Restructuring of the Honey Bee Chain and Varroa Resistance Breeding & Selection Programme

Written by

Project team

Landesbetrieb Landwirtschaft Hessen Bieneninstitut Kirchhain (LLH)
https://www.llh.hessen.de/bildung/bieneninstitut-kirchhain/
Coordinator: Dr. Ralph Büchler, ralph.buechler@llh.hessen.de

INRA Centre de Recherche Provence-Alpes-Côted'Azur (INRA) www.inrae.fr/en

Council for Agricultural Re-search and Economics – Research Centre for Agriculture
www.crea.gov.it/en/home

ConsulTech GmbH (CT) www.consultech.de

01-2022

EUROPEAN COMMISSION

Directorate-General for Agriculture and Rural Development

Direction G – Markets and Observatories

Unit G3 – Animal Products

Contact content: AGRI-ANIMAL-PRODUCTS-EXT@ec.europa.eu

Unit C.4 - Monitoring and Evaluation

Contact dissemination: AGRI-EVALUATION@ec.europa.eu

European Commission

B-1049 Brussels

EUROPEAN COMMISSION

EXECUTIVE SUMMARY

The information and views set out in this report are those of the authors and do not necessarily reflect the official opinion of the Commission. The commission does not guarantee the accuracy of the data included in this report. Neither the Commission nor any person acting on the Commission´s behalf may be held responsible for the use which may be made of the information contained therein

Directorate-General for Agriculture and Rural Development

2022

Europe Direct is a service to help you find answers to your questions about the European Union.

Freephone number (*)**:**

00 800 6 7 8 9 10 11

(*) The information given is free, as are most calls (though some operators, phone boxes or hotels may charge you).

Luxembourg: Publications Office of the European Union, 2022

PDF ISBN 978-92-76-28919-7 doi: 10.2762/452476 KF-02-21-040-EN-N

Compared to other agricultural sectors in Europe, the direct output of apiculture is small, but, due to its pollination services, it has a major impact on the efficiency of European food production and the sustainability of ecosystems. Even when managed by man, honey bees maintain basic differences compared to other livestock: 1) the main food source of a honey bee colony comes from the floral resources of the environment in which it is placed; 2) the mating biology is complex, with the aim of maximising within-colony diversity (difficult for man to control); 3) the colony self-regulates and stabilises its nest climate according to the conditions outside the hive. These factors constitute an extremely high level of interaction with the natural environment, which on the one hand has caused a great diversity evolving within the species, on the other hand it makes breeding activities more difficult compared to other livestock.

Reproductive material in honey bees is mainly represented by honey bee queens. Usually, queens are traded as the main unit, either by themselves (in a small cage, together with a few worker bees), as swarms (or nukes, small colonies with an active queen, on 4-5 combs with brood and food stores) or together with package bees (adult worker bees, without brood or food combs); the latter may sometimes be traded without a queen. In the EU, there is no official reporting system for honey bee queen production, or for the production of other kinds of reproductive material. One of the first tasks of the EurBeST team was to perform an overview of the market of apicultural reproductive material for all 28 EU Member States.

This was obtained by using various kinds of data sources: EU trade statistics (https://trade.ec.europa.eu/access-to-markets/en/statistics?includeUK=true), TRACES System, questionnaires to experts (EurBeST team survey) and Member States' national apicultural programmes. Based on the survey, we found that bee breeders in the EU represent less than 1% of the beekeepers, and the reproductive material they produce for the market adds up to 16% of the EU colonies, with a total annual value of 86,000,000 €. The number of breeders and the amount of reproductive material produced and traded varies greatly between countries, even between closely neighbouring ones. While the breeding structure and production volume in a few countries appear sufficiently well developed to satisfy their own demand on high-quality reproductive material, this is not the case in all countries across the EU. The countries with the highest numbers of breeders are Germany, France, Italy, Greece and Romania. We found that queen production and trade is widespread across EU28, while swarm and package bee production is restricted to fewer countries, mostly located in Southern Europe (countries with the highest queen production are Italy, Poland and France; with the highest swarm production: Italy, France, Spain; with noticeable package bee production: Greece, Italy and France). International trade seems to affect the honey bee reproductive market to a small extent, as the evidence we found shows that, within EU, trade represents about 3% of the total market value, and extra EU trade an even smaller proportion. However, according to TRACES data, the market of reproductive honey bee material within the EU has been in constant increase in recent years.

Despite huge demand, there is no well-established market for resistant stock in Europe to date. Moreover, reliable experience or experimental evidence regarding the resistance of stocks under different environmental and management conditions is still lacking. By examining the scientific literature, we find that the common characteristics of honey bee populations which are surviving without acaricide treatments, because they have naturally evolved resistance to the varroa mite, are based on traits such as reduced brood activity (which limits mites' reproduction and its population growth) that may cause conflict with the interests of commercial beekeeping. In breeding programs,

resistance traits observed in naturally resistant populations can be integrated: the most frequently used traits are grooming, hygienic behaviour and mite reproduction status, together with more simple testing of mite population development and colony survival. Several studies showed that environmental factors affect resistance, leading to the conclusion that potentially resistant strains must be evaluated under different local conditions and colony management. In the report, we present the results of a survey on the presence of naturally selected resistant honey bee populations and the state of selection programs on varroa resistance across the EU and some associated countries. Briefly, we identified six EU countries which have naturally selected varroa resistant populations (France, Italy, Ireland, Lithuania, the Netherlands, and Sweden), and several others where bee breeding programs focusing on varroa resistance are being conducted, albeit often on a small scale. Supplies of queens are, however, very limited in most areas; alternatively, breeders participating in selection programs are often very cautious about advertising their stock as "resistant". However, several countries have recently initiated new selection and breeding programs, so it is clear that there is an increasing interest in developing these aspects, either by using naturally varroa resistant bees, by adding suitable selection characters to existing selection schemes, or by devising entirely new programs.

Interviews were carried out with scientists and beekeepers known to be involved in breeding varroa resistant honey bees, to compile the traits in use and methods to assess them. The selection strategies are very diverse: whilst breeders of naturally surviving populations allow their bees to carry out natural selection by themselves, breeders deliberately selecting their bees for varroa resistance usually include one to four characters related to varroa resistance into their already established selection program on, for example, productivity, gentleness, and swarming behaviour. The breeders using naturally selected bee populations are mostly interested in one main trait: the survival of the colonies. The breeders selecting their bees for varroa resistance most frequently use the three characters SMR (suppression of mite reproduction), VSH (varroa sensitive hygiene) and REC (recapping of infested brood cells), or mite infestation and population growth and hygienic behaviour. Although out of the 28 EU states, six countries reported the existence of naturally resistant populations and 20 countries carry out or started selection programs for varroa resistance, only four countries reported commercial availability of varroa resistant stock.

To assess the current and future potential of honey bee selection for improving honey bee health and production for commercial breeding and beekeeping in Europe, the EurBeST core group (LLH-Germany, INRAE-France; CREA-Italy, ConsulTech-Germany) established an expert team of 131 queen breeders, performance testers and commercial beekeepers from seven EU countries. With the support of this network, the core group successfully organised five large-scale case studies in France, Germany (also involving some beekeepers from Austria and Croatia), Greece, Italy and Poland. To ensure that the results of the case studies can be taken as representative for the honey bee reproductive market, the countries were selected among those in which production and structure of the breeding market is more significant, but also diversified, to reflect the variability identified by the previously conducted overview of the reproductive market and state of play of varroa resistance in commercially available stock. Together with the European expert team, a methodology was established to develop commercial production of varroa resistant honey bees by breeders and to promote the dissemination of such bees to commercial beekeepers. Thus, the most central part of the EurBeST study was the implementation of the case studies to validate the methodology of

honey bee selection for varroa resistance. The case studies were coordinated by the core group and run by the expert team. Twenty-three genotypes were included in the case studies, either coming from selective breeding programs with a variable degree of selection for varroa resistance or from naturally selected populations with increased varroa resistance potential. They belonged to four subspecies (*A. m. carnica*, *A. m. siciliana, A. m. ligustica*, *A. m. macedonica*) and three mixed or undefined genetic origins (Buckfast, unspecified hybrid, or unspecified / unknown). In early summer 2019, more than 2 500 queens from the potentially resistant lines were produced by 25 queen producers, and distributed to 21 performance testers and 85 commercial honey producers.

Performance testers (PT) carried out comprehensive and thorough testing on the important apicultural traits, but also focused on the parameters related to varroa resistance. In each PT apiary, two to four lines, with eight to ten colonies each, were compared, and each line was tested in at least three different PT apiaries. In some PT apiaries, lines from other case studies were included to evaluate genotype-environment interaction effects on the resistance traits. The colonies in PT apiaries were built from artificial swarms, in order to ensure standard starting conditions within each apiary, for the different tested lines. Varroa infestation within and between different apiaries was standardised by applying an initial treatment; thereafter, no further varroa treatment was applied. At the end of the study, one year later (summer 2020), the queens were caged to stop brood production and to estimate the final mite infestation. VSH, SMR and recapping were evaluated in some selected test apiaries in close cooperation with local laboratories. Finally, data on work load and costs of testing and apiary management were collected for a detailed economic analysis.

Commercial beekeepers (CB) compared the potentially resistant lines with the stock they normally use for honey production. Most of the selected lines were tested in three to five commercial apiaries. Colony management and varroa treatment were enacted following the common practice and apiary standards of the respective beekeeper. Data were recorded for honey yield, manageability, varroa infestation and colony losses as traits of major apicultural interest.

At the end of one productive season, all data were collected by the regional coordinators in collaboration with the core group, using a tailor-made online database. An extended statistical analysis of the study data was performed to assess the commercial qualities and varroa resistance traits of the 23 selected lines.

The expert team was also used to perform a survey among queen breeders' customers, to gain insight on the degree of satisfaction that beekeepers have toward the queens they are buying, what characteristics they are seeking for when they buy reproductive material, and more specifically, what is their level of interest and hope towards varroa resistant stock. In total, almost 400 responses were obtained. Results showed that more than 2/3 of all customers identified disease and parasite resistance as the most important trait, followed by productivity. However, when assessing beekeepers' satisfaction with the purchased stocks, beekeepers are less satisfied with the resistance traits. This result highlights that beekeepers have high expectations and develop a growing demand for high quality queens originating from populations with improved resistance.

Results from the PT and CB observations showed that the factor most strongly affecting colony strength and development was the apiary in which the colony was located, confirming the strong dependency of the honey bee colony on the environment (which

includes beekeeping management) in which it is placed. The genetic origin of the bees, in terms of specific lines, was significant for overwintering index and for number of adult bees in the productive season. Instead, colony strength assessed by number of brood combs was not affected by genetic line, possibly highlighting an effect of environment on the adult bees / brood ratio. When the line had a significant effect on colony development, the interaction between line and apiary was also significant. When considering the factor "origin" (classifying lines according to whether local or non-local in each apiary) we noticed that when line was significant, the origin was also significant, with local colonies displaying greater values of colony strength. Thus, the importance of environment and of local adaptation on colony development, observed in previous research, is confirmed by the EurBeST case studies.

The measured behavioural and productive traits were all significantly influenced by genetic line and by apiary, both at the PT and CB level. We found that lines that have three or more generations of breeding effort towards gentleness were indeed significantly more gentle compared to other lines. In CB apiaries, the EurBeST lines were not overall assessed as less gentle than the beekeepers' expectations, and in some cases were even considered better. Overall honey production of CB stock was higher than EurBeST lines (+ 0.8 kg / colony on average), with exceptions in some case studies. We found indications of an effect of origin (local or non-local) for gentleness, for swarming and for honey production. In these cases, performance of local lines was better (more gentle, less prone to swarming, producing more) than when lines were non-local. Again, the role of adaptation to the environment for colony performance is highlighted.

At the end of one productive season, after one year without treatment against varroa, 57% of the colonies in the PT apiaries survived. In the CB apiaries, where most of the control and EurBeSt colonies were treated, the overall survival rate of colonies was higher (78%) than in the PT apiaries. Some of the EurBeST lines suffered higher losses than the beekeepers' own stock, indicating better adaptation of the local stock to the environmental conditions and local beekeeping practices.

The measured varroa infestation traits were all significantly influenced by genetic line and by apiary, both at the PT and CB level. When EurBeST lines were compared to beekeeper stocks, mite infestation levels at the end of one productive season were found to be lower in the EurBeST lines. In the PT apiaries, several lines were found to have mite levels lower than what is considered a safety threshold (3 mites / 10 g bees). On average, colonies in the three Mediterranean countries (EL, FR, IT) harbour higher mite loads than countries from Northern Europe (DE, PL).

Where it was analysed, selection effort on mite population development (MPD) was significant, with MPD lines showing lower mite levels than unselected colonies. Instead, lines originating from natural selection programs did not show a trend for lower levels of mite infestation compared to the other lines.

Traits linked with varroa-resistance were tested within the EurBeST project: hygienic behaviour in all PT apiaries, and VSH, REC and SMR in some PT apiaries. Results show that environment had a major effect on the expression of all resistance traits. The only trait that differed between lines and subspecies is hygienic behaviour, highlighting the effect of selection that several lines had already been subjected to for some time, while the other traits have only recently been the object of investigation.

Positive relationships were found between VSH and recapping, as well as VSH and hygienic behaviour which suggests a good mutual relationship between these traits.

While for recapping there was no correlation with adult bee infestation, both VSH and hygienic behaviour were negatively correlated with varroa infestation, meaning that colonies with high levels of VSH or hygienic behaviour have lower infestation rates of bees. Therefore, selection towards increasing the expression of those traits may contribute to reduce infestation of colonies. Correlations of VSH, REC and hygienic behaviour with SMR were not significant. As expected, a positive correlation was found between brood infestation and adult bee infestation.

As integral part of the EurBeST study, we performed the first economic analysis of the costs of honey bee selection, consisting of the basic elements of the breeding cycle (queen production, mating, colony evaluation and estimation of breeding values), and including the costs incurring for selection towards improved varroa resistance. In addition, we estimated the costs and benefits of use of stock selected for improved varroa resistance vs. the commonly used own stock in commercial beekeeping operations.

The average costs for queen production amount to 22.58 € per queen, with the main share of costs originating from labour, which significantly varies between countries. The average selling price per queen was 23.32 €. The difference between the selling price and the production price is on average 3.08 € per queen, ranging from 15.86 € to -12.3 €. We found that in Germany, Poland and Greece there is a positive balance, while in France and Italy the selling price does not compensate the cost of production. The negative balance results from the combined effect of high production costs and a low selling price per queen.

Colony evaluation costs average at 193 €, ranging from 273 € in Germany to 85 € in Greece. The differences are primarily the result of national labour market conditions and labour costs. The main costs of colony evaluation derive from assessing the varroa resistance traits. Varroa infestation monitoring and testing hygienic behaviour together reach almost 20%, while the highest share of the colony evaluation costs, with more than 60% of the total, results from assessing the SMR & REC and VSH traits. The colony basic performance testing costs amount to about 20% of the total colony evaluation costs. The average costs for breeding evaluation per one queen are 8.09 €. Finally, the average cost for a queen that has undergone selection in a breeding program is on average 224 €.

Lastly, to evaluate the economic worth of using stock selected for varroa resistance, a cost-benefit analysis was performed. To calculate the economic consequences of different levels of mite infestation, a 10% increase of colony mortality in the following winter per infestation increase of 1 mite/10 g of bees in summer was assumed. The model demonstrates the cost-benefit effects of different mite susceptibility levels based on the assumption that the beekeeper is realising a treatment-free colony management concept. Out of the thirteen lines for which this analysis was performed, eight lines showed that their use would give the beekeeper a positive gain.

The results of the EurBeST study underline the importance of selective breeding of honey bees to achieve the goals of the EU Green Deal, specifically of the Farm to Fork and Biodiversity strategies.

Based on the findings of the study, we develop the following recommendations for:

Queen breeders:

- Invest in high-quality output and continuously improve their knowledge and skills to optimise their production routines.
- Enhanced cooperation between queen breeders, performance testers and scientific breeding centres is needed to substantially improve the genetic traits of reproductive material and to ensure that breeding stock with good local adaptation is made available to the customers.

Commercial beekeepers:

- The use of well-selected breeding stock is a major factor of economic success in commercial beekeeping!
- Strong interactions between genotypes and local conditions prevail.
- Because of these strong interactions, it is recommendable to obtain stock from breeders in the same region, selected under similar colony management conditions.

Selection programs and performance testers:

- To be successful, breeding programs need to be clearly defined and consistently followed over long periods.
- Selection has to address the local environmental and management related conditions to develop well-adapted genotypes.
- Considering the correlation found between reduced varroa infestation and hygiene behaviour, together with the comparatively easy to perform and economic testing methods for this trait, it seems worthwhile to promote hygiene behaviour for wide-scale testing.

Politicians and public authorities:

- Selection of honey bees in general, and selection for improved mite resistance in particular, is an efficient way to increase the productivity, to reduce colony losses and to improve bee health.
- Improvement of the breeding sector highly depends on scientific support. Selection criteria for resistance can be further optimised, and introduction and implementation of new techniques like genetic markers and breeding value estimation can contribute to an increased selection success.
- As the costs for specific selection methods for improved mite resistance are quite high and difficult to cover with the market price of queens, public funding of some well-defined selection activities is recommendable to enhance and accelerate selection success.

Project team

Landesbetrieb Landwirtschaft Hessen Bieneninstitut Kirchhain (LLH)
https://www.llh.hessen.de/bildung/bieneninstitut-kirchhain/
Coordinator: Dr. Ralph Büchler, ralph.buechler@llh.hessen.de

INRA Centre de Recherche Provence-Alpes-Côted'Azur (INRA) www.inrae.fr/en

Council for Agricultural Re-search and Economics – Research Centre for Agriculture
www.crea.gov.it/en/home

ConsulTech GmbH (CT) www.consultech.de

Project duration 18.12.2017 - 18.6.2021
AGRI-2017-0346 www.eurbest.eu

GETTING IN TOUCH WITH THE EU

In person

All over the European Union there are hundreds of Europe Direct information centres. You can find the address of the centre nearest you at: https://europa.eu/european-union/contact_en

On the phone or by email

Europe Direct is a service that answers your questions about the European Union. You can contact this service: – by freephone: 00 800 6 7 8 9 10 11 (certain operators may charge for these calls), – at the following standard number: +32 22999696, or – by email via: https://europa.eu/european-union/contact_en

FINDING INFORMATION ABOUT THE EU

Online

Information about the European Union in all the official languages of the EU is available on the Europa website at: https://europa.eu/european-union/index_en

EU publications

You can download or order free and priced EU publications from: https://publications.europa.eu/en/publications. Multiple copies of free publications may be obtained by contacting Europe Direct or your local information centre (see https://europa.eu/european-union/contact_en).

EU law and related documents

For access to legal information from the EU, including all EU law since 1952 in all the official language versions, go to EUR-Lex at: http://eur-lex.europa.eu

Open data from the EU

The EU Open Data Portal (http://data.europa.eu/euodp/en) provides access to datasets from the EU. Data can be downloaded and reused for free, for both commercial and non-commercial purposes.

KF-02-21-040-EN-N

Publications Office
of the European Union

doi: 10.2762/452476

ISBN: 978-92-76-28919-7