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ORIGINAL ARTICLE

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Mating disruption controls the cherry tree borer, *Synanthedon hector* (Butler) (Lepidoptera: Sesiidae), in a steep orchard of cherry trees

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Abstract Mating disruption of the cherry tree borer, *Synanthedon hector* (Butler), with synthetic sex attractant was conducted for 6 years to test the efficiency of the method to control the borer population on the slopes in the Cherry Tree Forest of Tama Forest Science Garden, Hachioji, Tokyo. No male adult moth has been captured in traps baited with the synthetic attractant since the commencement of the control. The incidence of attack decreased to a low level in the third year and has remained low thereafter, indicating the effectiveness of mating disruption in controlling the borer population.

Key words *Synanthedon hector* · Mating disruption · Cherry tree borer · Sex attractant

Introduction

The cherry tree borer, *Synanthedon hector* (Butler), is one of the most serious pests of cherry trees, peaches, Japanese apricots, and other fruit trees of Rosaceae in Japan. Since the discovery that a mixture of (*Z*,*Z*)-3,13-octadecadienyl acetate (*Z*,*Z*-3,13–18:Ac) and (*E*,*Z*)-3, 13-octadecadienyl acetate (*E*,*Z*-3,13–18:Ac) is a potent sex attractant for the male moth of *S. hector* (Yaginuma et al. 1976), the sex attractant (Sukashiba-kon, Shin-Etsu Chemical, Tokyo) has been used for practical control of *S. hector*, for example, in orchards of Japanese apricot (Aono et al. 1989). Damage has been also successfully controlled by mating disruption of other sesiid moths, such as *Synanthedon exitiosa* and *S. pictipes* (Snow 1990), and *S. tipuliformis* (Thomas and Burnip 1991) using sex pheromones.

Tama Forest Science Garden (TFSG) of the Forestry and Forest Products Research Institute (FFPRI) has been maintaining ca. 200 varieties of cherry trees in its Cherry Tree Forest established in 1966–1968. Since their establishment, the trees have suffered severe attacks by the cherry tree borer (Fujita et al. 1988; Minai and Iwata 1988; Soné 1995; Niijima 1996; Matsumoto et al. 2001). Insecticide spraying was employed as a control measure and the borer population has been monitored using traps baited with the synthetic sex attractant since 1983 (Minai and Iwata 1988; Soné 1995). Due to subsequent drastic fluctuations in the borer population, the effectiveness of the insecticide has been unclear (Matsumoto et al. 2001).

Mating disruption has not been attempted in this forest, because the forest is on slopes that would probably make mating disruption inconsistent due to windy conditions and the likely consequent dilution of the pheromones (Wakamura 1992; Morishita 2000). It may also be likely that the plume produced by the pheromone may fall to the lower part of the slope and would not be able to cover the entire area of the forest. Therefore, in 2000, we introduced mating disruption using the sex attractant for *S. hector* to the cherry tree forest to reduce the conventional spraying of insecticide. In this article, we report on consequent changes in the moth population and its damage to the cherry trees in TFSG.

Materials and methods

Study site

The experiments were conducted in the Cherry Tree Forest of TFSG, FFPRI, located in the hilly outskirts of Hachioji City, Tokyo, from 2000 to 2005. The forest occupies ca. 8 ha in area and mainly occupies slopes along two adjoining small valleys with two detached compartments nearby (Fig. 1). The number of cherry trees has been gradually

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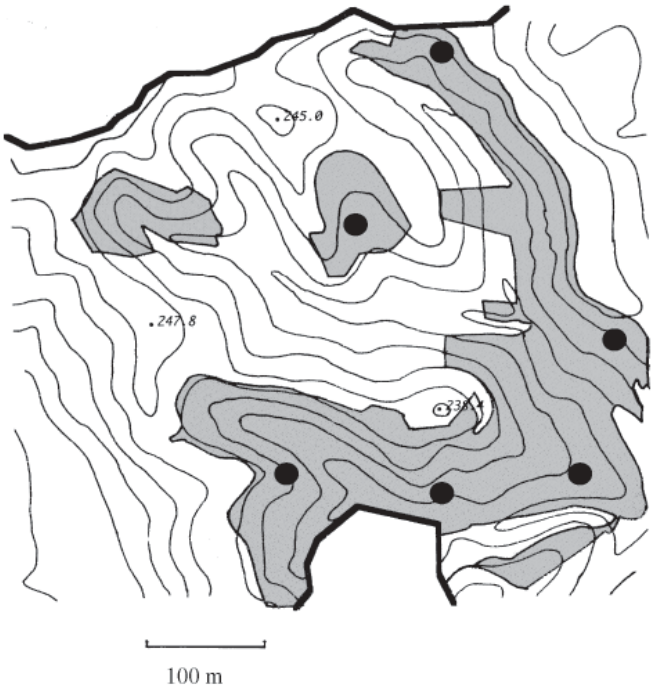

Fig. 1. A sketch map of the Cherry Tree Forest (*shaded areas*) in Tama Forest Science Garden (TFSG). The *thick lines* show the boundary of TFSG, the *thin lines* are 10-m contour lines, and the *dots* indicate positions of the monitoring traps

decreasing, mainly due to fungal invasion (*Armillaria* root rot) that accompanies borer attack. Cherry trees that are heavily injured by the borer are felled. The total number of trees was 1716 in 2000, but had decreased to 1515 in 2005. Until 1999, chemical insecticide (MEP, Sumitomo Chemical, Tokyo) had been employed to control the borer population.

Treatments

Each dispenser supplied from Shin-Etsu Chemical was loaded with 50 mg of synthetic sex attractant (50% *Z*,*Z*-3,13–18:Ac and 50% *E*,*Z*-3,13–18:Ac), which was released constantly for 7 months (Aono et al. 1989). Dispensers were placed on the branches or the trunks of the trees at a height of about 2 m above the ground. We set up two dispensers per tree, or 450 dispensers per hectare (225 g active ingredient/ha), in the middle of May every year.

Monitoring of male-mate locations

In the study area, the adult moths emerge continuously from May to October (Matsumoto et al. 2001). To monitor the mate locations of male moths, six delta traps (SE trap, Sankei Chemical, Tokyo) baited with a commercially available lure for *S. hector* (1 mg mixture of *Z*,*Z*-3,13–18:Ac and *E*,*Z*-3,13–18:Ac in a 1:1 ratio; Shin-Etsu Chemical) were placed in the forest as shown in Fig. 1 from early May to late November. Yaginuma et al. (1976) reported that a trap with a lure loaded with 2 mg of the same mixture captured more males than the trap with two or three unmated females; hence, the lure employed in the present study is competitive with females. The traps were checked every month. The lures were replaced with new ones every second month and the sticky bottoms were replaced when needed to maintain a clean surface.

Because no cherry tree stand of similar features was available nearby TFSG, we did not establish a control study plot. Instead, we assessed mating disruption effects by comparing our monitoring trap data with population monitoring trap data based on 12 traps for 1995 through 1999 available by courtesy of Dr. Keiko Niijima. Six of these previous trapping points were exactly the same as those in the present study.

Table 1. Trends in the number of male moths captured per trap

Year	Mean ± SD
1995	11.5 ± 5.5
1996	25.4 ± 8.5
1997	19.8 ± 8.8
1998	20.4 ± 7.5
1999	30.7 ± 13.7
2000	0
2001	0
2002	0
2003	0
2004	0
2005	0

Assessment of attack

Counts of injuries caused by the borer attack on the stems of cherry trees provide an ideal measure of incidence of attack or population level of the borer, because only the larval stage occurs in winter and presence of the larvae is easily detected by injuries accompanied by a mass of resin. We counted all injuries with new resin mass on the stems of all cherry trees in the forest once a year in late January or early February from 2000 to 2005.

The incidence of attack by the borer in the cherry forest of TFSG had been monitored twice in a similar way by Fujita et al. (1988) and Niijima (1996) before the commencement of the present study. These previous incidence data were used for comparison again instead of control plot data.

Results

As shown in Table 1, from 1995 to 1999, 11 to 31 males per trap were captured every year. Similar trapping results for 1983–1985 and 1988–1994 were also reported by Minai and Iwata (1988) and Soné (1995), respectively. However, since the introduction of mating disruption in 2000, no male moth has been captured by the trap at all, strongly indicating that attraction of male moths to the lures was almost completely prevented.

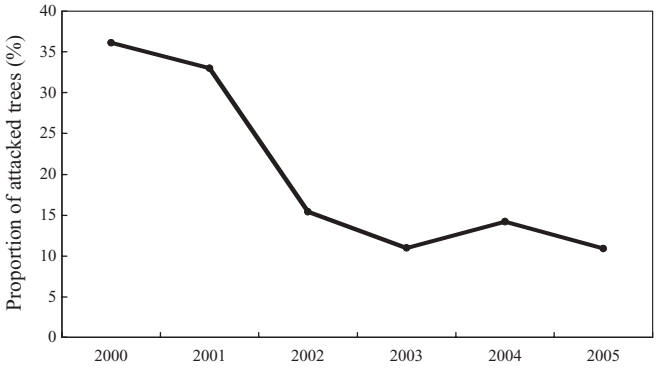

Fig. 2. Changes in proportion of cherry trees attacked by the cherry tree borer in the Cherry Tree Forest of Tama Forest Science Garden from 2000 to 2005

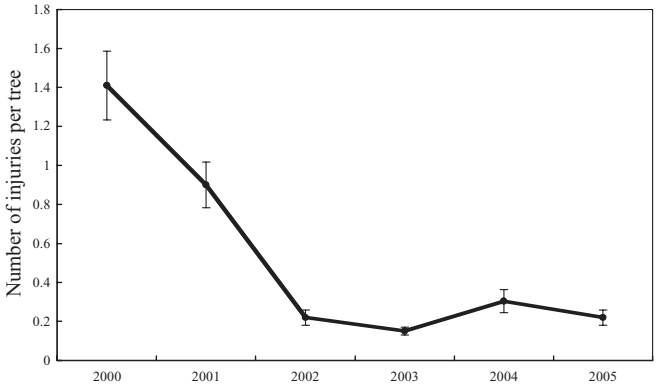

Fig. 3. Changes in the mean number of injuries (±1.96 standard error) per tree caused by cherry tree borer attack in the Cherry Tree Forest of Tama Forest Science Garden from 2000 to 2005

The percentage of attacked trees was about 36% and 33% in 2000 and 2001, respectively (Fig. 2). However, it decreased to 15% in 2002 and thereafter fluctuated between 11% and 14%. Injuries by the moths also decreased after the introduction of mating disruption from 1.41 per tree in 2000 to 0.22 per tree in 2002 and thereafter fluctuated between 0.15 and 0.31 per tree (Fig. 3). The total number of injuries observed in January or February, which could be a rough estimate of population size of the overwintering larvae in the forest, was 2418 in January 2000, whereas it was only 333 in January 2005.

Discussion

Mating disruption has been successfully applied to several insect pests of tea plants and fruit trees (Wakamura 1992), including sesiid species such as *S. hector* (Aono 1989), *S. exitiosa* and *S. pictipes* (Snow 1990) in fruit orchards. However, the method had never been applied to ornamental plantations of cherry trees, probably because cherry trees are often chosen for gardening in hilly landscapes with steep slopes to provide plenty of cherry blossoms in spring. Although it was generally considered that the control effect from mating disruption would be inconsistent in orchards on slopes (Wakamura 1992; Morishita 2000), the present study shows that mating disruption is feasible in such places. The plume of the artificial attractant remained in the cherry forest on the slope, because no male adult moths of *S. hector* was captured by the traps baited with the sex attractant from 2000 onward.

The incidence of attack dropped to a low level, but the attack continued from 2003 onward, indicating that the borer may still be reproducing. Although mating disruption was effective enough to depress the borer population in the Cherry Tree Forest, wind and/or gravity may drive out the attractant from the upper slopes, and allow a small portion of the moths to mate there. Secondly, a few adults may emerge and mate before and/or after the mating disruption effectively works, i.e., early in spring before the setting of the dispenser and late in autumn when the attractant dispensers run out. It may be worthwhile to try monitoring traps throughout the year or to set up the dispensers twice a year, very early in spring (e.g., in early April) and then in summer to see whether the incidence of attack can be further reduced. Immigration of gravid females from outside can also be considered as another possibility that allows the borer population to survive.

Insecticide had been sprayed in the Cherry Tree Forest from 1983 until 1999, but the number of male moths captured by the monitoring trap did not decrease; on the contrary, it increased from 1995 to 1999 (Table 1). According to the previous reports, 45.6% of the cherry trees ($n = 1589$) were attacked in January 1988 (Fujita et al. 1988), and the incidence was 27.1% ($n = 1833$) in early summer of 1995 (Niijima 1996).

A similar incidence observed in January 2000 (36%, $n = 1716$) may well represent a usual infestation level before the application of mating disruption. Remarkable reduction of the incidence from 2001 to 2002 without notable increase afterward indicates that the borer population has been effectively controlled. Because part of TFSG including the cherry tree forest has been open to the public since 1992, the spraying of chemical pesticide is not desirable for controlling pests. Based on the present results, we recommend replacing insecticide spraying with mating disruption for the control of *S. hector*, even in orchards on slopes.

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