ACTA IMEKO
ISSN: 2221-870X
June 2024, Volume 13, Number 2, 1 - 5

Preliminary study on the extention of the IT system ClassyFarm to the apiary

Clara Montagnin[1], Matteo Frasnelli[2], Francesca Fusi[3], Paolo Bonilauri[4] Luigi Bertocchi[3], Valentina Lorenzi[3]

[1] *Istituto Zooprofilattico Sperimentale dell'Umbria e delle Marche, via Gaetano Salvemini 1, 06126 Perugia, Italia*
[2] *Territorial office of Ravenna, Istituto Zooprofilattico Sperimentale della Lombardia e dell'Emilia Romagna, via Antonio Bianchi 7/9, 25124, Brescia, Italia*
[3] *Italian Reference Centre for Animal Welfare, Istituto Zooprofilattico Sperimentale della Lombardia e dell'Emilia Romagna, via Antonio Bianchi 7/9, 25124, Brescia, Italia*
[4] *Quality Assurance Service, Istituto Zooprofilattico Sperimentale della Lombardia e dell'Emilia Romagna, via Antonio Bianchi 7/9, 25124, Brescia, Italia*

ABSTRACT
ClassyFarm is a new IT system of the Italian Ministry of Health for the risk categorization of livestock farms in relation to four areas: animal welfare, biosecurity, antimicrobial usage and antimicrobial resistance. Within ClassyFarm, on-farm welfare measurement is carried out using protocols based on both resource-based indicators and animal-based indicators. The aim of this study was to develop a welfare measurement protocol for the apiary. Sixteen Italian beekeeping experts were involved into a focus group to discuss a list of resource-based and animal-based indicators, previously selected by the authors by means of a review of the scientific literature, in order to identify effective and significant welfare indicators to be collected in the field. Despite the difficulties encountered related to the nature of honey bees and the lack of scientific knowledge about their welfare, 12 resource-based and 7 animal-based indicators were identified as potentially able to screen the welfare of honey bee colonies in the apiary. This study represents the first step towards the future extension of the ClassyFarm system to the apiary.

Section: RESEARCH PAPER

Keywords: *Apis mellifera*; honey bee; welfare; beekeeping

Citation: C. Montagnin, M. Frasnelli, F. Fusi, P. Bonilauri, L. Bertocchi, V. Lorenzi, Preliminary study on the extention of the IT system ClassyFarm to the apiary, Acta IMEKO, vol. 13 (2024) no. 2, pp. 1-5. DOI: 10.21014/actaimeko.v13i2.1630

Section Editor: Leopoldo Angrisani, Università degli Studi di Napoli Federico II, Naples, Italy

Received August 10, 2023; **In final form** August 10, 2023; **Published** June 2024

Funding: This study was supported by the Italian Ministry of Health, grant IZS LER 06/20 RC

Corresponding author: Clara Montagnin, e-mail: c.montagnin@izsum.it

1. INTRODUCTION

ClassyFarm is the new integrated IT system of the Italian Ministry of Health for collecting and processing data on livestock farming (http://www.classyfarm.it). The system, developed by the Istituto Zooprofilattico Sperimentale della Lombardia e dell'Emilia Romagna, aims at categorizing the farms according to the risk and it covers 4 main areas: animal welfare, biosecurity, antimicrobial usage and antimicrobial resistance. ClassyFarm is hosted on the national veterinary portal (www.vetinfo.it) and it can be accessed by official veterinarians, farm veterinarians and farmers. This system is intended to promote the collaboration between farmers and the competent authority, in order to improve the quality of the livestock farming and to reduce antimicrobial use. Currently, ClassyFarm is the only system in Europe, recognized by the national competent authority, that categorizes herds on a risk basis. This system, thanks to its interoperability, is also able to transmit and receive data from other national public systems (such as the electronic veterinary prescription system and the national livestock database). Concerning the animal welfare area of the ClassyFarm system, data are collected on-farm by trained veterinarians using the checklists set up by the Italian Reference Centre for Animal Welfare (CReNBA), which include both resource-based indicators and animal-based indicators (ABIs) [1], and further elaborated by a tailored algorithm to obtain scores expressed in percentage. The resource-based indicators are referred to farm management and housing factors, useful for identifying potential welfare hazards (risk factors) or promoters (benefit factors). On the other hand, ABIs are used to directly assess the negative or positive welfare consequences experienced by the animals as a result of the exposure to the farm management and environment [1]. Currently, only ABIs able to measure negative welfare outcomes are included in the checklists. The ClassyFarm checklists are applied to several animal species, such as cattle, buffaloes, sheep, goats, pigs and poultry but not to honey bees.

Nowadays, abnormal high mortality rates of honey bee colonies have been recorded in Europe [2]. These losses are concerning since they have a strong impact on beekeeper sustainability and on honey bee pollination service, which connects honey bee health to food security and biodiversity. With rising levels of honey bee colony losses, there is a need for better beekeeping management practices, which can result in improved welfare and survivorship.

European honey bees (*Apis mellifera*) are semi-domesticated species, housed in manmade structures and subject to human selection, but free to forage in the landscape [3]. Their colonies are considered "superorganisms" since they consist of many individuals working together within a self-sustaining and self-regulated social unit. A superorganism can be defined as the collection of several individuals that possess together the functional organization of an organism [4]. Thus, there is not solitary existence for honey bees, which represent the cells and, by extension, the organs of the colony [5]. Moreover, the fertilized queen represents alone the reproductive system of the superorganism [5]. Due to their complex mechanisms honey bee colonies express high resilience against stressors [6]. As for other eusocial insect colonies, workers can be considered similar to somatic cells in a metazoan organism. Thus, like metazoans, superorganisms can endure losses of "somatic cells", provided that the colony functionality and the germ line are preserved. This is the most important element of the superorganismic resilience [7].

Poor management practices, parasites, diseases and intoxications may often be neglected by beekeepers, until the add up effect of winter results in colony losses in early spring. Further, honey bees have a close relationship with the surrounding environment and the complexity of this interaction is still difficult to understand [6]. Honey bees are subject to many interacting pressures that raise the visible effect of colony death or weakening only when they exceed the threshold of hives buffering ability [8], [9]. While some of these stressors are out of beekeepers control (e.g. weather, external pesticide applications, habitat quality), others can be mitigated by management choices (e.g. supplemental feeding) [10].

The aims of this study were to identify factors under beekeepers' control that can negatively or positively affect honey bees welfare and to identify possible ABIs for directly measuring the honey bee colony welfare. Once these factors and indicators have been identified, they can address on management and research priorities, in order to put the basis for a future extension of the ClassyFarm system to the apiary.

2. MATERIALS AND METHODS

2.1. Identification of the target population

According to the concept that the honey bee colony is a superorganism, a single honey bee does not express the whole range of behaviour and ecology of the species, but represents the cell of a larger organism, the colony, which can provide the whole picture. Thus, honey bee colonies kept within apiaries managed by beekeepers were the target population: each honey bee colony ideally represents one animal of the herd, i.e., the apiary.

2.2. Selection of the factors potentially influencing honey bee colony welfare

The selection of the factors influencing honey bee colony welfare was made by the authors by reviewing the available literature and then the list of factors was submitted for discussion during a focus group to 16 beekeeping experts with different backgrounds.

The selection of experts was carried out by taking into account the heterogeneity in competences and in the geographic working area. Field veterinarians and beekeepers, were chosen for their strong practical view of the beekeeping practice; other involved experts were veterinary and agronomy researchers, directed toward a scientific approach to beekeeping. Finally, official veterinarians were involved due to their knowledge of the health situation of apiaries in Italy and of the national and regional laws regulating beekeeping.

Only factors linked to honey bee colony housing and management were selected and proposed to the focus group. Most of the management and housing factors were picked from the list of good beekeeping practices (GBPs) developed as part of the Horizon 2020 BPRACTICES project [11]. The selection was carried out by the identification of those practices that were most likely to affect the health and welfare of honey bee colonies in the apiary. For this task, factors that could potentially have consequences on one or more of the four welfare criteria (i.e. good feeding, good housing, good health and appropriate behaviour) defined by the Welfare Quality® project were selected [12]. During the focus group, three different intensities of honey bee colony exposure were then defined for each proposed management and housing factor, based on scientific publications (Table 1). If no data were extracted from these sources, individual expertise were discussed and used instead.

Starting with the intensity of exposure that does not affect apiary welfare (acceptable threshold), a critical level, which can potentially be associated with a stressful condition for the apiary

Table 1. List of bee welfare indicators identified by the focus group

Resource-based indicators		***Management factors***
	1.	Beekeeper education
	2.	Number of hive inspections
	3.	Maintaining balanced the colonies strength within the same apiary
	4.	Queen selection
	5.	Queen replacement frequency
	6.	Nutrition
	7.	Availability of water resources
	8.	Monitoring the varroa infestation level
	9.	Anti-varroa treatment
		Housing factors
	10.	Choice and Management of the hive
	11.	Hive entrance
	12.	Hive placement
Animal-based indicators	1.	Winter mortality
	2.	Robbing during the active season
	3.	Mortality and depopulation during the active season
	4.	Presence of drone laying workers
	5.	Presence of orphan colonies
	6.	Symptoms of varroosis
	7.	Behavior abnormalities

(insufficient threshold), and a level of exposure at which welfare benefits could be observed (optimal threshold) were defined.

2.3. Selection of the animal-based indicators

The welfare outcomes of the management and housing factors can be measured through one or more ABIs, which could be direct or indirect. ABIs that can be directly measured on the animal are defined as direct (e.g. clinical symptoms of disease), while indirect ABIs can be assess through on-farm data collection (e.g. mortality rate) [1]. In farm animals, direct ABIs are generally collected at individual level on a sample of animals within the farm. The sample size is determined according to the current number of animals and animals are chosen by random sampling. Once measured, ABIs are usually aggregated at herd level [13]. In case of honey bee, direct ABIs are collected on a sample of colonies and the results are aggregated at apiary level. Indirect ABIs, such as mortality rate, are instead collected directly at apiary level.

The selection criteria for ABIs was similar to those used for management and housing factors, i.e. based on scientific evidence and on focus group expertise (Table 1). In addition, ABIs had to be easy to record by a trained assessor during an apiary visit. In this preliminary study only ABIs able to measure negative welfare outcomes were considered.

Two or three gradual threshold values were identified for each ABI (i.e. poor, good, optimal). When an ABI is poor, it identifies a condition of impaired apiary welfare resulting from a high prevalence, intensity and/or duration of the measured negative welfare outcome. On the other hand, the identification of a good or optimal ABI's threshold indicates a low or a very low prevalence, intensity and/or duration of the measured negative welfare consequences.

2.4. Selection of the experts of the focus group

The experts who constituted the focus group were selected on the basis of their experience and knowledge in beekeeping and honey bee welfare. A total of 16 Italian experts were selected and involved in three discussion session. Five experts involved on honey bee research came from three different Istituti Zooprofilattici Sperimentali, four were official veterinarians involved in beekeeping control, two were CREA (Consiglio per la Ricerca in Agricoltura e l'Analisi dell'economia agraria) members, three were honey bee-field veterinarians and one was a beekeeper.

3. RESULTS AND DISCUSSION

The main difficulties encountered during the focus group meetings were linked to the nature of honey bees. The panel members themselves often disagreed on what might improve or compromise apiary welfare. In contrast to the other species to which the on-farm welfare measurement system is usually applied, lack of domestication of honey bees and the strong relationship between honey bees and environment, which is out of beekeeper hands, represent a challenge to the identification of management and housing factors. Moreover, many of the elements that constitute and influence honey bee physiology, behaviour and welfare are still unclear and under-investigated.

At present, nine management factors and 3 housing factors were identified as able to positively or negatively influence the apiary welfare. For all the 12 factors, an insufficient and an acceptable thresholds were defined, while only for 5 factors an optimal threshold could be defined.

Training of beekeepers (indicator n. 1 - Table 1) is the first management indicator identified. According to the European legislation, honey bee are terrestrial animals and beekeepers should have adequate knowledge of good practices of animal husbandry, biosecurity principles and animal health as well as for others farm animals (Article 11 Reg (UE) 2016/429). Moreover, it has been observed that one of the main factors protecting apiaries from winter losses are beekeepers background and experience [14]. Training allows operators to achieve specific knowledge on good beekeeping practices and to early identify clinical signs of diseases. Thus, "beekeeping experience of at least 10 years or attendance at a specific training course on beekeeping practices" was identified as the acceptable threshold, while the factor was considered optimal when the beekeeper met both the requirements.

Inspection of honey bee colonies (indicator n. 2 - Table 1) plays a crucial role for honey bee welfare and health, given the fact it allows early detection of diseases, weak colonies, low honey stocks or absence of the laying queen. However, opening the hives stresses honey bees, so the frequency of the inspections during the active season should not be below but, at the same time, should not exceed the number of three or four per month to be acceptable. In addition, if the beekeeper records the findings it achieves the indicator optimal threshold. While visiting honey bee colonies, the smoker keeps honey bees calm and decrease the risk of death, however, its excessive use should be avoided.

In order to limit honey bee robbing behaviour, balancing of colony strength among colonies should be performed. In the checklist, the colony balancing procedure (indicator n. 3 - Table 1) is acceptable when it involves only healthy colonies and does not imbalance the nurse bees-brood ratio.

Managing both the queen choice (indicator n. 4 – Table 1) and its replacement frequency (indicator n. 5 – Table 1) is essential to have strong and resilient honey bee colonies in the apiary. According to the GBPs, the queen should be replaced every two to three years to achieve the acceptable judging in this indicator; higher frequency (once every two years) corresponded to the optimal judging. Replacing the queen has been associated to reduced losses during winter [15] and has a greatest effect on the family strength and on the overall mortality in the apiary [10]. In addition, buying queens with genetic certification means making genetic selection of the whole colony for the desired characteristics: resistance to diseases, adaptation to climatic conditions, hygienic behaviour, docility and productivity [16]. The queens introduced in the apiary should be provided with genetic certification to consider the practice acceptable.

Indicators of nutrition (indicator n. 6 – Table 1) and water availability (indicator n. 7 – Table 1) underwent a massive debate and, to date, the three thresholds are still not defined for these 2 indicators. It is out of doubt that nutrition can significantly impact honey bee colony health and welfare [10], [15]-[19], but it is also highly dependent on the foraging environment in which honey bees live, that is the floral composition of the landscape [20]. As the quantity and quality of floral resources can change throughout the year, supplementation becomes essential during winter and/or foraging dearth. However, there is a significant gap in the knowledge regarding nutritional honey bee needs [19] and the amount of feed supplement beekeepers give to their colonies per year.

With referment to water availability, the question among the experts was whether honey bees really need water supplementation, since they easily meet their water needs using the dew, that they find among the grass stalks or puddles. However, through the consumption of contaminated water, honey bees could be exposed to pesticides, such as neonicotinoids [21]. The experts were strongly convinced that providing water from known sources represents an important precaution measure to mitigate the risk of intoxication and to improve honey bee colony health. The threshold suggested as acceptable was 1lt/die of salted water per honey bee colony and the source of water should be located less than 1 km away from the apiary.

Among biotic and abiotic stressors, the infestation by Varroa destructor can greatly influence colonies welfare and health and it is strongly associated with colony winter failure [22]-[25]. Thus, it is fundamental the application of a strict Varroa control program, based on the correct implementation of Varroa treatment (indicator n. 9 – Table 1) and infestation monitoring (indicator n. 10 – Table 1). Ideally, the level of infestation should be constantly monitored, at least once every 1-2 months during and right after the brood-rearing season and at least once every 4 months during the inactive season. Keeping the records of the level of infestation allowed the beekeeper to obtain the optimal threshold. According to the guidelines of the Italian Ministry of Health, treatment against Varroa must be carried out twice a year and when needed. To obtain the optimal judgment in this indicator, the beekeeper treatment strategy should include the use of different active ingredients between treatments, in order to avoid mite resistance, and coordination with other beekeepers working in the same area.

As for other animal species, welfare also depends on the structures in which the animals live. Experts considered acceptable the condition in which standard hives are located in a firm area, 30 cm above the ground to avoid humidity accumulation and with the entrance orientated so that the sun can reach honey bees in early morning hours [11], [26]. In addition, to prevent drift occurrence, hives need to be coloured and kept in multiple rows, when their number is high. Finally, beekeepers raise the acceptable threshold in the indicators n. 10 (Table 1) when the hives are correctly maintained, that means avoid broken hives and growth of grassy weeds around or in front of the hives [11], [27].

The final list of management and housing factors selected and defined by the focus group became part of a welfare measurement checklist, since their potential impact, negative or positive, on honey bee colonies welfare was recognized. The checklist was then added with the list of the approved ABIs so that the negative welfare outcomes could also be assessed at the same time in the apiary.

Given the lack of scientific studies on honey bee welfare and the disagreement among the focus group members, only 7 ABIs were identified. Among the ABIs, only post-wintering colony loss had been previously investigated by Steinhauer et al. as a possible outcome of poor honey bee colony health and welfare associated with poor management in the apiary [10]. There were no defined thresholds in literature for this ABI, but experts have identified mortality above 20 percent as indicative of a poor level of welfare in the apiary, between 5 and 20 percent as a good level, and below 5 percent as optimal level.

However, honey bee colonies have a major ability for buffering stressors and defining meaningful, robust and early indicators of bee weakness, that can direct management decisions before the colony collapse is still challenging. In addition, the most significant ABIs, such as colony homogeneity within the apiary and adult bees-comb-honey stocks ratio, need further studies to define how to be easy measured in field and the thresholds to be used.

In addition to winter mortality, other six ABIs were identified: during the active season, mortality and depopulation during the active season, presence of drone laying workers, presence of orphan colonies, clinical symptoms of varroosis, behaviour abnormalities.

For some ABIs, the experts defined a percentage of colonies in the apiary, below which the parameter could be considered physiological; for other ABIs, the presence/absence of the outcome was defined as a discriminator between good and poor. Sporadic cases of robbing may occur due to factors beyond the control of the beekeeper (e.g. poor forage availability), and a percentage of robbed families is considered physiological, but must not exceed 2%. Clinical varroosis may also occur, but should never affect more than 5% of the colonies in the apiary. On the other hand, the occurrence of orphan families in apiaries or the presence of drone laying workers has been defined as indicative of a poor welfare.

The described activity and results are part of an ongoing research project, the panel of experts will then be involved in an expert knowledge elicitation exercise to weight the potential negative and positive effects of each management and housing factor on the apiary welfare and to score the ABIs on the basis of their appropriateness and the extent of the harm to the apiary welfare caused by the adverse effects they measure. An algorithm will then be developed, by which the scores assigned by the experts to the indicators will be elaborated to obtain an apiary overall welfare score, a tangible indicator of welfare in the apiary. Finally, the checklist will be subject to validation, through a field application, in order to assess its effectiveness, reliability and applicability in the apiary.

4. CONCLUSIONS

Understanding the most important factors of honey bee health and how they interact in the complex superorganism system is critical for the welfare of managed honey bee colonies and, by extension, for human and environmental health.

Among the management and housing indicators proposed, training and experience of the beekeeper, number of hive inspections and Varroa treatment were recognized to play a pivotal role in improving bee health and welfare. The major influence of beekeeper education and disease control was highlighted by previous studies [8] while the frequency of hives inspection allows early identification of clinical signs of disease and an effective treatment.

Further studies on honey bees are required to assess the relevance of management and housing in relation to other stressors, and hence weight the potential improvement in bee health and welfare from better beekeeping practices.

The future goal is to create a risk-based apiary categorization system to be included within the Italian ClassyFarm platform. The potential of the large amount of data collected through the ClassyFarm system in the future is obvious, even in the beekeeping field. In the era of Precision Livestock Farming, the information collected in a non-invasive way (by the checklists) can be supplemented with sensors-derived data that can provide additional outputs for hive welfare measurement. This information is crucial in order to increase knowledge of these insects (still unknown in many respects) and safeguarding the agri-food sector.

ACKNOWLEDGEMENT

The authors would like to thank the beekeeping experts of the focus group for their contribution in the development of the welfare measurement checklist.

REFERENCES

[1] L. Bertocchi, F. Fusi, A. Angelucci, L. Bolzoni, S. Pongolini, R. M. Strano, J. Ginestreti, G. Riuzzi, (+ 2 more authors), Characterization of hazards, welfare promoters and animal-based measures for the welfare assessment of dairy cows: Elicitation of expert opinion, Prev Vet Med 150 (2018), pp. 8–18. DOI: 10.1016/j.prevetmed.2017.11.023

[2] R. Brodschneider, A. Gray, R. van der Zee, N. Adjlane, V. Brusbardis, J.-D. Charrière, R. Chlebo. M. F. Coffey, (+ 30 more authors), Preliminary analysis of loss rates of honey bee colonies during winter 2015/16 from the COLOSS survey, Journal of Apicultural Research 55(5) (2016), pp. 375–378. DOI: 10.1080/00218839.2016.1260240

[3] B. P. Oldroyd, Domestication of honey bees was associated with expansion of genetic diversity, Molecular Ecology 21(18) (2012), pp. 4409–4411. DOI: 10.1111/j.1365-294X.2012.05641.x

[4] B. Holldobler, E. O. Wilson, The Superorganism: The beauty elegance and strangeness of insect societies, WW Norton, New York, 2009, ISBN 978-0-393-06704-0.

[5] R. F. A. Moritz, E. E. Southwick, Bees as Superorganisms: An Evolutionary Reality, Springer Berlin, Heidelberg, New York, 2012, ISBN 978-3-642-84666-3.

[6] C. Garrido, A. Nanetti, Welfare of Managed Honey Bees, The Welfare of Invertebrate Animals, C. Carere e J. Mather, A c. di Cham: Springer International Publishing, Cham, Switzerland, 2019, pp. 69–104. DOI: 10.1007/978-3-030-13947-6_4

[7] L. Straub, G. Williams, J. Pettis, I. Fries, P. Neumann, Superorganism resilience: Eusociality and susceptibility of ecosystem service providing insects to stressors, Current Opinion in Insect Science 12 (2015), pp. 109–112. DOI: 10.1016/j.cois.2015.10.010

[8] S. Tosi, J. C. Nieh, F. Sgolastra, R. Cabbri, P. Medrzycki, Neonicotinoid pesticides and nutritional stress synergistically reduce survival in honey bees, Proceedings of the Royal Society B: Biological Sciences 284 (2017), art. no. 20171711. DOI: 10.1098/rspb.2017.1711

[9] A. J. Vanbergen, The I. P. Initiative, Threats to an ecosystem service: pressures on pollinators, Frontiers in Ecology and the Environment 11(15) (2013), pp. 251–259. DOI: 10.1890/120126

[10] N. Steinhauer, D. vanEngelsdorp, C. Saegerman, Prioritizing changes in management practices associated with reduced winter honey bee colony losses for US beekeepers, Science of The Total Environment 753 (2021), pp. 141629. DOI: 10.1016/j.scitotenv.2020.141629

[11] Good beekeeping practices (GBP): the BPRACTICES guidelines. Online [Accessed 30 May 2024] https://www.izslt.it/bpractices/wpcontent/uploads/sites/11/2019/12/BPRACTCES-GBPs-BMBs.pdf

[12] L. Keeling, A. Evans, B. Forkman, U. Kjaernes, Welfare Quality® principles and criteria, Improving farm animal welfare: Science and society working together: the Welfare Quality approach, H. Blokhuis, M. Miele, I. Veissier, B. Jones, Wageningen The Netherlands (2013), pp. 91–114, ISBN 978-90-8686-216-0. DOI: 10.3920/9789086867707_007

[13] Welfare Quality (2009) Welfare Quality assessment protocol for cattle. Online [Accessed 30 May 2024] https://www.welfarequalitynetwork.net/en-us/reports/assessment-protocols

[14] A. Jacques, M. Laurent, EPILOBEE Consortium, M. Ribière-Chabert, M. Saussac, S. Bougeard, G.E. Budge, P. Hendrikx, M. P. Chauzat, A pan-European epidemiological study reveals honey bee colony survival depends on beekeeper education and disease control, PLOS ONE 12(3) (2017), pp. 0172591. DOI: 10.1371/journal.pone.0172591

[15] A. Giacobino, A. I. Molineri, N. V. Bulacio Cagnolo, J. Merke, R. E. Orellano, E. Bertozzi, G. Masciangelo, H. Pietronave, (+ 4 more authors), Queen replacement: the key to prevent winter colony losses in Argentina, Journal of Apicultural Research 55(4) (2016), pp. 335–341. DOI: 10.1080/00218839.2016.1238595

[16] W. C. Rothenbuhler, Behavior genetics of nest cleaning in honey bees. iv. responses of f1 and backcross generations to disease-killed blood, Am Zool 4 (1964), pp. 111–123. DOI: 10.1093/icb/4.2.111

[17] C. Alaux, F. Ducloz, D. Crauser, Y. Le Conte, Diet effects on honeybee immunocompetence, Biol Lett 6(4) (2010), pp. 562–565. DOI: 10.1098/rsbl.2009.0986

[18] G. Di Pasquale, M. Salignon, Y. Le Conte, L. P. Belzunces, A. Decourtye, A. Kretzschmar, S. Suchail, J. L. Brunet, (+ 1 more author), Influence of pollen nutrition on honey bee health: Do Pollen Quality and Diversity Matter?, PLOS ONE 8(8) (2013), pp. 72016. DOI: 10.1371/journal.pone.0072016

[19] J. M. Tsuruda, P. Chakrabarti, R. R. Sagili, Honey Bee Nutrition, Vet Clin North Am Food Anim Pract 37(3) (2021), pp. 505–519. DOI: 10.1016/j.cvfa.2021.06.006

[20] P. Donkersley, G. Rhodes, R. W. Pickup, K. C. Jones, K. Wilson, Honeybee nutrition is linked to landscape composition, Ecology and Evolution 4(21) (2014), pp. 4195–4206. DOI: 10.1002/ece3.1293

[21] O. Samson-Robert, G. Labrie, M. Chagnon, V. Fournier, Neonicotinoid-Contaminated Puddles of Water Represent a Risk of Intoxication for Honey Bees, PLOS ONE 9(12) (2014), art. no. 108443. DOI: 10.1371/journal.pone.0108443

[22] O. Boecking, E. Genersch, Varroosis – the Ongoing Crisis in Bee Keeping, J. Verbr. Lebensm. 3(2) (2008), pp. 221–228. DOI: 10.1007/s00003-008-0331-y

[23] Y. Le Conte, M. Ellis, W. Ritter, Varroa mites and honey bee health: can Varroa explain part of the colony losses?, Apidologie 41(3) (2010), pp. 353–363. DOI: 10.1051/apido/2010017

[24] P. Rosenkranz, P. Aumeier, B. Ziegelmann, Biology and control of Varroa destructor, J Invertebr Pathol 103(1) (2010), pp. S96-119. DOI: 10.1016/j.jip.2009.07.016

[25] M. A. Döke, M. Frazier, C. M. Grozinger, Overwintering honey bees: biology and management, Curr Opin Insect Sci 10 (2015), pp. 185–193. DOI: 10.1016/j.cois.2015.05.014

[26] A. Contessi, G. Formato, Malattie delle api e salute degli alveari. Edagricole Calderini, Bologna, Italia, 2018. ISBN 978-88-506-5537-3. [In Italian]

[27] B. Kyle, K. Lee, S. F. Pernal, Epidemiology and Biosecurity for Veterinarians Working with Honey bees (Apis mellifera), Veterinary Clinics of North America: Food Animal Practice 37(3) (2021), pp. 479–490. DOI: 10.1016/j.cvfa.2021.06.004