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Biological Control of *Thrips palmi* (Thysanoptera: Thripidae) with the Predatory Bug, *Wollastoniella rotunda* (Hemiptera: Anthocoridae) on Greenhouse Eggplant in Winter

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To evaluate the effectiveness of the predatory bug, *Wollastoniella rotunda* Yasunaga et Miyamoto, against *Thrips palmi* Karny on eggplants in greenhouses, we conducted experiments over two growing seasons. In the first experiment, 71 adults of *W. rotunda* were released in November 1997, and the release ratio was 1:4 (adult bug: thrips) for prey density of 0.06 thrips per leaf. This release was successful in controlling a *T. palmi* population that had such a low density at the release time. In the second experiment, a total of 180 nymphs of *W. rotunda* were released three times in October and November 1998. These releases were also effective in controlling a *T. palmi* population that had a low density (0.15 thrips per leaf) on the first release, and the release ratio of nymphal bugs to thrips was 1:2. Based on these results, we conclude that *W. rotunda* could be effective as a biological control agent against *T. palmi* in winter greenhouses.

INTRODUCTION

Thrips palmi Karny (Thysanoptera: Thripidae) is one of the most economic insect pests of eggplants both in greenhouses and in the field in Japan. Eggs and pupae of this thrips easily escape from insecticide applications, partly because of egg deposition in plant tissues and partly because of pupation in the soil (Kawai and Kitamura, 1990). Thus, repeated applications of insecticides are necessary to suppress the populations of *T. palmi* below economic injury levels and have resulted in the development of resistance by this pest to chemical insecticides (Takemoto and Ohno, 1996). Nagai (1993) proposed an integrated pest management (IPM) program for *T. palmi* on summer–autumn eggplant in the field. This program was based on the use of the predatory bug, *Orius sauteri* (Poppius) (Hemiptera: Anthocoridae) native to Japan and the selective chemicals harmless to this and other natural enemies of eggplant pests. Takemoto and Ohno (1996)

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demonstrated the effectiveness of an IPM program in commercial eggplant fields. On greenhouse eggplants, Kawai (1995) experimentally showed that releasing *Orius* spp. from summer to autumn is successful in controlling *T. palmi*. However, he pointed out that population density of *T. palmi* increased as the densities of *Orius* spp. decreased after mid–October probably due to reproductive diapause of these predators under short–day (cf. Kingsley and Harrington, 1982; Nagai, 1993). He also stated that in order to control *T. palmi* in winter, it may be necessary to lighten greenhouses or to use other non–diapausing predators.

In 1987 and 1988, Hirose *et al.* (1993) surveyed natural enemies of *T. palmi* in its native habitat Thailand, and recorded the predatory bug, *Wollastoniella rotunda* Yasunaga et Miyamoto (referred to as *Billia* sp., for details see Yasunaga and Miyamoto 1993) as an effective natural enemy of this pest. Because reproductive diapause of *W. rotunda* never occurred at 14L 10D day length and 15°C (Shima, 1997), this predator could be a promising biological control agent against *T. palmi* on greenhouse eggplants in winter. However, there has been neither information on the effectiveness of *W. rotunda* in greenhouses in Japan nor attempts to its release for pest control in any country. In the present study, we released *W. rotunda* on greenhouse eggplants infested with *T. palmi* in winter to determine the effectiveness of this natural enemy.

MATERIALS AND METHODS

Insects

T. palmi were obtained from a colony established from adults and larvae that were collected in eggplant gardens in Hisayama, Fukuoka Prefecture, in 1995. The colony was maintained on potted kidney bean plants at 25°C and 16L 8D in the laboratory.

W. rotunda were taken from a colony initiated from adults and nymphs that were collected in eggplant gardens in Bangkok, Thailand in 1995. Nymphs and adults of this predator were reared on *Tyrophagus putrescentiae* Schrank and *Ephestia kuehniella* Zeller (egg), respectively. Stems of young kidney beans were used as oviposition substrates for *W. rotunda*. The colony of this predator was kept in an incubator for more than one year at 25±1°C, 75±5%RH, and 16L 8D.

Experiments

Experiments were conducted in Fukuoka Agricultural Research Center in Chikushino, Fukuoka, during winter two times, i. e. from 1997 to 1998 and from 1998 to 1999, using two plastic greenhouses (9.1×2.9 m) for each experiment. Each greenhouse had openings on two sides, covered with mesh sleeves to avoid over heating and to prevent the insects from escaping. In each greenhouse, seedlings of 30 eggplants (cultivar "Chikuyo") were planted on Sept. 24, 1997 in two rows spaced 1.2 m apart and at intervals of 0.6 m between plants in a row. These plants were maintained till the end of the second experiment. The ground of each greenhouse was covered with black polyethylene films, a common practice for eggplant cultivation in Japan. Of the two greenhouses, one was used as a plot with *W. rotunda* release (hereafter BC plot) and the other as control plot. After the first experiment, all the shoots were trimmed in September 1998, and new offshoots that emerged from the stocks were used in the second experiment.

In the first experiment, 60 *T. palmi* adults were released in each plot on Oct. 20, 1997. Additional inoculation of 450 adults and 400 larvae of *T. palmi* in each plot was made on Oct. 30, 1997 by placing infested kidney bean on the plants. On Nov. 11, 71 adults of *W. rotunda* were released. The sex ratio of released *W. rotunda* adults was 0.5. In the release, *W. rotunda* adults were placed on four plants randomly chosen from BC plot together with *E. kuehniella* eggs which were previously killed by ultraviolet light.

In the second experiment, no *T. palmi* were released because the thrips were already established on Oct. 21, 1998. The 3 rd instar nymphs of *W. rotunda* were released three times. These releases were conducted on Oct. 21, Oct. 28 and Nov. 4, 1998 using 60 nymphs for every time. On each release, methods for releasing the predator were the same as those in the first experiment.

Sampling

T. palmi populations were monitored every seven days from Nov. 4, 1997 to Jan. 5, 1998 in the first experiment, and from Oct. 21, 1998 to Jan. 4, 1999 in the second experiment. On each sampling date, numbers of *T. palmi* and *W. rotunda* were counted by naked eyes on four randomly selected plants per plot. We recognized four areas in a plant by height. A total of ten leaves was sampled per plant; four from the top area of the plant and every two from other three lower areas. Population densities of *T. palmi* were estimated by adjusting the number of insects on leaves from an area of a plant according to the number of branches belonging to the area. We recorded daily maximum and minimum temperatures in both plots during the experiments to calculate average monthly temperatures.

RESULTS

The First Experiment

Temperature fluctuations during the first experiment in BC plot are shown in Fig. 1a. Differences in monthly averages of maximum and minimum air temperatures between BC and control plots were less than 1 °C. Average monthly temperatures in both plots during the first experiment were 16.1, 17.4 and 18.0 °C for November, December and January, respectively.

In control plot, *T. palmi* population increased exponentially except when temperatures were extremely low in December (Fig. 1b). In BC plot, *W. rotunda* were released at such a low *T. palmi* population density as 0.06 adults and larvae per leaf on Nov. 11. The release ratio (ratio of the number of *W. rotunda* adults released to the number of *T. palmi* adults and larvae) was 1:4. Significant differences between the densities of two plots were detected on Nov. 25 ($P<0.01$), Dec. 1 ($P<0.01$), Dec. 8 ($P<0.01$), Dec. 15 ($P<0.01$), Dec. 29 ($P<0.01$) and Jan. 5 ($P<0.0001$) (Mann–Whitney U test). On Jan. 5, *T. palmi* population density in BC plot was reduced to 1/7 of that in control plot (Fig. 1b).

Two days after the release, we found 8, 8, 6 and 4 of *W. rotunda* alive on each 50 leaves of the four eggplants on which those were released. Six days after the release, we found 2, 1, 1 and 0 of *W. rotunda* alive in the same way. This decrease of residents on

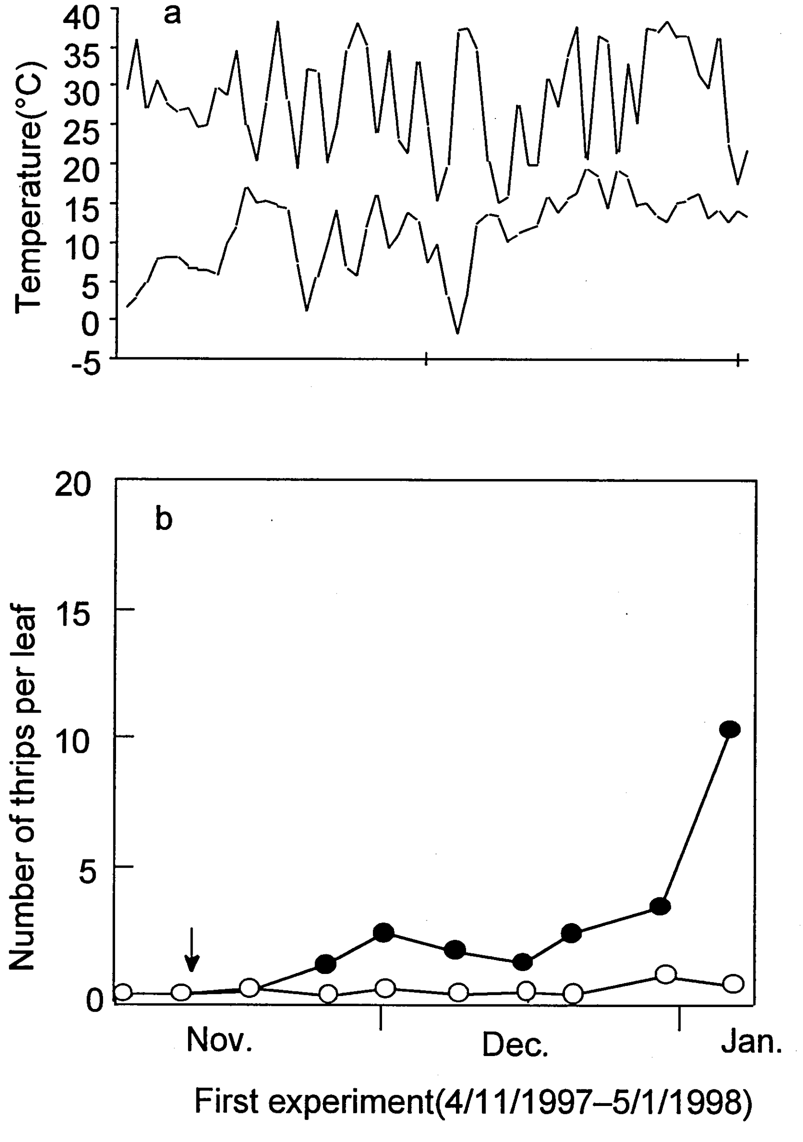

Fig. 1. Temperature and population fluctuations of *T. palmi* in the first experiment (1997–1998). a: Maximum (upper) and minimum (lower) daily air temperature in a plot with *W. rotunda* release. b: Density fluctuations of *T. palmi* adults and larvae in the control plot (black circle) and the release plot (open circle). Arrows indicate the release of *W. rotunda*.

the released plants seemed to indicate that these predators rapidly dispersed. However, we were not successful in recording the population fluctuations of *W. rotunda* after its release because of extremely low densities of this predator.

The Second Experiment

Temperature fluctuations during the second experiment are shown in Fig. 2a.

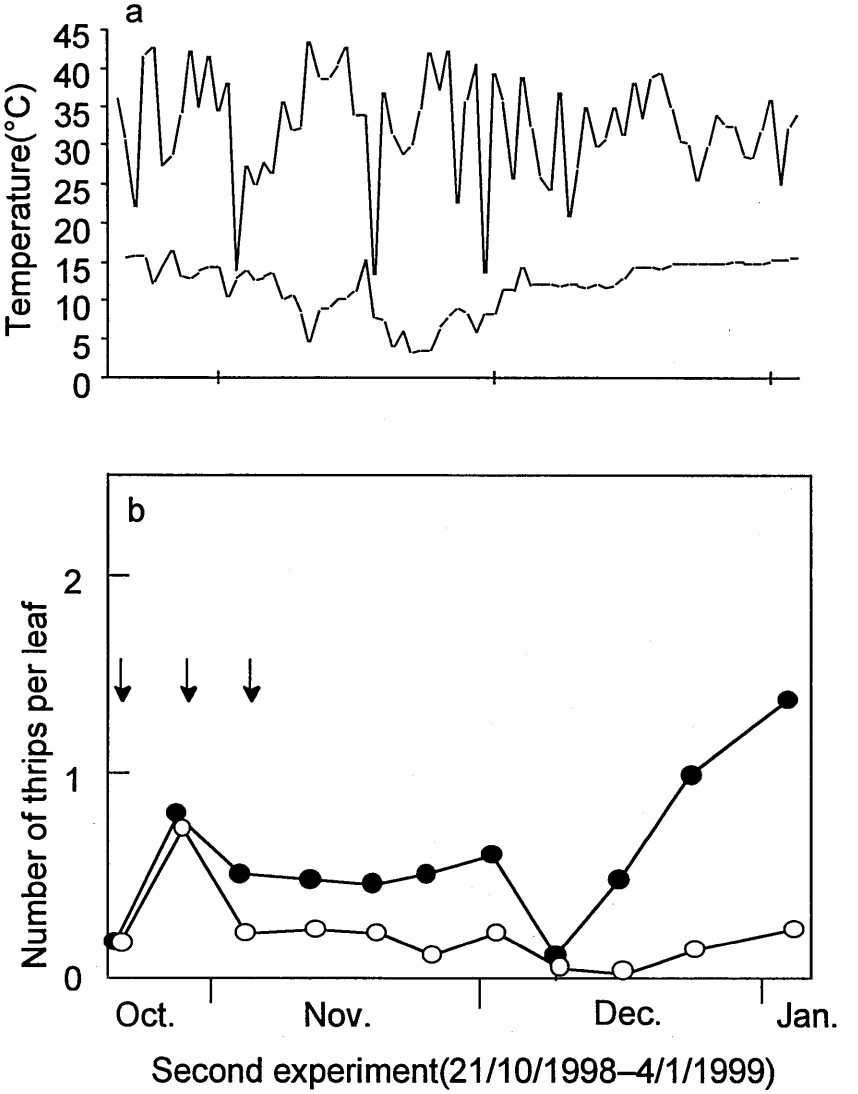

Fig. 2. Temperature records and population fluctuations of *T. palmi* in the second experiment (1998–1999). For further explanation, see Fig. 1.

Average monthly temperatures were 20.7, 16.1, 17.4 and 16.9 °C, in the latter half of October, November, December and January, respectively. In control plot, the *T. palmi* population fluctuated around 0.5 thrips per leaf for first 40 days, and after that it increased rapidly in the last three weeks. In BC plot, the releases were conducted for a low *T. palmi* population density, i.e. 0.15 adults and larvae per leaf, on the 1st release on Oct. 21. The release ratio was 1:2. One day after the first release, we verified successful residence of released insects by finding 9, 8, 7 and 7 of 3 rd nymphs of *W. rotunda* alive on each 50 leaves of the four eggplants on which those were released. After three releases, *T. palmi* population density in BC plot flucturated around 0.2 thrips per leaf and showed no increase for a 60-day period. Significant differences between thrips population densities in both plots were detected on Nov. 25 ($P<0.05$), Dec. 16 ($P<0.05$), Dec. 24 ($P<0.01$) and Jan. 4 ($P<0.01$) (Mann–Whitney U test). On Jan. 4, 1999, the thrips population density in BC plot was 1/6 of that in control plot (Fig. 2b).

DISCUSSION

It is important to determine if released predators are effective for a pest that has a low population density. They may disperse from a release plot at an extremely low prey population density. Kawai (1995) reported that when *Orius* spp. were released on each plant at a low population density of *T. palmi* (0.7 adults and larvae per leaf), the prey population was suppressed, fluctuating around 0.6 thrips per leaf for two months. In our experiments, *W. rotunda* were released at lower popuation densities of thrips (0.06 thrips per leaf in the first experiment and 0.15 thrips per leaf in the second experiment). Neverthless, these releases resulted in a slow increase in *T. palmi* population density to reach 1.5 thrips per leaf in the first experiment (Fig. 1b), and there was no increase in *T. palmi* population density in the second experiment (Fig. 2b). Both results indicate that *W. rotunda* releases are effective in controlling *T. palmi* populations that have such lower density at the release time.

Takemoto (unpublished) estimated an economic injury level (EIL) of *T. palmi* to be 17 adults and larvae per leaf as a permissible level of yield loss of 10% for eggplants in greenhouses from January to April. However, a good strategy for controlling *T. palmi* is not to keep this pest population density barely under EIL but to keep the population density low as long as possible. Our results demonstrated that *W. rotunda* is a promising biological control agent for such a purpose. Although *O. sauteri* also seems to have ability to control *T. palmi* populations having extremely low densities, it cannot act in winter season because of reproductive diapause under short–day.

Because *W. rotunda* takes 37.4 days in developing from egg to adult female at 20 °C (Shima and Hirose, 2002), one could not expect a rapid increase of *W. rotunda* population after release in greenhouses. Release impacts of this natural enemy on *T. palmi* populations should depend on predation by released individuals in first few weeks after the release. Thus, for a release of *W. rotunda*, 3 rd instar nymphs would be more adequate than adults, because the cost of nymph production is lower than that of adult production and because predatory activity during nymphs and adults continues a longer period than that of adults alone.

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