

## Control of Diamondback Moth Using Synthetic Sex Pheromones

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### Abstract

The sex pheromone of diamondback moth, *Plutella xylostella* (L.), consists of two compounds, (Z)-11 hexadecenal and (Z)-11 hexadecenyl acetate. Mass trapping of male moths by this pheromone in the field failed because of very limited active space of this pheromone. We then attempted communication disruption by using a commercial product 'Konaga-con' which is a polyethylene rope containing pheromone mixture, 25 g/100 m. The pheromone evaporates through the surface of polyethylene constantly for 3-4 months. Most results of open field experiments in Japan between 1984 and 1989 are successful. Maintenance at uniform high concentration of sex pheromone in the air throughout the season is critical. Major problems in achieving this are as follows: small fields, fields on steep slopes and strong winds. The results of green-house, vinyl house or plastic tunnel experiments were generally good. Under airtight conditions, almost complete inhibition in diamondback moth reproduction could be obtained. In ventilated areas the insect control was poor. Sex pheromone has no insecticidal action. Therefore, if the insect population density increases during the application of sex pheromone, use of insecticides may be necessary. Use of sex pheromone can reduce the need for insecticide application to less than a half.

### Introduction

The diamondback moth (DBM), *Plutella xylostella* (L.) (Lepidoptera: Yponomeutidae), is a notorious pest of cruciferous vegetables in many parts of the world. In Japan, since 1965 it has become the most serious pest of cabbage, Japanese radish (daikon) and Chinese cabbage. To control DBM, large amounts of insecticides have been applied. However DBM has recently developed resistance to many insecticides and only a few remain that can control this insect. We have therefore been trying to use synthetic sex pheromones since the early 1980s to control this pest.

Sex pheromones to control harmful insects have been studied for the past 15 years. For some insects, application methods had already been established and are being used commercially. However newer techniques are being developed constantly that are easier to apply and less costly and more effective than insecticides.

The structure of the female sex pheromone of DBM has been determined by Tamaki et al. (1977). It consists of two compounds: (Z)-11 hexadecenal and (Z)-11 hexadecenyl acetate. First we tried a mass trapping technique to catch entire male moth population in the field, but this did not work. This is because of a very narrow active space of this pheromone. We then used the communication disruption. The results of that test are described here.

## Materials and Methods

**Pheromone:** We used Konaga-con (Shin-Etsu Chemical Co., Ltd.), which is a polyethylene tube with an aluminum wire and containing 1:1 mixture of two sex pheromone components, together at 25 g AI/100 m tube. The pheromone evaporates through the surface of the polyethylene constantly for about 3-4 months.

**Application methods of Konaga-con in open field:** Tie the end of the rope at the top of a stake, which should be 40-50 cm high. Stretch the rope tightly between stakes placed at approximately 10-m intervals. Keep the rope tight stretching it along rows at intervals of 8-9 m. This amounts to the application rate of 100 m/0.1 ha.

**Communication disruption effect:** To examine the effect of communication disruption, we used the female sex pheromone trap. If the male DBM were confused with the pheromone from the tube, they could not approach the trap, even when the population density of mature moths was at a high level.

**Mating inhibition effect:** We used the tethered female method to examine the effect of mating inhibition. We tied the forewing of virgin female moths with fine thread and released it on the crop before normal mating time. We collected the females the next morning and checked the hatching of eggs. By comparing the mating ratio of pheromone-treated with the nontreated field, we can calculate the mating inhibition ratio.

## Results

**Effects of Konaga-con in open vegetable fields:** In 1985, we applied Konaga-con on 5 ha of open radish field. Initial density of moths was low, and remained low throughout the experiment (Fig. 1). Attraction of the male moth to the monitoring trap was evidently inhibited, and the population level was lower than in the nontreated field without chemicals. The good control of DBM on summer cabbage cultivation in a high altitude field is shown in Fig. 2. In this case, the population density of moth was high. The pheromone treatment was done on a 10-ha field where wind velocity was less. The control of DBM at this higher altitude sloped field was not satisfactory. Results of an experiment on a windy field located on a cliff are given in Fig. 3. The DBM population density on the treated field was not suppressed even when the attractive inhibition was evident.

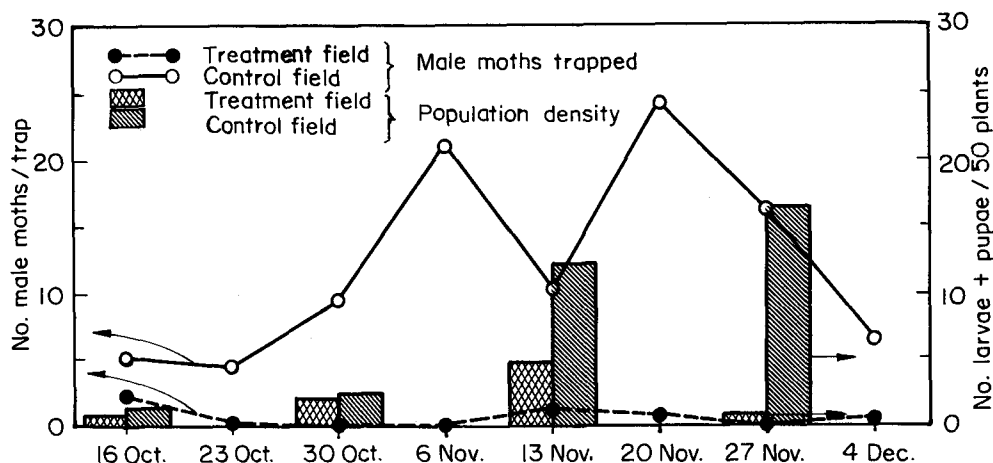


Fig. 1. Effect of Konaga-con in open radish field, Miura. 5.4 ha, 1985.

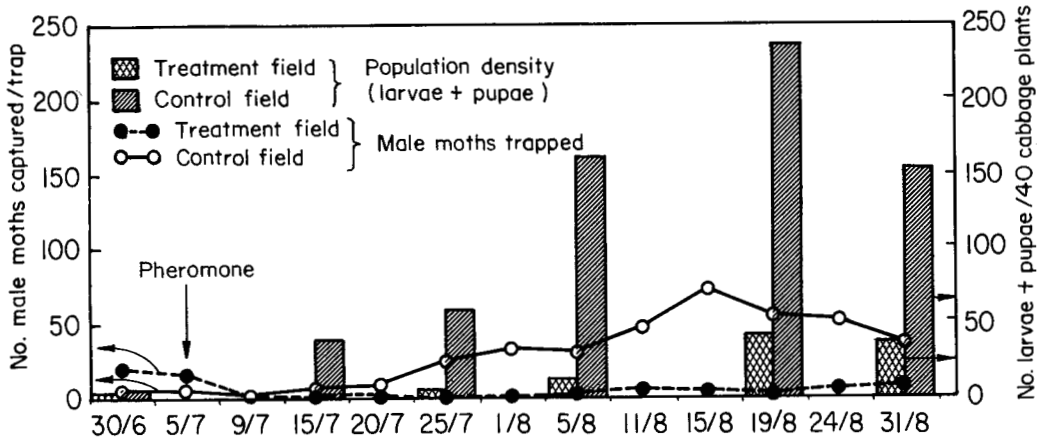


Fig. 2. Effect of Konaga-con in open cabbage field, Gumma. 10 ha, 1988.

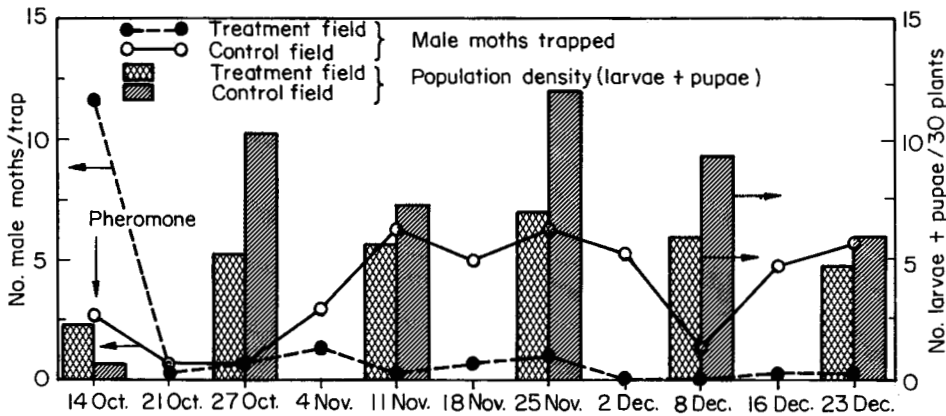


Fig. 3. Effect of Konaga-con in open cabbage field, Miura. 7.0 ha, 1987.

The results of the open field experiment in various parts of Japan from 1985 to 1988 are given in Table 1. The problems of pheromone application in getting consistent DBM control are shown by the results. For example, field No. 2 was a windy field on a cliff. It had high DBM population (Fig. 3); No. 4 showed good effects until mid May when the population of surrounding fields increased. Number 5 was a very complicated situation, with cabbage in an ornamental field and Japanese radish under plastic tunnel. The Konaga-con was therefore applied mainly on the cabbage and radish fields, but the radishes were harvested early, and the farmer removed the pheromone tube from the field. Number 9 was a small field that showed good control at the center, but inferior near the edge (Fig. 4). The results of the experiment at Gumma Prefecture in 1988 are shown in Fig. 5. Two chemical applications in addition to pheromone ensured DBM control.

**Application methods of Konaga-con under structure:** The results of greenhouse, vinyl house or plastic tunnel experiments are given in Table 2. To determine why some of the results were good and others poor, we tested the mating inhibition effect by modifying ventilation in plastic houses or methods of setting the pheromone tubes. (Table 3). If the house was under airtight conditions, an almost complete inhibition effect could be obtained. However, when the house was ventilated, the effect was reduced. The pheromone tube was more effective when

Table I. Control effect of communication disruption method in open field in various parts of Japan.

Exp. No. <sup>a</sup>	Period of experiment	Attractive inhibition	Mating inhibition	Population density reduction
1	10.16-12.20	93.9%	100.0% (11.20)	95.5%(11.27)
2	9.30-12.23	89.3	74.6 (11.17)	49.5 (11.25)
3	10.13-12.22	88.7	88.4 (11.28)	85.7 (11.10)
4	3.27-5.28	94.7	97.1 (5.1)	51.5 (5.28)
5	3.26-6.12	83.0	56.8 (5.13)	9.7 (6.12)
6	9.30-12.23	92.4	90.6 (11.7)	86.1 (11.11)
7	7.1-8.27	95.2	100.0 (7.23)	94.2 (7.23)
8	7.5-8.19	90.3	100.0 (8.16)	82.4 (8.19)
9	7.5-8.19	87.6	100.0 (8.16)	99.6 (8.19)
9 <sup>b</sup>			57.2 (8.16)	47.0 (7.25)

a1. Miura, Kanagawa	1985	5.4 ha,	radish field
2. Miura, Kanagawa	1987	2.7	cabbage field
3. Miura, Kanagawa	1988	3.2	cabbage
4. Yokohama, Kanagawa	1986	3.1	cabbage
5. Yokohama, Kanagawa	1987	7.0	cabbage
6. Choshi, Chiba	1988	14.4	cabbage
7. Tsumagoi, Gumma	1987	9.8	cabbage
8. Tsumagoi, Gumma	1988	10.0	cabbage
9. Tsumagoi, Gumma	1988	0.8	cabbage

<sup>b</sup>9. Same as above field but data were obtained from edge of field.

Source: Ohbayashi et al. 1989.

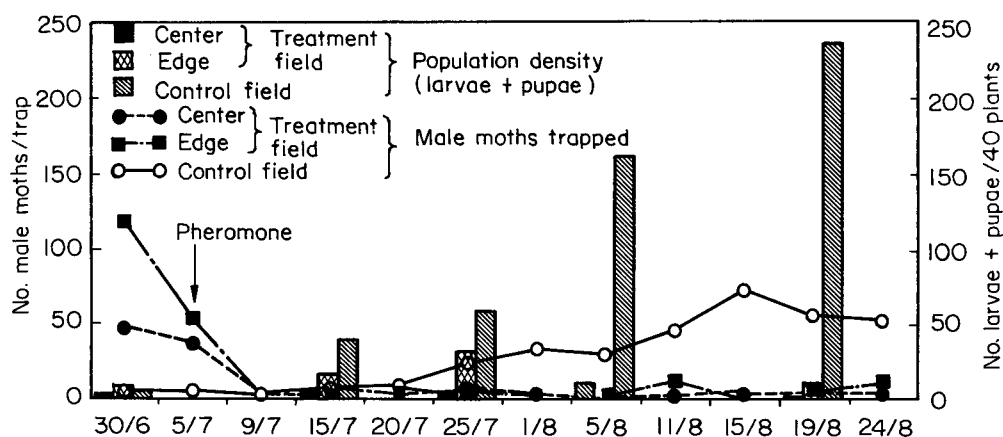


Fig. 4. Effect of Konaga-con in open cabbage field, Gumma 0.8 ha.

placed on the ceiling than on the top of cabbages. These results indicate that the active ingredients of sex pheromone must be kept high so that the pheromone will uniformly cover the crop where the mating takes place. It is therefore necessary to keep the house tightly shut in the evening and night when the DBM are mating. Comparison of concentrations of pheromone indicated that 200 m rope/0.1 ha stabilized the effect, and the scattered placement of pheromone tubes was better than concentrated application. Kawana and Shimizu (1990) have also shown that 400 m rope was superior to 100-200 m rope/0.1 ha.

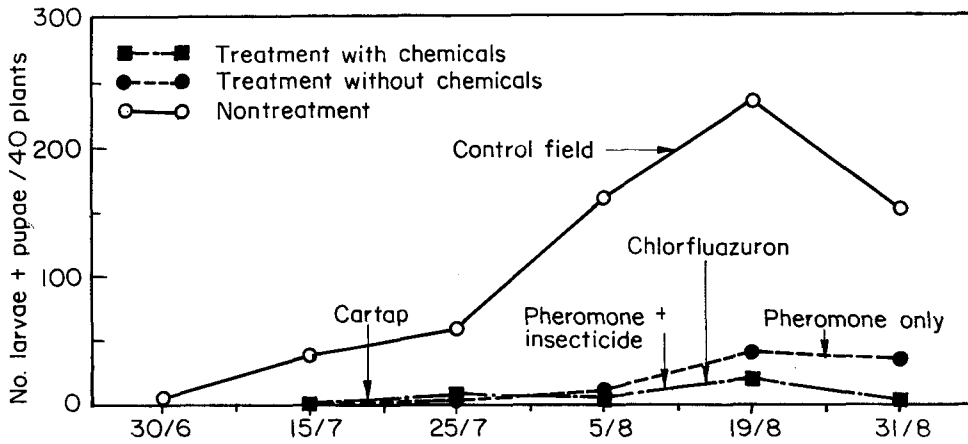


Fig. 5. Effect of Konaga-con with insecticides in open cabbage field, Gumma. 10 ha. 1988.

Table 2. Control effect of communication disruption method in greenhouse, vinyl house or plastic tunnel.

Exp. No. <sup>a</sup>	Period of experiment	Mating inhibition <sup>b</sup> (%)	Population density <sup>b</sup> reduction (%)
1	10.12-12.10	100.0 (10.16)	90.3 (11.27)
2	3.23-5.12	48.6 (5.12)	84.2 (4.30)
3	9.27-11.22	83.3 (11.22)	43.0 (11.22)
3	9.27-11.22	38.2 (11.22)	39.5 (11.22)
4	12.7-3.13	100.0 (3.13)	69.1 (3.13)
5	10.28-1.7	100.0 (12.15)	42.1 (12.4)
6	10.28-1.7	93.6 (12.15)	43.9 (12.4)

<sup>a</sup> 1. Miura, Kanagawa 1984	greenhouse	325m/0.1ha	Cabbage
2. Miura, Kanagawa 1987	greenhouse	300m/0.1ha	Radish
3. Miura, Kanagawa 1989	vinyl-house	100m/0.1ha	Cabbage
3. Miura, Kanagawa	vinyl-house	300m/0.1ha	
4. Choshi, Chiba 1985	plastic tunnel	50m/0.1ha	Radish
5. Choshi, Chiba 1987	plastic tunnel	50m/0.1ha	Radish
6. Choshi, Chiba 1987	plastic tunnel	100m/0.1ha	Radish

<sup>b</sup>Figures in parentheses are observation dates.

Source: Ohbayashi et al. 1989.

Table 3. Influence of ventilation and position of placement of sex pheromone (25 g/0.1 ha) on the mating inhibition in plastic house.

Ventilation method	Setting place of pheromone	Mating inhibition rate (%)
Bottom	on the ceiling	11.8
	over head of cabbage	7.1
Shoulder	on the ceiling	72.9
	over head of cabbage	40.9
No ventilation (airtight)	on the ceiling	100.0
	over head of cabbage	78.8

Ohbayashi et al. 1989.

## Discussion

Most female lepidopterous insects emit the sex pheromone to lure males of the same species. Males find the females by following the smell of the sex pheromone and then they mate. When the field is covered with sex pheromone, the communication for mating is confused. The mode of action of the pheromone is such as to affect the mating of DBM resulting in a reduction of the population. The communication disruption technique using DBM sex pheromone (Konaga-con) is quite useful in reducing the population density when applied on a field (> 3 ha). The results show that it is most important to keep the sex pheromone ingredient in the air constantly. This is difficult, of course, in small fields, steeply sloping fields, fields on a cliff, or fields in strong wind areas. It is also necessary to apply the pheromone at the beginning of emergence of moths, and to avoid applying on windy and sloping fields. Besides being species specific, the sex pheromone has no insecticidal function, so it is necessary to apply an insecticide if the population density of DBM itself or the other insect increases during the application of sex pheromone. The use of sex pheromone can usually reduce the need of chemical application to less than one half. We are continuing our research on the application of Konaga-con to small open fields and to greenhouse, vinyl house and plastic tunnels.

## References

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