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Use of Sex Pheromone for Control of *Spodoptera litura* (Lepidoptera: Noctuidae)

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ABSTRACT

The tobacco cutworm, *Spodoptera litura* (Lepidoptera: Noctuidae), is one of the most destructive pests of agricultural crops worldwide. Control of this pest strongly relies on chemical insecticides. In this paper, we combined sex pheromone and insecticide control of this pest in Chinese cabbage field. The results showed that the adoption of sex pheromone trapping can effectively suppress adults, largely decrease larvae or egg mass density and damage rate of *Spodoptera litura*. Furthermore, either spraying times or costs of chemical pesticide against *Spodoptera litura*, were significantly reduced by adoption of sex pheromone trapping. Economic-cost analysis implied that the adoption of sex pheromone trapping can help farmers get higher benefits by lowering costs and increasing yields than mere chemical control. This suggests that use of sex pheromone can be a viable alternative in integrated management of tobacco cutworm infestation.

Key words: Sex pheromone, *Spodoptera litura*, insecticide use, economic cost.

INTRODUCTION

The tobacco cutworm (TC), *Spodoptera litura* (Lepidoptera: Noctuidae), is one of the most destructive pests on agricultural crops due to its wide distribution and damage on various host plants (Xu, 1998; Qin *et al*., 2006). Since 1990s, the damage caused by TC on agricultural crops has been increasing, which led massive economic losses in many parts of China (Meng *et al*., 1988; Chen *et al*., 2001). In past years, control of TC has depended on excessive use of insecticides. However, high pesticide use has caused high levels of insecticide resistance in TC, as well as many negative impacts on agricultural environment and on human health (Huang & Han, 2007; Wu *et al*., 2006; Zhou & Huang, 2002). Therefore, alternatives to pesticides for TC control have attracted the attention of agricultural researchers.

Sex pheromones emitted by adult insects play an important role in success in their mate finding and reproduction (Men, 1997). Now, various formulations of synthesized sex pheromones have been widely applied to suppress insect pest populations through mass trapping and mating disruption (Chisholm *et al*., 1979; Fujiyoshi *et al*., 1979; Mclaughlin *et al*., 1994; Reddy & Urs, 1997; Srinivas & Rao, 1999; Reddy & Guerrero, 2000).

TC sex pheromone components have been identified as *cis*-9, *trans*-11-tetradecadienyl acetate and *cis*-9, *trans*-12-tetradecadienyl acetate (Tamaki *et al*., 1973). It has been revealed that the optimum ratio of these two compounds with respect to attractiveness to the male range from 8:2 to 39:1 (Yushima *et al*., 1974). At present, TC synthetic sex pheromone has been widely applied for TC control or population monitoring, and has previously demonstrated satisfactory capture effects of TC and can reduce pesticide use in the fields (Tang & Su, 1988; Chen, 2001; Xu *et al*., 2006; Qian *et al*., 2007). It has been considered as a possible alternative to pesticides for TC control and caused wide concerns amid agricultural researchers. However, although sex pheromone shows its high potential in TC control, the control efficacy could be influenced by many factors such as trap design, difference of lures, duration of lures, female competition and climate, etc. (Shih & Chu,1988; Rao *et al.*,1991; Shih & Chu,1995; Qian *et al*., 2007). This may influence the extensive application in near future. Meanwhile, the economic-cost aspect of sex pheromone is also very important to its further application, but there are few studies addressing this issue.

Vegetable industry is one of the most important agricultural industries in Yunnan province, southwest of China (Li, 2001). However, vegetable farmers rely on intensive use of chemical pesticides to control pests (Li, 2001; Yang *et al*., 2007), which has caused pesticide residue, environmental and health problems in this province (Li, 2001). To solve these problems caused by chemical pesticides, Yunnan government has been promoting IPM (Integrated Pest Management) programs among small household vegetable farmers to reduce pesticide use since 2003 (Yang *et al*., 2007). TC is one of the most destructive pests on vegetable, and distributed throughout Yunnan province (Liu *et al*., 2001). In recent years, as one of IPM methods, sex pheromone for TC control has been attempted in some rural communities. In this paper, we reported the control effect of a synthetic sex pheromone for mass trapping TC in Chinese cabbage (*Brassica campestris* L.ssp. *pekinensis*) fields, and explored the feasibility of extensive application of sex pheromone in rural communities by analyzing the economic-cost in Yunnan province of China.

METHODS AND MATERIALS

Sex pheromone lure and trap

The capillary lure (length: 78.0mm, diameter: 1.1 mm) containing synthetic sex pheromone blends (*cis*-9, *trans*-11-tetradecadienyl acetate: *cis*-9, *trans*-12-tetradecadienyl acetate =10:1; NewCon Inc., Ningbo, China) was used in this study. The trap was a plastic cylinder box (11.0 cm diameter, 20.0 cm high with eight 2.0 cm diameter holes facing each other) and a plastic box (1.0 L) containing water was attached on the bottom of the trap to collect male adults.

The suppression effect of TC sex pheromone lure used for mass trapping in vegetable field

The trapping trials were conducted in vegetable fields in Zhongsuo village of Jianshui county, from April 26 to July 10 2006. The total area of vegetable fields was 15ha, and 8ha among which was planted Chinese cabbage (*Brassica campestris* L.ssp. *pekinensis*). The Chinese cabbage fields were divided into two zones. One was sex pheromone trapping (SPT) zone with 5 ha, and another was non-sex pheromone trapping (NSPT) zone with 3ha. The treatments included: 1) blank control (field without any control method) (BC); 2) chemical control field (CC); 3) sex pheromone trapping plus chemical control field (SPT+CC), located in SPT zone. BC and CC fields were located in NSPT zone. NSPT zone was at upwind side of SPT zone, and two zones were at least 300 m apart (Fig.1). In SPT zone, lures and traps were placed on April 26, 2006, when Chinese cabbage was transplanted into fields. The traps with lures were placed 60cm above crop canopy and 1 trap was placed for each field of 0.067ha (about 75 traps in SPT zone). Lures were replaced once 35d before the harvesting of Chinese cabbage (total 2 lures were used for each trap in the whole growing season of cabbage). The male adults of TC captured were removed every 7 day.

Ten and 3 fields (about 0.067ha each field) were randomly selected as the CC and BC fields respectively in NSPT zone. In SPT zone, ten fields (about 0.067ha each field) were also randomly chosen as the SPT+CC fields. All sampling fields in different treatments were at least 3m separate to adjacent fields. 50 plants were randomly selected to examine TC larvae, egg mass and damage rate (%) in each sampled field every 7 days before harvesting of Chinese cabbage. Chemical control decision both in SPT+CC and CC fields was made by individual farmers. The pesticides applied for TC control in this study were pyrethroids and avermectins, which were similar in prices and commonly used in this region. The field management of Chinese cabbage maintained using similar conventional practices.

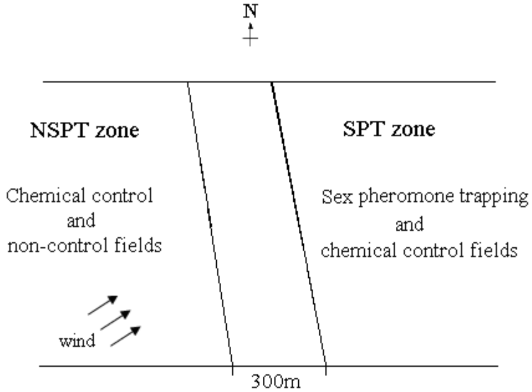

Fig. 1. The design of field investigation (NSPT: non-sex pheromone trapping; SPT: sex pheromone trapping).

Economic-cost analysis

The households of sampling fields in different treatments were selected to examine economic-cost analysis. Further interviews were carried out weekly to collect information on pesticide use for TC control (including spray schedules and costs) from farmers' records after the transplantation of Chinese cabbage (April 26 – July 10, 2006). The yields and gross incomes of Chinese cabbages were recorded when farmers sold cabbages to retailers. The yields, gross incomes and control costs of TC were compared between different treatments. The control cost mainly included expenses of insecticide/sex pheromone trap and labor input. The labor input of chemical control mainly included spraying and mixing of pesticide. The labor input of sex pheromone trapping included trap fixing, lure replacement, and adult removing.

Data analysis

Data from different treatments were analyzed by using SPSS 13.0. Means were calculated by One-sample *T* test and differences between means were compared by One-way ANOVA for significance at P=0.05. The profits evaluated in this paper were compared with blank control.

RESULTS

The suppression effect of TC sex pheromone lure in the field

The seasonal densities of TC larvae in different treatments were shown in Fig.2. In blank control fields, TC larvae population remained at the highest level during the whole growth season of Chinese cabbage, and the mean seasonal density was significantly higher than that in either CC or SPT + CC fields ($P<0.05$, Table 1). Moreover, in CC fields, the mean seasonal density of TC larvae was significantly higher that that in SPT + CC fields ($P<0.05$, Table 1). The similar results were also observed in the damage rates in different treatments (Fig. 3, Table 1).

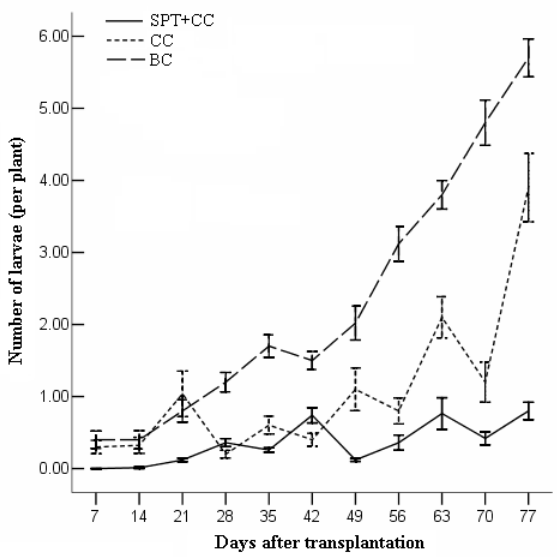

Fig. 2. Seasonal densities of TC larvae (Mean ± *S.E.*) in different treatments in 2006 (SPT + CC: sex pheromone trapping plus chemical control field; CC: chemical control field; BC: blank control).

Table 1. Mean seasonal number of larvae density, damage rate and egg mass density (Mean ± *S.E.*) in different control fields in 2006

Treatment	Larvae per plant	Damage rate (%)	Egg mass per 10 plants
SPT+CC*	0.36±0.04a**	19.05±1.31a	0.15±0.02a
CC	1.08±0.08b	24.91± 1.37b	0.71±0.11a
BC	2.31±0.09c	57.06± 5.40c	1.73±0.19b

*SPT+CC: Sex pheromone trapping plus chemical control fields; CC: chemical control fields; BC: blank control

**Different letters in the same column indicate significant differences ($P<0.05$).

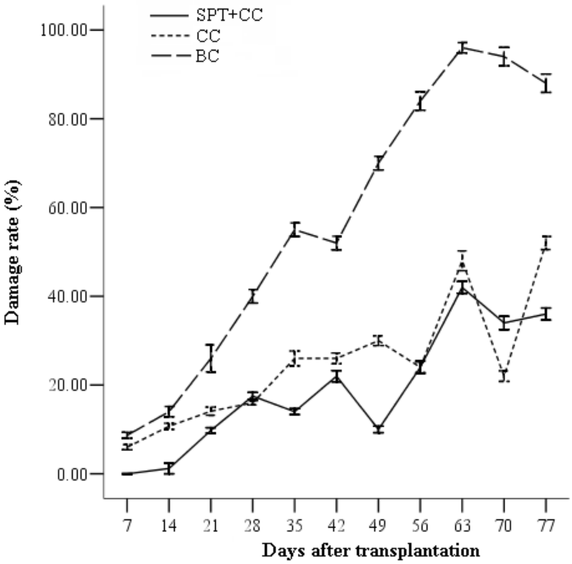

Fig. 3. Seasonal damage rates of TC larvae (Mean ± *S. E.*) in different treatments in 2006 (SPT + CC: sex pheromone trapping plus chemical control fields; CC: chemical control fields; BC: blank control).

The seasonal egg masses in different treatments were shown in Fig.4. The mean seasonal egg mass in BC fields was significantly higher than that in chemical control fields and SPT fields (P<0.05; Table 1). Although the mean seasonal egg mass in chemical control field and SPT field did not differ significantly, it was still much higher in chemical control fields (Table 1).

Economic-cost analysis

The results showed that BC fields had the lowest yield due to the severe damage of TC larvae in this region. The average yield both in sampling fields of SPT + CC and CC was significantly higher than that in BC fields (P<0.05; Table 2). However, the average yield in SPT + CC fields was much higher than that in chemical control fields, although there was no significant difference (Table 2). The spraying times of pesticide for TC control in SPT + CC fields were 3.6 times, which were significantly lower than that of 6.1 times in CC fields (P<0.05). The average cost of pesticide in SPT + CC fields was also significantly lower than that in CC fields (P<0.05). The total control cost in SPT + CC fields for TC control (988.0 RMB per ha) was lower than that of 1 122.4 RMB per ha in CC fields. Compared with BC fields, the profit farmers got in SPT + CC fields was 8240.0 RMB per ha, which was higher than that of 7288.6 RMB per ha in CC fields (Table 2). This indicated that farmers can get higher profits by getting higher yields and lower control costs with the adoption of sex pheromone to control TC.

Table 2. Economic-cost comparison between different control methods for tobacco cutworm in cabbage field in 2006.

Treatment	Yield(kg/ha) ±S.E (df=2,20)	Gross income (RMB/ha)++	Control cost (RMB/ha) ±S.E								Profit (RMB/ha)+++
			Insecticide cost per time (df=1,18)	Labor of spraying per time	Spraying times (df=1,18)	Cost of lure per time	Times of lures used	Cost of traps	Labor of sex pheromone trapping	Total (RMB/ha)	
CC+	69320.0±925.8a*	20796.0	144.0±2.45a	40	6.1±0.21a	-	-	-	-	1122.4	7288.6
SPT + CC	72045.0±1452.3a	21613.5	127.5±2.5b	40	3.6±0.27b	105**	2	105**	70***	988	8240.0
BC	41283.3±1260.1b	12385.0	-	-	-	-	-	-	-	-	-

+ CC: chemical control fields; SPT + CC: sex pheromone trapping plus chemical control fields; BC: blank control;

++ The market price of Chinese cabbage is 0.3RMB per kg.

+++ Profit= gross income of CC or SPT + CC-total control cost- gross income of BC.

* Different letters in the same column indicate significant differences ($P<0.05$).

** The price of lure and trap were both 7 RMB

*** The time of fixing 15 traps for 1ha needs 3h. Removing male adults and adding water needs 1h for 1ha (once a week, in total 10h). Lures were changed once and all the lures were replaced in 1h for 1ha. The total time of labor is 14h equal to 1.75 workdays (8h is equal to one workday and 40 RMB per workday).

DISCUSSION

Sex pheromone suppresses population of pest larvae through mass trapping and mating disruption of adults to decrease mating opportunities, and reducing egg densities or fertilized eggs of target pests (Chisholm *et al*., 1979; Reddy & Urs,1997; Fujiyoshi *et al*.,1979; Mclaughlin *et al*.,1994; Srinivas & Rao,1999). In this study, both mean seasonal density and damage rate of TC larvae in SPT + CC fields were significantly lower than those in CC and BC fields. Moreover, mean seasonal density of egg mass in SPT + CC fields was also lower that that in either CC or BC fields. In CC fields, insecticides were sprayed more than 6 times to control TC, which was significantly higher than that of 3.6 times in SPT + CC fields, but the population of TC larvae remained at a high level. This may be caused by the strong resistance of TC to chemical pesticides (e.g. pyrethroids, avermectins), which has been proved in many regions of China (Zhou & Huang, 2002; Wu *et al*., 2006; Huang & Han, 2007; Chen *et al*., 2008). However, in SPT + CC fields, because TC adults were largely suppressed with the adoption of sex pheromone, the population of TC larvae remained at a lower level and insecticides applied against TC were greatly reduced. Although insecticides were still sprayed to control TC at the beginning of adoption of sex pheromone trapping, our results indicate that sex pheromone could be a potential alternative for TC control.

The economic-cost of a new approach to control pest is a key factor influencing farmers to further adopt it, especially the small-scale farmers in developing countries like China. Thus, it is essential to analyze the economic aspects of applying sex pheromone to control TC. In our study, although insecticides were used significantly higher in CC fields, the average yield was lower than that in SPT + CC fields. Moreover, the total cost for TC control in SPT + CC fields was lower than that in CC fields. Thus, with the adoption of sex pheromone, farmers can get a higher profit than only adopting chemical control. It is worth noting that the traps can be reused for 3-4 years or even longer. This suggests that the cost of sex pheromone trapping will be reduced and higher profits can be obtained in the following years. Furthermore, farmers will have added benefit of less exposure to chemicals, and higher quality of products can be ensured.

Using sex pheromone to suppress pest population has been considered as an effective environment-friendly alternative for chemical control, especially in high insecticide resistance region (Wang *et al*., 2004; Qian *et al*., 2007; Chishholm *et al*., 1979). More importantly, it is very easy for farmers to apply this technique during their farming practices. Associated with its higher profit, use of sex pheromone to suppress population of TC should be widely applied and extended.

In conclusion, the results of this study demonstrated that the use of mass trapping of sex pheromone can suppress the adult population of TC, therefore reduce the larvae and egg mass densities on Chinese cabbage. Moreover, the mass trapping technique of sex pheromone can largely reduce chemical pesticide use and show a higher economic benefit than mere chemical control. These indicate the potential of use of sex pheromone in TC integrated management.

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