Insect Pollination

Toxicity of fungicides to honey bees *(Hymenoptera: Apidae)* and their effects on bee foraging behavior, pollen viability and fruit set on blooming apples and pears

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Summary: Fungicides fosetyl-AL, triadimefon, dodine, mycobutanil and fenarimol were tested for honey bee (Apis mellifera L.) mortality and effect on bee foraging, pollen viability and fruit set in blooming apple and pear. None of the materials were toxic to honey bees or reduced pollen gemination or fruit set.

Introduction

Honey bees *(Apis mellifera* L.) are the principal pollinators of apples and pears in the Pacific Northwest of the United States. In Washington, it is recommended that no insecticides be applied to blooming tree fruits because many registered materials are highly hazardous to bees *(Mayer* et al. 1996). In some cases, however, optimal pest control may require the application of a fungicide or insecticide during the period of blooming.

The fungicides captan, metiram, and thiophante-methyl do not reduce honey bee numbers when applied to blooming apples *(Fell* et al. 1983). The fungicides triforine, triflumizole, and DuPont 6573 do not reduce honey bee numbers when applied to blooming apples or pears *(Mayer & Lunden* 1986). Several fungicides have been shown to inhibit germination of apple pollen *(Eaton* 1963, *Church & Williams* 1977, 1978, *Fell* et al. 1983) although no significant reductions in fruit set have been reported. *Mayer* and Lunden (1986) showed pear pollen germination was significantly reduced by triforine and triflumizole, however, they did not determine the effects on fruit set.

The objective of our research was to determine the effects of the newer fungicides, fosetyl-AL, triadimefon, dodine, mycobutanil and fenarimol which are being registered for tree fruits on honey bee behavior and mortality and effects on pollen germination and fruit set of apples and pears.

This paper presents results of these tests conducted in central Washington during 1993–94. their effects on honey bees and the pollination process.

Material and methods

Small-scale poisoning bioassays were conducted with fosetyl-AL, triadimefon, dodine, mycobutanil and fenarimol

on honey bees in June, 1993. The low dosage rates used were those recommended by the pesticide companies and the high dose was twice that recommended. Materials were applied to plots (0.004 ha) (four replications) in a randomized complete block design of 'Washoe' alfalfa with a R&D CO_2 pressurized sprayer (R&D Sprayers, Inc., Opelousas, LA) using 1,758 g/cm^2 pressure and 234 liters of water per ha. Residual test exposures were replicated four times with each of four foliage samples per treatment. Alfalfa foliage samples (upper 15-cm portions of plants) were clipped into 2.5- to 5-cm lengths and ca. 500 cm^3 was placed in each cage. Cages were prepared from a plastic petri dish (15 cm) and a circular insert (45 cm long and 5 cm wide) was formed from a strip of metal screen (6.7 mesh per cm). Four to five week old foraging worker honey bees were collected from top supers of colonies for testing and anesthetized with CO_2. Thirty worker honey bees were placed in each cage and fed syrup prepared this needs 1:1 form a 50% sucrose and water in a wad of cotton (5 by 5 cm). The bees were held at 29.5 and 60% RH for 24-h mortality counts.

Direct effects were tested on 50 honey bees (collected as outline above) per cage in screen (package bee) cages (40 by 20.5 by 14.7 cm) (four replications) placed in each of the above mentioned plots immediately before spraying. The bees were sprayed directly with the fungicides.

Field studies were conducted in a 1 ha, 25-year-old uniform 'Bartlett' pear orchard on 29 April in 1993 and a 4.05 ha 15-year-old 2 uniform 'Red Delicious' apple orchard in 1993 on 8 May in the Yakima Valley of Washington. There were 8 honey bee colonies on the edge of the pear orchard and 16 in the center of the apple orchard. Materials were applied to individual flagged trees with a handgun sprayer and trees were sprayed using 37.4 liters of water per ha. Treatments were arranged in a randomized complete block design, with six replicates per treatment. The treatments were applied during full bloom at 1000 hr (PDT) when honey bees were foraging the flowers. Dosage rates were recommended by the pesticide manufacturers and are given in *Tables 1–4*.

The effect of the applications on the number of honey bee working the flowers was determined by counting bees visiting the flagged treated and untreated trees 30 min before and 30 min and 4 hr after applications. Honey bees observed foraging were counted by slowly moving around the individual trees and recording the number observed in 1 minute. Bees were also observed to determine if there was any abnormal behavior.

The effect of the applications on fruit set was determined by recording the number of spurs with flowers on marked branches on the flagged treated and untreated trees prior to treatment. The number of fruit on these limbs were recorded on 15 July. The number of flower clusters was multiplied by 6.5 (number of flowers per cluster for pears) and 5 (number of flowers per cluster for apples) and the number of fruit was divided by the number of flowers to determine percent fruit set.

The effect of the fungicides on pollen viability was examined by collecting pollen from flowers on the flagged treated and untreated trees 1 h and 6 h after application (six replications). Pollen was germinated on an agar medium containing 15.0% sucrose, 1.0% Difco Bacto agar, and 0.01 M boric acid in 85 ml of distilled water (modified from *Fell* et al. (1983)). Pollen was brushed from the anthers onto the agar medium in petri dishes and incubated for 6 h at 20 °C. Percent germination was determined by counting pollen with pollen tubes exceeding the grain diameter in length out of 100 pollen grains examined per replication *(Church & Williams* 1978).

Percent data was arc sin transformed and other data untransformed and then analyzed as a randomized complete block design using an analysis of variance with Newman-Keuls *(Lund* 1989) studentized range test for mean separations.

Results and discussion

Fosetyl-AL, triadimefon, dodine, mycobutanil and fenarimol directly applied did not cause any significant mortality to honey bees nor any significant mortality in the residue bioassays *(Table 1)*. In general, fungicides have not been found to cause mortality of adult bees and are not considered hazardous to bees *(Johansen & Mayer* 1990).

Table 1 Effect of fungicide treatments on alfalfa on mortality of honey bees. Prosser, WA. 1993.

Materials	Kg(AI)/ha	24-h % mortalities of bees (± SD)[a]	
		Direct application	Caged with treated foliage, age of residues 2 h
fosetyl-AL 80%	3.58	0a(± 0)	0a(± 0)
fosetyl-AL 80%	7.168	0.8a(± 1.3)	2.5a(± 0.6)
triadimefon 50DF	0.28	0a(± 0)	0a(± 0)
triadimefon 50DF	0.56	0.3a(± 0.4)	1.7a(± 1)
dodine 65WP	2.18	0.5a(± 0.5)	1.7a(± 0.5)
dodine 65WP	4.37	0.8a(± 0.4)	2.5a(± 0.4)
mycobutanil 40W	0.14	1.0a(± 0.5)	2.5a(± 0.5)
mycobutanil 40W	0.28	0.8a(± 0.4)	1.7a(± 0.3)
fenarimol 1EC	0.105	0.5a(± 0.9)	1.7a(± 0.8)
fenarimol 1EC	0.21	0.3a(± 0.4)	1.0a(± 0.4)
Untreated control	---	1.0a(± 0.7)	1.0a(± 0.5)

[a]None of the materials caused significant mortalities of bees (P = 0.05; Newman-Keuls studentized range test).
DF = dry flowable; WP = wettable powder; W = wettable; EC = emulsifiable concentrate

The treatments did not reduce the number of honey bees visiting the blooming apples or pears *(Tables 2 & 3)*. No abnormal bee foraging behavior or irritated bees were observed in these tests. *Fell* et al. (1983) found that the different fungicides captan, metiram, and thiophante-methyl did not reduce bee visitation to blooming apples. *Mayer & Lunden* (1986) found that the different fungicides triforine, triflumizole, and DuPont 6573 did not reduce bee visitation to blooming apples or pears.

Solomon & Hooker (1989) tested the fungicides dodine and triadimefon for possible repellency to honey bees by presenting them, dissolved in sucrose, at an artificial feeding station using concentrations recommended for standard field

Table 2 Effect of applying fungicides to blooming Bartlett pears at full bloom on 29 April on number of foraging honey bees and fruit set. Prosser, WA. 1993.

		x̄ no. honey bees per tree per 1 min (+SD[a])		
Material	Kg(AI)/ha	30 min Pre-application	30 min Post-application	% set
fosetyl-AL 80%	3.58	25a(± 8.1)	25a(±4.3)	3.8a(± 0.6)
triadimefon 50DF	0.28	23a(± 3.8)	28a(± 3.7)	4.1a(± 1.2)
dodine 65WP	2.18	26a(± 4.5)	28a(± 4.6)	3.8a(± 1.0)
mycobutanil 40W	0.14	24a(± 4.8)	27a(± 2.2)	4.7a(± 1.3)
fenarimol 1EC	0.105	23a(± 4.3)	26a(± 3.3)	4.5a(± 0.7)
Untreated control	---	26a(± 3.2)	28a(± 4.3)	3.3a(± 1.3)

[a] None of the materials caused a significant effect on bee visitation numbers or fruit set (P = 0.05; Newman-Keuls studentized range test).

Table 3 Effect of applying fungicides to blooming 'Red Delicious' apples at full bloom on 8 May on number of foraging honey bees and fruit set. Naches, WA. 1993.

		x̄ no. honey bees per tree per 1 min (+SD[a])		
Material	Kg(AI)/ha	30 min Pre-application	30 min Post-application	% Fruit set
fosetyl-AL 80%	3.58	10.4a (± 2.3)	10.4a (± 1.5)	26.9a (± 2.5)
triadimefon 50DF	0.28	9.2a (± 3.7)	10.0a (± 2.5)	24.2a (± 1.8)
dodine 65WP	2.18	12.0a (± 2.8)	10.4a (± 2.3)	16.3a (± 4.0)
mycobutanil 40W	0.14	10.0a (± 2.8)	10.0a (± 1.8)	22.7a (± 4.5)
fenarimol 1EC	0.105	12.2a (± 2.3)	10.0a (± 2.2)	21.4a (± 5.0)
Untreated control	---	10.4a (± 2.3)	10.2a (± 2.3)	25.5a (± 3.1)

[a] None of the materials caused a significant effect on bee visitation numbers or fruit set (P = 0.05; Newman-Keuls studentized range test).

use. They reported that dodine and triadimefon repelled bees from the feeding stations. Their test was an artificial test (syrup feeders) while our's was a field study that showed no repellency with either fungicide. The fungicides we tested can be applied during bloom without repelling honey bees.

Fosetyl-AL, triadimefon, dodine, mycobutanil and fenarimol did not reduce apple or pear fruit set *(Tables 1 & 2)* or apple or pear pollination *(Table 4)*. Other fungicides such as triflumizole and triforine reduced pear pollen germination *(Mayer & Lunden* 1986) and triforine reduced apple *(Church & Williams* 1978), blueberry *(Bristow* 1981) and cranberry pollen germination *(Bristow & Shawa* 1981).

Our results show that fosetyl-AL, triadimefon, dodine, mycobutanil and fenarimol can safely be applied to blooming apples and pears without inhibiting the pollination process.

Table 4 Germination of 'Red Delicious' apple pollen and 'Bartlett' pear pollen on artificial agar media at 1 h and 6 h after fungicide applications, Yakima Valley, WA.

Material	Kg(AI)/ha	x̄ % 'Red Delicious' pollen germination (±SD)[a]	x̄ % 'Bartlett' pollen germination (±SD)[a]
fosetyl-AL 80%	3.58	90a(± 1.5)	44a(± 2.5)
triadimefon 50 DF	0.28	94a(± 0.8)	48a(± 3.5)
dodine 65 WP	2.18	89a(± 1.4)	47a(± 2.0)
mycobutanil 40 W	0.14	90a(± 2.3)	46a(± 4.1)
fenarimol 1 EC	0.105	93a(± 1.1)	49a(± 3.8)
Untreated control	---	94a(± 1.3)	45a(± 3.6)

[a] None of the materials caused significant reduction in pollen germination (P=0.05, Newman-Keuls studentized range test).

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