects on honey bees and bumble bees when applied to blooming red raspberry.

Small-Scale Bioassay

Material and Methods. Tests were conducted with fenvalerate on honey bees, alkali bees, and alfalfa leafcutting bees in 1975 and 1985 (Tables 1 and 2). Fenvalerate was applied to 0.004-hectare plots of alfalfa with a Solo backpack boom sprayer, using 1758 g/cm^2 pressure and 234 liters of water/ha. Field-weathered fenvalerate residual test exposures were replicated four times with four foliage samples per treatment and time interval. Foliage samples consisting of ca. 500-cm^2 taken from the upper 15-cm portions of plants were cut into 2.5- to 5-cm diameter plastic petri disk and a circular insert formed from a strip of metal screen (6.7 meshes/cm) 45 cm long and 5 cm wide. In one test, foliage residues were held in the lab in the dark at 10°C and 29°C, and outdoors in 18-35°C variable day-night temperatures and daily sunlight. Residual toxicity of fenvalerate combined with Bond, (Loveland Industries, Inc., Loveland, CO) or Biofilm (Kalo, Overland Park, KS), was also tested. Active ingredients in Bond are synthetic latex and primary aliphatic oxyalkylated alcohol. Active ingredient in Biofilm is alkylaryl polyoxyethylenate.

Worker honey bees were obtained from top supers of colonies and anesthetized with CO_2 to facilitate handling. Leafcutting bee and alkali bee prepupae in leaf piece cells and soil cores, respectively, were incubated at 29.5° to 31°C and 60% relative humidity. Emerging adults were trapped in canisters fitted with screen funnels and chilled to facilitate handling. Residual test exposures were replicated four times by caging 60 to 75 worker honey bees, 25 to 40 leafcutting bees, and 15 to 20 alkali bees with each of four foliage samples per treatment and time interval. Bees were maintained in cages at 29.5°C/60% RH and fed syrup prepared from 50% sucrose and water in a cotton wad (5 by 5 cm). Bee mortality was determined after 24-hours.

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Results and Discussion. Table 1 presents the combined means of tests done in 1975 and 1985. The honey bee was more tolerant of fenvalerate than the other species. The mortality sequence was typical, in that alfalfa leafcutting bees were most susceptible, alkali bees were intermediate in susceptibility, and honey bees least susceptible to fenvalerate. Bee susceptibility is a function of size or surface/volume ratio which is related to chance adherence of residues to the body of a foraging bee (Johansen *et al.*, 1983). The mortality of bioassay bees in 24 hours continuous contact with foliage samples decreased as the age of residues increased. One day was required for residues of the 0.22 rate to degenerate to result in low mortality to honey bees.

Table 1. Mortalities of honey bees, alfalfa leafcutting bees, and alkali bees exposed to different age residues and rates of fenvalerate 2.4 EC applied to 0.004-ha plots of alfalfa. Bees confined with treated alfalfa for bioassay mortalities. Pullman and Prosser, WA. 1975, 1985.

Materials	Rate kg AI/ha	24 hr % mortalities of bees Caged with treated foliage, Age of residues		
		2 hr	8 hr	24 hr
			Alkali Bees	
Fenvalerate	0.11	64a	18a	--
Fenvalerate	0.43	100 b	96 b	--
Untreated check	--	8 c	5 c	--
			Honey Bees	
Fenvalerate	0.11	57a	17a	--
Fenvalerate	0.22	41 b	25 b	22a
Fenvalerate + Bond	0.22 + 8 oz	37 b	7 c	9 b
Fenvalerate + Biofilm	0.22 + 2 oz	44 b	14a	18a
Fenvalerate	0.43	100 c	97 d	--
Untreated check	--	1 d	2 c	1 c
			Leafcutting Bees	
Fenvalerate	0.11	82a	39a	--
Fenvalerate	0.22	92ab	63 b	--
Fenvalerate + Bond	0.22 + 8 oz	87ab	67 b	--
Fenvalerate	0.43	100 b	96 c	--
Untreated check	--	6 c	7 c	--

Means within a column for each test followed by the same letter are not significantly different (P = 0.05; Duncan's [1951] multiple range test).

The addition of a proprietary sticker did not reduce honey bee mortality in the 2-hour residue tests, but did in the 8 hour tests. Adding Bond significantly reduced honey bee mortality. Mayer *et al.* (1987) showed that Bond also reduces bee mortality when combined with other insecticides.

The effects of temperature and sunlight on activity of fenvalerate against honey bees are shown in Table 2. Two and eight hour residues held at 10°C and 29°C caused significantly more mortality than residues held in variable day-night temperatures (18°C-35°C) and daily sunlight. Therefore, fenvalerate residues may be more toxic to honey bees for a longer period of time when used under cool, cloudy conditions.

Field Test — Alfalfa

Materials and Methods. In 1978, fenvalerate was tested for been toxicity and effects on honey bee foraging activity on blooming alfalfa in a 4-ha field near Pullman, WA. Fenvalerate 2.4 EC was applied by airplane at 0.22 kg AI/ha/93.4 liters of water/ha at 6 a.m. A separate

Table 2. Mortalities of honey bees exposed to different age residues of fenvalerate 2.4 EC (0.22 kg AI/ha) applied to 0.004-ha plots of alfalfa and foliage held at different environmental conditions. Bees confined with treated foliage for bioassay mortalities. Prosser, WA. 1986.

	24 hr % mortalities of bees Caged with treated foliage Age of residues		
Treatment	2 hr	8 hr	24 hr
Fenvalerate			
10°C - dark	70a	96a	9a
29°C - dark	76a	58 b	5a
18°-35°C daily sunlight	49 b	40 c	9a
Untreated check	5 c	2 d	1a

Means within a column for each test followed by the same letter are not significantly different (P = 0.05; Duncan's [1951] multiple range test).

4-ha field several km away served as an untreated check. Two honey bee colonies with Todd dead bee traps were located adjacent to each field. The number of dead honey bees was recorded daily before and after application. Numbers of honey bees/23 m2 of foraging alfalfa were counted after the application. Colony conditions were evaluated before and after the application.

Results and Discussion. Table 3 presents the results of fenvalerate on blooming alfalfa. The application reduced numbers of foraging honey bees to zero, 5 h after application though numbers returned to normal 32 h after application. The application caused no increase in the number of dead bees and no harm to the colonies.

Moffett *et al.* (1982) found fenvalerate at 0.11 kg AI/ha did not cause any honey bee mortality, and bee visits to alfalfa flowers were 70% less on the afternoon after the applications. They also reported that fenvalerate applied at 0.4 kg AI/ha to a blooming alfalfa field did not seriously affect honey bee colonies.

Field Tests — Raspberries

Materials and Methods. In 1985, field tests of fenvalerate were conducted on honey bees on blooming red raspberries near Vancouver, WA. Fenvalerate 2.4 EC was applied at 0.22 kg AI/ha by ground with a hooded-boom sprayer at 8 p.m. Foliage samples taken after application

Table 3. Effect on honey bees of early morning application by air of fenvalerate 2.4 EC (0.22 kg AI/ha) applied to a 4-ha field of blooming alfalfa. Pullman, WA 1978.

Material	Number dead bees/colony				Number HB/23 m^2 sightings		
	Pre-treatment	Post-treatment			Post-treatment		
		24 hr	48 hr	72 hr	5 hr	10 hr	32 hr
Fenvalerate	36	22	23	35	0	6	20
Untreated check	34	70	14	43	19	21	18

were used to bioassay bee mortality. A battery-operated vacuum aspirator (Clinch, 1971) was used to collect 40 honey bees and 40 bumble bees foraging raspberry bloom in the plots. They were captured from the plots at different times after application and confined in the standard small cages for mortality determinations. Bee numbers and behavior in the plots were assessed at different times during the days after application. A stopwatch was used to determine the amount of time 100 individual bees spent working a berry flower before and 17 hours after the fenvalerate application. Test 1 was used to determine the amount of time 100 individual bees spent working a berry flower before and 17 hours after the fenvalerate application. Test 1 was on a 0.02-ha plot of 'Meeker' red raspberry and a separate 0.02-ha plot was left untreated. Two honey bee colonies were placed adjacent to the field seven days before application. Test 2 was on a 0.2-ha field of 'Amity' raspberry which was the only variety blooming during that time. In Test 2, honey bee mortality was assessed using Todd dead bee traps in two colonies placed adjacent to the field several days before application.

Results and Discussion. In Test 1, fenvalerate had no effect on the number of foraging honey bees, based on bee counts 14 h post-treatment (Table 4). In Test 2, foraging honey bees were reduced 19% 14 h after application though numbers returned to normal by 16 h. A mean of 40

Table 4. Effect of evening ground application of fenvalerate 2.4 EC (0.22 kg AI/ha) to blooming red raspberry on honey bees and bumble bees. Test 1 on 0.02-ha plot of 'Meeker.' Test 2 on 0.2-ha plot of 'Amity.' Vancouver, WA. 1985.

	% bees in treated plots compared to untreated at indicated hours after application				
	12 hr	14 hr	16 hr	20 hr	24 hr
Test 1 honey bees	--	125	112	115	--
Test 2 honey bees	33	81	120	91	130
bumble bees	17	33	47	39	8

Table 5. Mortalities of bees exposed to different age residues of fenvalerate 2.4 EC applied (0.22 kg AI/ha) to blooming red raspberry. Test 1 on 0.02-ha plot of 'Meeker.' Test 2 on 0.2-ha plot of 'Amity.' Bees confined with treated foliage for bioassay mortalities. Vancouver, WA. 1985.

		24 hr % mortalities of bees Caged with treated foliage Age of residues					
		Honey bees					Bumble bees
	Material	12 hr	15 hr	18 hr	24 hr	48 hr	18 hr
Test 1	fenvalerate	--	83a	36a	--	24a	--
	untreated check	--	2 b	2 b	--	2 b	--
Test 2	fenvalerate	30a	--	17a	15a	--	100a
	untreated check	1 b	--	1 b	0 b	--	25 b

Means within a column for each test followed by the same letter are not significantly different (P = 0.05; Duncan's [1951] multiple range test).

dead bees per day were captured in the Todd traps before application. At one and two days after application, 31 and 21 dead bees were caught respectivly — well below normal die-off levels (mayer and Johansen, 1983). In Test 2, bumble bee foragers were greatly reduced by the application for up to one day. On the 'Amity' raspberry, individual bees spent a mean of 14.8 (range 7 to 35) sec collecting nectar from a flower pre-treatment; at 17 h post-treatment, the mean dropped to 8.9 (range 4 to 23) sec. We have seen this decrease in the amount of time individual bees spend working blossoms following insecticide applications (unpublished data), but the mechanism involved in such behavior is not known.

Raspberry foliage showed honey bee mortality decreased as residual time increased, but there was significant mortality at one day post-treatment (Table 5). Honey bees in the cages showed an aversion to treated raspberry by clumping together as far away from the treated foliage as possible. We have not observed this repellent type behavior with other insecticides in caged trials with alfalfa treated foliage or with fenvalerate treated alfalfa foliage. Bumble bees did not show this behavior. However, bumble bee poisoning was acute; the 18 hr residues caused 100% mortality.

Foraging honey bees captured in the fenvalerate treated plots had significant mortality up to 20 h post-treatment, but bumble bees captured from field treated plots showed no mortality (Table 6).

Field Tests — Corn

In 1980 and 1986, fenvalerate was tested for bee toxicity on pollen-shedding 'Jubilee' corn in 0.5-ha fields near Prosser, WA. In 1980, fenvalerate 2.4 EC was applied by helicopter before 7 a.m. on four different dates, using 0.22 kg AI/ha in 45 liters of water. In 1986, fenvalerate 2.4 EC was applied by airplane before 7 a.m. on four different dates, using 0.22 kg AI/ha in 51 oz of water (ULV rates). In both years, 0.5-ha fields 0.5 km away served as the untreated check. A daily record was maintained on the number of bees foraging in the field based on one to two 8-min counts on 365 m of row recorded between 10 a.m. and 1 p.m. Two strong, healthy, honey bee colonies with Todd dead bee traps attached, were placed adjacent to each field three days before the first application. The numbers of dead honey bees were recorded daily before and after the applications. Colony conditions were evaluated during the test.

Table 6. Mortalities of bees foraging on blooming red raspberry with different age residues of fenvalerate 2.4 EC applied (0.22 kg AI/ha). Test 1 on 0.02-ha plot of 'Meeker.' Test 2 on 0.2-ha plot of 'Amity.' Foraging bees collected from flowers and confined without foliage in small cages for mortality determinations. Vancouver, WA. 1985.

		24 hr % mortalities of bees Age of residues					
						Bumble bees	
	Material	13 hr	15 hr	20 hr	96 hr	14 hr	20 hr
Test 1	fenvalerate	--	20a	40a	0	--	--
	untreated check	--	10 b	20 b	0	--	--
Test 2	fenvalerate	77a	--	35a	--	0	0
	untreated check	25 b	--	10 b	--	0	0

Means within a column for each test followed by the same letter are not significantly different (P = 0.05; Duncan's [1951] multiple range test).

Results and Discussion. Bee mortality and bee foraging numbers for the sweet corn trials are shown in Table 7. Pre-application and one day post-application comparisons revealed dead bee counts increased two-fold with fenvalerate, but were still considered low based on the range of normal bee die-off (Mayer and Johansen, 1983). Fenvalerate applications reduced the number of honey bees foraging the corn for pollen.

Discussion

It is evident from these studies that fenvalerate is toxic to varying degrees to the bee species studies. Others have reported similar findings. For example, honey bee colonies exposed to beeswax foundation impregnated with 1,000 ppm fenvalerate had poor egg hatch and very low survival through the sealed brood stage (Stoner *et al.*, 1985). However, in a study by Stoner *et al.*, (1984), where fenvalerate was fed at the rate of 100 ppm to honey bee colonies, noticeable toxicity was observed, but not sufficient to pose a serious threat to honey bees. Atkins *et al.*, (1981) reported fenvalerate was highly toxic to honey bees present in the field during applications, though there was no residual toxicity at 1 day post-treatment. In our studies, the residual degradation time in hours (RT) required to bring bee mortality down to 25% in cage test exposures to field-weathered spray deposits applied at standard rates, was slightly more than 8 h for the four bee species we evaluated. Materials with an RT 25 of 8 h or less are useful in terms of bee safety, if applied judiciously, *i.e.* if applied during the late evening or at night.

Table 7. Effect on honey bees of early morning applications by air of fenvalerate (0.22 kg AI/ha) applied to a 0.5-ha field of pollen shedding corn. Prosser, WA. 1986.

Treatment	No. HB/365 m of row		Number dead bees/colony		
	Post-treatment		Pre-treatment	Post-treatment	
	24 hr	48 hr		24 hr	48 hr
1980[1]					
Fenvalerate	111	115	--	24	15
Untreated check	428	361	--	16	11
1986[2]					
Fenvalerate	6	--	30	66	42
Untreated check	12	--	3	26	3

[1]fenvalerate applied 29 July and 3, 7, 11 August.

[2]fenvalerage applied 29 July and 1, 4, 7 August.

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