EIP-AGRI Focus Group
Bee health and sustainable beekeeping

MINIPAPER 07: Sustainable beekeeping and breeding

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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

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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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