Development and reproduction of *Ceranisus menes* (Hymenoptera: Eulophidae), a larval parasitoid of thrips: effects of two host species, *Frankliniella intonsa* and *Thrips palmi* (Thysanoptera: Thripidae)

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**Abstract**

*Ceranisus menes* is an effective parasitoid of *Thrips palmi*. To determine whether *C. menes* reared on *Frankliniella intonsa* can develop and reproduce on *T. palmi*, we studied the effects of these two host species on development and reproduction of a thelytokous strain of this parasitoid in the laboratory. There was no significant difference in total developmental time of the parasitoid between the two host species. *C. menes* reared on *F. intonsa* were larger than those reared on *T. palmi*. The reproduction of *C. menes* was examined for three host treatments: (1) the parasitoid reared on *F. intonsa* was allowed to oviposit in *F. intonsa* (*F. intonsa* to *F. intonsa*), (2) *F. intonsa* to *T. palmi* and (3) *T. palmi* to *T. palmi*. Adult longevity and total fecundity of *C. menes* did not differ significantly among those treatments. This thelytokous strain of *C. menes* had a higher reproductive rate than both host species. We conclude that the mass-reared thelytokous *C. menes* strain using *F. intonsa* may be a viable option in controlling *T. palmi*.

**Key words:** Biological control, *Ceranisus menes*, *Frankliniella intonsa*, *Thrips palmi*

**INTRODUCTION**

Since its introduction into Japan in 1978, *Thrips palmi* Karny has become a major pest of many kinds of vegetables. Fifteen species have been reported as natural enemies of this pest in Japan (Hirose et al., 1999). Of these 15 species, *Ceranisus menes* (Walker) is the only important parasitoid of *T. palmi* in Japan and Thailand (Hirose et al., 1992, 1993). In Japan, this parasitoid was first found parasitizing *Thrips tabaci* Lindemann in 1931 (Ishii, 1933) and was so effective that it was introduced into Hawaii as a biological control agent (Sakimura, 1937a, b, c). Recently, Hirose et al. (1992) and Takagi et al. (unpublished) showed that in autumn, *C. menes* is an important parasitoid of *T. palmi* on eggplant in Amagi near Fukuoka, Japan. Hirose et al. (1993) also reported that this parasitoid is an effective control agent of *T. palmi* on eggplant in Thailand.

Loomans and Murai (1997) established a *C. menes* mass rearing system, using *Frankliniella intonsa* (Trybom) as a host. *F. intonsa* can be easily reared using pollen as food (Murai, 1988). Therefore, it is possible that *F. intonsa* could prove useful as an alternative host for mass-rearing of *C. menes* for the control of *T. palmi*. However, it is not known whether *C. menes* reared on *F. intonsa* parasitize and reproduce on *T. palmi*. Our objective was to determine whether *C. menes* reared on *F. intonsa* can develop and reproduce successfully on the *T. palmi* host.

**MATERIALS AND METHODS**

**Insects.** Larvae and adults of *F. intonsa* were collected from white clover, *Trifolium repens* L., in Fukuoka to initiate a laboratory culture in 1990. The culture was maintained as described by Murai (1988). Pollen of black pine, *Pinus thunbergii* Parl. and water (for adults) or 10% honey solution (for larvae) were provided as food. Eggs deposited by *F. intonsa* females taken from the culture were collected and transferred to a piece of 1.5×1.5 cm sealonfilm® (Fuji Film) which was floated on water in a petri dish (6 cm diameter) until larvae hatched. Newly hatched larvae were used in the experiments.

A laboratory culture of *T. palmi* was initiated using larvae and adults collected from eggplant gardens in Amagi during 1990. The culture was maintained on potted eggplants in the laboratory for several generations. To obtain newly hatched *T. palmi* larvae for experiments, adult females taken
from the culture were allowed to oviposit in a glass tube (3 cm diameter×4 cm high). One side of the tube was covered with an eggplant leaf disk (3 cm diameter) on which 10 to 15 adult females were released, and both sides of the tube were sealed with sealonfilm®. Females were removed after 24 h, and the disk was maintained on moist filter paper in a petri dish (6 cm diameter) covered with sealonfilm® until larvae hatched.

The C. menes culture originated from parasitoids which emerged from T. palmi larvae collected in Amagi during 1990. This “Amagi” strain reproduced by thelytokous parthenogenesis. After rearing on F. intonsa for six to ten generations, parasitoids were used in experiments. When C. menes prepupa could be seen through the host body, each of the parasitized hosts was placed on moist filter paper and transferred to a vial (1.5 cm diameter×6.5 cm long). Laboratory cultures of the parasitoid and hosts were maintained at 25°C and 16L–8D.

Development of C. menes reared on two host species. Development of C. menes reared on F. intonsa and T. palmi was examined at 20 and 25°C. To obtain parasitized F. intonsa larvae, female wasps were individually allowed to oviposit for 6 h in a glass tube (3 cm diameter×4 cm high) containing about 20 newly hatched F. intonsa larvae. Parasitized hosts were reared at 16L–8D as described by Murai (1988). When parasitoid pupae emerged from host bodies, they were individually transferred to a vial (1.5 cm diameter×6.5 cm long) and kept until adult wasps emerged. To obtain parasitized T. palmi larvae, female wasps were allowed to oviposit for 6 h in a glass tube (3 cm diameter×4 cm high) covered by an eggplant leaf disc with about 20 newly hatched host larvae. Parasitized hosts were reared on eggplant and kept as described above.

To determine whether parasitoid size was affected by host species, we measured the size of C. menes emerged from F. intonsa and T. palmi. We used pupal length, pupal width and adult forewing length as size indexes of C. menes, measuring with an ocular micrometer.

Reproduction of C. menes reared on the two host species. To evaluate the effect of host species on C. menes reproduction, we compared age-specific survival rate and fecundity of adult parasitoids among the following three host treatments: (1) the parasitoid reared on F. intonsa was allowed to oviposit in F. intonsa (F. intonsa to F. intonsa), (2) F. intonsa to T. palmi, and (3) T. palmi to T. palmi. Newly emerged wasps were individually reared in a glass tube containing 50 to 60 newly hatched host larvae and honey at 25°C and 16L–8D. Host larvae were replenished daily throughout the life of each wasp. To determine the number of eggs laid per day, hosts were dissected after rearing for 24 h. We calculated the parameters of population growth of C. menes for each of the three host treatments as described by Birch (1948). The net reproductive rate (R₀), the mean generation time (T) and the intrinsic rate of natural increase (rₘ) were computed on the assumption of a 1.0 female-biased sex ratio and 100% survival rate during the immature stage.

RESULTS

Development of C. menes reared on two host species

Table 1 shows developmental times of C. menes reared on F. intonsa and on T. palmi at 20 and 25°C. No significant difference was found in the developmental time between F. intonsa and T. palmi at 20°C. At 25°C, the egg and larval duration

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Host species</th>
<th>No. of parasitoids examined</th>
<th>Developmental times (mean±SD, days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Egg + Larva</td>
</tr>
<tr>
<td>20</td>
<td>F. intonsa</td>
<td>20</td>
<td>14.5±1.1 a</td>
</tr>
<tr>
<td></td>
<td>T. palmi</td>
<td>15</td>
<td>14.2±0.9 a</td>
</tr>
<tr>
<td>25</td>
<td>F. intonsa</td>
<td>20</td>
<td>9.2±0.5 b</td>
</tr>
<tr>
<td></td>
<td>T. palmi</td>
<td>20</td>
<td>8.7±0.7 c</td>
</tr>
</tbody>
</table>

*Means followed by the same letters in each column are not significantly different (Mann-Whitney U-test, p>0.05).
of parasitoids was significantly shorter on \textit{T. palmi} than on \textit{F. intonsa} ($p<0.05$, Mann-Whitney \textit{U}-test), but there was no significant difference in total developmental time between these two host species ($p>0.05$, Mann-Whitney \textit{U}-test).

The size of emerged \textit{C. menes} differed between the two host species (Table 2). \textit{C. menes} reared on \textit{F. intonsa} was significantly larger than those reared on \textit{T. palmi} in all three size indexes ($p<0.01$, Mann-Whitney \textit{U}-test).

**Reproduction of \textit{C. menes} reared on two host species**

Figure 1 shows age-specific survival rates and fecundity of \textit{C. menes} for the three treatments. There were no significant differences in longevity and total fecundity (total number of eggs laid throughout a life span) of \textit{C. menes} among the three treatments ($p>0.05$, Kruskal-Wallis test) (Table 3).

Parameters of population growth of \textit{C. menes} for the three treatments at 25°C are shown in Table 4. The intrinsic rate of natural increase of the parasitoid was highest in the treatment of \textit{F. intonsa} to \textit{T. palmi}. When allowed to oviposit in \textit{T. palmi}, the parasitoid reared on \textit{F. intonsa} (\textit{F. intonsa} to \textit{T. palmi}) had a higher intrinsic rate of natural increase than that reared on \textit{T. palmi} (\textit{T. palmi} to \textit{T. palmi}).

**Table 2.** Body size of \textit{C. menes} reared on two host species, \textit{F. intonsa} and \textit{T. palmi}

<table>
<thead>
<tr>
<th>Host species</th>
<th>No. of parasitoids examined</th>
<th>Body size (mean±SD, mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Pupal length</td>
</tr>
<tr>
<td>\textit{F. intonsa}</td>
<td>30</td>
<td>0.86±0.05 a</td>
</tr>
<tr>
<td>\textit{T. palmi}</td>
<td>30</td>
<td>0.75±0.05 b</td>
</tr>
</tbody>
</table>

\(a\) Means followed by the same letters in each column are not significantly different (Mann-Whitney \textit{U}-test, $p>0.01$).

**Table 3.** Adult longevity and total fecundity of \textit{C. menes} for three host treatments, \textit{FI-FI}, \textit{FI-TP} and \textit{TP-TP} at 25°C

<table>
<thead>
<tr>
<th>Host treatment</th>
<th>No. of parasitoids examined</th>
<th>Adult longevity (mean±SD, days)</th>
<th>Total no. of eggs laid (mean±SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>\textit{FI-FI}</td>
<td>20</td>
<td>5.5±2.5 a</td>
<td>118.6±49.7 a</td>
</tr>
<tr>
<td>\textit{FI-TP}</td>
<td>17</td>
<td>4.5±1.9 a</td>
<td>99.2±61.5 a</td>
</tr>
<tr>
<td>\textit{TP-TP}</td>
<td>7</td>
<td>8.0±3.7 a</td>
<td>109.7±53.9 a</td>
</tr>
</tbody>
</table>

\(a\) See Fig. 1.

\(b\) Means followed by the same letters in each column are not significantly different (Kruskal-Wallis test, $p>0.05$).
Table 4. Parameters of population growth of *C. menes* for three host treatments at 25°C

<table>
<thead>
<tr>
<th>Host treatment</th>
<th>$R_o$</th>
<th>$T$</th>
<th>$r_m$</th>
</tr>
</thead>
<tbody>
<tr>
<td>FI-FI</td>
<td>118.6</td>
<td>26.8</td>
<td>0.178</td>
</tr>
<tr>
<td>FI-TP</td>
<td>99.0</td>
<td>26.4</td>
<td>0.174</td>
</tr>
<tr>
<td>TP-TP</td>
<td>109.8</td>
<td>27.8</td>
<td>0.169</td>
</tr>
</tbody>
</table>

*See Fig. 1.

**DISCUSSION**

Different host species often influence developmental time, size, sex ratio, morphology, fecundity and longevity of parasitoids (Salt, 1940, 1941). In the case of *C. menes*, developmental time is related to the host thrips species (Loomans and van Lenteren, 1995). In comparing three host species, *F. intonsa*, *Thrips tabaci* and *T. hawaiiensis*, Murai and Loomans (1995) found that the egg and larval duration of *C. menes* was longer on *T. tabaci* than on the other two host species. However they showed that, similar to the present study (Table 1), there was no significant difference in pupal duration of *C. menes* among host species. These results suggest the possibility that the egg and larval development of *C. menes* is affected by the endocrine system of its host and is synchronized with host development, as hypothesized by Murai and Loomans (1995). Host species can influence not only developmental time of *C. menes* but also adult size (Murai, 1988). We also found that *C. menes* reared on *F. intonsa* were larger than those reared on *T. palmi* (Table 2). Comparing unparasitized insects, the body length of *F. intonsa* is longer than that of *T. palmi* (Kudo and Haga, 1988). Although *C. menes* is a koinobiont species (parasitoid that allow hosts to continue to grow in size after parasitism) (Askew and Shaw, 1986), the difference in host size among host species may be related to the wasp size.

Wasp size may affect its fitness through the impact of size on searching efficiency, longevity, egg supply, etc. (Godfray, 1993; Jervis and Copland, 1996). In general, larger parasitoids have greater fecundity and longevity than their smaller counterparts (Wylie, 1966; Smith and Pimentel, 1969). In this study, *C. menes* reared on *F. intonsa* were significantly larger than those reared on *T. palmi* (Table 2). However, there were no significant differences in adult longevity and total fecundity between the two host treatments, *F. intonsa* to *T. palmi* and *T. palmi* to *T. palmi* (Table 3). These results may be related to host defense against parasitoid. It is reported that thrips larvae exhibit defensive behavior toward host-attacking *C. menes* (Sakimura, 1937a; Loomans et al., 1993). If large parasitoids can more easily overcome this host defensive behavior than small ones, they might lay more eggs soon after emergence due to a larger supply of mature eggs. However, it is possible that this advantage makes large parasitoids use more energy for oviposition per day than their smaller counterparts, which may eliminate significant differences in adult longevity and total fecundity (Table 3).

In Amagi, *T. palmi* usually appears in July. Although a low rate of parasitism of native thrips by *C. menes* was found in June in some home eggplant gardens, the effectiveness of this parasitoid as a natural control agent of *T. palmi* becomes the greatest in September–October (Hirose et al., 1992; Takagi et al., unpublished). The question remains as to the sources of *C. menes* attacking *T. palmi* on eggplant in September. In this study, there were no significant differences in adult longevity, oviposition pattern and total fecundity between the two host treatments, *F. intonsa* to *F. intonsa* and *F. intonsa* to *T. palmi* (Fig. 1 and Table 3). Therefore, the parasitoids reared on *F. intonsa* can reproduce on *T. palmi* as well as on *F. intonsa*. These results suggest that *C. menes* is capable of switching host species from native thrips including *F. intonsa* to *T. palmi* seasonally in the field.

The intrinsic rates of natural increase of the two host species, *F. intonsa* and *T. palmi*, at 25°C were 0.158 (Murai, 1988) and 0.102 (on eggplant) (Kawai, 1986), respectively. The “Amagi” strain of *C. menes* has a higher reproductive rate than both host species (Table 4). Murai and Loomans (1995) studied development and reproduction of another Japanese strain of *C. menes* (collected in Shimane Pref.) on *F. intonsa*. Their “Shimane” strain had a shorter egg and larval duration, and a longer and more variable pupal duration than our “Amagi” strain. The value of 0.178 calculated as the intrinsic rate of natural increase for the “Amagi” strain (Table 4) was much higher than that of 0.1019 computed for the “Shimane” strain on *F. intonsa* at 25°C because of the shorter generation time of the
former (T=51.9 for the “Shimane” strain) (Murai and Loomans, 1995). For the “Shimane” strain, pupal durations were 105.9±63.1 (mean±SD, days) at 20°C and 38.5±7.4 at 25°C, respectively (Murai and Loomans, 1995). The lower variability in developmental time of the “Amagi” strain (Table 1) may be an additional advantage for mass rearing and release of the parasitoid. From these facts, we conclude that the mass-reared “Amagi” strain of C. menes using F. intonsa may be a viable option in controlling T. palmi.

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REFERENCES


