



Article

A Comprehensive Analysis of Beekeeping Risks and Validation of Biosecurity Measures against Major Infectious Diseases in *Apis mellifera* in Europe

Alessandra De Carolis ¹, Adam J. Newmark ², Jieun Kim ³, Junxia Song ³, Marco Pietropaoli ¹, Veronica Manara ¹, Andrea Gyorffy ¹, Joseph Cazier ⁴ and Giovanni Formato ¹,*

- Istituto Zooprofilattico Sperimentale del Lazio e della Toscana Toscana "M. Aleandri", Via Appia Nuova 1411, 00178 Rome, Italy; alessandra.decarolis-esterno@izslt.it (A.D.C.); marco.pietropaoli@izslt.it (M.P.); veronica.manara-esterno@izslt.it (V.M.); andrea.gyorffy-esterno@izslt.it (A.G.)
- Department of Government and Justice Studies, Appalachian State University, 287 Rivers St., Boone, NC 28608, USA; newmarkaj@appstate.edu
- Food and Agriculture Organization of United Nations, Viale delle Terme di Caracalla, 00153 Rome, Italy; jieun.kim@fao.org (J.K.); junxia.song@fao.org (J.S.)
- Department of Information Systems, Arizona State University, 975 S. Myrtle Ave, Tempe, AZ 85281, USA; joseph.cazier@asu.edu
- * Correspondence: giovanni.formato@izslt.it

Abstract: Background/Objectives: In a collaborative effort, FAO, the International Federation of Beekeepers' Association "Apimondia", the Appalachian State University, and the Istituto Zooprofilattico Sperimentale del Lazio e Toscana (IZSLT), the FAO Reference Centre for Animal Health and Food Security Discipline Apiculture, health, and biosecurity, designed an online international survey ("Knowledge, Awareness and Practice"-KAP) as a risk assessment tool to validate biosecurity measures able to prevent and control the main honeybee (Apis mellifera subsp.) infectious diseases. Methods: The KAP survey was disseminated through various channels for 14 months (January 2019-March 2020). Beekeepers' knowledge on nosemosis, American foulbrood (AFB), and European foulbrood (EFB) management was assessed. Beekeepers' attitudes were investigated by asking them to provide a score called "Acceptance by beekeepers". Results: Of the 410 respondents, the majority of them (68.3%, n = 252) were from Europe. European beekeepers (n = 252) considered "Highly acceptable" the following practices: removing combs that show signs of dysentery and feeding colonies for nosemosis; the quick identification and management of affected hives for American foulbrood and European foulbrood. Instead, the following practices were considered as not acceptable by beekeepers: for nosemosis, the use of antibiotics and sampling of hive debris for early detection; for American foulbrood and European foulbrood, the shook swarm, the destruction of the whole apiary, as well as their treatment with antibiotics. Conclusion: This study demonstrated the validity of the present "Knowledge, Awareness and Practice" (KAP) survey to validate the best practices for the main infectious honeybee diseases, considering the pragmatic point of view of beekeepers. Sustainable practices for disease control are preferred by the European beekeepers. While having an adequate knowledge base for the early detection of the investigated honeybee diseases, European beekeepers tend to be aware of the health status of their hives, embracing advanced, practice-oriented training. Authors highlight that the selection of practices and their validation should be revised on a regular basis, to be adapted in a timely manner to the current infectious honeybee disease situation, in order to build up a resilient and effective stock of practices.

Keywords: biosecurity measures in beekeeping; nosemosis; American foulbrood; European foulbrood; sustainable beekeeping; KAP survey



Citation: De Carolis, A.;
Newmark, A.J.; Kim, J.; Song, J.;
Pietropaoli, M.; Manara, V.;
Gyorffy, A.; Cazier, J.; Formato, G.
A Comprehensive Analysis of
Beekeeping Risks and Validation of
Biosecurity Measures against Major
Infectious Diseases in *Apis mellifera* in
Europe. *Agriculture* 2024, 14, 393.
https://doi.org/10.3390/
agriculture14030393

Academic Editor: Elena Gonella

Received: 22 January 2024 Revised: 7 February 2024 Accepted: 27 February 2024 Published: 29 February 2024



Copyright: © 2024 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

Agriculture **2024**, *14*, *393*

1. Introduction

In the beekeeping sector, maintaining strong colonies is the key to controlling honeybee diseases while reaching optimal productivity. The strength of the colonies is negatively affected by several stressors that in some cases can act synergistically [1-4]. While some variables, like the weather, are outside of the beekeeper's control, others can be regulated through management choices [5]. Among the latter are pathogens which may affect not only bee health, but also the quality and quantity of hive products and the services provided by the honeybees, reducing both the annual income for beekeepers and the benevolent effect of bees on the environment [6]. Honeybees have been strongly impacted by a variety of recurring and emerging diseases [7,8], many of which are infectious diseases, including nosemosis, American foulbrood (AFB), and European foulbrood (EFB), which are responsible for most of the colony losses [9,10], thus posing a threat to beekeeping worldwide. Nosemosis may be caused by two species of microsporidia, by Nosema apis and mainly by Nosema ceranae [11]; once Nosema ceranae is associated with virosis or high Varroa infection levels, it might result in colony losses. AFB, caused by the spore forming of bacterium *Paenibacillus larvae*, is considered the most serious brood infection of honeybees [12]. Instead, the bacterium *Melissococcus plutonius* is the ethologic agent of EFB, frequently associated with secondary invaders [13] and modulated by environmental factors [14]. Awareness combined with early and accurate diagnosis are crucial in the control of the mentioned infectious honeybee diseases, which can be implemented in the framework of proper biosecurity measures (BMBs) [15] and Good Beekeeping Practices (GBPs) [16]. Within BPRACTICES (ERA-NET SUSAN, EU-cofounded project) [17]), methods and guidelines to prevent and control infectious honeybee diseases in a sustainable way, including harmonized methods and identifying a list of GBPs and BMBs, were cross-validated at the EU level. As highlighted by Jacques et al. (2017) [18], scarce experience and poor beekeeping management have a strong negative impact on colony survival, warranting the mapping of beekeepers' knowledge and the development of mitigation actions where needed. At the same time, national policymakers should be aware of the prevalence of honeybee diseases to be able to improve sustainable beekeeping with appropriate support (e.g., extension service, availability of veterinary medicines registered for treating honeybees, etc.). To reveal the baseline landscape of the management of infectious honeybee diseases on an international level, a survey was developed based on the "Knowledge, Awareness and Practice" (KAP) model. A KAP survey is a tool that was identified as appropriate for worldwide monitoring management aspects in the beekeeping sector, enhancing the progressive adoption of proper measures to support beekeepers in achieving sustainable apiculture [19]. The present KAP tool proved to be suitable for the worldwide validation of the beekeeping practices identified for controlling infectious honeybee diseases by the BPRACTICES project [17].

2. Materials and Methods

The present survey is part of a series of three interdependent surveys [20,21] codesigned by FAO, the International Federation of Beekeepers' Association "Apimondia", Appalachian State University, and the Istituto Zooprofilattico Sperimentale del Lazio e Toscana (IZSLT). Between January 2019 and March 2020, the survey was disseminated through various communication channels, including direct invitation by e-mails, social media, beekeeping magazines, newspapers, involvement of the Center for Analytics Research and Education (CARE), and publication on the authors' websites. Additional distribution, Apimondia scientific and regional, occurred via commissions, FAO Technologies, and practices for small agricultural producers (TECA partners), including La Federación Internacional Latinoamericana de Apicultura (FILAPI), and the Beekeeping Network North–South (BNNS) facilitated the dissemination of the survey.

The survey (Appendix A) focused on the management and control of the three main infectious diseases of honeybees: nosemosis, AFB, and EFB. The survey was available in nine different languages: Chinese, Danish, Dutch, English, French, Italian, Russian,

Agriculture **2024**, 14, 393 3 of 10

Slovenian, and Spanish. The online questionnaire and data collection process was facilitated with Qualtrics[©] version 2020 software [22]. The completion of the survey was voluntary and anonymized. The survey contained 30 semi-closed (Sm), closed (Cl), and open-ended (Oe) questions concerning the management of the mentioned diseases. The questionnaire was divided into five sections: beekeeper data (section A), apiary management (section B), knowledge and experience in regards to infectious honeybee diseases (section C), control and management of infectious honeybee diseases (section D), and interest in further training (section E). The study was conducted according to the relevant ethical measures, and participants were asked to agree with the ethical guidelines before answering the questions. Section "A" (7 questions) aimed to classify users demographically based on age, gender, education, and location. Section "B" (6 questions) was designed to collect preliminary information regarding apiary management during active beekeeping season, including the beekeepers' experience in years, the number of hives managed, the frequency of hive inspections, the type of hives used, hive movement patterns, and self-assessment about profession (hobbyist or professional beekeeper). Section "C" (11 questions) was designed to assess the general knowledge and recognition of the three infectious diseases. Specifically, respondents were asked to correctly identify pictures showing the symptoms from among a collection of imagines depicting various honeybee diseases. Respondents were asked to self-assess their own disease knowledge, experience, and usefulness to correctly identify the signs of the diseases. Section "D" (3 questions) assessed beekeepers' perception on the relevance of each of the BMBs related to preventing/managing nosemosis and AFB/EFB diseases. For nosemosis, we investigated which practices were considered feasible as well as useful. For AFB and EFB, we investigated how much the beekeeping practices were useful, according to the practical experience of the beekeeper. Section "E" (3 questions) aimed at gathering information on beekeepers' interest in training courses, including those specialized in bee health.

According to the type of data, percentages or weighted averages were prepared for each question of the survey. To evaluate practices in the total number of answers given, a modified equation was used to calculate the weighted arithmetic means.

$$\sum_{i=1}^{n} = \frac{w_i \times x_i}{T_p}$$

where n = responses to the question, w_i = weight assigned to the practice impact parameters (i), T_P = total number of answers from respondents for each practice listed (p), x_i = number of users who chose the parameters (i) for each practice (p). Each respondent was asked to evaluate usefulness and/or feasibility of the practices as extremely, very, moderately, slightly, or not useful, on a non-standard five-point scale ranging from 4 to 0. Weighted means were coded as "Acceptance by Beekeepers": "High", "Medium", and "Low" according to the 1st (1st quartile = "Low") and 3rd quartiles (3rd quartile = "High") of the average.

3. Results

A total of 410 beekeepers responded to the survey, out of which 369 completed more than half of the survey questions. All answers originating from surveys completed more than 50% were included in the analysis of the geographical distribution of the users in Section "A". For the survey questions and answers analyzed in the other sections of the present publication, only responses from Europe (n = 252) were considered.

3.1. Section A: Demographic Data

Out of the 369 respondents, the majority (86.7%; n=320) answered all the questions of the survey. Geographically, most of the respondents were from Europe (68.3%; n=252). Among the surveys completed by European beekeepers, 48.8% (n=123) were from the United Kingdom, 19.4% (n=49) from Italy, 13.5% (n=34) from Denmark, and 7.1% (n=18) from Belgium, while other countries were less represented among the respondents. One-

Agriculture **2024**, 14, 393 4 of 10

third of the responses originated from outside of Europe (28.2%; n = 91): 19.0% from the Americas, 6.5% from Africa, 1.9% from Asia, and 0.8% from Australia and Oceania.

The majority of European respondents used the English version of the survey (56.7%; n=143), compared to 19.8% who used the Italian and 12.7% who used the Danish versions. Beekeepers also completed the survey in other languages: French (5.2%), Dutch (4.4%), Russian (0.8%), and Spanish (0.4%). Among all European beekeepers (n=252) who completed the relevant part of the survey, 66.8% (n=168) were male and 29.4% (n=74) were female. The average age of the respondents was 57 years. Most European respondents had post-graduate qualifications (29.4%; n=74) and a similar percentage held a university degree (29.8%; n=75). However, a lower percentage of the respondents had vocational or technical degrees, associatate or college degree (21.0%; n=53), while the highest education level for 17.9% (n=45) of the respondents was high school or a low-grade diploma.

3.2. Section B: Apiary Management

The paper focused on European beekeeping practices. Therefore, in the next sections, we exclusively focus on the results derived from respondents who claimed Europe as their geographical location (n = 252).

Regarding the years of experience in apiculture, the majority of European beekeepers (62.7%; n = 158) indicated having zero to ten years of beekeeping experience. The majority of the respondents (82.5%; n = 208) considered themselves as hobby beekeepers rather than professional ones. Most beekeepers in Europe managed one to ten colonies (57.9%; n = 146). One-third (28.2%; n = 71) of them managed 11 to 50 colonies. A smaller percentage of beekeepers managed 51 to 100 hives (3.2%; n = 8) or 101 to 500 hives (6.0%; n = 15). Three respondents (1.2%) claimed to oversee more than 1000 colonies. The majority of beekeepers in Europe (79.8%; n = 201) did not move their own colonies during the year. In terms of the types of beehives used in Europe, we found that beekeepers did not favor a single hive type. Beekeepers use a variety of beehive types, like Dadant Blatt (20.6%; n = 52), Langstroth (6.3%; n = 16), Warrè (1.2%; n = 3), Top-Bar (2.0%; n = 5), and "Others or multiple types" (68.7%, n = 173). Those indicating "Others or multiple types" indicated the type of beehive used at the local or national (28.2%, n = 71) level (e.g., national hive 28.2%; n = 71). With regard to the number of beehive inspections during the active season, most of the 252 European respondents inspected their own colonies "four times a month" (46.8%; n = 118), while the rest carried out hive inspections "two to three times a month" (29.4%, n = 74), "more than four times a month" (12.7%, n = 32), or "once a month" (7.1%, n = 18). Almost three percent of beekeepers (2.8%, n = 32)n = 7) reported that they "never" inspect their colonies.

3.3. Section C: Knowledge and Experience as Regards Infectious Honeybee Diseases

The majority of European respondents selected the correct picture for the symptoms of nosemosis (89.7%, n = 226), of AFB (89.3%, n = 225), and of EFB (80.2%, n = 202), respectively, while some respondents (15.1%, n = 38) confused the symptoms of mentioned diseases either with Chalkbrood or Varroa mite. Almost five percent of the beekeepers (4.8%, n = 12) chose multiple pictures for one disease, while 9.5% (n = 24) of them did not answer the relevant questions. The respondent's self-assessment about their knowledge of the mentioned diseases was moderate knowledge (nosemosis 41.3%, n = 104; AFB 38.9%, n = 98 and EFB 40.1%, n = 101), little knowledge (nosemosis 25.8% n = 65; AFB 26.6%, n = 67 and EFB 28.2%, n = 71), much knowledge (nosemosis 17.1%, n = 43; AFB 18.3, n = 46 and EFB 16.7%, n = 42), and exceptional knowledge (nosemosis 7.5%, n = 19; AFB 8.3% n = 21 and EFB 5.2%, n = 13), while a lower percentage (nosemosis 2.8%, n = 7; AFB 2.0% n = 5 and EFB 4.4%, n = 11) declared having no knowledge. One-third of the beekeepers (31.7%, n = 80) reported never experiencing nosemosis in the field, while the majority of them never encountered AFB (57.1%, n = 144) and/or EFB (56.0%, n = 141). More than half of the beekeepers (nosemosis 56.7%, n = 143; AFB 81.7%, n = 206 and EFB 75.0%, n = 189) declared that recognizing the symptoms of infectious diseases is extremely useful.

Agriculture **2024**, 14, 393 5 of 10

3.4. Section D: Control and Management of Infectious Honeybee Diseases

Concerning the practices adopted against nosemosis, overall, "Acceptance by Beekeepers" considering the weighted arithmetic means, coded in Table 1 using the quartile method (first quartile, "Low", if the mean is lower than 1.87; third quartile, "High", if the mean is higher than 2.52), highlighted that "removing combs that show signs of dysentery" and "feeding of colonies when need" are practices "Highly acceptable" for managing nosemosis, while "treat with antibiotics" and "sampling of hive debris for diagnostics" are considered "Lowly acceptable" by European beekeepers.

Table 1. Acceptance by beekeepers regarding BMBs for nosemosis. According to 1st (1st quartile = "Low") and 3rd (3rd quartile = "High"), considering the weighted average (mean) of each practice listed.

BMBs Related to Nosemosis	Mean	Acceptance by Beekeepers	
Remove combs that show signs of dysentery Feed colonies when needed	2.94 2.53	High	
Take samples of forager bees for diagnostics Treat for Varroa	2.52 2.38	Medium	
Replace the queen Select and breed Nosema-resistant bees	2.23 1.88	- Medium	
Take samples of hive debris for diagnostics Treat with antibiotics	1.82 0.83	Low	

Table 2 reports the weighted arithmetic mean scores of the BMBs related to AFB and EFB using the quartile method (first quartile, "Low", if the mean is lower than 2.12; third quartile, "High", if the mean is higher than 3.10). Practices including "disinfect or incinerate the infected bee tools, facilities, equipment", "quick management of the disease", "destroying only infected colonies showing the symptoms the disease" are considered "High acceptable", along with "performing the ropiness test to confirm clinical outbreak of AFB". On the other hand, "performing a shook swarm of the infected hives or of the whole apiary" and "the destruction of the whole apiary" are considered as "Lowly acceptable", similar to "treat with antibiotics".

Table 2. Acceptance by beekeepers regarding BMBs for both AFB and EFB disease. The practices were listed according to 1st (1st quartile = "Low") and 3rd (3rd quartile = "High") considering the weighted average (mean).

BMBs Related to AFB/EFB Diseases	Mean	Acceptance by Beekeepers		
Disinfect or incinerate the infected bee tools, facilities and equipment	3.74			
Take steps quickly to manage the disease	3.67	High		
Perform the ropiness test to confirm clinical outbreak of AFB	3.38			
Destroy only infected colonies with signs of the disease	3.14			
Be aware of the odor opening the hive	3.09			
Select queen breeders free of AFB/EFB	3.04			
Send samples from hives showing signs of the disease to a lab	3.01	Medium		
Find AFB and EFB typical scales	2.92			
Process wax safely in order to control the disease	2.82			
Inspect hives more frequently to detect the disease earlier	2.79			
Adopt commercial on-field kit for self-diagnosis	2.30			
Monitor the presence of the disease even from apparently healthy hives, sending samples to the lab as a preventative measure	2.13			
Do a shook swarm of the infected hives	2.08			
Destroy the whole apiary	1.85	T		
Do the shook swarm of the whole apiary	1.56	Low		
Treat with antibiotics	0.61			

3.5. Section E: Interest in Training

The majority of European respondents (75.4%; n = 190) expressed their interest in additional training in bee health, even attending it online (71.0%; n = 179). Half of the

Agriculture **2024**, 14, 393 6 of 10

beekeepers (52.4%, n = 132) articulated their interest contacting veterinarians specialized in bee health. A lower percentage of beekeepers were "somewhat" interested (21.0%, n = 53) in relevant trainings, while some of the respondents chose the option "not interested at all" (13.1%; n = 33) in further education.

4. Discussion

In sustainable beekeeping, GBPs and BMBs are the key factors ensuring optimal honeybee management and bee health. Since beekeepers tend to have a very pragmatic approach and they adopt different practices daily in different countries to control infectious honeybee diseases, we used a KAP survey to verify their awareness and acceptance of the listed beekeeping practices and biosecurity measures. In the present analysis, we focused on the European survey responses that formed most of the surveys completed (more than 50%). Our investigation proved to be appropriate to validate practices previously identified by the EU BPRACTICES project [17], which provided the first published, harmonized list of science-based beekeeping practices suitable for preventing and controlling the main honeybee diseases in Europe [15]. Concerning the number of hive inspections realized on a seasonal basis, most European beekeepers declared that they inspect their own colonies frequently during the active season, "four times a month" or "from two to three times a month". Even if this approach is time-consuming, the awareness of beekeepers of the necessity of regular hive inspections demonstrates proper education of European beekeepers, as frequent inspection of the colonies is indispensable for maintaining good bee health status, as it allows early diagnosis as well as prompt management of bee diseases [23,24]. Concerning the recognition of the symptoms of the main infectious honeybee diseases, most of the European beekeepers were able to pair the pictures showing the symptoms with the name of the disease. By recognizing the clinical signs of the main infectious honeybee diseases, European beekeepers can be more aware of the health status of their colonies and can control them in their own apiaries in time, preventing the spread of the diseases. In the case of AFB, which is a notable disease in a wide range of countries, early recognition enhances the implementation of the relevant state veterinary services' protocol. Despite the fact that beekeepers assessed their knowledge on the relevant diseases as moderate and that the majority of respondents never experienced the outbreak of either disease (AFB or EFB), most of them could clearly identify the symptoms of the diseases. Our results show that the European beekeepers possess well-acquired, readily applicable theoretical knowledge. In regards to the validation of the biosecurity measures to prevent and control nosemosis, European beekeepers considered "remove combs that show signs of dysentery" and "feed colonies when need" as "Highly acceptable" measures. Dysentery, a consequence of infection in honeybees, significantly promotes the spread of the disease throughout the colony. Typically, bees relieve themselves during flight outside the hive, but dysentery disrupts this behavior [25]. To avoid the widespread transmission of nosemosis, the European beekeepers reported these to be good measures to embrace. In addition, the administration of herbal supplements to the feed [26] is reported to be a good measure to adopt to reduce infection levels in affected honeybee colonies, enhancing their strength and reducing winter mortality [27]. On the contrary, the two biosecurity measures that were ranked with the lowest scores for "Acceptance by Beekeepers" were "take samples of hive debris for diagnostic of nosemosis" and "treat colonies with antibiotics". Early detection of infectious diseases using hive debris requires a robust laboratory background. Nosema spp. Can be detected and quantified in the bottom scraps and frass collected in the beehives using qPCR diagnostic assays [28]. The precise information to carry out the reaction is described in BeeBook [29]. However, several reliable diagnostic methods for Nosema spp. Infection in honeybees exist, and each has advantages and disadvantages ([30,31] reported the utility of debris analysis for detecting EFB). These new concepts require better understanding by European beekeepers, and greater educational emphasis should be placed on early detection. The use of antibiotics in apiculture is clearly evaluated by European beekeepers as not acceptable for managing nosemosis, and for the treatment of both AFB and EFB, highlighting European beekeepers' awareness towards sustainability

Agriculture **2024**, 14, 393 7 of 10

in beekeeping. Fumagillin, the antibiotic employed in the treatment of nosemosis, was removed from use in EU countries in 2016. Consequently, researchers have been exploring compounds of both natural and synthetic origin as potential alternatives to fight nosemosis [32]. Antibiotics are not permitted in the European Union for treating honeybees, to prevent the risk of residues in hive products [33], as well as antibiotic resistance in the One Health scope [34]. The results demonstrate more awareness of European beekeepers of the applicable legislation, as well as their inclination towards alternative solutions in managing honeybees. Similar results were observed in a previous study by Mezher and colleagues (2021) [35]. In regard to the two bacterial diseases (AFB and EFB) investigated, European beekeepers "Highly accepted" the practices to "disinfect or incinerate the infected bee tools, facilities and equipment", and to "take steps quickly to manage the disease". In addition, European beekeepers preferred to "perform the ropiness test to confirm clinical outbreak of AFB" (the contents of a cell can be stretched into threads with a toothpick or matchstick for a few centimeters), considering it as "Highly acceptable", instead of "adopting commercial on-field kit for self-diagnosis" or "sending samples to a diagnostic laboratory". A recent review by Matović and colleagues (2023) [36] provided an overview of the most recent information on AFB across multiple chapters. The latter result highlights the need for providing beekeepers with the support of specialized advisors (veterinarians or veterinary technicians) and diagnostic laboratories. European beekeepers generally disagreed with "performing shook swarm in case of the infected bee hives" and were even more reluctant to implement that on all hives of the apiary. The rejection of shook swarm might be due to the fact that it is a time-consuming practice and may lead to relapses of the diseases as well as to the weakening of the families and/or losing the queen. Previous works [37,38] showed that even if it requires extra effort in organization and logistics planning from the beekeeper, shaking the bees of infected colonies on new material (shook swarm) could provide an effective sustainable solution to reduce both the incidence of AFB outbreaks as well as the continued transmission risk. Over recent decades, several methods have been tried to control AFB and EFB, such as colony destruction by incineration [39]. In our study, "Destroy only infected colonies with signs of the disease" was well-accepted by the respondents, while the practice "Destroy the whole apiary" scored low acceptance, underlying the relevance and awareness of bee welfare even in the beekeeping sector. Previous works [40,41] have shown that some beekeeping management practices are associated with lower colony loss rates. Beekeepers who are not open to improving their knowledge may be at risk of high mortality rates among their bee colonies. Most of the respondents expressed their interest in attending bee health-specific trainings and indicated their willingness to contact veterinarians specialized in bee diseases. Similar results were observed in the survey by Giunè and colleagues (2023) [42] about the highest global interest in training on apiary health and control of pests that affect bee colonies. Life-long learning is indispensable in all sectors and also for keeping pace with the challenges with which sustainable beekeeping must cope. It seems indeed that the online knowledge transfer methods are well-accepted by beekeepers, allowing for the flexibility needed due to the nature of the beekeeping seasons.

5. Conclusions

In the context of the One Health initiative, both GBPs and BMBs represent a crucial step to mitigate the current risk for bee health and the beekeeping economy posed by the main infectious honeybee diseases. The use of the KAP survey proved to be a useful tool able to validate in EU the first published, harmonized list of GBPs and BMBs previously described in the B-PRACTICES project. Most European beekeepers prefer sustainable disease control practices, have the necessary knowledge for early detection of the main infectious honeybee diseases and are open to acquiring more expertise on those diseases with the help of extension services. With the understanding that the number of European respondents is not representative enough to cover virtually the entire beekeeping sector on the continent, our aim here was to propose a new approach in evaluating and validating BMBs, according to the beekeepers' acceptance. In addition, considering that both BMBs

Agriculture **2024**, 14, 393 8 of 10

and infectious honeybee diseases may evolve across time and in any geographical context, both the list of practices and their validation should be tested and updated periodically.

Author Contributions: Conceptualization, G.F., J.C. and J.S.; methodology, G.F., J.C., J.S., A.D.C., M.P. and J.K.; software, J.C., and M.P.; validation, G.F., A.J.N., J.K. and J.S.; resources, J.S. and J.K.; data curation, J.C.; writing—original draft preparation, A.D.C., A.J.N. and M.P.; writing—review and editing, G.F., A.J.N., V.M. and A.G.; supervision, G.F. and J.S.; project administration, G.F. and J.K.; funding acquisition, J.S. All authors have read and agreed to the published version of the manuscript.

Funding: The activity presented here was realized in the context of the collaboration between the FAO and IZSLT under Letter of Agreement (PO number 334292).

Institutional Review Board Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy.

Acknowledgments: The authors owe thanks to the TECA beekeeping platform for assistance with the dissemination of the survey, APIMONDIA for their collaboration and contributions to this project, and the beekeepers who made the effort to participate in this survey. Moreover, the authors wish to thank the members of the FAO AMR Working Group for contributing to the development of the survey, which was the basis of this study.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. Structure of the questionnaire: Questions were divided into five main parts, A, B, C, D, and E; type of questions (Sm) 1 = Semi-closed, (Cl) 2 = Closed, (Oe) 3 = Open-ended.

Question Number	Text (Type of Question)	Section
1	In which region are you located? (Oe)	
2	User Language (Cl)	
3	Year you are born (Oe)	
4	Make your gender (Cl)	A
5	Mark your highest education level (Cl)	
6	Select the country in which you primarily house your bees (Cl)	
7	Select the region of the country you selected that you primarily house your bees in (Cl)	
8	How many years have you been a beekeeper? (Oe)	
9	Do you consider yourself a professional beekeeper? (Cl)	
10	Do you move your bees at all throughout the year? (Cl)	В
11	Estimate the number of hives you are currently managing (Sm)	D
12	What type of hive are you using? (Sm)	
13	How often do you inspect your hives during the active season? (Cl)	
14-15-16	Which of the following photos is an example of nosemosis, American Foulbrood and European Foulbrood? (Cl)	
17-18-19	How knowledgeable are you in nosemosis, American Foulbrood, and European Foulbrood bee disease? (Cl)	С
20-21-22	Please tell us your experience in recognizing nosemosis, American Foulbrood, and European Foulbrood (Cl)	
23-24	How useful is it to be able to recognize the signs of nosemosis, American Foulbrood, and European Foulbrood bee disease? (Cl)	
	Please indicate how useful each of the following practices are in preventing/managing nosemosis (1–8) (Cl)	
25	 Remove combs that show signs of dysentery Treat for Varroa Feed colonies when needed Take samples of hive debris for diagnostics Take samples of forager bees for diagnostics Replace the queen Treat with antibiotics Select and breed Nosema resistant bees 	D

Agriculture **2024**, *14*, *393*

Table A1. Cont.

Question Number	Text (Type of Question)	Section
26	Please indicate how feasible each of the following could be in your beekeeping activities $(1-8, Question number 25)$ (Cl)	
	Please indicate how useful each of the following practices are in preventing/managing AFB/EFB, according to your experience $(1-16)$ (Cl)	
	1. Inspect hives more frequently to detect the disease earlier	
	2. Be aware of the odour opening the hive	
	3. Perform the ropiness test to confirm clinical outbreak of AFB	
	4. Find AFB and EFB typical scales	
	5. Adopt commercial on-field kit for self-diagnosis	
	6. Disinfect or incinerate the infected bee tools, facilities and equipment	
	7. Process wax safely in order to control the disease	
27	8. Monitor the presence of the disease even from apparently healthy hives sending to	
27	the lab samples as a preventative measure 9. Send samples from hives showing signs of the disease to a lab	
	9. Send samples from hives showing signs of the disease to a lab10. Do a shook swarm of the infected hives (moving bees to fresh new comb	
	foundations and destroying the old combs)	
	11. Do the shook swarm of the whole apiary	
	12. Treat with antibiotics	
	13. Destroy only infected colonies with signs of the disease	
	14. Destroy the whole apiary	
	15. Take steps quickly to manage the disease	
	16. Select queen breeders free of AFB/EFB	
28	How interested are you in a nationwide service connecting beekeepers with veterinary	
20	experts specialized in bees? (CI)	E
29	Would you be interested in bee health training? (CI)	E
30	Would you be interested in an online training course? (Cl)	

¹ "Semi-closed" is a single-choice question with the option to further specify the answer by writing a response. ² "Close" is a question that can only be answered by selecting one or more of the choices from a narrow range of options. ³ "Open-ended" is a question that allows the respondent to provide a free-form answer by writing a response.

References

- 1. Tosi, S.; Nieh, J.C.; Sgolastra, F.; Cabbri, R.; Medrzycki, P. Neonicotinoid Pesticides and Nutritional Stress Synergistically Reduce Survival in Honey Bees. *Proc. R. Soc. B Biol. Sci.* **2017**, 284, 20171711. [CrossRef]
- 2. Straub, L.; Williams, G.R.; Vidondo, B.; Khongphinitbunjong, K.; Retschnig, G.; Schneeberger, A.; Chantawannakul, P.; Dietemann, V.; Neumann, P. Neonicotinoids and Ectoparasitic Mites Synergistically Impact Honeybees. *Sci. Rep.* **2019**, *9*, 8159. [CrossRef]
- 3. van Dooremalen, C.; Cornelissen, B.; Poleij-Hok-Ahin, C.; Blacquière, T. Single and Interactive Effects of Varroa Destructor, Nosema Spp., and Imidacloprid on Honey Bee Colonies (*Apis mellifera*). *Ecosphere* **2018**, *9*, e02378. [CrossRef]
- 4. Meixner, M.D. A Historical Review of Managed Honey Bee Populations in Europe and the United States and the Factors That May Affect Them. *J. Invertebr. Pathol.* **2010**, *103*, S80–S95.
- Steinhauer, N.; Saegerman, C. Prioritizing Changes in Management Practices Associated with Reduced Winter Honey Bee Colony Losses for US Beekeepers. Sci. Total Environ. 2021, 753, 141629. [CrossRef]
- 6. FAO; IZSLT; Apimondia, C.A.A.S. *Good Beekeeping Practices for Sustainable Apiculture*; FAO Animal Production and Health Guidelines No. 25; FAO, IZSLT, Apimondia and CAAS: Rome, Italy, 2021; ISBN 978-92-5-134612-9.
- 7. Pasho, D.J.M.; Applegate, J.R.; Hopkins, D.I. Diseases and Pests of Honey Bees (Apis Mellifera). *Vet. Clin. Food Anim. Pract.* **2021**, 37, 401–412. [CrossRef]
- 8. Bartlett, L.J. Frontiers in Effective Control of Problem Parasites in Beekeeping. *Int. J. Parasitol. Parasites Wildl.* **2022**, 17, 263–272. [CrossRef]
- 9. Grover, A.; Kalia, P.; Sinha, R.; Garg, P. Colony Collapse Disorder: A Peril to Apiculture. J. Appl. Nat. Sci. 2022, 14, 729–739.
- 10. Parveen, N.; Miglani, R.; Kumar, A.; Dewali, S.; Kumar, K.; Sharma, N.; Bisht, S.S. Honey Bee Pathogenesis Posing Threat to Its Global Population: A Short Review. *Proc. Indian Natl. Sci. Acad.* **2022**, *88*, 11–32. [CrossRef]
- 11. Marín-García, P.J.; Peyre, Y.; Ahuir-Baraja, A.E.; Garijo, M.M.; Llobat, L. The Role of Nosema Ceranae (Microsporidia: Nosematidae) in Honey Bee Colony Losses and Current Insights on Treatment. *Vet. Sci.* **2022**, *9*, 130. [CrossRef]
- 12. Genersch, E. American Foulbrood in Honeybees and Its Causative Agent, Paenibacillus Larvae. *J. Invertebr. Pathol.* **2010**, *103*, S10–S19. [CrossRef] [PubMed]
- 13. Forsgren, E.; Budge, G.E.; Charrière, J.-D.; Hornitzky, M.A.Z. Standard Methods for European Foulbrood Research. *J. Apic Res.* **2013**, 52, 1–14. [CrossRef]
- 14. Forsgren, E. European Foulbrood in Honey Bees. J. Invertebr. Pathol. 2010, 103, S5–S9. [CrossRef] [PubMed]
- 15. Pietropaoli, M.; Ribarits, A.; Moosbeckhofer, R.; Köglberger, H.; Alber, O.; Gregorc, A.; Smodis Skerl, M.I.; Presern, J.; Bubnic, J.; Necati Muz, M.; et al. Biosecurity Measures in European Beekeeping. *Rev. Sci. Tech. L'oie* **2020**, *39*, 725–735. [CrossRef]

Agriculture **2024**, 14, 393

16. Rivera-Gomis, J.; Bubnic, J.; Ribarits, A.; Moosbeckhofer, R.; Alber, O.; Kozmus, P.; Jannoni-Sebastianini, R.; Haefeker, W.; Köglberger, H.; Smodis Skerl, M.I.; et al. Good Farming Practices in Apiculture. *Rev. Sci. Tech. L'oie* **2020**, *38*, 879–890. [CrossRef]

- 17. ERA-NET SUSAN. Available online: https://era-susan.eu/content/bpractices (accessed on 16 February 2024).
- 18. Jacques, A.; Laurent, M.; Consortium, E.; Ribière-Chabert, M.; Saussac, M.; Bougeard, S.; Budge, G.E.; Hendrikx, P.; Chauzat, M.-P. A Pan-European Epidemiological Study Reveals Honey Bee Colony Survival Depends on Beekeeper Education and Disease Control. *PLoS ONE* **2017**, *12*, e0172591. [CrossRef]
- 19. FAO; IZSLT. *Responsible Use of Antimicrobials in Beekeeping*, 1st ed.; Formato, G., Yu, L., Song, L.J., Mintiens, K., Ferrari1, G., Eds.; FAO Animal Production and Health Guidelines No. 26; FAO: Rome, Italy, 2021; ISBN 978-92-5-135005-8.
- 20. Robinette, C.; Scott, S.; Yu, L.; Croppi, S.; Hassler, E.E.; Newmark, A.J.; Cazier, J.A.; Song, J.; Formato, G. An International Survey Comparing Antimicrobial Resistance Risk and Awareness between Beekeepers in Europe, the United Kingdom and North America; FAO: Rome, Italy, 2021.
- De Carolis, A.; Newmark, A.J.; Kim, J.; Cazier, J.; Hassler, E.; Pietropaoli, M.; Robinette, C.; Formato, G.; Song, J. Results of an International Survey for Risk Assessment of Honey Bee Health Concerning Varroa Management. Appl. Sci. 2022, 13, 62. [CrossRef]
- 22. Qualtrics. Qualtrics software Copyright © 2024; Qualtrics: Provo, UT, USA, 2020.
- 23. Scott, A.; Hassler, E.; Formato, G.; Rünzel, M.A.; Wilkes, J.; Hassan, A.; Cazier, J. Data mining hive inspections: More frequently inspected honey bee colonies have higher over-winter survival rates. *J. Apic. Research* **2023**, *62*, 983–991. [CrossRef]
- 24. Giacobino, A.; Molineri, A.; Cagnolo, N.B.; Merke, J.; Orellano, E.; Bertozzi, E.; Masciangelo, G.; Pietronave, H.; Pacini, A.; Salto, C. Key Management Practices to Prevent High Infestation Levels of Varroa Destructor in Honey Bee Colonies at the Beginning of the Honey Yield Season. *Prev. Vet. Med.* 2016, 131, 95–102. [CrossRef]
- 25. Galajda, R.; Valenčáková, A.; Sučik, M.; Kandráčová, P. Nosema Disease of European Honey Bees. J. Fungi 2021, 7, 714. [CrossRef]
- 26. Martín-Hernández, R.; Bartolomé, C.; Chejanovsky, N.; Le Conte, Y.; Dalmon, A.; Dussaubat, C.; García-Palencia, P.; Meana, A.; Pinto, M.A.; Soroker, V. Nosema Ceranae in Apis Mellifera: A 12 Years Postdetection Perspective. *Environ. Microbiol.* **2018**, 20, 1302–1329. [CrossRef]
- 27. Shumkova, R.; Balkanska, R.; Hristov, P. The Herbal Supplements NOZEMAT HERB[®] and NOZEMAT HERB PLUS[®]: An Alternative Therapy for N. Ceranae Infection and Its Effects on Honey Bee Strength and Production Traits. *Pathogens* **2021**, *10*, 234. [CrossRef] [PubMed]
- 28. Copley, T.R.; Giovenazzo, P.; Jabaji, S.H. Detection of Nosema Apis and N. Ceranae in Honeybee Bottom Scraps and Frass in Naturally Infected Hives. *Apidologie* **2012**, *43*, 753–760. [CrossRef]
- 29. Fries, I.; Chauzat, M.-P.; Chen, Y.-P.; Doublet, V.; Genersch, E.; Gisder, S.; Higes, M.; McMahon, D.P.; Martín-Hernández, R.; Natsopoulou, M. Standard Methods for Nosema Research. *J. Apic. Res.* **2013**, *52*, 1–28. [CrossRef]
- 30. Mazur, E.D.; Gajda, A.M. Nosemosis in Honeybees: A Review Guide on Biology and Diagnostic Methods. Appl. Sci. 2022, 12, 5890. [CrossRef]
- 31. Biová, J.; Charrière, J.-D.; Dostálková, S.; Škrabišová, M.; Petřivalský, M.; Bzdil, J.; Danihlík, J. Melissococcus Plutonius Can Be Effectively and Economically Detected Using Hive Debris and Conventional PCR. *Insects* **2021**, *12*, 150. [CrossRef]
- 32. Kunat-Budzyńska, M.; Budzyński, M.; Schulz, M.; Strachecka, A.; Gancarz, M.; Rusinek, R.; Ptaszyńska, A.A. Natural Substances, Probiotics, and Synthetic Agents in the Treatment and Prevention of Honeybee Nosemosis. *Pathogens* 2022, 11, 1269. [CrossRef] [PubMed]
- 33. Shoaei, F.; Talebi-Ghane, E.; Ranjbar, A.; Mehri, F. Evaluation of Antibiotic Residues in Honey: A Systematic Review and Meta-Analysis. *Int. J. Environ. Health Res.* **2023**, *34*, 1064–1075. [CrossRef]
- 34. Regulation (EU) 2019/6 of the European Parliamentand of the Council of 11 December 2018 on Veterinary Medicinal Products and Repealing Directive 2001/82/EC. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX: 32019R0006 (accessed on 15 February 2024).
- 35. Mezher, Z.; Bubnic, J.; Condoleo, R.; Jannoni-Sebastianini, F.; Leto, A.; Proscia, F.; Formato, G. Conducting an International, Exploratory Survey to Collect Data on Honey Bee Disease Management and Control. *Appl. Sci.* **2021**, *11*, 7311. [CrossRef]
- 36. Matović, K.; Žarković, A.; Debeljak, Z.; Vidanović, D.; Vasković, N.; Tešović, B.; Čirić, J. American Foulbrood—Old and Always New Challenge. *Vet. Sci.* 2023, 10, 180. [CrossRef]
- 37. Locke, B.; Low, M.; Forsgren, E. An Integrated Management Strategy to Prevent Outbreaks and Eliminate Infection Pressure of American Foulbrood Disease in a Commercial Beekeeping Operation. *Prev. Vet. Med.* **2019**, *167*, 48–52. [CrossRef]
- 38. Pernal, S.F.; Albright, R.L.; Melathopoulos, A.P. Evaluation of the Shaking Technique for the Economic Management of American Foulbrood Disease of Honey Bees (Hymenoptera: Apidae). *J. Econ. Entomol.* **2008**, 101, 1095–1104. [CrossRef] [PubMed]
- 39. Roetschi, A.; Berthoud, H.; Kuhn, R.; Imdorf, A. Infection Rate Based on Quantitative Real-Time PCR of Melissococcus Plutonius, the Causal Agent of European Foulbrood, in Honeybee Colonies before and after Apiary Sanitation. *Apidologie* 2008, 39, 362–371. [CrossRef]
- 40. El Agrebi, N.; Steinhauer, N.; Tosi, S.; Leinartz, L.; de Graaf, D.C.; Saegerman, C. Risk and Protective Indicators of Beekeeping Management Practices. *Sci. Total Environ.* **2021**, 799, 149381. [CrossRef]
- 41. Chauzat, M.-P.; Jacques, A.; Laurent, M.; Bougeard, S.; Hendrikx, P.; Ribière-Chabert, M. Risk Indicators Affecting Honeybee Colony Survival in Europe: One Year of Surveillance. *Apidologie* **2016**, *47*, 348–378. [CrossRef]
- 42. Guiné, R.P.F.; Oliveira, J.; Coelho, C.; Costa, D.T.; Correia, P.; Correia, H.E.; Dahle, B.; Oddie, M.; Raimets, R.; Karise, R. Professional Training in Beekeeping: A Cross-Country Survey to Identify Learning Opportunities. *Sustainability* 2023, 15, 8953. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.