Potential of *Haplothrips brevitubus* (Karny) (Thysanoptera: Phlaeothripidae) as a predator of mulberry thrips *Pseudodendrothrips mori* (Niwa) (Thysanoptera: Thripidae)


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Abstract

The predation potential of *Haplothrips brevitubus* (Karny) for thrips was evaluated in the laboratory. When second stage larvae of *Pseudodendrothrips mori* (Niwa) were presented to an adult *H. brevitubus* at densities of 10, 20, 30, and 40 larvae per cage at 25 °C over 24 h, the number of larvae consumed per day increased with an increasing density up to 30. Predation of *H. brevitubus* exhibited the type II functional response. The mean development time of the egg, larva, and pupa of *H. brevitubus* were 4.5, 9.6, and 4.8 days, respectively, at 25 °C. The survival rate from egg to adult emergence was 94.7%. One *H. brevitubus* larva consumed 41.6 *P. mori* larvae on average during the total larval period. Adult longevity was 35.2 days in females and 34.6 days in males. The pre-oviposition period was 2.7 days and the oviposition period was 31.5 days. The lifetime fecundity was 120.1 eggs and the mean daily oviposition rate was 3.6 eggs. Calculated mean generation time (*T*) was 29.5 days, intrinsic rate of natural increase (*r*) was 0.162, and net reproductive rate (*R*0) was 56.5. The *r* value of *H. brevitubus* was higher than that of *Thrips palmi* Karny and almost equal to that of *Frankliniella occidentalis* (Pergande). These results indicate that *H. brevitubus* has good potential as a predator of *P. mori* and is likely to be useful for controlling thrips.

Keywords: Predatory thrips; *Haplothrips brevitubus*; Biological control; Natural enemy; Thrips; Functional response

1. Introduction

Thrips are one of the most important crop pests in the fields and in greenhouses because of their high level of resistance to insecticides and their cryptic habit that result in reducing the effects of insecticide application (Brödsgaard, 1994; Immaraju et al., 1992). Therefore, biological control as an alternative control method has attracted much attention recently.

Anthocorid bugs and phytoseiid mites are already used for successfully controlling thrips in greenhouses (Chambers et al., 1993; Gillespie, 1989; Kawai, 1995; Ramakers et al., 1989; Riudavets and Castane, 1998). Also, in Japan, a predatory thrips, *Frankliniorthrips vesiformis* (Crawford), has been established as a biological control agent for *Thrips palmi* Karny and *Frankliniella occidentalis* (Pergande) (Arakaki and Okajima, 1998; Ohishi and Yasuda, 2002). However, more species should be added to the list of avail-
able biological control agents for thrips; the predators that are currently being used do not possess optimal characteristics. They have, for example, low reproduction and predation under low-temperature conditions (Nagai and Yano, 1999, 2000; Tommasini and Benuzzi, 1996), variable effectiveness on different crops (Riudavets, 1995), low establishment rate, and high production costs.

Members of the genus *Haplothrips* Amyot & Serville are mostly herbivorous (Miyazaki and Kudo, 1988). For example, *Haplothrips chinensis* Priesner has been recorded as a pest of rose and *Hibiscus* in Taiwan (Wang and Hsu, 1996; Wang, 1997). Yet some *Haplothrips* species are known to prey on thrips (Riudavets, 1995). For example, *H. victoriensis* Bagnall has been reported to be a natural enemy for the two-spotted spider mite, *Tetranychus urticae* Koch (Bailey and Caon, 1986). In a mulberry field in Kagoshima, Japan, we observed *H. brevitubus* (Karny) adults and larvae preying on the mulberry thrips, *Pseudodendrothrips mori* (Niwa) (Fig. 1). *H. brevitubus* is a common species widely distributed in the temperate region of Japan (Okajima, unpublished data). However, the biology of *H. brevitubus* has not been studied. Clarification of its feeding habits is important for the determination of its pestiferous status. Moreover, if we could ascertain that *H. brevitubus* is an effective thrips predator, we may be able to exploit it as a biological control agent.

To evaluate the predation potential of *H. brevitubus*, we conducted experiments on its functional responses and life history parameters, using *P. mori* as prey in the laboratory. We demonstrate here that *H. brevitubus* is a predator of thrips and a potentially useful biological control agent.

2. Materials and methods

2.1. Insect and its rearing

*Pseudodendrothrips mori* was collected from mulberry fields at the Kagoshima Sericultural Experiment Station, Higashi-ichiki, Kagoshima, Japan (31°40.0’N, 130°19.8’E), in September 2002. They were reared in a 9 cm diameter × 12 cm depth plastic boxes with mulberry leaves at 25°C and a 16:8 h light:dark (L:D) cycle. *Haplothrips brevitubus* adults were collected from the same mulberry fields mentioned above and identified using male genitalia. To maintain the *H. brevitubus* culture, sufficient numbers of *P. mori* larvae were provided with a piece of mulberry leaf (7 × 7 cm) in each plastic box and reared at 25°C under 16:8 (L:D). A sheet of filter paper (9 cm diameter) was laid on the bottom of the rearing box to control the humidity. Offspring produced by rearing for two or three generations were used for the following experiments.

2.2. Predation by adult *H. brevitubus* on second stage larvae of *P. mori*

We examined the functional response of adult *H. brevitubus* to second stage larvae of *P. mori*. Female adults were starved for 24 h before the experiment by being confined singly in 3.5 cm diameter × 7.5 cm depth glass vials at 25°C and 16:8 (L:D). These females were placed singly with second stage larvae of *P. mori* at densities of 10, 20, 30, or 40 per vial with a piece of mulberry leaf (2 × 2 cm) and a piece of filter paper (2 × 2 cm) at 25°C and 16:8 (L:D). After 24 h, the number of *P. mori* larvae killed by the adult *H. brevitubus* was counted. The number of replication was from 10 to 12 at each prey density. To estimate the mortality rate of *P. mori* larvae under conditions without predators, 40 second stage larvae of *P. mori* were confined in a glass vial with a piece of mulberry leaf (2 × 2 cm) at 25°C and 16:8 (L:D). After 24 h, the number of dead *P. mori* larvae was counted.

2.3. Development, survival, and reproduction of *H. brevitubus*

Development time of the egg, larva, and pupa of *H. brevitubus* fed on second stage *P. mori* larvae were examined at 25°C and 16:8 (L:D). To obtain eggs of *H. brevitubus*, 30 *H. brevitubus* female adults were placed in the plastic box (9 cm diameter × 12 cm depth) with a piece of mulberry leaf (7 × 7 cm) and sufficient amount of *P. mori* larvae for 24 h. Mulberry leaf pieces (0.5 × 0.5 cm) with *H. brevitubus* eggs

![Fig. 1. Predation by Haplothrips brevitubus adult (A) and larva (B) on Pseudodendrothrips mori larva.](image-url)
on them were singly placed in plastic tubes (1 × 5 cm) with a piece of filter paper (1 × 1 cm). A piece of moist cotton wool was put in each tube to provide humidity. Newly hatched *H. brevitubus* larvae were singly transferred to 3.5 cm diameter × 7 cm depth polystyrene bottles with more than 20 second stage larvae of *P. mori* on a piece of mulberry leaf (2 × 2 cm) and a piece of filter paper (2 × 2 cm) and were reared at 25 °C and 16:8 (L:D). The number of *P. mori* larvae killed by *H. brevitubus* was counted daily and new prey larvae were supplied every day.

Second stage pupae of *H. brevitubus* were singly transferred to plastic tubes (1 × 5 cm) with a piece of moist cotton wool and a piece of filter paper (1 × 1 cm) and kept until adults emergence. To examine lifetime fecundity and longevity, a pair of *H. brevitubus* adults captured within 24 h after emergence was reared in the polystyrene bottle (3.5 cm diameter × 7 cm depth). A mulberry leaf chip (2 × 2 cm) containing a sufficient number of *P. mori* larvae, as well as a piece of moist cotton wool and a piece of filter paper (2 × 2 cm) were placed in the rearing bottle. If the male died before oviposition by the coupled female, another newly emerged male was supplied. The leaf chip containing *P. mori* larvae was renewed every 24 h and the number of eggs laid on the leaf chip was counted under a binocular microscope at 50× magnification. Oviposition rates and survival of adults were observed until the female died.

### 2.4. Data analysis

Data obtained from the functional response experiment were fitted to the Holling disc equation (Holling, 1959):

\[
\frac{N_x}{P} = \frac{aNT}{1 + aT_hN},
\]

where \(N_x\) is the number of successful attacks per predator during a specific time period (\(T\) (=1 day in this study)); \(N\) is the initial density of the prey, and \(a\) and \(T_h\) are the rate of successful attack and the time required to handle the prey, respectively. Parameters were estimated using Mathematica 3.0 software (Wolfram Research Inc., 1996).

The intrinsic rate of natural increase (\(r_m\)) was calculated from the survival rate (\(l_x\)) of immature and adult stages and the age-specific fecundity schedule (\(m_x\)) by using an iterative technique after substituting trial values (Birch, 1948):

\[
\sum_{x=1}^{\infty} l_x \cdot m_x \cdot \exp(-r_m \cdot x) = 1,
\]

where \(x\) is the age in days. The female sex ratio was assumed to be 0.5. The net reproductive rate (\(R_0\)) and the mean generation time (\(T\)) were calculated from Birch (1948) and Laughlin (1965):

\[
R_0 = \sum_{x=1}^{\infty} l_x \cdot m_x,
\]

\[
T = \frac{\sum_{x=1}^{\infty} x \cdot l_x \cdot m_x}{\sum_{x=1}^{\infty} l_x \cdot m_x}.
\]

### 3. Results

#### 3.1. Functional response of *H. brevitubus* on second stage larvae of *P. mori*

Because the mortality of *P. mori* under conditions without a predator was 0%, all deaths of *P. mori* larvae were counted as due to predation by *H. brevitubus*. The number of *P. mori* larvae consumed by *H. brevitubus* adults increased with an increasing density up to 30 larvae and was saturated at 40 (Fig. 2). Predation of *H. brevitubus* on *P. mori* larvae exhibited the type II functional response (Holling, 1959). Parameters \(a\) (=rate of successful attack) and \(T_h\) (=handling time) were 0.762 and 0.043, respectively. The number of prey consumed per day at the densities from 20 to 40 was significantly higher than that at a density of 10 (Fig. 2). The mean maximum number of prey consumed per day was 12.4 on average at a prey density of 30.

#### 3.2. Development, survival, and reproduction

The development time of egg, larva, and pupa are shown in Table 1. Individual developmental rates in the same stage were nearly equal. The survival rate from egg to adult emergence was 94.7%. Only one individual of the initial 20 insects died at the pre-pupal stage.

The numbers of prey consumed each day during the larval stages are shown in Fig. 3. The numbers of prey consumed by a first stage *H. brevitubus* larvae were 2.4–2.7 per day, and there were no significant differences among ages within the same stage. The number of prey consumed...
by a second stage \textit{H. brevitubus} larva was 4.1–6.1 per day; this was significantly larger than the numbers consumed by a first stage larva, with the exception of the first stage on day 3. Consequently, one \textit{H. brevitubus} larva consumed 41.6 \textit{P. mori} larvae on average to complete their pre-imaginal development.

Oviposition and survivorship curves of female adult \textit{H. brevitubus} are shown in Fig. 4. Oviposition started 2 days after emergence and continued intermittently until the female died. Female and male longevities were 35.2 and 34.6 days, respectively. The mean oviposition rate per female per day was 3.6 eggs, and the total lifetime fecundity per female was 120.1 eggs. Calculated mean generation time (\(T\), in days) was 29.5 days, the net reproductive rate (\(R_0\)) was 56.5, and the intrinsic rate of natural increase (\(r_m\), day\(^{-1}\)) was 0.1602, respectively.

4. Discussion

The genus \textit{Haplothrips} includes more than 230 species worldwide, mostly feeding in flowers (Mound and Zapater, 2003). However, feeding habit of \textit{H. brevitubus} has not been unknown. It is known that some \textit{Haplothrips} species are carnivorous (Riudavets, 1995). Ours is the first report of \textit{H. brevitubus} as a predator of thrips.

\textit{Aeolothrips intermedius} Bagnall, a predatory thrips, consumes about 25 \textit{Thrips tabaci} Lindeman larvae during its larval stage (Bournier et al., 1979). On the other hand, \textit{A. intermedius} and \textit{Frankliniorthrips vespiformis} female adults respectively consume 2.3 and 4.7 of \textit{Frankliniella occidentalis} larvae each day (Zegula et al., 2003). The quantity of \textit{P. mori} larvae (41.6 larvae) consumed by \textit{H. brevitubus} during the larval stage was larger than that of \textit{A. intermedius}. \textit{H. brevitubus} female adults each consumed about 12 \textit{P. mori} larvae. This consumption is higher than those of \textit{A. intermedius} and \textit{Frankliniorthrips vespiformis}.

Further, the mean daily oviposition rate of \textit{H. brevitubus} (3.6 eggs) fed on \textit{P. mori} larvae was larger than that of \textit{Frankliniorthrips vespiformis} fed on \textit{Frankliniella occidentalis} (0.67 eggs) (Zegula et al., 2003). Thus, \textit{H. brevitubus} seems to have higher predatory and reproductive ability as a natural enemy of thrips than do other predatory thrips such as \textit{A. intermedius} and \textit{Frankliniorthrips vespiformis}.

The intrinsic rate of natural increase (\(r_m\)) of pests thrips reared at 25 \(^\circ\)C were 0.134 in \textit{Thrips palmi} (Kawai, 1985), 0.141 (Katayama, 1997) and 0.166 (Van Rijn et al., 1995) in \textit{Frankliniella occidentalis}, and 0.17 in \textit{T. tabaci} (Murai, 2000), respectively. The \(r_m\) value of \textit{H. brevitubus} in this present study was higher than the \(r_m\) value of \textit{T. palmi} and nearly equal to that of \textit{Frankliniella occidentalis}, and lower than that of \textit{T. tabaci}. Comparison of the \(r_m\) value between natural enemies and pests can be used for pre-selecting of natural enemies in augmentative use of natural enemies (Van Lenteren and Manzaroli, 1999). Thus, the high \(r_m\) value of \textit{H. brevitubus} suggests that \textit{H. brevitubus} is a promising natural enemy for pests thrips.

The \(r_m\) value of phytoseiid mites when provided with \textit{Frankliniella occidentalis} or \textit{T. tabaci} were from 0.14 to 0.18 in \textit{Amblyseius cucumeris} (Oudemans) (Castagnoli and Simoni, 1990; Van Rijn and Van Houten, 1991) and 0.22 in \textit{A. barkeri} (Hughes) (Van Rijn and Van Houten, 1991) at 25 \(^\circ\)C. And at 25 \(^\circ\)C, \textit{A. cucumeris} female adult consumes 6.6 \textit{Frankliniella occidentalis} larvae and 3.6 \textit{T. tabaci} larvae daily (Castagnoli et al., 1990). \textit{A. barkeri} female adult consumes 3.0 \textit{T. tabaci} larvae daily (Bonde, 2000).
It seems that while *H. brevitubus* have lower reproductive ability, *H. brevitubus* have higher predatory ability than thysanopterous mites. On the other hand, mean value of thrips species *Orius* species about at 25°C is 0.116 in *O. insidiosus* (Say) (Tommasini and Nicoli, 1993), 0.105 in *O. laevisgatus* (Fieber) (Coccuza et al., 1997), 0.128 in *O. sauteri* (Poppius) (Nagai and Yano, 1999). *O. insidiosus* female adult consumes about 40 *Sericothrips variabilis* (Beach) adults daily (Isenhour and Yeargan, 1981) and *O. sauteri* female adult consumes about 40 *T. urticae* larvae daily (Nagai and Yano, 2000), respectively when provided with sufficient amount of prey. Consequently, *H. brevitubus* seems to have medium potential as natural enemy of thrips between thysanopterous mites and anthocorid bugs.

However, here we studied the biology of *H. brevitubus* provided only with *P. mori* larvae. We need to investigate the performance when provided with other thrips such as *T. palmi*, *Frankliniella occidentalis*, and *T. tabaci*. Furthermore, we need to clarify the feeding habits of *H. brevitubus* including flower and pollen. For example, it is known that the development time of *T. urticae* larvae became shorter when provided with seed lucerne crops flower than provided with *T. urticae* eggs (Bailey and Caon, 1986). The role of *H. brevitubus* as a biological control agent against thrips in greenhouses also needs further study, in regard to mass rearing protocols, diapause incidence under short-day conditions, and estimation of effectiveness in the fields.

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## References


