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CODLING MOTH (LEPID.: TORTRICIDAE): DISRUPTION OF SEXUAL COMMUNICATION WITH AN ANTIPHEROMONE [(*E*,*E*)-8,10-DODECADIEN-1-O1 ACETATE]

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ABSTRACT

When broadcast applications of [*E*, *E*]-8,10-dodecadien-1-ol acetate an antipheromone of the colding moth, *Cydia pomonella* (L.), were made to apple or pear orchards, the catch of male codling moths was reduced in traps baited with either synthetic sex pheromone or virgin females. When the antipheromone, at a rate of 11.25g AI/0.4 ha was applied broadcast to pear trees using a ground dispenser, male response to pheromone- or female-baited traps was completely inhibited for 9 days with no significant reduction thereafter. Based on these and earlier results, it is concluded that (*E*,*E*)-8,10-dodecadien-1-ol acetate inhibits male codling moth response, whether the sources are placed in close proximity to the attractive agent or distributed in a broadcast application. These results contradict previous arguments that antipheromones as a group may not be effective in the field when used to permeate large volumes of air.

The codling moth, *Cydia pomonella* (L.), is key pest of apples and pears in most parts of the world and is generally controlled by multiple applications of organophosphorous insecticides (Quist 1966). However, use of some of these organophosphorous insecticides can significantly increase populations of the McDaniel spider mite, *Tetranychus mcdanieli* McGregor, on apples and pear psylla, *Psylla pyricola* Foerster, on pears by reducing populations of their natural enemies (Hoyt 1969). Development of alternatives to the standard insecticide program which would control the codling moth and also allow biological control of other important insect or mite pests is highly desirable.

It has been shown that pheromonal communication between the sexes, as measured by catches in traps baited with either synthetic sex pheromone or live virgin female moths, and subsequent mating of codling moth can be disrupted by exposing moths to high concentrations of the synthetic sex pheromone, (*E*,*E*)-8,10-dodecadien-1-ol (hereinafter referred to as 8,10-D) (Moffitt 1974, Hathaway, *et al.* 1979). In field studies, satisfactory levels of control have been achieved in pears using the pheromone as a mating disruptant (Moffitt, *et al.* 1979).

Antipheromones, i.e. nonpheromone chemicals that directly block or inhibit responsiveness of insects to their natural pheromones, have been reported for a number of Lepidoptera (Shorey 1977). Hathaway, *et al.* (1974, 1979), showed that (*E*,*E*)-8,10-dodecadien-1-ol acetate (hereinafter referred to as 8,10-Da) reduces the catch of male codling moths in traps baited with either synthetic sex pheromone or virgin females. In these laboratory and small scale field studies, substrates were impregnated with the inhibitor and placed by hand in close proximity to the pheromone sources in the tree. Shorey (1977), in his review of the manipulation of insect pests of agricultural crops

Footnotes

[1]Mention of a commercial product does not constitute a recommendation for use by the U.S. Department of Agriculture. Received for publication 19 June, 1985.

through use of behavior-modifying chemicals, concluded that antipheromones as a group, when released into the air immediately adjacent to pheromone-emitting sources, prevent males from orienting to these sources, but the same chemicals have little or no effect in preventing males from approaching sources when the chemicals are used to permeate a large amount of air surrounding these sources. Previous results we have obtained with 8,10-Da (Hathaway, *et al.* 1979) have indicated to us that the compound, in contrast to the conclusion of Shorey (1977), might also be effective when used to permeate the atmosphere in or around trees containing pheromone sources. In this paper we report the disruptive effects on response of male codling moths to virgin female- or pheromone-baited traps of 8,10-Da when formulated in the Conrel® chopped hollow fiber controlled release system and: (1) Placed by hand on the foliage of the tree in close proximity to the attractant source; (2) Applied to blocks of trees as a broadcast application from a helicopter; or (3) Applied to blocks of trees as a broadcast application using a ground dispenser. These studies were conducted at the Yakima Agricultural Research Laboratory during 1979-80.

METHODS AND MATERIALS

To obtain 8,10-Da, we prepared (*E,E*)-8,10-dodecadien-1-ol by the method of Mori (1974) and purified it to a melting point of 29-30°C (= 100% purity) as described by Descoins and Henrick (1972). The acetate was then prepared from that product as described by George *et al.* (1975) and subsequently formulated into the Conrel system by Albany Inernational.

Experiment I — Fibers placed in close proximity to pheromone-baited traps:

In this experiment, 10 fibers, each containing ca. 139 mg 8,10-Da, were coated with BioTac 3® adhesive and applied singly by hand to apple foliage in close proximity to and surrounding a Sectar I® trap baited with 1.0 mg of 8,10-D, the synthetic sex pheromone (Maitlen, *et al.* 1976). The fibers were placed ca. 15 cm apart and 15 cm from the trap. The formulation contained 4.6 g of 8,10-Da/100 g, and 100 g of formulation contained ca. 33,000 fibers. For this test a pheromone-baited trap surrounded by the fibers was placed in each of 2 non-commercial apples trees, heavily-infested by codling moth. A trap baited with pheromone but not surrounded by fibers containing 8,10-Da was also placed in each of two other trees at least 20 m from the test tree. Evaluation of the degree of disruption of communication between the sexes was based on the response of native males to the pheromone-baited traps. Trap catches were counted daily. This test was conducted from 10 August to 26 September 1979.

Experiment II — Broadcast application of fibers by helicopter:

In experiment II, a preliminary, unreplicated test, fibers containing 8,10-Da were applied to apples trees using a modified Conrel dispenser mounted on a helicopter. The formulation used contained 9.0 g of 8,10-Da/100 g (D. Swenson, personal communication). Two dosages of 8,10-Da were evaluated: 13.5 g AI 150 g formulation and 6.75 g AI 75 g of formulation per single 0.4 ha block (by trees). The formulation was mixed immediately prior to application with BioTac 3 adhesive in a 1:2 ratio by volume. The helicopter was flown directly over the rows of trees at ca. 112 km/h and 16 m above the tree canopy. Subsequently, four wing traps (Howell 1972), two baited with 1.0 mg of 8,10-D and two with ten 1-day-old, laboratory-reared, virgin female codling moths were placed in each plot. Two traps baited with the same attractant source were placed in each plot, one in each

TABLE 1. Catch of male codling moths in sex pheromone-baited traps (1 mg 8,10-D/trap) surrounded with hand-placed hollow fibers containing 8,10-Da (10 single fibers/trap location). Selah, Washington, 1979.

	Average no. moths/trap/week[2]		% Reduction
Week[1]	8,10-Da Treated	Control	in response
1	0*	6.0	100.0
2	0*	5.0	100.0
3	1.0*	12.6	92.0
4	2.5*	10.5	76.2
5	1.5*	7.7	80.0
6	1.5*	13.3	88.9
7	2.1	8.4	75.0

[1] = Application made 10 August 1979.

[2] * = Values marked with an asterisk are significantly different from the value for the control on the same line. Analysis of variance with Duncan's multiple range test, P = 0.05 (Duncan, 1955).

TABLE 2. Catch of male codling moths in pheromone (1 mg 8,10-D/trap) or female-baited traps (10♀♀/trap) in single 0.4 ha plots treated with 8,10-Da applied by helicopter, Naches, WA, 1979.

	Average no. males/trap/week					
Week[1]	Pheromones	Female	Pheromones	Female	Pheromones	Female
	6.75 g 8,10-Da/75 g form		13.5 g 8,10-Da/150 g form		Control	
1	0	0	0	0	9.5	0.5
2	1.5	0.5	0.5	0.5	8.5	0.5
3	13.0	0.5	14.0	0.5	11.0	1.5
4	8.4	0.7	7.0	0	7.7	0.7

[1] Applied 23 August 1979.

diagonally opposite corner. A similar plot, not treated with 8,10-Da, served as the untreated control. The impact of the application of 8,10-Da on the response of male codling moths to either the synthetic sex pheromone or that produced by females was determined by the response of males to the sources in the traps as measured by trap catches.

Experiment III — Broadcast application of fibers by ground dispenser:

In experiment III, Conrel fibers containing 8,10-Da were applied to a 0.4 ha block of pear trees with a ground dispenser designed to apply an adhesive to the fibers, meter fibers at controllable rates, and deliver them into the tree canopy (Moffitt and Short, 1982). A dosage of 11.25 g AI 125 g formulation per 0.4 ha was applied. Evaluation of the degree of disruption of the response of males to the synthetic sex pheromone or that produced by females was carried out in the same manner as in experiment II.

RESULTS AND DISCUSSION

Fibers placed in close proximity to pheromone-baited traps. During the 1st two weeks of the 7-week test period, the response of males to 8,10-D in the traps, as measured by catches of males in these traps, was completely inhibited when 10 fibers contaiing 8,10-Da were placed singly on foliage in close proximity to the traps (Table 1). During weeks 3-6, significant reductions in the response of males of 92.0, 76.2, 80.0, and 88.9%, respectively, were achieved. No significant reduction in response was achieved the 7th and last week of the test. These results were similar to those earlier obtained with the codling moth where 8,10-Da sources were placed in or near the sex pheromone-baited trap (George *et al.* 1975, Hathaway *et al.* 1979), and did indicate that the Conrel chopped hollow fiber formulation is a satisfactory substrate for 8,10-Da.

TABLE 3. Catch of male codling moths in pheromone- (1 mg 8,10-D/trap) or female- (10♀♀/trap) baited traps in pear trees treated with 8,10-Da (11.25 g/125 g. formulation/0.4 ha) applied by ground dispenser, Naches, WA, 1980.

Days	No. males responding	
Post-treatment	Treated w/8,10-Da	Control
1-9	0*[2]	15
10-16	15	23
17-23	15	36

[1] Applied 15 July 1980.

[2] For analysis, catches in pheromone- and female-baited traps have been combined. Values marked with an asterisk are significantly different at the P = 0.05 level from the value for the control on the same line (Kuskal-Wallis, one-way analysis of variance [Siegel, 1956]).

Broadcast application of fibers by helicopter. In this unreplicated, preliminary test of a broadcast type of application, the response of male codling moths to either synthetic sex pheromone or that produced by females, as indicated by catches in appropriately baited traps, was eliminated for the 1st week and greatly reduced for the 2nd week of the test (Table 2). During the 2nd week, the lower dosage, 6.75 g AI/0.4 ha, resulted in a 77.8% reduction in the response of males while the higher dosage, 13.5 g AI/0.4 ha, yielded an 88.9% reduction. After the 2nd week no reduction in response of males was observed.

Broadcast application of fibers by ground dispenser. When 8,10-Da in chopped hollow fibers was applied in a broadcast type of application by ground equipment, the response of male codling moths to pheromone- or female-baited traps was completely inhibited for 9 days (Table 3). During the 10-23 day post-treatment period after males began to respond in the treated plots, no significant differences in response between the treated or control plots occurred. These results are similar to those obtained in the preliminary test where the formulation was applied by helicopter, also in a broadcast type of application.

Based on these and earlier obtained results, we conclude that 8,10-Da is an effective inhibitor of male response to either synthetic sex heromone or that produced by the females when the sources of 8,10-Da are placed either in close proximity to the pheromone source or in a broadcast type of application where large volumes of air are to be permeated, contrary to previous conclusions on the effectiveness of use of antipheromones to permeate large volumes of air (Shorey, 1977). To insure that we would have a sufficient amount of the antipheromone we doubled the concentration of the antipheromone used in our tests compared to the pheromone studies previously conducted that had shown the pheromone to be effective in disrupting communication and mating (Moffitt and Westigard, 1984). Hathaway *et al.* (1979) found that half-life of the 8,10-Da in natural rubber to be 47.1 days (95% confidence limit = 40.5 - 56.5 days). They also found that the initial rate of evaporation of 8,10-Da (207gha-^{1}) was 127 mgh-^{1}ha-^{1}.

Both the pheromone and the antipheromone are subject to chemical decomposition. This may explain why there was such a short period of control when the antipheromone was used in a broadcast application. Shani and Klug (1980) and Hoffmann, *et al.* (1983) both discuss the fact that light can catalyze the isomerization of conjugated dienes and that light and air may cause fast decomposition of pheromone or antipheromones especially when they are incorporated into a polyethylene formulation. We feel that another kind of formulation for the inhibitor would give us a longer period of distuption.

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VERTICAL DISPERSION OF TWOSPOTTED SPIDER MITES[1] ON HOPS THROUGHOUT THE GROWING SEASON[2]

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ABSTRACT

Studies were conducted in 1968 and 1982 to determine the vertical dispersion of twospotted spider mites, *Tetranychus urticae* Koch, on hops during the growing season. Data from both years were combined.

Twospotted spider mites were primarily on the lower half of the plants from May, when the plants initiated growth, through early July. By early-to mid-August most of the spider mites were on the upper half of the plants. Since the apical growth of hops is very heavy at this time, conventional, contact spray pesticides cannot reach these mites. However, systemic pesticides may be effective for mite control.

INTRODUCTION

Hops, *Humlus lupulus* L., grown in the dry areas of the Pacific Northwest, are subject to foliage injury by the twospotted spider mite, *Tetranychus urticae* Koch, and the hop aphid, *Phorodon humuli* (Schrank). Both damage the plant by feeding on the leaves, and severe infestations of either pest can potentially result in total crop loss if left uncontrolled. Thus, growers repeatedly apply several pesticides with tractor-drawn, air-blast sprayers or aircraft.

Hops grow from a perennial subterranean crown, wind around and climb strings to a 5.5 m high wire trellis. Crowns are spaced 2.1 x 2.1 m apart in the hop yard. The hop growing season extends from early-May to mid-September when the vines are cut and removed from the yard. By mid-August apical growth becomes extremely dense and pesticides applied with a tractor-drawn, air-blast sprayer or with aircraft do not adequately cover the canopy. If a large pest population continues to exist in the canopy, crop damage will still occur.

Vertical dispersion of spider mites on hops has received little attention. Knowledge of pest dispersion patterns on the plant over time would aid in more effective placement of pesticides, thereby reducing the amount of pesticide needed and, in turn, reducing the residue burden in the hop cones. Therefore, the purpose of this study was to determine the vertical dispersion of twospotted spider mites on hops during the growing season.

MATERIALS AND METHODS

This study was conducted in south-central Washington during the growing seasons (i.e., June-August) of 1968 and 1982. The variety of hops used was "Yakima Valley Clusters." A row of 32 plants was divided into 8-hill plots, replicated 4 times, with 1-hill borders between plots. Plant height intrvals of 0.0-0.9, 0.9-1.8, 1.8-2.7, 2.7-3.7, 3.7-4.6 and 4.6-5.5 m were sampled weekly in 1968 and twice per week in 1982. Ten leaves/ height interval/ plot were collected, placed in plastic bags, and returned to the laboratory. Each plant was sampled. A pruning pole was used to remove leaves from the 3 uppermost height intervals.

Leaves were brushed with a modified Henderson-McBurnie (1943) brushing machine. Leaf surface materials including spider mites, mite eggs, aphids and predators were deposited onto a circular, glass plate covered with a water soluble, sticky substance. A 1/10 subsample was examined using a dissecting microscope, mechanical stage, and backlighting. Mobile forms of *T. urticae*, mite eggs, hop aphids, and miscellaneous predators were counted. From these data we determined the numbers of spider mites/leaf at each interval. The 4

[1] *Tetranychus urticae* Koch; Acarina, Tetranychidae.

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