

## Good farming practices in apiculture

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## Summary

Modern European beekeeping is facing numerous challenges due to a variety of factors, mainly related to globalisation, agrochemical pollution and environmental changes. In addition to this, new pathogens threaten the health of European honeybees. In that context, correct colony management should encompass a wider vision, where productivity aspects are linked to a One Health approach in order to protect honeybees, humans and the environment. This paper describes a novel tool to be applied in beekeeping operations: good beekeeping practices (GBPs). The authors ranked a list of GBPs scored against their importance and validated by an international team, including researchers, national animal health authorities and international beekeepers' associations. These activities were carried out in the project 'BPRACTICES', approved within the transnational call of the European Research Area Network on Sustainable Animal Production

(ERA-NET SusAn) in the Horizon 2020 research and innovation programme of the European Union. This study, created through an international collaboration, aims to present an innovative and implementable approach, similar to applications already adopted in other livestock production systems.

## Keywords

Apiculture – BPRACTICES – GBPs – GFPs – Good beekeeping practices – Good farming practices – Honeybee.

## Introduction

Beekeeping, or apiculture, is the practice of managing honeybee colonies for farming purposes. Bees provide a wide variety of products: honey, pollen, royal jelly, propolis, wax and venom. Many beekeepers also sell colonies, rear queen bees and provide pollination services to farmers (1). According to the World Organisation for Animal Health (OIE) (2) and the European Union (EU) legislation (3) bees are classified as terrestrial animals and as such fall under veterinary care. The most common species used in beekeeping are the western honeybee (*Apis mellifera*) and the eastern honeybee (*Apis cerana*) (2).

Honeybees are vital pollinators of wild plants and crops. As pollinators, honeybees alongside other wild pollinators support biodiversity of wild plants and contribute to higher yields of important highly valued agricultural crops. Considering the recent ‘pollination crisis’ due to the decline in numbers of wild pollinators and occasional extensive losses of domestic honeybee colonies (4, 5, 6, 7, 8), the European Parliament (9) stated: ‘the beekeeping sector throughout the world, and more particularly in Europe, is encountering very serious difficulties... [and] only bees, in sufficient numbers, can guarantee pollination, it is essential to respond without delay to the crisis in bee health in an appropriate manner and with effective weapons’.

International trade in bees and bee products continues to spread throughout the world. It has increased considerably over the past few

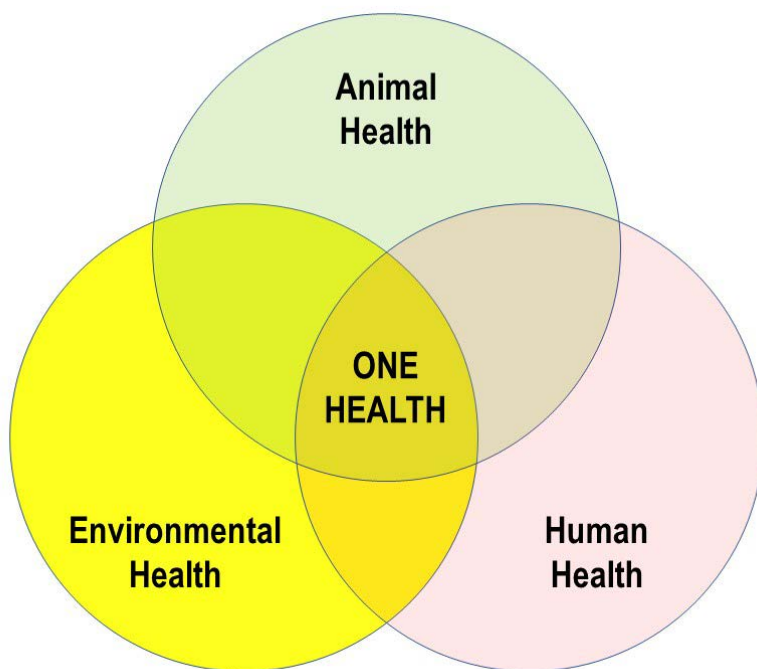
decades, and is likely to continue to grow as technology makes movements easier and lowers national barriers to trade (10, 11). This, however, also facilitates the spread of diseases, an example being the recent introduction from Africa of the honeybee pest *Aethina tumida* in Southern Italy (12).

The introduction of relatively recent pesticides, such as neonicotinoids, is also among the factors contributing to environmental pollution which predispose bees to increased stress and pathogen sensitivity; owing to their high toxicity these pesticides often cause death (13, 14).

The widespread establishment of varroosis has caused an increase in viral infections in hives due to the mite's role as a mechanical and biological vector (15). Viruses such as acute bee paralysis virus (ABPV), Kashmir bee paralysis virus (KBPV) and Israeli acute paralysis virus (IAPV), which once caused covert infections and had limited impact on bee health, are now seeing an increase in virulence, with clinically significant diseases affecting susceptible hives that have been weakened by various parasites or stress (16).

Finally, climatic change and the considerable heterogeneity of the European beekeeping industry and its managerial factors (11) are parameters to consider in prevention of honeybee losses.

Given the emerging challenges that beekeeping has to face, along with the more traditional ones (e.g. *Varroa destructor*, *Nosema* spp., American and European Foulbrood, etc.), an innovative, integrative approach that takes into account all steps of the beekeeping value chain, from breeding bees to harvesting hive products, is highly advisable. One Health is the modern denomination of the multi-sectorial worldwide-accepted strategy to design and implement programmes, policies, legislation and research in which different preventive areas communicate and work together to achieve better public health outcomes. The main sectors where the implementation of the One Health approach is particularly relevant are human, animal and environmental health protection (17) (Fig. 1).



**Fig. 1**  
**Elements of the One Health approach**

In the above-described scenario, good farming practices (GFPs) should be considered as a preventive tool able to control those factors that negatively affect honeybee health and have consequences for human health, the environment and farm productivity. Despite this, the scientific literature and relevant regulations covering the beekeeping sector contribute only a few general references to the definition of good beekeeping practices (GBPs).

This study was intended to identify and define GBPs through the process of definition, validation, classification, identification and evaluation, in order to obtain a list of validated and effective practices to be shared with all stakeholders. To fulfil these goals, the OIE–FAO (Food and Agriculture Organization of the United Nations) guidelines ‘Guide to good farming practices for animal production food safety’ were used as a starting point (18).

The study was performed in the framework of ‘BPRACTICES’, a transnational project funded within the Horizon 2020 research and innovation programme of the EU, called the European Research Area

Network on Sustainable Animal Production (ERA–NET SusAn). The project consortium is made up of a multidisciplinary group representing research institutes, the FAO and international beekeepers' associations (Table I).

## **Table I**

### **The BPRACTICES project**

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Consortium partners
<b>Research Institutes</b>
Istituto Zooprofilattico Sperimentale del Lazio e della Toscana (IZSLT), Italy
Namik Kemal University, Turkey
Agricultural Institute of Slovenia, Slovenia
Centro de Investigación Apícola y Agroambiental de Marchámallo (CIAPA), Spain
Austrian Agency for Health and Food Safety (AGES), Austria
Istituto Zooprofilattico Sperimentale delle Venezie (IZSVE), Italy
University of Genoa, Italy
European Union Reference Laboratory (EURL) for Bee Health, French Agency for Food, Environmental and Occupational Health and Safety (ANSES), France
<b>Food and Agriculture Organization of the United Nations (FAO)</b>
Beekeeping Exchange Group, Technologies and Practices for Small Agricultural Producers (TECA), FAO, Italy
<b>Beekeepers' associations involved in the project</b>
International Federation of Beekeepers' Associations (APIMONDIA), Italy
European Professional Beekeepers Association (EPBA), Germany

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## **Materials and methods**

### **Classification of good beekeeping practices**

Good beekeeping practices were classified by taking into consideration the most relevant ‘headings’ of the OIE–FAO guidelines (18). In addition, GBPs were classified in ‘categories’ similar to those used by Formato & Smulders (19), adapted to consider productivity and the One Health approach: human health, animal health and ecosystem health.

### **Identification of good beekeeping practices**

The 11 participant partners identified, listed and ranked GBPs by relevance using a consensus approach. Direct, simple and easily understandable language was used to write the list of GBPs, to ensure that comprehension by all beekeepers was facilitated.

### **Validation of good beekeeping practices**

During the process, crucial relevance was attributed to the practical point of view of beekeepers. Some of the most important international beekeepers’ associations (the International Federation of Beekeepers’ Associations [APIMONDIA] and European Professional Beekeepers Association [EPBA]), together with the members of the BPRACTICES consortium, participated in the identification and evaluation of GBPs according to their importance in daily apiary activities, in order to validate them.

### **Assessment of good beekeeping practices**

A transparent and documented prioritisation process for GBPs was duly conducted among the different partners and stakeholders of the BPRACTICES project, using as a reference previous attempts at prioritisation conducted in similar fields (20).

In order to allow the project partners to perform a relevance-based assessment of GBPs, they received a Microsoft excel (Excel® 2016, Microsoft Corporation, Redmond, WA, United States of America) file

for completion, correction, amendment and rating of the GBPs. Partners evaluated each GBP according to its importance through the adoption of a score ranging from 1 to 4 (1 = not important; 2 = slightly important; 3 = important; 4 = very important). A score of 4 was given to those beekeeping practices deemed of crucial relevance according to the legal requirements within individual countries and in accordance with the experience of the participants, based on the magnitude of the impact they can have in the context of the One Health approach (colony health, human health, environmental protection). In order to avoid bias, all scores were provided without allowing individuals to view the scores given by other participants.

### **Statistical methods**

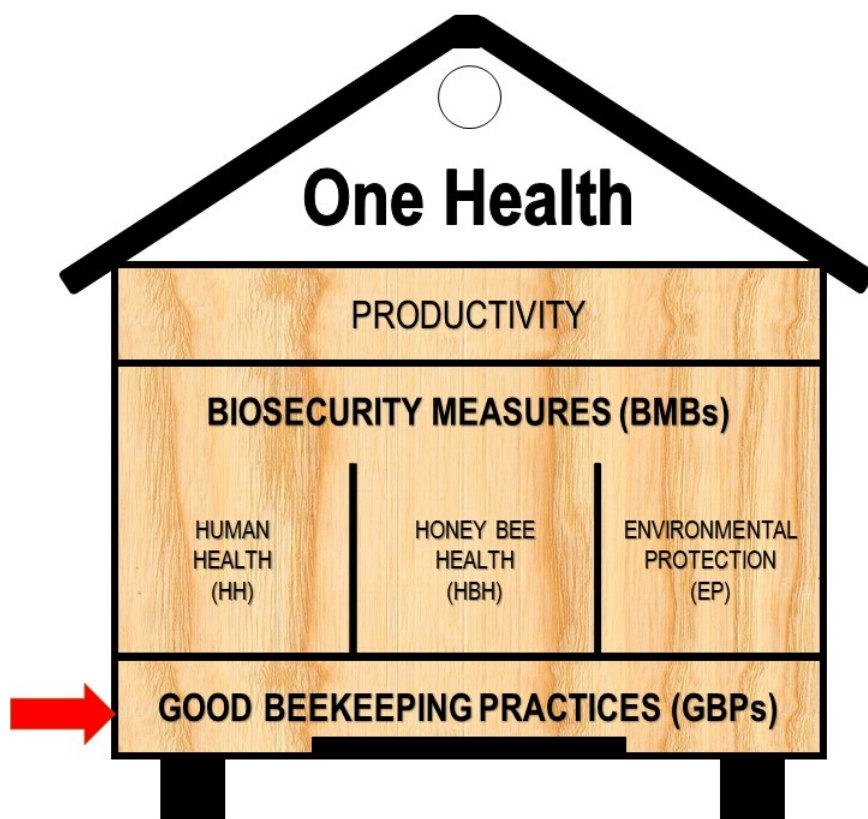
To rate each GBP, the mean result was calculated from the scores received and the answers were sorted according to the ‘relevant’ and ‘mandatory’ criteria. All ratings were statistically processed to obtain a final list containing a reasonable number of GBPs to recommend to beekeepers. For the final ranking, only scores with means higher than the 75th percentile threshold were considered.

## **Results**

### **Definition of good beekeeping practices**

As a result of the process mentioned above, GBPs were defined as ‘those integrative activities that beekeepers apply for on-apiary production to attain optimal health for humans, honeybees and the environment’ (Fig. 2). The implementation of the GBPs, therefore, would have a positive effect on colony health and on society, and at the same time could favour high production standards.





**Fig. 2**  
**Elements of the One Health approach in beekeeping**

Arrow indicates good beekeeping practices

**Classification of good beekeeping practices**

According to the OIE–FAO classification of GFPs, GBPs were classified by considering the following headings: general apiary management, veterinary medicines, disease management (general), hygiene, animal feeding and watering, record keeping and training (Tables II and III).

**Table II****General good beekeeping practices**

1. General apiary management		Mean score (1–4)	Category
1.1. Transportation	Comply with legal obligations concerning restrictions on animal movements in the case of notifiable diseases	4.0	HBH
	Transport/move only healthy colonies	3.8	HBH
	Transport hives avoiding the warmer hours of the day, providing adequate openings for air ventilation in the hives	3.7	HBH
1.2. Hygiene	Respect hygiene rules (e.g. periodically clean suits, gloves, etc.)	3.8	HBH
	Practise good hygiene when dealing with dead colonies (combs, food stores, boxes, etc.)	3.8	HBH
	Disinfect levers and other potentially contaminated equipment (e.g. gloves) after inspection of hives affected by transmissible diseases	3.7	HBH
	Do not place honey supers directly on the ground (avoid contamination with <i>Clostridium botulinum</i> )	3.7	PS
	Avoid contact with dust during the transport of the supers from the apiary to the honey house	3.6	PS
	Do not place beehives directly on the ground	3.3	PS
	Use disposable gloves when handling diseased hives	3.3	HBH

1.3. Bee health	For nuclei use only bees and brood combs from healthy colonies	3.8	HBH
	Balance colony strength among colonies, transferring frames only in the case of healthy hives	3.7	HBH, PR
	Buy new bee colonies only after thorough inspection for bee diseases, preferably with a health certificate from a veterinarian	3.6	HBH
	Keep only healthy strong colonies in the apiary	3.5	HBH, PR
	Avoid areas with environmental pollutants (e.g. pesticides, heavy metals, etc.) to place apiaries	3.2	HBH, HH, PR
	Do not imbalance the proportion between nurse bees and brood while equalising the hives; preferably use combs with hatching bees to fortify weak colonies	3.2	PR, HBH
	Perform genetic selection in order to have queens that are more resistant to disease and adapted to local climatic conditions	3.0	HBH
	Keep newly introduced colonies separate from the existing stock for an appropriate period (at least one month) in order to monitor them against diseases to prevent transmission	2.9	HBH
	Avoid, as far as possible, the introduction of swarms of unknown origin, or colonies or queens from other apiaries	2.8	HBH
	Keep purchased or weak colonies in a quarantine apiary	2.8	PR
	Reduce bee stress (e.g. avoiding unnecessary winter inspections of the hives; limiting the use of the smoker; feeding the bees properly, etc.)	1.3	PR, HBH

1.4. Apiary management	Evaluate the melliferous and pollen capacity of the area and the availability of water resources	3.3	HBH	
	Do not have beekeeping material abandoned in the apiary	3.2	PS	
	Keep a good balance between the number of hives and the amount of melliferous plants/pollen sources in the area where the apiary is located	3.1	PR	
	Avoid windy areas when placing apiaries	3.0	HBH	
	Place apiaries in an accessible area	3.0	HBH	
	Adjust the number of hives in the apiary according to season, pollen, nectar, honeydew resources	3.0	HBH, PR	
	Adjust the number of hives within a flight range according to season, pollen, nectar, honeydew resources	3.0	HBH, PR	
	Place apiaries on a firm area	2.8	HBH	
	Prevent drift occurrence: avoid keeping too many colonies in a single row	2.7	HBH	
	Place apiaries in an area accessible to vehicles	2.7	HBH	
	Avoid having broken hives with openings or poorly maintained hives, to prevent robbing	2.6	HBH	
	1.5. Wintering	Before winter, reduce the empty space in the hive	3.0	PR
		Wintering: reduce the size of the hive entrance	3.0	HBH
		Wintering: perform beehive box maintenance (replacing parts or painting; verify the integrity of hive boxes, if needed)	2.8	PR
Wintering: verify the external position of the frames with stores in the hive		2.5	PR	

	Wintering: reduce the number of frames in the hive box	2.3	PR
	Wintering: insert a divider board to reduce the volume for the hive nest	2.3	PR
	Wintering: wrap the hive in black tar paper, if needed	1.3	PR
1.6. Human health	Have the support of an expert (e.g. veterinarian, technician, etc.) to provide assistance in case of need	3.3	PR, HBH, PS
	Use personal protective clothing and equipment when visiting honeybee colonies	2.8	HH
	Avoid areas where toxic (e.g. with pyrrolizidine alkaloids) plants (e.g. <i>Echium</i> spp., <i>Eupatorium</i> spp. and <i>Senecio</i> spp.) can be found in a significant quantity	2.5	PR, HH
	Keep corticosteroids or other appropriate medicines ready to use during apiary inspections to guarantee health of operators (for example, in case of anaphylaxis)	2.4	HH
	Limit the weight lift (e.g. when harvesting supers or when moving hives) and, if needed, use back protector devices	2.3	HH
	Avoid areas where allergenic plants (e.g. <i>Ambrosia trifida</i> and <i>Artemisia vulgaris</i> ) can be found in a significant quantity	2.0	HH, PS
1.7. Colony management	Practise hive management according to region, season, strength of colony	3.7	PR
	Replace the queens at least every two or three years except for those of high genetic value	3.6	HBH, PR
	Prevent swarming by insertion of new wax foundations	3.1	HBH

Prevent swarming by colony splitting	3.0	PR
Comply with the planned schedule for beehive inspection	3.0	PR
Prevent swarming by placing of supers	2.8	PR
Prevent swarming by taking off the entrance reducer	2.8	HBH, PR
Prevent swarming by adopting genetic selection of the queens	2.8	PR
Use a queen excluder	2.8	HBH
Reduce the opening of the hive entrance during robbing and cold periods and increase the opening of the hive entrance during the hot season	2.8	HBH
Mark the queen bee according to the date of birth	2.7	PR, HBH
Orientate hive entrance so that the sun can reach the bees in the early morning hours	2.5	PS
Prevent swarming by insertion of drawn combs	2.2	PR
Prevent drift occurrence: paint/draw numbers or identification signs on the front and entrance of the hive	2.2	HBH
Indicate the age of the combs on the top bar of the frame (e.g. the year of placement of the frame with foundation)	1.6	HBH
Prevent swarming by removal of the beehive's bottom board	1.2	PR
Provide adequate openings in the hive for air circulation, if needed	1.2	PR, HBH

2. Veterinary medicines	Mean score (1–4)	Category
Use only veterinary medicines for honeybees registered in your country or medicines legally imported	4.0	HH, HBH, PS
Ensure that all treatments or procedures are carried out correctly as described in the instructions (respecting dosage and method of application)	4.0	HH, HBH, PS
Do not carry out illegal treatments	4.0	HH, HBH, PS
Use only pharmacological products registered for beekeeping use, follow the usage instructions and record the treatments	4.0	HH, HBH, PS
Observe the withdrawal period of veterinary products and ensure that products from treated hives are not used for human consumption until the withdrawal periods have elapsed	4.0	PS, HH
If using instruments for the application (formic acid dispenser, sublimators for oxalic acid treatment), ensure that they are appropriate and correctly calibrated for the administration	3.7	HH, HBH, PS
Respect the required storage conditions for veterinary medicines and feeds	3.6	PS, HBH
Dispose of used instruments and devices in a biosecure manner	3.5	HH, HBH
3. Disease management	Mean score (1–4)	Category
In the case of notifiable diseases follow the instructions from the veterinary regulations and competent authorities	4.0	HBH
In the case of infectious diseases clean all beekeeping material between uses (e.g. hive bodies, hive bottom boards, feeders, hive tools)	4.0	HBH, PR
Clean or disinfect (in the case of infectious diseases) the hive box before installing new colonies	4.0	HBH, PR
Carry out thorough inspections for clinical signs of bee diseases and presence of the queen in spring	3.8	HBH, PR
Carry out thorough inspections for clinical signs of bee diseases and presence of the queen at the end of the beekeeping season	3.8	HBH, PR
Quickly remove beehives with dead colonies	3.8	HBH
Take samples for laboratory analyses when sick or dead bees are found, if needed	3.8	HBH (Subcategory [PCI])

Clean equipment, scrape off wax and propolis, on a regular basis	3.8	HBH
Remove and process wax of all combs from dead, affected colonies	3.7	HBH, PR
Record the health status of the colonies: diseased/infected colonies (dates, diagnoses, ID of colonies affected, treatments and results)	3.6	PS, HBH
Renew 30% of the hive combs every year	3.5	HBH, PR
Record the health status of the colonies: mortality (dates, diagnoses, ID of colonies affected)	3.4	HBH
Verify promptly any signs of disease, asking a veterinarian (or a specialist)	3.3	HBH (Subcategory [PCI])
Do not move frames or any kind of biological material (for example, to balance hives) from one hive to another if their health status is not well known	3.3	HBH, PR
Inspect diseased hives only after inspections of healthy hives are ended	3.3	HBH
Select the best performing stocks of honeybees	3.2	HBH, PR
Burn dead colonies	3.2	HBH
Remove queens from colonies with clinical history of AFB disease	3.0	HBH, PR
Remove queens from colonies with clinical history of EFB disease	3.0	HBH, PR
Try to select and breed colonies that are more disease tolerant/resistant	3.0	HBH, PR
Record the origin and use of all disinfectants and consumable items used, keep all the records relating to the cleaning and disinfection procedures used on equipment or honey house (including data sheets for each detergent or disinfectant used) as well as all the records showing that these procedures have been effectively implemented (task sheets, self-inspection checks on the effectiveness of the operations)	3.0	PS, HBH, HH
Disinfect equipment (for example, with NaOH, hypochlorite) on a regular basis	2.8	HBH, PR
Carry out thorough inspections for clinical signs of bee diseases and presence of the queen before supering the hives	2.7	HBH, PR

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4. Hygiene	Mean score (1-4)	Category
Torching (blue flame) used as a disinfection method for hives and beekeeping tools in the case of transmissible diseases	3.3	HBH
Bleaching (soda, NaOH, etc.) used as a disinfection method for hives and beekeeping tools in the case of transmissible diseases	3.2	HBH
Incineration of affected colony, if needed in the case of transmissible diseases	2.3	HBH

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Always incinerate affected colony in the case of transmissible diseases	1.8	HBH
Water under high pressure and heated (90°C) used as a disinfection method for hives and beekeeping tools in the case of transmissible diseases	1.6	HBH
Autoclaving used as a method of disinfection of hives and beekeeping tools in the case of transmissible diseases	1.6	HBH
Gamma-irradiation as a method of disinfection of beekeeping tools in the case of transmissible diseases	1.5	HBH

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5. Animal feeding and watering	Mean score (1–4)	Category
Do not feed the bees with honey, pollen or supplements, unless the absence of pathogens (spores of AFB, chalkbrood, <i>Nosema</i> , EFB, etc.) is certified	4.0	HBH
Provide artificial feeding during times of shortage or to build up winter stores, when needed	3.7	HBH, PR
Wintering: verify that there is a sufficient amount of stores in the hive	3.7	HBH
Provide nucleus and swarms with adequate food supply when needed	3.6	HBH, PR
Ensure the bees have access to safe water sources	3.3	HBH, PR
Do not feed bees openly in the field to prevent robbing and spread of diseases	3.3	HBH, PR
During transport provide adequate watering if needed	3.0	HBH

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6. Record keeping	Mean score (1–4)	Category
Keep records of veterinary medicine treatments	4.0	PS, HBH
Registration of the beekeeper in the National Beekeeping Registry	3.8	PS, HBH
Record the exact position of the bee yards	3.8	PS, HBH
Identify with numbers/letters all the hives in each apiary	3.6	PS, HBH
Keep records of honeybee diseases and colony mortality or depopulation	3.5	PS, HBH
Set up a data-recording system that can be used to trace exactly which batches of commercial feed the colonies were fed with	3.5	PS, HBH
Keep all documents/certificates about the commercial feed used	3.5	PS, HBH
For each colony or group of colonies, require and keep all commercial and health documents, enabling their exact itinerary to be traced from their farm or establishment of origin to their final destination	3.4	PS, HBH
Record all reared colonies	3.4	PS, HBH

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Record all colony arrivals, with origin and date of arrival, to ensure that movements of incoming colonies are traceable to their source	3.4	PS, HBH
Keep records of movements of hives, swarms, queen bees	3.4	PS, HBH
Record period of collection of hive products from each apiary	3.4	PS
Keep detailed records of the origin and use of all medicines, including batch numbers, dates of administration, doses, treated hives and withdrawal times; treated hives or apiaries should be clearly identified	3.3	PS, HBH, HH
Keep all documents/certificates that indicate the raw materials used in feed manufactured by the beekeeper and given to the colonies	3.3	PS, HBH
Create a unique identification number for the apiary to easily trace the location of the hive (for stationary apiaries)	3.2	PS, HBH
Keep records of breeding activities (e.g. all breeding stock, queens' birth dates, their origin and arrival, the breeding dates and outcomes in cases of instrumental insemination, etc.)	3.2	HBH
Establish a data-recording system to ascertain the exact origin (batch) of bee products produced	3.2	PS, HBH
Keep all documents regarding self-checks and official controls on the proper management of the colonies and the sanitary and hygienic quality of the bee products	3.1	PS
Keep all documents proving that the bacteriological and physicochemical quality of the water used in the honey house, given to the colonies or used in feed preparation meets official national standards for tap water	3.0	PS
Record the origin and use of all feeds used, keep all records of any feed manufacturing procedures and records for each batch of feed	2.9	PS, HBH
Keep a list of certified suppliers	2.8	HBH
Record any other management changes that may occur	2.5	HBH
Record any change in feeding	2.4	PS, HBH
Keep all laboratory reports, including bacteriological tests and sensitivity tests	2.4	PS
Keep reference samples (-20°C) of all feeds administered to the bees	2.3	PS, HBH

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7. Training	Mean score (1-4)	Category
Training/knowledge on honeybee diseases and clinical signs	3.5	PS
Follow a training programme in beekeeping and honeybee diseases	3.5	HBH
Attend personal training on beekeeping	3.1	HBH, PS, HH, PR

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Record datasheets for each detergent/disinfectant used	3.0	HBH, PS, HH
Record disinfection procedures used	3.0	HBH, PS, HH
Record that disinfection procedures have been implemented	3.0	HBH, PS, HH
Keep the documents certifying qualification and training of persons working with bees	1.9	PS

AFB: American foulbrood  
 EFB: European foulbrood  
 HBH: honeybee health  
 ID: identification number  
 HH: human health  
 NaOH: sodium hydroxide  
 PCI: preclinical indicators  
 PR: productivity  
 PS: product safety

### Table III

#### Headings for good beekeeping practices and number of most relevant good beekeeping practices identified

Headings	Number of GBPs identified in each heading
General apiary management	63
Veterinary medicines	8
Disease management (general)	23
Hygiene	7
Animal feeding and watering	7
Record keeping	25
Training	7

GBPs: good beekeeping practices

### Identification of good beekeeping practices

An overall list of 251 GBPs was identified ([www.izslt.it/bpractices/good-beekeeping-guidelines/](http://www.izslt.it/bpractices/good-beekeeping-guidelines/)) (21).

### Assessment of good beekeeping practices

The 251 GBPs were arranged according to the average score attributed by the different partners. Then, in order to obtain a smaller, more practical and reasonable list of GBPs to provide to beekeepers, only the GBPs with a mean score within the 75th percentile were considered for each heading and category, reaching a total of 140 GBPs (Tables II and III).

Finally, a list of the 140 most relevant GBPs was obtained, classified as shown in Table III. For each heading, the following categories were considered: honeybee health (HBH), product safety (PS), human health (HH) and productivity (PR) (Tables II and IV). Some GBPs were included in more than one category (Table IV).

**Table IV**

#### Categories of good beekeeping practices with their abbreviations and number of most relevant identified good beekeeping practices

Categories for GBPs and abbreviations	Number of GBPs identified in each category
Honeybee health (HBH)*	109*
Product safety (PS)	44
Human health (HH)	16
Productivity (PR)	45

\*including the subcategory 'Preclinical indicators' (PCI)  
GBPs: good beekeeping practices

## Discussion and conclusions

The aim of this work was to contribute to a first definition of GBPs in accordance with FAO and OIE guidelines (18) in close collaboration among scientists, Technologies and Practices for Small Agricultural Producers (TECA)–FAO and international beekeepers' organisations (APIMONDIA and EPBA).

Good beekeeping practices are intended to be implemented in the primary production of hive products. Moreover, GBPs are pre-requisites for the 'biosecurity measures in beekeeping' (BMBs). The latter are those operational activities aimed at limiting the spread of specific honeybee diseases. Only if GBPs are systematically implemented by the beekeeper can BMBs be properly tackled.

A clear definition of GBPs will ease the development of guidelines or recommendations to the beekeeping sector from international institutions involved in animal production, animal health and food safety (e.g. Codex Alimentarius, Joint FAO/World Health Organization [WHO] Expert Committee on Food Additives (JECFA), OIE, FAO, International Organization for Standardization [ISO]). Furthermore, this definition and the methodologies should be valuable for legislative bodies (e.g. EU Regulation 2016/429) (3), producers, Veterinary Services, capacity building activities, progressive management pathways in beekeeping, etc.

Daily implementation of GBPs in apiary management should result in multiple beneficial impacts:

- a)* for honeybee health, due to generally better management of hives (e.g. proper wintering, apiary position, feeding) and appropriate control of honeybee diseases (e.g. adopting preventive measures and integrated pest management with proper use of acaricides);
- b)* for human health, owing to appropriate use of antimicrobials and food safety of hive products;

- c) for environmental protection, by preferring the use of organic compounds and avoiding the use of antibiotics;
- d) from the economical point of view (22, 23, 24), healthier animals reduce the need for medicines (and the subsequent costs) and are able to increase the production (and the income) per hive.

The GBPs were classified by adapting the FAO and OIE guidelines ‘Guide to good farming practices for animal production food safety’ (18) to the beekeeping sector. In this study, the collaboration and the involvement of international associations of beekeepers (e.g. APIMONDIA and EPBA) represented an important, innovative approach that allowed consideration of the feasibility of applying the GBPs in everyday apiary activities.

Following the FAO and OIE guidelines for GFP (18), the same headings were adopted when collecting GBPs: general apiary management, veterinary medicines, disease management (general), hygiene, animal feeding and watering, record keeping and training (Table III).

Record keeping, in particular, has the potential to improve the other best practices through monitoring of the recorded practices. This can be useful for beekeepers on both small and commercial scales. Maintaining consistent and accurate records is an ongoing challenge for all sectors of the beekeeping community; however, various practical solutions have been devised to facilitate record keeping, including markings or indicators in the apiary, notebooks and spreadsheets, as well as recently introduced specialised apiary management and monitoring technology.

Of course, in order to extend the value of record keeping beyond the individual beekeeper to the global beekeeping community, it will be necessary to use standardised data (25, 26) and promote the sharing of relevant data to a common repository for analysis. At the same time, guidelines and policies that protect the beekeeper will also be needed to encourage data sharing. New technologies and best practices could

not only be recommended, but also built into software systems. Educational objectives could be enhanced through the application of smart software, which will also collect the data needed to finely tune and adapt current best practices to a customised solution.

The use of advanced analytical techniques will help beekeepers to recognise not only threats to the hive, but also what particular GBPs are best for that hive, with the help of a recorded history that will ensure the best outcome for that colony.

The list of 140 GBPs identified will allow more effective and harmonised training of beekeepers, veterinarians and paraprofessional technicians, as well as the application of effective biosecurity measures in beekeeping.

In conclusion, the authors have defined and listed those GBPs that, at the international level, represent universally accepted pre-requisites that will guarantee the sustainability, competitiveness and resilience of the apiculture sector and enable it to face the current challenges of modern beekeeping.

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