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Acquisitions and evaluation of beehive parameters through an electronic system

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ABSTRACT
This study highlights the management of the hive superorganism, with the help of technology. Precision beekeeping is today a growing sector, used as apiary management strategy, based on the constant monitoring of families, minimization of consumption of resources and maximizing of productivity. Thanks to the scales and a probe placed inside each hive, we obtained data relating to winter 2021 and spring 2022, where we had flowerings 30 days in advance of the seasonality. The fluctuation of temperatures entailed the early start of laying of the queen with fresh brood to feed and heat, even when temperatures dropped drastically, having to draw on pollen and honey stocks massively. The role of the beekeeper becomes crucial, to avoid compromising the annual production and to help the survival of the colony. To know the situation inside the hive without opening it and administering an adequate nutrient supply at the right time is not always easy, and the death of beehives due to hunger is typical of the spring period. Climate changes are increasingly affecting the survival of bees and remote monitoring of beehives is becoming increasingly important to ensure their survival and productivity.

Section: RESEARCH PAPER

Keywords: beekeeping; measurements; support feeding; technology; overwintering

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1. INTRODUCTION

In recent years, the life of honeybees and the management of hives by beekeepers have become increasingly complex and articulated. To obtain performing and healthy bees in spring, wintering must be as close as possible to their physiology. Climate changes and global warming create internal imbalances in the hives, altering the biology of the "superorganism" and causing a temporal misalignment between biology of bees and the flowering of botanical essences essential for their survival, a combination that has stabilized for thousands of years [1]. Today it is possible to monitor constantly the physical variables of the colonies, thanks to the use of increasingly precise and performing electronic devices [2], [3]. Data such as weight, external and internal temperature, humidity, and sound of the hive represent parameters that can be used to better understand the life of the hive without creating disturbance, avoiding visual inspections of families, harmful in periods such as winter [4]. Honeybees tend to maintain a stable environment inside the hive, despite external altering factors that may force them to make behavioural changes that the beekeeper must promptly know to support them. They are heterothermic animals and the adjustment of body temperature to the environmental one strongly constrains their physiology and ethology, for survival. It is now established that honeybees are subject to biochemical and physiological changes linked to seasonality and food availability [5]. Honeybees have implemented strategies to survive even in periods of shortage of pollen and nectar: eusociality, the formation of clusters and the blocking of deposition by the queen are fundamental strategies for resistance to winter temperatures.

The reduction of autumn temperatures and of the photoperiod, as well as the decrease in pollen resources and collection, trigger the onset of wintering [6]. A good winter metabolism allows honeybees to preserve energy reserves which will be very useful in spring at the beginning of the new season. Cycles of freezing temperatures alternating with warmer temperatures can reduce honeybees' tolerance to low temperatures [7].

Overwintering is a complex process and is influenced by multiple biotic and abiotic factors. Although honeybees can adapt to temperature variations, the climate has a significant impact on the collection of food and on individual and social behaviour. Autumns characterized by gradual drops in nighttime temperatures and relatively mild days trigger wintering in the appropriate way, with the production of the fat body. Due to neuro-hormonal influence, honeybees prepare themselves from an anatomical-physiological point of view to survive in winter. "Winter bees" change their abilities, focusing on heat production and cluster survival [8]. Only the rise in temperature, the presence of brood and the resumption of flowering allow the restoration of the specialization of the honeybees.

The respiration and muscular activity of the honeybees stops below 10°C; to avoid this eventuality, the honeybees form the cluster, producing heat thanks to the vibration of their thoracic muscles. In the outermost layer of the cluster, therefore, the temperature never drops below 6°C, a critical temperature for the survival of the single individual. Usually, the external temperature of the cluster settles on 12°C while the internal one on 25°C, and it is maintained even with external temperatures below zero. If, on the other hand, the mild or hot temperatures continue too much in the autumn or even in the winter season, the honeybees show a greater expenditure of energy, not forming the cluster [9].

Even excessively cold temperatures can limit the reaching of food supplies and therefore cause honeybee mortality. Approximately, 20% of the winter mortality variability can be explained by meteorological conditions [10]. Studies conducted in Austria [11] and the Netherlands [12] support the evidence that warmer and drier weather conditions in summer are associated with increased mortality winter. In winter 2018-19, the losses were estimated in Europe from 2% to 32% [13].

Larger colonies have a better energy balance, use food reserves more efficiently with lower *per capita* consumption and have greater ease in overwintering and higher production in the following season [14], [15].

All these problems make the winter period very critical for honeybees' survival: the knowledge of the factors that influence their state of health, even using electronic systems, is today essential to know how to prevent or intervene promptly in case of difficulties of the families.

2. MATERIAL AND METHODS

A total of 4 hives, that constitute the Didactic Apiary of the School of Biosciences and Veterinary Medicine of the University of Camerino, was used in this study. Three of these, with the respective families, were transported from Emilia Romagna in 2020 to Matelica, MC, Italy, at the School's Didactic Apiary. The colony of the last hive was of indigenous origin. The Didactic Apiary is located in the city of Matelica, MC, Italy, a hilly area, 360 m above sea level, surrounded by mountains. This area has always honey been characterized by cold winters with rainy autumns and springs and not particularly hot and dry summers. In recent years the situation has completely changed, the seasons have moved with very dry and windy summers, mild winters, and intermediate seasons with very fluctuating temperatures.

To monitor the hives, a remote monitoring system (3BEE S.r.l.), able to provide several parameters, including weight variations, hive sound, internal temperature and humidity, and external temperature, was applied to each of them. This system records each parameter in real time, making it accessible in the form of graphical data and tables. The combined temperature/sound probes were placed within the hives, in the inter-frames space just adjacent to the cluster. For this study, the following parameters were considered: weight, internal temperature, sound, and external temperature.

The study was carried out from October 1, 2021, to March 22, 2022. In this period the families were fed with 1 kg candy. For winter preparation, the following conditions were created:

- Colony 1 (C1) was distributed over seven honeycombs with abundant honey stores, for a total weight of the hive of 34.9 kg;
- Colony 2 (C2) out of six honeycombs with good stocks for a total weight of 32.4 kg;
- Colony 3 (C3) out of 5 honeycombs with good stocks for a total weight of 30.6 kg;
- Colony 4 (C4) out of seven honeycombs with abundant stocks for a total weight of 35.5 kg. C1 lives in a "Marchigian" hive, while C2, C3 and C4 live in Dadant Blatt (D.B.) hives.

All the four hives have bee queens of the year. All families received an anti-Varroa treatment (Api-Bioxal, Alveis, Chemicals Laif S.p.A., Vigonza, PD, Italy) according to manufacturer protocol, before the start of the study.

3. RESULTS

3.1. Sound intensity

From the monitoring and comparison of the sound intensity in the four families, it can be observed that the sound of C2, C3 and C4 is higher than that of C1, which maintained a very low profile until February (Figure 1).

3.2. Inner temperatures

The internal temperature trend of the four families is superimposable, but C3 had a lower temperature throughout the period. A correlation also emerges with the trend of the environmental temperature associated with the poor thermal elasticity inside the hives, reaching high peaks of almost 20°C and lows very close to 0°C (Figure 2).

3.3. Weather temperature

The trend of the external temperatures during the study period was recorded. Since the hives are all located in the same environment, there is no variation between the four families (Figure 3).

3.4. Total weight

At the end of March, the weight of each hive was:
C1, 32.2 kg;
C2, 28.3 kg;
C3, 27.8 kg;
C4, 33.7 kg.

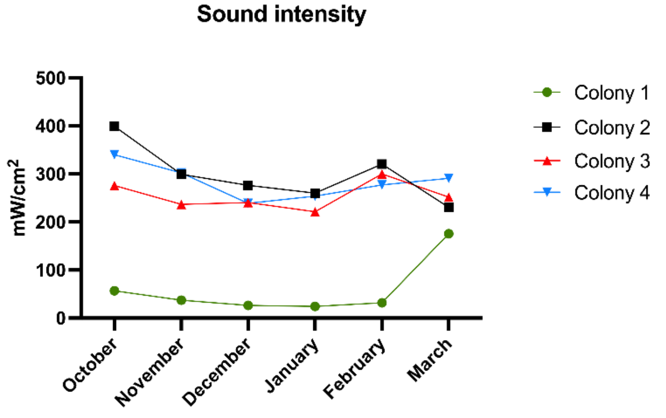

Figure 1. Sound intensity of the four honeybee families.

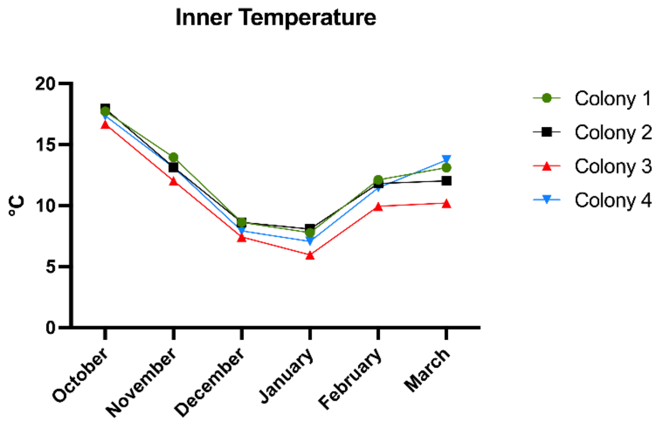

Figure 2. Inner temperature of the four honeybees families.

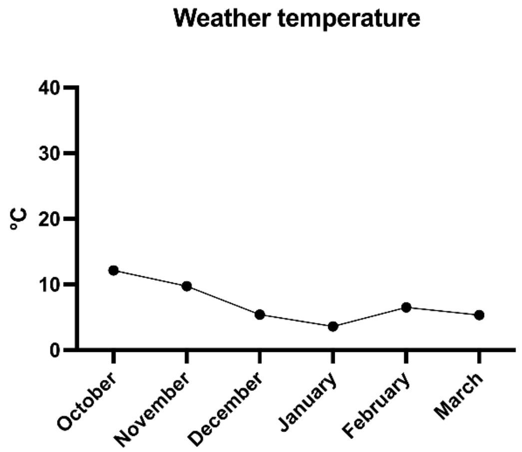

Figure 3. Weather temperature around the apiary.

Compared to October, a reduction in weight was observed in each colony:

C1, - 2.1 kg (- 6.04 %);
C2, - 4.1 kg (- 12.7 %);
C3, -2.7 kg (- 8.9 %);
C4, -1.8 kg (- 5 %).

Analysing the weight variations in association with the month, we observed an increase in weight in the months of November and December in C2, while C1 and C3 have had a constant decrease throughout the period (Figure 4).

The most important decreases in weight, on the other hand, occurred in periods of more marked cold, especially in spring, given that temperatures of the environment were well above normal in February and, on the contrary, very low in March.

C4 had a minimum decrease in weight until December but it increases until February, aligning the weight loss with of the other families in the last month of observation, obtaining at the end of the period a similar weight loss than the others.

4. DISCUSSION

Sound measurements show how the C1, being autochthonous, is the only one that formed a cluster, while C2, C3 and C4, coming from an area characterized by a milder winter, had an insufficient adaptation to the local climate, letting record higher sound values with peaks throughout the winter period. The genotype of the colony surely represents a factor influencing the success in wintering [16]. It has been demonstrated in Europe that the genotype has an influence on seasonal adaptability and

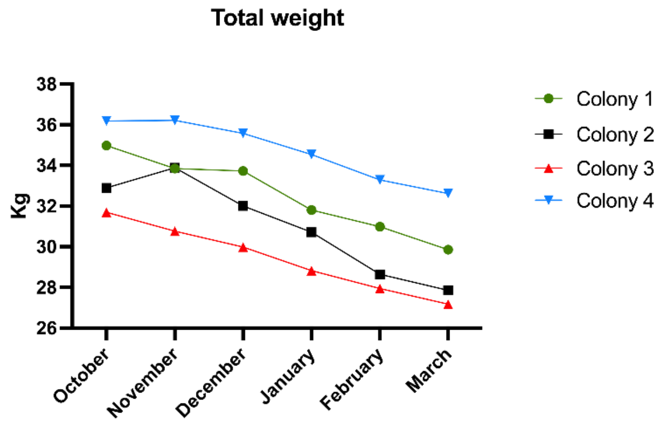

Figure 4. Total weight during the winter

families with local queens have survival rates that are 83 days higher on average than colonies with non-native queens [17], [18]. These data support the theory that the use of native families is always the most recommendable choice.

The external temperature represents another element of central interest. It is wrong to think that higher temperatures improve the winter survival of bee families, but a hot and dry summer drastically reduces the weight of colonies and the winter survival of families and also mild winters are not favourable to bee biology [19]. Even the extension of the summer can be a cause of very high autumn levels of Varroa infestation, negatively affecting winter survival [19].

In relation to the hive weight, it can be observed that C2 had rather important peaks in weight gain in the months of November and December. These peaks are probably connected to robbing carried out by the colony at the expense of other weaker hives considering that in that period the blooms were scarce.

There is a relationship between sound, internal temperature, and colony swarming [20]. In the present study, a probe, placed in the free space between partition frame and cluster, was used to evaluate the sound, reducing the interaction with families during winter. The relationship between external and internal temperature and the evaluation of the minimum and maximum thermal differences inside the hive, is an important factor that the bees must modulate to bring the cluster, or the brood, to the temperature suitable for survival. Evaluating the recorded data, it is noted that in the four hives, high peaks of almost 20°C and lows very close to 0°C, are reached. These are not the internal temperatures of the cluster but collected in the periphery. Such low temperatures at the periphery of the cluster had certainly requested the colony to tighten the cluster and produce considerable heat, consuming energy. Therefore, by relating the external and internal temperatures and the sound of C1, it is possible to observe how it maintained a constant low sound throughout the winter period, with only some slight peaks in autumn. From the second half of March, sound activity jumped to very high values compatible with the spring recovery of activities. C2 maintained a good sound activity in the autumn period which decreased in the period from December to February, while always maintaining the alternation of high and low peaks. In February, the presence of mild temperatures above the norm probably caused the resumption of activities with increasing sound intensity values which decreased again with the reduction in temperatures in March. C3, containing the smallest colony, maintained a very high constant sound intensity throughout the studied period, with ever higher peaks towards spring. These data suggest the efforts of this colony to maintain the internal temperature at sustainable values for survival. A greater reduction in internal temperature during the coldest period, with a weight loss of 9% was observed, with an important consume of supplies to feed all the honeybees. For this reason, the practice of wintering smaller families is counterproductive as improve the risk of death from cold and hunger, consuming more supplies to keep a constant temperature inside the hive. C4, the most populous hive, presented a percentage weight loss lower than the other families, despite a greater weight decrease was expected in function of the number of the honeybees. This validates the idea that larger families have a better ability to winter thanks to a lower individual consumption of stocks and greater ease in maintaining a suitable temperature even in the presence of the brood.

5. CONCLUSIONS

The use of electronic devices for the continuous monitoring of the hives represents a practice of significant importance as these systems are useful for both research and production activities. Overwintering is a complicated process and even more so due to climate change. Honeybees use various environmental (temperature, photoperiod, type and quantity of food) and endocrine signals to activate those physiological and molecular changes that will lead to the formation of "winter bees", able to survive until the following spring. High quality local queens are to be preferred over imported subjects of uncertain origin and genetic value, as the queen induces important effects also on the wintering phase and on the winter survival of the colony. An important fact that emerges from this study is that bigger families can thermoregulate the cluster more effectively, are more resistant to sudden changes in temperature and are able to use food supplies more efficiently, reducing their per capita use. On the contrary, smaller families suffer more from thermal stress and the aging of the workers, with the risk of showing up in spring unable to be operational for the new season. Obviously, arriving in autumn with abundant supplies is essential, as is carrying out adequate prophylaxis against the Varroa mites. Climate changes actually impact the beekeepers' job, and it is necessary that they try to improve the health status of their hives. The use of latest generation analytical tools can early alert the beekeeper in case of loss of resilience in families, through the recording of highly detailed information. Access to new data can provide tangible tools to monitor colony activity and development in an additional way to that used up to now.

REFERENCES

[1] M. Gérard, M. Vanderplanck, T. Wood D. Michez, Global warming and plant–pollinator mismatches, Emerging Topics in Life Sciences 4(1) (2020), pp. 77–86.
DOI: 10.1042/ETLS20190139

[2] W. G. Meiklei, N. Holst, Application of continuous monitoring of honeybee colonies, Apidologie 46 (2015), pp. 10–22.
DOI: 10.1007/s13592-014-0298-x

[3] O. Debauche, M. El Moulat, S. Mahmoudi, S. Boukraa, P. Manneback, F. Lebeau, Web monitoring of bee health for researchers and beekeepers based on the internet of things, Procedia Computer Science 130 (2018), pp. 991-998.
DOI: 10.1016/j.procs.2018.04.103

[4] A. Zacepins, V. Brusbardis, J. Meitalovs and E. Stalidzans, Challenges in the development of Precision Beekeeping, Biosystems Engineering, vol. 130 (2015), pp. 60-71.
DOI: 10.1016/j.biosystemseng.2014.12.001

[5] A. Prado, J. L. Brunet, M. Peruzzi, M. Bonnet, C. Bordier, D. Crauser, Y. le Conte, C. Alaux, Warmer winters are associated with lower levels of the cryoprotectant glycerol, a slower decrease in vitellogenin expression and reduced virus infections in winter honeybees, Journal of Insect Physiology 136 (2022).
DOI: 10.1016/j.jinsphys.2021.104348

[6] H. R. Mattila, G. W. Otis, Dwindling pollen resources trigger the transition to broodless populations of long-lived honeybees each autumn, Ecological Entomology 32(5) (2007), pp. 496–505.
DOI: 10.1111/j.1365-2311.2007.00904.x

[7] J. S. Bale, S. A. L. Hayward, Insect overwintering in a changing climate, Journal of Experimental Biology 213(6) (2010), pp. 980–994.
DOI: 10.1242/jeb.037911

[8] B. Heinrich, The mechanisms and energetics of honeybee swarm temperature regulation, Journal of Experimental Biology 91(1) (1981), pp. 25-55.
DOI: 10.1242/jeb.91.1.25

[9] M. J. Angilletta, Thermal Adaptation: A Theoretical and Empirical Synthesis, Oxford University Press Inc., New York, (2009), ISBN: 978-0-19-857087-5, pp. 1–302.

[10] B. Becsi, H. Formayer, R. Brodschneider, A biophysical approach to assess weather impacts on honeybee colony winter mortality, Royal Society Open Science 8(9) (2021).
DOI: 10.1098/rsos.210618

[11] M. Switanek, K. Crailsheim, H. Truhetz, R. Brodschneider, Modelling seasonal effects of temperature and precipitation on honeybee winter mortality in a temperate climate, Science of Total Environment 579 (2017) pp. 1581-1587.
DOI: 10.1016/j.scitotenv.2016.11.178

[12] I. A. R. Yasrebi-de Kom, J. C. Biesmeijer, J. Aguirre-Gutiérrez, Risk of potential pesticide use to honeybee and bumblebee survival and distribution: A country-wide analysis for The Netherlands, Diversity and Distributions 25(11) (2019), pp. 1709–1720.
DOI: 10.1111/ddi.12971

[13] D. Cressey, EU states lose up to one-third of honeybees per year. Nature (2014), art. No. 15016.
DOI: 10.1038/nature.2014.15016

[14] J. B. Free, P. A. Racey, The effect of the size of honeybee colonies on food consumption, brood rearing and the longevity of the bees during winter, Entomologia Experimentalis et Applicata 11 (1968), pp. 241– 249.
DOI: 10.1111/j.1570-7458.1968.tb02048.x

[15] E. Genersch, W. von der Ohe, H. Kaatz, A. Schroeder, C. Otten, R. Büchler, S. Berg, W. Ritter, W. Mühlen, S. Gisder, M. Meixner, G. Liebig, P. Rosenkranz, The German bee monitoring project: a long term study to understand periodically high winter losses of honey bee colonies, Apidologie 41(3) (2010), pp. 332–352.
DOI: 10.1051/apido/2010014

[16] M. Kovačić, Z. Puškadija, M. M. Dražić, A. Uzunov, M. D. Meixner, R. Büchler, Effects of selection and local adaptation on resilience and economic suitability in *Apis mellifera carnica*, Apidologie 51 (2020), pp. 1062-1073.
DOI: 10.1007/s13592-020-00783-0

[17] R. Büchler, C. Costa, F. Hatjina, S. Andonov, M. D. Meixner, Y. L. Conte, A. Uzunov, S. Berg, (+ 11 more authors), The influence of genetic origin and its interaction with environmental effects on the survival of *Apis mellifera L.* colonies in Europe, Journal of Apicultural Research, vol. 53 (2014) 2, pp. 205-214.
DOI: 10.3896/IBRA.1.53.2.03

[18] M. D. Meixner, P. Kryger, C. Costa, Effects of genotype, environment, and their interactions on honey bee health in Europe, Current Opinion in Insect Science 10 (2015), pp. 177-184.
DOI: 10.1016/j.cois.2015.05.010

[19] M. Switanek, K. Crailsheim, H. Truhetz, R. Brodschneider, Modelling seasonal effects of temperature and precipitation on

honey bee winter mortality in a temperate climate, Science of the Total Environment 579 (2017), pp. 1581-1587.
DOI: 10.1016/j.scitotenv.2016.11.178

[20] S. Ferrari, M. Silva, M. Guarino, D. Berckmans, Monitoring of swarming sounds in bee hives for early detection of the swarming period, Computers and Electronics in Agriculture, vol. 64 (2008) pp. 72-77.
DOI: 10.1016/j.compag.2008.05.010