Honey Bees Don`t Like It Hot

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Temperature Measurements in Beehives during High Sunlight

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Summary: First measurements with the help of several temperature sensors in a beehive show that a high heat input through solar radiation in a beehive leads to stress in the bee colony. The bees show cooling behavior that can be observed directly and with sound analyses in order not to let the temperature in the hive rise above 38°C. A measurement without bees shows a difference in internal temperature of up to 7°C in a comparison between a shaded and an unshaded hive. The heat input can be reduced by simple measures such as shading by placing a rear-ventilated radiation shield. It is recommended to shade hives in summer.

Keywords: honey bee, beehive, temperature, regulation

1. Introduction

Honey bees can be exposed to many stresses during the year, e.g. lack of food at the beginning of the year (BRELL 2020), infestation with Varroa mites (TAUTZ 2012), foraging gaps in summer (SCHMIDT o.J.) and swarm lust (BIENEFELD 2005) in late spring. A cost-effective way to detect these critical stress conditions without having to open the hive - a bee colony in its housing - is to combine temporally and spatially resolved temperature measurements (BRELL 2020) with sound analyses (BRELL 2022b). The analysis of sound events in a bee colony can support the detection of the health status of the bees (TERENZI & CECCHI 2020; ROBLES-GUERRERO et. al. 2017).

Our project called Biene40 aims to develop digitally networked sensors for measuring honey bee colonies and thus create opportunities for beekeepers to detect bee stress indirectly from a distance. The project does not primarily serve basic research; the concrete benefit for beekeeping and bee health is essential here. We initially rely primarily on temperature measurements, as temperature is a good indicator of conditions in the hive. Bee larvae need a constant brood nest temperature between 32 °C (BECHER et al. 2009) and 37 °C (FAHRENHOLZ et al. 1989) to develop into healthy bees. The fluctuations of the brood nest temperature are only between 1 °C (SEELEY 1995) and 2 °C (FAHRENHOLZ et al., 1989). The queen bee needs a temperature above 15 °C in the hive (MCAFFEE et. al. 2020). The bees generate the required heat by vibrating their flight muscles without moving their wings. This vibration of the flight musculature generates airborne sound in the audible range of about 240 Hz. This makes it possible to include sound measurements in the investigations. When kept in artificial housing, honey bees can become temperature stressed when exposed to strong sunlight (SEELEY & MORSE 1976). If temperatures are too high, brood damage occurs; the stability of the honeycomb is also endangered (STABENTHEINER et. al. 2021). Moreover, above 38 °C, the viability of sperm stored in the spermatheca of the mated queen decreases (MCAFFEE et. al. 2020). When hive temperatures rise above 36 °C, bees begin active cooling behavior. In the first step, "fan bees" gather at the entrance hole and try to transport the warm air out of the hive by flapping their wings (TAUTZ 2016). If ventilation is not sufficient, collectors get water and distribute it on the honeycomb. The evaporation of water cools additionally. The vibration of the flight muscles and wings during ventilating produces airborne sound in the audible range with a frequency of about 190 Hz (WOODS 1957). In the following we report on first results, which show the direct benefit of the methodology we have developed (temperature measurements, sound measurements).

2. Material and Methods

The focus of the measurements is on temperature measurements, which are supplemented by evaluations of sound events. The observation level for the measurements in the Biene40 project is the beehive and its immediate surroundings (marking (2) in Fig. 1, modified after ZACEPINS et al. 2015). Further observation levels to be distinguished from this in Fig. 1 are the individual bee (1), an entire apiary (3) or the entire foraging area around an apiary (4). The setup for the measurements is shown in Fig. 2 (BRELL 2022a). Three digital temperature sensors (2) and a condenser microphone (3) are used in the hive (1). A Linux small computer (4) is used here as a recording device for the data. Temperatures are measured at 5-minute intervals and transmitted to a server (7) via a wireless Internet access router (5) and the Internet (6). In 15-min intervals, an additional sound recording of 10 seconds duration is made. The data can be viewed by a user (8) via an Internet page on the server. Basically, four different arrangements of temperature sensors in beehives can be distinguished (Fig. 3) (a) Single sensor on a top bar. A top bar is the upper wooden strip of a frame in which the bees build their combs. (b) Multiple sensors on the top bars to measure the lateral temperature distribution at the top of the hive. (c) Measurement of the vertical temperature distribution with a temperature lance - several sensors are arranged vertically. (d) Free arrangement of several sensors depending on the interest of knowledge. An exemplary position of the winter cluster or the brood nest - the main heat sources in the hive - is marked with "*" in Fig. 3. Of the various possibilities of placing temperature sensors in hives, the vertical arrangement of three sensors in the front third of the hive, close to the entrance, was identified as promising in preliminary tests (marking (c) in Fig. 3). As a reference, the temperature is also measured on the outside of the hive directly above the entrance. Sound events are recorded with a condenser microphone in a protective cover on the top bar near the temperature sensors.

3. Results

3.1. Measurement on Beehives

Figure 4 shows the temperature profile inside (4, 5, 6) and outside (1) the hive for two consecutive hot days (22.06.2022 and 23.06.2022). The surface temperature on the outside of the hive at the entrance exceeded 50 °C (1). As a result, the temperatures inside under the hive lid on the top bar increased rapidly from 16:00 on 22.06.2022, which can be seen on the left in Fig. 4 (2). By active cooling, the bees limited the temperature on the top bar to below 38 °C (3). The cooling behavior could be observed from outside, fan bees gathered on the approach board and ventilated the air from the hive. Simple shading by a radiation shield in the form of a back-ventilated wooden board on the hive lid reduced the heat input on 23.06.2022, the following day. The outdoor temperature (right in Fig. 4) also increased (1), the temperature on the top bar always remained below 36 °C (4). An active cooling behavior of the bees outside on the entrance board was not observed with this shading. For comparison, the internal temperature near the entrance (5) and at medium height (near the brood nest, (6)) is plotted. The temperature near the brood hardly varies. The cooling behavior can be detected by analyzing the sound events. Figure 5 shows two spectrograms, one without shading (Fig. 5 top) and one with shading (Fig. 5 bottom). The main difference in the spectrograms is a peak around 189 Hz, which can only be seen in the unshaded case (1), but not in the shaded case (2). Other noticeable peaks in the spectrograms (3) are technical artifacts and are due to interference from the power supply.

3.2 Control Measurement on Empty Hives

The temperature input due to solar radiation was checked in dark painted styrofoam hives with empty frames, but without bees. The temperature sensors were attached to the top bar. One hive (Fig. 6 right) received a radiation shield made of simple poplar plywood on two bearing timbers, the other hive (Fig. 6 left) did not. The bottoms of the hives were open and there was no wind at the time of measurement. The temperature in the unshaded hive was 7 °C higher at noon than in the shaded hive, and this was largely independent of the outside temperature. An effect comparable to shading could be measured with a white styrofoam lid instead of a dark lid with radiation shield.

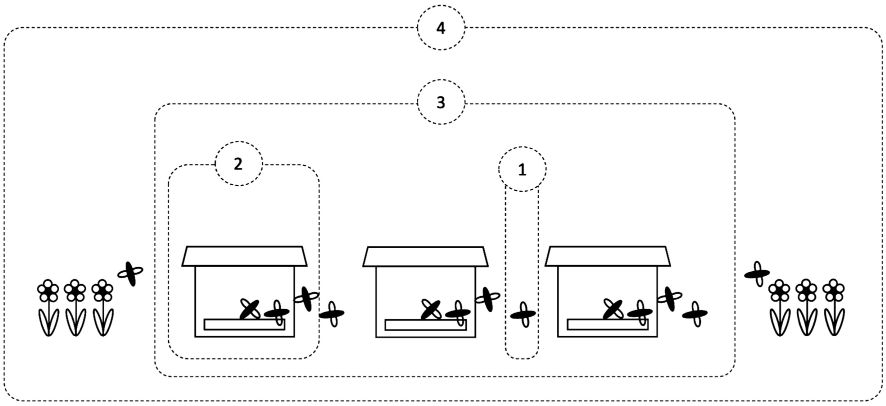

Fig. 1: Observation levels for measurements on honey bees according to Zacepins et. al (2015). They mean: (1) single bee, extent approx. 2 cm, (2) hive and immediate surroundings, extent approx. 1 m, (3) apiary with several hives, extent approx. 50 m, (4) foraging area, extent approx. 9 km.

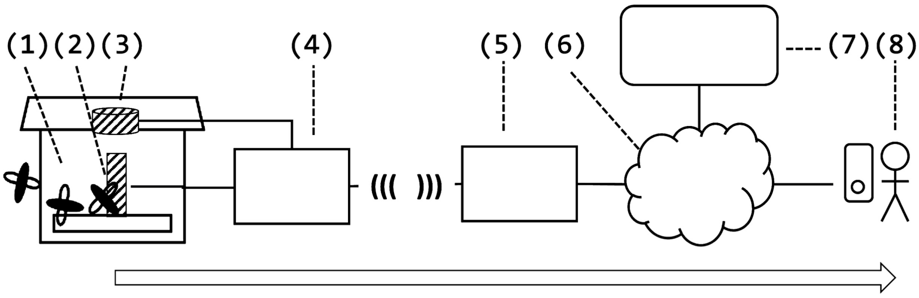

Fig. 2: Principle sketch of the monitoring of temperatures and sound events in hives. It means: (1) interior of the hive, (2) one or more temperature sensors, (3) microphone, mounted inside on the top bar (upper wooden strip of a frame), (4) microcontroller, which collects the data from the sensors and transmits it via wireless Internet access, (5) wireless Internet access router for connection to the Internet, (6) Internet, (7) Server on the Internet that receives the data, processes it and makes it available on the Internet via a website, (8) user with smartphone. Using this data communication channel, a user can also read the data from the hive remotely. The arrow below indicates the direction of the information flow from the left to the right.

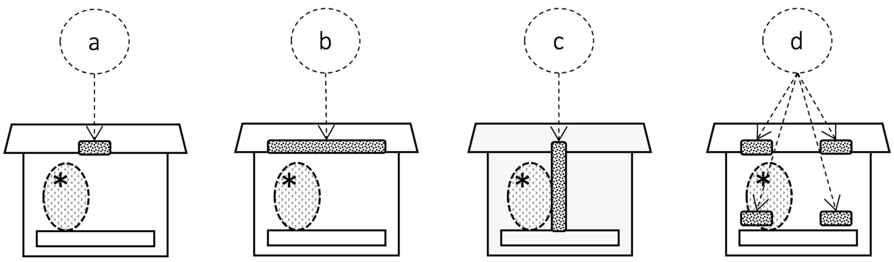

Fig. 3: Arrangement options for temperature sensors in the beehive. Differentiated are (a) single sensor, centrally positioned on the top bar, (b) multiple sensors in a horizontal plane at the top, (c) multiple sensors in a vertical arrangement, (d) project-specific arrangement of multiple sensors at different locations in the hive. The hypothetical position of the bees in the hive is indicated with *. The temperatures measured in each case depend on the heat gen rated by the bees, the distance of the sensors from the heat source, and - to a minor extent – the insulation of the hive. The measurements in this study were conducted using an arrangement according to (c).

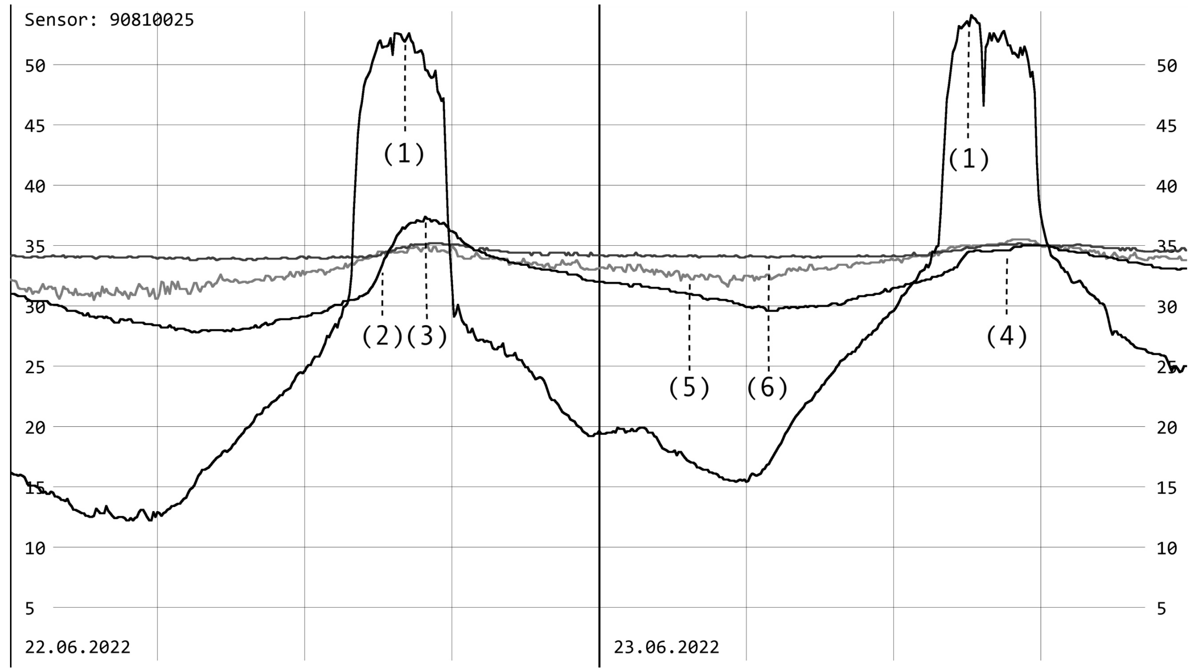

Fig. 4: Temporal temperature profiles inside and outside the beehive. Two days are depicted (horizontal axis), with a time interval of six hours between two vertical lines. It represents (1) the external temperature trend, noting the increase due to sunlight, (2) a vertical arrangement temperature sensor inside at the top, observe the steep temperature rise and the plateau at (3), the rise and height of the plateau on the second day at (4) are significantly lower, (5) temperature trend at the sensor located lower, near the flight entrance, (6) temperature trend at the sensor in the middle of the hive, close to the brood nest. Inside the brood nest, bees maintain a constant temperature at around 35°C.

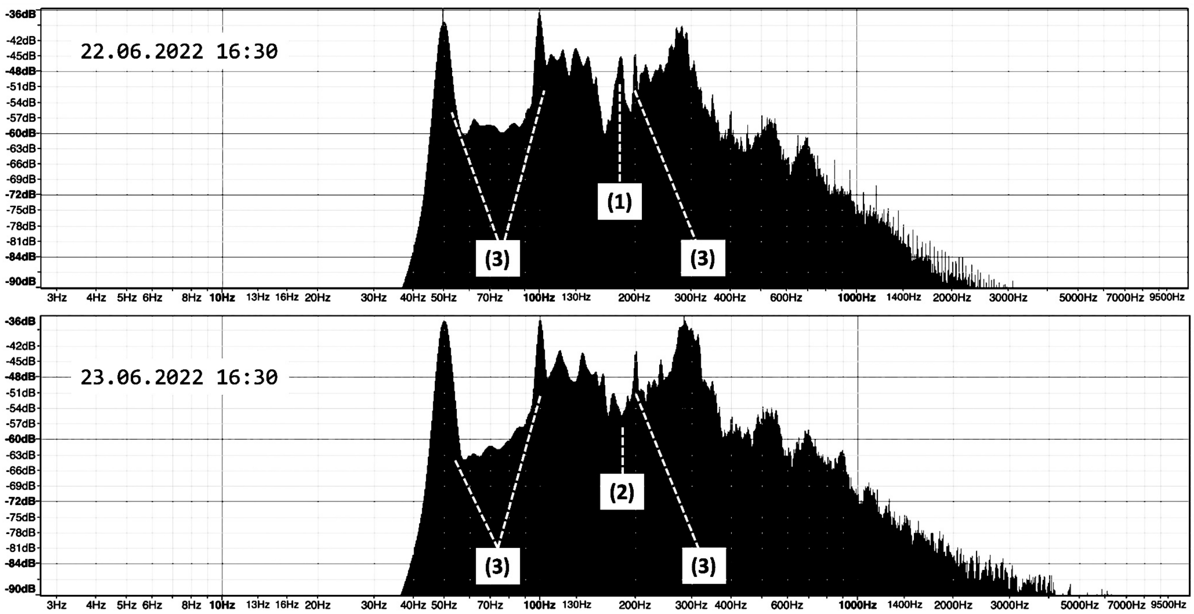

Fig. 5: Spectrograms of the sound events in the hive at the time without shading (above, June 22, 2022) and with shading (below, June 23, 2022). Note the peak at around 190 Hz on June 22, 2022 (1), which is not visible on June 23, 2022 (2). The peaks marked with (3) are measurement artifacts, caused by power supply interference.

Fig. 6: Setup for the control measurement in hives without bees. Styrofoam hives in Mini Plus format are used. On the left side of the image is the hive without a radiation shield, and on the right is the hive with a radiation shield, which is ventilated by resting on square wooden blocks. The box in the middle contains the microcontroller for displaying temperatures. Temperatures are measured according to arrangement (a) in Fig. 3.

4. Discussion

4.1. Interpretation and Critical Consideration

The measurements show that the temperature in an unshaded hive rises when exposed to sunlight both with and without bees. The temperature increase is actively limited by the bees in the unshaded hive through cooling behavior. Bees that actively cool do not bring in nectar and cannot take care of the brood. The rise in temperature thus represents a burden for the bee colony and may mean a reduction in beekeeping yields. With little effort in the form of back-ventilated shading (such as in Fig. 6), a reduction in the stress and thus an improvement in the animal welfare of honey bees can be achieved.

4.2 Consequences for beekeeping

In the Alpine region in Europe, beekeepers often work with shading, small bee houses or box-like enclosures for the hives. Hives are also painted white or light blue to reduce the heating of the hives by reflection. In the Lower Rhine area for instance, a white paint is rather unpopular, because white hives are more conspicuous and many beekeepers fear theft or vandalism. Damage or theft are not rare events. As our initial measurements show, simple shading is sufficient to significantly reduce heat gain. Shading can consist of a simple coated wood mat on 2 cm thick bearing timbers. A shade can be designed to be more inconspicuous than, for example, a light coat of paint. The use of shading - as an alternative to white painting - is therefore recommended when bee colonies are placed in the sun in summer.

Acknowledgement

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