Susceptibility of four bee species (Hymenoptera:Apoidea) to field weathered insecticide residues

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ABSTRACT

Deltamethrin, methamidophos, methidathion, methyl parathion, permethrin, phosmet, pyridaben, thiocarb, and trichlorfon can all be applied in late evening with minimal hazard to bumble bees. Deltamethrin, formetanate, pyridaben and thiocarb can be applied in late evening with minimal hazard to honey bees. Deltamethrin, pyridaben and trichlorfon can be applied in late evening with minimal hazard to alkali bees. Deltamethrin, pyridaben and trichlorfon can be applied in late evening with minimal hazard to alfalfa leafcutter bees. In general the typical pattern of bee susceptibility to insecticide residues was the alfalfa leafcutter bee was more susceptible than alkali bee which was more susceptible than the honey bee which was more susceptible than the bumble bee.

Key words: Insecticides, honey bees, alfalfa leafcutter bees, alkali bees, bumble bees, toxicity

INTRODUCTION

Bee poisoning from pesticides is a serious problem worldwide (Crane & Walker 1983, Johansen and Mayer, 1990, OEPP/EEPO 1992). However, there are few publications on comparative toxicology of insecticides to different species of bees using laboratory toxicology methods (Torchio, 1973; Tasei *et al.* 1987; Helson *et al.* 1993) and fewer still using the residue bioassay method (Johansen 1972, Johansen *et al.* 1983, Mayer *et al.* 1994).

Honey bees (*Apis mellifera* L.) produce honey and are valuable pollinators of many crops. Alfalfa leafcutter bees (*Megachile rotundata* (F.)) and alkali bees (*Nomia melanderi* Cockerell) are used to pollinate alfalfa seed. Bumble bees are good pollinators of many crops and since 1983 commercial colonies, including *Bombus occidentalis* Greene have been available (Free, 1993).

Organophosphates inhibit cholinesterase with consequent disruption of nervous activity caused by accumulation of acetylcholine at nerve endings. Carbamates are inhibitors of cholinesterase. Pyrethroids cause a rapid paralysis, consistent with their effects upon nerves (central or peripheral) or muscle.

This paper reports the effects of 14 different insecticides on honey bees, alfalfa leafcutter bees, alkali bees and bumble bees using our standard residue bioassay test.

MATERIALS AND METHODS

Insecticides were applied to 0.004-hectare (40.5 m^2) plots of alfalfa with a R&D CO_2 pressurized sprayer (R&D Sprayers, Inc., 225D Hwy 104, Opelousas, LA 70570) in 234 liters of water mix/ha and the rates used are given in Table 1. The untreated check plots were sprayed with water. Tests of field-weathered insecticide residues were replicated four times with four foliage samples per treatment and time interval (Table 1). Samples consisting of about 500 cm^2 of foliage taken from the upper 15 cm parts of plants were placed in cages. Residual tests were conducted by caging 50 worker honey bees, 25 female leafcutter bees, 25 female alkali or 25 bumble bees with each of 4 foliage samples per treatment and time interval. The four bee species behaved similarly in the cages, crawling over the foliage to feed and on the sides of the cages. The bees were maintained for 24-hour mortality counts in cages at 26 to 29° C, about 50% RH and fed 50% sucrose solution in a cotton wad (5 x 5 cm) placed on the cage bottom.

Cages were made from plastic petri dishes (15 cm diam.) with tops and bottoms separated by a cylindrical wire screen (6.7 meshes/cm) insert (45 cm long and 5 cm wide). The metal screen was stapled to form a circular insert which provided room in the cage for bees to fly.

Worker honey bees were taken from the top of colonies and anesthetized with CO_2 to facilitate handling. Leafcutter bee prepupae in leaf-piece cells were incubated at 30° C and 50% RH. Emerging adults were allowed to fly in the lab and collected off the windows. Alkali bees were gathered in a net from nesting sites and chilled to facilitate handling. Worker bumble bees (*B. occidentalis* southern strain) were obtained from the colonies (purchased from Bees West, Freedom, CA) in a dark room with a red light by removing bees and placing them in vials for later transfer to the cages. One hundred individuals of each species were weighed and the average weight per bee was 126, 31, 87, and 114 mg for honey bee workers, female alkali bees and female alfalfa leafcutter bees, and bumble bee workers respectively.

Abbott's (1925) formula was used to correct for the natural mortality. For each replicate, the number of dead individuals was recorded after 24 hours exposure. Data were analyzed using a two-step procedure. ANOVA was used to test for significant differences between means. The null hypothesis was rejected. Therefore we used Newman-Keuls studentized range test as a post hoc multiple comparison (Lund, 1989).

RESULTS AND DISCUSSION

Pesticide toxicity varied across bee species and insecticides (Table 1). Deltamethrin was the least hazardous to all four bee species, while conversely oxamyl was uniformly highly hazardous to all bee species tested. The residual degradation time in hours (RT) required to bring bee mortality down to 25% was calculated from the residue bioassay data (Johansen *et al.*, 1983). Insecticides with an RT_{25} of 2 h or less can be applied with minimal hazard to bees when they are not actively foraging. Insecticides reaching RT_{25} within 2-8 h present a minimal problem to bees, if they are applied during late evening or night. Those with an RT_{25} greater than 8 h are highly hazardous to bees and should not be applied or allowed to drift on blooming crops or weeds.

Deltamethrin, methamidophos, methidathion, methyl parathion, permethrin, phosmet, pyridaben, thiocarb, and trichlorfon with RT_{25} less than 8 h can be applied in late evening with minimal hazard to *B. occidentalis*. Deltamethrin, formethanate, pyridaben and thiocarb with RT_{25} less than 8 h can be applied in late evening with minimal hazard to honey bees. Deltamethrin, pyridaben and trichlorfon with RT_{25} less than 8 h can be applied in late evening with minimal hazard to alkali bees. Deltamethrin, pyridaben and trichlorfon with RT_{25} less than 8 h can be applied in late evening with minimal hazard to alfalfa leafcutter bees.

Johansen (1972) suggested the typical sequence of susceptibility of bees to insecticides is alfalfa leafcutter bee > alkali bee > honey bee > bumble bee and that this pattern was related to the size of the bee. However, in this test, bumble bees, although smaller than honey bees, were in general less susceptible to the insecticides. Of the 14 insecticides we tested, the leafcutter bee was less susceptible to none of the insecticides, alkali bees to one, honey bees to two and bumble bees to seven. Our results also showed that susceptibility followed the typical pattern although the ordering is tentative because many of the insecticides tested killed all the bees and differences could not be measures. Cypermethrin was less hazardous to alkali bees than to the other bees. Fenpropathrin and formethanate were less hazardous to honey bees than to the other bees.

Table 1.
Mortalities of bumble bees (BB), honey bees (HB), alkali bees (AB), and alfalfa leafcutter bees (LB) exposed to different age residues of insecticides applied to 0.004 hectare plots of alfalfa

		24 hr % mortalities of bees caged with treated foliage							
		BB		HB		AB		LB	
TREATMENT[a]	Kg (AI)/h	2 hr	8 hr	2 hr	8 hr	2 hr	8 hr	2 hr	8 hr[b]
carbofuran 4F (Furadan)	0.275	63a	10a	100b	100b	100b	100b	100b	100b
cypermethrin 2.5E (Ammo)	0.055	100a	40b	63b	68a	76ab	29c	83ab	75a
deltamethrin 0.2E (Decis)	0.209	3b	0b	10b	4b	15b	17a	27a	19a
fenpropathrin 2.4EC (Danitol)	0.22	95a	94a	52b	29b	100a	100a	100a	100a
formetanate 92SP (Carzol)	1.1	63b	50a	48a	20b	100c	40a	100c	100c
methamidophos 4EC (Monitor)	0.75	6b	2b	100a	99a	100a	92a	100a	100a
methidathion 2E (Supracide)	0.825	58b	20b	100a	100a	100a	100a	100a	100a
methyl parathion 2F (Penncap-MS)	0.55	73b	6b	100a	100a	100a	100a	100a	100a
oxamyl 2L (Vydate)	1.1	29b	46b	100a	96a	100a	100a	100a	100a
permethrin 2E (Ambush)	0.055	44c	11c	100a	79a	73b	36b	100a	89a
pyridaben 75WP (Samite)	0.44	0b	10b	23a	31a	36a	15b	48b	6b
phosmet 50WP (Imidan)	1.1	75b	17b	100a	100a	100a	100a	100a	100a
thiocarb 3.2AF (Larvin)	1.1	0b	3c	12b	8c	67a	39b	69a	50a
trichlorfon 80SP (Dylox)	1.1	7c	0c	73a	85a	76a	6c	45b	25b

[a] Means within a row of a chemical and for the same age residues followed by the same letter are not significantly different at the $p = 0.05$ level; Newman-Keuls studentized range test.
[b] Age of residues

The organophosphates seem more hazardous to honey bees than bumble bees (Table 2). It may be that bumble bees can detoxify thiophosphates faster or oxidize them to their toxic form more slowly than honey bees.

This work confirms and extends the work of Johansen *et al.* (1983) and Johansen and Mayer (1990) with three bee species and adds data on the hazard of insecticides to bumble bees. In general, bumble bees were the most tolerant to the insecticides. Our study clarifies which insecticides are safer for bumble bees, and adds to previous field weathered tests of Johansen (1972) and Mayer *et al.* (1994). Our study shows that the typical pattern of susceptibility of bees to insecticides has exceptions, so that each insecticide should really be tested on each bee species to determine the hazard.

Table 2.
Summary of effects of field weathered residues on alfalfa leafcutter bees (LB), alkali bees (AB), honey bees (HB) and bumble bees (BB).

Common Name	Chemical Type	LB	AB	HB	BB
carbofuran	carbamate				
cypermethrin	pyrethroid				
deltamethrin	pyrethroid	+	+	+	
fenpropathrin	pyrethroid				
formetanate	carbamate			+	
methamidophos	organophosphate				+
methidathion	organophosphate				+
methyl parathion	organophosphate				+
oxamyl	carbamate				
permethrin	pyrethroid				+
pyridaben	pyridazinone	+	+	+	+
phosmet	organophosphate				+
thiocarb	carbamate			+	+
trichlorfon	organophosphate	+	+		+

+ = not-hazardous

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