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

Michael Burgett[1], *Manas Titayavan*[2] *and Chutikarn Kitprasert*[3]

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° 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*

[1] Department of Entomology, Oregon State University, Corvallis, OR 97331, USA.
[2] Department of Entomology, Chiang Mai University, Chiang Mai, 50200, Thailand.
[3] Ministry of Agriculture, Division of Entomology, Bangkok, Thailand.
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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 ±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° to a high of 35.0°C (T_{diff} = 7.5°C). The T_a ranged from a low of 22.3° to a maximum of 33.5°C (T_{diff} = 11°C). The maximum recorded difference between T_b and T_b was 9.5°C which was recorded at 0430 h on 3 July when

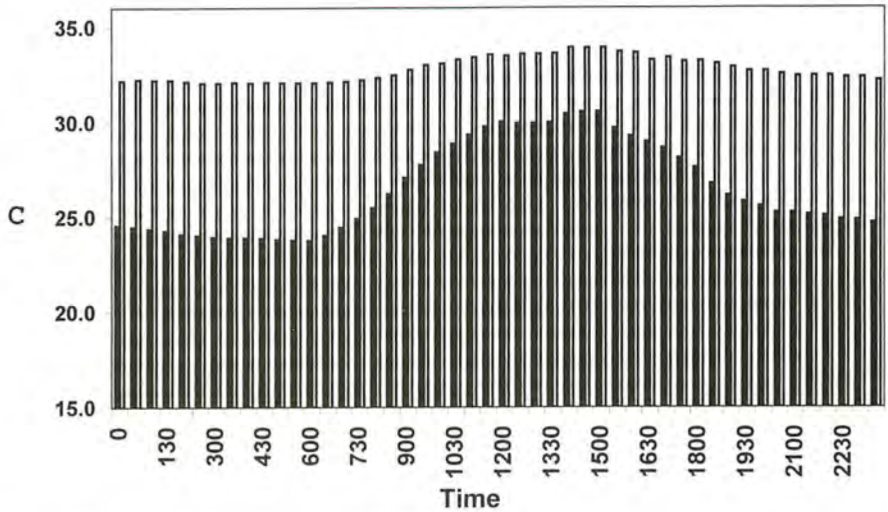

Figure 1. Diel means for T_b and T_a at each 30 min temperature recording interval (0000–2330 h). N = 16 for each time interval. Open bars = T_b, closed bars = T_a.

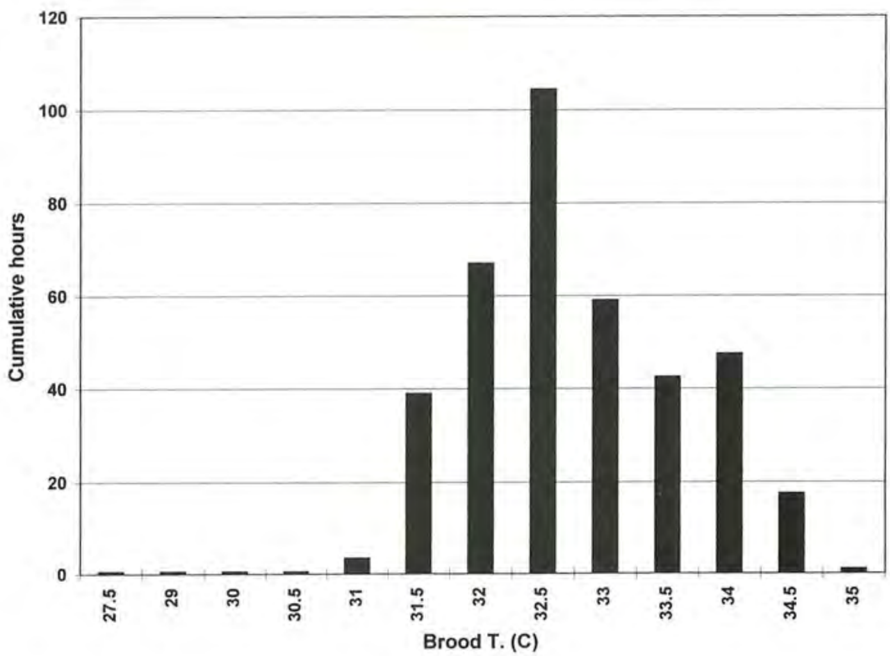

Figure 2. Summation for the number of hours T_b was at the measured temperature intervals.

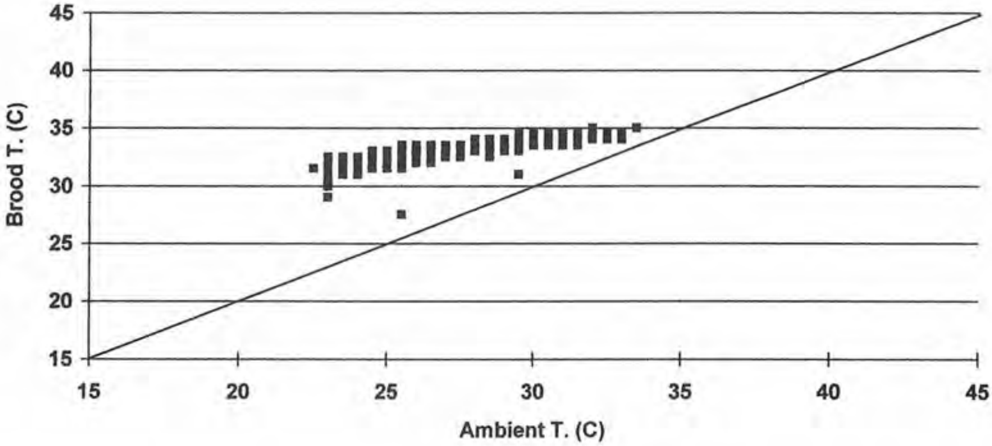

Figure 3. T_b plotted over a range of T_a. $r^2 = 0.78$. N = 767 paired T_b/T_a observations. The line through the origin represents the hypothetical $T_b = T_a$. The regression equation is y = 0.275 + 25.47.

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.

	mean	standard error	median	mode	standard dev.	min	max	n
T_b	32.8	0.032	32.5	32.5	0.890	27.5	35	767
T_a	26.5	0.103	25.5	24.0	2.859	22.5	33.5	767

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 31.5°C and above 34.5°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° range of 31.5° to 34.5°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° 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 surpress *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° 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 RUTTNER (1988) about a paucity of information in this area of *A. cerana* biology.

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