BROOD THERMOREGULATION BY THE DWARF HONEY BEE
(APIS FLOREA F.)

Michael Burgett1, Manas Titayavan2 and Chutikarn Kitprasert3

ABSTRACT

The brood temperatures ($T_b$) of a dwarf honey bee colony, Apis florea F., concurrent with the ambient temperatures ($T_a$), were recorded for a continuous 16-day period during the early monsoon season (June-July) in northern Thailand. For the period $T_b$ averaged 32.8°C while $T_a$ averaged 26.5°C. For 98% of the recording period the $T_b$ fell within a 3°C range delimited by 31.5°C and 34.5°C. The total $T_b$ range was 7.5°C while the $T_a$ range was 11°C. This brood temperature range is greater than that reported for the congener species A. mellifera L. and it is less than the range for A. dorsata F., another single-comb nesting species. The average brood temperature for A. florea is similar to that reported for other species within the genus. It is apparent that A. florea is able to maintain thermal control of the brood nest although without the precision of cavity nesting Apis species.

INTRODUCTION

Within the monophyletic genus Apis, the two species of giant honey bees, A. dorsata and A. laboriosa (Cockerell) and the two species of dwarf honey bees, A. florea and A. andreniformis Smith, build single comb nests which are exposed to ambient conditions of temperature, light, and relative humidity (Ruttner, 1988). These exposed-comb species maintain curtains of adult bees over the surface of the comb which function to provide nest thermoregulation and defense. Open-comb species ought to be less stenothermic in the rearing of brood than other Apis species, e.g. A. cerana F., A. koschevnikovi (Buttel-Reppen) and A. mellifera, which utilize cavities within which to construct multiple comb nests.

A. florea is described as a honey bee of the lowlands of South Asia (Ruttner, 1988). It is distributed from Malaysia and Indonesia in the east, to eastern areas of the Arabian peninsula. It therefore possesses the western-most distribution of any of the Asian Apis.

The microclimate, including the temperature, of an A. florea brood nest is maintained by a curtain of worker bees which is variable in thickness and distance from the comb (Lindauer, 1957). Free & Williams (1979) reported a brood temperature range of 33° to 38°C when the ambient temperatures were between 18° and 32.5°C. Lindauer (1957) reported a brood nest temperature that ranged between 34° and 36°C when the shade temperature was 42°C. Whitcombe (1984) reported a stable brood temperature just above 34°C during the daytime when the ambient temperature ranged from 32° to 36°C. A. florea

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is reported to be more efficient in cooling of the brood nest during periods of high ambient temperatures than heating the brood during periods of low ambient temperatures (Ruttner, 1988). Cooling is accomplished by fanning behavior of worker bees (Wongsiri et al., 1996), varying the thickness of the worker bee curtain, and by evaporation (Lindauer, 1956, 1957; Akratanakul, 1977; Whitcombe, 1984).

Our study presents the longest known continuous record of brood nest temperature regulation for A. florea. This temperature record is restricted however by the conditions of the early monsoon period (June–July) when ambient temperatures are characterized as relatively stable and not displaying any extremes at either the high or low range.

**MATERIALS AND METHODS**

The study was conducted during the period 24 June through 10 July 1993 in the Mae Rim District, Chiang Mai Province, in northern Thailand. The A. florea colony chosen for the study had nested 3 meters high in a longan tree (Dimocarpus longan Lour.). The nest comb was formed around a horizontal branch ca. 3 cm in diameter. Nest dimensions were 20 cm in width and 24 cm in length (top to bottom). The adult bee population was estimated to be 7,500 workers and a full brood pattern was evident throughout the course of the temperature measurements.

Brood and ambient temperatures were continuously recorded for 16 days using an electronic 2-channel temperature recorder (Omnidata Datapod microprocessor DP 212). One of the temperature probes (TP 10 V) was positioned perpendicular to the comb so as to just touch the surface area of the capped brood in the central area of the brood nest. The second probe, used for recording ambient temperatures, was positioned 50 cm below the bottom edge of the nest comb. The colony was in shade conditions during daylight hours. \( T_b \) and \( T_a \) were electronically recorded at 30-min intervals, with a clock accuracy of \( \pm 3 \) min/month. Recording began at 0800 h on June 24 and continued to 0730 h July 10, for a total of 767 paired \( T_b \) and \( T_a \) measurements. This produced a temperature record over a continuous 384.5 h.

The period of the temperature record was the early monsoon season in northern Thailand. Measurable precipitation fell on 13 of the 16 days of the recording period. A total of 64.5 mm of rain was recorded from 24 June through 10 July, with the heaviest precipitation (11.7 mm) on 9 July. During the recording period the maximum local ambient temperature was 35°C and the minimum was 23°C. The average daily relative humidity for the recording period was 71%. The local weather data were recorded at a Ministry of Agriculture weather station in Mae Taeng ca. 3 km from the nest location.

**RESULTS**

For the 16-day recording period the mean \( T_b \) was 32.8°C, while the mean \( T_a \) was 26.5°C. The \( T_b \) ranged from a low of 27.5°C to a high of 35.0°C (\( T_{diff} = 7.5°C \)). The \( T_a \) ranged from a low of 22.3°C to a maximum of 33.5°C (\( T_{diff} = 11°C \)). The maximum recorded difference between \( T_b \) and \( T_a \) was 9.5°C which was recorded at 0430 h on 3 July when
Figure 1. Diel means for $T_b$ and $T_a$ at each 30 min temperature recording interval (0000–2330 h). $N = 16$ for each time interval. Open bars = $T_b$, closed bars = $T_a$.

Figure 2. Summation for the number of hours $T_b$ was at the measured temperature intervals.
Figure 3. $T_b$ plotted over a range of $T_a$. $r^2 = 0.78$, $N = 767$ paired $T_b/T_a$ observations. The line through the origin represents the hypothetical $T_b = T_a$. The regression equation is $y = 0.275 + 25.47$.

Figure 4. An archetypal *A. florea* colony. Note propolis barrier for defense against ants. Photography by P. Akratanakul.
Table 1. Statistical summary of $T_b$ and $T_a$ data for the period 0800 h June 24 to 0730 h 10 July.

<table>
<thead>
<tr>
<th></th>
<th>mean</th>
<th>standard error</th>
<th>median</th>
<th>mode</th>
<th>standard dev.</th>
<th>min</th>
<th>max</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_b$</td>
<td>32.8</td>
<td>0.032</td>
<td>32.5</td>
<td>32.5</td>
<td>0.890</td>
<td>27.5</td>
<td>35</td>
<td>767</td>
</tr>
<tr>
<td>$T_a$</td>
<td>26.5</td>
<td>0.103</td>
<td>25.5</td>
<td>24.0</td>
<td>2.859</td>
<td>22.5</td>
<td>33.5</td>
<td>767</td>
</tr>
</tbody>
</table>

The $T_a$ was 23°C and the $T_b$ was 32.5°C. The $T_b$ maximum of 35°C was recorded at 1130 h on 28 June at a time when $T_a$ was also maximum for the recording period (33.5°C). Table 1 provides a statistical summary of $T_b$ and $T_a$ data.

The diel means derived for each 30-min recording period are shown in Fig. 1. The mean $T_b$ was maintained above the mean $T_a$ at each 30 m interval throughout the period. The minimum difference between the mean $T_b$ and $T_a$ (3.5°C) occurred at 1430 h ($T_b = 33.9°C$, $T_a = 30.4°C$), while the maximum $T_{diff}$ (8.3°C) was during the period 0500 to 0600 h ($T_b = 32.1°C$, $T_a = 23.8°C$), times which correspond to the coolest and warmest parts of the diel period. The average $T_{diff}$ between $T_b$ and $T_a$ for the recording period was 6.3°C. $T_a$ displays an expected cyclical diel pattern, and, although higher and much dampened in range, $T_b$ displays a partiality to track the circadian $T_a$.

The number of hours recorded for each temperature interval for the $T_b$ are shown in Fig. 2. Outliers of low temperature, *i.e.*, below 31°C and above 34°C, represent only 6.5 h of the 383.5 h recording period (2%). For 98% of the recording period the $T_b$ fell within the 3°C range of 31°C to 34°C.

The recorded low for $T_b$ (27.5°C) occurred in the afternoon of 9 July (1630 h). The $T_b$ 30 min preceding, at 1600 h, was 34°C, which is a 6.5°C drop in 30 min. For the same time period $T_a$ fell a corresponding 4°C, and a further 2.5°C from 1630 to 1700. We would suggest this is a local weather related phenomenon. This date recorded the highest amount of precipitation of any day during the recording period (11.7 mm).

Figure 3 shows the regression plot of the 767 $T_b$ recordings against a $T_a$ range of 15°C to 45°C. The regression formula for $T_b$ is $y = 0.275x + 25.47$, which is highly significant ($P<0.001$). This relatively small slope reflects the colony’s ability to thermoregulate the brood through a relatively wide range of ambient temperatures.

**DISCUSSION**

Although *A. florea* builds exposed combs, it maintained brood temperature within a narrow range. Evidence for this is seen in the small slope generated by the regression analysis, and the temperature record which shows that for 98% of the 16-day recording period the $T_b$ was maintained within the confines of a 3°C temperature zone. Dramatic changes in local weather could account for $T_b$ outliers.
A. florea is known to forage under conditions of high ambient temperatures. Adult A. florea workers have been shown to forage at ambient temperatures that will suppress A. mellifera foraging, i.e., >40°C (Whitcombe, 1984). The eastern-most distribution of A. florea extends along the western edge of the Persian Gulf where it is exposed to extremes of summer temperatures in excess of 50°C (Whitcombe, 1984). Extrapolating from our regression formula, at a $T_a$ of 40°C, the $T_b$ would be 36.5°C and at a $T_a$ of 50°C, the $T_b$ would be 39.2°C. In Thailand, a $T_b$ high of 39°C has been reported for A. dorsata, another open-comb species (Burgett & Titayavan, 1993).

The average $T_b$ of 32.8°C for A. florea is similar to that reported for other Apis species. For A. dorsata, another open comb species, an average $T_b$ of 33.2°C has been reported (Burgett & Titayavan, 1993). For the cavity nesting species, A. mellifera, Simpson (1961) reported a $T_b$ of 35°±0.5°C. Curiously, for A. cerana, a relatively well-studied species, we could find no published data specifically concerning brood nest temperature regulation, which is in agreement with Ruttnert (1988) about a paucity of information in this area of A. cerana biology.

REFERENCES


