CONTROL OF THE BEET ARMYWORM, *SPODOPTERA EXIGUA* (HÜBNER), WITH SYNTHETIC SEX PHEROMONE

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ABSTRACT

The feasibility of synthetic sex pheromone as a communication disruption agent for the control of the beet armyworm, Spodoptera exigua (Hübner), was examined by dispensing a 7:3 mixture of (Z,E)-9, 12-tetradecadienyl acetate and (Z)-9-tetradecen-1-o1. When this mixture was dispensed into a 155 ha field, the attraction of male moths to sex pheromone traps was completely inhibited, while the density of egg masses was reduced to 6%, and that of young larvae was reduced to 1%, relative to densities in an untreated field about 9 km away. Follow-up studies showed that the rate of mating inhibition in the treated field was C. 97%.

When the mixture was dispersed into greenhouses covering .07 to .13 ha, the larval density was drastically reduced within 1 month. In the untreated greenhouse, larval density increased to about 9 times the initial density. Treatment with 500 dispensers in a .02 ha greenhouse reduced the estimated mating rate of females to 20-50%, whereas the mating rate was 95% without treatment. When sex pheromone treatment was combined with a light trap, the mating rate was reduced to 2-3%.

These results show that the pheromone treatment gives effective control of beet armyworm population densities in both the open field and greenhouse.

INTRODUCTION

The beet armyworm, *Spodoptera exigua* (Hübner), is a serious pest in southeast Asia. This insect has attacked Welsh onion in Japan since the early 1980s (Horikiri 1986, Takai 1988a) and is now the most important pest of Welsh onion in southwestern Japan. The effectiveness of most of the insecticides used, including methomyl, EPN and synthetic pyrethroids, has been declining as the insect has developed resistance (Takai 1988b, 1991). The development of new techniques to supplement or replace insecticide sprays is necessary to control this insect.

Accordingly, communication disruption for the control of beet armyworm was tried in both the open field and in greenhouses, using a synthetic sex pheromone consisting of two compounds, (Z, E) -9, 12-tetradecadienyl acetate and (Z)-9-tetradecen-1-o1 (Tumlinson *et al.* 1981, Mitchell *et al.* 1983). A 7:3 mixture (Wakamura 1987) was used in a series of experiments. The results of these experiments are described below.

MATERIALS AND METHODS

Communication Disruption in Welsh Onion Fields

Experiments were conducted in two areas in Kochi Prefecture, in Shikoku, Japan, in 1987. The treated area was about 155 ha, of which 24 ha was planted in Welsh onion. This treated area was isolated from other agricultural areas, and was 9 km distant from the untreated control.

Keywords: Communication disruption, *Spodoptera exigua* (Hübner), synthetic sex pheromone, Welsh onion

The sex pheromone dispensers were supplied by the Shin-Etsu Chemical Co., Ltd. and consisted of sealed polyethylene tubes 20 cm long, each containing 80 mg of a 7:3 mixture of ZE 9, 12-14:Ac and Z9-14:OH and an aluminum wire. Dispensers were set out evenly in the 24 ha Welsh onion fields at a rate of 1000 dispensers/ha. Other parts of the treated area (about 130 ha), including rice fields, orchard and forests, were treated with 330 dispensers/ha. In fields, each release point had three dispensers attached to the top of a 60 cm plastic stick. Forest and orchard trees had dispensers directly attached to them, at 1-1.5 m above the ground. Sex pheromone dispensers were set out on July 16 and 17, and removed on September 17 and 18.

Effects of Communication Disruption

Water-pan type sex pheromone traps were set 1 m above the ground at four locations in the treated area, and two locations in the untreated area, in order to evaluate the effect of communication disruption. A light trap (lamp: FL-6 W) was placed at the center of the treated area. Each trap was checked daily, and the number of captured beet armyworm moths was counted. The mating ratio of females captured in the light trap was investigated, based on the presence of spermatophores in the bursa copulatrix.

Effects on the Beet Armyworm Population

Larval field density was surveyed in every fifth or sixth plot in the central and marginal parts of the treated area, and in the untreated area, once every week from three weeks before the dispensers were set out (July 26) until six weeks after their removal (October 30). Plots and ridges for the survey were randomly selected where onion plants were 30-60 cm high.

Surveys were conducted on all 500 hills on 10 m of ridge of each plot. Most larvae were inside hollow leaves. Damaged leaves were collected and dissected so that the instar could be recognized, and the number of larvae counted. As larval density became higher, fewer hills were sampled to save time and labor.

Farmers sprayed insecticides against beet armywarm in both the treated and the untreated areas, independently of the experiment. However, this spraying was ineffective, and was not considered to have any effect on population density.

Follow-up Experiments in 1988

In 1988, sex pheromone was released at a higher rate into a smaller area than in 1987, to confirm the population suppression effect. The treated area was the northern third (about 50 ha) of the experiment area of 1987. Dispensers were set out evenly in Welsh onion plots at a rate of 1500 tubes/ha, and in other cultivated plots at a rate of 600 tubes/ha. Sex pheromone dispensers were put out on July 6 to 8 and removed on September 30. Surveys were conducted by the same methods used in 1987.

Communication Disruption in Greenhouses

Preliminary Experiments in Farmers' Greenhouses

Beet armyworm is also a severe pest in Welsh onion cultivated in greenhouses. The greenhouses used in the experiment had a roof of polyvinyl film, but sides made of plastic net (mesh 3 x 4 mm). Since Welsh onion was cultivated continuously in the greenhouses, repeated generations of beet armyworm were possible. In this experiment, four greenhouses of Welsh onion were used. The volume of treated dispensers was as follows: greenhouses A and B, 5,000 dispensers/ha; greenhouse C, 1,000 dispensers/ha; while Greenhouse D was used as a control and had no dispensers. The greenhouses were at least 1 km apart. Light traps (lamp: BLB 20 W) were set in and around greenhouse A.

The number of captured adult moths was surveyed daily, and the mating ratio of captured females was examined by dissection. The larval density was surveyed in each greenhouse at 7 or 14 day intervals. The number of larvae were counted within 20 m^2 at two locations in each greenhouse.

Evaluation of the Effects of the Sex Pheromone and Light Trap

A series of experiments were carried out to evaluate the effect of the synthetic sex pheromone and a light trap on beet armyworm populations in September 1988. Marked beet armyworm moths were released into a green- house (.02 ha). Some moths were treated and some were not treated with the synthetic sex pheromone and/or light trap. The light trap was switched on 3 days after the first release, and released adult moths were recaptured in the trap. However, the light trap in the combination plot was switched on for 3 days running from the first day of release. The mating ratio of recaptured females was examined by dissection.

RESULTS AND DISCUSSION

Communication Disruption in Welsh Onion Fields

Effects of Communication Disruption

Beet armyworm moths were captured in the light trap in the treated area throughout the treatment period (Fig. 1). This indicates that adults emerged in the treated area throughout the period of the experiment. Conversely, catches in the sex pheromone trap were low during the treatment period. This showed that communication disruption was certainly effective throughout the treatment period.

The mating ratio of the females caught in the light trap increased during the treatment period; 40-60% in late July and early August, 70-80% in mid and late August, and 70-90% in early and mid September. However, considering that the efficiency of capturing virgin females was about 25% of that for mated females, the real mating rate in the field population was estimated to be 20-50% during the treated period (Wakamura and Takai 1990). This estimate seems too high to explain the reduction in the field population density, but Wakamura (1990) reported that the delay in mating resulted in a drastic decline in fertility.

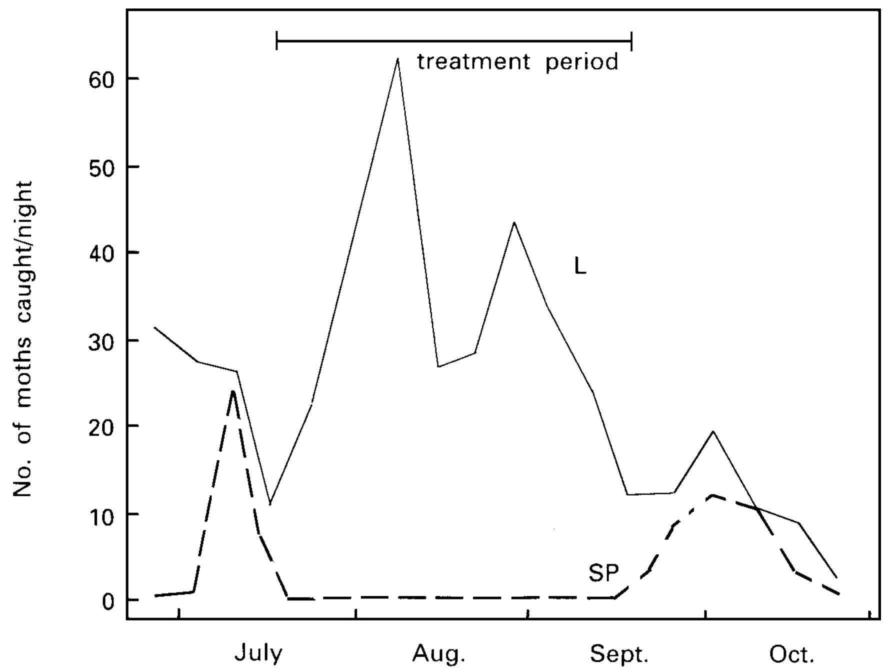

Fig. 1. Catches of *Spodoptera exigua* with sex pheromone traps (SP) and light trap (L) in the area treated with synthetic sex pheromone

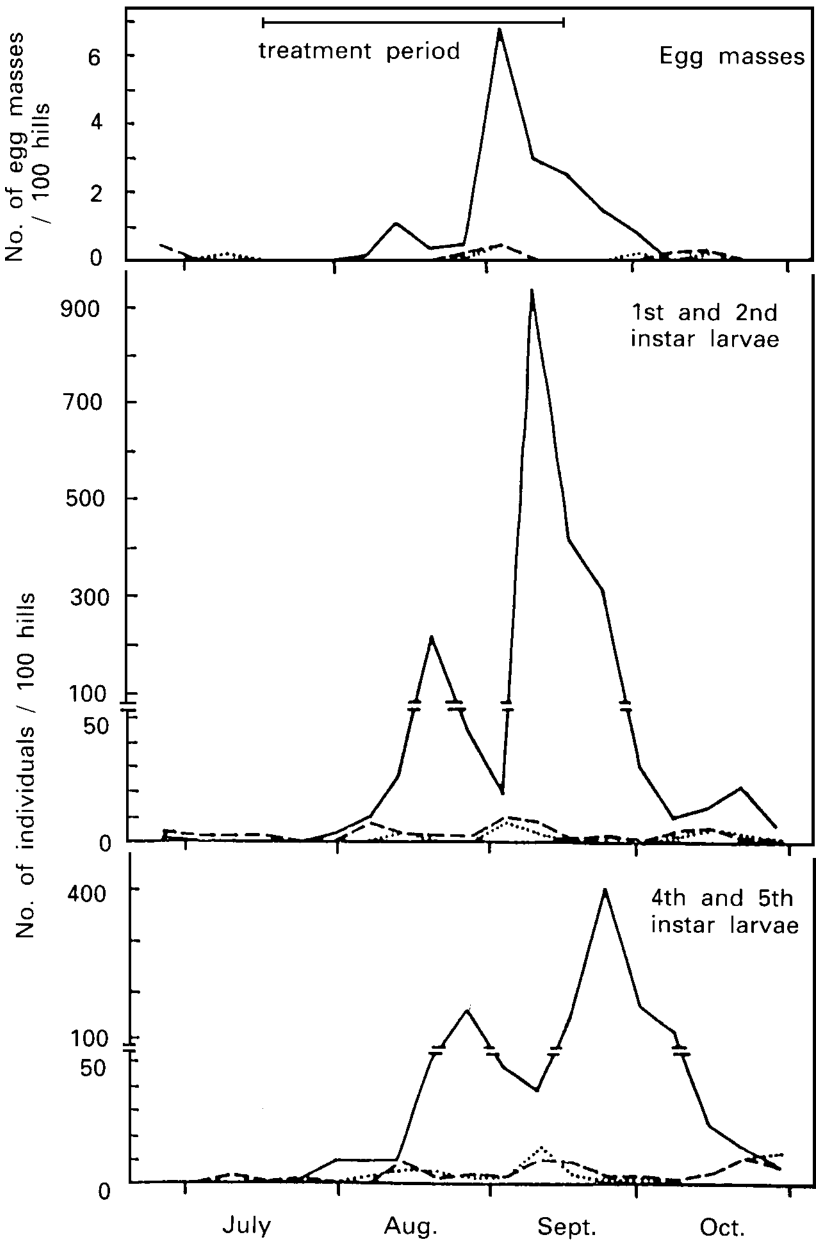

Fig. 2. Population densities of *Spodoplera exigua* egg masses and larvae in Welsh onion fields in areas treated/not treated with synthetic sex pheromone. Broken and dotted lines indicate the densities in central and peripheral parts of the treated area, respectively. The solid line indicates the untreated area.

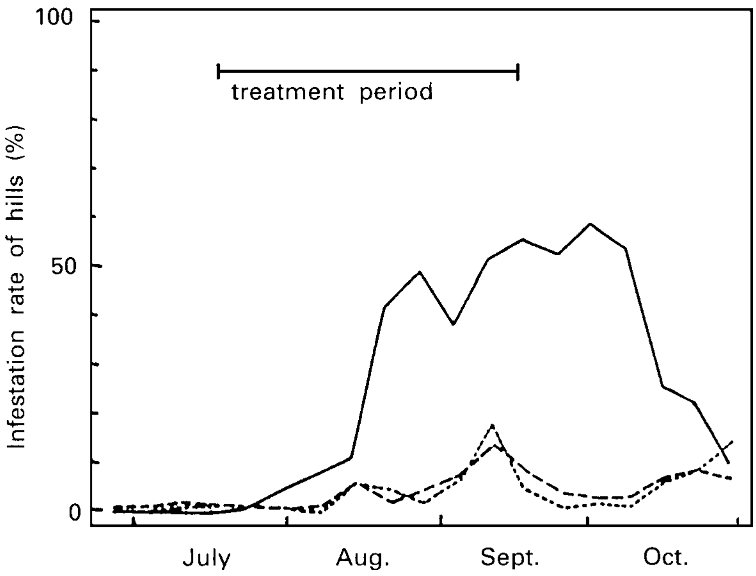

Fig. 3. Infestation rate of Welsh onion hills by *Spodoptera exigua.* Broken and dotted lines indicate the percentages in central and peripheral parts of the treated area, respectively. The solid line indicates the untreated area.

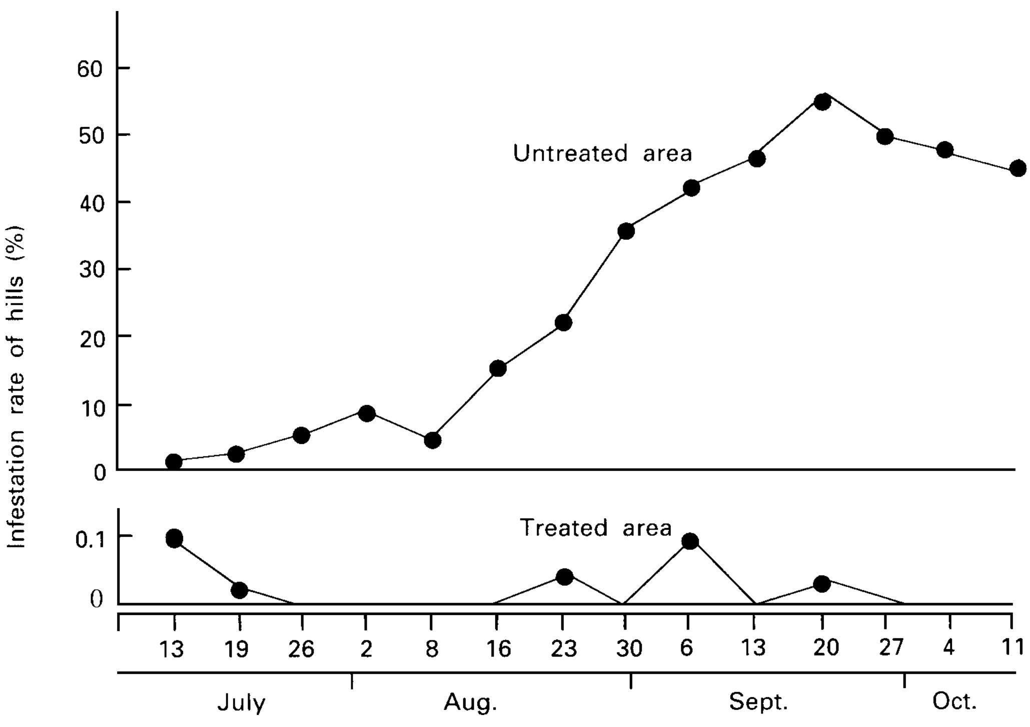

Fig. 4. Infestation rate of Welsh onion hills by beet armyworm in 1988 (Nii, Kochi, Japan).

Table 1. Densities of beet armyworm larvae in greenhouses treated with synthetic sex pheromone (1987 Kochi)

Date	No. of larvae/20m^2			
	House A[a]	House B	House C	House D
7/30	74 (1.00)	63 (1.00)	450 (1.00)	36 (1.00)
8/12	21 (0.28)	68 (1.08)	33 (0.74)	167 (4.64)
8/19	1 (0.01)	23 (0.35)	333 (0.74)	325 (9.10)
9/2	0 (0.00)	0 (0.00)	—[b]	—[b]

[a] For the treatment of the greenhouses, see text. Pheromone dispensers were set on July 22 and removed on September 22. Values in parentheses represent the relative densities (1.00 on 7/30).
[b] All the crops had been harvested.

Table 2. Catches and mating ratio of beet armyworm moths with light traps in and outside a greenhouse treated with synthetic sex pheromone (1987 Kochi)

Date	No. of moths caught			
	In greenhouse		Outside greenhouse	
	Male	Female	Male	Female
7/30	14	9 (0.00)	39	13 (0.77)
7/31 - 8/02	162	188 (0.005)	144	84 (0.54)
8/03 - 8/06	231	131 (0.069)	172	124 (0.41)
8/07 - 8/09	120	110 (0.064)	175	76 (0.76)
8/10 - 8/12	22	18 (0.000)	53	23 (0.78)
8/13 - 8/19	38	15 (0.13)	37	41 (0.58)

Values in parentheses represent mating ratio of females

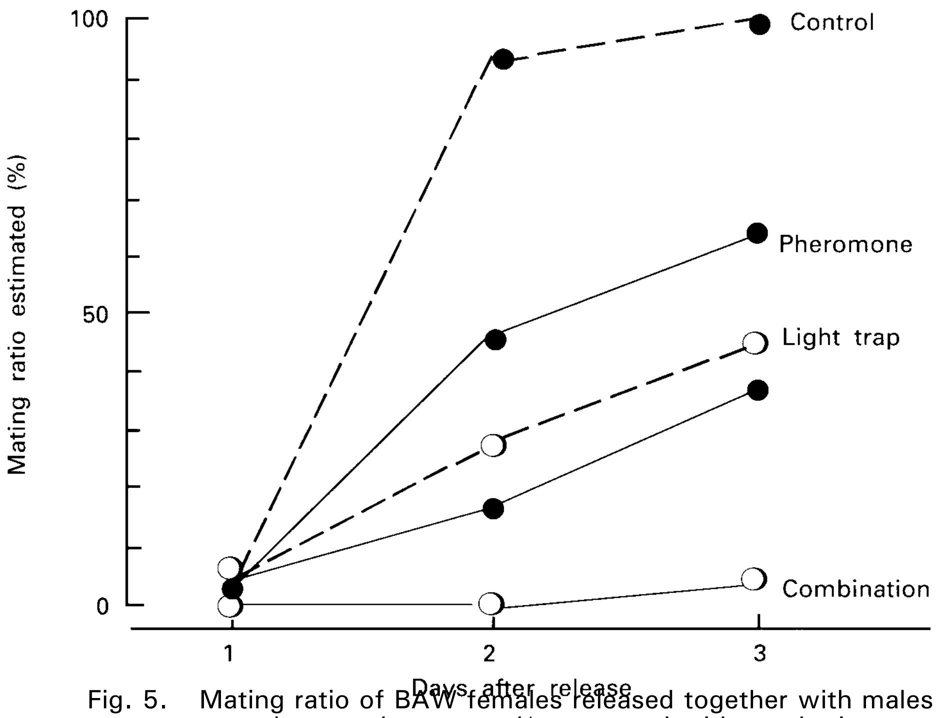

Fig. 5. Mating ratio of BAW females released together with males in greenhouse when treated/not treated with synthetic sex pheromone and/or with light trap (September 1988, Kochi)

Effect on the Beet Armyworm Population

The mean densities of egg masses, 1st and 2nd instar larvae, and 4th and 5th instar larvae are shown in Fig. 2. In the treated area, the egg mass density was less than 0.5 masses/100 hills in both the central and marginal plots throughout the treatment period. Conversely, in untreated areas, mean egg mass density twice reached a peak. These peaks were followed by peaks of young larvae and then of older larvae.

The infestation rate of hills is shown in Fig. 3. In the treated area, the maximum infestation rate of hills was about 13% in early September. In contrast, the infestation rate of hills in the untreated area was 40-55% between late August and early September.

Follow-up Experiment in 1988

The results are presented in Fig. 4. In the treated area, the beet armyworm population was suppressed at a very low level, and the infestation rate was less than 0.2% throughout the treatment period. Conversely, in the untreated area, population density increased gradually until late August, and then increased rapidly in early September. The maximum density of young larvae was more than 400 individuals/100 hills. The mean infestation rate of hills increased to more than 50% in mid-September.

These results confirmed that treatment with synthetic sex pheromone successfully reduced the field beet armyworm population.

COMMUNICATION DISRUPTION IN GREENHOUSES

1. Preliminary Experiment in Farmers' Greenhouses

The larval density fell markedly in the treated greenhouses A and B, whereas it increased rapidly during the experiment period in the untreated greenhouse D (Table 1). The mating rate of females captured in the treated greenhouse A was very low, compared with that of females trapped outside the greenhouse (Table 2). These data indicate that treatment with synthetic sex pheromone reduced the mating rate and resulted in a decrease in the larval population density.

However, the light trap captured so many beet armyworm moths that it seemed to influence the population density. Therefore, follow-up experiments are considered necessary to confirm the effect of pheromone in greenhouses.

Evaluation of Effects of Pheromone and Light Traps

The results are presented in Fig. 5. When the greenhouse was not treated with phero-mone, the mating ratio reached around 95% by the second night. This indicates that most females mated in the first night after release, since the mating of beet armyworm moths begins after midnight and continues until dawn (Wakamura 1989). Thus, the mating ratio in the sample taken during the second night should reflect the mating ratio of the first night (Wakamura 1990).

In greenhouses treated with synthetic sex pheromone, the mating ratio was only 20-40% on the second night and 40-60% on the third night. This shows that even though there was a higher dosage of synthetic sex pheromone dispensers in the greenhouse than in the open field, their use was insufficient to inhibit mating completely.

When the pheromone treatment was combined with a light trap, the mating ratio was less than 5% even by the third night. This seems to be the combined effect of communication disruption by the pheromone and mass trapping of male moths by a light trap. These results suggest that this combined effect caused the population reduction observed in the preliminary experiment (Table 2).

CONCLUSION

The control effect of synthetic sex pheromone as a communication disruption agent against beet armyworm was confirmed in both the open field and in greenhouses. The sex pheromone formulation has already been registered as a pest control agent by the Ministry of Agriculture, Forestry and Fisheries of Japan. Although the use of beet armyworm pheromone is limited at present, it is likely to be a powerful tool in integrated pest management programs.

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