APPLICATION OF BEE HIVE TEMPERATURE MEASUREMENTS FOR RECOGNITION OF BEE COLONY STATE

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Abstract: *Rapid improvements in modern temperature measurement systems and information technologies overall led to a possibility for temperature data to be used to monitor individual biological objects within the whole biological system. Beekeeping is one of the agricultural sub directions where information technologies and precision agriculture methods can be used too. In the field of beekeeping temperature measurement system can be adapted for the individual bee hive monitoring and maintenance, substituting the traditional monitoring methods. The main objective of bee hives temperature measurements is to monitor and control bee behavior and activity using an individual access to objects. Bee hive temperature measurements can provide beekeeper with continuous, real time data about the state of the bee colony. The main activity parameter for bee colonies is temperature, higher the temperature more active is bees. Based on this parameter beekeepers can make important conclusions and if needed perform some additional actions. Mainly monitoring the bee colony temperature is needed to find out if colony is started the brood rearing process and in case of need to slow down this process, because too early start can lead to the death of the whole colony. Based on author achieved measurement results during the passive wintering period, while bees are kept in the specific wintering building, it can be concluded that it is possible to precisely find out the date, when the bee colony died and find out the dates of the potential start of the brood rearing process.*

Keywords: temperature measurements; state recognition; bee colony monitoring.

Introduction

Bee hive temperature measurements can be used to understand and to monitor the honey bee colony activity and changes in it behavior. Many researches were connected with the bee hive temperature measurements and various researches using the available information and sensing technologies tried to complete the measurement task. Mainly bee colony temperature were monitored while bee hives were placed outside in open environment, but our research and this paper is concentrated on bee colony state recognition during the passive wintering period, while bee hives are kept in closed environment in special bee wintering building. In our case we artificially made the needed external environment with constant air temperature.

Activity and behavior features of bees have been as investigation object for many researches, starting from far 1926 when W.E.Dunham measured temperature inside one bee hive using 8 thermometers. Using this thermometers bee hive temperature was measured each hour. As a result graph of average bee hive temperatures were obtained (Dunham, 1926). Already at that time it was concluded, that air temperature affects the bee activity much more than other environmental parameters, such as humidity and gas composition. Also from that measurements, were obtained data that showed, that in active brood rearing state bee colony temperature increases till 30°C.

One more research were made in Rumania in 2004, when hive temperature changes, humidity and dew point were registered using the three digital sensors. Research aim was to develop information system for real time parameter monitoring. Monitoring task was to find out adverse effects on bees and to develop preventive methods (Vornicu and Olah, 2004).

Scientifically valuable research took place in Riga, Latvia in 2000, when E.Stalidzans developed the bee hive temperature monitoring system. The aim of that system was to monitor hive temperature changes during the whole year to determine the start and end dates of the bee activity states (Stalidzans et al., 2002).

One more interesting research was made in Jelgava, Latvia in 2008, when J.Meitalovs developed bee hive humidity and temperature measurement system for determination of honey bee pre swarming condition. System consists of temperature and humidity sensors network, control application and video monitoring module (Meitalovs et al., 2009).

Paper author have made bee hive temperatures measurements with main aim to determine honeybee colony developmental stage and to understand if temperature changes really corresponds to the changes of the bee colony activity state. Main feature of this research is that during the measurements bee hives were kept in artificially made environment (wintering building).

Bee wintering buildings practically in Latvia are not used. Observations in "Vecbebru" beekeeping technical college shown, that heated wintering building in Latvia are not economically beneficial (Ārgalis et al., 1970). But in Canada these special buildings are successfully applied (Furgala and McCutcheon, 1992; Fingler and Small, 1982).

With the development of wintering building installation technologies, the main aspect goes to microclimate regulation and control (Fingler and Small, 1982). A rational building construction and installation calculation for Latvia region also is made (Kristapsons et al., 1996).
Looking at such building application worldwide, it can be concluded that they are used in such climatic conditions, where winters are especially harsh, where bee wintering in open air ends with very high percent of dead bees. But very low temperatures are only the one factor, another one is often temperature changes from plus to minus degree. This can be seen also in Latvia climate region.

Recognition of the bee colony state

Author proposed model of the bee colony activity state recognition is demonstrated in Fig.1:

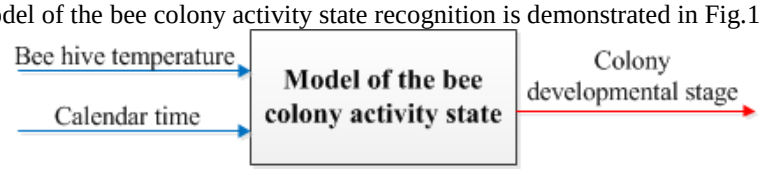

Fig. 1. **Model of the bee colony activity state recognition**

This model can be used during the whole bee colony life cycle, but information that can be mined from temperatures data differs from calendar time. It means, for example, that same data in summer and in winter shows different information.
During the passive wintering process based on temperature data it is possible to distinguish three bee colony activity states (see Fig.2):

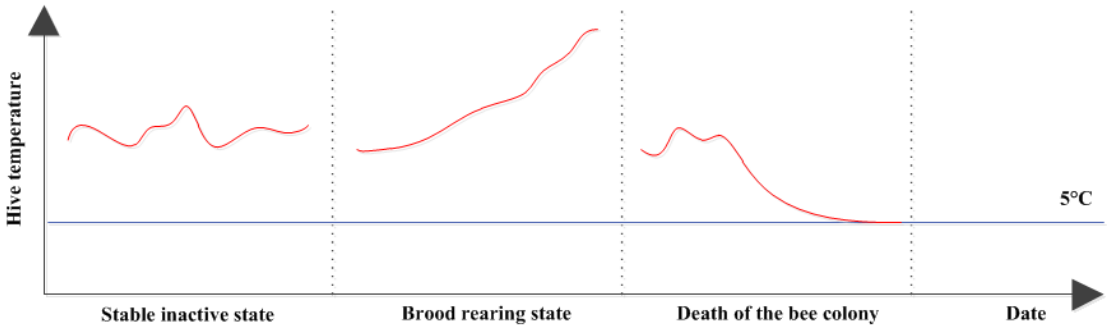

Fig. 2. **Three honey bee colony developmental stages during the wintering process**

Based on temperature data it is possible to conclude if the bee colony is in a passive/inactive state, if the brood rearing process has started and if the bee colony is still alive. This information is very useful for the beekeeper, because it is needed to monitor the brood rearing process, and if this process has started too early it is needed to slow down or stop this process. Premature start of bee breeding in the winter can cause high energy consumption of the bee colony that, in turn, can lead to a possible death of that colony. That is the main risk factor during the wintering in the special building.

Experiment configuration

The main microclimate parameter for bees is temperature. Temperature is an important factor that influences the start of brood rearing in the winter (Seeley, 1985; Mattila, 2001; Mobus, 1998).
Main feature of author research is that during the measurements the bee hives were kept in artificially created environment with controlled microclimate. Bee hives were placed in special wintering building, where an automated control system was used to keep inside temperature at a constant level. According to the literature and practical investigations, desired temperature band for bees during the winter is between 3°C and 8°C (Jeskov, 1983). When the temperature is outside of this band the food consumption of bees increases (Fig. 3).

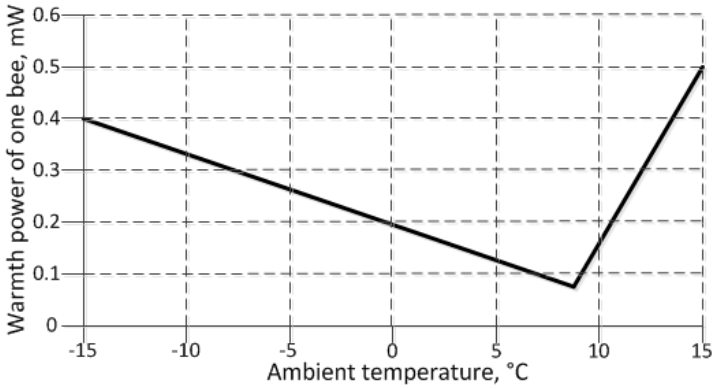

Fig. 3. **Dependence of bee warmth power from ambient temperature (Jeskov, 1983)**

The honey bee wintering building is a building sized 6,25m×4,00m×2,40m made of sandwich panels with wall thickness of 80 mm and the roof thickness of 100 mm (Osadcuks and Stalidzans, 2008) (Fig. 4.):

Fig. 4. **Honey bee wintering building**

To control the building temperature it is needed to develop automatized control system. In author case building temperature control was accomplished by a PLC device (Siemens S7-200 controller with CPU 224XP). PLC is a digital computer used for automation of electromechanical processes and is designed for multiple input and output arrangements. PLC controlled other needed equipment in the wintering building. The controlled equipment were: air recirculation fan for homogenizing the air and its temperature inside the building, cooling ventilator system, fresh air fan and electrical duct heater (Zacepins et al., 2010).

The main task of the system is to control the temperature changes in the wintering building. Inner temperature is measured, using the Siemens Sitrans TF2 sensor. Duct heater is functioning using the PLC integral PID algorithm. The air is heated till the target temperature is reached. PLC user program is written using the Ladder Diagram programming language (Zacepins et al., 2010).

Author did practical experiments obtaining the bee hive temperature measurements in closed environment created in the wintering building. In this building up to 30 bee hives were placed. Each hive was equipped with small digital temperature sensor (Fig.5). All sensors were sequentially connected with Temp08 interface device, while it was connected with the end PC using the COM port. All data from the sensors were transmitted to the PC database (Zacepins et al., 2011).

Fig. 5. **Developed bee hive temperature measurement system in wintering building**

When developing such temperature measurement systems one of the main aspects is to choose the right sensor and sensing technology. In our case it was possible to use both wireless and wired solutions. Wireless solution is a modern one, but it is needed to evaluate also other factors. For example in author situation system had to work up to 4 month without maintenance and it was hard to find wireless sensors with so high battery capacity.

Author have developed wired temperature measurement system. Small ds18s20 sensors were used for temperature measurements. These small sensors were soldered to a small plate, granting wire connection.

Then sensors were sequentially connected one with another using the 1-wire network protocol. 1 wire protocol was developed by Dallas Semiconductors Company. With such network it is possible to connect different types of devices and sensors. Classic 1-wire network connection scheme is shown in Fig. 6:

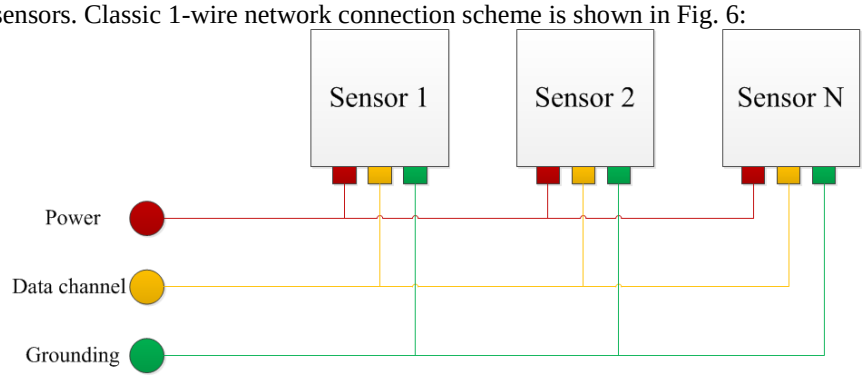

Fig.6. **Classic 1-wire network connection scheme**

1-wire system allows to use almost unlimited count of sensors, allows to decrease cable length, exclude the impact of the line length to precision of the result (Baums et al., 2004).

When developing large 1-wire systems it is important to create the network correctly already during the design stage, otherwise some problems can occur during the data harvesting process.

For data saving and analysis all sensors were connected to the special interface device Temp 08, which transmitted all the data to the end device (PC).

Results and Discussion

Author experimental temperature measurement system consisted of 34 sensors, where 30 sensors were placed into the bee hives, 2 sensors measured inside temperature of the wintering building and 2 sensors – the outside air temperature.

During the data analysis stage, when all temperature data were summarized in MS Excel using the pivot tables and pivot charts author received many temperature data curves that were almost ideally reduplicated proposed model of the bee colony activity state. Analyzing the achieved measurements author founded examples for each bee colony activity stage.

Three graphs (Fig. 7, Fig. 8, Fig. 9.), demonstrates examples of practical results with some single bee colony activities.

Figure 7 demonstrates situation when a whole bee colony died. This conclusion can be made at the point when honey bee hive temperature sharply decreases and converges with external air temperature. Unfortunately for the beekeeper, it is not possible to predict that bee colony will die – it is only possible to conclude the fact when the colony is already dead. To someone this information seems to be unnecessary, but making survey to Latvian

beekeepers they approved, that knowing the count of dead colonies during the winter is useful. It can help to prepare and to predict economic situation, which is likely to appear in summer.

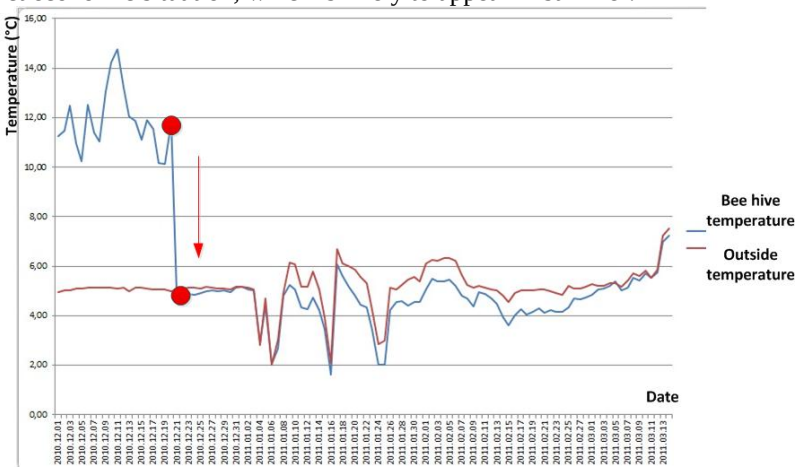

Fig. 7. **Dead of the bee colony**

Figure 8 demonstrates situation when bee colony were in passive state. This conclusion can be made when honey bee hive temperature is not fluctuating. In this state the bee colony food consumption is optimal.

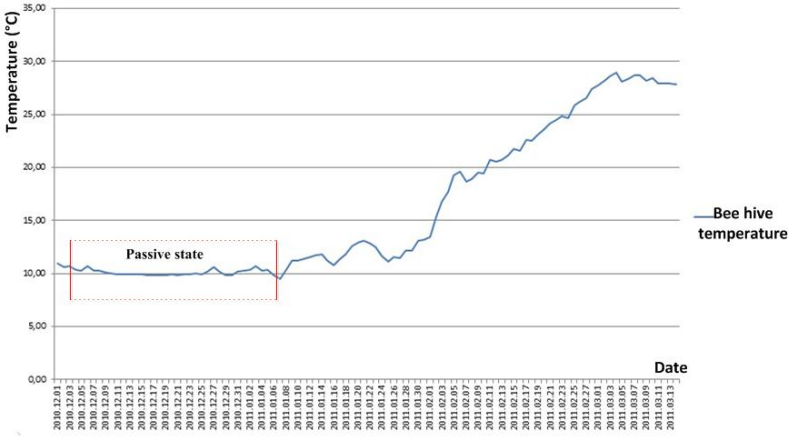

Fig. 8. **Passive state of the bee colony**

Figure 9 demonstrates situation when bee colony were in brood rearing state. This conclusion can be made when honey bee hive temperature is starting to increase. For the beekeeper it is very important to find out when the brood rearing process starts and if it is needed to slow down this process.

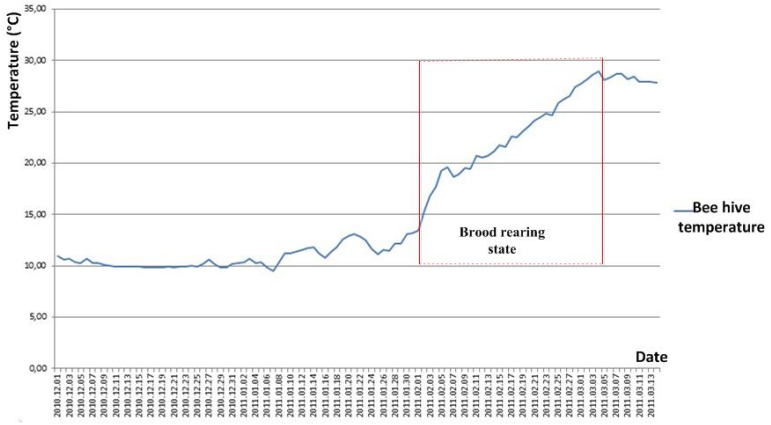

Fig. 9. **Brood rearing state of the bee colony**

Conclusions

Bee hive temperature measurements offer possibility of collecting data about bee activity and behavior in a continuous, real time and automatic way. But of course while monitoring bee colony processes it is not possible to fully replace the beekeeper "eyes", it remains as an important end decision maker.

Author have made temperature measurements to monitor the activity of bees inside each individual hive during the passive indoor wintering period in a closed environment as it is honeybee wintering building, where it is possible to grant stable and convenient microclimate conditions for bees. In passive wintering period it is important to mark such events as the death of the bee colony and have up to the date information about the state of the brood rearing process. The process of intensive brood rearing leads to the increased consumption of food and to the waste of energy. As a result, the whole bee colony can die. The rapid increase of temperature is a signal of a potential start of intensive brood rearing.

Practical results showed that it is possible to obtain the needed information during the temperature measurement process with high precision.

The developed temperature measurement system can be used also in other agricultural fields where it is needed to make some precise decisions based on temperature data.

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