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BROOD THERMOREGULATION BY THE EASTERN HONEY BEE (*APIS CERANA* F.)[1]

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ABSTRACT

The brood nest temperature (T_b) of the eastern honey bee, *Apis cerana* F., along with the ambient temperature (T_a), were recorded for a continuous 30-day period during the cool season in northern Thailand. For the period, T_b averaged 35.2°C while T_a averaged 22.8°C. The T_b range was 3.2° while the range for T_a was 19.6°. The T_b range was modest relative to the T_a range and data are presented which demonstrate the exceptional ability of this honey bee species to maintain a thermal homeostasis within the brood rearing area of the colony.

INTRODUCTION

Brood nest thermoregulation by honey bees in the genus *Apis* is well documented for the western honey bee, *A. mellifera* L. (SIMPSON, 1961); the giant honey bee, *A. dorsata* F. (BURGETT & TITAYAVAN, 1993); and the dwarf honey bee, *A. florea* F. (BURGETT *ET AL.*, 1997). For the eastern honey bee, *A. cerana* F., there are few reports specific to brood thermoregulatory ability. KAPIL (1960) and VERMA (1970) published limited data on temperature from *A. cerana* clusters, but not specifically from the brood nest. DYER & SEELEY (1991) reported a brood temperature that ranged between 33° and 35° for *A. cerana* colonies maintained under incubator conditions as well as outdoors; however, they did not specify the breadth of their database in terms of the number of measurements, time periods, or locality. The absence of research in the thermoregulatory ability of *A. cerana,* a well-studied species, seems a curious anomaly (RUTTNER, 1988).

A. cerana is a multiple-comb-building, cavity-nesting species which has a long history of human management in its Asian expanse, an association which is probably as old as beekeeping with *A. mellifera* L. (RUTTNER, 1988) in Africa and Europe. The range for *A. cerana* is large and extends as far north as 46°N latitude in far eastern Russia (LAVREKHIN, 1958) to as far south as 7°S in the Indonesian Archipelago (RUTTNER 1988). Within the large geographical reach of *A. cerana* at least four subspecies are recognized (RUTTNER, 1988).

Beekeeping with *A. cerana* runs the gamut from traditional fixed-comb hives to moveable-frame colonies. The relatively recent introduction of *A. mellifera* into Asian beekeeping cultures has frequently resulted in a reduction of traditional *A. cerana* beekeeping. Nonetheless, *A. cerana* remains an important bee of commerce throughout its Asian range.

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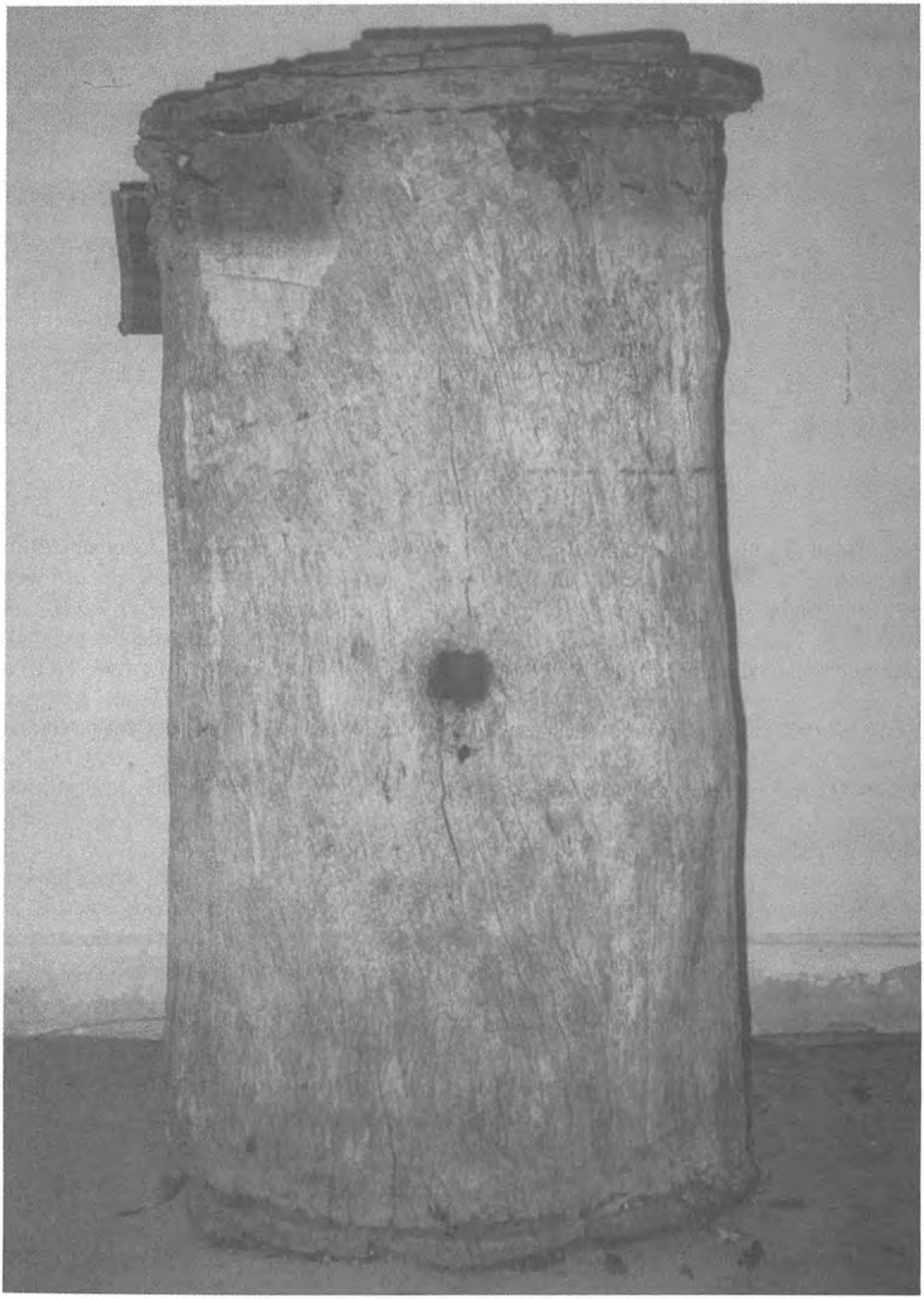

Figure 1. *Apis cerana* study colony. A stereotypic fixed-comb, "log" hive.

Our study presents the first record of *A. cerana's* ability to precisely regulate the temperature of the brood rearing area of the colony. It is based on continuous 30–day temperature sampling of the brood nest in a colony maintained under fixed-comb conditions, in a traditional, minimal intervention, management system.

MATERIALS AND METHODS

The study was conducted during the period 24 January through 22 February 1998 on the campus of Chiang Mai University in Chiang Mai Province, Thailand (18°78'N; 98° 98'E). This is during the dry, "winter" period in northern Thailand. No measurable precipitation was recorded during the 30–day period of temperature measurements.

The *A. cerana* study colony was housed within the cavity of a palm log, which had been modified with a crude bottom board and a top cover (Fig. 1). The colony represents a stereotypic "log" hive that receives minimal management on the part of a human beekeeper. The hive measured 58 cm in height and had a circumference of 108 cm. The interior wall to wall diameter was 25 cm, which provided a cavity volume of 28.97 l. The colony entrance was 6.25 cm^2 in area and was positioned centrally, 29 cm from the top of the hive. The hive entrance faced in a compass direction of 255°. The colony was in partial to complete shade during the entire study period. The hive was initiated from a feral swarm sometime near the end of December, 1997, and had been purchased from a local beekeeper in early January and moved to the Chiang Mai University campus.

At the initiation of temperature recording on 24 January the colony possessed six combs and an estimated adult population of 10,000. Brood (eggs, larvae and pupae) were observed in the four interior combs of the colony at the beginning and at the conclusion of temperature recordings. We observed the daily foraging by worker bees for nectar and pollen as well as afternoon drone flights, beginning in early February. These behaviors are indicators of a healthy and normal colony.

Brood (T_b) and ambient (T_a) temperatures were recorded continuously using electronic single channel temperature recorders fitted with external probes on 2–m cables (StowAway XTI data loggers, Onset Computer Corporation, Pocasset, MA, USA). For rigidity within the brood nest, the probe for measuring T_b was fixed to an insulated wire. The probe tip was positioned centrally between combs 3 and 4 and was located 9 cm from the top of the combs. The probe for measuring T_a was positioned 30 cm above ground and 20 cm to the north of the test hive. The loggers were programmed for reading the temperature every 15 minutes, which resulted in a temperature record of 2,880 paired readings over the 30–day period (0015 h 24 January through 0000 h 23 February).

RESULTS

For the study period the mean T_b was 35.2°C and the mean T_a was 22.8°C. Figure 2 displays the entire temperature record for T_b and T_a during the 30–day recording period. The T_b ranged from a low of 34.7° to a high of 37.9° (T_{range} = 3.2°). The T_a range was from a low of 13.6° to a maximum of 33.2° (T_{range} = 19.6°). The maximum recorded

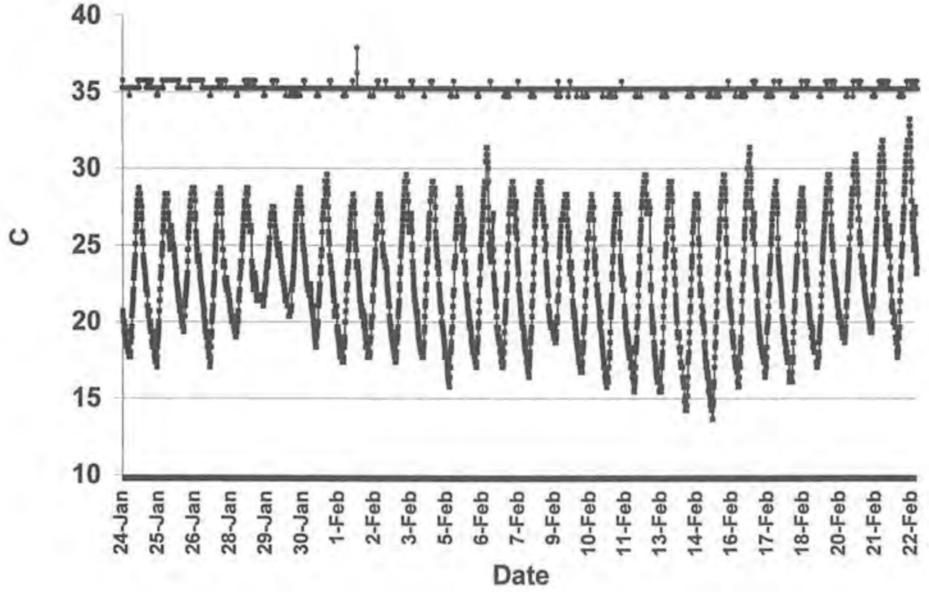

Figure 2. T_b and T_a record for the period 24 January through 22 February 1998. Circles = T_b; squares = T_a.

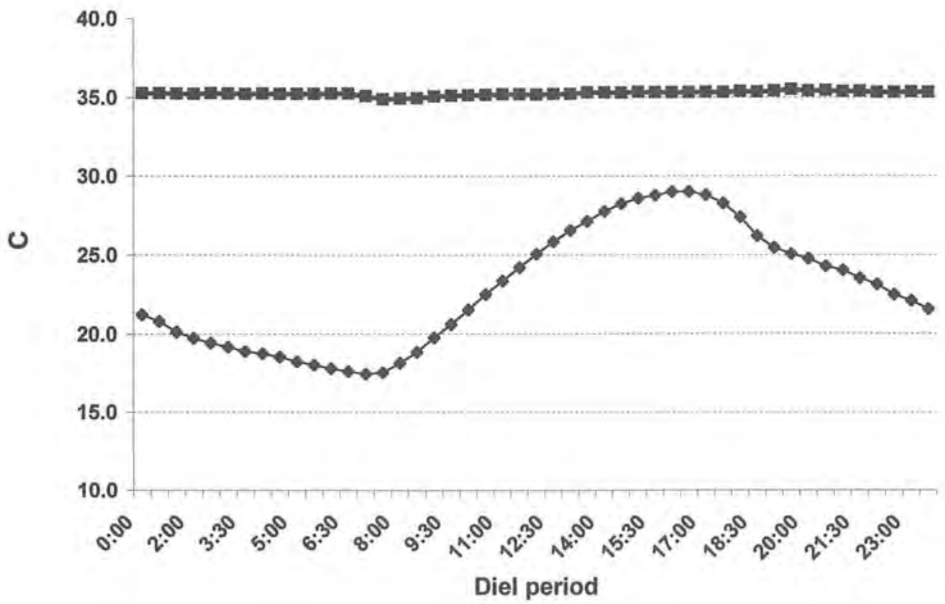

Figure 3. Diel means for T_b and T_a at 30-min temperature recording intervals (0000–2330 h). N = 30 for each time interval. Squares = T_b; diamonds = T_a.

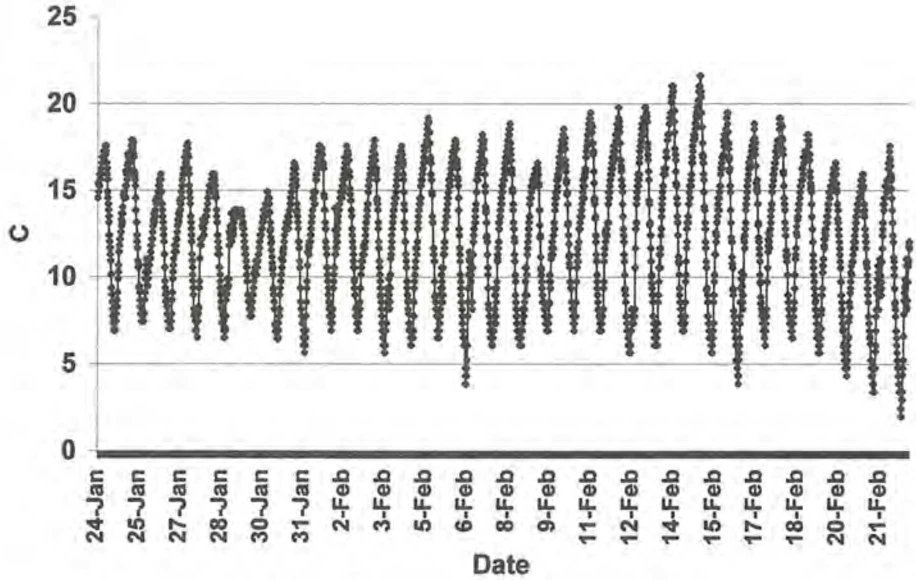

Figure 4. Temperature differential between T_b and T_a for the 30-day study period. Average T_{diff} = 12.4°C. $T_b > T_a$ for all 2,880 paired temperature measurements for the 30–day period.

difference between the T_b and T_a was 21.6° during an early morning period when the T_a was 13.6° and the T_b was 35.2°. The minimum recorded difference between T_b and T_a was 7.3°, when the T_a was 27.4° and the T_b was 34.7°. Table 1 provides the statistical summary for T_b and T_a data.

The diel means derived from averaging the temperature record at 30–min intervals are shown in Figure 3. The mean T_b was maintained above the mean T_a for each measured time interval throughout the day. The T_a displays an expected daily cycle for the mean diel period, while the T_b maintains a thermal constancy throughout the diel period. At the mean T_a low of 17.5° at 0700 h, the average T_b was 35.1° (T_{diff} = 17.6°). At the mean T_a high of 29.0° at 1600 h, the average T_b was 35.3° (T_{diff} = 6.3°).

Figure 4 displays the values for the parameter T_b minus T_a for the 30–day period. As the T_b was maintained above the T_b for all 2,880 recorded events, only positive values are produced. The average T_{diff} between T_b and T_a was 12.4°.

Plotting the individual 2,880 T_b values against the T_a range of 13.6° to 33.3° provides the database for Figure 5. The regression formula for T_b is $y = 34.83 + 0.02T_a$. The r^2 value is 0.10. Both parameters demonstrate the near independence of T_b relative to T_a.

In analyzing the number of hours for T_b in the recorded temperature range 34.7° to 37.9°, it is shown that 99.9% of all recordings fall between 34.7° to 35.7°, a rather remarkably small one-degree interval.

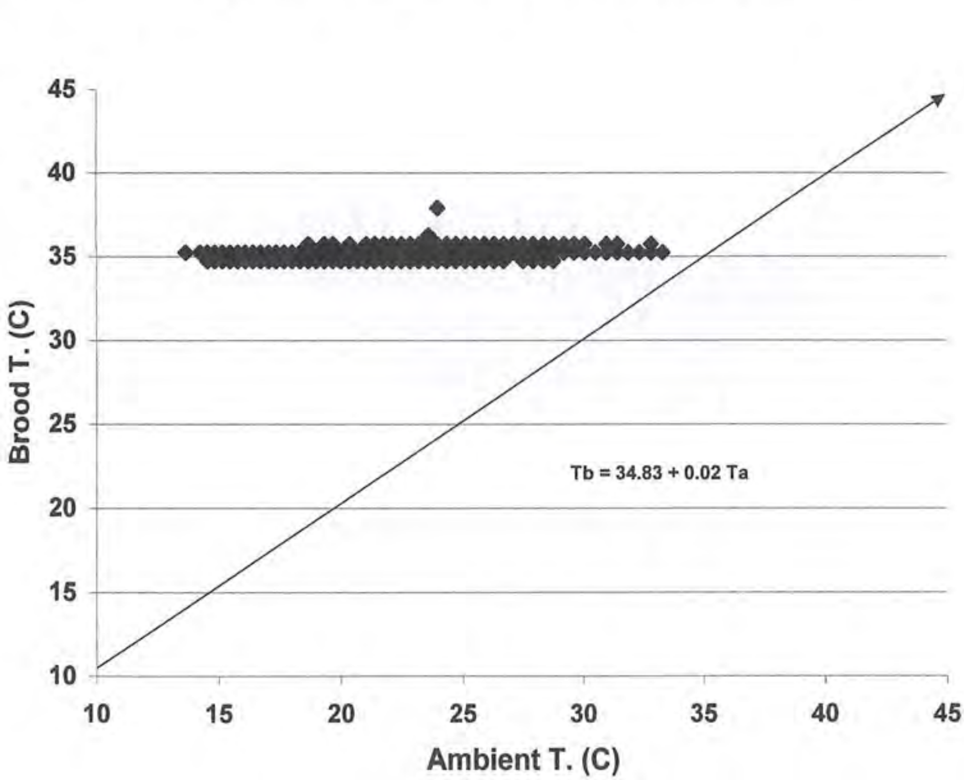

Figure 5. T_b plotted over a range of T_a. $r^2 = 0.10$, N = 2,880 paired T_b/T_a observations. The line through the origin represents the hypothetical $T_b = T_a$. The regression equation is $y = 34.83 + 0.02T_a$.

DISCUSSION

The temperature data reveal *A. cerana* to possess a finely-honed ability to maintain thermohomeostasis within the confines of the brood rearing area of the colony, which is, by and large, independent of ambient temperature. This is certainly aided by the cavity-nesting inclination of this species, as well as by the construction of multiple combs, both of which provide insulation and assist in the maintenance of a stable thermal environment. Throughout the 30–day period T_b was maintained above the T_a, which required the adult worker bees to provide the thermal input necessary to maintain the brood nest at 35.2°, a temperature that was significantly above the ambient throughout the study period.

In comparing brood temperature maintenance with other *Apis* species, *A. cerana* is classed with *A. mellifera*, another cavity nesting, multiple-comb building species whose T_b is reported at 35° ± 0.5°C (SIMPSON, 1961). SEELEY (1995), in a review of brood thermoregulation by *A. mellifera,* notes that the average T_b is 34.5° and varies less than 1° throughout a diel period during the active brood rearing seasons. These T_b limits are very similar to those we report for *A. cerana.* Both species are able to exert acute control over the T_b. The brood temperature maintenance for the open comb nesting species, *A. dorsata* and *A. florea,* while demonstrable, is not accomplished with nearly the same precision as *A. cerana* and *A. mellifera.* Table 2 compares the brood thermoregulatory competency for these four species.

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