EIP-AGRI Focus Group
Bee health and sustainable beekeeping

FINAL REPORT
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Table of content

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Executive summary

In the course of 2019, the EIP-AGRI Focus Group (FG) on "Bee health and sustainable beekeeping" explored and provided a state of play for different key factors that are important to honeybee health. The group of experts discussed the main drivers for change from today's situation to a sustainable future. Their goal was to answer the overarching question: **How to ensure the sustainability of beekeeping in the face of challenges linked to pests and diseases, intensification of agriculture, and climate change?**

Through a discussion about challenges, opportunities, and good practices and solutions that are available, the Focus Group has identified a set of priorities and ways forward.

Key factors to keep bee colonies healthy (priorities):

- Availability of knowledge and skills (research and practice)
- Maintaining a sustainable environment around the honeybee colony
- Determination and evaluation of the health status of honeybees
- Resilience of honeybees and improvement of their well-being
- Interpretation of data from monitoring, precision beekeeping (PB)
- Management methods adapted to local conditions
- Supporting honeybee genetic diversity
- Sublethal effects of chemicals in an environment of multiple stressors

Ways forward (solutions to the problems)

Despite the many innovations and advances of recent years, also in the fields of some of these key factors, further work is still needed to fulfil all these priorities. To address the key factors mentioned above, the Focus Group recommended to:

- Create a European platform to better connect research and practice (Research need from practice – RN)
- Develop a kind of licence for beekeepers, a pan-European standard
- Develop and implement a practical index synthetising the health status of bees (RN)
- Develop and evaluate technical methods for controlling Varroa, for sustainable beekeeping (e.g. trapping mites in workers or drone brood, queen caging and artificial swarms) (RN)
- Interpretating and sharing collected data from monitoring, both biotic- and abiotic factors
- Assess the exposure to stressors from agriculture in combination with resource quality (RN)
- Identify, implement and communicate mitigation practices among beekeepers and farmers (RN)
- Manage complexity through collaboration among relevant stakeholders
- Mapping the landscape situation around the apiary for sustainability (make monitoring results available in maps)
- Highlight the importance of genetic diversity for sustainable beekeeping, and develop programmes for local breeding (RN)

But is that enough? What activities need to be put in place, e.g. in the next 10 years, to reach the desired (long-term) goal of **healthy honeybees in a sustainable environment**? Following a theory of change model (https://www.theoryofchange.org) it can be concluded that a supporting environment for implementating and mainstreaming the listed priorities is necessary. This includes reducing the threats to honeybee health and meeting the needs of all actors involved. These actions should be supported by enabling conditions and means of implementation including financial resources, capacity and technology. Specifically, the six ways forward marked as "**RN**" are research needs from practice that have been identified by the Focus Group. These research gaps demand the specific involvement of the scientific community to be fully addressed.

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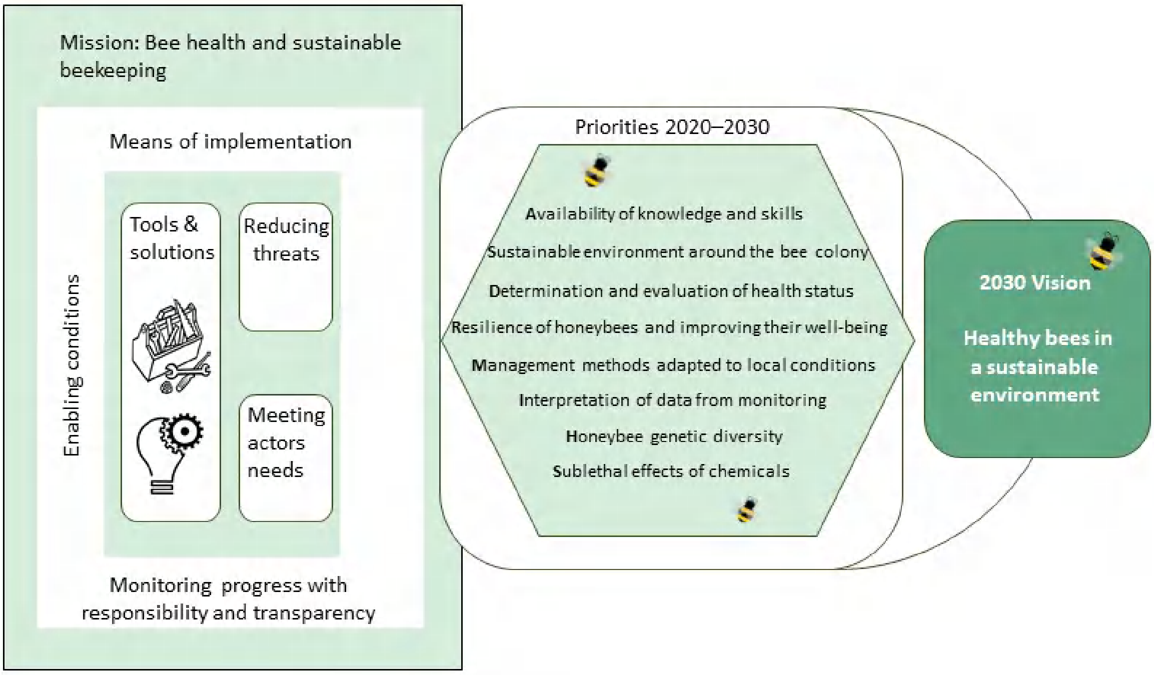

Figure 1: A framework illustrating the enabling conditions and means of implementation to support the priorities defined by the Focus Group to achieve the vision "healthy honeybees in a sustainable environment" in 2030.

In addition, with the aim of inspiring innovative actions that contribute to this framework, the Focus Group elaborated eight ideas for **EIP-AGRI Operational Groups**. The proposals for projects cover a wide range of project types, from testing solutions or management practices at hive level to ways of cooperation or knowledge exchange.

Focus Group Experts Bee health and sustainable beekeeping

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1. Introduction

Defining whether a honeybee colony is in good health or not is not easy. However, the following four points by Vidal-Naquet (2015) may provide a good indication:

- There are no clinical signs of disease
- The brood/adult ratio is in line with the expected development of the colony and the time of year (there must be enough workers to rear brood)
- There is foraging activity and production of honey and bee bread
- The total quantity of pollen and honey stored around the brood is estimated to match the need of the colony.

Therefore, it is not only diseases, pests and predators that affect honeybee health. The beekeeping practice and the environment in and around the apiary have a big impact on how the colony develops, how strong it will be and how much honey and pollen will be produced and stored.

Figure 2: Honeybee health is an issue dependent on the beekeeper as well as on the environmental situation in the forage area. It is a multi-actor and multi-factorial interaction at landscape level.

The EIP-AGRI Focus Group (FG) on Bee health and sustainable beekeeping was established in spring 2019 to identify, structure and develop answers to this main question:

How can we ensure the sustainability of beekeeping in the face of challenges linked to pests and diseases, intensification of agriculture, and climate change?

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The FG consisted of 20 experts (see **Annex 1**) from 16 different EU countries and with different professional backgrounds. The group included beekeepers, advisers, researchers and consultants coming from private businesses, universities, public authorities, NGOs and other organisations. They were selected considering their practical experience and technical knowledge on the topic. In the Focus Group, they jointly worked for a year and a half, meeting twice during this period. During the group's first meeting, discussions focused on challenges for bee health, and good practices and sources of innovation to overcome these challenges.

Based on the central question, the group explored solutions and good practices in the frame of four themes. These were collectively set, based on clusters of the main challenges of the FG topic:

- Beekeeping practices
- Agricultural practices
- Communication/collaboration
- Monitoring

The main ideas that were discussed at each table resulted in seven areas that were selected for further exploration in so called "minipapers". The list of minipapers can be found in **Annex 2**. The papers covered the following topics:

1. Knowledge transfer and capacity building. What knowledge is reliable as valuable information for beekeepers? How can we bridge best available knowledge and existing beekeeping practices?

2. Beekeeping practices to improve disease control and to ensure high efficacy without any adverse effects of the chemicals used, with the lowest costs, and ensuring the highest quantity and quality of all hive products.

3. Considering the well-being of honeybees in beekeeping. The point of view of "honeybees first", while also trying to meet the needs of the various stakeholders.

4. How to respond to the needs for training and advice that beekeepers have.

5. Monitoring of colonies and the environment to support management decisions for the beekeeping sector.

6. The impact of major stresses on honeybee health: pesticides and a lack of food resources (quality and quantity).

7. Support management decisions for honeybee breeding to maintain genetic diversity, avoid losing adaptation possibilities and secure resilient bees.

Following the work done at the first meeting and in the minipapers, the group looked at new ideas for innovation during the second meeting, where they suggested ideas for Operational Groups (OGs) and proposed possible directions for further research.

The minipapers, together with the **starting paper**, provided the basis for this final report.

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2. State of play and what we can do

What do we know about the challenges for honeybee health and what can we do to solve the problems? The FG has identified a number of "do's" or priorities to keep honeybee colonies healthy. To make the key factors and their solutions easier to understand, they are here divided into different levels of action: a) the honeybee colony; b) the apiary; c) the landscape; and d) the beekeeper.

2.1 The health status of the honeybee colony

The honeybee colony is a superorganism, an organism consisting of several individual organisms that jointly make rational decisions. On the honeybee colony level, the stress factors are e.g. pesticides, pathogens, poorly mated queens, honeybees that are not adapted to local conditions, unadapted abiotic factors like temperature and humidity, and inappropriate beekeeping practices changing the dynamics and resilience of the colony.

Framing key issues

An examination of the **health status** of a honeybee colony is not entirely simple. To get the overall picture one needs to make both an internal and an external examination.

- *Internal* means looking for clinical symptoms in the brood frames, looking for honey and pollen storage, looking for vitality signs and the colony's adaptability to stress factors, including genetic diversity, nutritional needs, Varroa (*Varroa destructor*) pressure or other diseases, pests and predators, in-hive hygrothermal climate by measuring abiotic factors (temperature/humidity) and the effect of chemicals used in the forage area.

- *External* includes the activity of the honeybees in the apiary and in front of the hive entrances, on the ground in front of the hives, the appearance of the hive, the bottom board and the entrance as well as environmental factors.

The records regarding the colony history during the seasons also need to be reviewed. In these records there should be notes of deviations from the normal actions taken and other events. However, in many cases the data are scarce and superficial.

For example, in 2016 the European Food and Safety Authority (EFSA) published a toolbox to facilitate harmonised data collection that could support the assessment of the health status of managed honeybee colonies (https://www.efsa.europa.eu/en/efsajournal/pub/4578). This **HEALTHY-B toolbox** (EFSA Journal 2016; 14(10): 4578) for assessing the health status is based on:

- Characteristics of a healthy, managed honeybee colony
- An adequate size, demographic structure and behaviour
- An adequate production of bee products
- Both in relation to the annual life cycle of the colony and the location
- Provision of pollination services (measured in volume of bee products)

Analysing the surrounding environment, in particular land cover/use of a honeybee colony is very important when assessing its health status. However, **good tools that could be used at apiary level are currently lacking**. Therefore, how can the beekeeper make a correct analysis of the actual health status for the colony without any proper tools? The ongoing B-GOOD project is one of the European projects addressing this question (https://b-good-project.eu).

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Another challenge is how to ensure high efficacy of methods used to control diseases: a) without any adverse effects of the chemicals used; b) with the lowest costs; and c) ensuring the highest quantity and quality of all hive products. There is very little knowledge regarding how the **natural behaviour of honeybees** is important for the health of a colony. Honeybees are to be looked at as semi-domesticated species. The beekeepers have changed the genetics very little but the environment has changed a lot, such as the choices of beehive construction and the location of the honeybee colony (T. D. Seeley 2019). What does the beehive construction mean for the survival of a colony? **Management methods adapted to local conditions** are known factors for good honeybee health.

Moreover, the **genetic diversity** of the European honeybee is at risk. Climate change, with altered season features is challenging the adaptation capacity of honeybees. The success factor throughout the millions of years that honeybees have existed is their ability to adapt to changes in the surrounding environment. To meet these challenges a broad genetic diversity is key. The honeybee colony breeds (the virgin queens fly out and mate with multiple drones high up in the air) with the honeybee colonies that are in the area in which the beekeeper has placed it. This is an important factor in the environment. Beekeepers should breed local resilient honeybees and this is not easy, since in most regions there are no regulations about what kind of honeybee races are allowed. The diversity of beekeeping in Europe should be the driver for regional regulations that allow sustainable conservation of varieties of local honeybees in Europe.

Key issues identified:

- Determination and evaluation of the honeybee health status
- Management methods adapted to local conditions
- Honeybee genetic diversity

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Examples of good practices

PREVENTING IS BETTER THAN CURING

American foulbrood is a brood disease caused by the spore-forming bacteria *Paenibacillus larvae*. It is considered to be one of the most destructive brood diseases on honeybees and it is a notifiable disease to the OIE (World Organisation for Animal Health). The spores, which can be dormant for decades, can be found on the honeybees, in the beeswax, in the honey and in the hive material. The spores can be present in a honeybee colony without resulting in clinical symptoms in the brood. By testing a colony for spore levels, the beekeeper gets an indication of the risk of an outbreak of the disease. By taking measures such as cleaning the equipment, frequent wax renewal and conducting general hygienic management techniques in beekeeping, the beekeeper might be able to avoid outbreaks of American foulbrood.

In New Zealand, the goal of the American Foulbrood National Pest Management Plan is to eliminate American foulbrood in managed colonies (https://afb.org.nz). Some New Zealand beekeepers have shown that elimination on a national level is possible. By destroying colonies with American foulbrood instead of using antibiotics and by using management techniques to avoid the spread of the disease to other hives, they have effectively eliminated the disease from their own businesses.

According to Swedish research, the beekeeping practice of testing honeybee colonies for American foulbrood spores in adult honeybees, using a systematic quarantine system, and cleaning the equipment, can eradicate the spores from the beekeeping operation (Locke et al. 2019). Analysing adult honeybees for spores is also used in conjunction with contact tracing at outbreaks of the disease in Sweden.

BREEDING PROGRAMME FOR THE PRESERVATION OF LOCAL RACES

Rather than searching for "the best bee", local adaptation will be the key to sustainable beekeeping. Preservation of local adaptation can be done by arranging bee breeding cooperatives, running regional selection programmes and promoting honey produced by regional bees. There have been several successful initiatives to conserve and/or restore original endemic bee races in Europe. The most prominent one is an Italian breeding programme to promote *Apis mellifera ligustica* and *A.m. carnica* in the native region of the subspecies. Beekeeping will need to become more regional and less global to allow for sustainable strategies to preserve honeybee diversity (R. Moritz and R. Crewe, 2018).

Sustainable conservation to improve and conserve the native or locally adapted honeybee populations or subspecies is an increasingly used breeding approach. The basic philosophy behind this is to reduce importation and instead utilise and improve the local populations in comparison to the non-local ones (A. Uzunov, E. W. Brascamp & R. Büchler, 2017). However, it is difficult to avoid crossbreeding while both local races and more commercial breeds coexist in the same area. Within the SMARTBEES project – sustainable management of resilient bee populations –, a protocol for field testing and the selection of local bee populations was produced and evaluated (http://www.smartbees-fp7.eu/Extension/Performance/). The data is collected in an online database at www.beebreed.eu (hosted by the Institute for Bee Research, Hohen Neuendorf, Germany).

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What can we do?

As described in **minipaper 2** (Disease control and emergency situations), there are several monitoring tools for each disease. However, there is still not one simple monitoring tool for all diseases, which even includes environmental factors (e.g. stressors from agriculture and nutritional quality and quantity). It is possible that an index for honeybee "Health Status" and data standardisation, if established, could be a monitoring tool for predicting the fate of a colony, under specific circumstances (EFSA AHAW Panel, 2016).

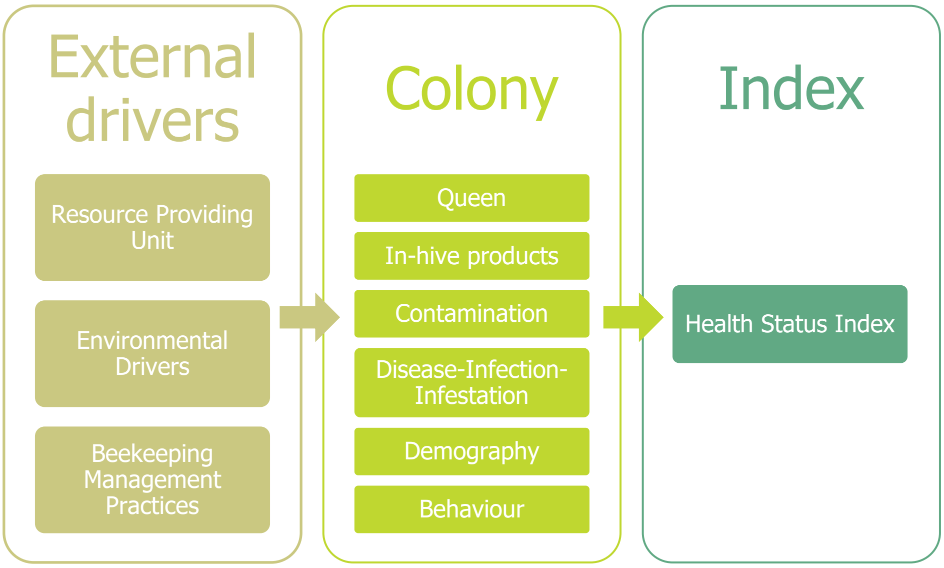

Figure 3: The Health Status Index integrates different sources of data, and it can quantify the health status of a honeybee colony based on the characteristics of each scenario (EFSA AHAW Panel, 2016, Gilioli et al 2019)

An example of disease detection is BeeScanning (**https://beescanning.com/**) which is an app that enables beekeepers to instantly diagnose Varroa infestation. Images taken of live bees on the brood frame are automatically analysed with artificial intelligence. The result is calculated in %, number of Varroa/number of bees. A factor is used to multiply the result compensating for hidden Varroa. This factor is derived from comparing results with alcohol washing. Besides finding Varroa, deformed-wing-virus and the queen, the project is developing analyses to detect another 13 classes, for instance to be possible to detect, American foulbrood for instance.

In **minipaper 7** (Sustainable honeybee breeding) the components to a holistic approach for local breeding programmes are discussed. One of these factors is the importance of communication on the value of locally bred honeybees and to provide beekeepers with technical support to monitor honeybee genetics.

Ways forward:

- Develop and implement a practical index synthesising the health status of bees
- Develop and evaluate technical methods for controlling Varroa for sustainable beekeeping
- Communicate the importance of genetic diversity for sustainable beekeeping

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Inspiration from the minipapers

MINIPAPER 2: VARROA CONTROL THROUGH MONITORING AND RESISTANCE

Management of Varroa control is key for sustainable beekeeping. Chemical control methods ('hard' or 'soft', e.g. through organic substances) may lead to Varroa resistance or weakening of the colony. Sustainable Varroa management calls for synchronised control in terms of period of the year, and type of application, which can minimise the risk of re-infestation in permanent/non-migratory apiaries. Training is also very important in Varroa monitoring or control schemes. There is a great need for innovative and cost-effective methodologies, as well as breeding efforts for resistance (see more in **minipaper 2**).

MINIPAPER 7: GENETIC CONSERVATION PROGRAMME IN BELGIUM

A new association based in Belgium was founded in November 2018. This network aims to become a tool for worldwide honeybee queen producers & breeders, a place where they can meet, exchange ideas and experiences; conservation and sustainable breeding are the main goals (**https://www.beesources.com/en/assistenza-tecnica/international-honey-bee-breeding-network-ihbbn-founded/**). Arista Bee Research is another example of local breeding for Varroa-resistant bees (**https://aristabeeresearch.org**). For more examples see **minipaper 7**.

MINIPAPER 3: QUANTITATIVE ASSESSMENT OF THE WELL-BEING OF HONEYBEES

Apicultural research is starting to embrace a "natural beekeeping" perspective and more and more results are available on the effects of such practices on the well-being of honeybees. But there is, in particular, a need to assess quantitatively with scientific studies the impact of each stress factor on the honeybee's well-being in order for beekeepers to make informed practical choices regarding for example the limitation of treatments, winter honey supplies, improvements to the beehive model, etc. (see more in **minipaper 3**). By knowing more about how honeybee colonies live in the wild, how they choose nesting sites and how they build their nest, beekeeping might find solutions on how to improve honeybee health.

Dream home for honeybees
The dream home for honeybees in the wild (T. Seeley 2010) is:

- Nest entrance height above the ground: high entrance, 5 m
- Size of entrance to the nest: small entrance, 12.5 cm^2
- Space of the cavity: spacious cavity, 40 litres
- Entrance direction: south
- Cavity dryness: the honeybees can remove wet substance and waterproof a leaky cavity
- Cavity draftiness: honeybees can caulk cracks and holes with propolis

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2.2 Bee health from the colony to the apiary

Several honeybee colonies placed in the same location are called an apiary. The stress factors at the apiary level (in-apiary stressors) are e.g. robbery (when honeybees from one colony steal honey from another bee colony), re-infestation of Varroa, transfer of brood or food frames between colonies and agricultural practices in the surrounding environment.

This section reflects on what beekeepers need to know and work with while choosing an apiary. More about the interaction with the landscape, and specifically with all the actors involved in the surrounding environment, in the following section 2.3.

Framing key issues

An important part of beekeeping is to keep the honeybee colonies healthy. Part of the beekeeper's job is the selection of an apiary site. But how does the beekeeper know if the location of the apiary is good or not? Part of the knowledge is of course to **know the basic needs for the bee colony** regarding food supply and access to water during the whole season. The area where the honeybees search for food is rather large, about 28 km^2 (calculated on a flight radius of 3 km). First thing is to have the possibility to **compare the development of the honeybee colonies** in one apiary with the development in another apiary over a certain period. This also includes that the colonies in the apiaries are supposed to be healthy, to be representative for the natural development. If they are not, then it is hard to evaluate to what extent other factors in the surrounding landscape actually affect the health of the honeybees. A wide range and type of variables must be monitored, such as the influence of environmental drivers, pressure of human activities and management strategies on honeybee colony health and productivity.

A helpful tool, apart from keeping records manually, is to continuously collect data through any automatic **monitoring** equipment, both at colony and environment level. Discussed in minipaper 5 (Monitoring – from Precision beekeeping towards Decision support systems) collecting data would not solve the problems if the data collected cannot be interpreted correctly, thus translated into a practice responding to a need. By sharing information and creating tools for interpretation, beekeeping might advance and become more exact regarding doing the right thing at the right time. This can be called '**precision beekeeping**' (PB). The minipaper also discusses the need to develop standards for used hardware and open source software for monitoring colony performance.

The apiary is one component among others in the landscape, and the health of the honeybee colonies depends on the **surrounding activities**. From the honeybee's point of view, a sustainable environment is a prerequisite for survival. In most cases, the land where the apiary is located and where the honeybees forage for food is not owned by the beekeeper. Usually one or more landowners are involved with the ongoing activities of land use. This means that all activities performed in the area around the apiary have implications for the health of the honeybees. The beekeeper has very little control over the activities. How can the activities and their impact on the honeybees become visible to both the beekeeper and the land managers?

Key issues identified:

- Collaboration for collecting, sharing and interpreting data from monitoring, precision beekeeping
- Sustainable environment around the bee colony – the surrounding activities

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Examples of good practices

To choose an apiary is like choosing a home. There are a lot of demands to be fulfilled. Will the site cause a nuisance to neighbours or the general public? Is it safe from vandals? Is there forage for the honeybees? How many apiaries are nearby? Is the environment of the site suitable for bees? Is the access convenient, with minimal carrying for the beekeeper to bring in equipment and remove honey supers? Is the space suitable for the number of hives? Is the microclimate favourable? And so on.

In many books for beekeeping beginners there are instructions on how to find a good apiary site. It might be quite easy to find if you only have a few colonies, but if you increase the number of colonies then it is not that easy anymore. Establishing a good relationship with neighbours, local farmers, landowners and the general public is a major factor in finding and maintaining a successful site for the bee colonies. The beekeeper should talk to them about the value of honeybees as pollinators; inform them about swarms, flight paths etc., and try to capture their interest and cooperation, gaining respect for the honeybees and the beekeeper.

One example of a user-driven communication and coordination tool to protect honeybee health is BeeConnected (**https://beeconnected.org.uk**). It is a UK-based initiative that aims to connect beekeepers with farmers and give information on crop protection activities nearby. It is a voluntary initiative, supported by the Crop Protection Association.

Another example is provided by the **EIP-AGRI Operational Group NOMADI APP**[1], which involves remote beehive monitoring, an opportunity for migratory beekeeping. It is a regional monitoring network that consists of computerised apiaries, equipped with sensors that collect data from the hives. Hive data (humidity, brood temperature) will be elaborated and integrated with other (including historical) information, such as meteorological forecasts, or data from the nectariferous species phenology (such as flowering time) to provide useful information for apiary management. They also have an acoustic sensor outside the hive to detect frequency of *Vespa velutina*.

When honeybees fly to other hives than their own, this is called drifting. To avoid spread of disease or pests due to drifting between the colonies in the apiary, the hives can be put in different ways to help the honeybees find their way back home to the right hive. The different solutions demand a different amount of space.

What can we do?

As discussed in **minipaper 5**, electronic devices should be developed to enable new functionalities for precision beekeeping. This will be a shift from "smart" to "intelligent" hives. Intelligent hives would be able to:

- Monitor the hive for signs of trouble and send alerts before trouble hits.
- Monitor regional and national trends in real time, and make adjustments based on how these trends might affect the honeybees.
- Suggest ways to improve the production, pollination, or honeybee health.
- Prescribe the best management practices customised for a particular hive in a particular place at a particular time.
- Preventively suggest treatments before trouble manifests.
- Identify the treatments most likely to succeed given the hive characteristics, current environmental conditions, and history.

1 For further information about NOMADI APP see the EIP-AGRI Inspirational idea: **https://ec.europa.eu/eip/agriculture/en/news/inspirational-ideas-monitoring-bee-health-through**

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To find out the actual situation for the honeybee colonies in an apiary, we need to monitor the bee colony, and apart from this also measure and assess the exposure to stressors like agricultural practices and the nutritional quality and availability. The accessibility of data by mapping the landscape situation is crucial to be able to evaluate the appropriateness of an apiary.

Ways forward:

- Measure and evaluate the exposure to stressors from agriculture in combination with food resource quality and availability at the apiary level
- Interpretating and sharing collected data from monitoring, both biotic- and abiotic factors
- Mapping the landscape around the apiary for its sustainability

Inspiration from the minipapers

MINIPAPER 5: MONITORING

In **minipaper 5** examples of different national monitoring projects are listed. One that has been running since 2004 is the German Bee monitoring project, DeBiMo, administrated by a number of Apicultural state institutes in Germany (**https://bienenmonitoring.uni-hohenheim.de/en/88571**). More than 100 beekeepers are involved in the collaborative project. They provide representative, up-to-date information on colony management and overwintering dynamics of their bee colonies. In addition, samples of bees, honey and pollen are supplied by these beekeepers for the analysis of bee diseases and chemical residues. Based on the results a report of the status is delivered annually.

MINIPAPER 3: QUANTITATIVE ASSESSMENT OF THE WELL-BEING OF HONEYBEES

In **minipaper 3** a list of the stress factors with which honeybees are confronted is compiled. The table ranks them according to their scale, whether they are external factors which depend on other activities that are less controllable by the beekeepers themselves, or whether they are internal factors for which beekeeping management methods can provide opportunities for intervention. For example, materials for beehive construction and location have an impact on swarming, on the energy required for thermoregulation or on risks of infestations by bacteria or parasites. We can highly contribute to the well-being of the hives by opting for natural material (wood or polystyrene only for nuclei), no chemical wood protection, no varnish, and regular disinfection of hive material with heat and steam only.

2.3 The interaction with the landscape (involving all actors in the landscape)

The stress factors at landscape level are e.g. insufficient supply of high-quality diet (pollen and nectar), lack of sources for propolis, lack of water, exposure to plant protection chemicals, poorly coordinated land management measures and food competition or disease/parasite pressure from other beekeepers' colonies.

This chapter analyses the role of the different actors involved in the management of the landscape, in order to improve the bee health of the apiaries located in their surrounding areas.

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Framing key issues

The landscape surrounding the beekeeping practice is a complex multi-actor and multi-factorial environment.

Depending on the kind of landscape in which the beekeeping is performed, different elements have an impact on honeybee health. There are regulations that limit the **exposure of pollinators to plant protection products**. Despite this, bees are widely exposed to chemicals used in agriculture and other areas that can thus cause lethal and sublethal effects on honeybees. Due to the resilience at colony level, the effects sometimes are not easily detectable. Signs like a colony being less productive or weaker in terms of nourishment and immunity could be caused by other health problems as well. The chemicals also interact with other bee stressors like pathogens, nutritional deficiencies or adverse climatic conditions (Tosi et al. 2017). In this sense the project POSHBEE (http://poshbee.eu/) aims to provide the first pan-European quantification of the exposure hazard of chemicals not only to managed honeybees but also to wild bees, and to determine how chemicals alone, in mixtures, and in combination with pathogens and nutrition, affect bee health.

The exposure occurs in crops that are attractive for honeybees but also in non-attractive crops, weeds or wildflowers in the border zones of the cultivated fields (Simon-Delso et al. 2017). This makes the current risk assessment rather limited (Sgolastra et al. 2020). The mixture of different chemicals (so called 'cocktail') makes the assessment further complicated (Simon-Delso et al., 2014; Tosi et al. 2018). In 2013 EFSA published a guidance document intended to extend testing requirements for risk assessment, https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/j.efsa.2013.3295.

In areas with intense land use, the plant diversity is usually low. Honeybees are vulnerable to reduced flower availability, and **nutritional stress** affects the colony health by reducing its strength and fitness. Nutritional deficiencies were identified as one of the major causes of honeybee colony losses in the USA between 2007 and 2015 (Seitz et al. 2016). Importantly, nutritional stress can also interact synergistically with pesticides amplifying honeybee mortality (Tosi et al. 2017).

There is an urgent need for **collaborations and partnerships** between the persons involved, such as farmers, other land managers and beekeepers, to create a sustainable landscape for honeybees and beekeeping. The actors in the landscape need to work together on strategies and implement mitigation measures to make the surrounding landscape fit for sustainable beekeeping. The best available knowledge about the landscape level status needs to be made available beyond beekeeping and include other actors in the forage area.

Key issues identified:

- Sublethal effects of chemicals in an environment with multiple stressors
- Sustainable environment around the bee colony and collaboration among actors involved

Good practices

"Multifunctional buffer zones" are areas of land surrounding fields on which carefully combined strips of different herbs and grasses are planted. They contribute to the farm and the environment in many ways: minimising the risk of leakage of unwanted substances from arable land, increasing biodiversity by attracting pollinators and 'natural enemies', acting as field roads for farming vehicles to avoid soil compaction, and more. A Swedish Operational Group (OG) is testing this concept, defining buffer strips with two different goals: promotion and protection (https://ec.europa.eu/eip/agriculture/en/news/inspirational-ideas-multifunctional-buffer-zones).

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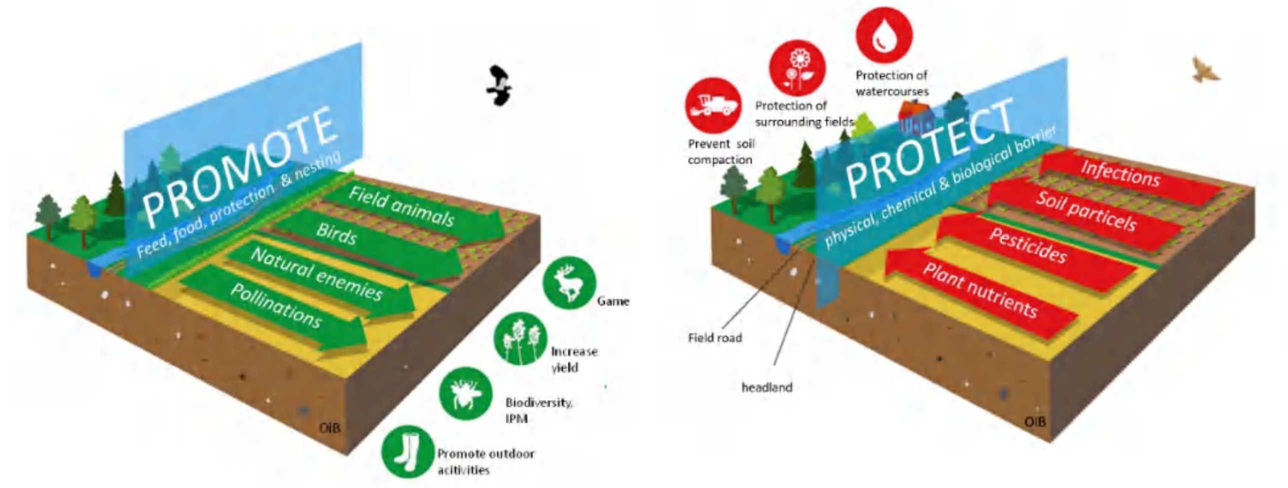

Figure 4: Multifunctional buffer zones (SamZones) by the OG, considering the two main goals: a) Promote feed, food, protection and nesting for field animals, birds, natural enemies, pollinators b) Protect (physical, chemical and biological barrier) against infections, soil particles, pesticides, plant nutrients (©odlingibalans)

What can we do?

Honeybees in agricultural landscapes need a better environment. Some ideas to achieve this goal are presented in minipaper 6 (Developing and enhancing good practices to mitigate major bee health stressors: pesticides and lack of resources) and Figure 5.

The landscape level is a complex reality, and complexity should not be simplified. One solution in one area might not be applicable in another area. Each given element with its connected actor has to be identified, analysed and assigned a task in the sustainable landscape system. This calls for collaboration. But who has the responsibility in a given area to initiate and develop the collaboration?

An example of a collaborative approach on landscape level is tested in the **Interreg project BioGov** (https://www.interregeurope.eu/biogov/). The project is about how to improve natural and cultural heritage policies. The expected changes are more effective policies due to improved governance and broad stakeholder support. The different sub-projects are using participatory governance and/or policy instruments that actively encourage participatory governance as a new priority.

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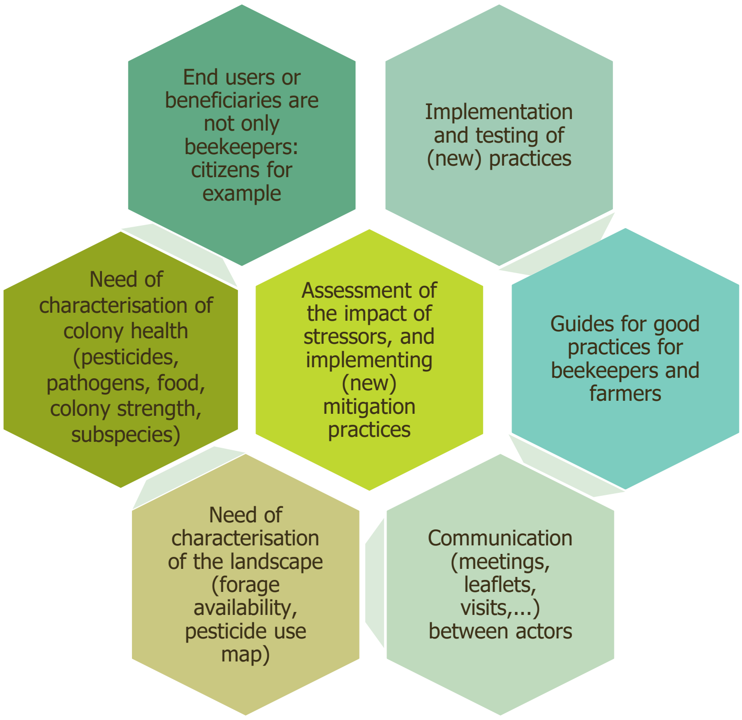

Figure 5: Honeybees in agricultural landscapes need a better environment. Some ideas to achieve this goal are shown in the figure.

Another example is the **Research strategy of the German Agricultural Research Alliance** (DAFA) (https://www.dafa.de/wp-content/uploads/Brosch-DAFA-FF-Bienen-LaWi_en_klein.pdf). This strategy aims to provide scientific recommendations to actors in politics, research funding and economics concerning ways to improve environmental conditions for bees and foster synergistic interactions between bees and agriculture, taking into consideration the entire agricultural landscape. The long-term goal is to achieve substantial impacts for diversity-promoting and sustainable agriculture, as well as regeneration of the entire agricultural landscape. This can only succeed if all the actors are brought on board. The strategy, therefore, specifically addresses farmers, professional and hobby beekeepers, nature conservationists, NGOs, citizens and the public in general, specialist advisers and scientists. Recommendations to political decision makers complete the strategy, with the aim of improving the framework conditions for the synergistic cooperation between bees and agriculture.

Ways forward:

- Identify, implement and communicate mitigation practices among beekeepers and farmers
- Manage complexity through collaboration

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Inspiration from the minipapers

MINIPAPER 6: GOOD PRACTICES TO MITIGATE MAJOR BEE HEALTH STRESSORS

In **minipaper 6**, mitigation practices are discussed. They are essential to reduce stressors on honeybees in agroecosystems. Mitigation and support measures to honeybees must be complementary and integrated with the existing approach of Integrated Pest Management (IPM) (**Figure 5**). In this way, the development of Integrated Pest and Pollinator Management (IPPM) concept should be useful (P. A. Egan et al. 2020 and Biddinger et al. 2015). This approach promotes pollinator-friendly strategies for sustainable food production by supporting beneficial insects (with flowering strips, for example) and reducing risks from pesticides (avoiding the use of conventional pesticides and pesticide drift).

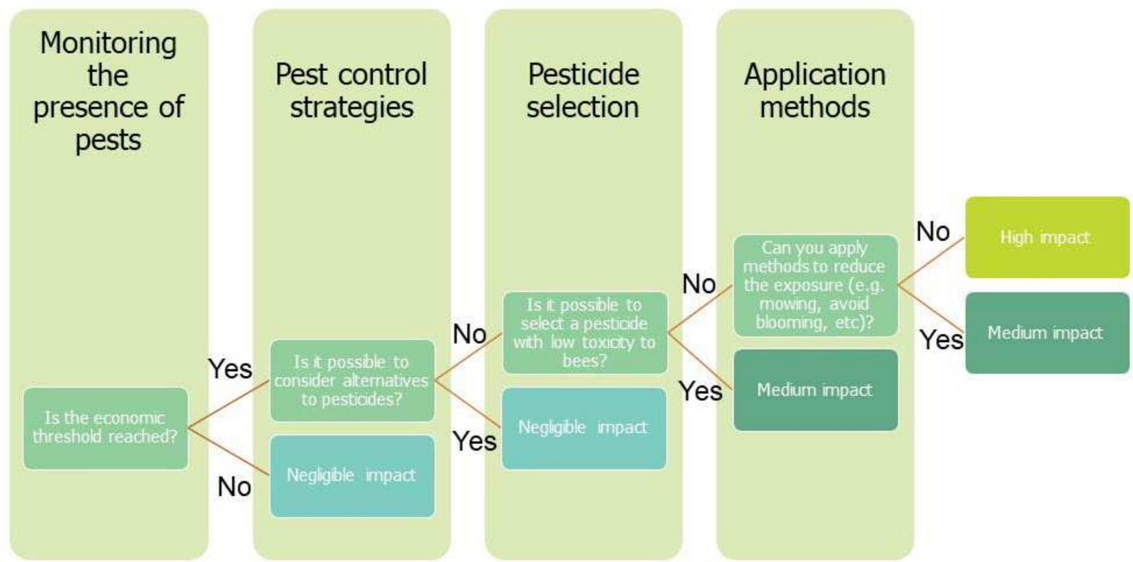

Figure 6: Decision tree in the IPPM approach and possible consequences on pollinators

These are some examples of existing collaborations between farmers and beekeepers:

- *Survey of apiaries in connection with farmers and advisers* – SURVapi – France
  - **https://nouvelle-aquitaine.chambres-agriculture.fr/agro-environnement/ecophyto/survapi/**
- *Platform for networking between beekeepers and farmers* – Beewapi – France **http://www.beewapi.com/**
- *Meeting at an apiary* – ADA NA – France **http://adana.adafrance.org/infos/Communication.php**
- *Memorandum of understanding between seed producers and beekeepers* – SEMENTI – Italy **http://www.sementi.it/comunicato-stampa/450/firmato-protocollo-intesa-per-valorizzare-colture-sementiere-e-tutelare-il-patrimonio-apistico**
- *Platform for farmers and beekeepers for pollination purposes* – Beeweb – Serbia **https://www.beeweb.co/en**
- *Increase awareness of honeybees in several cities, collaboration with farmers* – BeepathNet – Slovenia, Greece, Italy, Portugal, Hungary, Poland **https://urbact.eu/beepathnet**

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2.4 The beekeeper: knowledge and skills for healthy bees

The beekeeper has a responsibility for the well-being of his/her honeybee colonies. To practise beekeeping, knowledge and skills are crucial to be able to take the right measures at the right time, to give the colony the best conditions for a good health. How is the actual situation for knowledge development and exchange in Europe today? How is the beekeeping sector gaining access to information? Where and how can good quality knowledge and information be found?

Framing key issues

In **minipaper 1** (Platform of information at EU level) beekeeping is compared to other agricultural practices with further specific challenges within: a) a diversified target group; b) mainly micro-businesses and self-subsistence; c) rural entrepreneurs, geographically scattered; d) gender and wide age structure; e) low will or ability to pay for professional advisory services; f) lack of tradition in formalised competence development; g) trainers and educators are self-trained as instructors. Due to these challenges, the situation about how to get access to knowledge must be analysed. In **minipaper 1** three key issues are discussed:

- Diversity of beekeeping across Europe
- Access to and quality of information
- Connection between research and practice (which is also key to introduce the following point on advisers)

Beekeepers work in many different environments. Every season is unique, and the beekeepers have to adapt their management techniques. If there is more than one beekeeper in the same forage area, what one beekeeper does or does not do has an effect on other beekeeping business, especially regarding honeybee health. As discussed in **minipaper 4** (Beekeeping advising unit. Information and training for beekeepers) beekeepers need to be advised properly on how to overcome external factors in order to keep productive colonies. How can **supporting services for beekeepers** be organised in order to improve colony survival and productivity? Sustainable apiculture needs sustainable extension and advisory services. The suggestion from **minipaper 4** is that the EU platform of beekeeping knowledge (discussed in **minipaper 1**) would serve as a primary source of information and a tool for training activities. Even so, it should be noticed that the scientific and research data would need to be turned into practical information, in the appropriate format and language, useful for the beekeeping practice or training.

By using the B-KIS (**Beekeeping Knowledge and Innovation System**) approach one gets a structural overview of the main knowledge actors, their roles and relationships. It aims to:

- Describe the general structure and function of activities aiming for knowledge development, innovation and learning
- Better understand how today's services for beekeepers are embedded into the national B-KIS
- Provide some conceptual elements to support the development of a national or regionally adapted communication strategy for improved sustainability of apiculture

Key issues identified:

- Make knowledge available (from research and practice)
- Skills development

Good practices

The "Certificate for European Consultants in Rural Areas" (CECRA) is the first European competence development programme with an international certificate, meeting the rising demand for advisory methods training. It combines practical training with tried and tested advisory techniques. The networks Internationale Akademie für ländliche Beratung (IALB) and European Forum for Agricultural and Rural Advisory Services (EUFRAS) are the providers of the CECRA Certification. This certificate is made for advisory services for farmers but could very well be applicable for beekeeping.

https://www.teagasc.ie/media/website/about/our-organisation/connected/CECRA-flyer.pdf
https://www.cecra.net/index.php/de/

Mentioned as an example in **minipaper 4**, BeeBase is the Animal and Plant Health Agency's (APHA) National Bee Unit website. It is designed for beekeepers and supports Defra, Welsh Government and Scottish Government's Bee Health programmes. The National Bee Unit, NBU has been involved in the management and control of bee pests and diseases, training and dissemination of information to beekeepers for over 60 years. NBU comprises laboratory diagnostics, programme support, research personnel and 60 home-based Bee Inspectors. A beekeeper may sign in to BeeBase on a voluntary basis. By doing this, beekeepers are able to put the details of their honeybees and apiaries onto BeeBase, including inspections information, being able to arrange an apiary visit from the local inspector who can provide the comprehensive help and advice needed. The website includes quality assured information and knowledge for beekeepers.

http://www.nationalbeeunit.com

What can we do?

As suggested in **minipaper 1** (Platform of information at EU level) we can organise a **network of credible and validated information** gathered in different regions of the European Union in order to be able to take the best possible account of local specificities linked to culture, climate, land use, and the main existing beekeeping practices. Thus facilitating the structuring and standardisation of the information received from research and practice. This information would be centralised by a European platform and made accessible to national/regional 'antennas' and/or directly to beekeepers. Another way forward could be the development of a '**beekeeping licence**', a pan-EU standard of beekeeping qualification for beekeepers, achieved through formal education, professional training and/or extension services as discussed in **minipaper 4** (Beekeeping advising unit. Information and training for beekeepers).

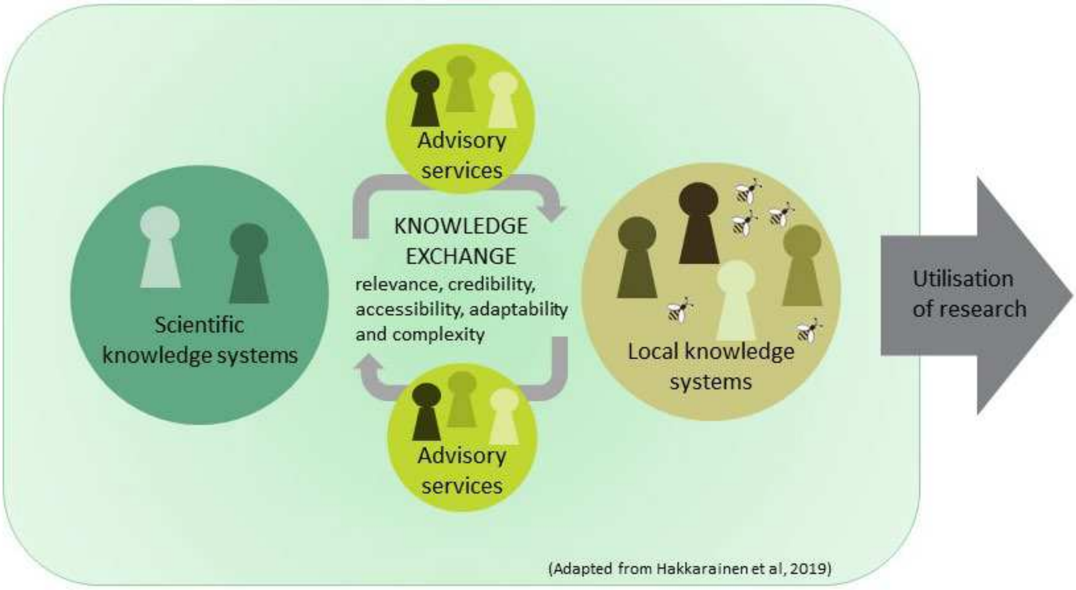

Figure 7: Bridging research and practice. A functional advisory system with the ability to make scientific knowledge available and accessible for practical use is essential and so are the knowledge and the needs generated by beekeepers, to be communicated to research through the same channels. The advisers facilitate this process.

Ways forward:

- Create a European platform for beekeeping knowledge connecting research and practice
- Licence for beekeepers, a pan-European standard

Inspiration from minipapers

MINIPAPER 4: AN ENCOURAGING STORY FROM SCOTLAND

A crisis situation in Scotland surrounding heavy levels of European foulbrood in 2009 forced a radical look at developing a strategy to deal with the situation. Initially it was felt that the beekeeping sector worked well amongst itself being kept well abreast of relevant situations. However, it quickly became apparent that this was not the case. When meetings were called to outline developing plans, it was apparent that the beekeepers were initially reticent and suspicious but as time went on the barriers broke down and a true partnership was formed.

Once the disease came under control, the strategy evolved to further improve the situation. Rather than simply have a meeting some became workshops dealing with bee health issues and then an accreditation developed where the beekeepers were tested against identification of disease and treatment. Success even resulted in a certificate acknowledging the new knowledge gained, something some had never received.

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MINIPAPER 1: SCIENTIFIC DATABASES

The International Bee Research Association, IBRA **https://ibra.org.uk** is a well-known scientific database in the field of beekeeping. It has published the Apicultural Abstracts since 1950, and continued to edit Bee World and Journal of Apicultural Research. Scientific information is structured and refers to Google scholar, PubMed, Scopus (paid) search engines, but many articles are linked to a subscription and only abstracts are accessible.

Another international non-profit association that focused on improving the welfare of honeybees worldwide is COLOSS (Prevention of honeybee COlony LOSSes **https://coloss.org/**). This association is composed of professional scientists, including researchers, veterinarians, agricultural extension specialists and students. In order to maintain cooperation and dialogue to better understand the reasons why bee populations are threatened in today's world, it maintains a website full of information, and holds regular meetings and workshops.

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3. Recommendations from the Focus Group

Following the work that was done exploring available knowledge, practices and technologies, the Focus Group experts looked at what is missing, what are the remaining needs that would need to be addressed in the future. Based on this, they have proposed new ideas for innovation, suggesting ideas for Operational Groups (OGs) and provided indications for possible directions for further research.

Most of the ideas fall into four main themes:

- Beekeeping data and their availability, management, standardisation, collection, interpretation and use.
- Beekeeper knowledge and needs in terms of training, information gaps from practice, social aspects of beekeeping.
- Beekeeping practices: health indicators, adaptation to and mitigation of climate change, dealing with farming practices with an impact on the bee's environment, cooperation with farmers.
- Bees at the centre: health and well-being, exposure to stressors, conservation of populations, genetics, breeding, effects of beekeeping practices.

3.1 Research needs from practice

Despite the many innovations and findings, still many research results are translated into practical applications very slowly, or not reaching the ground at all. On the other hand, professionals such as farmers or beekeepers may have the impression that research does not meet their needs. Therefore, the Focus Group was invited to identify remaining research needs from practice and propose possible directions for further research.

Six priority research needs from practice were highlighted by the FG. Other identified research needs can be found in **Annex 4** and are further articulated in the minipapers.

1. Create a European platform better connecting research and practice and contributing to efficiently gathering and exchanging knowledge. It should relay and be connected to local centres to properly consider context-specific issues, and ensure accessibility, credibility and visibility of the information for beekeepers. For this, specifically issues related with language and standardisation or interpretation of data from monitoring tools would need to be considered.

2. Determine and evaluate an index to synthesise the health status of individual honeybees and their colonies, which can be useful for several purposes related to honeybee health and risk assessment (effects of stressors from agriculture). Even developing an emergency tool such as the creation of the *Bee ambulance* to provide assistance in case of emergency situations (e.g. disease outbreaks).

3. Explore the effects of exposure to stressors from agriculture, including e.g.: knowledge of the effect of novel chemicals, including their sublethal effects and interactions with other chemicals or stressors such as flowering resource quality and quantity.

4. Improve technologies and methods for sustainable beekeeping, such as the use of a natural wax cell size (as would be natural for honeybees), in combination with the regular removal of drone brood or applying organic substances instead of synthetic chemicals.

5. Improve breeding efforts in all countries in order to maintain the local populations of honeybees, as well as to identify resistant populations to Varroa. Breeding local honeybees and honeybees that are well adapted to their climatic conditions will improve resilience.

6. Work on identification, communication and implementation of mitigation practices amongst beekeepers, and with farmers. Test and find out best mitigation practices in terms of effectiveness, increase farmers' awareness on the importance of honeybees and pollinators, work on agreements between beekeepers and farmers – enforced by local authorities –, etc.

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3.2 Ideas for Operational Groups

With the aim of inspiring innovative actions, seven main ideas for EIP-AGRI Operational Groups were elaborated by the FG. The proposals cover a wide range of types of projects, from testing solutions or management practices at hive level to ways of cooperation or knowledge exchange.

Theme: Varroa control

IDEA 1: TESTING THE EFFECTS OF CUTTING THE DRONE BROOD AND REDUCING THE CELL SIZE FOR VARROA CONTROL

The objective is to keep the Varroa level as low as possible during the whole season, by properly managing drone brood and choosing the most suitable comb cell size. The most common size nowadays is 5.4 mm, but it is not clear whether this is suitable to fight against Varroa. Moving to a more natural size of cells (allowing the bees to show us the exact size) might be the way forward to fight Varroa. Bees will build a different size of cells in the different climatic zones as well according to their own body size, as adaptation to the microclimate they live in. The same applies to the type and the size of the hive.

The project would require involvement from researchers, advisers and beekeepers. The outcomes – mainly for the beekeepers – would be:

- Recommendation of the best comb cell size in each area
- Recommendation of the best hive type (or size)
- Recommendations on frequency and efficiency of drone brood removal
- Low Varroa infestation levels throughout the year, increased survivability of colonies.

The activities of the project would include:

1. Testing different cell sizes of combs in 2-3 different ecotypes or conditions
2. Testing different sizes of hives in different ecotypes or conditions
3. Testing and combining the above with drone brood removal, at different frequencies
4. Monitoring Varroa levels and colony productivity together, and under all these different conditions, during the year
5. Formulating the recommendations based on all these trials.

This project could be implemented in different countries to test the differences.

IDEA 2: BETTER COLLABORATION FOR LESS VARROA

Varroa treatments are usually applied individually by beekeepers. Thus, the objective of this project is to mitigate Varroa infestation across apiaries at local level, by encouraging the cooperation of beekeepers to organise and implement a common calendar for Varroa treatment. There is some experience on this in Switzerland and Germany, thus the idea is to adapt and replicate the example in other areas.

This is a collective approach that would require the cooperation of for example 5-6 beekeepers, who would agree and coordinate the timing of the treatments. Benefits would be the decrease of the risk of Varroa, reducing chemical treatments, or better monitoring of Varroa especially in areas with high density of apiaries.

The practical outcome would be a communication tool (such as an application) for beekeepers, associations and other relevant experts (e.g. vets, advisers) which should provide info as proposed data for treatments, current levels of infestation of the different colonies in the region, localisation of apiaries, alerts, etc.

In parallel to the platform, the project would look at potential incentives that might encourage the use of the application and the coordination of treatments by the beekeepers.

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Theme: Hive construction and management methods

IDEA 3: MANAGEMENT OF APIARIES IN THE WORST/EXTREME CONDITIONS

Climate change impacts are increasing all over Europe, threatening honeybees and beekeeping activity. The objective of this project would be to contribute to maintaining the beekeeping activity focusing on protecting the apiaries against the main threats posed by climate change on a specific area. For example, helping to overcome specific adverse conditions such as very hot weather, drought or threats such as birds or *Vespa velutina*. The main topic is bee health but also how to preserve pollination activities for farmers.

The expected results are two-fold:

1. Improving the immunity of honeybees based on practices of artificial nutrition, multiplication of bee colonies, management of Varroa, etc.
2. Designing hives and apiaries to avoid adverse conditions (e.g. covers for apiaries which could help to deal with very extreme environmental conditions such as very dry and hot summers)

The idea is to run the project on a specific location. The steps towards the results would be:

1. To select the study area and identify the main climate-related adverse conditions and threats expected on the area
2. To design the apiary with the specific material and equipment to protect the apiary against the foreseen adverse conditions in the study area.
3. To define the best management practices e.g. for nutrition, multiplication of colonies or pest management.

Participants needed for the project would be some beekeepers (or an association), advisers, manufacturing companies and researchers.

IDEA 4: SMALL CHANGES, "BEEG" OUTCOMES. DIFFERENT DESIGNS OF WALLS OF THE BEEHIVE

The objective of the project is a better understanding of beekeeping and husbandry practices, looking specifically at beehive materials and techniques, depending on the climate and local situation. For example, the thickness of walls and materials of the hive have a direct impact on isolation of the hive (so affecting temperature and humidity), propolis harvest or swarming management.

The aim is to increase resilience of honeybees and improve their well-being and health, thus direct beneficiaries would be first the bees, and then the beekeepers.

The expected results would be guiding material about "Do's and Don'ts" in beekeeping, and delivering advice concerning:

1. Materials to be used in beekeeping (including feeds, etc.)
2. Practices for husbandry management

To achieve the results, the project would need to collect and study the existing beekeeping practices and materials available, e.g. designs of hives and belonging equipment. Then it would set up protocols and tests to study the performance of the different materials and practices and, if possible, under different environmental conditions. Finally, it would derive recommendations and disseminate the findings.

Specific participants needed for this project would be manufacturers and suppliers of beehive products and equipment, engineers and designers of equipment, and practitioners such as vets or advisers with knowledge on bee health.

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It should be noted that the project recognises the benefits of the standardisation of practices or equipment, thus it is not aiming to look for new developments, but it would try to deliver recommendations about what might perform better, within the wide range of existing practices and materials, depending on the local conditions.

Theme: Collaboration

IDEA 5: CREATING BRIDGES BETWEEN FARMERS AND BEEKEEPERS FOR BEE-FRIENDLY FARMING

The motivation of the project is the lack of communication and awareness of the importance of honeybees for agriculture. Do we have a common understanding about what is "bee-friendly" farming?

Expected results are:

1. Developing an app/platform to share information in real time between farmers and beekeepers. The platform would include all relevant information as for example land use, pesticide application or crops.
2. To get a common agreement on what is a "bee-friendly" strategy. For example, abundant nectar sources in the late season should not be considered a bee-friendly practice, because it shortens the life of the worker bees. These late food sources delay the overwintering of the workers. As a consequence, colonies are too weak after winter and likely too small for building up a strong colony in time for spring crops.

Participants who would be welcomed for the project are beekeeping associations, advisory services, local farmer associations, organic farming associations, among others.

IDEA 6: BRIDGES BETWEEN FARMERS AND BEEKEEPERS, TO DISCUSS AND COMMUNICATE GOOD PRACTICES AND ADAPT THE PRACTICES ON A LOCAL SCALE

Bees in agricultural landscapes need a good environment, thus the idea is to improve the implementation of bee-friendly practices by farmers. The idea for this project is to develop a communication guide to farmers and beekeepers, at a very local scale. This guide could be disseminated later on to another region with similar conditions.

The steps to follow will be, first to test and select agricultural practices to be implemented by farmers and which benefit the health of bees. Secondly the project would focus on communicating those practices amongst famers, e.g. through guidelines, visits, joint meetings with beekeepers, etc.

For this the project would need to characterise, at a very local scale:

1. The landscape (forage availability, pesticides use, etc.)
2. The colonies' health (impact of pesticides, pathogens, food quality and quantity, colony strength, etc.).

Apart from beekeepers and farmers, the project would also indirectly benefit citizens and public administration.

IDEA 7: FOOD FOR BEES

The motivation of this project is the lack of food for honeybees in some places, for example in The Netherlands, where due to the high density of apiaries, honeybees are suffering from shortage of food. Also, there is a shift in food sources due to climate change. This lack of food is affecting not only the honeybee but also wild bees and lies behind the bad reputation that beekeepers are having in some contexts.

This, as well as some other project ideas, includes a cooperation aspect amongst farmers, beekeepers and other actors, but with the main focus on increasing the availability of food for bees (not looking, for example, at reducing the impact of pesticides etc.).

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The expected results would be:

1. A better organisation and distribution of hives over the area of study
2. The description of the nutritional value of the landscape features and crops
3. An increase of the number of flowering plants and trees
4. An increase in biodiversity and building a better reputation for beekeepers

The beneficiaries would not only be beekeepers but also citizens, as the project aims to improve the quality of the ecosystems and environment.

Some of the tasks the project would carry out are:

1. Study the impact of climate change on plants which are supplying food for bees, including gardens
2. Establish "bee gardens", also for public awareness
3. Establish recommendations for landscape design (agriculture, forestry, etc.) favouring bee food sources
4. Monitor honeybee health and wild pollinators in different landscape features.

The participants of the project would be local governments in charge of landscape developments, researchers, beekeeping organisations, agricultural organisations. Additionally, "community influencers" might be a good asset to boost dissemination and raise awareness about the topic amongst citizens, farmers and beekeepers.

IDEA 8: EDUCATIONAL PROGRAMMES FOR BEE BREEDERS

Most knowledge of breeding bees lies within a few breeding organisations and not within the overwhelming majority of hobby beekeepers. For local breeding of honeybees we need to educate local bee breeders. The gain of good breeding practices by hobby beekeepers would be beneficial for all bees, and therefore for the whole beekeeping business. The development of such a programme could consist of the following steps:

1. Gathering the knowledge from different breeding organisations. This will be a mixture of different race breeders, different countries and different ecological systems.
2. Comparison of different breeding practices and mapping the practices in a scheme for different ecologies.
3. Converting the acquired breeding knowledge in locally adapted programmes.
4. Developing an implementation plan for the breeding programmes.

Step 1 would require cooperation of several bee breeding organisations like BeeBreed, Buckfast breed organisations and black bee breeders, either professional or non-professional. The gathered breeding knowledge should not focus on races, but on traits, like aggressiveness, swarm behaviour and Varroa resistance.

Step 2 and 3 require the independent assessment of the knowledge, preferably by academic researchers and/or lectures. The complete set of final specifications for the programme should be determined.

Step 4 requires the involvement or even better the participation of all local beekeeper associations or organisations. They should implement the programme at least partially in local beginner programmes or completely in educational programmes for advanced beekeeping.

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Annex 1: List of members of the Focus Group

Name of the expert	Profession	Country
Simone Tosi	Researcher	France
Fabio Sgolastra	Researcher	Italy
Marc Bock	Farmer	Finland
Florence Aimon-Marie	Adviser	France
Aleš Gregorc	Researcher	Slovenia
Stephen Sunderland	Civil servant	United Kingdom
Fani Hatjina	Researcher	Greece
Petko Simeonov	Farmer	Bulgaria
Salvador Garibay	Adviser	Switzerland
Louis Hautier	Researcher	Belgium
Ulrich Bröker	Adviser	Germany
José Antonio Ruiz-Martínez	Adviser	Spain
Frens Pries	Researcher	Netherlands
Etienne Bruneau	Working at an NGO	Belgium
Pilar De la Rua	Researcher	Spain
Ana Paula Sançana	Working at an NGO	Portugal
Anna Dupleix	Researcher	France
Constantin Dobrescu	Working at an NGO	Romania
Zeid Nabulsi	Farmer	Italy
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Facilitation team		
Lotta Fabricius Kristiansen	Coordinating expert	Sweden
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You can contact Focus Group members through the online EIP-AGRI Network.
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If you want to become part of the EIP-AGRI Network, please register to the website through this link

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Annex 2: List of minipapers

No.	Topic	Contributors
MP 1	**Platform of information at EU level**	Etienne Bruneau (Coord), Salvador Garibay, Florence Aimon-Marie, Ana Paula Sançana, Aleš Gregorc, Ulrich Bröker, Petko Simeonov
MP 2	**Disease control and emergency situations**	Hatjina, Fani (Coord.), Marc Bock, Pilar De la Rua, Constantin Dobrescu, Aleš Gregorc, Zeid Nabulsi, Ana Paula Sançana
MP 3	**Taking into account the well-being of honeybees in production**	Anna Dupleix (Coord.), Etienne Bruneau, Ulrich Bröker, Robert Chlebo, Salvador Garibay, Petko Simeonov
MP 4	**Beekeeping Advising Unit. Information and training for beekeepers**	Stephen Sunderland (Coord.), José Antonio Ruiz, Louis Hautier, Zeid Nabulsi, Aleš Gregorc
MP 5	**Improving the bee health status through monitoring of the colonies and the environment**	Petko Simeonov (Coord.), Frens Pries, José Antonio Ruiz, Rober Chlebo, Louis Hautier, Fabio Sgolastra, Zeid Nabulsi, Simone Tosi
MP 6	**Developing and enhancing good practices to mitigate major bee health stressors: pesticides and lack of resources**	Simone Tosi and Louis Hautier (Coord.), Frens Pries, José Antonio Ruiz, Florence Aimon-Marie, Zeid Nabulsi, Fabio Sgolastra
MP 7	**Sustainable bee breeding**	Frens Pries (Coord.), Pilar De la Rúa, Ana Paula Sançana, Fani Hatjina, Salvador Garibay

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Annex 3: List of honeybee research projects and initiatives and Operational Groups

This is a list of projects (past or ongoing) related to bee health and monitoring, compiled during the second meeting of the FG, and of the main themes they're addressing (updated July 2020)

1= Pests and diseases 2= Pesticides, agricultural practice	3= bee food supply and landscape 4= Well-being of bees	5= Monitoring 6= Breeding, local races	7= Knowledge exchange, advice 8= Beekeeping practice

Project		Theme addressed							
		1	2	3	4	5	6	7	8
LIFE4POLLINATORS	LIFE 4 Pollinators (**Involving people to protect wild bees and other pollinators in the Mediterranean**) – (LIFE18 GIE/IT/000755) LIFE4Pollinators wants to improve the conservation of pollinator insects and entomophilous plants by creating a virtuous circle leading to a progressive change in the anthropogenic practices that are currently threatening wild pollinators across the Mediterranean region. Events, citizen science activities, training to key stakeholders are planned to fulfil this objective by increasing awareness in four European countries: Italy, Greece, Spain and Slovenia. **https://www.life4pollinators.eu/**		x					x	
Smarthives	Smarthives (part of FRACTAL) is an **online support system that will help beekeepers in their everyday beekeeping activities and duties.** The basis of the concept is an ERP (Enterprise Resource Planning) system customised for beekeepers to facilitate better handling and management of honeybees (sites and families), equipment, expenditures and revenues. The software is operational on itself, but, for automatisation reasons, beekeepers can connect sensors to the system as well. **http://www.r-key.eu/**	x				x	x	x	x

Project		Theme addressed							
		1	2	3	4	5	6	7	8
POSHBEE	PoshBee (**Pan-european assessment, monitoring, and mitigation Of Stressors on the Health of BEEs)** (Jun 2018 - May 2023) addresses the issue of agrochemicals to ensure the sustainability of bees. It will assess the exposure to chemicals and their co-occurrence with pathogens and nutritional stress for solitary, bumble, and honey bees. The info will be integrated with the MUST-B project to develop a dynamic landscape model for risk assessment of bees. **https://cordis.europa.eu/project/rcn/215953/factsheet/en** **https://poshbee.eu/**	x	x	x		x	x	x	
APENET	APENET (**Monitoraggio e ricerca in apicoltura**) (2009-2011) was a project funded by the Italian Ministry of Agriculture. The aim of this project was to monitor and study the possible causes of honey bee mortality and colony losses in Italy. The project was organised in six pillars: Bees and agrochemicals; Bees and dressed seeds; Bees and Diseases; Bees and Environment; Interaction between stressors; Monitoring. **https://www.reterurale.it/apenet**	x	x	x	x	x			
BEENET	BEENET (**Apicoltura ed ambiente in rete**) (2012-2014) was a project funded by the Italian Ministry of Agriculture within the European Network for Rural Development (Action 1.2.2 "Interregional Laboratories for the Development") to support the Rural Development Programme in Italy. The aim of this project was to monitor the health status of honey bees and to assess the main causes of bee mortality in Italy. Recently, BEENET (now called "BEENET: api e biodiversità al servizio dell'ambiente") (2019-2023) has been re-funded by the Italian Ministry of Agriculture within the European Network for Rural Development (2013-2020) (Action 1.1.3) with the aim to evaluate the quality of the agro-environment using honey bees and wild bees as bioindicators. **https://www.reterurale.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/9026**	x	x	x	x	x			x
POLBEES	PolBEES (**Risk assessment for honeybees and osmie bees of exposure to systemic pesticides and nutritional stresses via pollen, bee bread and osmie bread**) studies the presence of systemic pesticide residues (neonicotinoids, fungicides) and the limited diversity of food resources in Wallonia. An exposure assessment will be carried out in different landscape contexts (field crop, arboriculture, grassland, urban areas) by collecting trap pollen and bee bread from hives and nests of osmias. **https://www.cra.wallonie.be/fr/polbees**		x	x		x			

1= Pests and diseases 2= Pesticides, agricultural practice	3= bee food supply and landscape 4= Well-being of bees	5= Monitoring 6= Breeding, local races	7= Knowledge exchange, advice 8= Beekeeping practice

Project		Theme addressed							
		1	2	3	4	5	6	7	8
BEESYN	BEESYN (**Identification of the impact of chemical products on honey bee mortality in Belgium, bearing in mind the interactions of these products with other plausible causes of mortality**) aims to answer the following questions: • What are the colonies' chemical contamination levels and what is the origin of this contamination? • To what extent may such a contamination determine the colony's fate when put in its context: its genetic, pathogen/parasite load, nutritional status, climate conditions and land use around it? • Which recommendations could be proposed to mitigate the problem of colony mortality at several levels: decision making, scientific, and practice? • Can we propose a tool box, including indicators of bee health and pesticide exposure, methods for pesticide surveillance carried out by honey bees or cost-effective surveillance programmes for colony mortality?. **https://www.cra.wallonie.be/fr/beesyn**	x	x	x		x		x	
DNA marker for VSH genes	(**Sustainable control of the Varroa mite in the Dutch beekeeping business)**. It would be ideal if bee colonies fight the Varroa mite themselves and this Varroa mite control (VSH: Varroa Sensitive Hygiene) behaviour occurs sporadically in existing bee colonies. This research project aims at a rapid cultivation of populations with this VSH behaviour. The partner Arista Bee Research breeds Varroa-resistant honeybees (buckfast, carnica, black bee) by challenging potential colonies and measuring reproducing mites in the brood. Hogeschool Van Hall Larenstein observes VSH (Varroa Sensitive Hygiene) behaviour in individual bees. Hogeschool Inholland isolates DNA from honeybees and has the DNA sequenced. With Bejo Zaden the DNA bioinformatics will be done and a marker for VSH behaviour will be established. Goal is to use the DNA marker for breeders to make apiculture possible without chemical control of Varroa. If all beekeepers will waive chemical control, in the long run all honeybee populations will be Varroa resistant, even without testing with the DNA marker. **https://www.sia-projecten.nl/project/duurzame-bestrijding-van-de-varroamijt-in-de-nederlandse-bijenhouderij**	x					x		x
GREEK QUEENS	**Conservation and genetics improvement of selected populations of Macedonian and Cecropian bees** based on performance and resistance to Varroa						x		

1= Pests and diseases 2= Pesticides, agricultural practice	3= bee food supply and landscape 4= Well-being of bees	5= Monitoring 6= Breeding, local races	7= Knowledge exchange, advice 8= Beekeeping practice

Project		Theme addressed							
		1	2	3	4	5	6	7	8
BEEPATHNET	BEE PATH – Good Practice logic is very simple: bees are the best indicators of a healthy environment! The BeePathNet Transfer network aims to upgrade and transfer the BEE PATH concept, solutions and results from Ljubljana to 5 other EU cities. It will address **urban environmental, biodiversity and food self-sufficiency challenges linked to urban beekeeping** through integrated and participative approaches, build key stakeholders' capacity to influence relevant policies, develop and implement efficient solutions. **https://urbact.eu/beepathnet**				x			x	
RESCUE-B	The RESCUE B (**Risk and Exposure Survey on Chemical Use in the Environment**) research project aims at better understanding the risk that environmental stressors, especially pesticides, cause to bees. First, it aims at developing methods to estimate pesticide risk in bees, including lethal and sublethal effects of single and multiple stressors. Second, it uses several multi-year national and international honey bee health surveys that measure pesticide contamination in the environment and in bee food to identify the pesticides that pose a greater threat to bees, nationally and internationally. This work aims at laying the foundation of future integrations of bee health surveillance initiatives, guiding policy makers through refined risk assessment methods, towards a greater protection of bee health and environmental sustainability. This project is hosted by the French Agency for Food, Environmental and Occupational Health and Safety (ANSES), and was developed in the framework of the "**Make Our Planet Great Again**" research initiative, publicly funded by the President of the French Republic.		x		x	x		x	
INSIGNIA	INSIGNIA (**Environmental monitoring of pesticide use through honeybees)** is an innovative project which will build on the wide range of expertise of the applicants developed during previous projects such as the COLOSS "CSI Pollen project". INSIGNIA involves the development of a protocol for a citizen science monitoring programme using beekeepers to collect biweekly pollen samples from honeybee colonies for analysis for pesticide residues and botanical origin. In the first year, in four EU member states representing all authorisation zones, monitoring using the well-established technique for collecting pollen samples using pollen traps, will be compared with two innovative techniques: the collection of beebread using a novel sampling device, and the use of passive in-hive sampling devices. **https://www.insignia-bee.eu/**		x						

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Project		Theme addressed							
		1	2	3	4	5	6	7	8
EurBeST	EurBeSt network (**European honey Bee breeding and Selection Team**). Selective breeding is a powerful tool to improve the economic basis of beekeeping and to cope with challenges to honey bees due to parasites, diseases, climatic and environmental changes. We know that the selection progress in productivity, gentleness and resistance to the parasitic Varroa mite (*Varroa destructor*) that can be achieved by modern selection methods, and also about the development of high levels of Varroa resistance under natural infestation pressure. The establishment of mite resistance in commercial populations depends on selective breeding supported by an adaptation of colony management and treatment procedures. EurBeST would like to demonstrate how these ideas can work in practice and which technical and economical consequences derive from these. **https://eurbest.eu**				x		x	x	x
Beewood/SAPIC	Beewood studies the **influence of wood material for building beehive** from physical (insulation) and chemical (wood odours) influence on bees health with a link to personal experience knowledge of beekeepers. **http://www.lmgc.univ-montp2.fr/perso/anna-dupleix/beewood-research-projet/**				x	x			x
NO PROBLEMS	NOPROBLEMS "**Nourishing PRObiotics to Bees to Mitigate Stressors**" is a project funded by the EU under the MSCA-RISE - Marie Skłodowska-Curie Research and Innovation Staff Exchange (RISE) with the aim to define a strategy to improve honey bee health based on the use of beneficial bacteria and plant extracts. The project aims also to evaluate the impact of the developed formulation on the bee gut. **https://site.unibo.it/h2020-msca-no-problems/it** **https://cordis.europa.eu/project/id/777760**			x	x				x
BEE-RER	BEE-RER is a research project of the University of Bologna funded by the Emilia Romagna Region within the Apiculture supporting work programme. The full title is "**Analysis of honey DNA and of honey contaminants to support the apiculture sector and monitor hive pathogens in Emilia Romagna region** - (BEE-RER)". BEE-RER aims to face the problems of the beekeepers by applying genomics to the apiculture sector. The project is focused on the application of honey DNA analysis to obtain several information that could be useful to authenticate the honey, identify the Apis mellifera subspecies from this matrix and to identify pathogens **https://site.unibo.it/bee-rer/en**	x			x	x	x		x

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Project		Theme addressed							
		1	2	3	4	5	6	7	8
SURVapi	The SURVapi Project (**MONITORING environmental contamination with phytosanitary products via beekeeping matrices to improve and reduce their uses**) is part of the Ecophyto plan. It is a multi-year project which aims to set up a collaborative work between farmers and beekeepers, to improve the field practices practices taking into account the issue of protecting bees. On each site, joint facilitation by advisers from the Chamber of Agriculture and the Beekeeping Development Association will facilitate joint work. Scientific support is provided by ITSAP - Institut de l'Abeille. https://nouvelle-aquitaine.chambres-agriculture.fr/agro-environnement/ecophyto/survapi/		x	x				x	
BeeWallonie	BeeWallonie defines itself as the "**showcase for Walloon beekeeping and the skills developed by beekeepers**". It aims to support Walloon beekeepers and the initiative counts with the support of research organizations and the regional government. https://www.beewallonie.be	x	x			x		x	
B-GOOD	B-GOOD (**Giving Beekeeping Guidance by cOmputatiOnal assisted Decision making**) is an EU wide bee health and management data platform. It consist on a digital bee data logbook, a database for automated data acquisition and a web portal. The EU-funded B-GOOD project aims to create a health status index (HSI) that will be linked to apiarists, and will collect and process data from a wide range of sources. https://www.b-good-project.eu/				X	X		X	X
HIVEOPOLIS	Hiveopolis (**Futuristic beehives for a smart metropolis**) (2019-2024) will implement a variety of traits into this modern honey bee hive. For example, every honey bee colony will be equipped with an inbuilt dance robot. These dance robots will be able to direct forager bees to certain nectar or pollen sources. Vibrating plates built into combs will prevent colonies from foraging at harmful food sources, such as flowers treated with pesticides or dying colonies which are heavily infested by *Varroa* mites. https://www.hiveopolis.eu/ https://cordis.europa.eu/project/rcn/218714/factsheet/en					X			X
BPRACTICES	BPRACTICES by ERA-NET SUSAN ((**New indicators and on-farm practices to improve honeybee health in the *Aethina Tumida* ERA in Europe**) will develop new management practices (Good Beekeeping Practices – GBPs) adopting new clinical methods, biomechanical and innovative biomolecular techniques respecting the natural behaviour of honeybees. The economic impact on beekeeping industry will be quantified and beekeepers and	x				X		X	X

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Project		Theme addressed							
		1	2	3	4	5	6	7	8
	consumers will be aware of the project results thanks to a cutting-edge traceability system using the QR-code/RFID technology https://era-susan.eu/content/bpractices								
SAMS	SAMS (**International Partnership on Innovation in Smart Apiculture Management Services**) (Jan 2018 - Dec 2020) SAMS is a multi-national, interdisciplinary project, with the goal to promote beekeeping in tropical regions by applying Internet of Things (IoT) systems and Information and Communication Technology (ICT). The solutions created by the project are accessible open source. The three-year project enhances international cooperation on ICT technology and sustainable agriculture between the SAMS partners from Ethiopia, Indonesia, Latvia, Austria and Germany. https://sams-project.eu/					X		X	X
IOBEE	IoBee (**Beehive health IoT application to fight Honey Bee Colony Mortality**) (2017-2020). The IoBee project concluded in April 2020 with the development of in-hive and in-field monitoring, as well as the implementation of satellite imagery and Spatial Decision Support Systems (SDSS). IoBee also initiated the first steps in the construction of a platform to integrate and communicate on pollinator-related data from various sources, The Bee Hub http://cordis.europa.eu/project/rcn/210011_en.html https://io-bee.eu/	x				X		X	X
WARMHIVE	WarmHive (**SMART thermotherapy solution for Varroa mite treatment**) (Jan-Jun 2019) https://cordis.europa.eu/project/rcn/220042/factsheet/en	x				X			
BEEHOME	BeeHome (**Automated beekeeping platform powered by AI that increases honey production by 50%, reduces labour use by 90%, and reduces colony loss by 80%).** (Jan – Apr 2019) BeeHome is a patent-protected modular commercial apiary that automates beekeeping powered by Artificial Intelligence. The BeeHome platform consists of a hardware and software solution that fully automates beekeeping and honey production and that optimises pollination. The platform will house up to 40 colonies (hives) and streamline their activities. https://cordis.europa.eu/project/rcn/220635/factsheet/en					X			

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Project		Theme addressed							
		1	2	3	4	5	6	7	8
FOG	FOG (**Frequency protector generator for honeybees**) (Jan - June 2019) https://cordis.europa.eu/project/rcn/220056/factsheet/en					X			
BeeXML	BeeXML (**Collaboration platform for the standardisation of the exchange of data about bees and beekeepers**). Governmental institutions, academic research projects as well as breeding programmes of beekeeping associations inevitably gather data about bees and beekeepers. Unfortunately these databases become data islands and the information is of limited value for the beekeeping community as a whole. beeXML is intended to be the answer to this problem. The project is not about creating a central database. Rather, XML is a self-describing data format that can allow the exchange of data. http://beexml.org/					X			
Hostabee	Hostabee has **developed B-Keep and B-Swarm.** These connected units enable professional and amateur beekeepers to monitor hives and their inhabitants remotely. The data, collected each hour by sensors, can be consulted via a dedicated application. This information (humidity, temperature, etc.) provides fast answers on the state of health of the bee colony. https://youtu.be/jmVYbDXf3Fg https://youtu.be/-L9IBD6CDVQ https://hostabee.com					x			
MUST-B	MUST-B is an initiative by the European Food and Safety Authority (EFSA). The MUST-B project draws on EFSA's expertise in areas such as animal and plant health, data collection and analysis, modelling, pesticides and environmental risk, but will also involve a range of experts and stakeholders from beyond EFSA. It comprises a number of interlinked activities that are being carried out either in-house or in collaboration with external experts, researchers and bodies such as EU Member States, the European Commission, EU sister agencies, and the European Reference Laboratory for Bee Health. http://www.efsa.europa.eu/en/topics/topic/bee-health	x	x	x	x	x	x	x	x

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Project		Theme addressed							
		1	2	3	4	5	6	7	8
AGROAPIS*	AGROAPIS is a project to raise the value of apiculture production by using agricultural crops beneficial to bees and pollinators in compliance with the agri-environmental conditions. The target is to test in-field conditions melliferous vegetal species that may be cultivated both for the benefit of bees and other pollinators and farmers. The testing will provide an objective assessment of the value of various plants both from the apicultural point of view and for the vegetal farming sector. The project is in its final stage of approval and will be, hopefully, financed via the Romanian National Program for Rural Development, measure 16.1.		x	x	x	x			
APISANA*	APISANA is about a mobile laboratory for sampling and conservation of the samples collected for assessment of the toxicity of agricultural cultures on honeybees. This project will explore the best methods for sampling, preservation and transport in safety conditions of the samples of bees and bee products collected from hives as well as parts of plants, soil or water in order to ensure relevant results of the lab analyses for assessment of the toxicity of agricultural crops and environment that harm the bees and other pollinators. The project is in its final stage of approval and will be, hopefully, financed via the Romanian National Program for Rural Development, measure 16.1.	x	x		x	x			
PUROWAX*	The project PUROWAX is about helping beekeepers to obtain residue-free beeswax for sustainable agriculture and for improving bees' health. The project aims to develop a method for purification of beeswax of contaminants that impact the health of honeybees and to create a scalable production process for purifying beeswax at industrial level. The project is in its final stage of approval and will be, hopefully, financed via the Romanian National Program for Rural Development, measure 16.1.	x	x						x

*Assessment in progress

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Annex 5: EIP-AGRI Operational Groups working on bee health

The table below compiles the Operational Group (OG) projects currently listed at the EIP-AGRI database (https://ec.europa.eu/eip/agriculture/en/eip-agri-projects/projects/). Date of consultation is July 2020. This is not an exhaustive list and more projects can be found at the national and regional databases of Operational Groups. See here the list of other available sources:

https://ec.europa.eu/eip/agriculture/en/links-existing-operational-groups

Title	Country
Control and minimiation of damage by the invasive species Vespa velutina nigrithorax (Vespa velutina) in beekeeping	Portugal
2016-008 - SOCIOECONOMIC STUDY on the impact of VESPA VELUTINA in the Apiculture of the Autonomous Community of the Basque Country	Spain
BeeOShield An innovative biomolecular defence against bee parasites	Italy
Selection and Establishment varroa tolerant bee colonies VSH / SMR - short SETBie in BW	Germany
VarroaForm - Development of an effective formulation for the control and prevention of varroatosis in domestic bee (Apis mellifera)	Spain
Practice-research-bees: improvement of varroa management strategies for hessian beekeeper	Germany
BeeScanning 2.0 - monitoring a biological system	Sweden
Remote beehive monitoring, a new opportunity for nomadic beekeeping (NOMADI-App)	Italy
PICA: Innovative Platform for beekeeping	Spain
"Beekeeping, Agriculture and Environment" - Associate fruit growing and beekeeping for an agro-ecological and innovative management of production	France
DivInA- Diversification and Innovation in Beekeeping	Portugal
Biodivers Fruit Growing Limburg	Netherlands
Pasture for pollinators	United Kingdom
Pollinators for fruit growers and fruit growers for pollinators	Slovenia
Stimulation Pollination mix for climate adaptation	Netherlands

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eip-agri
AGRICULTURE & INNOVATION

The European Innovation Partnership 'Agricultural Productivity and Sustainability' (EIP-AGRI) is one of five EIPs launched by the European Commission in a bid to promote rapid modernisation by stepping up innovation efforts.

The **EIP-AGRI** aims to catalyse the innovation process in the **agricultural and forestry sectors** by bringing **research and practice closer together** – in research and innovation projects as well as *through* the EIP-AGRI network.

EIPs aim to streamline, simplify and better coordinate existing instruments and initiatives and complement them with actions where necessary. Two specific funding sources are particularly important for the EIP-AGRI:

- the EU Research and Innovation framework, Horizon 2020,
- the EU Rural Development Policy.

An EIP-AGRI Focus Group* is one of several different building blocks of the EIP-AGRI network, which is funded under the EU Rural Development policy. Working on a narrowly defined issue, Focus Groups temporarily bring together around 20 experts (such as farmers, advisers, researchers, up- and downstream businesses and NGOs) to map and develop solutions within their field.

The concrete objectives of a Focus Group are:

- to take stock of the state of art of practice and research in its field, listing problems and opportunities;
- to identify needs from practice and propose directions for further research;
- to propose priorities for innovative actions by suggesting potential projects for Operational Groups working under Rural Development or other project formats to test solutions and opportunities, including ways to disseminate the practical knowledge gathered.

Results are normally published in a report within 12-18 months of the launch of a given Focus Group.

Experts are selected based on an open call for interest. Each expert is appointed based on his or her personal knowledge and experience in the particular field and therefore does not represent an organisation or a Member State.

*More details on EIP-AGRI Focus Group aims and process are given in its charter on:
http://ec.europa.eu/agriculture/eip/focus-groups/charter_en.pdf

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EIP-AGRI Focus Group
Bee health and sustainable beekeeping

MINIPAPER 01: Platform of information at EU level
September 2020

Authors

Etienne Bruneau (Coordinator), Florence Aimon-Marié, Ulrich Bröker-Bauerer, Salvador Garibay, Aleš Gregorc, Ana Paula Sançana, Petko Simeonov

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Table of contents

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1. Introduction - Motivation

Knowledge exchange and capacity building for healthy honeybees and sustainable beekeeping is of major concern. But what knowledge is to be trusted as valuable information and how can we bridge best available knowledge and existing beekeeping practices? Communication is a two-way activity, meaning that if we want to make a change the bottom-up perspective is important. Some countries e.g. Slovenia, has long-standing tradition of beekeeping and beekeeping is also part of cultural heritage. This aspect beside the environmental and economic importance, need to be considered during the knowledge transfer and capacity building for healthy honeybees and sustainable beekeeping. We need to address issues like:

- Effective dissemination of quality information
- Enabling access to best available knowledge/best practice
- Regional adaptation of general information
- Creating arenas for joint learning
- Developing new products, business models and markets
- Gaining access to and linking with beekeepers needs

If we compare beekeeping to other agricultural practices, there are some specific challenges to take into account: diversified target group (large- to small-scale), mainly micro-businesses and self-subsistence, geographically scattered rural entrepreneurs, gender and wide age structure (mainly men and aged), the will or ability to pay for professional services, lack of tradition in formalised competence development and autodidacts (trainers and educators are self-trained as pedagogues).

Due to these challenges, the situation about how to get access to knowledge have to be analysed. This minipaper is describing the actual situation for knowledge exchange in Europe today and is defining the trends of how the beekeeping sector is gaining access to information. Are there any risks concerning bee health and sustainable beekeeping practices connected to this? What are the challenges for good quality information not being accessible? Where can valuable information and knowledge be found? Can a platform at European level for access of good quality information help to reach out with research results to practice? How can we use the social media and other new communication systems to provide beekeepers with the information they need? We cannot control the web or social media, but if we are seen there with up to date good quality information, we are visible and reachable for beekeepers.

2. Dissertation

General issues related to platform of information

Diversity of beekeeping in countries

There are very different management types of beekeeping among countries and even though among groups of beekeepers (e.g. beekeepers association) within a country that makes almost impossible to describe all of them. Beekeeping is directly linked with its environment (flora, climate etc) and will develop specificities. Beekeepers can be influenced on the way of beekeeping from different perspectives that they receive during courses, oral presentations, exchange with other beekeepers etc., and as well the way of thinking of the beekeepers themselves. Such information sometimes relays on empirical experiences and often are missing knowledge based on scientific research. Furthermore, the management types of beekeeping vary among the size of the beekeeper's operation. Professional beekeepers are strongly oriented to profit and reduce of cost, hobby beekeepers often do not care if a practice can be costly as long it offers a satisfaction for them.

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There are big differences among the "knowledge systems in beekeeping", (B-KIS), across Europe (actors, networks, funding, etc) and every country needs to find its own way of how to implement the knowledge to fit in a structure.

Access to information and its quality

Currently access to information on beekeeper issues is huge in the internet, social networks, books etc., however the validation of such information is difficult if in the case of practical experiences which makes sometimes confusing to the beekeepers on how to implement such knowledge into own conditions. The beekeepers are used to take responsibility for their own learning, finding information from many different sources. Here comes the ability of critical being able to sort out information that are correct and based on evidence and to understand the language the information is produced in.

Data collection on the situation of beekeepers, market, consumer opinion, image of beekeeping in the countries

There is very little information and data that is published and updated yearly on the different issues as situation of beekeepers, market, consumer opinion and image of beekeeping at European level. At European level, the European Commission presents twice a year a situation of the honey market and every 3 years the evolution of the beekeeping situation in EU. Some countries like France and Italy have a specific organization to monitor the evolution of the beekeeping market. The French Ministry of Agriculture publishes every year a summary on beekeeping sector and honey market[1] and ISMEA (Istituto di servizi per il mercato agricolo alimentare) publishes a report on the national beekeeping sector in Italy[2]. This tool exists also in US and in Argentina. In the case of the organic beekeeping sector, there is an effort from the Research Institute of Organic Agriculture (FiBL) to gather data on the situation of organic beekeepers at European level but here is still missing much precise information on the situation of beekeepers, market, consumer opinion, image of beekeeping etc. For example, on the level of a country the information is almost not available if beekeepers work under one organic beekeeping standard or manage the bees under different organic beekeeping standards. The same can be mentioned for other topics.

Data collection of research work, applied research

Scientific papers are often hard to reach and understand in a practical way for most beekeepers. Extension services at the universities where research is being done are no longer in function in most countries in Europe. On this issue, as far as is known, there is few information available to the beekeeper's language, specifically on applied research for many different issues. It is necessary to have validation and local adapted experiences based on research. For this, research experiences together with professional beekeeping practices implemented through policy makers are core solutions for beekeeping sector and are important for promotion beekeeping as part of local economy.

Knowledge transfer based on research work many times fails due to almost non-existent channels for dissemination among beekeepers (and as well farmers) on issues of beekeeping and agriculture and honeybees. To bring research results into practice we need to know the target group. It is important for successful knowledge transfer. Advisory services need to collaborate close to research to bridge the gap.
In the last decades, beekeepers have been confronted with honeybee colony losses caused by interactions between various internal and external factors including new disease and technological challenges. Researcher groups from all over the world have extensively studied impacts of variety of factors. There were several new

[1] https://www.franceagrimer.fr/Actualite/Filieres/Apiculture/2019/Production-francaise-de-miel-et-de-gelee-royale-en-2018
[2] http://www.ismea.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/10772

findings, but the communication gap between research organizations and beekeepers/farmers have prevented the large-scale and effective dissemination and solutions implementation into practice of all potential innovations. There are also obstacles in plethora of advising agencies organized in countries to be flexible in new findings adoption and implementation into practice.

Diversity of risks and challenges, image of beekeeping and bee products, relations with farmers and environmentalists

Communication from the beekeeping world to the general public is also important. If until recently, the honeybee appeared as a sentinel of the environment, which is justified; it is more and more often perceived as a generalist species that is essential and competes with other bee species. Scientifically based information is essential to avoid generating new emotional conflicts such as the conflict experienced in the past with some farmers. In order to address problems such as the massive adulteration of honeys, adequate information must also be disseminated to consumers to preserve the positive image of hive products.

Existing practices, tools, projects

Many different tools exist in the field of information and learning. Here is a table to summarize the current situation.

Journals and magazines	• SUPPORT : Paper - often associated with a web version • PUBLIC : small to large scale beekeepers
Books	• SUPPORT : Paper - sometimes associated with a web version • PUBLIC : all
Social networks	• SUPPORT : web version • PUBLIC : all, and non beekeepers
Web sites	• SUPPORT : internet • PUBLIC : all
Conferences, technical days	• SUPPORT : events • PUBLIC : small to large scale beekeepers
Scientific databases	• SUPPORT : web version of papers • PUBLIC : scientist
Project reports	• SUPPORT : Paper - often associated with a web version • PUBLIC : members of the project + scientist ans technicians
Advisory services	• SUPPORT: Individual • Public: all, if available in the country

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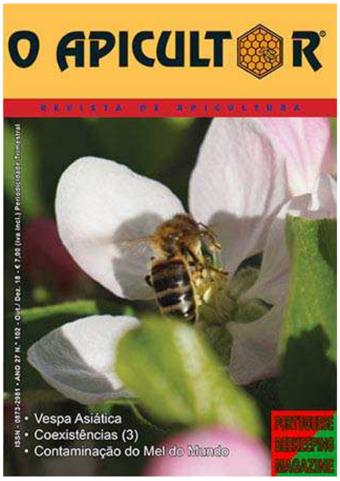
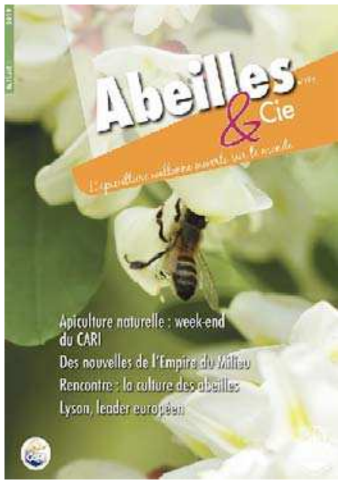
Journals of beekeeping associations

Each beekeeping association has its own information medium in the form of a journal, which can be either monthly, bimonthly or even less frequent. It's one of the most important sources of information for most of the beekeepers in EU. Some cover all the aspects of beekeeping and other are specialized like for breeding or pathology.





Some relevant examples of existing journals all over Europe are available in the annex.

A review of existing beekeeping magazines is available from Apimondia. https://www.apiservices.biz/en/databases/beekeeping-journals

Books

Beekeeping books are very numerous but less and less consulted by beekeepers. Some libraries are very well stocked. The best known is the IBRA.[3]
For other examples, see the Annex.

Web sites

The interest in web sites increase a lot during the 20 last years. Today each association has its own website. Some are free to access, and others are reserved for their members or are subject to a fee. This source of information can transmit the best and the worst. It is often difficult to verify the reliability of the source. In each language, you can find specific portals in the EU, where you will find many links to other sites. Very few are multilingual. We have also to present an international platform on beekeeping, TECA Beekeeping exchange group, manage by FAO[4].

Social network and monitoring systems

Social networks are becoming increasingly important in beekeeping. They are probably the most important way of communication today even for beekeepers. As for the websites, it's where good and bad information is disseminated most quickly. We can of course mention the Facebook pages, Twitter, LinkedIn but also blogs (see a list of the most popular[5]) mailing lists, WhatsApp.

Communication by smartphones or websites is also used by companies who manage the monitoring systems of hives, beekeeping activities, local flora and climate[6]. The management of the Data Warehouse linked to these control systems is a key challenge for the future.

[3] https://ibra.org.uk/
[4] http://www.fao.org/teca/forum/beekeeping/en/
[5] https://blog.feedspot.com/beekeeping_blogs/
[6] https://mybees.buzz/, https://www.arnia.co.uk

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Scientific databases

The best known in this field is the IBRA, which for years has published the Apicultural Abstracts and who continues to edit Bee World and Journal of Apicultural Research. Scientific information is better structured and refers to Google scholar, PubMed, Scopus (paid) search engines, but many articles are linked to a subscription and only abstracts are accessible. Some journals such as Plos On, Diversity, Insect e are open to the public. One can also search for an author's work on Research gate.

Project reports

European projects normally have a website on which they report on the progress of their work and the publications available. On the EUROPA website,[7] there is a page dedicated to beekeeping and there are more beekeeping programmes entered by the Member States in the context of beekeeping.

Courses – teaching resources

Beekeeping courses are offered throughout Europe but there are only a few courses that are freely accessible to all beekeepers (e.g. Austria). There are also internet courses and online training courses (MOOC on beekeeping and the environment). As the vast majority of beekeeping courses do not form part of an official course curriculum, checks on the subjects taught are rare. It's due to the fact that except in some countries where official school organize lesson for professional beekeepers, most of the beekeeping school are manage by hobbyist with a lack formalised competence development and most of the trainers and educators are self-trained as pedagogues (autodidacts).

Some examples	**Country**	**Language**	**Public**	**Content**					**Comments**
				Beekeeping techniques	Products and trade	Farming	Environment	Research	
MOCC abeilles et environnement	FR	French	Beginner BK Everyone interested in bees and beekeeping	x		x	x		
Escola Nacional de Apicultura, LOUSAMEL	PT	Portuguese, english	Beginner BK, advanced beekeepers and everyone interested in bees and beekeeping	X	X	X	X	X	x

[7] https://ec.europa.eu/info/food-farming-fisheries/animals-and-animal-products/animal-products/honey_en

Videos, films

Today, there are more and more videos from conferences, videos illustrating beekeeping operations, the use of specific equipment, etc. Beekeepers like this kind of media that brings a lot of practical informations in a very short time. Youtube is the most common platform for researching videos (more than 12 Million result just for beekeeping).

Conferences, technical days

At the international level, some meetings allow for exchanges on a very large scale. At European level, we can of course mention the major national congresses (FR - Congrès national d'apiculture, Donaueschingen in Germany, Apimel in Italy, etc). Beecome is a European congress that change of place every year. The Apimondia symposiums cover more specific themes such as pathology, organic beekeeping, apitherapy, etc.

Evaluation of the existing tools of information

- There are several books on the market, reference courses, etc that offer a good vision of general beekeeping. Quite often, the different information media are in competition and seek to stand out from each other to improve their visibility. There is therefore little exchange between the different structures (beekeeping associations, private firms, etc.) in charge of information.
- Technical information very often remains localized (regions, countries, communities grouped around the same language) or circulates only in specific groups of actors according to their level of professionalism, their ability to understand scientific texts and/or their field (products of the hive, breeding, race conservation, pathology - pesticides).
- At the research level, the research tools make it possible to reach a much higher level of selection (key words, year of publication, references, citations, recommended articles).
- There is hardly any general tool for all beekeepers at European level at the moment, even if some sites present their information in several languages. The most complete site at this level is managed by Apiservice[8].

How to manage the information?

- As clearly presented above, despite a very large number of sources of information in various forms, it is still very difficult to get an idea of all the data available on a particular subject. There are many search tools such as Google or other search engines that direct you to the information most often consulted in your geographical area but which, to our knowledge, do not value the quality or relevance of the information conveyed. In addition, some information collected e.g. in regional projects with beekeepers, is still inaccessible due to the absence of free online media or in a language not supported by the search engine. Moreover, little field information highlights the reliability of the published information and its real interest for beekeepers.
- 'When we have the information we are looking for, we must filter it on the basis of its reliability, the relevance of the answer it provides and its updating. There, very few tools exist in beekeeping. It must also be adapted to the level of scientific knowledge of the reader and be applicable to the different regions and to beekeeping practices. The type of medium on which it is stored is also important: text, sound, video. It would be necessary to set up a filter that makes it possible to quickly select the type of information we are looking for without having to pay the cost of all this selection work, which is sometimes not even possible given the lack of information on how the information was produced.

[8] https://www.apiservices.biz/fr/

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Advisory services, information centres

- The information centres are run by different structures depending on the Member States. There are structures financed very largely or even totally by public funds up to voluntary groups, like school apiaries. Their role can range from a simple information centre that centralises all the necessary information in order to provide it to beekeeping specialists or beekeepers through training or information days or publications or reviews. Some centres will also collate the information collected from beekeepers in order to obtain advice and recommendations or even development paths. Still others will develop services (analyses, sale of equipment, etc.) or applied research to answer beekeepers' questions, for example in terms of health or product development. It can be seen that the fieldwork carried out by beekeeping consultants generally meets the needs of many beekeepers. The mission of these people is generally to transmit to beekeepers the information essential to their hive management in order to maintain them in a satisfactory sanitary state and to enable them to ensure good production. Some specialised structures can provide a more targeted framework, for example for the management of pollination or royal jelly production.

- Today, few centres work on the interface between agriculture and beekeeping and few agricultural advisors specialize in pollination and the maintenance of favourable conditions for pollinators.

Sweden provides example of organisation at national and local scale to enhance links between beekeeping and farming sectors

The advisors at the Swedish Board of Agriculture
http://www.jordbruksverket.se/amnesomraden/miljoklimat/ettriktodlingslandskap/mangfaldpaslatten.4.e01569712f24e2ca09800012316.html

Advisor in nature conservation at Hushållningssällskapet
https://hushallningssallskapet.se/blommande-faltkanter/

Odling I blanas (Farming in balance) **https://www.odlingibalans.com**

EIP-agri Operational Group SamZon on multifunctional buffer zones
https://ec.europa.eu/eip/agriculture/en/news/inspirational-ideas-multifunctional-buffer-zones

3. Conclusions/Key messages

Summary: lessons learnt on the key issue

The dissemination of apiculture information at European level is confronted with various types of problems, the most important of which come from the diversity of beekeepers' profiles and production conditions, as well as from information sources that are often not reliable, up-to-date, complete and adapted to their current needs.

It should thus be possible to disseminate validated basic information that meets the needs of as many people as possible in terms of health, the environment or good apicultural practices, by adapting its presentation and the channels of dissemination according to the places and people affected. The more the information is adapted to the target audience and the closer the transmission channel is, the better the transmission will be. Today, new tools in full development could be used without forgetting the personal contacts that remain essential. The link between research and the field is essential both to adapt scientific articles to the beekeepers' level of knowledge and to validate and disseminate the observations and field tests carried out by beekeepers.

4. Ideas for innovations and research needs

Creation of a European platform assisted by a series of centres located by linguistic regions

The scope of this innovation will be to:

- Organise a network of credible and validated information gathering in the different regions of the European Union in order to be able to take the best possible account of local specificities linked to culture, climate, land use and the main existing beekeeping practices. The information should cover beekeeping health, sustainable practices, economic aspects, etc (results of local scientific projects, education material, monitoring of production and prices, field information of international interest, etc.).
- Facilitate the structuring and standardisation of the information received (definition of a common approach on the content and format of the information to be collected) in order to be able to correctly analyse the information collected. This information would be centralised by the European platform and made accessible to all cells and/or directly to beekeepers. This should take into account existing tools.
- The information sent to the platform would be supplemented by scientific monitoring on subjects of direct interest to beekeepers in the field. Requests scientists to share their research results. Possibly popularized articles and scientific publications geared more particularly to field beekeeping and to scientific advances with a short or medium-term impact on the beekeeping sector, could be centralized on a site accessible to all (different languages) with indication of the number of views, re-direction to other sites, downloads and an indicator of interest for beekeepers. This will need to set up and manage a database directly accessible by beekeepers.
- On the basis of these two main sources of information, production of dossiers, summary reports, articles and other information & education material on current topics responding to the priority needs defined by the beekeeping sector in European countries.
- Redistribute the info to the regional centres who could translate the information into their own language and adapt it to local production conditions (local beekeeping).
- In parallel, it would be useful to set up a **study to better describe the different sociological profiles of beekeepers at European level** in order to better understand their real needs and the motivations that lead them to become beekeepers.

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Aspects to take into account while addressing the issues

- Ensure the promotion in communication among stakeholders at all levels: national, EU, international level. New stakeholder synergies and networks can be established to support the existing and initiating new projects in mentioned fields and topics.
- New tools and services, including education materials, on-site trainings, visits, demonstrations, need to be performed by educated and professional personnel. Exchange of good practices and fostering a long-term network to support exchange of knowledge on existing research solutions findings and implementation into beekeeping practice.
- Specific challenges need to be addressed at national levels, by boosting the communication between stakeholders (researchers, advisors, farmers/beekeepers, policy makers etc.). Current official advising agencies need to be functional and be able to create a long-term network to support exchange of knowledge on existing best practices and research findings. A set of tools and services need to be re-evaluated and renewed in order to promote essential innovative beekeeping and adjacent practices.
- New tools need to be identified, to recognise and solve existing or potential problems in beekeeping. End-users (beekeepers/farmers) included in communication need to express their concerns and/or expectations. Experts and policy makers present research results, best beekeeping practices in their fields and policy-based solutions.
- Innovative practices have to be established through collaboration between actors of the beekeeping industry, honeybee research groups/labs and national or international beekeepers' associations.

Further research needs coming from practice, ideas for EIP AGRI operational groups and other proposals for innovation can be found at the final report of the focus group, available at the FG webpage
https://ec.europa.eu/eip/agriculture/en/focus-groups/bee-health-and-sustainable-beekeeping

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ANNEX

Review of some beekeeping journals

Title	Country	Language	Public	Content					Comments
				Beekeeping techniques	Products and trade	Farming	Environment	Research	
Abeilles & Cie	BE	French	All beekeepers	x	x	x	x	x	6/year
Abeilles et fleurs	FR	French	All beekeepers	x	x		x		Monthly
L'abeille de France	FR	French	All beekeepers	x	x		x		Monthly
La santé de l'abeille	FR	French	All beekeepers	x		x	x	x	Monthly. Mainly deals with sanitary aspects
Info Reines	FR	French	Professionnal	x				x	4/year Mainly about breeding
Revista o Apicultor	PT	Portuguese	All beekeepers	x	x	x	x	x	4/year
Bitidningen	S	Swedish	All beekeepers	x	x				8/year

Books

Title	Country	Language	Public	Content					Comments
				Beekeeping techniques	Products and trade	Farming	Environment	Research	
Traité Rustica de l'apiculture	FR	French Spanish	Beginners	x	x		x		
Mina första år som biodlare and Min biodling	S	Swedish	Beginners	x					Both textbook, workbook and teacher's book

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Websites

Title	Country	Language	Public	Content					Comments
				Beekeeping techniques	Products and trade	Farming	Environment	Research	
Apiservices.biz	FR	French English Spanish German	Beekeepers	x	x		x	x	
ITSAP	FR	French	All bk advisors	x	x	x	x	x	Website and blog available. Links to Guide des bonnes pratiques apicoles
INTERAPI	FR	French	Farmers Bk advisors			x			Description of plants & crops linked to interest for bees
www.cari.be	BE	French	Beekeepers	X	X		X	X	

EIP-AGRI Focus Group
Bee health and sustainable beekeeping

MINIPAPER 02: Disease control and emergency situations

September 2020

Authors

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Table of contents

1. Introduction

This minipaper aims to summarize and highlight briefly the best beekeeping practices and the innovative methodologies available in order to improve disease prevention, diagnosis and control under the pressure of conflicts such as migratory beekeeping, resistance to chemicals and climate change. At the same time, we intend to highlight that any control measures should also maintain the quality and safety of hive products given as they are used not only as human food but also as cosmetics and medicines.

The need for this paper has come about because the beekeeping sector is facing many challenges in the 21st century. One of the main challenges is how to ensure high efficacy of methods to control diseases, a) without any adverse effects of the chemicals used, b) with the lowest costs, and c) ensuring the highest quantity and quality of all hive products. The main problem in dealing with disease control arises from the intensive use of veterinary medicines, the resistance of varroa mite on the chemicals used, the accumulation of residues in the honeybee products and the synergy with the agricultural products used in the environment of the colonies. At the same time, the income of the beekeepers can only be assured through the improvement of their products' quality and the continuous monitoring of colony health and status.

Therefore, there is a great need for innovative and cost-effective methodologies to be used and anticipated in education, research and extension, at national and international level. In addition, the increase in information transfer within the beekeeping community as well as among all stakeholders (scientists, beekeepers, farmers, consumers, policy makers), will ensure that all steps needed in research and extension programmes are taken to tackle the specific problems, their solutions and their dissemination.

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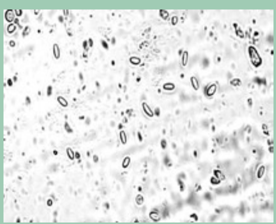
2. Dissertation

The honeybees are afflicted by several pests and pathogens, which are considered to play a key role in the global decline of honeybee populations. A comprehensive summary of the main pests/ pathogens is given in Table 1. At the same table there is information on monitoring methods and links to the recent research or surveillance projects. Apart from pests and diseases, environmental variables, nutrition issues and hive management practices are adding stress to the honeybee colonies.

	Description	Monitoring/ detection/diagnosis	Recent projects *
Varroa destructor (Varroa mite, a, b)  	• The female feeds on the fat body and haemolymph • It reproduces in the capped brood cells • Is known to be a vector and activator for several bee viruses, the most profound being the Deformed Wing Virus (DWV) • It damages the immune system, shortens the life span and diminishes the productivity of the colony	- Naturally fallen varroa mites among debris found on the bottom board - Adult varroa mites on adult bees (using icing sugar, ether, alcohol, CO_2) - Varroa reproduction rates in capped brood cells - Varroa infestation in capped brood cells - Molecular identification of varroa biodiversity- - Digital scanning of mites on bodies of bees (beescanning)	**SMART BEES** http://www.smartbees-fp7.eu/ **EurBeST** https://eurbest.eu/ **BeeScanning** https://beescanning.com/
Nosema apis/ Nosema ceranae (Nosema desease, c) 	• It infects the epithelial cells of the midgut of adult bees • It causes digestive disorders which leads to a shorter life span • It also leads to energetic stress • *N. ceranae* is more destructive • *N. ceranae* spores are smaller and they do not germinate after been subjected to cold temperatures • *N. ceranae* affects the colonies all year round • North European countries face lesser problem by Nosema disease	- Combs are soiled with faeces only in the case of *N. apis* infection - Lack of apparent symptoms connected to *N. ceranae* infection besides the poor colony fitness and depopulation (Martín-Hernández *et al.* 2018) - Samples of live old workers for microscopic examination in both cases (Cantwell 1970) - PCR-methods are used for species identification (Martín-Hernández *et al.* 2007; Bourgeois *et al.* 2012)	**BPRACTICES** http://www.izslt.it/bpractices/the-project/ **NOLESSBEES** https://www.eurostars-eureka.eu/project/id/5928

Melissococcus plutonius (European Foulbrood, EFB, d) 	• Non-spore forming bacteria • EFB is not notifiable in all countries • Cappings of pupae are higher than cell walls and irregular • Larvae have abnormal colour and position in the cell • Smell not as AFB, but as dead larvae • Capped and uncapped cells being found scattered irregularly over the brood frame	- Symptoms of EFB may easily be confused with other diseases or abnormalities in the brood, making diagnosis difficult - Capped and uncapped cells being found scattered irregularly over the brood frame - Use of the EFB diagnostics kit	**Bee Aware** https://beeaware.org.au/archive-pest/nosema/#ad-image-0 **POSHBEE** http://poshbee.eu/
Paenibacillus larvae (American Foulbrood, AFB, e) 	• Spore forming bacteria • Affects larval stages from 12 hours to 13 days post hatching • Capped brood have the dark brown, glue-like larval remains of infected larvae • Smell very strong like a glue • Capped and uncapped cells being found scattered irregularly over the brood frame • AFB scales cannot be removed from the cells	- PCR methods for identification and genotyping of the pathogen from comb samples have now been extensively developed, also for honey (De Graaf *et al.*, 2013) - There is also a great need to develop early diagnosis tools that might prevent the spread of the disease - Use of the AFB diagnostics kit	**EPILOBEE** https://www.anses.fr/en/content/european-epilobee-programme **DeBiMo** https://ag-biene.uni-hohenheim.de/en/debimo
Aethina tumida (Small hive beetle, f, g)  	• A pest of the sub-Saharan African honeybees, where it is a minor pest • Very harmful to European subspecies • Recently discovered in Calabria (Italy) • An invasive and a very rapidly established species	- Different types of commercial traps, homemade traps and many different materials have been employed in order to monitor - Knowledge about beetle appearance is needed - DNA analysis of the hive debris can also be used as a detection tool - As it prefers the dark, it would be easy to spot under the roof, or at the bottom of the hive	**APENET/ BeeNET** https://www.izsvenezie.com/bee-health-in-italy-national-monitoring-results/
Vespa velutina (Yellow legged hornet or Asiatic wasp)	• First recorded in southwestern France in	- Measure to control the entrance at the ports	**STOP VESPA**

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	2004. Latest distribution is shown in Fig. 2 • Predates on all insects, preferably honeybees • Mainly stands at the entrance of the hive, snatching and killing returning bee foragers, the colony responds by closing foraging efforts so that is weakened by predation levels and may starve to death by lack of food • Limited scientific assessment of the overall impact of *V. velutina* (Monceau *et al.*, 2014). • Protein supplementation and slight energy supplementation of the colonies might be necessary	and unintentional human transport - Pest preventive programmes (e.g. surveillance and quarantine programmes) at the European level - Detection methods for nests radio-telemetry (Kennedy *et al.* 2018) or drones (unmanned aircraft system or UAS) - - Establish traps filled with different substances (mainly sugar, but also fish or proteins) in the surrounds of the bee yards	https://www.vespavelutina.eu/en-us/ **BeeBase** http://www.nationalbeeunit.com/index.cfm?pageid=206 **COLOSS** https://coloss.org/

* The above-mentioned projects, do not necessarily refer to only one type of pathogen

Table 1: Short description of the main bee pests and pathogens

(a) The Varroa mite females feeding on a honeybee pupa. (b) A bee with deformed wings and shortened abdomen due to the DWV infection. (c) *Nosema ceranae* spores seen in 400x magnification. (d) A brood comb with twisted, diseased larvae attacked by *Melissococcus plutonius*. (e) a brood comb with brood cappings clearly punctured and scattered brood pattern attached by *Paenibacillus larvae*. (f) The small hive beetle images. (g) The small hive beetle larva. (h) The yellow-legged hornet (Photos a, b, c, d, e, f, g: Anna Gajda, Photo h: Per Kryger) (Hatjina *et al.*, 2019).

Fact No 1.

VARROA MITE IS THE ONLY PEST OF THE HONEYBEE FOR WHICH CHEMICAL TREATMENTS ARE ALLOWED!

Varroa control through beekeeping practice

- For over 25 years, a number of "hard" chemicals has been used to fight varroa, with their success diminishing as resistance of varroa is increasing. This type of varroa control is also leading to residues in beeswax, honey, pollen, propolis, royal jelly and bees larvae. As these are also consumer products for humans, the residues will finally end up in human organism. To limit these effects, or even prevent them, the management of varroa control is one of the keys for sustainable food products from honeybees.

- Several 'soft' chemicals or organic substances such as organic acids and essential oils, namely formic acid, oxalic acid, lactic acid and thymol have also been used with increasing frequency, mainly aiming at controlling varroa resistance to chemicals and reducing chemical residues in wax and honey. However, with the use of all the above substances (although at not at the same level) one cannot avoid the partly destruction of the flora and fauna in the beehive.

- Extension for varroa control also calls for synchronised control in terms of period of the year, and type of application, which can minimise the risk of reinfestation in permanent/non migratory apiaries. Training is also very important in varroa monitoring or control schemes, as good beekeeping practices also include measurements of infestations level and then control of varroa if infestation is above a certain threshold. Especially young beekeepers should be trained to use all sampling methods available and recognise early symptoms of apparent viruses.

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Alternative Varroa control

- Alternative ways to control varroa have also been developed such as trapping of mites in worker or drone brood, making artificial swarms, use of wire netting bottom boards, heat and powder sugar (Rosenkranz *et al*, 2010; Gregorc and Sampson, 2019), as well as complete brood removal or caging of the queens (Gregorc *et al*, 2017; Buchler *et al*, 2020).
- Breeding for resistance: *Varroa* resistant colonies are however thought to be the best solution in eliminating the problem of colony losses due to this parasite, but it seems that global beekeeping and varroa management need to be controlled and advised in a way, that will allow for the resistant bees to thrive. Recent European projects address this issue in detail (SMART BEES, EurBeST).

Example of practical experience from Finland!

Use of cell size of 5.1mm instead of 5.4. This management practice together with the removal of capped drone brood keeps varroa levels very low. "It is important that varroa has always open brood at her disposal". Results are yet to be confirmed!

THE GOOD BEEKEEPING PRACTICE SUGGESTS SAMPLING VARROA INFESTATION BEFORE ANY TREATMENT.

AS AN EXAMPLE, WE PRESENT HERE THE ILLUSTRATION OF THE ICING SUGAR METHOD (FIG. 1).

Figure 1 Icing sugar sampling method for varroa infestation on adult bees

Fact No 2.

NOSEMA CERANAE **SPORES DO NOT GERMINATE AFTER THEY HAVE BEEN SUBJECTED TO COLD!**

Fight against Nosema!

- Negative effects on queen survival and egg-laying of newly emerged queens in queen-breeding apiaries should be prevented to assure good quality of queens.
- Nosema shortens bee honeybee lifespan and survival may be dependent on the level of infection.
- Selective breeding for Nosema resistant bees could also become an important tool in reducing the incidence of nosema infections in honeybee colonies.
- It is crucial for the beekeeper to minimize the negative effects of potential nosema infestation on colonies development and also their survival.
- The vast negative effects of nosemosis on individual honeybees and whole colonies call for effective and accurate diagnosis, preventive methods and therapy without the use of antibiotics.
- Extension/training including 'good beekeeping practice' and colonies management need to be carried out.
- Fresh running water is essential and the colony density in an apiary needs to be controlled. Training of beekeepers in good beekeeping practice, nutritional aspects and early diagnosis is needed, especially for young beekeepers.

Fact No 3.

THERE ARE SEVERAL GENES IN THE HONEYBEE RESPONSIBLE FOR RESISTANCE AGAINST AFB AND EFB!

Eradication of the two bacterial diseases

- **EFB**

✓ As there is no treatment for bacterial diseases, burning of infected combs, is the best solution so far. Furthermore, all that apply to AFB can be regarded as important also for EFB.

- **AFB**

✓ There is no easy method to control AFB, apart from burning the infected beehives. In some countries, the antibiotic oxytetracycline (OTC) has been used for decades but there are several studies now showing resistance to it. In any case antibiotics do remain in the honey for years and do not kill the spores or destroy the AFB scales. However, the best method for controlling it is prevention by testing and keeping resistant populations, using the hygienic behaviour test (Spivak and Reuter, 2001). Buying second-hand material or colonies must be done after careful examination. Old hives should be thoroughly disinfected prior to reuse.

- **Extension/training**

✓ There is still a great need for intensive educational courses and training sessions for young beekeepers in this infectious disease. All beekeepers should be able to recognise the symptoms immediately, and most importantly they should know how to look and recognise the scales in empty frames.

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Fact No 4.

IF *AETHINA TUMIDA* ESTABLISHES IN AN AREA IT IS IMPOSSIBLE TO GET RID OF IT!

Measures against Small hive beetle

- Avoid over-supering hives, which increases the area that the honeybees must patrol.
- Maintain a clean apiary and honey house to reduce attraction to beetles.
- Avoid tossing burr comb onto the ground around hives, which may attract pests. Adult beetles tend to prefer shady locations.
- Good beekeeping management practices in the bee yard and in the honey house are sufficient to contain hive beetle problems in most cases.
- Making splits from heavily infested hives can cause a serious outbreak.
- The use of grease patties for tracheal mite control, or the addition of protein supplement patties for spring build-up, may attract more the SHB.
- Adult beetles tend to prefer shady locations.
- Wax cappings are an attractive food for beetles. Cracked and rotten hive bodies provide beetles with many places to hide.
- Unnecessary complicated hive systems might also offer an ideal habitat for SHB in the honeybee colonies.

Fact No 5.

THE ASIAN HORNET IS HERE AND ITS TERRITORY IS EXPANDING!

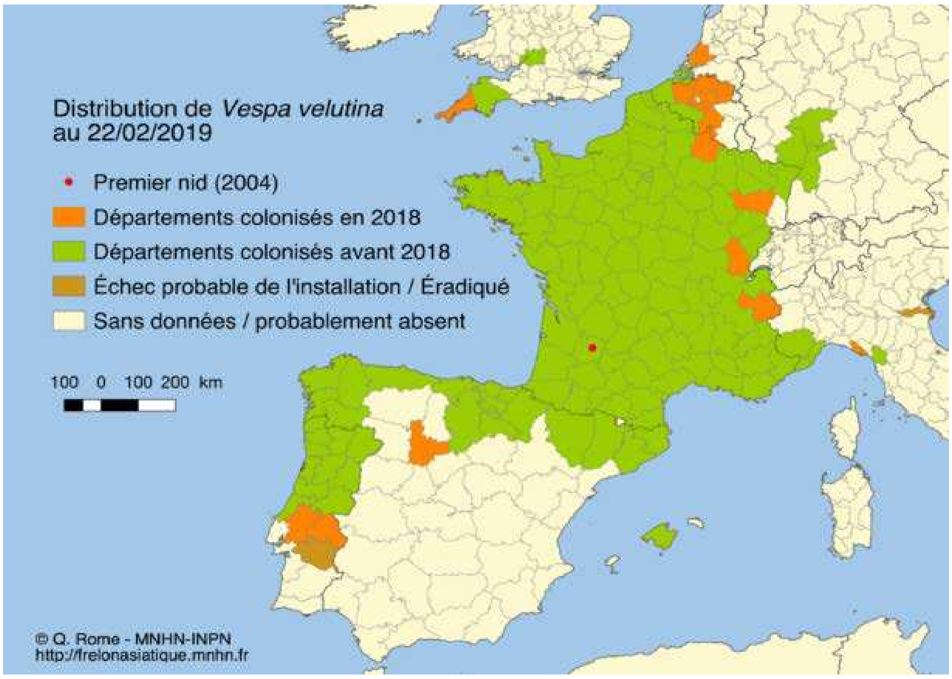

Figure 2 Map of distribution of the Asian hornet (*Vespa velutina*) in Europe, date 22/02/2019: In green, areas colonised before 2018. In orange, those colonised during 2018

Source http://frelonasiatique.mnhn.fr/

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Asian hornet: Management of apiaries

--- Maintain strong colonies and the viability of the colonies with focussed and regular breeding programmes. Here, the importance of good-quality queens arises. It is important to ensure the balance of the population/reserves, so that there is no longer a stress factor, as well as ensuring an adequate relation space and volume of the hive/population.
--- Nest destruction (mechanically or chemically in using insecticides or biocide gas like sulphur dioxide injected in the nest). Hornets can be trapped using food baits (carbohydrates or proteins). Those traps can be used for monitoring or for reducing the predation pressure (mass trapping or traps baited with insecticides).
--- After chemical destruction (if any) the nests should be removed.
--- Traps decrease predatory pressure in the bee's apiary and 'defensive' behaviour. The placement of traps should be the target of adapted scheduling in each country, depending on the phenological stages of the wasp, bees and other pollinating insects. They should be as selective as possible and should be monitored.

Alternative control aspects

-- Some colonies tend to adopt strategies to fight against *Vespa velutina*. A behaviour of adaptation? For example, they form a kind of mat of honeybees covering the entrance board in order to disturb the hornet from knowing from which point the forager would fly. This behaviour is known as "honeybee carpet".
--- Other honeybees adopt the "shimmering" behaviour: they are moving their abdomens thus creating specific patterns said to frighten the hornet.
--- Still others do the "heat balling": to trap the hornet in order to heat up its body temperature up to lethal limit.

Emergency situations

The honeybees are in need!

A honeybee health emergency occurs when a beekeeper is confronted with direct events related to the health of their bees that need urgent intervention, otherwise risking massive losses of their colonies and/or endangering neighbouring ones. In such a situation the beekeeper needs urgent advice from bee health experts. Coping with an emergency should follow the following steps:

1. The beekeeper makes a correct, comprehensive and relevant description of the situation and relays it to the expert;
2. The expert attempts to understand the emergency and advises the beekeeper;
3. The beekeeper acts according to the advice of the expert;
4. The expert monitors the situation after the action of the beekeeper and, if needed, advises him on further action.

The most common bee health emergencies are the following:

a. Intoxications
b. AFB
c. *Vespa velutina* or SHB (invasive species entry)

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d. Unidentified severe and generalized situation of poor health of bee colonies whose causes must be discovered

Intoxication incidents

Pesticide toxicity is a complex issue, with new debates emerging regularly. Intoxication incidents occur mainly by the use of synthetic phytosanitary products due to the bees behaviour to collect nectar and pollen from flowers. Exposure to pesticides can impact foraging honeybees, nurses and larvae as well as reproductive individuals. Intoxication incidents have also been documented due to some substances of botanical origin used in organic farming. However, several chemicals used by the beekeepers against varroa can also cause intoxication.

- Symptoms - direct effects and behavioral changes - indirect effects

The usual symptoms of the acute intoxication are death of foragers, reduced thermoregulation, loss of nurses, reduced larvae survival, reduced worker longevity, decreased queen weight and colony survival. However, sublethal effects caused by various pesticides can lead to physiological modifications, changes in individual honeybee behavior, and alterations in cellular physiology consistent with chemically induced stress. Since honeybees can be exposed to multiple chemical agents at once, synergistic or antagonistic interactions among these pesticides could also play a role in bee and colony health. Honeybees are very sensitive to most of the pest control chemicals and the reasons and mechanisms for this sensitivity are mostly unclear. Specifically, for the veterinary medicines used against varroa, tau-fluvalinate, coumaphos, amitraz, thymol, even oxalic acid and formic acid (under some circumstances).
Interestingly, intoxication can occur through residues accumulated in wax, therefore all substances (pesticides, acaricides, miticides) could be blamed for this.

- Remedies, recommendations

It is difficult to identify methods to remedy the intoxication. However, simple management practices can always help, such as the removal of the contaminated food, the reinforcement of the colony with workers and the movement of the colonies away from the problem, when the cause is a phytosanitary product. When the cause is a veterinary product, the problem is caused from inside the colony and it is not easy to be remedied. However, the recovery of an affected colony depends always on the dose as well as on the duration of the effect.

The EFSA approach

Risk Assessment of Bee Pest Entry into the EU

The European Food Safety Authority (EFSA) and its Animal Health and Welfare (AHAW) Panel have published a report on methodologies and recommendations for risk assessment of the exotic pests such as small hive beetle and *Tropilaelaps* mite. Further information can be found in this link: **http://www.efsa.europa.eu/en/press/news/130314**

3. Research needs

Research needs from practice identified by the Focus Group experts

- Implementing Health Status Index (HSI) in order to predict colony losses.
- Pilot testing for varroa control strategies in different countries using local honeybee subspecies and populations.
- Testing good apiculture practices (feeding regimes, hygiene practices) and promoted through experts to beekeepers.
- Need of surveillance projects against invasive species.
- Need to engage epidemiological studies in research projects.
- Need for continuously develop and improve diagnostic and control methods: applied research and extension.
- Identifying the sub-lethal effects of the veterinary medicines used in each country.
- Research of effectiveness of synchronized varroa control treatments (a social approach inside the beekeepers communities for controlling varroa based on a simple synchronization of treatments at the level of the whole neighborhood in a certain locality (like a village).

Directions for further research proposed by the experts

- Holistic approach on the effects of veterinary medicines and the buffer capacity of the colony to recover.
- Use of standardization data and tools (such as HSI) for identifying the fate of the colonies.
- Good beekeeping practices for different beekeeping topics (honeybee health, honey production, hygiene, preventive, etc) need to be further tested in field conditions. Special attention should be given to the testing and development of simple and accurate varroa diagnosis and controls as well as their application into practice in the different European countries.
- Establish the biological and economical thresholds of varroa infestations in several countries, according to the climatic conditions.
- Test and determine the size of the cells in combination with the capped drone brood removal in maintaining colonies without therapy for varroa.
- Studies of the understanding of the role of all the potential environmental pollutants and their synergy with pathogens.

4. Ideas for innovations

The "Bee Ambulance"

A Smart phone application could provide a valuable help in emergency situations.

1. Description by the beekeeper of the situation.

   1.1 The App must provide the beekeeper with basic information on the symptoms specific to several bee diseases. In this way they can provide the most relevant information to the expert in the attempt to identify or confirm the bee health issue that is suspected. In this stage the beekeeper should be able to see a list of symptoms and check the ones that they recognise. According to their response, the App will take them to the required information they have to provide to the expert.

   1.2 Information automatically sent by the App: the GPS location and the phone number of the beekeeper.

1.3 Information sent by the beekeeper via the App:
- taking photos of honeybees, hives, frames, surrounding vegetation, etc;
- recording short videos or at least sounds;
- checking menus provided by the App;
- providing written text.

2. After receiving information from the beekeeper, the expert may have a positive diagnosis or need more information, in which case they can contact the beekeeper via the App. In the end the expert identifies the nature of the emergency and gives proper advice to the beekeeper.
3. The beekeeper performs the actions recommended by the expert.
4. According to the nature of the emergency, the App reminds the expert at the adequate interval of time to contact the beekeeper in order to monitor the development of the situation. If needed, the expert may inform the competent authorities via the same App.

The name of this App can be 'Bee Ambulance', which has the potential of turning into a powerful honeybee health surveillance tool in the future. An example of an existing smartphone App of a somehow similar kind is 'Bee Health', available both for iOS and Android.

Bee Connected

As most beekeepers have a smart phone nowadays and the cost for at least one intelligent monitoring device for GPS location is not high, ALL beekeeper members of an organization could ask for a subsidy to be connected in a global network/platform by just registering their location (e.g. APIMONDIA could manage the platform). In case of an emergency (a disease breakout or a disaster such as a fire, flood or AFB) all surrounding apiaries/beekeepers are immediately notified to move their colonies. The electronic registry of the beekeepers and their apiaries (permanent or temporary) is a must in each country.

Artificial Intelligence and varroa monitoring

Counting on bottom boards is a quite simple method, which can be even faster with an automatic counting device, and it will be very helpful to beekeepers in order to monitor varroa (Dupleix *et al.* 2019).

Bio-monitoring Stations

Permanent monitoring stations as a basic and preventive strategy for epidemiological and environmental studies. Biomonitoring stations can be of great importance in providing permanent information on different parameters of environmental quality (extrinsic factors) and the health of the colonies (intrinsic factors). Over time, we would be able to have data banks of great interest. From the epidemiological point of view, they can prevent the appearance of diseases and pests, know their prevalence, facilitate their control, study their evolution and avoid their extension. Beekeepers, Technicians or Advisers and Researchers (BAR) can participate and collaborate in them.

5. Conclusions

- Honeybees are very sensitive to be affected by several pests and pathogens as well as to the use of chemicals outside and inside the colony. Apart from varroa for which veterinary medicines exist for control, all other pathogens and pests need to be controlled mainly by using a combination of management practices. Therefore, good beekeeping practices are essential to be communicated to beekeepers and mainly to young professionals.

- It is also apparent that although many research projects have been undertaken, a lot of knowledge has not yet been communicated to beekeepers. One of the essential parameters for improving the health of bees is organic beekeeping and to use less medicines in the hive, which still needs to be developed further. The adverse effects of several veterinary medicines needs to be determined with accuracy.

- Monitoring for the health parameters of bees might be a solution for disease prevention. There are several monitoring tools for each disease, but still there is no one simple monitoring tool for all diseases, as well as environmental factors. It is possible that the Health Status Index and data standardization, if established, could be a monitoring tool for predicting the fate of a colony, under specific circumstances.

- Many attempts have been made recently in order to consider the epidemiological cycle when it comes to quantify the disease, to determine the risk factors or to evaluate the methods used to reduce disease occurrence and their efficiency in controlling the disease. In the future, epidemiological approach could and should be broadly used to study and prevent honeybee diseases. Long-term solutions require long-term projects and international cooperation.

- Intensification of breeding efforts towards resistance to varroa might be the solution for the future (**IHBBN, reducing colony losses by breeding locally adapted honeybees: https://ihbbn.org/**).

- Finally, tools need to be developed for dealing with emergency situations.

Further research needs coming from practice, ideas for EIP AGRI operational groups and other proposals for innovation can be found at the final report of the focus group, available at the FG webpage **https://ec.europa.eu/eip/agriculture/en/focus-groups/bee-health-and-sustainable-beekeeping**

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EIP-AGRI Focus Group

Bee health and sustainable beekeeping

MINIPAPER 03: Taking into account the well-being of bees in production: Developing husbandry staying as close as possible to the natural living conditions of bees while being productive.

September 2020

Authors
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Table of Contents

1. Introduction – motivation

The overall objective of this minipaper is to develop a reflection on beekeeping practices that allow a breeding that takes into account the well-being of bees by remaining as close as possible to the natural living conditions of bees while being productive for beekeepers.

This minipaper is needed because of:

- society's growing general demand for ethical consideration of animal welfare in animal production systems and specific attention to the care of bees in the current critical situation for their survival,
- amateur beekeepers who do not depend on their hives for production and income and can therefore adopt extensive beekeeping practices,
- professional beekeepers willing to consider changes in their practices and production in a context where all solutions are good to take to save the lives of bees, threatened from year to year.

The objective of this minipaper is to introduce the well-being of bees into the reflection on beekeeping. To do this, the "bee first" point of view is taken into account here, while trying to meet the needs of the different actors, i.e. without forgetting that beekeeping is based on an interrelation between the beekeeper, the bees and the environment and must meet the production needs of beekeepers, market conditions, ecosystem requirements and the health of bees. A real challenge is therefore to be met here because each actor has different interests to defend. The point of view developed in this minipaper attempts to avoid a polarization on "a truth" - which would oppose good and bad approaches to beekeeping - but is interested in presenting the bases of certain "apicentric" beekeeping approaches (also called "Darwinian beekeeping" or "natural beekeeping") in order to put them at the centre of a reflection still too often conducted on beekeeping practices applicable in the work of beekeepers and recognized for their utility to the well-being of bees.

2. Dissertation

Organic beekeeping follows the general principles of organic production in accordance with European Regulation 834/2007 or 889/200; it requires mandatory certification in beekeeping by an independent body with annual inspection of the colonies. Inspired by Darwin's theory of the evolution of living systems based on natural selection, Darwinian beekeeping is based on the implementation of practices that tend to minimize differences between the conditions of man-managed honeybee colonies and the evolutionary adaptation environment that has shaped the biology of wild honeybee colonies. However, there is no official definition or official practices to follow for Darwinian beekeeping, only private associations (e. g.

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Naturland, **Demeter**, **Nature&Progrès**) and recommended practices. These two approaches are based on the same assumption that conventional beekeeping practices tend to modify the environment of the colony's livestock (in order to increase productivity) to such an extent that these changes make the bees' living conditions unsuitable for their survival (because they are subject to pests, pathogens, lack of floral resources, environmental toxicity, etc.).

Tab.1 below lists the stress factors cited in the literature for their impact on the well-being on bees (the reference articles are listed at the end of the paper) and with which bees are confronted. Tab.1 ranks them according to their scale (see also minipaper 4), whether they are external factors (which depend on other activities less controllable by the beekeepers themselves) or internal factors on which beekeeping management methods can provide opportunities for intervention.

Stress factors	Scales	Problems/Causes	Risks for the well-being of bees	Responsible actors	Possibilities of intervention	Solutions in terms of Darwinian beekeeping practices	Solutions in terms of organic beekeeping practices
External	**Global**	**Climate change**	- Mismatch between honeybee colony development and plant phenology - Global climate and local microclimate changes - Plant phenology change - Drought, floods - Threats by invasive species	Human societies	+		
		Trade globalisation	- Dissemination of non-endemic parasites with which bees have not co-evolved and against which they do not have the means of defence (*Varroa, Vespa*)	Human societies			
	Regional	**Environmental quality and resources/Land use** - Monofloral resources - Intensive industrial agriculture - Electromagnetic radiation	-Reduction in the lifespan of bees -Reduction of plant biodiversity -Change in the distribution and diversity of wild pollinators in natural habitats	Human societies Agricultural systems Companies Farmers Beekeepers	++		-During flowering period, honey plants (grasslands, forests, wastelands, wetlands, green manure or organic crops) must represent more than 50% of food sources within a radius of 3 km
		Physicochemical exposure - High concentration of pesticides with synergistic effects in agriculture, forestry and gardening - Dust and small sized particles (nanoparticles)	- Effects on bee health (mortality, microbiome, neurological activity), lack of natural development means of resistance			- Hives have to be far from pollution sources (heavy industry, chemicals industry, coal-fired power plants)	
Internal	**Regional/ Apiary**	**Diseases and biological agents** - *Varroa* - Effect of microorganisms (fungi, bacteria, virus)		Beekeepers	+++	-Monitor and control *Varroa*. -Remove colonies with high infestation rates to limit the spread of *Varroa* mites	-Organic acid varroacides, mechanical and thermal methods only -Diligent diagnosis of infestation
	Apiary	**Apiary management** - Spacing of the colonies	-Competition for foraging, reproductive problems, transmission of pathogens and parasites.	Beekeepers	+++	-Create small apiaries (depending on the local conditions) (ex: no more than 10 colonies)	-Standards limiting the number of bee colonies in apiary

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Stress factors	Scales	Problems/Causes	Risks for the well-being of bees	Responsible actors	Possibilities of intervention	Solutions in terms of Darwinian beekeeping practices	Solutions in terms of organic beekeeping practices
Internal	**Apiary**	**Beehive construction and location** - Geometry, volume and architecture - Beehive wall thickness - Timber building material	-Limitation of swarming -Energy cost of colony thermoregulation (hive insulation) and stress for bees to keep up with favourable internal hygrothermal climate -Antibacterial action of the chemical properties of the hive building material (limitation of the rate of infestation by the Varroa parasite and micro-organisms)	Beekeepers	+++	-Hive structure (geometry, building material, wall thickness) reproducing the parameters naturally chosen by wild domestic colonies in nature (natural nest). - Choose appropriate hive location (shadow, safe from disturbers and hazards from agriculture) and beehive vertical position -Provide uncontaminated water source -Use movable boards	-From natural material (wood or polystyrene only for nucleis), no chemical wood protection, no varnish, regular disinfection of hive material with heat and steam only -Interior surface of wood: not planed for safehousing beneficial organisms (chelifera), - Beehive shape ensuring that bees can properly manage the internal climate of the hive (good ventilation management)
		Brood and colony management - Drone brood removal - Brood nest disruption	- Natural selection hampering (via drones gene) - Thermoregulation and queen egg laying hampering	Beekeepers	+++		-Keeping up genetic diversity, based on swarm drive -Possibility of having a broodless period linked to swarming
		Colony genetics selection - Queen shipping and trade - Rearing of queens on selected eggs	- Reduction of queen lifetime, disruption of natural choice of patrilines by bees themselves, unadaptation to geographical locations			-Locally adapted genetics -Selections of bee colonies according to vitality traits.	-Preference for *Apis mellifera mellifera* and its ecotypes premises -Obligation to buy organic queens and swarms (max. 10% of non-organic swarms)
		Honey and pollen harvest - Compensating artificial diets	- Reduction of worker bees' quality			Limit the harvest (1 to 2 kg honey per hive)	-Leave honey in sufficient proportion for the winter provisions -Organic honey or sugar only
		Migratory beekeeping - Relocations for honey harvest	-Troubles on colony weight gain evolution, pathogen and parasite transmission			-Avoid relocation of hives only to local and regional migrations	-Any relocation of apiaries requires information with the certifying body -No migration to conventional crops for harvest or hive products downgraded
		Wax management - Wax removal and replacement	- Energetic burden to produce wax, chemical remaining in wax from unknown origin			Avoid using wax from unknown origin	-Frequent removal of old combs (progressive renewal of body waxes over 3 to 5 years) with organic wax -Recycling of virgin wax only -Wax processing with heat only, no solvents

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3. Conclusions/Key messages

Taking the well-being of bees into account in beekeeping practices is not only about choosing the most effective treatment against parasites or infectious diseases. For an organism such as a bee colony to be strong and robust, its natural methods of propagation, habitation, feeding and life management must be respected. But for economic reasons and to make a living from beekeeping, it is inevitable to control some of these elements. Some beekeeping approaches manage to keep the impact of stress to a low level, which is positive for the well-being of bees, but also leads to lower profitability and, consequently, customers willing to pay fair (i.e. higher) prices for bee products. Such "natural beekeeping" practices (whether non-certified or certified like in organic beekeeping) emphasizing the well-being of bees are being integrated within the practices of many "in-between" small-scale and professional beekeepers who tend to keep their colonies as close as possible to their natural living conditions. However, such practices would require, on the one hand, quantitative data on the impact of these practices on production levels in order to convince more beekeepers to apply them on their farms and, on the other hand, traceability on production practices for consumers to make informed choices. Apicultural research is starting to embrace a "natural beekeeping" perspective and more and more results are available on the effects of such practices on the bee's well-being. But there is, in particular, a need to assess quantitatively with scientific studies the impact of each stress factor on the bees well-being in order for beekeepers to make informed practical choices regarding for example the limitation of treatments, winter honey supplies, improvements to the beehive model, etc (see next section). Actually, there is no evidence that such beekeeping practices are able to deliver the expected anticipated positive results by applying particular measures (as given above) on the short run. From the holistic point of view it can be assumed however that in combination with organic agricultural practices (such as abandoning the use of pesticides, enhancement of biodiversity by using farmer seeds), bees and other pollinators will obtain advantages for stress relief, which is crucial for their well-being and survival on the long run.

4. Research needs

In general, further research is needed to **assess quantitatively the impact on the well-being of bees of each human solution or practice** for rearing that differs from the natural way of life of the colony. In addition to this global question, the effects of organic and Darwinian beekeeping compared to conventional practices on the well-being of bees are subjects that question beekeepers and require scientific results to guide practices efficiently towards better bee health.

To return to the list of identified stress factors and the main control solutions implemented (Tab.1), here is a list of practical research questions ranked in order of research priority (the issues raised in each category of stressors are not ranked in order of importance):

Stress factors	What are the quantitative impact on well-being of bees
1. Environmental quality and resources/Land use	• electromagnetic radiation/5G technology • quality of the sources of nectar • flower biodiversity (including using farmer seeds) • pesticides • veterinary products • presence of underground watercourse/water vein
2. Beehive construction and apiary management	• spacing of the colonies • natural wax comb production • beehive components to fight against vespa • beehive structure (materials incl. roof, shape, entrance hole position and size, thickness) and practices around the beehive (orientation, shading) to limit the thermoregulation workload in the actual context of climate change (with heat waves) • beehive location (e.g. underground watercourse, radiation) including the effect of shadow, orientation regarding the sun regarding bee's thermoregulation efforts • inner beehive macrobiote analysis (ex: chelifera scorpion) • effectiveness of hyperthermia • migratory beekeeping (transhumance)
3. Honey and pollen harvest	• artificial and supplementary feeding to balance out the lack of resources or the important harvest
4. Brood and colony management	• using swarming process for reproduction • man-made choice of genetics instead of autochtonuous bee species related to pest tolerance

5. Ideas for innovations

Innovations should be directed towards:

- Facilitating the acquisition of data of quantitative measurements related to bee health and implement them in practical tools to be integrated in the practices of beekeepers in order to assist them with a sort of decision-making tools (see Minipaper 7). Some examples of useful data to be recorded are: varroa load, biotic factors influencing the health status (see health status index), abiotic factors (temperature, humidity) influencing the thermoregulation workload, etc.
  In addition to data collection, such innovations should provide:
  -interpretation tools for beekeepers because otherwise, these data remain gadget information that is of little practical use (e.g. temperature and humidity data should be interpreted according to the condition of the colonies, the thermoregulatory workload; the number of varroas should be interpreted according to the level of infestation, etc.).
  -advise for beekeepers on how to implement their choices and practices in the more adaptive way to promote the well-being of bees.

- Developing biotechnological methods, including biocontrol methods (through the use of insects, mites, weeds and plant diseases for predation, parasitism or other natural mechanisms) that are not yet developed in beekeeping as is already the case in other agricultural sectors (orchards, wines, etc.) and that are an important element of integrated pest management programmes (See Minipaper 2).
  In beekeeping, biocontrol could work to develop interactions based on natural interactions observed between bees and microorganisms or insects' parasites of varroa (such as chelifera scorpion) by playing on the inner environment of the hive to be attractive to such hosts.

Further research needs coming from practice, ideas for EIP AGRI operational groups and other proposals for innovation can be found at the final report of the focus group, available at the FG webpage
https://ec.europa.eu/eip/agriculture/en/focus-groups/bee-health-and-sustainable-beekeeping

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Example of traditional sedentary beekeeping (in hollow chestnut tree) practices
https://freethebees.ch/en/
https://www.mellifera.de/blog/freibeuter/renaissance-der-waldbienenhaltung.html

Published scientific papers available related to "natural beekeeping"
https://www.naturalbeekeepingtrust.org/the-science-p2?list=1
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EIP-AGRI Focus Group
Bee health and sustainable beekeeping

MINIPAPER 04: Beekeeping Advising Unit. Information and training for beekeepers.
January 2020

Authors
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funded by European Commission

Table of contents

1. Introduction – Motivation

Beekeeping is enjoying something of a renaissance in most parts of Europe including both the professional and hobbyist sector. In some countries or regions, governments pay grants or offer financial support for motivating young people with less than one-year experience to become professional beekeepers and a few courses for several weeks. Beginner beekeepers, professional, or amateur, often struggle and lose their colonies in their first years of beekeeping. The high level of losses in bee colonies is a main issue for the economy of the whole beekeeping sector. Most member states implement a triennial national programme for the production and marketing of apiculture (total amount of € 36 million for every apiculture year over the 2017-2018 period). It is incumbent therefore that a good level of beekeepers' training/skills is also a condition for not squandering this public money.

Beekeepers have many problems to tackle and sometimes they do not find the right answer. Beekeepers need to get relevant and immediate advice from trusted official bodies as to how to manage their colonies in extreme external - environmental conditions. Information through social networks is not always true or secure. Applied research should ensure and offer practical answers to beekeepers through relevant extension service.

The objective of this minipaper is to present how to organize supporting services for beekeepers in order to improve colonies survival and colonies productivity:

- how to help to establish connection between the research, extension and beekeeping sectors
- how to respond to the needs for training and advice that beekeepers have.

This minipaper will look at 3 strands which could help the situation.

1. Formalise Beekeeping Advising and Training Centres or Units.
2. Developing a pan Europe standard of beekeeping qualification.
3. Knowledge exchange opportunities.

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2. Dissertation

Beekeeping as in intensive agriculture practice depends on several internal and external influences, including honeybee colonies vitality, health, disease resistance potential and nectar foraging sources in the environment or artificial nutrition, microclimatic conditions, colony density. Honeybee colonies selection, breeding and queen rearing require highly professional approach to the sector. General beekeeping practices require permanent monitoring for colonies hygiene and disease diagnosis and control. In this regard the plethora of educational and training programmes needs to be available for small scale and professional beekeepers in order to keep productive honeybee colonies.

INFLUENCES	SCALE	CAUSES/ PROBLEMS	RESPONSIBLE ACTORS	POSSIBILITIES OF INTERVENTION/ SOLUTIONS
EXTERNAL	Global	(1) climate change and variability	Human being	+
	Regional	(2) change in land use and fragmentation of the landscape; (3) chemical exposure; (4) diseases and biological agents. (*)	Society Agricultural systems Companies Farmers Beekeepers	++
INTERNAL	Apiary	(4) diseases and biological agents. (*) (5) beekeeping practices;	Beekeeper	+++

(*) Cause 4 can also be located at apiary or regional level when there is contagion of diseases and biological agents between apiaries.

Educating beekeepers is a challenge and although many training opportunities exist, it can be difficult to bring trainer and pupil together. Hence, for a lack of basic education the renaissance is thwarted. In some institutions there are specialists for beekeeping without appropriate experiences and qualifications and their service does not reflect real needs from the sector. Therefore, advisors also need to get proper education and practice and be trained. This is also the reason why research sometimes does not respond properly to requirements from the field, or research results are not transferred into practice. Commercial and professional beekeepers also work in isolation to a large degree. They pursue their own practices handed down by elder generation or developed themselves. Most (very few) have any formal beekeeping qualifications. Given the intense nature of the active season most have minimal contact with fellow beekeeping "colleagues" so are unaware of current situation as regards recent disease outbreaks or other current matters let alone a crisis.

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Beekeepers are active in a variety of environmental conditions: rural, urban and extensive agricultural. Therefore, different beekeeping technologies and practical solutions need to be pursued in order to keep healthy and productive honeybee colonies. In 2019 many beekeepers were faced with weak colonies because of severe weather conditions during spring and many colonies died. Consequently, in some areas honey production was below normal national production, self-sufficiency on honey production was drastically reduced. Due to extreme weather conditions (long periods of rain, prolonged dry periods, dearth of nectar) beekeepers need to be advised properly, how to overcome that external phenomenon in order to preserve productive colonies.

Advisers are necessary because of important differences between researchers and beekeepers. Advisers can work as link or translation between them.

DIFFERENCES	RESEARCHERS	BEEKEEPERS
They hope	Generate knowledge	Solutions and practical applications to increase production
They answer questions	Why	How, when and where
They want	Impact journals	Produce to market. Sustainable activity
They depend on	Funding, public or private	Social and economic organization and commercial structure of sector
Their time scale	years	Few weeks/months of a season

Formalise Beekeeping Advising and Training Centre/Unit

One of the supporting services to the farmers could be establishing a functional and operational Beekeeping Advising Unit that responds to the reality and needs of the sector, with the following objectives:

- Form and coordinate the Technical Assistance of Beekeepers.
- Create and update a Beekeeping Documentation Center.
- Plan and prioritize strategic R + D plans, according to the reality and necessity of the producers.
- Serve as an advisory body to the Administration.

Training of the beekeepers must be progressive and have at least three levels:

- Beginner
- Intermediate
- Advanced

Examples throughout Europe

The beekeeping centers or units receive numerous requests from researchers from universities, society in general, consumers or, social media, not only from beekeepers. Some organization and coordination is necessary to give a correct and reliable answer to these questions. Some countries as Italy, Slovenia, United Kingdom, France, Germany, Belgium, have National or Regional Centers.

In Italy, national centres of excellence for beekeeper's education and training are performed through national/regional Universities and/or Governmental institutions. A wide variety of beekeeping topics and practices are taught; including honeybee colonies management, good beekeeping practice, hygiene in beekeeping, disease prevention, honeybee queen rearing, sustainable disease control and breeding. Certificates are issued for specific professional topic.

The National Bee Unit (NBU) in UK delivers the Bee Health Programmes on behalf of Department for Environment Food and Rural Affairs (Defra) and Welsh Government (WG) in England & Wales. It has been involved in the management and control of bee pests and diseases, along with training and dissemination of information to beekeepers for over 60 years. **www.nationalbeeunit.com/index.cfm?sectionid=43**

CREA - API is the Italian reference body for beekeeping. The institution was born as a result of the legislative decree 454/99 and was officially founded in 2004, when the Specialized Section for Bachiculture of the ex-Experimental Institute for Agricultural Zoology was established at the National Beekeeping Institute (INA). (Isza). The institution is engaged on two main fronts: scientific research and services. **http://api.entecra.it/index.php.**

At EU level there exist the *Commission Implementing Decision (EU) 2019/974 of 12 June 2019 approving the national programmes to improve the production and marketing of apiculture products submitted by the Member States under Regulation (EU) No 1308/2013 of the European Parliament and of the Council (notified under document C(2019) 4177)*. **https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32019D0974**

The programme starts on August 1, 2019 and ends on July 31, 2022. These programmes are designed by the member states. The measures include, for example, training for beekeepers, support to start a beekeeping business, fight against parasites that damage hives and research or measures to improve the quality of honey.

Developing a pan Europe standard of beekeeping qualification

Currently most countries have some form of beekeeping qualification. Under the proposals of this minipaper these countries programmes will be evaluated and recognized by their excellence in specific professional topics. Qualifications are considered necessary for development of contemporary beekeeping practices, to improve beekeeping techniques and knowledge exchange and extension to new beekeepers.

This minipaper proposes an accreditation facility from EU. Under these proposals at the EU level a new consortium of national experts for beekeeping excellence would be established. Their objectives are:

- to assess what is currently available in terms of beekeeping qualifications throughout Member States and rank them accordingly with a scale;
- to establish and/or standardise nonformal beekeepers educational programmes;
- to propose and standardise certifications issued at the national levels;

to recognize non-governmental and independent institutions to conduct educational programmes which will have standardised levels.

- Recognised seal or stamp/logo used to give recognition and accreditation across Europe. Advantage to:
    - beekeepers as it would standardise beekeepers qualification levels.;
    - potential for landlords in future be able to check proven skills before allowing beekeepers access to their land;

- assurance for customers particularly large customers such as supermarkets assured that honey was produced by beekeepers knowledgeable and operating to the recognised standard;
- given the sometimes troublesome nature bees can cause to the public by inexperienced beekeepers a recognised beekeeping qualification should go a long way to harmonising relations;
- it would also provide assurance and qualification criteria for governments allocating public money to "trained" beekeepers (for example what criteria to apply to funds);
- to the whole beekeeping sector, it could allow a better collaboration between all stakeholders involved in beekeeping in its various forms.

Knowledge Exchange Opportunities

Existing best practices, tools, projects

Professional beekeeping organizations together with University/Gov. institutions normally organize different educational and/or extension programs for beekeepers. They organize workshops, training events, demonstrations, field trips, etc. During non-formal education programmes, they also produce variety of educations materials: books, leaflets, DVD presentations, 3D presentations, virtual demonstrations, etc. Activities are also organized not only for beekeepers, but also for general public, students in high and/or elementary schools, kindergartens, etc.

A crisis situation in Scotland surrounding heavy levels of European foulbrood in 2009 forced a radical look at developing a strategy to deal with the situation. Initially it was felt that the beekeeping sector worked well amongst itself being kept well abreast of relevant situations. However, it quickly became apparent that this was not the case. When meetings were called to outline developing plans, it was apparent that the beekeepers were initially reticent and suspicious but as time went on the barriers broke down and a true partnership was formed.
Once the disease came under control the strategy evolved to further improve the situation. Rather than simply have a meeting some became workshops dealing with bee health issues and then an accreditation developed where the beekeepers were tested against identification of disease and treatment. Success even resulted in a certificate something some had never received.

The plan has to be kept fresh and the latest is a Knowledge Transfer event where world class speakers deliver practical beekeeping knowledge to the audience. See also Annex.

In some countries, they also have apiculture museums for demonstrations of beekeeping as cultural heritage with specific themes. For example, in 2019 the Apicultural Museum in Radovljica, SLO, organized an exhibition on queen breeding and maintaining isolated mating station in high mountain areas.

There is a growing interest in bee training and advising in Europe. Research does not always translate into practical applications. Companies have served as advisors, but this advice can be unreliable. Some of the large honey producing countries have their training and technical advice programs.

Countries like Argentina with high levels of professional beekeeping have interesting projects where research, advising and rural development are well integrated. **https://inta.gob.ar/proyectos/apicultura**

In some beekeeping regions with apicultural demonstration units they have managed to advance the productive cycle of *Apis mellifera* by two months. You can read the next manual: BEEKEEPING MANUAL for SUBTROPICAL ENVIRONMENTS which was prepared with the collaboration of the researcher, teachers and technicians that make up the School Network Team. **https://inta.gob.ar/sites/default/files/inta-manual_apicultura_reglon_47-2.pdf**

State-of-the-art of research/practice

Although the mission of universities is usually research and training of students, some universities have assumed the role of training beekeepers and extension.

Bee Lab in Minnesota University assumes the training of beekeepers through different training programs and activities: Beekeeping Classes, Beekeeping Manuals, Beekeeper Hands-on training, as **Mentoring Apiary** Classes and **Home Apiary Help**. **https://www.beelab.umn.edu/bee-squad/education/**

Also the Beekeeping Extension and Research Laboratory of the University of Florida. **https://entnemdept.ifas.ufl.edu/honey-bee/extension/**

In Europe, CARI and RådNu can be two good examples, working both as research and advising and training units. CARI (**http://www.cari.be/t/cari/**) is a non-profit Belgian association created in June 1983 by a team of researchers from the Ecology Laboratory of the Catholic University of Louvain (UCL). CARI's missions:

1. Technical assistance to beekeepers: information - continuous training - valorization of the quality of the products of the hive - services (network of scales, analysis of honey, health follow-up, follow-up of honey, etc.)
2. Applied research related to the problems encountered in the field
3. Sector monitoring
4. Representation of beekeepers at regional, federal, European and international level
5. Public information on bees and beekeeping

The Swedish RådNu, National Competence Centre for Advisory Services (**http://bee-extension.org/about-us/**) is a regional anchored node in Västra Götaland, with the hub of SLU (Sveriges Lantsbruks Universitet) in Skara. RådNu works nationally and has an international perspective. A common competence platform helps to strengthen the entire knowledge system; agricultural and rural entrepreneurs, advisors, authorities and researchers. RådNu builds a national collaborative platform and develops a new work model for how the research needs of rural areas can be captured, refined and converted into concrete research and development projects if necessary. Their goal is to become a natural partner for research and competence development in the counseling of rural and agricultural sectors. All aspects of the agricultural knowledge system need to increase their skills to achieve increased sustainability and a competitive agricultural and food sector. Effective counseling is crucial. RådNu created Bee-Extension.org as part of the Smartbees project WP 5.

Regional Centers need to be supported in terms of required profession, better equipment and problem-solving project basis. Regional centers in connection with universities can guarantee a high level of knowledge, critical mass for teaching and extension activities that ensure self-sustaining and creates further growth. These types of centers can be a source of new technologies development, immediate transfer into practice, ensure knowledge and quality of teachers for beekeepers. Beekeeping tutors are an essential component in the beekeeping sector.

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One exercise would be to collect information on the economic aid or grants to beekeeping established in each country of the European Union in recent years and analyze its effect on bee health and beekeeping sustainability, especially if they were not used to advise and train.

3. Conclusions

From discussions through this Focus Group, common areas have been highlighted which would benefit from reform. For this minipaper these needs have been identified as:

1. Formalise beekeeping advising and training centres.

2. Developing a pan European standard of beekeeping education.

3. Knowledge exchange opportunities.

There is a range of standards of education available or not available to beekeepers throughout Europe. In addition, the accelerated use of social media has introduced a major risk to quality of training and mentoring. In general, social media promotes the author to expert regardless of their ability and yet those reading the material assume them to be experts.

Where the knowledge exchange opportunities exist, they are well received and achieve excellent outcomes. The willingness of those taking part, being willing to share their knowledge and experience and work practices is a major part of the secret of their success.

5. Research needs and ideas for innovations

There is a need for the standard educational material for different beekeeping professional activities and solutions. Protocols are needed for theoretical, practical courses for student, public and other interested public groups.

Further research needs coming from practice, ideas for EIP AGRI operational groups and other proposals for innovation can be found at the final report of the focus group, available at the FG webpage **https://ec.europa.eu/eip/agriculture/en/focus-groups/bee-health-and-sustainable-beekeeping**

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2. **https://www.juntadeandalucia.es/agriculturaypesca/ifapa/cursosyjornadas/es?f[0]=programa:107&f[1]=estado:P**

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Annex

A GOOD ENCOURAGING NEWS STORY FROM SCOTLAND

In 2009 Scotland faced a serious situation amongst the bee population not to mention its beekeepers. A major infestation of European foulbrood (EFB) was uncovered.

Having no surveillance or inspection programme in place the Scottish Government (SG) was relying in beekeeper notification as required in the legislation. There had only been 30 cases of American foulbrood (AFB) reported in the previous 25 years and 9 cases of EFB recorded in the previous 26 years. Overall there were 310 EFB cases and 136 AFB recorded in 2009 with many more EFB cases being dealt with by the beekeepers themselves once they knew what the disease was.

A task force was mustered bringing together up to 15 Bee Inspectors to deal with the crisis. Given the low incidence in the preceding years only one of the Inspectors had experience of dealing with EFB in the apiary. It was therefore a steep learning curve for everyone. To top it off the manager of the laboratories where sample testing took place had just left on maternity leave.

Whilst the Inspectors built up a strong team and networking with the industry, others came together under the Secretariat of the SG. Scientists, policymakers, beekeepers, statisticians and everyone we could think of was drawn into a partnership group to share their ideas of not only the problem being faced but also possible solutions. This group came together from scratch and developed many practical ideas to deal with the crisis.

Whilst the Inspectors were still assessing the scale of the infection the summer was drawing to a close. To buy time the SG arranged prescription of antibiotic and as the Inspectors couldn't get around all the affected producers a special licensing was approved allowing the affected beekeepers to undergo training and to be authorized to administer the OTC themselves albeit under SG supervision. This was to hopefully keep as many of the infected colonies alive over winter and allow the inspection program to resume the following spring. A rigorous programme of sampling the colonies the following year was also upgraded to ensure no residual antibiotic remained within the colonies.

Those observing and gauging the problem reported that the infection, given its scale, must have been present for several years. With the migratory nature of the beekeepers from spring sites to summer sites and eventually to the heather sites in the hills and then back to wintering sites having gone on for many years the practice was allowed to continue provided the statutory reporting continued.

The following year a programme of inspections continued but a training programme was also instigated. The beekeepers were trained to recognize the notifiable diseases and the protocol to follow if they suspected disease. This protocol was in essence to report the find to SG and either cull or Shook Swarm the affected colony. If Shook Swarming, the colony was moved under license to a quarantine site. Once Shook Swarmed the colony stayed in quarantine for a minimum period of 6 weeks. No colonies were allowed out of the quarantine site until certified by an Inspector to be clear of clinical signs of EFB.

The process has taken a few years, but we are now in a transformed position with all stakeholders still working well under the partnership and the infection density not eliminated but significantly reduced. Plans are still afoot to hopefully reduce the infection rates even lower.

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Hopefully this report will assist others facing similarly insurmountable problems and encourage you that all is not lost. With goodwill on all sides and a fresh thinking approach, real achievements can be made allowing you to punch well above your combined weights.

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EIP-AGRI Focus Group
Bee health and sustainable beekeeping

MINIPAPER 05: Monitoring

September 2020

Authors

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Table of contents

1. Introduction

Honeybees are highly influenced by environmental conditions and quality, beekeepers' management practices, socio-economic conditions and policies adopted for cropping and land use. The beekeeping sector lacks suitable tools for risk assessment and decision making which can be used by relevant stakeholders (e.g. beekeepers, risk assessors, policymakers). To support management decisions for the beekeeping sector multiple types of variables must be monitored.

The aim of this minipaper is to summarise which variables can be collected
(i) by beekeepers or other personnel manually,
(ii) by remote sensors automatically, and
(iii) using GIS or existing/proposed networking systems.

We described the relevance of monitoring each variable in terms of bee health and beekeeping success. The main goal is to propose a path towards the identification and validation of best management practices, to subsequently integrate into a novel system supporting right decisions of beekeepers and relevant stakeholders.

2. Dissertation

Emerging and existing apiary management strategies called **precision beekeeping** (PB) are based on the monitoring of individual bee colonies to minimize resource consumption and maximize the productivity of bees. Tools used in PB are called also "smart hive" - a hive that can tell you about itself (usually hive weight, temperature, humidity, sounds, images). Smart hive is a progressive step towards building an "intelligent hive". Rather than just transmitting data about the current state of the hive, the intelligent hive would be able to tell you what the hive needs to perform better than it does today. It would take all of the data collected from a smart hive, combine it with knowledge of best management practices and data from thousands of other hives, risk maps using GIS and use machine learning and artificial intelligence techniques to optimize colony health, production, and pollination performance.

In some EU countries proper systems of hive registration exist, in some not. Unreliable data are collected by officials not specialized in beekeeping. Beekeepers are not motivated to up-date registers. Most beekeepers have very poor records of their beekeeping operations. Even for those who kept records,

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the data would still need to be digitised and shared. Probably only "automated" systems, collecting data from many hives, will work properly.

The data collection process in PB can be classified into two groups:

- apiary-level parameters (meteorological parameters and video observation);
- colony-level parameters (weight, temperature, humidity, gas content, sound, vibration, the number of incoming/outgoing bees, the number of bees in the hive entrance area etc.).

The causes that influence honeybee colony health are multiple and may be subdivided into 5 categories, all susceptible to be monitored:

- climate change and variability;
- change in land use and fragmentation of the landscape;
- chemical exposure;
- diseases and biological agents.
- beekeeping practices;

The variables that influence the health of bee colonies can be analysed from the general to the particular, for example moving from a global scale, to a regional or local scale, and finally apiary scale. In this transit, there are different actors and responsibility, as well as different possibilities of intervention for their solutions, summarised in Table 1.

Table 1: Factors that influence honeybee colony health, the main actors, and possibility of mitigation through intervention, rated from low (+) to high (+++)

SCALE	FACTORS	MAIN ACTORS	INTERVENTION
Global	(1) climate change and variability	Human being	+
Regional	(2) change in land use and fragmentation of the landscape (3) chemical exposure (mainly agricultural) (4) diseases and biological agents (across apiaries)	Society Land owners Companies Farmers, Industry	++
Apiary	(3) chemical exposure (beekeeping treatments) (4) diseases and biological agents (within an apiary) (5) beekeeping practices	Beekeepers	+++

Implementation of PB can be split into three phases: data collection, data analysis and application. EFSA (2016) has proposed a hierarchical framework for the definition of the health status of a honey bee colony, including "colony attributes", "external drivers", and "colony outputs", which could be monitored by PB (EFSA, 2016).

Colony attributes include:

- Demography of the colony (DEM), including brood extension, adult number and bee mortality.
- Behaviour and physiology (BEH), including foraging disruption, atypical behaviour.
- Queen (QUE) presence and performance.
- In-hive products (IHP): amount of honey and beebread in colony.
- Contamination (CON): chemical residues in honey, beebread and beeswax.

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- Disease, infection and infestation (DII), including presence and abundance of parasites, bacteria and viruses.

Each attribute is composed by a set of indicators (i.e. variables) that could be directly measured.

External drivers include:

- Resource Providing Unit (RPU): land cover, land use, nectar and pollen availability and quality characterising landscape within 3 km around the hive.
- Environmental drivers (ENV): factors related to weather and climate influencing bee colony status (precipitation, humidity, temperature), chemical contamination including pesticides, electromagnetic pollution.
- Beekeeping management practices (BMP) include variables like hobby or professional, conventional or organic etc.

Colony outputs include:

- Pollination services provided by the colony.
- Products harvested by the beekeeper, the hive rental service and the live honeybees extracted from the colony.

According to the declaration of cooperation on "A smart and sustainable digital future for European agriculture and rural areas" signed by representatives of 25 European countries in April 2019, technologies such as artificial intelligence, robotics, block chain, high performance computing, the Internet of Things and 5G have the potential to make farming more efficient, productive and sustainable.

Relevant EU projects (web pages presented in the Annex):

H2020 (big projects – more than 7 million € each):

- POSHBEE: Pan-European assessment, monitoring and mitigation of stressors on the health of bees (2018-2023). http://poshbee.eu
- B-GOOD: Giving Beekeeping Guidance by computational assisted decision-making (2019-2023). https://b-good-project.eu/
- HIVEOPOLIS: Futuristic beehives for a smart metropolis (2019-2024). https://www.hiveopolis.eu/

H2020 (projects with budget between 1 - 2 million € each):

- BPRACTICES New indicators and on-farm practices to improve honeybee health in the *Aethina tumida* in Europe (2017-2020). http://www.izslt.it/bpractices/
- SAMS: International Partnership on Innovation in Smart Apiculture Management Services (2018-2020). https://sams-project.eu/
- IOBEE: Beehive health IoT application to fight Honey Bee Colony Mortality (2017-2020) http://io-bee.eu

H2020 (small projects with budget ca. 0,05 million € each acting in year 2019):

- WARMHIVE: Smart thermotherapy solution for *Varroa* mite treatment. https://cordis.europa.eu/project/id/836015
- BEEHOME: Automated beekeeping platform powered by AI that increases honey production by 50%, reduces labour use by 90%, and reduces colony loss by 80%. https://cordis.europa.eu/project/id/854754
- FOG: Frequency protector generator for honeybees. https://cordis.europa.eu/project/id/836486

Several Digital Innovation Hubs and EIP Operational Groups (**https://ec.europa.eu/eip/agriculture/en/eip-agri-projects**) exist as well, for example the ones on the list below. Main past project was **FP7** SWARMONITOR: Development of a tool for effective diagnostic monitoring of honeybee colonies.
EIP-AGRI Operational Groups (funded under the Rural Development programmes, measure 16)

- BeeScanning 2.0 - monitoring a biological system
- Remote beehive monitoring, a new opportunity for nomadic beekeeping (NOMADI-App)
- PICA: Innovative Platform for beekeeping

Other on-going initiatives:

- COLOSS (Prevention of honeybee COlony LOSSes) honeybee research association. **https://coloss.org/core-projects/colony-losses-monitoring/**
- Apimondia working group "Standardization of data on bees and beekeeping". **https://www.apimondia.com/en/activities/working-groups**
- BeeXML project: Exchanging Data about Bees and Beekeeping. **http://beexml.org/**

Global list of scientific/educational projects, open source and commercial projects on beehive monitoring is listed at the **www.hiveeyes.org** and **www.colonymonitoring.com** web pages.

Existing tools:

PB Monitoring approaches that are already widely used and relatively cheap:

- **Weight monitoring** of the colony can be used to identify (i) occurrence of nectar flow during the foraging season; (ii) consumption of food during non-foraging periods; (iii) the occurrence of swarming events through a decrease in the hive weight; (iv) estimation of the number of foragers. Measuring the weight of the colony can be done by automated or manual scales.
- Bee **colony temperature** measurements using various methods including: (i) Manual temperature measurements by different loggers; (ii) Wired sensor networks; (iii) Wireless sensor networks; (iv) Infrared imaging. Temperature data can help to identify colony states as (i) death; (ii) swarming; (iii) brood rearing; (iv) broodless state.

Tools available but not widely applied:

Audio signals and audio processing techniques to estimate bee behaviour. Many devices and methods have been developed for sound analysis but not widely applied because of the complexity of sound interpretation. Systems for **gas concentration** (carbon dioxide) and **forager traffic** (counters, RFID) are also tested.

Companies:

Current sensing and other components available as well as list of companies offering electronic colony monitoring systems are summarised at the hiveeyes.org and colonymonitoring.com pages. Examples of companies operating in Europe: **BeeLabel**, **OpenHiveScale** or **Optibee** from France, **ApisProtect** (Ireland), **APiSTech** (Portugal), **Arnia** (England), **Beeing** and **Melixa** from Italy, **Pollenity** (Bulgaria), **Save-bees** (Greece), **XLogBee** (Croatia), **Wolf Hive Scale** (Germany) **BeeKing** (Latvia) or **Beescanning** (Sweden).

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Some vendors of colony monitoring system design their products specifically for commercial beekeepers, f. e. **ApisProtect** and **Beehero**. Links to the web presentations of named companies/consortiums are listed at the References.

Examples of state-of-the-art of research/practice

External drivers:

- Resources (RPU): **BeeHero** project - tracking and optimizing pollination and **BeeScape** project -maps the landscape around the apiary.
- Environment (ENV): effects of temperature and precipitation on honeybee winter mortality - Switanek *et al.*, 2017.
- Beekeeping management practices (BMP): BMP implemented in Europe and its influence on honeybee colony health – Sperandio *et al.*, 2019.

Colony variables:

- Queen (QUE): SMARTBEE project, future sensors based on vibrations or brood temperature signals from hive – Cejrowski *et al.*, 2018.
- In-hive products (IHP): weight monitoring by electronic scales or using ripe honey detectors (colonymonitoring.com).
- Contamination (CON): environmental monitoring of bee food and bee products, e.g. Tosi *et al.* 2018; Manning *et al.*, 2018; Sánchez-Bayo *et al.*, 2019; POSHBEE project and several citizen science initiative projects.
- Disease-infection-infestation (DII): **COLOSS** Monitoring Group – winter mortality via standardised questionnaires, several disease-related risk factors evaluations, e.g. Morawetz *et al.*, 2019.
- Demography (DEM): **COLOSS** Monitoring Group – winter mortality via standardised questionnaires; model of honeybee colony population – Khoury *et al.*, 2011.
- Behaviour (BEH): e.g. Siviter *et al.*, 2018, landing board activity sensors (colonymonitoring.com).

Examples of national monitoring projects covering both external and internal drivers:
Italy: ApeNet - monitoring project (2009-2010) - Porrini *et al.*, 2016.
Italy: BeeNet - monitoring project (2011-2014).
Spain: Environmental evaluation of pesticides by means of biomonitoring stations with *Apis mellifera* colonies. Extramadura, 2007.
Spain: Development and starting of network of biomonitoring stations with *Apis mellifera* colonies to evaluate urban pollution at real time in Cordoba City. 2008-2011.
Germany: (**DeBiMo**) German bee monitoring project. – Genersch *et al.*, 2010.

3. Research needs

The development of **decision support systems** is suggested to be a mid-term task. In the long term, specific DSS-controlled electronic devices should be developed to enable new functionalities for PB. This will be a "shift" from "smart" to "intelligent" hive. "Intelligent" hive would be able to do:

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- Monitor the hive for signs of trouble and send alerts before trouble hits.
- Monitor regional and national trends in real time and adjust for how those trends might affect your bees.
- Suggest ways to improve your production, pollination, or bee health.
- Prescribe the best management practices customized for a particular hive in a particular place at a particular time.
- Pre-emptively suggest treatments before trouble manifests.
- Identify the treatments most likely to succeed given your hive characteristics, current environmental conditions, and history.

Data from many beekeepers are necessary, need to be transcribed digitally, shared, and converted to a standard format that could be combined with data from other beekeepers in other micro-climates with different genetic stock and conditions. Integration of Data Collection, Machine Learning, and Best Management Practices into an Intelligent Apiary Management System is needed. Researchers will be willing to share datasets from previous projects if there will be motivation (f. e. indexed scientific journal specialised in datasets publishing). Data from automated systems should be supplemented by surveys, questionnaires and data collection at the field level, which opens the doors for CS (citizen science) projects. Projects incorporating external drivers (nectar/pollen sources, weather/climate conditions and beekeeping management practices) with colony variables could bring interesting outputs.

4. Ideas for innovations

There are opportunities for companies to differentiate themselves by addressing different segments of the beekeeping market, e.g. backyard beekeepers, small honey producers, large honey producers, pollination providers, packaged bee producers, queen breeders, and researchers will each have a need for monitoring devices adapted to their specific circumstances.

From practical point of view, a colony monitoring device should tell beekeepers:

- What is the approximate level of *Varroa* in the colony?
- Is the colony queenright? Is the queen there? Is she healthy? Is she the mated queen I introduced?

Other parameters are for now in the eyes of beekeepers less important. However, sensors allowing precise feeding, time for honey harvest, presence and levels of *Varroa*, interpreting bees pheromone communications, detecting nectar scents and other hive odours and predicting swarm mood needs to be designed or improved.

Another inspiration from practice includes:

- Systems of precise apiary feeding/predicting of nectar flow.
- Definition of optimal hive/livestock density for different regions/landscapes.
- Use a beehives/bee products as biomonitoring networks to inform society about pollution and environmental quality via Citizen Science projects.

Further research needs coming from practice, ideas for EIP AGRI operational groups and other proposals for innovation can be found at the final report of the focus group, available at the FG webpage **https://ec.europa.eu/eip/agriculture/en/focus-groups/bee-health-and-sustainable-beekeeping**

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5. Conclusions

One third of the existing honeybee colonies die each year and beekeepers would gladly pay for monitoring devices that reduce their losses by a significant amount. Modern technologies enable beekeepers to remotely monitor brood health, honey production, cluster size and location, stores in hive, and many colony activities such as swarming and robbing.

Currently the field of hive monitoring devices and systems is wide open. Few entrepreneurs provide colony monitoring devices or systems that are low cost, reliable, and useful. There are some sensors not actually available on the market, or they are not designed for beehives. These sensors would monitor the level of liquid feed, detect when supers were full, measure the quality of honey, detect the presence and levels of *Varroa*, detect bees pheromone communications, detect nectar scents and other hive odours, monitor the level of carbon dioxide, and sense the hive's ventilation processes.

The details of the devices that sense, transmit, analyse, report and store colony health data in a robust, economical and useful manner will continue to evolve as the industry matures and beekeepers come to understand the value of their monitoring systems. Hives and their products can be used for pollution and environmental quality biomonitoring, which can be possibly used for environmental evaluation of CAP measures adopted.

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Project web presentation

BEEXML: Exchanging Data about Bees and Beekeeping **http://beexml.org**

BEEWISE: Autonomous beehive **https://www.beewise.ag**

B-GOOD: Giving Beekeeping Guidance by computational assisted decision-making **https://b-good-project.eu/**

BPRACTICES New indicators and on-farm practices to improve honeybee health in the *Aethina tumida* in Europe **http://www.izslt.it/bpractices/**

HIVEOPOLIS: Futuristic beehives for a smart metropolis **https://www.hiveopolis.eu/**

IOBEE: Fighting Honey-Bee Colony Mortality through IoT **http://io-bee.eu**

POSHBEE: Pan-European assessment, monitoring and mitigation of stressors on the health of bees. **http://poshbee.eu**

SAMS: Smart apiculture management services **https://sams-project.eu**

SWARMONITOR: Development of a tool for effective diagnostic monitoring of honey bee colonies **https://cordis.europa.eu/project/rcn/105847/factsheet/en**

The World Bee Project Global Hive Network **http://worldbeeproject.org**

Remote hive monitoring existing tools

ApisProtect	**https://www.apisprotect.com**
ApiSTech	**https://apistech.eu**
Arnia	**https://www.arnia.co.uk**

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BeeHero	https://www.beehero.io
BeeKing	https://beeking.eu
Beeing	https://beeing.it
BeeLabel	https://www.label-abeille.org
BeeScape	https://beescape.org
BeeScanning	https://beescanning.com
Beewatch	http://beewatch.de
BeeWise	https://www.icko-apiculture.com/beewise.html
Hiveeyes	https://hiveeyes.org
Melixa	http://melixa.eu
OpenHiveScale	http://www.openhivescale.org
Optibee	http://www.optibee.fr
Pollenity	https://pollenity.com
SaveBees	http://www.save-bees.com
Wolf Hive Scale	https://www.wolf-waagen.de
XLog	http://www.xlogbeescale.com

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EIP-AGRI Focus Group

Bee health and sustainable beekeeping

MINIPAPER 06: Developing and enhancing good practices to mitigate major bee health stressors: pesticides and lack of resources

September 2020

Authors

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Table of contents

1. Introduction – Motivation

Bees are essential for the pollination of wild plants and crops, contributing to the EU food production (fruits, vegetables, seeds, etc). However, agricultural practices can impact directly on the bee health, and agroecosystems expose bees to pesticides and nutritional stress (for example, low-quality food resources). Though, farmers are not always aware of the importance of insect pollination in the elaboration of yield and product quality.

It is possible to reduce stress to bees and thus improve bee health by adapting or changing agricultural practices. There are already some initiatives in several EU member states to raise awareness of farmers about honeybees. Some measures are effective or could be improved. Other are not adapted or not adopted by the farmers for several reasons (technical problem, "lock-in"). In some cases, farmers ask the help of beekeepers to improve pollination and partnerships are established by pollination contracts.

By gathering and sharing these experiences, we will be able to identify some good practices for the bee health targeting beekeepers and farmers, that could be promoted at the EU and national level.

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2. Dissertation

Stress from pesticides and lack of food resources

In the following chapter, the state of the art and the most relevant and recent discoveries on the topic are highlighted below.

Pesticides

Pesticides can cause lethal and sublethal effects on bees, for example making them less productive and weaker in terms of nourishment and immunity. Pesticides also interact with other bee stressors like pathogens, nutritional deficiencies or adverse climatic conditions. Pesticide-exposed bees are more susceptible to overcome harsh conditions, such as overwinter (Lu *et al.* 2014).

a) Exposure

Pesticides are typically used on crops to control pests (insects, pathogens, weeds), and they can be sprayed, used in the soil or as seed dressing. Bees are exposed to pesticides during spraying operations when they are foraging in the fields, but also by drift from treated field, or by dust during seeding with coated seeds. They can also be indirectly exposed when foraging in crops, weeds or wildflowers near and in the crops, where they can be exposed to residues in the fields just after spraying. As systemic products are mostly persistent in soil and water, they can be found at significant concentrations in pollen or nectar that bees will collect in buffer zones, flowering strips, cover crops and catch crops. Systemic pesticides can in fact move up into all aerial plant parts (stems, leaves, nectar, and pollen). Bees can as well be exposed through pesticide residues in water, or by guttation water from plants they collect in the first hours of the day (EFSA, 2013).

b) Acute and chronic toxicity

Mechanisms of pesticide toxicity can be summarized in two major categories:

- Acute toxicity occurs in the field when bees are exposed to high levels of pesticides by contact or ingestion. In the laboratory, acute toxicity is measured by the LD50, which estimates the dose of the chemical (in µg per bee) required to kill 50% of the exposed population of bees.
- Chronic toxicity occurs when bees are exposed to low doses of pesticides for a long period. It can affect adult worker honeybees but also larvae in the beehive through contaminated nectar, pollen water (even in long-term storage of food reserves) and wax.

c) Sublethal effects

Pesticide exposure can lead to sub-lethal effects (Henry *et al.*, 2015, Tong *et al.*, 2019), such as reduction in learning, navigation, foraging, flight, locomotion disrupting their ability to return to the nest (i.e. homing) and thermoregulation, all of which are essential to honeybee colony survival. With the development of functional analysis, alteration in the levels of expression of some proteins, translation and protein synthesis, and ATP synthesis are also detected in honeybee exposed to pesticides. These sublethal effects are a major concern for bees (Ruiz-Martínez, 2018).

Nutritional stress

Nutritional stress is a common problem for bee colonies that is often involved in bee losses.

a) Exposure and hazard

Industrialized (high input) agriculture changes land use, reduces plant diversity and natural habitats, and impacts the quality and quantity of food resources (i.e. nectar and pollen). Honeybees are vulnerable to

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such reduced food quality and availability, because nutritional stress plays a crucial role in colony health and dynamic (disruption of egg laying, brood and worker activities) and is therefore closely linked to the bee losses and poor colony health. Numerous studies observed a link between nutrition and immunity (DeGrandi-Hoffman & Chen, 2015). Immune functions are affected by restriction of protein (pollen) and carbohydrates (nectar and honey). The flower abundance and richness are key elements to guarantee a good nutrition to bees, and nutritional stress can depend upon the lack of plant biodiversity (Naug, 2009). Nutritional limitations can also be caused by beekeeping management: excessive density of beehives in relation to the nutritional resources available, unbalanced artificial diets (sugar and protein supply). In addition, with global warming, a change in the resources available to bees in time and space are observed. Nutritional deficits were identified as one of the major causes of honeybee colony losses by beekeepers in the USA between 2007 and 2015 (21-58%) (Seitz *et al.* 2016).

b) Interaction nutritional stress-pesticides

A nutritional stress, such as starvation, can interact synergistically with pesticide exposure and reduce honeybee survival, hemolymph energy levels and food consumption (Tosi *et al* 2017). The combination of these stresses can have individual level impacts on bee behaviour and physiology (Tong *et al.*, 2019) and likely affect the health of the colony.

Interaction between bee stressors

One most concerning aspect for bees is related to multi exposure of bees to stressors. Combined effect of multiple stressors are indeed often more harmful than stressors alone. Even one stressor that does not incur any significant effect can result in sub-lethal or lethal effect in combination. Yet it is well known now that bees are chronically exposed to a wide range of pesticides mixtures. For example, fungicides such as ergosterol biosynthesis inhibitors (EBI), have very low toxicity in themselves but can synergistically increase the toxicity of neonicotinoids (Sgolastra *et al.* 2017), pyrethroids, and even novel insecticide classes such as butenolides (Tosi and Nieh, 2019), in certain cases up to 1,000-fold (Goulson *et al.*, 2015). Recent studies indicate that interactive effects between pesticides-nutritional stress (Tosi *et al.*, 2017) and pesticides-pathogens (Alaux *et al.*, 2010) could be especially harmful. A large number of infectious and parasitic agents affect bee colonies too, interacting with pesticide residues and other stress factors (lack of food for example) to which bees may be exposed both concomitantly and successively. The role of co-exposure to pesticides, nutritional stress, and infectious agents play a major role in bee health (ANSES report, 2015).

Limitations of risk assessment

The risk assessment is currently based both on the probability of exposure to stress and its hazard. To the light of scientific knowledge, this risk assessment procedure has some limits (Decourtye *et al* 2013). For example, it is difficult to determine exactly the pesticide exposition. For example, non-attractive crops for bees can also be a source of exposure (Simon-Delso *et al* 2017). In addition, we observe multiple and unpredictable pesticides combination (cocktail) in the hive, even including non-authorised products (Simon-Delso *et al.*, 2014; Tosi *et al.* 2018). The hazard study of all these cocktails is complex, especially because pesticide toxicity is altered by numerous stressors (diseases, nutrition) and factors (bee age, seasonality, climatic conditions) further complicating the risk assessment (Tosi and Nieh 2019).

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Existing best practices, tools, projects

Reducing pesticides risk to bees

Figure 1 Many regulations apply to limit pollinators exposure to pesticide (France, Nouvelle-Aquitaine)
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In the last few years, some actions were established to reduce pesticide risk to honeybee at European or state level. Other measures coming could be implemented. Some measures are given in Annex 1. In addition, EFSA published in 2013 a Guidance document intended to extend testing requirements in risk assessment, with the need to better take into account for sub-lethal effects to bees, effects on brood or larvae and better determine effects in bees from exposure to systemic pesticides (EFSA 2013).

Farmers can put in place several strategies and mitigation measures in order to reduce the risk from pesticides to bees as presented in table 1. The selection of pesticides with low persistence, systemicity and toxicity for bees is likely the most effective and feasible strategies in the reduction of pesticide risk. The other strategies may locally and/or temporally reduce the risk but show some limitations if highly toxic, systemic and persistent pesticides are used. For several strategies, their feasibility is low for obvious practical reasons. For example, pesticide application in the absence of wind is difficult to observe if the optimal timing of pesticide application coincides with a windy period.

Mitigation strategies/measures	Effectiveness	Feasibility
Selection of pesticides with low persistence, systemicity and toxicity for bees	High	Medium/High
Avoid pesticide drift (e.g. do not apply in the presence of wind or use anti-drift nozzle)	Medium	Medium/High
Apply pesticides when bees are not foraging on the target crop, either at dusk or when plant is not flowering	Medium	Low/Medium
Reduce surface water contamination	Medium	Medium
Avoid tank mixtures with pesticides that can interact synergistically.	High	Medium
Avoid pesticide application in an area (buffer zone) at the edge of the crop	Medium	Medium
Know where managed bee colonies are located and notify beekeepers when pesticides are applied	Medium/High	Low/medium

Table 1 List of mitigation strategies/measures to reduce pesticide risk and their relative effectiveness and feasibility for farmers

Reducing nutritional stress

Bee nutrition is becoming better known with still some shadow areas about bee requirements. Nutritional aspects of honeybee were recently integrated in the reflection of agricultural landscape. Resources can be improved by off-field and on field practises (Garibaldi *et al* 2014). Off-field practices consists to diversify

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and increase the abundance of resources outside the crop field, without affecting crop management: nesting resources, hedgerows and flower strips, conserving or restoring (semi-) natural areas, enhancing farmland heterogeneity and smaller crop fields.

Figure 2 Catch crop providing food for pollinators (France, Nouvelle-Aquitaine)
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In contrast on-field practices are all applied directly in the crop field: reducing the use of herbicides, no-tillage farming, enhancing flowering plant richness within crop fields, organic farming. For example, agri-environment measures were developed to support farmers in creating flower-rich feeding fields and strips for beneficial insects and pollinators. However, studies are needed to know in the field the real benefits of these measures.

In any case, the maximum livestock load has to be suited to the nutritional support of the environment (urban, nature, several types of rural ecosystems) and the season (flowering of agri or natural monocultures, other flowering).

Artificial feeding goal is the maintenance of the colonies (usually in winter) to its stimulation for the population increase (in different seasons, for long periods, and with protein foods in addition to sugary ones). It takes place at the end of summer or the beginning of autumn to replace harvested honey (so that the population does not rapidly decay or renew the old summer bee for a new bee for winter), at the end of winter (for a rapid development of colonies before spring) and between blooms or times of drought. In the European beekeeping practices, nutritional supply is often limited to provide sugar syrup before the winter or solid sugar during the winter. North American beekeeping is more interventionist with for example pollen patties supplements. Nutritional supply becomes a tool that can help both the health of bees, reducing nutritional stress, and the sustainability of professional beekeeping.

In Annex 2, some measures and practices favourable to bee nutrition are presented.

Listing of partnerships of farmers - beekeepers

Figure 3 Farmers and beekeeper meeting at an apiary for a better understanding and cohabitation (France)

Partnerships of farmers – beekeepers are developed in different contexts as in the pollination service. By bringing hives in the crop, the farmer increases the chance of the crop pollination and thus probability of harvest increase in quantity but also in quality. For the beekeeper, many advantages can be back of the partnerships like knowing farmer's practices around the hives (like using pesticides), honeybee use the resource to the colony development, and in addition the beekeeper can receive a monetary benefit.

Some projects exist and are listed in Annex 3.

3. Conclusions/Key messages

Bee stressors such as pesticides and nutritional resources are becoming better known. However, novel challenges are appearing like new exposure routes, chemical products, and interactions (synergism) with other stressors (climate change).

To reduce stressors effect on bees, numerous mitigation measures are known, but scarcely implemented and mostly local - those already implemented should be more widely adopted by the farmers. A lack of farmer awareness and lock-ins exist. With the help of agricultural advisers and enhancing incentive measures supported by political authorities, mitigation measures would be more efficient and a transition towards bee-friendly agriculture must be initiated. Pollinators preservation in agroecosystem is not incompatible with an agriculture generating yields and gross margins (Catarino *et al*. 2019, see also results of the EIP-AGRI Focus Group on Ecological Focus Areas).

4. Research needs

Increase the scientific knowledge about exposure and effects of stressors from agriculture

New pesticides coming on the market can cause threats via novel mechanisms, like the recent butenolides (flupyradifurone) and sulfoxamines (sulfoxaflor). To assure safety, research is needed to develop ecotoxicological methods able to detect sublethal effects at the bee and colony level before releasing the substance in the fields. In addition, these new pesticides that have potential new fate and behaviour in the environment could be leading to chronic exposure or exposure outside the treated field.

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Therefore, monitoring efforts should be reinforced, especially for new substances, and to identify new exposure routes (intercrops, persistent substances). This is even more important in the context of climate change with unknown consequences on the behaviour and toxicity of substances and leading to a fast agricultural practice changes. All of these elements could give unexpected adverse effects.

Food resources are also a challenging and relevant topic for bee health research. Assessing resource capacity of environments must be improved, as well as the investigation of resource quantity and quality from new hybrid varieties in comparison to current ones. On the other hand, progress must be made in understanding bee nutrition and its role for honeybee health. For example, it appears important to determine the nutritional needs of colonies to support bee fitness (for example, immune function) throughout the year. The role of microbiome in nutrient processing and immunity should also be investigated. Links between nutrition and other stressors, such as pesticides toxicity and pathogen development should be further developed.

Interactive effect between stressors is a crucial point because bees are not exposed to a single stressor but to a large number of stressors in the field, acting together or subsequently. Interactions exist between pesticides and nutrition, pesticides and pathogens, or pathogens-pesticides-nutrition together. It is important to improve the risk methodologies to deal with these field interactions.

Implementation of mitigation agricultural practices to reduce stressors on bees in agroecosystem

Mitigation practises are essential to reduce stressors on bees in agroecosystem. Research is needed to develop new mitigation practises and assess impacts on bee health, for example via large scale assessments. Mitigation and support measures to bees must be complementary and integrated with the existing approach of Integrated Pest Management (IPM) (Figure 1). In this way, the development of Integrated Pest and Pollinator Management (IPPM) concept should be useful (Biddinger *et al*. 2015). This approach must include practices to support bees (flower strips) and reduce risks (pesticide drift, use of harmful pesticides, mowing of potential contamination sources such as wildflowers in orchards).

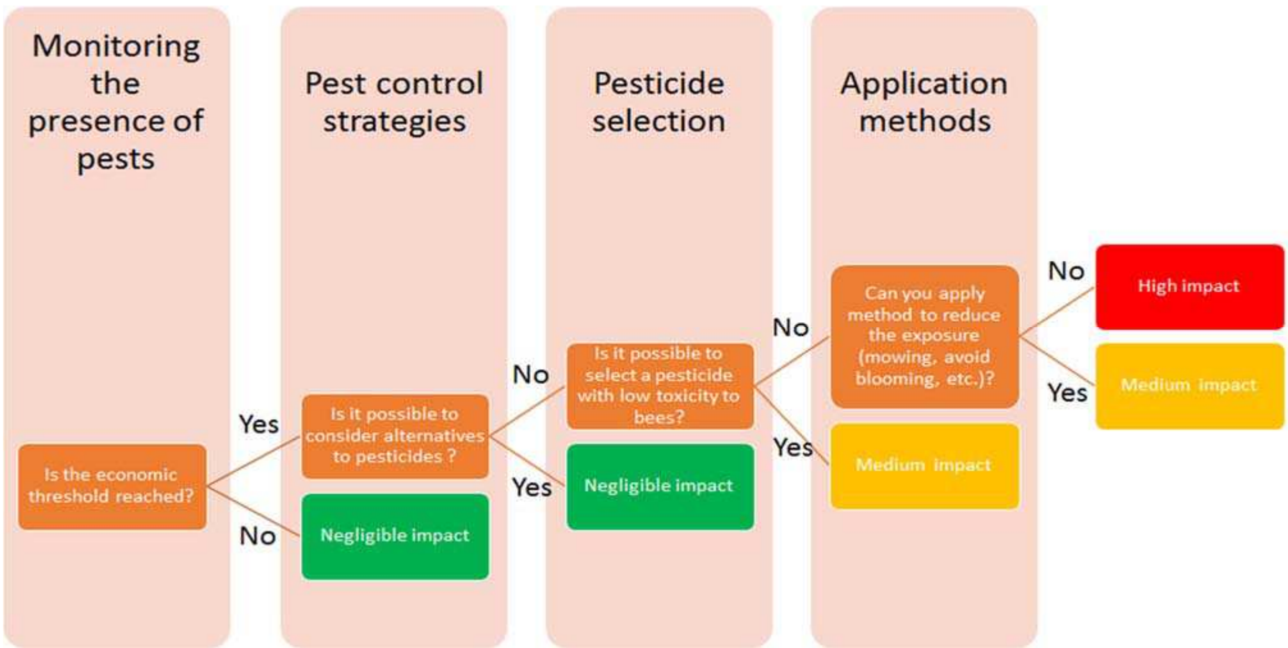

Figure 1 Decision tree of an IPM approach taking into account of pollinators

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Once mitigation practises are validated, a dissemination work should be done by different ways not only about mitigation practise but also on the importance of bees for agriculture. This dissemination work should be realized by independent advisers and also advisory bodies on pollination health and consequent benefits for farmers. Agreements between beekeepers and farmers, enforced by local authorities could also be developed. Associations should agree upon indicators, tools, and practices to measure added value of pollinator preservation.

5. Ideas for innovations

Bees in agricultural landscapes need a better environment. Some ideas to achieve this goal:

Further research needs coming from practice, ideas for EIP AGRI operational groups and other proposals for innovation can be found at the final report of the focus group, available at the FG webpage https://ec.europa.eu/eip/agriculture/en/focus-groups/bee-health-and-sustainable-beekeeping

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Annexes

Annex 1 - Initiatives to reduce pesticide risk

Goal	Measures / Practices	Country	(1) Frame work	(2) Adopted	(3) Efficacy	(4) Improvement	Description	Link
Reduce PPP exposure in attractive crops	Spraying at the end of the day, outside foraging periods	BE, FR, GR	Yes	Yes	Yes	More farmer sensitization, not only for toxic product to bee		http://adana.adafrance.org/infos/Communication.php
Reduce PPP exposure in attractive crops	Ban on some systemic insecticides (i.e. neonicotinoids) on flowering crops (2013-2018)	EU	Yes	Yes	Yes		Regulatory	
Reduce PPP exposure in attractive crops	Ban on systemic pesticide for all crop	FR	Yes	Yes	Yes	Reduce residues in non-target crop (especially melliferous crops such as sunflower and rapeseed) and wildflowers	Regulatory	
Reduce PPP exposure by reducing drift towards outside the crop (wild flowers, hedge, water,...)	Use specific spray nozzle, avoid pesticide spraying when windy weather	BE,	Yes	Yes	Unknown			https://protecteau.be/fr/phytos/professionnels/pulverisation/reduction-de-la-derive
Reduce PPP risk	Pesticide selectivity list for pollinator	USA	-	-	-	Reduce toxicity risk when a pesticide is sprayed in orchard		Example from USAA Pesticide Decision-Making Guide to Protect Pollinators in Tree Fruit Orchards
Reduce PPP risk	Ban / restriction of pesticide mixture in tank (ex triazol with pyrethrinoids)	FR (but no in BE)	Yes	?	?	Extend to all EU members		https://bourgognefranchecomte.chambres-agriculture.fr/fileadmin/user_upload/Bourgogne-Franche-Comte/061_Inst-Bourgogne-Franche-Comte/CA71/71AGRI_Techniques/71Grandes_cultures/reglementation_aout2018.pdf
Reduce PPP exposure in attractive crops	Do not apply pesticides dangerous to bees and other insect pollinators during bloom	IT	Yes	Yes	Yes		Regional regulatory	http://bur.regione.emilia-romagna.it/dettaglio-inserzione?i=2408a8b35f2047258a402224bcb742b0

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Goal	Measures / Practices	Country	(1) Frame work	(2) Adopted	(3) Efficacy	(4) Improvement	Description	Link
Controling pesticide uses	Introduction to organization and implementation of training activities on the sustainable use of plant protection products in compliance with provisions of Directive 2009/128/EC	EU, GR	Yes	Yes	Unknown	?	Regulatory	http://www.minagric.gr/images/stories/docs/agrotis/Georgika_Farmaka/elenxoi/01._Introduction_to_EU_legislation_regarding_PPP_and_their_use.pdf
	Legal requirements		Yes	Yes	Unknown	?	Regulatory	http://www.minagric.gr/images/stories/docs/agrotis/Georgika_Farmaka/elenxoi/02._Legal_requirements.pdf
	Safe use – Identification of hazards and risks to humans		Yes	Yes	Unknown	?	Regulatory	http://www.minagric.gr/images/stories/docs/agrotis/Georgika_Farmaka/elenxoi/02._Legal_requirements.pdf
	Safe use – Measures to minimize risks to humans		Yes	Yes	Unknown	?	Regulatory	
	Safe use – application equipment		Yes	Yes	Unknown	?	Regulatory	http://www.minagric.gr/images/stories/docs/agrotis/Georgika_Farmaka/elenxoi/05._Safe_use_-_application_equipment.pdf
	Environmental aspects and sustainable use of PPPs: Drift		Yes	Yes	Unknown	?	Regulatory	http://www.minagric.gr/images/stories/docs/agrotis/Georgika_Farmaka/elenxoi/06._Environmental_aspects_and_sustainable_use_of_PPPs_Drift.pdf
	Environmental aspects and sustainable use of PPPs: IPM		Yes	Yes	Unknown	?	Regulatory	http://www.minagric.gr/images/stories/docs/agrotis/Georgika_Farmaka/elenxoi/07._Environmental_aspects_and_sustainable_use_of_PPPs_-_IPM.pdf
	Minimisation of side effects of PPPs for the environment		Yes	Yes	Unknown	?	Regulatory	http://www.minagric.gr/images/stories/docs/agrotis/Georgika_Farmaka/elenxoi/08._Minimisation_of_side_effects_of_PPPs_for_the_environment__new.pdf
	Post-training dissemination		Yes	Yes	Unknown	?	Regulatory	http://www.minagric.gr/images/stories/docs/agrotis/Georgika_Farmaka/elenxoi/09._Post-training_dissemination.pdf

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Annex 2 - Initiatives to reduce nutritional stress

Goal	Measures / Practices	Country	(1) Frame work	(2) Adopted	(3) Efficacy	(4) Improvement	Description	Link
Increase food availability in time and space	Flower strips	BE	Yes Agri environ mental scheme			Species composition must be selected more specifically for bees	-	Natagriwal
Facilitate the selection of bee-friendly crops	Publish a list of crops/flowers of interest	FR	No	_		Need of financial/regulatory scheme	Database with information regarding attractivity for bees, and interest for pollen/nectar	http://www.interapi.itsap.asso.fr/ https://agriculture.gouv.fr/decouvrez-la-liste-des-plantes-attractives-pour-les-abeilles
Limitation hives load	Total amount of bee colonies is determined and cannot be increased	IL	Yes	?	?			-
Increase food resources (indirect effect)	Sowing lavender and other aromatic plants among the olive trees	ES						Honey olive grove (https://revistaalmaceite.com/2017/01/31/el-olivar-de-miel-evita-la-erosion-potencia-el-oleoturismo-y-diversifica-la-produccion/)
Increase food availability in time and space	National platform for sharing initiatives	NL	No	Yes	?	More flowers for bees in general	Nederland Zoemt! : national platform for the promotion of initiatives by governments, farmers and civilians to improve more flowers in agricultural and urban areas	https://www.nederlandzoemt.nl/?gclid=EAIaIQobChMInrH0s7Dk5QIVF-R3Ch1LgQS-EAAYASAAEgK7A_D_BwE
Protect beekeeping flora	It is forbidden to cut or eradicate beekeeping plants and trees	GR	Yes	Yes	?	Aid for planting bee plants	Also through the EC directive for the honey	Law 657/2-11-1963
Protect beekeeping flora	Permission to place honey bee colonies in the forests	GR	Yes	Yes	Yes			Law 190/4-3-81

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Annex 3 - Farmer-beekeeper partnerships

Which producer?	Description	Country	Contract (yes/no)	Reward (yes/no)	Conditions	Improvement	Description	Link
Farmers (orchards, …)		BE	No systematically	Not always	Yes		Contract example provide	Contract pollinisation
Farmers		BE						http://www.cari.be/article/offres-et-demandes-de-pollinisation/
Farmers and beekeepers	Survey of apiaries in connection with farmers and advisers	FR	No	No	Experimental project for cooperation	Understanding of relationships between contaminations in beehives and farming practices		SURVapi
Farmers (especially for seed production)	Platform for networking between beekeepers and farmers	FR	Yes	Yes/no		Written contracts not always expected by seed producers nor beekeepers	Beewapi : networking plateform created by ANAMSO, GNIS, UFS, ITSAP	http://www.beewapi.com/
Mutual understanding between farmers and beekeepers	Meeting at an apiary	FR	No	No	None		ADA NA actions	http://adana.adafrance.org/infos/Communication.php
Beekeepers	Protection of the local subspecies of Apis mellifera	IT	No	No			Regional regulatory	http://bur.regione.emilia-romagna.it/dettaglio-inserzione?i=2408a8b35f2047258a402224bcb742b0
Mutual understanding between farmers and beekeepers	Memorandum of understanding between seed producers and beekeepers	IT	No	No	Yes			http://www.sementi.it/comunicato-stampa/450/firmato-protocollo-intesa-per-valorizzare-colture-sementiere-e-tutelare-il-patrimonio-apistico
BeeWeb	Platform for farmers and beekeepers for pollination purposes	RS	Yes	Yes	Depends on producers		Contracts for pollination	https://www.beeweb.co/en
Beepath	Increase awareness of bees in Lijubljana and collaboration with farmers	SL	No	No		The relationship and understanding is improved	They form common exhibitions	https://urbact.eu/bee-path
BeepathNet	Increase awareness of bees in several cities, collaboration with farmers	SL, GR, IT, PT, HU PL	No	No		The relationship and understanding is improved	In progress!	https://urbact.eu/beepathnet
Save the bees and farmers	Towards a bee friendly agricultural environment	DE			A new initiative		New citizens initiative starting the collection of 1.000.000 signatures	https://beesfarmers.armada.digital/

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EIP-AGRI Focus Group
Bee health and sustainable beekeeping

MINIPAPER 07: Sustainable beekeeping and breeding

September 2020

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Table of contents

1. Introduction

At present, honeybees suffer from a number of health issues. There are several reasons for that, one of them is that beekeeper practices may not be sustainable. The practices cause a smaller genetic basis for the honeybees, making them potentially less resilient. Use of acaricides, certain breeding methods and migratory practices cause low selection pressure against Varroa infestation and ample transmission of diseases.

This minipaper addresses the issues about existing and new breeding techniques to maintain locally adapted honeybee populations. This paper is about preserving honeybee genetic diversity and proper treatments in order to reduce the impact on honeybees and to limit the number and quantity of chemical agents in honey. The main aim is a call for sustainable beekeeping to convince beekeepers of the need of that.

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Figure: *Apis mellifera iberiensis* on oilseed rape flower (Pilar De la Rúa)

2. Dissertation

Losing adaptation possibilities

Beekeepers face many challenges, such as swarming of their honeybees, aggressive behaviour, parasites like Varroa and other mites, fungi as Nosema, bacterial and viral infections. The most sustainable way to meet those challenges is to do breeding. In this way the honeybees swarm less, become less aggressive and will become more resilient against health problems. Throughout the centuries, beekeepers have tried to select honeybees with desirables characteristics. The Buckfast bee, bred by brother Adam at Buckfast abbey in England, is the most successful example of this. Brother Adam used for his breeding scheme local honeybees and subspecies as *Apis mellifera carnica* and *A. m. ligustica*.

In the process of breeding, breeders do not only select for desirable phenotypes of their breed, but they may also counter-select against other traits. Sometimes this occurs on purpose. For instance, in the breeding process of acquiring honeybees that gather more honey, the size of honeybee hives has become larger. And larges hives means more possibilities for serious health problems. Sometimes the counter selection is accidental and sometimes even unnoticed. For instance, beekeepers tend to raise queens that produce compact, consecutive brood. Likely, but unprovable, they selected not for a queen egg-laying trait but they counter-selected the trait to perform adequate hygiene of diseased brood by the workers. It is clear that it is important to examine the effect of losing traits when breeding. With every trait lost, so with losing biodiversity within the honeybee populations, honeybee colonies become possibly less resilient (Mattila & Seeley, 2007). Facing the fact that more and more challenges are emerging, this is worrying process. We might lose or even have lost ways for the honeybees to deal with viruses with higher infectious profiles or the small hive beetle.

Use of commercial breeds

The situation has become even more complex, as beekeepers do not tend to breed themselves, but depend on commercial breeds. The commercial bees are usually inbred strains. The consequence tendency will be that the apiaries are inhabited with genetically more or less the same kind of queens, leading to a lack of genetic diversity within the honeybee populations, limiting the response of the workers to a health challenge or a change of environment or climate. This lack of genetic diversity can lead to diseases having a greater impact on bee colonies.

Spreading diseases

In the case of pathogens and parasites that can affect *A. mellifera* more than 20 have been described, belonging to a great diversity of organisms: fungi, bacteria, protists, mites and virus. The spread of pathogens and parasites may be influenced by many factors including beekeeping practices, such as importation of honeybee queens and replacement of local queens. In this sense an increase of the presence and distribution of *Nosema ceranae* was observed in honeybee populations on the Canary Islands in parallel with a higher introduction of foreign queens (Muñoz *et al.* 2014). Albeit such queen replacement could help maintaining low rates of Nosema infection, healthy local queens should be used in order to conserve native honeybee diversity.

Climate change

At present, there is some regulation about the conditions to be complied in relation with the trade of honey bees in the European Union (intra-EU or imports), contained in the Directive 92/65/EEC (European Commission 1992). Certificates have to be used for the trade, notably to avoid introduction (or further spread) of pathogens throughout the EU, but the reality is that this regulation does not cover all known bee pathogen species. In addition, the analytical methods available for some pathogens are destructive, involving the death of many honeybees so that it is very difficult to ensure the absence of pathogens in commercial hives. One solution is training veterinarians acting as beekeeping inspectors and beekeepers themselves for detecting early disease symptoms.

Local breeding programs

As far as autochthonous (local) breeds are concerned, this activity must have a number of components for a holistic approach. Thus, it is important that:

- The entities responsible for breeding and breeding programs of indigenous breeds establish partnerships with public authorities at the governance and research levels.
- Entities should be recognized for their work in the area of preservation of indigenous breeds and have a distinctive stamp issued by a European entity.
- The majority of beekeepers in an area participate in a breeding programme; it helps preserve the genetic variability of the honeybee population and thus supports and improves the intensity of selection.
- All queens selected should have a record of the genealogy that originated them, the selection process, and the information until they entered into the producer's holding.

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- Projects of students of various academic degrees should be fostered to carry out internships, master's degrees and doctorates in this area.
- A science-based training program should be set up in the field of genetic improvement, sustainable production and the multiple apiculture resources for beekeepers, zootechnicians, farmers, veterinarians and any other sector professionals.
- A cycle of lectures, workshops and seminars related to the autochthonous populations, open to all civil society, should be carried out.
- Projects relating to indigenous breeds should be scientifically based and, in addition to implementing a process, will serve as a basis for improving beekeepers holdings for the preservation of the species.
- It is important to provide technical support to beekeepers to monitor the evolution of honeybee genetics.

Quarantine periods

With the increasing global trade in honeybees, the introduction of healthy queens is a prerequisite for maintaining healthy livestock. The development and application of quarantine treatments to prevent the introduction of pathogens into apiaries raises many research and regulatory issues. This technique, which is practiced in other agricultural activities, is not widely used in Europe, but is used in other countries such as Chile. The isolation of boxes with queens from the USA for an appropriate period of time allowed the early detection of the small hive beetle in Portugal in 2004. This is an example of how important such activities are to prevent the spread of pathogens and parasites to which local honeybee populations are not adapted.

Best practices

Treatments at the same time (if treatment)

Beekeepers usually have their hives very close together in the apiaries due to space limitations and ease in carrying out beekeeping operations. In fact, honeybee colonies do not like to be too close to each other (Seeley 2015) for one reason: when hives are very close to each other, diseases can be spread more easily by mismatching honeybees returning to their homes (drifting) or by overlapping foraging areas. Beekeepers must be aware of this fact and therefore carry out sanitary treatments against diseases, mainly against Varroa, of the hives at the same time. In this way, untreated infected hives cannot re-infect cured hives.

Migratory practices (communication)

More or less the same as above accounts for migratory practices. Beekeepers should be aware that travelling with honeybees is not without risk for their health. When hives gather closely together from different environments an ill colony can easily infect neighbouring hives. In this way diseases are spread over long distances in short periods of time. Control of migratory behaviour by beekeepers is needed to monitor spreading of diseases. Moreover, research is needed to determine the level of colony density in certain ecological systems to limit the risk of spreading diseases.

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Projects

Conservation programs in EU

Growing recognition of the importance of using native honeybee subspecies and breeds as a source of genetic material for sustainable beekeeping has led to enact conservation laws (i. e. on La Palma, Canary Islands in 2001) and to establish protected areas in different regions of Europe in order to preserve the genetic integrity of the different European subspecies and breeds of honeybees. The organisation Societas Internationalis pro Conservatione *Apis mellifera mellifera* (SICAMM) was established in 1995 for protecting the dark European honeybee, and several research projects funded by the European Union (BABE, ALARM, SMARTBEES, POSHBEE) have among their objectives the conservation of the endemic subspecies as a way to prompt a sustainable beekeeping. In relation to the European black honeybee *A. m. mellifera*, pure protected breeding populations have been established from queens mated on islands (Læsø, Denmark; Texel, Netherlands; Colonsay, Scotland) or in isolated stations on the mainland (France, Belgium, Switzerland and Norway) in order to maintain and preserve the genetic identity of this subspecies. The molecular analyses of honeybee colonies included in these protected populations suggest that, despite controlled breeding, some protected populations still require adjustments in management strategies to eliminate gene flow generated from the presence of foreign bees (Pinto *et al.* 2014).

Breeding and selection techniques have a long tradition, almost starting at the end of the 19th century. However, what makes the difference is the initiation of breeding towards *Varroa* resistance. The high diversity of honeybee subspecies and ecotypes in Europe is a great genetic resource for such programs. In fact, there are several examples of honeybee populations in Europe showing resistance to varroa as it is expressed through the high survival rates. Resistance depends on genetic material, on hive management, environmental conditions and is based on very complex mechanisms which are still only partially understood (Büchler *et al.*, 2010). A recent European project called EurBeST involves applied research on varroa resistance of naturally selected European breeds, and it will investigate the relevant resistance traits such as Varroa Sensitive Hygiene (VSH), Suppressed Mite Reproduction (SMR) and recapping (REC), to the utilisation of molecular genetic tools to improve performance testing, breeding value estimation and the maintenance of mating stations and artificial insemination (**https://eurbest.eu/**).

Additionally, the Research network for Sustainable Bee Breeding (RNSBB) was founded in 2013 with the aim of exchanging experience and of harmonizing breeding methods among scientists, countries and initiatives (**https://www.beebreeding.net/**). Furthermore, a new association based in Belgium was founded on November 2018 which aims to become a tool for worldwide honeybee queen producers & breeders, a place where to meet, exchange ideas and experiences; conservation and sustainable breeding are the main goals (**https://www.beesources.com/en/assistenza-tecnica/international-honey-bee-breeding-network-ihbbn-founded/**)

Selection of local bees (black honeybee as example) by extensive management

The dark honeybee *A. m. mellifera* is the west and central European honeybee subspecies adapted to local conditions for millennia. In this sense it can hibernate well in harsh climates and provides a balanced honey yield. Their local strength is also reflected in their pronounced flying power even at low temperatures. The winter brood break and the brood brakes during lack of nectar flow, inhibit the development of the Varroa mites, which is interesting again today.

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According to the breeders, dark honeybees can only be successfully kept today if the beekeeper take into account the characteristics of purebred and buys them from breeders. This may rise certain one-sidedness, such as the loss of genetic diversity and vitality. The basis for the preservation of the dark honeybee is therefore small, because it is limited to the work of the pure breeders. Just to avoid this loss of vitality and to enable breeding for the normal beekeeper, a basic breeding for the preservation and stabilization of the dark honeybees would be important.

In an extensive honeybee-friendly organic beekeeping, the natural swarming process is the most important element to multiply and maintain the honeybee colonies. This means that the honeybee generations that develop there are not purebreds.

According to the experiences of extensive bee-friendly beekeeping, breeding consists of the elements of breeding techniques and breeding selection. Therefore, swarm queens guarantee the best natural quality in this case.

Due to the above-mentioned aspects, a project for selecting local honeybees should aim to answer the following questions:

- Can we breed purebred dark honeybees in an extensive organic beekeeping?
- Which breeding techniques and methods can be developed or used to ensure the preservation of the dark honeybees in an extensive beekeeping apiary?
- Can one promote, or at least maintain, the vitality through the element of good selection?

With the goal to preserve local honeybees, such project should have the following goals:

- Development of a breeding concept under an extensive bee-friendly organic beekeeping.
- Development and implementation of selection criteria to consider the honeybee colony as a whole organism with its vitality and needs.
- Observing, comparing and propagating local honeybees in different locations.
- Strengthening the basic breeding for the local honeybee, where everyone can multiply them.
- Improving the distribution of the local honeybee and increasing its attractiveness.
- Breed for resistance to diseases.

State of the art of research/practice

Interactions of genotypes by environment.

Through COLOSS bee research association (Prevention of honeybee COlony LOSSes, (**http://www.coloss.org/**) a systematic comparison of different genotypes of honeybees under standardised conditions in a range of environments (GxE) took place from 2009 till 2012. The aim of the study was to increase the knowledge about the adaptation of honeybees to their local environment compared with introduced genotypes. A total of 621 colonies of 16 different genetic origins were tested in 21 apiaries in 11 different European countries and the study was unique in its dimensions.

In general, a strong interaction between genotype and environment was found, and the locally adapted honeybees survived better than introduced ones (Büchler *et al.*, 2014). Furthermore, a tendency was detected towards specific adaptations of the local genotypes in terms of adult honeybee population, honey production and overwintering ability (Hatjina *et al.*, 2014). The conclusions were: 1. The "best

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honeybee" does not exist; 2. No genotype can show excellent performance and superior disease tolerance across all environmental conditions; 3. The local honeybees are not only the most long-lived, but they grow bigger, they collected more honey and, in some cases, they were more gentle and with less diseases (Meixner *et al.,* 2015).

3. Research needs

Focus Group experts have identified following research needs from practice to address the sustainable beekeeping issue further on:

- To establish conservation areas and breeding programs in each country. Recommendation to support the programs that can combine research and extension.
- To determine the differences in genotype's behaviour due to climatic change. A kind of GxE interactions experiment but this time it needs to address the differences in behaviour of the selected ecotypes/subspecies in a changing environment (e.g., progressively warmer and dryer, as well as to address the effects of climate change).
- To characterise in detail the behaviour of selected ecotypes. Breeding programs cannot be established without knowing in detail the behaviour and performance of the local stock, ecotypes.
- Breeding associations, foundations or organisations should be educated about proper breeding techniques especially on maintaining biodiversity. Research is needed to prove lack of genetic diversity and related less resilient behaviour.
- Further research is needed for a better understanding of resistance mechanisms to varroa, and suitable selection methods need to be developed and improved. Identification of the genes involved in *Varroa* resistance is essential and establishing of genetic markers for resistance traits will facilitate breeding efforts towards this direction.

4. Ideas for innovations

Focus Group experts are proposing to set up an Operational Group idea:
- to develop a platform for sharing best breeding practices, so beekeepers are facilitated in breeding
- in this process research should be done to established which critical criteria for best breeding practices under certain conditions and local ecosystems lead to best traits for swarming, aggressive behaviour, varroa resistance and honey gathering qualities.

The working title of this OG could be of "OG on local breeding of honeybees".

Further research needs coming from practice, ideas for EIP AGRI operational groups and other proposals for innovation can be found at the final report of the focus group, available at the FG webpage **https://ec.europa.eu/eip/agriculture/en/focus-groups/bee-health-and-sustainable-beekeeping**

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5. Conclusions

Honeybees are needed for pollination and products they provide, but they suffer from several threats. Beekeepers should be aware of that and take care of honeybees by implementing sustainable beekeeping through breeding local resilient honeybees.

Veterinarians and extension agents from different administrations should explain why working with local honeybees is better than with imported honeybees. Policies to promote beekeeping with endemic subspecies of honeybees must therefore take into account not only the biological aspects of honeybees, but also the diversity of beekeeping activities in the different countries of Europe. That is why, instead of a single pan-European directive, regional regulations that allow for sustainable conservation of the great variety of local honeybees in Europe should be enacted.

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