Control of hive environment by honeybee (*Apis mellifera*) in Japan

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Introduction

It is known that honeybee, a kind of social insects, could control hive environment in order to survive in drastic environmental changes in field condition. Colonies of honeybee can keep the temperature within fairly narrow limits over a wide range of outside temperatures (Simpson, 1961). In order to know the thermoregulation mechanisms in honeybee hive, intensive studies have been conducted to correlate the temperature variability with changes in metabolic activity and honeybees' behaviors (e.g. Kronenberg and Heller, 1982). Existence of control mechanisms of humidity and carbon dioxide (CO_2) concentration are also suggested (Seeley, 1974; Human et al. 2006), but little is known about whether they are controlled independently from temperature because controls of temperature normally accompany with changes in respiratory emission of CO_2 and evaporation of hive water and nectar. It is also unclear how the colonial regulation of hive environment varies with diurnal and seasonal changes in ambient environment. Therefore, continuous measurements of multiple factors of hive and ambient environments are likely important in order to reveal the mechanism of environmental regulation of social insects, which differentiate them from other insects. In this study, we aimed to measure temporal changes in temperature, humidity, and CO_2 concentration simultaneously within and out of a honeybee hive. Changes of the hive weight were also measured in order to estimate how much energy consumed for the colony homeostasis.

Material and methods

Measurements have started in December 2007 using a hive of European honeybee (*Apis mellifera*). During the winter (December-February), the hive was placed in a large container (2.6W x 1.4D x 2.0H meters), where light environment was controlled in a fixed cycle (12 hours irradiation every day), but moved into field condition thereafter. We measured hive temperature and humidity using a bandgap and polymer sensor (Seirision; SHT-11) every minute and CO_2 concentration using nondispersion infrared radiation analyzer (Vaisala; GMT220, GMD20) every 10 seconds by 25 January and minute thereafter. These measurements were also conducted in an empty hive and the ambient in order to determine the impact of honeybee on the colonial environment. Hive weight was measured using a weight meter (A and D: FG-60KAL) hourly.

Results and discussion

The weight of hive decreased continuously around 30 g per day during the winter. Temperature within the hive increased in daytime and decreased in nighttime, which was constantly higher than outside. The diurnal pattern had a peak occurring later than that of the ambient, suggesting a time lag of temperature fluctuation between the two locations. The temperature of empty hive had similar tendency to the ambient, but the peak also delayed. This result suggests that the increase of active hive temperature caused by the presence of honeybee, supporting the former studies about the colonial thermoregulation of honeybees (e.g. Simpson, 1961). The humidity within the hive was higher than that of the ambient and fluctuated little even when the ambient humidity changed considerably. Since the magnitude and fluctuation patterns of the active hive were almost same with those of the empty hive, the humidity variation might be caused by the hive material and structure, not by the activity of honeybee. The hive CO_2 concentration fluctuated corresponding to the hive temperature even when atmospheric CO_2 concentration was in stable. We also observed that it sometimes increased drastically in midday, which might be caused by a circadian rhythm of honeybee (Kronenberg and Heller, 1982). In this study, we found that honeybee hive has a different microclimate from those of ambient, which partly caused by the honeybee activity. We also observed that humidity and CO_2 concentration could get effects from their own fluctuation, suggesting another controlling mechanisms for these factors that were different from those for the thermoregulation.

References

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