Biosecurity measures in European beekeeping

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Summary

Emerging pathogens of honey bees represent an important threat to the development of the beekeeping sector. The implementation of biosecurity measures in beekeeping (BMBs) plays an essential role in supporting honey bee health within the beekeeping sector. A group of experts, in collaboration with the BPRACTICES (Grant Agreement No. 696231, European Research Area on Sustainable Animal Production Systems [ERA-Net SusAn]) project partners, provided for the definition of BMBs. Thus, BMBs are all those operational activities implemented by the beekeeper in controlling the risk of introduction and spread of specific honey bee disease agents. In this paper the BMBs in the European beekeeping context are identified for the most relevant honey bee diseases in Europe: varroosis, American foulbrood (AFB), European foulbrood (EFB), nosemosis and aethinosis. Moreover, BMBs were classified in 'categories' adapted to consider productivity and the 'One Health' approach: human health, honey bee health and protection of the environment. The 84 BMBs described by the panel of experts were ranked according to the priority score attributed. The implementation of BMBs represents an essential step forward to increase the resilience and sustainability of European beekeeping.

Keywords

Apiculture – Biosecurity measures – BPRACTICES – Europe – Honey bee.

Introduction

Globalisation of markets, massive and extensive transport networks and climate change are key factors in the spread of disease agents (1). In general, it is possible to record an increased emergence of pathogens in animals and plants that are introduced accidentally or deliberately into a natural environment where they are not normally found, causing serious impacts. Invasive alien species represent a priority worldwide as they are a major threat to native plants and animals, causing massive economic damage every year (2, 3, 4).

In the beekeeping sector, several pathogens are spread in different areas of the world. Notable concerns are (5, 6):

- the varroa mite (*Varroa destructor* Anderson & Trueman, 2000, Family: Varroidae, Order: Parasitiformes) and varroa-associated viruses
- nosema disease (*Nosema ceranae* Fries *et al*., 1996, Family: Nosematidae, Order: Dissociodihaplophasida)
- the small hive beetle (SHB) (*Aethina tumida* Murray, 1867, Family: Nitidulidae, Order: Coleoptera)
- American foulbrood (AFB) (*Paenibacillus larvae* White, 1906, Family: Paenibacillaceae, Order: Bacillales)
- European foulbrood (EFB) (*Melissococcus plutonius* Trüper and De'Clari, 1998, Family: Enterococcaceae, Order: Lactobacillales)
- predators such as the Asian hornet (*Vespa velutina* var. *nigrithorax* Lepeletier, 1836, Family: Vespidae, Order: Hymenoptera).

After their introduction into a colony, these pathogens usually have a negative effect on honey bee health and the productivity of the population's colonies and thereby affect the development, sustainability and profitability of the affected beekeeping sector. Moreover, given the important role of honey bees as pollinators, the additional negative effects on biodiversity, crops and animal production merit acknowledgement (7).

Several registered veterinary products can be used in honey bee colonies for disease control. However, their misuse may lead to pharmacological resistance, which has already been reported in honey bee pests in some areas. For example, bacteria causing AFB have been observed to be resistant to oxytetracycline (7, 8). *Varroa destructor* is gaining resistance against synthetic acaricides such as pyrethroids (fluvalinate), organophosphates (coumaphos) and formamidines (amitraz) (9, 10, 11, 12, 13). Furthermore, the use of veterinary medicines is a persistent source of contamination for honey bee products, as shown by the use of the lipophilic synthetic acaricides, which are mainly absorbed in beeswax (14, 15, 16, 17), and antibiotic residues, which are mainly absorbed in honey (18, 19).

Application of good beekeeping practices (GBPs) and disease-specific biosecurity measures in beekeeping (BMBs) can prevent honey bee diseases, thereby reducing the use of veterinary medicines in apiculture and the risk of residues in hive products.

Good beekeeping practices have been defined as 'those integrative activities that beekeepers apply for on-apiary production to attain optimal health for humans, honey bees and the environment' (20), and thus encourage conscious beekeepers to improve honey bee health in the context of the 'One Health' approach (21, 22). It is important to expand knowledge on: *a)* honey bee pathologies, *b)* good beekeeping practices and *c)* biosecurity measures in beekeeping.

The International Food Safety Authorities Network (INFOSAN) (23) states: 'Biosecurity is a strategic and integrated approach to analysing and managing relevant risks to human, animal and plant life and health and associated risks for the environment. It is based on

recognition of the critical linkages between sectors and the potential for hazards to move within and between sectors, with system-wide consequences'. European Regulation 2016/429 (24) informs its membership that biosecurity is '…the sum of management and physical measures designed to reduce the risk of the introduction, development and spread of diseases to, from and within: *a)* an animal population, or *b)* an establishment, zone, compartment, means of transport or any other facilities, premises or location'. Hence, biosecurity is key for a healthy production system and ensuring consumer safety.

The aim of this manuscript is to define and classify the BMBs in detail, identifying and scoring harmonised measures for the main honey bee diseases in Europe.

Materials and methods

A group of experts belonging to eight research institutes, two international beekeepers' associations and the Food and Agriculture Organization of the United Nations (FAO) (see Table I for details), in the context of the European Union (EU) project 'BPRACTICES', gave a general definition and classification of biosecurity measures adapted to the European beekeeping context.

Table I

The BPRACTICES project

Title
'New indicators and on-farm practices to improve honey bee health in the *Aethina tumida* era in Europe', whose acronym is 'BPRACTICES', is a transnational project funded within the Horizon 2020 Research and Innovation Programme of the European Research Area on Sustainable Animal Production Systems (ERA-NET SusAn) under Grant Agreement No. 696231 (www.izslt.it/bpractices).

Consortium partners
Research institutes (*), Food and Agriculture Organization of the United Nations (FAO) and the International Federation of Beekeepers' Associations (Apimondia).

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University of Genoa, Italy

European Union Reference Laboratory (EURL) for Bee Health, French Agency for Food, Environmental and Occupational Health and Safety (ANSES), France

Food and Agriculture Organization of the United Nations (FAO)

Beekeeping Exchange Group, Technologies and Practices for Small Agricultural Producers (TECA), FAO, Italy

Beekeepers' associations involved in the project

International Federation of Beekeepers' Associations (Apimondia), Italy

European Professional Beekeepers Association (EPBA), Germany

Other collaborations

Appalachian State University, United States of America

Danish Beekeepers' Association, Denmark

Definition of biosecurity measures in beekeeping

The general definition of BMBs provided by the group of experts listed in Table I was based on the previous studies on biosecurity measures reported by Dewulf & van Immerseel (25) and Rivera-Gomis *et al.* (20).

Classification of biosecurity measures in beekeeping

Biosecurity measures in beekeeping were classified using a 'One Health' approach (22), according to the categories (sector of impact) adopted by Formato & Smulders (26).

Identification of biosecurity measures in beekeeping

According to Dewulf & van Immerseel (25), biosecurity can address each specific pathogen, designing measures that are specifically adapted to its control. After the generic definition of BMBs, specific measures were identified in the European beekeeping context in relation to the five most common diseases affecting honey bees in Europe: varroosis, AFB, EFB, nosemosis and aethinosis.

Experts identified BMBs by relevance for the European Union during a team exercise. Direct, simple and easily understandable language was used to write the list of BMBs for the most common honey bee diseases.

Validation of biosecurity measures in beekeeping

During the process, crucial relevance was attributed to the practical point of view of beekeepers. To achieve complete and extensive integration with the stakeholders, the International Federation of Beekeepers' Associations (Apimondia) and the European Professional Beekeepers Association (EPBA) actively participated in the identification and evaluation of BMBs, which were validated according to their importance in daily apiary activities.

Assessment of biosecurity measures in beekeeping

Previous attempts at prioritisation conducted in similar fields (27) were considered as a reference for a transparent and documented BMB prioritisation process. In order to allow the panel of experts to evaluate BMBs according to their importance, one questionnaire (Microsoft Excel 2007, Microsoft Corporation) was distributed for completion, correction, amendment and rating of the BMBs by the scientific manager of each research institute/organisation/association. The scientific manager was responsible for returning the questionnaire with an evaluation of each BMB according to its importance, through the adoption of a score for relevance ranging from 1 to 5 (1 = not important; 2 = slightly important; 3 = important; 4 = very important; 5 = mandatory). The collection of scores could be performed by

consultation of other experts, and a single questionnaire for each institute, organisation or association was received by the project leader. To avoid bias, all participants gave their score in a blinded mode. The scores obtained from the evaluation process indicate the estimated relevance of the BMBs.

Statistical methods

All ratings were added to a Microsoft Excel™ spreadsheet (Microsoft Excel 2007, Microsoft Corporation) and the Excel function QUARTILE (array, quart) was used to obtain a final list of prioritised BMBs for the use of European beekeepers. Finally, the authors considered only scores with means higher than the 75th quartile for the final ranking.

Results

Definition of biosecurity measures in beekeeping

Biosecurity measures in beekeeping are described as 'all those operational activities implemented by the beekeeper to reduce the risk of introduction and/or spread of specific honey bee disease agents'.

Identification of biosecurity measures in beekeeping

A total of 84 BMBs were identified by the panel of experts for the most common honey bee diseases in Europe: varroosis, AFB, EFB, nosemosis and aethinosis (Table II).

Table II

Biosecurity measures in beekeeping for the most common honey bee diseases in Europe

1. Varroosis (*Varroa destructor*)	**Mean score (1–4)**	**Category**
Treat varroosis always according to national legislation and registration	4.0	HBH, HH, PR, PS, EP, AH
Adopt/provide hives with screened bottom boards	3.8	HBH, PR
Nuclei and swarms should originate from colonies with no clinical signs of *Varroa*-related diseases (ABPV, DWV, IAPV, KBV, SBV, etc.)	3.8	HBH, PR
Treat according to an integrated pest management concept, taking *Varroa* thresholds into account	3.8	HBH, PS, PR
Maintain the number of *Varroa* below the harmful threshold in each colony	3.8	HBH, PR
Adopt diagnostic tools for measuring *Varroa* infestation levels (for example, icing sugar method, CO_2 test, mite fall, etc.) after treatments and during the year (for example, in spring at the beginning of the beekeeping season or before harvesting)	3.8	HBH (PCI), PR
Treat simultaneously all colonies of the apiary and those in the same area	3.6	HBH, PR
Prepare colonies (e.g. absence of brood) before treatment to get the highest possible efficacy, depending on type of treatment and product	3.5	HBH, PR
Monitor efficacy of acaricide treatments, verifying *Varroa* fall after treatment	3.5	HBH (PCI), PS, PR
Have good knowledge of the clinical signs and of the transmission methods of varroosis and viruses	3.4	HBH, PR
Perform at least two treatments per year	3.3	HBH, PR
Monitor efficacy of acaricide treatments, verifying the absence of clinical signs of varroosis in the colony (for example, presence of *Varroa* mites on adult honey bees) after treatment	3.2	HBH, PR
Rotate active principles of veterinary medicines to avoid *Varroa* resistance	3.2	HBH, PR, HH, AH, EP

Check the health status of drones producing colonies, especially for viruses	3.2	HBH, PR
Preferably use medicines allowed in organic farming to control *Varroa*	3.1	HBH, PS, AH, PR, EP, HH
Provide a sufficient number of healthy spare bee colonies at the right time depending on climate and vegetation conditions	3.0	HBH, PR
Try to select and breed colonies that are *Varroa* tolerant/resistant	2.8	HBH, PR, PS, HH, AH, EP
Treat nuclei and swarms (no brood) with oxalic or lactic acid	2.6	HBH, PR, PS, HH, AH, EP

2. American foulbrood (*Paenibacillus larvae*; AFB)	**Mean score (1–4)**	**Category**
Perform the ropiness test to confirm a clinical outbreak of AFB in the apiary	4.0	HBH, PR
Quick management of affected hives	4.0	HBH, PR
Check for *P. larvae* in asymptomatic colonies by laboratory tests (e.g. stored honey in combs, hive debris) to control the disease. Take samples of colonies (hive debris/adult nurse bees/powder sugar/stores of honey in combs) in winter season to detect *P. larvae* (by PCR method or microbial isolation) to control the disease	3.8	HBH (PCI), PR
Perform laboratory analysis (isolation and/or PCR) to confirm a clinical outbreak of AFB in the apiary	3.7	HBH, PR
Melt down the combs of all colonies (with and without clinical signs) in the affected apiary and process wax safely in order to control the disease	3.6	HBH, PR
Verify presence of AFB-typical scales (not removable, firmly adherent to the cell wall) to confirm a clinical outbreak of AFB	3.3	HBH, PR
Destroy only hives that show AFB clinical signs	3.3	HBH, PR
Disinfection/incineration of all beekeeping equipment (beehives, nucs, mating boxes, boards, frames, queen excluders, etc.) of symptomatic hives. Disinfect all beekeeping equipment of asymptomatic hives located in AFB outbreaks	3.3	HBH, PR

Disinfection/incineration of all beekeeping equipment (beehives, nucs, mating boxes, boards, frames, queen excluders, etc.) of asymptomatic hives. Disinfect all beekeeping equipment of asymptomatic hives located in AFB outbreaks	2.7	HBH, PR
Make shook swarms of hives that show clinical signs of AFB	2.5	HBH, PR
Increase frequency of hive inspections in asymptomatic colonies (and in other apiaries of the same beekeeper) in cases with lab positivity for spores of *P. larvae* or in cases with clinical signs of the disease in other hives of the same apiary	2.5	HBH, PR
Apply an AFB-test (field kit) to confirm a clinical outbreak of AFB in apiary	2.4	HBH, PR
In the case of an AFB outbreak, make shook swarms of all colonies (with and without AFB signs)	2.3	HBH, PR
Use stamping out (destruction) of all colonies in the apiary (with and without AFB signs) only if eradication is achievable	1.4	HBH, PR

3. European foulbrood (*Melissococcus plutonius*; EFB)	**Mean score (1–4)**	**Category**
Manage affected hives quickly to control the disease	3.8	HBH, PR
Search for the presence of removable scales and yellow and contorted larvae to diagnose a suspicious EFB clinical outbreak	3.7	HBH, PR
Perform laboratory analysis (isolation and/or PCR) to confirm clinical suspicion of EFB	3.7	HBH, PR
Select queen breeders free of EFB	3.6	HBH, PR
Make a shook swarm of hives that show EFB clinical signs	3.6	HBH, PR
Disinfect/incinerate the contaminated beekeeping equipment (beehives, nucs, mating boxes, boards, frames, queen excluders, etc.) of EFB symptomatic colonies in the case of a clinical outbreak	3.5	HBH, PR
Increase hive inspections in symptomless colonies in cases of lab positivity for *M. plutonius* or in cases with clinical signs of the disease in other hives of the same apiary	3.4	HBH, PR
Destroy hives that show EFB clinical signs	2.8	HBH, PR

Take samples (hive debris/adult nurse bees/powder sugar/stores of honey in combs) from asymptomatic colonies for laboratory testing in winter or in the case of an outbreak, to detect presence of *M. plutonius* (by PCR method or microbial isolation)	2.8	HBH (PCI), PR
Apply an on-field EFB kit to confirm a clinical outbreak of EFB in symptomatic hives	2.5	HBH, PR
Make a partial (take off only brood combs, leaving store combs) shook swarm of colonies that show EFB clinical signs	2.4	HBH, PR
Disinfect/incinerate all beekeeping equipment (beehives, nuc-boxes, mating boxes, boards, frames, queen excluders, etc.) of EFB asymptomatic colonies in the case of a clinical outbreak	2.3	HBH, PR
Be aware of the odour when opening the hive – typically a sour smell occurs in suspect cases of the clinical form of EFB	2.1	HBH, PR
Make a shook swarm of all colonies of the apiary (with and without EFB signs) in the case of an EFB outbreak, to achieve eradication	1.7	HBH, PR
Make a partial (take off only brood combs, leaving store combs) shook swarm of all colonies of the apiary (with and without EFB signs) to control the disease	1.6	HBH, PR
Destroy affected colonies of the apiary to achieve eradication	1.3	HBH

4. Nosemosis (*Nosema apis*, *N. ceranae*)	**Mean score (1–4)**	**Category**
Do not reuse combs (empty or with stores of honey and/or pollen) originating from depopulated (few workers and the queen) or collapsed hives	3.7	HBH, PR
Prevent pollution of artificial water sources with faeces or drowned or dead bees	3.7	HBH, PR
Select queen breeders from *Nosema* spp. free stocks	3.7	HBH, PR
Select and breed *Nosema* spp. resistant honey bees, if possible	3.7	HBH, PR
Remove combs with signs of dysentery	3.5	HBH, PR
Take samples of forager honey bees (or powder sugar or debris) early in autumn or spring to diagnose nosemosis (PCR and microscopic methods)	3.4	HBH (PCI), PR

Adopt appropriate pathogen (e.g. *V. destructor*) control, to ensure a proper balance (nurse–forager bees) in the composition of the bee colony	3.2	HBH, PR
Treat (if there are any registered/permitted products available in the country) the colony for *Nosema* spp. when percentages of infected bees are high (>40%)	2.8	HBH, PR, PS, HH, AH
Strengthen and stimulate the colonies in autumn and spring with the administration of stimulant integrators or feed supplements	2.5	HBH, PR

5. Aethinosis (*Aethina tumida*; SHB)	**Mean score (1–4)**	**Category**
Ensure that the bees cover all frames in the hive (no empty space)	4.0	HBH, PR
Do not leave outside beehives any frames, combs or other material that could be attractive and edible for *A. tumida*	3.8	HBH, PR
Carry out hive inspections periodically to detect and eliminate the parasite (adults and larvae)	3.8	HBH, PR
Trace movement of hives meticulously (identify hives, dates of movements, exact position)	3.6	HBH, PR
Control transport conditions, adopting proper isolation of beekeeping equipment and avoiding spread of SHB during transport	3.6	HBH, PR
Store combs, in order to prevent survival of SHB eggs and larval development, in a cold chamber at a temperature below 10°C	3.6	HBH, PR
Give artificial nutrition at low amounts each time so the bees can consume it in a short time (pollen/protein feed/supplements are a good substrate for SHB reproduction)	3.6	HBH, PR
Have only healthy, strong colonies in the apiary	3.6	HBH, PR
Trace movements of supers and wax meticulously	3.6	HBH, PR
Use traps to monitor and control SHB presence in the apiary	3.6	HBH, PR
Store combs, in order to prevent survival of SHB eggs and larval development, in a chamber at less than 34% relative humidity	3.4	HBH, PR
Have only young queens with hygienic behaviour	3.3	HBH, PR
Use queen bee excluder in order to avoid the presence of brood in the supers	3.2	HBH, PR

If SHB is not present in the area		
Have good knowledge of morphology of SHB eggs, larvae and adults	4.0	HBH, PR
Have good knowledge of hive inspection methods to detect SHB	4.0	HBH, PR
Do not leave outside beehives any frames, combs or other material that could be attractive and edible for *A. tumida*	3.8	HBH, PR
Have only healthy strong colonies in the apiary	3.6	HBH, PR
Have only young queens with hygienic behaviour	3.4	HBH, PR
Do not transport live material at risk (hives, queens, nucs, etc.) from areas where SHB is present into the apiary	3.4	HBH, PR
Ensure that the bees cover all frames in the hive (no empty space)	3.4	HBH, PR
Do not transport material at risk (supers, wax, pollen, etc.) from areas where SHB is present into the apiary	3.4	HBH, PR
Adopt specific traps for quick visual detection of SHB	3.4	HBH, PR
Monitor periodically for the presence of SHB by sampling debris or honey	3.2	HBH (PCI), PR
Do not transport live material at risk (hives, queens, nucs, etc.) from areas where SHB could be present into the apiary	3.0	HBH, PR
Do not transport material at risk (supers, wax, pollen, etc.) from areas where SHB could be present into the apiary	3.0	HBH, PR
Use queen bee excluder in order to avoid the presence of brood in the supers	2.9	HBH, PR

Acronyms of biosecurity measures in beekeeping categories (sectors of impact)

AH	Animal health
EP	Environmental protection
HBH	Honey bee health
HH	Human health
PCI	Preclinical indicators
PR	Productivity
PS	Product safety

Acronyms of honey bee diseases

ABPV	Acute bee paralysis virus
AFB	American foulbrood
DWV	Deformed wing virus
EFB	European foulbrood
IAPV	Israeli acute paralysis virus
KBV	Kashmir bee virus
PCR	Polymerase chain reaction
SBV	Sacbrood virus
SHB	Small hive beetle

Classification of biosecurity measures in beekeeping

The list of BMBs for the main honey bee diseases was classified in categories (sectors of impact): honey bee health (HBH), human health (HH), animal health (AH), environmental protection (EP), product safety (PS) and productivity (PR) (Tables II and III). The HBH category included the subcategory of the 'preclinical indicators' (PCI) of disease. These represent all those activities and methods that can identify the presence of a specific causative agent before it becomes clinically evident.

Table III

Impact of the identified biosecurity measures in beekeeping for each category

Disease	Categories (sectors of impact)					
	HBH	HH	PR	PS	EP	AH
Varroosis	18 (2 PCI)	5	17	6	5	5
American foulbrood	15 (1 PCI)	0	15	0	0	0
European foulbrood	16 (1 PCI)	0	15	0	0	0
Nosemosis	9 (1 PCI)	1	9	1	0	1
Aethinosis	26 (1 PCI)	0	26	0	0	0
Total	**84** (6 PCI)	**6**	**82**	**7**	**5**	**6**

Acronyms of categories
AH Animal health
EP Environmental protection
HBH Honey bee health
HH Human health
PCI Preclinical indicators
PR Productivity
PS Product safety

Discussion

A harmonised list of BMBs (Table II) represents the starting point for application and improvement of biosecurity in beekeeping at the European level. This will result in an increase of resilience and sustainability for the beekeeping sector.

The biosecurity measures with the highest scores for *Varroa destructor* reported in Table II are strongly related to the management of the infestation (proper use of medicines and rotation of active principles, adoption of hives with screened bottom boards, use of diagnostic and monitoring tools) because these actions are crucial for the colonies' survival (28). Other important measures were related to the selection of varroa-tolerant bees, because this is the main long-term solution for varroosis (15).

Bacterial diseases in beekeeping (AFB and EFB) need effective management measures to reduce the risk of spread into and within apiaries (29, 30). *In primis*, application of detection tools is fundamental, using the 'ropiness' test to confirm clinical outbreaks of AFB in the apiary and laboratory tests on samples from asymptomatic colonies. Moreover, disinfection/incineration of contaminated beekeeping equipment (beehives, nucs, mating boxes, boards, frames, queen excluders, etc.) is necessary in clinical outbreaks.

The spread of *Nosema* spp. is strongly related to BMBs (5). The age of the queen and selection of queen breeders from stocks free of *Nosema* spp. play important roles in the evolution of infection and honey bee colony strength (5). Removal of combs originating from depopulated or collapsed hives and removal of combs with signs of dysentery are other measures that were evaluated to be of great importance. The contemporaneous control of other pathogens (e.g. *V. destructor*) ensures a proper balance (of nurse–forager bees) in the composition of the bee colony (5), resulting in an effective method to prevent nosemosis. In addition, the application of specific active ingredients (such as oxalic acid, formic acid and thymol) used for *Varroa* control has been demonstrated to be effective in reducing

Nosema infection (5). In this case there is a mutual interaction of BMBs aimed at two different honey bee diseases.

The most important BMBs for *Aethina tumida* management are related to practical on-field actions that should be undertaken during the beekeeping season (31, 32). Reproductive success is limited if no narrow space secured from bee aggression is left in the hive and no pollen or brood is available. At the same time, transport and stocking conditions of combs and bee feeds should be evaluated by the beekeepers to reduce the risk of spread and reproduction of the beetle.

Adopting the 'One Health' approach, it could be verified that most of the BMBs have an impact on the sectors of honey bee health (HBH) and productivity (PR). Indeed, as evidenced by Table III, HBH and PR are closely inter-related sectors. A more limited number of BMBs have an impact on human health, animal health (other than bees), environmental protection and product safety. This is probably because the impact of BMBs on these sectors is mainly related to the use of veterinary medicines and to antimicrobial resistance: in European beekeeping few antimicrobials (and no antibiotics) are registered for honey bees. Moreover, as previously discussed, residues of acaricides do not easily persist in honey.

The BMBs focus on honey bee health and can vary according to geographical area, due to local factors (e.g. climatic conditions, beekeeping technology, bee races or breeds) (25, 33) or the different prevalence, virulence and economic impact of the pathogens. As in most livestock husbandry systems, there is a wide variety in beekeeping practices between and within areas (34). Moreover, regulatory provisions and compliance systems have a strong impact on disease management and institution of control strategies. Finally, BMBs are evolving and should be periodically revised depending on changes concerning the introduction and the spread of new invaders, and, more generally, changes in prevalence of the honey bee pathogens and of abiotic stressors (e.g. climatic changes that can interfere with the biology of honey bees or pathogens). Good beekeeping practices are the basis for sustainable and resilient

beekeeping and represent a prerequisite for the implementation of BMBs in day-to-day apiary management (Fig. 1). Only if GBPs are systematically implemented by beekeepers can BMBs be properly applied (19). The adoption of biosecurity measures aims to prevent both introduction and spread of bee diseases in an individual apiary or colonies in a defined region.

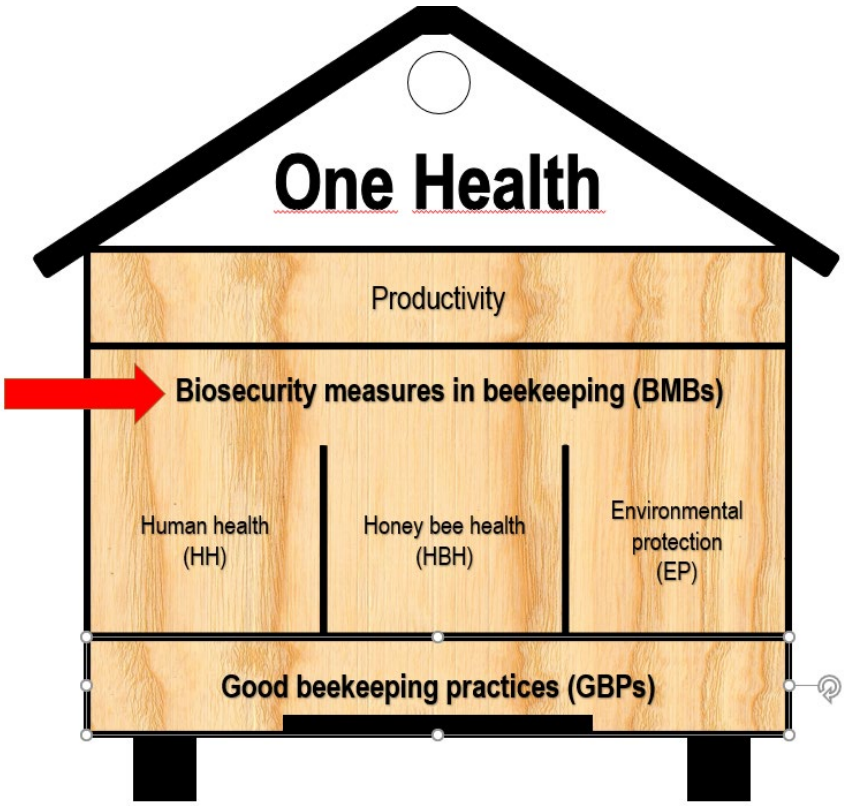

Fig. 1

Figurative representation of the biosecurity measures in beekeeping in the One Health approach

The red arrow indicates biosecurity measures in beekeeping (20)

Together, GBPs and BMBs, in their application in daily activities by beekeepers, represent a crucial step to mitigate the current local and global situation in disease incidence to ensure honey bee health. In fact, they can guarantee, in the context of a One Health policy (35), honey bee health and production, being essential for the sustainability of biodiversity and global pollination, as well as the fight against hunger.

Biosecurity is the foundation of all disease control programmes, irrespective of the animal species. If biosecurity is well implemented, it is a substantial tool to reduce therapeutic treatments at the apiary level. In fact, reducing disease pressure may also result in substantial reductions in veterinary medicine usage and, thus, lead to improvements in production quantity, quality and consumer safety (25).

The often-observed absence or limited implementation of biosecurity measures in farming practices is likely to be due to insufficient knowledge of risk factors (e.g. diseases, routes of introduction and spread, operator practices, etc.), motivation and training. A risk assessment on the awareness of beekeepers of honey bee diseases, and on application of GBPs and BMBs, may be provided by surveys. Surveys are a useful risk-assessment tool that, with a quantitative approach, may supply sources of data to examine the GBPs and BMBs adopted by beekeepers in a certain geographical area. Previous examples have been published (36, 37, 38, 39).

Specific surveys, similar to the above-mentioned examples, could be set up by experts in different geographical regions to assess awareness and application of biosafety measures in beekeeping. Results obtained from different areas could be compared, as well as being reassessed periodically after implementation of corrective actions.

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