ノート (Note)

Observation of egg incubation by a founding queen of the hornet *Vespa analis* (Hymenoptera, Vespidae) with thermography

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Social wasps, particularly of the subfamily Vespinae (hornets and yellow jackets), often cause sting incidents among people engaged in forestry or recreation activities in the forests. However, vespine wasps are important predators of insects, including forest or agricultural pests (Edwards 1980, Matsuura and Yamane 1990). Therefore, information on their biologies is indispensable to assess their negative and positive effects on ecosystem services.

Nests of temperate vespine species are initiated in the spring by single mated queens (founding queens). It takes 30–50 days from nest initiation to the emergence of the first batch of workers in the Japanese species (Matsuura and Yamane 1990). This period, known as "pre-emergence stage," is critical for the reproductive success of the founding queen, because approximately 50% of the initiated nests are abandoned or destroyed during this stage for various reasons (Matsuura and Yamane 1990). Therefore, it would be advantageous to the founding queen if she could shorten the duration of the pre-emergence stage by accelerating the hatching of eggs that produce workers.

One possible way for the founding queen to accelerate the hatching of eggs is to produce heat and warm the eggs. The founding queens of *Vespa simillima* and *Dolichovespula maculata* have been demonstrated to produce heat by studies in which temperatures inside pre-emergence nests were measured with thermistor thermometers (Makino and Yamane 1980, Stein and Fell 1994). Furthermore, Makino and Yamane (1980) found that temperatures of cell walls, to which the eggs were attached, increased by 2.5–4.0ºC when a *V. simillima* founding queen coiled herself around the pedicel of the comb (Fig. 1). This behavior, or "curling" (Makino and Yamane 1980), has been recorded among various vespine species. The above observations strongly suggest that vespine founding queens incubate eggs by transmitting the heat that they produce. However, it remains unclear whether the eggs are really warmed, because the eggs are so small and fragile to measure their temperatures using a contact thermometer. In addition, the body parts responsible for heat production remain to be determined in vespine queens, although the mesosoma that contains strong flight muscles is the most probable heat source as demonstrated in bumblebee queens that also produce heat in early nests (Heinrich 1972).

Thermography would show the heat distribution in the nest including the eggs and the founding queen without using a contact thermometer. Therefore, using thermography, I observed the temperatures of the body surfaces of the founding queen and how those of the cell walls and eggs changed with her behavior in a pre-emergence nest (i.e., the nest before worker emergence) of the hornet *V. analis*.

I selected an early pre-emergence nest for the thermographic observation in the arboretum of Hokkaido Research Center, Forestry and Forest Products Research Institute (HRC, FFPRI: 43.0ºN, 141.4ºE), in Sapporo, Japan, in June 2013. Pre-emergence nests of *V. analis* are composed of a single small comb and a single envelope sheet which is flask-shaped when completed (Matsuura and Yamane 1990). The nest used for the study was made on a twig of shrub at a height of 60 cm above the ground covered with short herbaceous plants; the envelope sheet was still incomplete so that the comb was visible through the large opening (entrance). The thermographic images of the founding

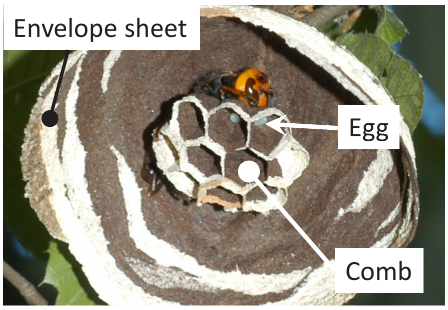

Fig. 1. A nest of *Vespa analis* in the pre-emergence stage. The founding queen is curling herself in the roof of comb. Envelope is partly removed to show the interior.

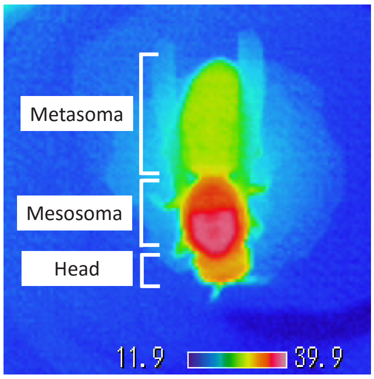

Fig. 2. Thermographic image of the founding queen of *Vespa analis* walking on the comb.

サーモグラフィーを用いたコガタスズメバチ創設女王による抱卵行動の観察
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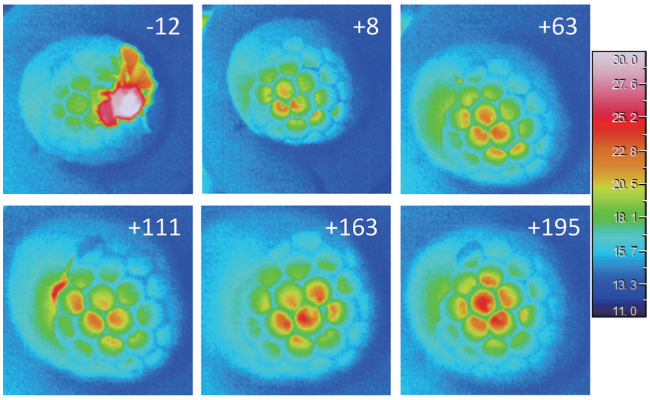

Fig. 3. Sequential thermographic images of the comb (19:58–20:02, June 21). Numbers in the images show elapsed time in seconds from the beginning of the curling behavior of the queen. Air temperature was 12.6 ºC at 20:00.

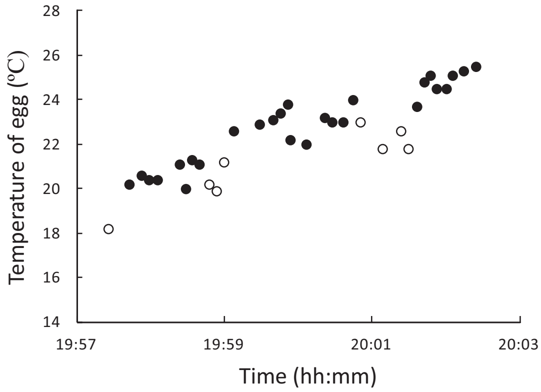

Fig. 5. Changes in the surface temperature of an egg in a central cell read from thermographic images (June 21). Air temperature was 12.6ºC at 20:00. Solid and open circles are as in Fig. 4.

queen and nest were obtained on June 20 (19:00–20:00), 21 (19:50–20:10), and 22 (16:00–18:00) with Thermoshot F30 (NEC Avio). The thermographic camera was placed under the nest, and images inside the nests were taken through the nest entrance that opened downward. Surface temperatures of cells, eggs, and the founding queen were determined from the obtained images using the software "NS9200LT" that came with the camera. The nest had 21 cells on June 20 and 21, and 22 cells on June 22; all immatures in the nest were eggs on June 20 and 21, while first instar larvae appeared in the central three cells on June 22. Air temperatures at a height of 1.5 m above the ground were also recorded every hour by a meteorological observation system near the arboretum.

Temperatures of the body surfaces of the founding queen constructing the nest envelope or walking on the comb were highest on the mesosoma (Fig. 2): 30.8–35.4ºC (air temperatures: 13.7–14.1ºC) and 28.3–34.1ºC (air temperatures: 12.5–15.0ºC) on June 20 and 22, respectively. While the temperatures of the head and metasoma were also higher than air temperatures, they were always lower than those of the mesosoma by approximately 6–10ºC. This demonstrates that the mesosoma is the primary source of heat as expected.

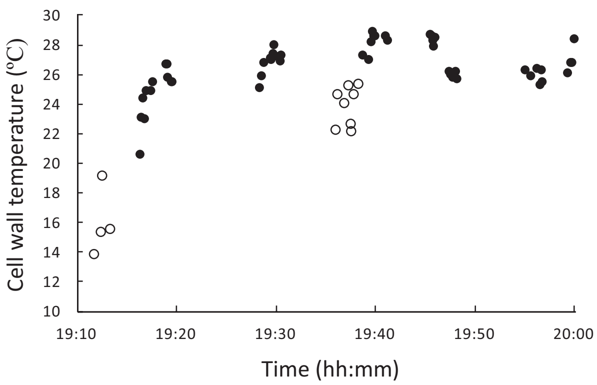

Fig. 4. Changes in the temperature of a point on a cell wall in the center of comb read from thermographic images (June 20). Air temperature was 14.1°C at 19:00 and 13.7ºC at 20:00. Solid and open circles show temperatures when the queen was performing curling behavior and those when she was walking or staying on the comb, respectively.

Sequential images in Fig. 3 show how the temperatures of cell walls changed with the behavior of the founding queen. Temperatures of the cell walls of central cells, but not of peripheral ones, immediately began to rise when the founding queen moved to the roof of the comb and curled herself around the pedicel. Fig. 4 shows the changes in the temperature of a cell wall in the central part of the comb; it began to rise when the queen moved from the undersurface of the comb to its roof and was maintained between 28ºC and 29ºC, while she was performing "curling," whereas it soon declined when she quit the behavior and descended from the comb roof. Temperatures of the egg surface also increased when the queen performed "curling" (Fig. 5).

These observations with thermography clearly demonstrate that the founding queen of *V. analis* warms eggs, at least those in the central cells, by transmitting the heat produced in the mesosoma in the early stage of nesting. Further study is warranted to understand to what extent the incubation period of eggs is shortened by this behavior.

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