**Effects of temperature on immature development of the parasitic fly**

*Bessa parallela* (Meigen) (Diptera: Tachinidae)

**Ryoko ICHIKI,**¹,* Keiji TAKASU² and Hiroshi SHIMA¹

¹ Biosystematics Laboratory, Graduate School of Social and Cultural Studies, Kyushu University; Fukuoka 810–8560, Japan
² Faculty of Agriculture, Kyusyu University; Fukuoka 812–8581, Japan

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**Abstract**

Laboratory experiments were designed to determine the effects of four constant temperatures (15, 20, 25, and 30°C) on immature development of the gregarious larval parasitoid, *Bessa parallela*, using *Pieris rapae crucivora* as a host. The developmental rate from oviposition to adult emergence increased with increasing temperature. The lower developmental threshold from oviposition to adult emergence was 8.0°C for females and 7.5°C for males. The total effective temperature from oviposition to adult emergence was 333.3 degree-days for females and 250.0 degree-days for males. We estimated that *B. parallela* could have nine generations at most per year in Fukuoka City. Immature survival was not influenced by temperature, but the adults emerged at 30°C tended to have smaller body size than those at the lower temperatures.

**Key words:** *Bessa parallela*; Tachinidae; larval parasitoid; immature development; temperature

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**INTRODUCTION**

The parasitic fly, *Bessa parallela* (Meigen), is a gregarious larval parasitoid of serious lepidopteran pests such as *Pieris rapae crucivora* Boisduval and *Pryeria sinica* Moore (Shima, 1999). *B. parallela* females lay macrotype eggs on hosts, its hatched larvae developed within the host body and finally killed the hosts (Shima, 1999). Thus, *B. parallela* has a potential for a biological control agent of these pests. To use this tachinid effectively in biological control programs, it is necessary not only to conduct fundamental biological studies (Greathead, 1986). *B. parallela* is multivoltine and occurs from spring to autumn in the temperate zone of Eurasia (Herting, 1984; Belshaw, 1993). However, its life-history characteristics are unknown.

In this study, we examined developmental rates for immature stages of *B. parallela* at different constant temperatures to estimate its lower developmental threshold and total effective temperature. We also investigated the effects of temperature on the immature survival, adult body size and sex ratio at emergence. Based on these results, a suitable temperature range for immature development of this parasitoid was estimated.

**MATERIALS AND METHODS**

**Host and parasitoid.** Adult females of *P. r. crucivora* were collected at Hakomatsu, Nogochi, Ropponmatsu and Sakato in Fukuoka Prefecture, Japan during the period from April to November, 2001. These butterfly females were provided leaves of cruciferous plants in a plastic container (9.5 cm dia.×5.5 cm depth) or a plastic bag (30.0 cm length×40.0 cm width) for oviposition. After the eggs had hatched, the larvae were provided leaves of cruciferous plants until they reached the 5th stadium in a plastic dish (9.0 cm dia.×3.0 cm depth).

The colony of *B. parallela* originated from 12 female flies collected at Minami Park, Fukuoka City, in April, 2001. The colony has been maintained using *P. r. crucivora* and the silkworm, *Bombyx mori* (Linnaeus), as hosts in the laboratory.

**Effects of temperature on immature development.** Individual female flies within at least 96 h after mating were provided a host within 24 h after molting to the 5th stadium and allowed to lay one egg on the host in a plastic dish (9.0 cm dia.×3.0 cm depth) under room temperatures (22±3°C...
and 50±20% RH). If two or more eggs were laid on a host, all eggs except one were removed with tweezers. The parasitized hosts were individually placed in a plastic cup (7.5 cm dia. × 4.0 cm depth) and provided leaves of cruciferous plants. The cups with parasitized hosts were placed at 15, 20, 25, and 30℃ under a photoperiod of 16L : 8D and 50±20% RH. When parasitoid larvae emerged from the hosts and pupated, each puparium was transferred into a plastic cup (6.0 cm dia. × 3.5 cm depth) until adult emergence. The number of females used in this experiment was 8 for 15℃, 28 for 20℃, 6 for 25℃ and 7 for 30℃. The sex and head widths of newly emerged adult flies were individually measured under a stereo microscope.

Linear regression was performed to analyze developmental rates (the reciprocal of the number of days required for development) as the dependent variable and temperature as the independent variable. Based on the linear regression, the lower developmental threshold (\( T_0 \)) and total effective temperature (\( K \)) were estimated.

**Statistical analyses.** The development time and head widths of emerged adults were compared using Mann-Whitney’s U-test or Tukey-Kramer test. The \( \chi^2 \) test was conducted to determine whether or not sex ratios (to females) of emerged adults differed among the four temperatures. Pearson’s correlation coefficient was used to estimate the association between temperature and developmental rate. All analyses were conducted using StatView, version 5.0 (SAS Institute, 1998).

### RESULTS AND DISCUSSION

The mean development time for each developmental stage from oviposition to adult emergence decreased with increasing temperature in both sexes (Table 1). The pupal development time for males was significantly shorter than that for females at 20, 25 and 30℃ (Mann-Whitney’s U-test, \( p<0.05 \)), but not at 15℃ (\( p>0.05 \)). The total development time from oviposition to adult emergence was significantly shorter in males than in females at 15, 25 and 30℃ (Mann-Whitney’s U-test, \( p<0.05 \)), except for that at 20℃ (\( p>0.05 \)). These results indicate that *B. parallela* males tended to emerge a few days earlier than the females. In other tachinids, also, males are known to emerge a few days earlier than females (e.g. Webber, 1932;
Development of Bessa parallela

### Table 2. The linear regression equation, lower developmental threshold and total effective temperature for B. parallela

<table>
<thead>
<tr>
<th>Developmental stage</th>
<th>Sex</th>
<th>Linear regression equation</th>
<th>$p$</th>
<th>$r^2$</th>
<th>Lower developmental threshold ($T_0$) (°C)</th>
<th>Total effective temperature (K) (degree-days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eggs</td>
<td></td>
<td>$Y = 0.024X - 0.12$</td>
<td>$&lt; 0.05$</td>
<td>$r^2 = 0.997$</td>
<td>5.0</td>
<td>41.7</td>
</tr>
<tr>
<td>Larvae</td>
<td></td>
<td>$Y = 0.011X - 0.106$</td>
<td>$&lt; 0.05$</td>
<td>$r^2 = 0.996$</td>
<td>9.6</td>
<td>90.9</td>
</tr>
<tr>
<td>Pupae Female</td>
<td></td>
<td>$Y = 0.006X - 0.041$</td>
<td>$&lt; 0.05$</td>
<td>$r^2 = 0.999$</td>
<td>6.8</td>
<td>166.7</td>
</tr>
<tr>
<td>Pupae Male</td>
<td></td>
<td>$Y = 0.007X - 0.055$</td>
<td>$&lt; 0.05$</td>
<td>$r^2 = 0.997$</td>
<td>7.9</td>
<td>142.9</td>
</tr>
<tr>
<td>Oviposition Female</td>
<td></td>
<td>$Y = 0.003X - 0.024$</td>
<td>$&lt; 0.01$</td>
<td>$r^2 = 1$</td>
<td>8.0</td>
<td>333.3</td>
</tr>
<tr>
<td>-adult emergence Male</td>
<td></td>
<td>$Y = 0.004X - 0.03$</td>
<td>$&lt; 0.05$</td>
<td>$r^2 = 1$</td>
<td>7.5</td>
<td>250.0</td>
</tr>
</tbody>
</table>

*a* Linear regression analyses were applied to the developmental data within 15–25°C.

The parasitic fly, Exorista japonica Townsend (Diptera: Tachinidae), is oviparous and a generalist (Shima, 1999), and belongs to the same tribe Exoristini (e.g. Herting, 1984) as B. parallela. Naka- mura (1993) reported that the $T_0$ of E. japonica was 10–11°C (eggs: 10.0°C, larva: 10.7°C, pupa: 10.4–10.6°C, oviposition-adult emergence: 10.4–10.8°C). Because the $T_0$ of B. parallela was lower than that of E. japonica, the immature parasitoid of the former may be capable of developing in lower temperatures than that of the latter. B. parallela occurs widely in cool temperate and temperate zones of Eurasia (Herting, 1984), whereas E. japonica occurs in East and Southeast Asia (Crosskey, 1976) where it is generally warmer than the distribution...
area of *B. parallela*, although they occur sympatrically in some areas.

When parasitized hosts were incubated at 15–30°C, hatching rates of parasitoids were 71–96% and pupation rates were 50–68% (Table 3). Percentages of survival from oviposition to adult emergence ranged from 43–68. Percentages of survival from oviposition to hatching, pupation and adult emergence were not significantly different among four temperatures ($\chi^2$ test, $p>0.05$). Head widths of the females emerged at 30°C were significantly smaller than those at 20°C (Tukey-Kramer test, $p<0.05$, Table 4). Head widths of the males emerged at 30°C were significantly smaller than those at the lower temperatures (Tukey-Kramer test, $p<0.05$). Head widths of emerged adults were not significantly different between sexes (Mann-Whitney’s U-test, $p>0.05$), except at 20°C at which temperature head widths were significantly larger in females than in males.

In tachinids, the sex ratio is commonly about 0.5 (Waage, 1986; Godfray, 1994; Nakamura, 1995). In this study, there was no significant difference in the sex ratios among the four temperatures ($\chi^2$ test, $p>0.05$, Table 4). However, the sex ratio of the adults emerged at 30°C were the most male-biased. Sex ratio of emerged adults in parasitic wasps is influenced by either primary sex ratio or differential mortality for female and male progeny (King, 1987). In this study, the primary sex ratio among temperature treatments would not have been different, since hosts were parasitized at room temperature and the parasitized hosts randomly selected were placed at 15–30°C. Thus, it is likely that female progeny suffered a higher mortality than male progeny at 30°C.

In this study, the developmental rate at 30°C (females: 0.061, males: 0.071) appeared to be lower than that predicted from the linear regression line determined by data from 15°C to 25°C (females: 0.066, males: 0.090). The survival rate of the immature stages tended to be lower and the head widths of emerged adults tended to be smaller at 30°C than at the lower temperatures (Tables 3 and 4). The sex ratio of the adults emerged at 30°C was the most male-biased in the present study (Table 4). These results indicate that development of *B. parallela* at 30°C is above the optimal temperature for the immature stages.

### ACKNOWLEDGEMENTS

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### Table 3. Survival rates of *B. parallela* at four temperatures

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>No. of eggs examined</th>
<th>% hatching</th>
<th>% pupation</th>
<th>% adult emergence</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>20</td>
<td>90.0</td>
<td>60.0</td>
<td>50.0</td>
</tr>
<tr>
<td>20</td>
<td>38</td>
<td>73.7</td>
<td>63.2</td>
<td>50.0</td>
</tr>
<tr>
<td>25</td>
<td>22</td>
<td>95.5</td>
<td>68.2</td>
<td>68.2</td>
</tr>
<tr>
<td>30</td>
<td>28</td>
<td>71.4</td>
<td>50.0</td>
<td>42.9</td>
</tr>
</tbody>
</table>

*a There was no significant difference in survival rate (% hatching, % pupation and % adult emergence) among the four temperatures by $\chi^2$ test ($p>0.05$).

### Table 4. Head widths and sex ratios of *B. parallela* at four temperatures

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Head width (mm) (Mean±SE (N))</th>
<th>Sex ratio (to females)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Females</td>
<td>Males</td>
</tr>
<tr>
<td>15</td>
<td>2.30±0.09 (7) abA</td>
<td>2.10±0.00 (3) aA</td>
</tr>
<tr>
<td>20</td>
<td>2.31±0.04 (11) aA</td>
<td>2.18±0.02 (8) aB</td>
</tr>
<tr>
<td>25</td>
<td>2.21±0.05 (8) abA</td>
<td>2.13±0.02 (7) aA</td>
</tr>
<tr>
<td>30</td>
<td>2.03±0.06 (4) bA</td>
<td>1.90±0.04 (8) bA</td>
</tr>
</tbody>
</table>

*a Values followed by the same small letter within the same column are not significantly different by Tukey-Kramer test ($p>0.05$). Values followed by the same capital letter within the same row are not significantly different by Mann-Whitney’s U-test ($p>0.05$). b There was no significant difference in sex ratio among the four temperatures by $\chi^2$ test ($p>0.05$).
REFERENCES


