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Suppression of Lepidopterous Pest Populations in Apple Orchards through Mating Disruption with Synthetic Sex Pheromones

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Abstract

Effect of mating disruption using the major component of the sex pheromone, (z)-7-eicosen-11-one, on the peach fruit moth, *Carposina sasakii* Matsumura, was more pronounced at lower moth densities. When supplemented with adequate insecticide sprays, the treatment caused a drastic decrease in the pest population even at extremely high levels. Release of the common pheromonal component onto leafrollers of the tribe Archipini, (z)-11-tetradecenyl acetate, prevented the population recovery of the apple tortrix, *Archips fuscocupreanus* Walsingham, the Asiatic leafroller, *A. braviplicanus* Walsingham, and the summer fruit tortrix, *Adoxophyes orana fasciata* Walsingham, under conditions of reduced insecticide sprays, The effect on the last species, however, decreased remarkably under outbreak conditions. Also, a significant increase of the incidence of the brown tortrix, *Pandemis heparana* (Schiffermuller et Denis), occurred in a few pheromone-treated fields. Mixture of the two pheromone components, (z)-10-tetradecenyl acetate and E4, z10-tetradecadienyl acetate, in the ratio of 10:3 showed a significant disruptive effect on the mating of the apple leafminer, *Phyllonorycter ringoniella* (Matsumura).

Discipline: Insect pest
Additional key words: apple leafminer, integrated pest management, leafroller, peach fruit moth

Introduction

In Japan, the occurrence of arthropod pests resistant to spray chemicals is a serious constraint on apple production. Moreover presently in the case of dessert apple the consumers prefer cleaner fruits with fewer chemical residues. These conditions require the development of an integrated pest management (IPM) system, in which the conventional sprays are, at least in part, substituted by new control techniques. Mating disruption of pests by using synthesized sex pheromones is a method of control that could be implemented. The technique has been developed for some lepidopterous pests of apple, and has recently been used for the control of the peach fruit moth and a few apple leafrollers. Experiments are currently in progress for the apple leafminer also. Main aspects of the studies concerned are reviewed in this article, including unpublished data.

The peach fruit moth

1) Control problems

The peach fruit moth, *Carposina sasakii* Matsumura [= *niponensis*: auct.], has long been the most important fruit borer in the major apple-growing areas. The life cycle of the moth has been described by Narita & Otake[2]. Adult emergence of the overwintering generation continues for more than 2 months, which results in the partial overlapping of the two separate generations and continuous oviposition from June to early September. Repeated sprays to control the moths were responsible for the development of insecticide resistance in some other pests, although the fruit moth itself has not become

resistant to the chemicals yet[4].

2) Synthetic pheromone

Among the pheromone components of the peach fruit moth, the major one, (z)-7-eicosen-11-one, alone attracts male moths[4]. It is also effective in the mating disruption against the pest, without enhancement of the effect by the addition of the minor element, (z)-7-nonadecen-11-one[5]. The role of the minor component is still unknown. Thus, only the major element was employed as 'peachflure' for practical use. Two types of pheromone dispensers are available for mating disruption; a capillary tube made of polyethylene containing more than 35 mg of the synthesized pheromone for hanging on, and a paste containing it at the rate of 1.8% for sticking on branches. Unless otherwise stated, the data on the control effect given later are based on the tube-type material, from which the pheromone can be released at a steady rate for 2 months or more.

3) Method for field evaluation

The peach fruit moth adult showed a limited response to optical and chemical attractants[2]. Catches by pheromone traps were substantially prevented by the disruption treatment, irrespective of the levels of the control[5]. Tethered females were of limited significance for the evaluation of the disruption effect, as their mating rate was unexpectedly low in untreated plots[7] and the effect could only be evaluated by direct examination of larval attacks on fruits.

4) Control effect

Pheromone-trap catches revealed that the synthetic pheromone can be continuously distributed over the field, if it is released at a rate of more than 300 mg per day from 1,000 to 1,500 points per ha with some addition to the periphery of the treated orchard[6]. Field trials of the peach fruit moth control were undertaken along this line.

Fig. 1 shows some of the results obtained under conventional sprays in small plots of approximately 0.5 ha in Fukushima Prefecture[7]. Comparison of the population trend between the treated and untreated plots indicated that the mating disruption reduced the fruit moth population by about 75% on an average for the 3-year results. A similar estimate was provided based on questionnaires prepared for farmers who participated in another trial covering an area of 15 ha. The paste-type dispenser was similarly effective in the same experiment.

Besides, a series of tests was continued for a period of 7 years in a European pear orchard of a few ha in the vicinity of Morioka[5]. The overall results are illustrated in Fig. 2. Suppression of the moth abundance was not achieved by the disruption alone and with 1 or 2 sprays at the initial high population levels. However, the same pheromone treatment in combination with 4 well-timed sprays was able to cause a drastic population decrease, which was followed thereafter by a subsequent decrease with

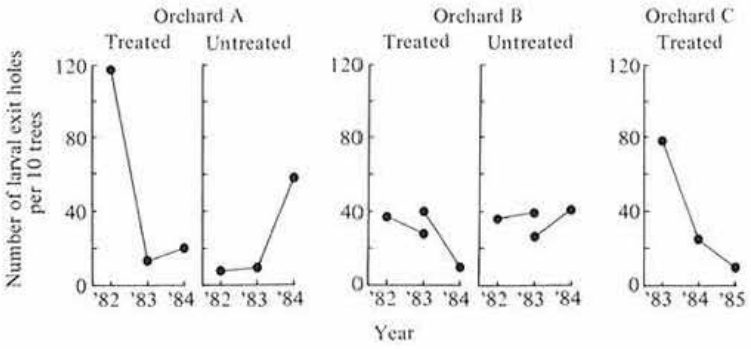

Fig. 1. Annual change in the number of larval exit holes of the peach fruit moth on harvested apple fruits in treated and untreated plots with pheromone for mating disruption at Fukushima
Conventional sprays were applied over the test period. In orchard B, plots were exchanged with each other in 1983.
Source: Sato (1986)[7].

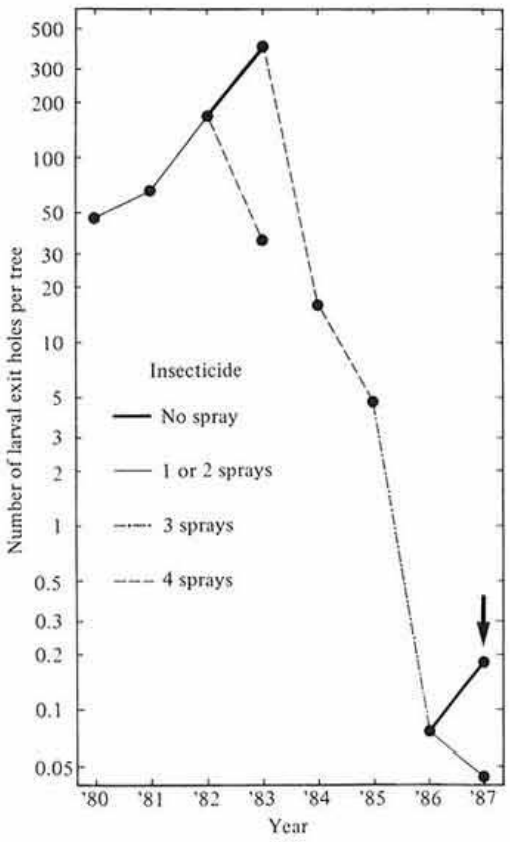

Fig. 2. Annual change in the larval population of the peach fruit moths in a European pear orchard treated with pheromone for mating disruption in the vicinity of Morioka
Number of larvae is indicated in a logarithmic scale. The annual population was estimated based on the total number of exit holes on fruits and of larvae left within them at harvest. See the text for the arrow.
Source: Oku et al. (1989)[5].

reduced sprays. In the final trial, half of the orchard was kept unsprayed. Although the fruit injury slightly increased there (indicated by an arrow in Fig. 2), the resumption of infestation was restricted to some of the outermost trees.

These and some other results suggested that the control effect may be more conspicuous at lower moth densities and could be stabilized by simultaneous treatment over a wide area, especially if well protected from the wind. This technique has been used in combination with conventional sprays to improve the peach fruit moth control in commercial orchards[4]. Some local associations of farmers plan to reduce the frequency of sprays by the introduction of simultaneous mating disruption for the fruit moth and for the leafrollers (see the next section).

Apple leaf-rollers

1) Control problems

Recently, major apple leafrollers in Japan have been limited to the tribe Archipini, Tortricidae, including the summer fruit tortrix, *Adoxophyes orana fasciata* Walsingham, the apple tortrix, *Archips fuscocupreanus* Walsingham, the Asiatic leafroller, *A. breviplicanus* Walsingham, and the brown tortrix, *Pandemis heparana* (Denis et Schiffermuller). Their seasonal occurrence has been described by Oku[3]. Local populations of the former two species have developed a resistance to some spray chemicals recently. The larvae of the apple tortrix are active around the apple blooming period when insecticide sprays against them are avoided for the safety of the pollinators.

2) Synthetic pheromone

A multi-component pheromone material has been used for the control of the summer fruit tortrix in Europe[1]. In Japan, on the other hand, the single component, (z)-11-tetradecenyl acetate, is utilized for simultaneous mating distruption of two leafrollers, *Adoxophyes* sp. and *Homona magnanima* Diakonoff, in tea plantations[12]. As this substance is a common component of the sex pheromones to the leafrollers of the tribe Archipini, the possibility of applying the same control material as that used in tea plantations, 'tetradecenylacetate', for the control of the apple leafrollers was considered. The tube-type dispenser which contains 80 mg of the synthesized pheromone component releases it steadily for 2 months or more.

3) Methods for field evaluation

Pheromone-trap catches and mating rate of tethered females were of limited significance in the evaluation of the control efficacy for these apple leafrollers, as in the case of the peach fruit moth. As the apple tortrix is univoltine and lays eggs on the trunk and branches[3], reliable estimates for the disruption effect can be obtained by the annual changes in the number of egg-masses in experimental plots.

Table 1. Annual change in the number of egg-masses of the apple tortrix in treated and untreated plots with pheromone for mating disruption at Morioka[a)]

Year of treatment	Plot	No. of trees examined	No. of egg-masses[e)]		(B) ÷ (A) × 100
			(A)	(B)	
1990	Treated[b)]	198	1,906	95	5.0
	Untreated	90	32	46	143.8
1991	Treated[c)]	372	105	4	3.8
	Untreated	195	95	169	177.9
1992	Treated[d)]	174	137	29	21.4
	Untreated	196	169	123	72.8

a): Tube-type dispensers were applied to the 'treated' plot from mid-May to mid-June. Two plots were not subjected to effective spray for the leafroller. Source: Oku & Ohira (unpublished).
b): 3 ha, with 1,500 dispensers/ha.
c): 3 ha, with 1,000 dispensers/ha.
d): 1.2 ha, with 1,000 dispensers/ha.
e): (A); Before treatment, (B); After treatment.

Molasses-trap attracted the female moths after mating, and enabled to estimate the mating period.

For the other polyvoltine leafrollers, egg-mass counting was very difficult, as they oviposit on leaves. Evaluation of their control can solely be based on the numbers of shoots and fruits damaged.

4) Control effect

In tea fields, leafroller adults are active immediately above the crown. This open condition requires a very large number of dispensers, more than 4,000 per ha, for effective control. Adults of the apple leafrollers, in contrast, become active within the tree-crown, and only 1,000 to 1,500 dispensers per ha afford an adequate distribution of the released pheromone. Some results in the leafroller control are described below based on unpublished data.

At Morioka, the late-spring treatment clearly reduced the number of egg-masses laid by the apple tortrix during the current summer (Table 1). Female moth catches by molasses-traps in the pheromone-treated plots were delayed by about one week, as compared with those in the untreated plots (Fig. 3). In captivity, the delay of mating for such a period resulted in a considerable decrease of egg deposition by the female moths. The control effect in the field could be substantiated not only by the complete prevention of mating but also by its delay.

Trials for the control of polyvoltine leafrollers have been carried out under different spray conditions in several prefectures. Mating disruption without or with only one effective spray prevented

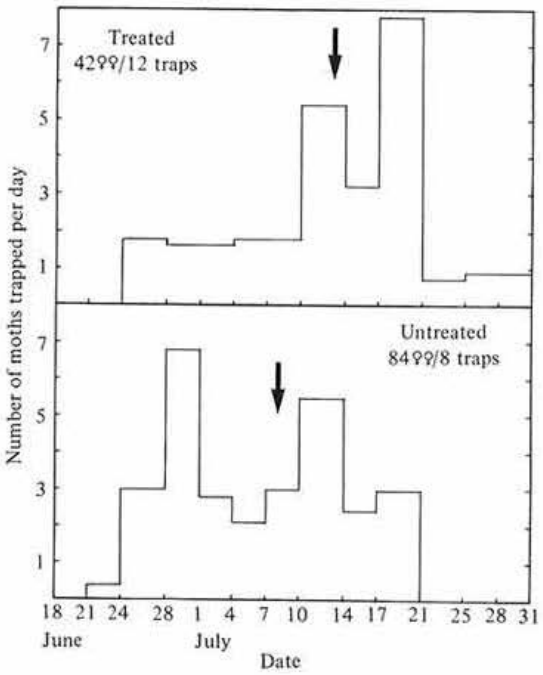

Fig. 3. Daily mean catches of mated female moths of the apple tortrix by sticky traps baited with molasses in treated and untreated plots at Morioka
Trap catches were derived from the field test, 1990, shown in Table 1; date corresponding to 50% moth catches is indicated by an arrow in each column.

an appreciable increase in the incidence of the summer fruit tortrix over one season, when the initial population was relatively low. Under outbreak

Table 2. Larval injuries of the summer fruit tortrix in treated and untreated plots with pheromone for mating disruption in Akita Prefecture[a)]

Test	Plot	Spray	Rate of injury (%)		Leafroller population
			Shoot[b)]	Fruit[c)]	
No. 1	Treated A	Conventional	29.0	15.0	High
	Treated B	Conventional	31.7	15.0	High
	Untreated	Conventional	29.7	16.5	High
No. 2	Treated	Conventional	-	5.9	Medium
	Untreated	No insecticides	-	5.4	Medium

a): 1,500 dispensers of tube-type/ha were applied to the 'treated' plots in late May.
Source: Takahashi (unpublished).
b): On July 3, 50 shoots from 6 trees/plot were examined.
c): At harvest, more than 600 fruits from 3 central trees/plot were examined.

conditions, however, the disruption treatment did not enable to control the larval attacks, even when combined with conventional sprays (Table 2). Although the resistance of the local moth population to the sprayed chemicals may have been responsible for this failure of control, it accounted only partially for the phenomenon observed and the disruption effect appeared to change with the moth density. The Asiatic leafroller did not cause any problem throughout these experiments in different areas, while the incidence of the brown tortrix significantly increased in a few plots along with the reduction of the number of summer sprays.

These facts suggest the presence of differences in sensitivity to the disruption treatment among the species. This aspect can not be overlooked for improving local spray programs. At least, one effective spray has to be maintained in the program against the brown tortrix in areas, where the species predominates.

The apple leafminer

1) Control problems

The apple leafminer, *Phyllonorycter ringoniella* (Matsumura), became an important pest of apple after World War II[10)], presumably due to the elimination of effective parasitoids by the intensive use of organic insecticides. Sekita[8)] studied the population dynamics of the pest in detail. Although the parasitoids are recovering in some areas, they have usually failed to afford an economic control of the leafminer only by themselves.

2) Synthetic pheromone and preliminary control tests

Two components of the apple leafminer pheromone, (z)-10-tetradecenyl acetate and E4, z10-tetradecadienyl acetate, have been isolated[11)]. Their mixture in a ratio between 10:1 and 10:3 attracted male adults. Important aspects in the unpublished results of control experiments in the field are as follows. The synthetic pheromone in the mixture ratio of 10:1 showed only a limited disruptive effect on the mating. Change of the mixture ratio to 10:3 was more effective. Studies are currently underway to confirm this observation.

Concluding remarks

Mating disruption for the peach fruit moth and a few leafrollers was highly effective, especially when a wide area was treated and provided that the pest populations were not very high. This measure was also effective for the control of the apple leafminer. Thus, the disruption technique has reached a practical phase, and its introduction into the pest control program may contribute significantly to the development of a new IPM system, because the technique is not detrimental to natural enemies of pests in general. Studies on the simultaneous disruption on mating of these major lepidopterous pests are promoted. However, it is generally recognized that the incidence of predominant apple pests has changed depending on the control measures currently adopted[10)]. In fact, the reduction of sprays in the disruption plots resulted in occasional attacks by such 'old' pests as caterpillars, beetles, and scale insects.

Therefore, in the second step, the IPM system should be centered on the development of methods that can be applied to these secondary pests without appreciable disturbance of the natural enemy complex. The apple IPM does not involve only the development of new control measures but entails a continuous process of improvement in taking account of the equilibrium among faunal components in orchards[4].

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