DISRUPTION OF SEXUAL COMMUNICATION IN *LASPEYRESIA POMONELLA*[1] (CODLING MOTH), *GRAPHOLITHA MOLESTA*[1] (ORIENTAL FRUIT MOTH) AND *G. PRUNIVORA*[1] (LESSER APPLEWORM) WITH HOLLOW FIBER ATTRACTANT SOURCES

BY

R. T. CARDÉ, T. C. BAKER and P. J. CASTROVILLO

Department of Entomology, Michigan State University, East Lansing, Michigan 48824, U.S.A.

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R. T. CARDÉ, T. C. BAKER and P. J. CASTROVILLO

Department of Entomology, Michigan State University, East Lansing, Michigan 48824, U.S.A.

Emission of (*Z*)-8-dodecenyl acetate [7% (*E*) isomer] from hollow fiber dispensers at 0.15 g/ha/day from 1700 points (units of 10 fibers)/ha effects complete disruption of male *Grapholitha molesta* (Busck) attraction to synthetic lure and virgin females. Attraction of *G. prunivora* (Walsh) to synthetic lures is also completely disrupted. Emission of (*E,E*)-8,10-dodecadien-1-ol at 0.05 g/ha/day from 1700 points/ha effects complete disruption of male *Laspeyresia pomonella* (L.) attraction to synthetic pheromone, to virgin females and prevents mating with tethered females.

Atmospheric permeation with synthetic sex attractants to effect disruption of mating has been investigated in numerous species of Lepidoptera (reviewed by Cardé, 1976, Mitchell, 1975, Shorey *et al.*, 1976, Roelofs & Cardé, 1977). Evaluations of the efficacy of disruption technique have relied on contrasting between the treated and check areas either the catches of synthetic and organism-baited traps, the incidences of mating of native and laboratory-reared individuals or subsequent pest infestation, damage and population trends. Techniques for emission of the disruptant into the atmosphere have included spaced discrete stations, various microdispersable formulations and hollow fibers. Potential disadvantages of spaced evaporative stations include incomplete or variable permeation, leaving layers or windows of atmosphere where the concentration of disruptant is below that requisite for disruption. An advantage of the discrete source procedure is evaporation of a known quantity of chemical at a constant rate. Microdispersable formulations (such as encapsulation and wettable powders) may effect comparatively uniform permeation. Notwithstanding, the formulations currently available emit only a small portion of the active ingredient at a rate that declines as a first order function, so that estimation of the actual atmospheric concentration of disruptant is difficult. Hollow fiber dispensers (Conrel®)[2] offer a constant rate of emission from numerous point sources (1000 to 10,000/ha).

[1] Lepidoptera: Tortricidae: Olethreutinae

[2] Supplied by FRL, a division of Albany International Company, Norwood, Massachusetts, 02062, U.S.A.

In this paper we report the disruptive effects of attractants emitted from hollow fibers on male attraction and mating in the three species of tortricids.

MATERIALS AND METHODS

Chemicals

Compound purity was assessed by gas chromatography on nonpolar OV-1 (methyl silicone on 100-120 mesh Gas-chrom Q) and polar XF-1150 (10% cyanoethyl methyl silicone on 100-120 mesh Gas-chrom Q) columns (1.8 m × 2 mm) at 140°. The (*E,E*)-8,10-dodecadien-1-ol (E8E10-12:OH) was obtained from Zoecon Corporation, the (*Z*)-8-dodecenyl acetate (Z8-12:Ac) and the (*E*)-8-dodecenyl acetate (E8-12:Ac) from Farchan Chemicals and the dodecyl alcohol (12:OH) from Eastman Organic Chemicals. All compounds or mixtures were >99% pure when placed in the field.

Disruptant formulation

The chemicals were emitted from Conrel® hollow fibers of ca. 1 cm in length. The E8E10-12:OH was admixed with 2% BHT (butylated hydroxy toluene, 2,6-di-tert-butyl-4-methylphenol), an antioxidant. The E8E10-12:OH evaporated at a rate of 2.7×10^{-6} cm^3/day/fiber (3.4×10^{-4} cm^2 lumen area) at 21°. The Z8-12:Ac and E8-12:Ac mixture (93:7) evaporated at 8.8×10^{-6} cm^3/day/fiber (2.0×10^{-3} cm^2 lumen area) at 21°.

Fibers initially were placed in the field from May 15 to 20, 1976. Samples of fibers from several positions in the canopy and the trunk were returned for analyses of attractant evaporation and purity on August 8 and September 29. The Z8-12:Ac (7% E8-12:Ac) fibers showed ca. 50% visible loss (by a drop in the meniscus) by August 8 and ca. 75% loss by September 29. Attractant was removed from the fibers with a μl syringe. Gas chromatographic analyses showed <1% degradation of the Z8-12:Ac (7% E8-12:Ac) mixture, with slight (*Z*) to (*E*) isomerization to 9% (*E*) isomer.

The E8E10-12:OH fibers showed nearly complete evaporation of disruptant by August 8, although fibers from comparatively shaded areas in the canopy had ca. 1/10 of the formulated material remaining. Fibers were cut into small pieces and placed in CS_2. Comparison of extracts with fresh fibers treated similarly verified that some E8E10-12:OH was present in the fibers on August 8. Fibers from September 29 showed no detectable disruptant by gas chromatography.

Experimental apple orchard

All but two tests were conducted in an orchard of standard size trees of several varieties planted on a 12 × 12 m spacing. The orchard was located in Cascade, Michigan and the trees had received no pesticide treatment during ca. the previous 10 years. The disruptant area consisted of a block of trees approximately 6 × 12 rows with occasional missing trees. The disruptant block was separated from the check (non-disruptant) area by 100 m of grass meadow. Disruptant fibers were held on sticky tape (10/tape) and 25 tapes each of the E8E10-12-OH and Z8-12:Ac (7% E) were stapled to each tree. The tapes were positioned throughout the tree (from 1 to 6 m) so that the emission of disruptant would be evenly dispersed in the canopy and near the trunk. Based on the emission rates in the laboratory at 21°, the field rates would have been ca. 0.05 g/ha/day for the E8E10-12:OH and ca. 0.15 g/ha/day for the Z8-12:Ac and E8-12:Ac mixture.

Evaluation of male attraction

White Pherotrap 1C sticky traps (Zoecon Corporation) were baited with 5 × 7 mm rubber septa (Arthur H. Thomas Company) charged with 1000 μg E8E10-12:OH for *L. pomonella*, 100 μg Z8-12:Ac (7% E8-12:Ac) plus 300 μg 12:OH for *G. molesta* and 100 μg Z8-12:Ac (2% E8-12:Ac) for *G. prunivora*. Virgin female-baited white Pherotrap 1C traps held either two *L. pomonella* or three *G. molesta* contained in cylindrical screen cages 2.5 cm in diameter × 3 cm in height. Females had access to water. Females were less than 2 days old when they were placed in the field and generally they were replaced after 3 or 4 days. The females originated from laboratory colonies derived from material collected in East Lansing in 1975 and maintained on thinning apples. The photoperiod of the laboratory colonies was timed to coincide closely with the natural photoperiod.

Synthetic attractant dispensers were replaced every 3 weeks with fresh dispensers. At the same time all sticky trap bottoms (for synthetic, females and check traps) were replaced with new units. All traps were deployed at one per tree in the central sections of the disruptant and check blocks at a height of 2.5 m. The distance between the center of the trap locations in the disruptant and check blocks was approximately 300 m. Treatments were replicated twice in each block.

Mating of G. molesta *confined in close proximity*

All moths tested were laboratory-reared, one day-old virgins that had been maintained on a photoperiod timed to coincide with the natural conditions. Fifteen males were confined for 24 h in cylindrical screen cages 30 cm in length × 15 cm in diameter and held in the shaded center of tree canopies in the treatment and check blocks. Fifteen females were added to each cage for the next 24-h period, after which females were returned to the laboratory and confined individually to ascertain if they laid fertile ova. Throughout the trial moths had access to water.

Mating of L. pomonella *confined in close proximity*

This comparison was conducted between August 29 to September 6, 1976 in East Lansing in blocks of standard size apple trees abandoned for ca. 10 years. The same number of E8E10-12:OH fiber dispensers as were employed in trees in the disruptant block in the Cascade orchard was stapled evenly over the canopy and trunk of two individual apple trees 1 km apart. The two check (non-treatment) trees were located 15 m away from the trees with the disruptant fibers. Photoperiod entrainment, rearing, 24 hours' exposure of the males in the disruptant trees prior to addition of the females, and scoring of mating were as described for the mating of *G. molesta* confined in close proximity. Five and ten pairs per cage were tested.

Attraction and mating of L. pomonella *wild males with tethered females*

This comparison was conducted between 19-27 August, 1976 in East Lansing using the same experimental and check trees as in the previous test. One day-old virgin, laboratory-reared females were held at 5° (without disturbing light cycle entrainment) for one hour and then quickly denuded of scales on the dorsum of the thorax with a fine brush. A small drop of rubber cement (Sanford®) was placed on the denuded area and another small drop on the end of a fine, black thread 5 cm long. The drops of cement on the thread and thorax were joined for hardening. The other end of the thread was attached to the bottom of a non-sticky Pherotrap 1C. The traps were hung in the canopy at a height of 1.8 to 2 m. This procedure afforded males the opportunity to be attracted to and to mate with the experimental females.

Five or six tethered females were set out on a 2-m spacing between individuals. Females were placed out at between 19:30 and 20:00 (Eastern Standard Time) and retrieved between 06:00 and 06:30. (This timing was necessitated by significant losses of females to vespids and other predators with either earlier placement or later retrieval.) Females were confined to ascertain the oviposition of fertile ova.

Percent disruption for a particular attractant treatment was calculated as follows:

$$\frac{\text{(catch in untreated area)} - \text{(catch in disruptant area)}}{\text{catch in untreated area}} \times 100\%$$

In the field tests reported here season-long catch in unbaited traps was negligible (<1%) so that correction for random trap catch was unnecessary.

RESULTS AND DISCUSSION

Disruption of Grapholitha *communication*

Comparison (Table I, Fig. 1, A-B) of the season-long catches of *G. molesta* at synthetic and female-baited traps in the disruptant and nontreatment areas indicated 100% disruption of attraction into September. Additionally, similar comparison of the catches of *G. prunivora* with synthetic lures (Z8-12:Ac with 2% and 7% E8-12:Ac) also suggests effective communication disruption in this species. These data suggest that the males' location of native females of both *Grapholitha* species can be prevented by emission of a 93:7 blend of Z8-12:Ac and E8-12:Ac at ca. 0.15 g/ha/day.

Notwithstanding, mating of male and female *G. molesta* held in close proximity

TABLE I

Catches of males from 21 May to 19 September 1976

Trap Lure	Summed season male trap catch					
	Laspeyresia pomonella		*Grapholitha molesta*		*Grapholitha prunivora*	
	disruptant	check	disruptant	check	disruptant	check
E8,E10-12:OH	47[1]	1088[1]	0	0	0	0
2 *L. pomonella* ♀♀[2]	0	383	1	0	0	0
Z8-12:Ac(7%E)	0	0	1	216	0	191
3 *G. molesta* ♀♀[2]	1	3	0	239	0	2
Z8-12:Ac(2%E)	0	2	1	23	0	86
Unbaited	1	3	1	0	0	0

1. On 7 August cumulative catch was 0 in disruptant plot and 284 in check plot; on 13 August, 5 and 787, respectively.
2. Female-baited traps were in orchard from 4 June to 10 July and from 25 July to 25 September.

was not prevented by the emission of the disruptant, even though the males were exposed to the disruptant for 24 h prior to the introduction of the females. Females confined with males at 15 pairs per cage (seven replicates between August 5 to 15, 1976) mated with a frequency of 71% in the check block and 63% in the disruption block (N.S. at the 5% level by χ^2). Although male habituation (alteration of threshold of pheromone response) may have occurred, clearly male mating initiative was not entirely eliminated. The ability of a particular atmospheric concentration of attractant to discupt location of attractant sources but not eliminate male mating initiative closely parallels field tests with *Argyrotaenia velutinana* (Walker) (Cardé *et al.*, 1975c). In both the *G. molesta* and *A. velutinana* field tests the disruptants consisted of two components that elicit long-range anemotaxis and lacked the third components that effected landing in both species and precopulatory behavior in *G. molesta* (Cardé *et al.*, 1975a, 1975b; Baker *et al.*, 1976).

The natural pheromone system of female *G. molesta* is only partially defined. Only Z8-12:Ac has been identified from the female abdominal tip (Roelofs *et al.*, 1969). The E8-12:Ac and 12:OH attractant system components were discovered by empirical field screening of compounds related to Z8-12:Ac (Beroza *et al.*, 1973; Roelofs *et al.*, 1973; Roelofs & Cardé, 1974). The natural chemical communication system of *G. prunivora* is unknown, but Z8-12:Ac and E8-12:Ac in 98:2 to 93:7 blends have been found to lure large numbers of males of this species (Roelofs & Cardé, 1974; Gentry *et al.*, 1975). Thus, in both *Grapholitha* species the possibility of more attractive synthetic lures based on the natural communication systems cannot be ruled out. However, elimination in *G. molesta* of the male's location of the female remains the most pertinent evidence of successful disruption.

Other investigations also have demonstrated apparent communication disruption in *Grapholitha* species. Gentry *et al.* (1975) reported in *G. molesta* disruptive effects for ca. 14 days with 19 g/ha (but not 5 g/ha) of encapsulated attractant. The actual rate of release of active ingredients into the atmosphere was unknown and

A

B

C

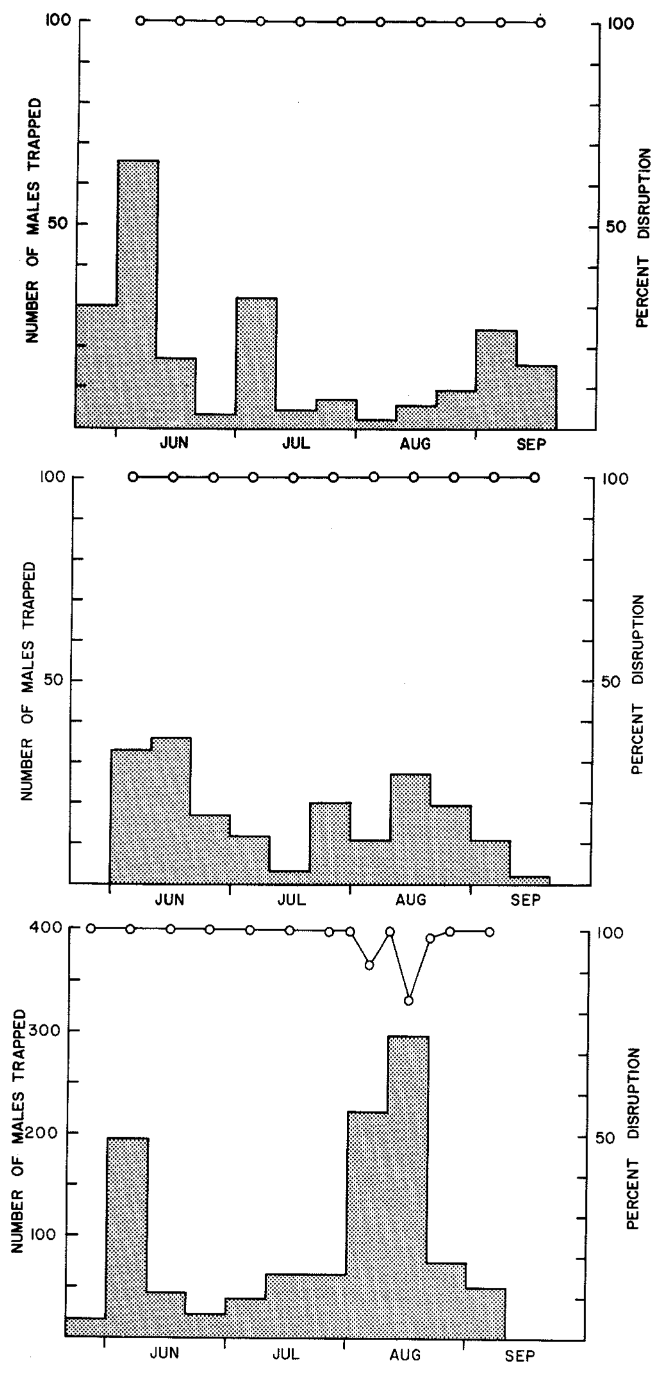

Fig. 1. Seasonal catch (histogrammes) in the non-disruptant area of males at synthetic-baited traps. Percent disruption of communication (open circles) is relative to the catch in the treatment area. A. *Grapholitha molesta*, B. *Grapholitha prunivora*, C. *Laspeyresia pomonella*.

the capture levels of native and marked, released males in untreated plots were low. Rothschild (1975) working with *G. molesta* in Australia found that Z8-12:Ac (2%-3% E-12:Ac) emitted at 0.12 g/ha/day from closed polyethylene microcapillary tubes effectively disrupted male catch at traps baited with Z8-12:Ac (2%-3% E8-12:Ac). This treatment yielded subsequent fruit and shoot infestation levels of peaches comparable to the control achieved by applications of conventional insecticides. In both Gentry *et al.* (1975) and Rothschild (1975) the effects of the disruptive treatment on either the attractiveness of virgin females or the mating of native individuals were not directly assessed by mating experiments.

In a related species, *Grapholitha funebrana* (Treitschke) male attraction to a synthetic lure, Z8-12:Ac with 3%-5% E8-12:Ac was effectively eliminated at emission rates of 0.6 to 1.2 g/ha/day (Arn *et al.*, 1976). Subsequent larval damage in the disruption area appeared to be comparable with that obtained by conventional pesticide treatment. As in *G. prunivora*, the natural pheromone system of *G. funebrana* is unknown.

Disruption of Laspeyresia pomonella *communication*

The location by male *L. pomonella* of E8E10-12:OH and virgin female-baited traps (Table I) was 96% and 100% disrupted over the two flight periods. Evaluating the levels of disruption of synthetic-baited traps seasonally (Fig. 1C), the catches were 100% disrupted to August 7 and 99% disrupted to August 13. The partial breakdown of disruption occurred in two samples of peak flight in August.

Unlike Z8-12:Ac — E8-12:Ac hollow fibers which emitted the disruptant at a constant rate until mid-September, the E8E10-12:OH fibers showed nearly complete evaporation of E8E10-12:OH by August 8 and no evidence of E8E10-12:OH remaining in the fibers on September 29. Thus, the slight breakdown in communication disruption of synthetic traps (but not to virgin female traps) could be related to lowered emission of disruptant after August 8.

As in *G. molesta*, the mating of pairs of males and females held in small cages was not affected. Females confined with males at 10 pairs per cage (6 replicates) mated with a frequency of 73% in the check block and 52% in the disruption block (differs at the 5% level by χ^2). However, when the pair density was five per cage (12 replicates), the frequency of mating was 57% in both blocks. Fluri *et al.* (1974) showed in *L. pomonella* that removal of both male antennae eliminated mating, pointing out that perception of female pheromone is a prerequisite to the male's mating behavior. In our tests 0.05 g/ha/day evidently did not eliminate the close range response to pheromone.

Of particular interest was the complete disruption of the mating of tethered virgin females (n = 100) in disruptant trees whereas with directly comparable females 15 m away (n = 112) the mating frequency per 24-hour interval was 44%, a difference significant at the 0.1% level by χ^2. Fluri *et al.* (1974) using tethered females reported a reduction in mating from 75% per evening to 22.5% with a probable disruptant emission rate of E8E10-12:OH of 93 mg/ha/day when the evaporator stations (at 23/ha) were placed in the field.

CONCLUSIONS

In a season-long test with these three species, atmospheric-permeation with synthetic attractants successfully disrupted the males' location of attractant-baited traps that normally would have elicited substantial catches. Similarly, the attraction of *G. molesta* and *L. pomonella* to conspecific virgin calling females as well as the mating of tethered *L. pomonella* females were eliminated. Notwithstanding, when *G. molesta* and *L. pomonella* were confined in close proximity, the frequencies of mating were unaffected by the omnipresence of synthetic attractants.

Although the precise behavioral mechanisms that effect successful disruption of communication are as yet undefined, these experiments as well as those of Cardé *et al.* (1975c) on *A. velutinana* suggest that in some species of Lepidoptera disruption of long-range orientation alone may be sufficient to prevent mating. This strategem may yield efficacious population control, particularly when the initial population density is sufficiently sparse to prevent many chance encounters of males and females.

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RÉSUMÉ

INTERRUPTION DE LA COMMUNICATION SEXUELLE CHEZ LASPEYRESIA POMONELLA *(CODLING MOTH),* GRAPHOLITHA MOLESTA *(ORIENTAL FRUIT MOTH) ET* G. PRUNIVORA *(LESSER APPLEWORM), AVEC DES ÉMETTEURS D'ATTRACTIF SUR FIBRE CREUSE*

L'émission du composé (Z)-8-dodecenyl acetate (7% de l'isomère E 8-12 Ac dans le texte), à la dose de 0,15 g/ha/jour, à partir d'émetteurs formés d'une fibre creuse (type Conrel (R)), répartis en 1700 points/ha, chaque point comportant des unités de 10 fibres, annihile complètement l'attraction du mâle de *Grapholitha molesta* à l'égard de femelles vierges ou de leures chimiques de synthèse. L'attraction de *G. prunivora* pour des leures synthétiques est également totalement interrompue.

L'émission du composé E8 E10-dodécadien - 1-ol (E8 E10-12:OH) à la dose de 0,05 g/ha/jour, à partir de 1700 points/ha, entraîne la destruction totale du comportement attractif de *Laspeyresia pomonella* pour des hormones de synthèse, ou pour des femelles vierges et empêche l'accouplement avec des femelles non mobiles liées par un système adhésif à un dispositif attractif (pherotrap 1C).

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