Trapping Effect of Synthetic Sex Pheromone of *Acleris fimbriana* (Lepidoptera: Tortricidae) in Chinese Northern Orchard

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The yellow tortrix, *Acleris fimbriana* Merick (Lepidoptera: Tortricidae), is an economically important insect pest on fruit trees with four generations a year in North China. In order to develop a new and effective method for forecasting and controlling the pest, the sex pheromone was studied. We have identified the female sex pheromone as (*E*)-11,13-tetradecadienal (*E*11,13–14:Ald), (*E*)-11,13-tetradecadienyl acetate (*E*11,13–14:Ac) and (*E*)-11-tetradecenyl acetate (*E*11–14:Ac). Trapping effect of synthetic chemicals *E*11,13–14:Ald, alone and in combination with *E*11,13–14:Ac or/and *E*11–14:Ac to *A. fimbriana* males was tested in Beijing Xishan Orchard (2001). *E*11,13–14:Ald on its own was much attractive to *A. fimbriana* males. Neither *E*11,13–14:Ac nor *E*11–14:Ac alone caught any moths. The catches markedly increased by adding *E*11,13–14:Ac to *E*11,13–14:Ald. The optimum ratio of *E*11,13–14:Ald and *E*11,13–14:Ac was 6:4 to 5:5. This attractiveness was apparently enhanced when 5% to 10% of *E*11–14:Ac was added. The best field activity was in the lure baited with a 6:4:1 ratio of *E*11,13–14:Ald, *E*11,13–14:Ac and *E*11–14:Ac at a dosage of 1000 μg/septum. The effect of antioxidant, 2,6-di-*tert*-butyl-4-methylphenol [butylated hydroxyluene (BHT)], to the synthetic pheromone blends on its duration and catching efficacy was also tested. Addition of 5–10% BHT to the synthetic pheromone could prolong the life-span of pheromone chemicals for 6–8 weeks, thereby increased its catching efficacy.

Key Words: Acleris fimbriana, Sex Pheromone, Field Trapping

Introduction

Yellow tortrix, *Acleris fimbriana* Meyrick (Lepidoptera: Tortricidae), is an economically important insect pest in Chinese northern orchards. It injures apple, peach, apricot, plum, Chinese flowering crabapple, hawthorn and other fruit trees. With four generations a year, it is widely distributed in Beijing, Liaoning, Hebei, Henan, Shanxi, Shaanxi, Shandong, Gansu, and other regions in China (Zhu, 1980). In severe infestations, larvae consume all foliage and leave only the mid-rib of the frond, thus causing setback of fruit production (Ma *et al.*, 1999). The control of this pest by pesticides has shown only limited efficacy. Even after increasing the application frequencies and varying the types of insecticides used, 83% of the leaves were still found to be damaged. In order to avoid, or at least reduce, the indiscriminate use of insecticides in fruit fields, it is essential to develop an efficient method for monitoring the pest population. Knowledge of the female sex pheromone is required for current attempts to develop control by mating disruption and mass trapping techniques. Analysis of the behavioral function of each component is important for an understanding of the chemical language used during courtship and, in particular, for successful use of pheromones in pest control.

In our previous study, three active components in the extract of female sex pheromone gland were identified as (*E*)-11,13-tetradecadienal, (*E*)-11,13-tetradecadienyl acetate and (*E*)-11-tetradecenyl acetate (Liu and Meng, 2002). This paper deals with the further experiments in search of the optimum formulation of the sex pheromone for the attraction of male *A. fimbriana* in the field.

Materials and Methods

Insect

Acleris fimbriana larvae were collected from peach, plum or apricot trees in Beijing Xishan Orchard. Leaves rolled by *A. fimbriana* larvae were

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picked up in mid-May, then put into wooden containers and kept in natural light and temperature condition until emergence. Emerging adults were transferred to separate containers every 24 h and used for virgin female-traps (VF-traps).

Chemicals

(*E*)-11,13-tetradecadienal (*E*11,13–14:Ald), (*E*)-11,13-tetradecadienyl acetate (*E*11,13–14:Ac), (*E*)-11-tetradecenyl acetate (*E*11–14:Ac) and their analogues were synthesized in our laboratory (Liu and Meng, 2002). They were subsequently purified by column chromatography on silica gel. The purity of all compounds was more than 97% in respect to positional and geometric isomerism. Antioxidant 2,6-di-*tert*-butyl-4-methylphenol [butylated hydroxyluene (BHT)] was purchased from Sigma Company.

Baits and traps

Solutions of *E*11,13–14:Ald, binary blend (*E*11,13–14:Ald + *E*11,13–14:Ac), ternary blend (*E*11,13–14:Ald + *E*11,13–14:Ac + *E*11–14:Ac), and other chemical composition were prepared with hexane. Appropriate volumes of solutions were loaded on red rubber septa to obtain baits. The solvent was allowed to evaporate for 24 h at room temperature. Sticky traps with triangle section, dimensions of 19 × 19 × 21 cm with edge of 25 cm were used. Each septum was hung with wire about 2 cm above the sticky face in the trap. Virgin female traps were used as a control. A net cage containing two 2-day-old virgin females and a cotton wick impregnated with diluted sucrose solution in a glass tube was placed beneath the roof of a sticky trap. The moths were renewed every day. For another control, a rubber septum containing no pheromone but treated with the same amounts of hexane was hung in a trap.

Field tests

All tests were conducted in the peach orchard, plum orchard and apricot orchard (each area: *ca.* 80 ha) at Beijing Xishan Orchard from 1st of June to 11th of November, 2001. Traps were hung on 1.5 m height at about 15 m intervals in orchard. Trap catches were checked every morning and trap locations were randomized in the site to cancel any possible effects of trap location.

Statistical analysis

The number of male captures in traps was submitted to an analysis of variance (ANOVA), followed by Duncan's multiple range test (SPSS Int. 1999). Significance level was set at 0.05.

Results and Discussion

Trapping effect of synthetic pheromone components

Current field tests were conducted to confirm the function of each sex pheromone component and their analogues and to investigate in some detail attraction and synergism. Results are summarized in Table I. Component *E*11,13–14:Ald on its own caught mean 36.6 males per trap, which was much more than the mean of the males caught by 6 virgin females. Other components alone did not catch any males. Addition of *E*11,13–14:Ac to *E*11,13–14:Ald remarkably enhanced the mean male catches from 36.6 to 58, which indicated that *E*11,13–14:Ac was a synergist of *E*11,13–14:Ald. Addition of *E*11–14:Ac to *E*11,13–14:Ald showed no effect on male catches (35.4 to 36.6), while the other three chemicals exhibited inhibitory effect.

Optimum ratios of E11,13–14:Ald and E11,13–14:Ac

To determine the optimum ratio of the attractant-to-synergist for trapping males, rubber septa impregnated with blends of *E*11,13–14:Ald and *E*11,13–14:Ac at different ratios were baited in the traps at three different fields in late June, 2001. In Table II maximum catches were obtained with the 6:4 and 5:5 blends. They were significantly greater than those with the other ratios on rubber septa or with two 2-3-day-old virgin females. No remarkable difference was found between the two ratios.

Effect of E11–14:Ac

The effect of addition of the minor component *E*11–14:Ac to the 6:4 blend of *E*11,13–14:Ald and *E*11,13–14:Ac was evaluated from July 25 to August 5, 2001. Results are indicated in Table III. The

Table I . Capture of *A. fimbriana* males with *E*11,13–14:Ald and related components[a].

Trap lure Composition	Dosage (µg/septum)	Males caught /trap mean ± SE[b]
Virgin Females		21.2 ± 1.4bc
*E*11,13–14:Ald	500	36.6 ± 4.1b
*E*11,13–14:Ac	500	1.7 ± 0.2d
*E*11–14:Ac	500	1.3 ± 0.1d
*E*11,13–14:OH	500	0.00d
*E*11–14:OH	500	0.00d
*E*11–14:Ald	500	0.00d
*E*11,13–14:Ald + *E*11,13–14:Ac	500 + 500	58 ± 4.8a
*E*11,13–14:Ald + *E*11–14:Ac	500 + 500	35.4 ± 3.2b
*E*11,13–14:Ald + *E*11,13–14:OH	500 + 500	18 ± 1.5c
*E*11,13–14:Ald + *E*11–14:Ald	500 + 500	9.5 ± 0.9cd
*E*11,13–14:Ald + *E*11–14:OH	500 + 500	11 ± 1.1cd
Control (Hexane)	500 µl	0.7 ± 0.1d

[a] The tests were conducted in Beijing, June 18–24, 2001;
[b] six replicates, numbers with the same letters are not significantly different by Duncan's multiple range test (p = 0.05).

Table II. Males captured of *A. fimbriana* with different ratios of *E*11,13–14:Ald and *E*11,13–14:Ac[a].

Composition (*E*11,13–14:Ald: *E*11,13–14Ac)	Males caught/trap mean ± SE[b]
100:0	39.7 ± 3.1b
90:10	41.2 ± 3.6b
70:30	43.8 ± 2.9b
60:40	78 ± 4.5a
50:50	71.2 ± 5.1ab
40:60	31.5 ± 1.6bc
0:100	0.00d
Control	0.00d
Virgin females	21.8 ± 1.2c

[a] The total dose of each treatment is 500 µg; the tests were conducted in Beijing, June 18–24, 2001;
[b] six replicates; numbers with the same letters are not significantly different by Duncan's multiple range test (p = 0.05).

Table III. Males captured with different ratios of ternary blends of *E*11,13–14:Ald + *E*11,13:14:Ac + *E*11–14:Ac[a].

Composition (*E*11,13–14:Ald: *E*11,13–14Ac)	Males caught/trap mean ± SE[b]
6:4:0	41 ± 3.3c
6:4:0.1	54.5 ± 4.2bc
6:4:0.2	70.3 ± 5.6ab
6:4:0.5	89.4 ± 6.1a
6:4:1	93.8 ± 6.9a
6:4:2	58.4 ± 5.2b
6:4:5	56.5 ± 4.3b
Control	0.00e
Virgin females	23.2 ± 2.7d

[a] The total dose of each treatment is 500 µg; the tests were conducted in Beijing, July 25-August 5, 2001;
[b] six replicates; numbers with the same letters are not significantly different by Duncan's multiple range test (p = 0.05).

attractive effect was significantly increased with addition of *E*11–14:Ac. For the first three mornings, trap catches were increased and reached maximum levels by the addition of 5–10% of *E*11–14:Ac, which were about two times more than when *E*11–14:Ac was not blended. When the amount of *E*11–14:Ac was increased to 20% or more, however, trap catches were apparently decreased.

Optimum dosage of ternary blends

Further tests were conducted on various amount levels of ternary blends of *E*11,13–14:Ald, *E*11,13–14:Ac and *E*11–14:Ac at a ratio of 6:4:1 to obtain better catches. Results are shown in Table IV. In the experiment on September 5–15, optimal capture of males was observed in 1000 µg. However, in another test (data unpublished) the optimum was in 500 µg on October 15–25. This difference apparently depends on the wind velocity at the nights. The results also indicate that high concentrations of lure suppress the capture of males. Therefore, some slow release formulations are requisite for lure application in the field.

Effect of antioxidant BHT

Numbers of moths caught with different percentage of BHT in synthetic pheromone with ternary blends are shown in Table V. During the first 20 days, there was no significant difference between various treatments. From the second 20 days, no-BHT and 1% BHT bait became

Table IV. Male captures with different dosage of the ternary blends[a].

Dosage (μg/eptum)	Males caught/trap mean ± SE[b]
50	13 ± 0.3d
100	39 ± 2.5c
200	43 ± 2.9c
500	91 ± 4.6a
1000	93.8 ± 4.9a
2000	72 ± 3.6b
Control	0.00e
Virgin females	28.9 ± 2.3cd

[a] The tests were conducted in Beijing, September 5–15, 2001;
[b] six replicates; numbers with the same letters are not significantly different by Duncan's multiple range test (p = 0.05).

decreasing and from the forth 20-days to the end, the no-BHT and 1% BHT bait showed little or no trapping effect to *A. fimbriana* males. These data showed that 1.0 mg/septum of 3-component could be used for population monitoring for only about 20–30 days. From the second 20-day on, the 5% BHT and 10% BHT bait always showed maximum moth catches compared with other treatments and virgin females. This suggested that persistence and catching efficacy of synthetic chemicals was improved by addition of the antioxidant BHT. The optimum percentage was obviously obtained at 5–10% BHT. The data of Table V also exhibited that high percentage of BHT (20%) inhibited the attractiveness of pheromone chemicals.

In summary, this study demonstrates that the *Acleris fimbriana* males were attracted best to the 6:4:1 blend of *E*11,13–14:Ald, *E*11,13–14:Ac and *E*11–14:Ac. The optimum amount of lure was 1000 μg. The effective duration of lure for trapping was 20–30 days. The duration of pheromone chemicals is of great importance in pheromone based systems for control or monitoring of insects. When pheromones are subjected to heat and light, two competing chemical processes take place – thermal decomposition (oxidation) and photo-isomerization. There have been many studies that dealt mainly with the oxidation and isomerization of double bonds (Sychev *et al.*, 1987), with transformations of aldehydes (Dunkelblum *et al.*, 1984), and with hydrolysis of acetates in the field (Shani and Klug, 1980). Our study showed that addition of an antioxidant prolonged the life-span of the diene system for several 20-days. The results showed that antioxidant protected pheromone chemicals, therefore increased catching efficacy.

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Table V. The effect of different percentage of the antioxidant BHT to the synthetic pheromone on the male captures[a].

Date	Males caught/mean ± SE[b]						
	No-BHT	1% BHT	5% BHT	10% BHT	20% BHT	VF	Control
6.1–6.20	9.5 ± 0.6a	10.8 ± 0.9a	8.7 ± 0.7a	11.3 ± 1.1a	7.6 ± 0.5a	13 ± 1.2a	0.00b
6.21–7.10	34.8 ± 3.2a	35.7 ± 3.3a	32.1 ± 3.1a	37.9 ± 4.2a	28.4 ± 2.2ab	15.4 ± 1.6b	0.00c
7.11–7.31	22.5 ± 2.4b	24 ± 2.8b	41.9 ± 4.9a	57.3 ± 5.1a	27.1 ± 1.0ab	18 ± 1.1c	1.3 ± 0.2d
8.1–8.20	9.4 ± 0.9c	11.3 ± 0.1c	49.5 ± 3.1a	53.4 ± 4.2a	31.4 ± 3.2b	13.4 ± 0.7c	0.00d
8.21–9.10	3.2 ± 0.1bc	8.1 ± 0.7b	18.6 ± 0.9a	21.3 ± 1.3a	9.5 ± 0.9b	11.9 ± 1.1b	0.00c
9.11–9.30	1.0 ± 0.1d	6.5 ± 0.2cd	37.2 ± 3.2a	45.3 ± 4.9a	32.2 ± 3.3b	19.8 ± 0.6c	0.00d
10.1–10.20	0.00c	2.0 ± 0.2c	22.5 ± 1.9a	29.8 ± 2.3a	11.3 ± 0.6b	10.5 ± 0.2b	0.00c
10.21–11.10	0.00c	1.2 ± 0.1c	17.4 ± 1.6a	19.3 ± 0.8a	8.5 ± 0.5b	8.9 ± 0.4b	0.7 ± 0.1c

[a] The total dose of each treatment is 1000 μg; the tests were conducted in Beijing, June 1–November 10, 2001;
[b] six replicates; numbers in a row with the same letters are not significantly different by Duncan's multiple range test (p = 0.05); sticky plates were renewed every 20 days; VF = Virgin Female Traps.

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