

In 2017, 2022 (2x) en 2023 zijn er vier artikelen verschenen in Bee World over selectieprogramma's bij honingbijen.

Als je belangstelling hebt kun je ze opvragen bij info@beebreed.nl.

ARTICLE

The Basic Concept of Honey Bee Breeding Programs

A. Uzunov, E. W. Brascamp and R. Büchler

Selective honey bee breeding is a phenomenon that fascinates beekeepers around the world. They often regard one of the most enigmatic and complex aspects of beekeeping. Indeed, according to our experiences participating in international projects, both beekeepers and bee experts without a background in plant or animal breeding often have trouble correctly interpreting and conceptually visualizing the breeding process. These difficulties arise partly because of the complex reproductive biology of honey bees, where queens mate with a multitude of drones. Fundamental difficulties are the greatest struggle for people to understand how selection of animals with particular characteristics in one generation leads to improved progeny in the next.

The leading misconception regarding honey bee breeding is confusing it with the simple rearing and multiplication of queens, where individual queens are evaluated predominantly by their laying ability and body size. These markers of queen quality (fecundity and size) are certainly important for the propagation of queens, but selective breeding requires more than propagation. Selective breeding implies the intentional selection for genetic improvement of the population as a whole, with every generation improved compared to the previous one ideally for all traits of interest.



Figure 1. Elements of a breeding program for selecting towards the breeding generation for performance testing. The diagram shows the flow from selection to breeding and then to the brood population.

ARTICLE

Initiation and Implementation of Honey Bee Breeding Programs

Aleksandar Uzunov, Evert W. Brascamp, Manuel Du and Ralph Büchler

As usual in science, where one answer raises new questions, following our attempt to demystify the basic concept of honey bee breeding with our article *The Basic Concept of Honey Bee Breeding Programs* (Uzunov et al., 2017) several questions were raised on details about the implementation of a breeding program.

Aspects, such as prioritisation of the traits to select for, selection using breeding values, time management of the breeding program, and mating control, prevailed most intriguingly and are indeed aspects which previously only limited attention has been given. These particular and relevant questions indicate, however, that the message from our previous article reached our target group. This time, we will address in more detail trait prioritisation, the timing of a breeding program and the selection process. Mating control will only be addressed in a general sense

Trait Prioritisation
"Which traits should I choose to improve?" is the most important question as it determines the direction in which traits will change over generations by selection. It is the first step towards the initiation of a breeding program, together with the recording of these traits to allow selection.

Based upon experience and subjective sense, beekeepers have been selecting bees for a very long time, though perhaps not fully systematically. However, with the ground-breaking invention of movable frames over a century ago, that allowed direct access to the queen and her easy replacement, selection of honey bees advanced. It did not only allow easy exchange of the queen, which also meant a change of the genetic composition of the colony, but also enabled a better scientific understanding of the enigmatic biology and in particular the reproductive biology and genetics of honey bees. With such tools at disposal, beekeepers started

ARTICLE

The Relevance of Mating Control for Successful Implementation of Honey Bee Breeding Programs

Aleksandar Uzunov, Evert W. Brascamp, Manuel Du and Ralph Büchler

This article mainly focuses on the challenges associated with implementing mating control and is the next in line of the series on the concepts of honey bee breeding programs that puzzle many beekeepers around the globe (Uzunov et al., 2017, 2022).

A few years after initiating a breeding program, the honey bee breeders and beekeepers mastered the performance testing and data collection and, with help from a breeding expert, have learned how to select queens based on the list of their estimated breeding values. But, of course, that experience comes with practice, training, and access to tailored guidelines (Büchler et al., 2013; Uzunov et al., 2015). Nevertheless, mating control appears the most complex step towards completing breeding (Uzunov et al., 2017). Unfortunately, when initiating or rebooting breeding programs during the SMARTBEEES-project for many honey bee populations around Europe, this challenge of mating control was installed quite late or was still missing even after a few generations of performance testing. Examples of such circumstances are the breeding programs in Malta (*Apis mellifera ratti-*ner), the Basque Country in Spain (*A. m. iberiensis*), Macedonia (*A. m. macedonica*, Figure 1), Greece (*A. m. macedonica*, *A. m. cecropia*, and *A. m. adami*), and other regions where mating control, due to a lack of expertise, financial and/or logistic reasons, was still in the "primordial stage". In contrast, mating control, employing mating stations, and instrumental insemination has been well-known and a long-standing practice in honey bee breeding programs in Germany, Austria, Switzerland, Poland, and the USA (Cobey et al., 2013).

Why
For many reasons, mating control is often a challenge for beekeepers. One reason is that the use of breeding values is more complicated than in farm animals. This is because controlled mating is a challenge (Uzunov et al., 2022b), and queens are mated to several drones from multiple queens. Moreover, traits like honey yield and varroa resistance are not measured on single bees but on colonies as a group of related individuals (known as superorganisms) from two generations (mother and daughters).

This paper starts by explaining the meaning of breeding values and finishes by discussing how to utilize estimated breeding values in honey bee breeding.

Phenotypes and Breeding Values
The phenotype measured on a colony, for example honey yield or hygienic behaviour, is influenced by the genetic qualities of the workers and the queen and by environmental factors. This is illustrated in Figure 1. Unlike environmental effects, genetic qualities are passed on over generations and thus are valuable for breeding. Hence, the genetic contribution to the phenotype is commonly called the breeding value. For honey yield, for example, the breeding value of the queen

other scarce of genome with keeping record for their own. On running to mating insert and finally expert play a role of mating control.

Why
For many reasons, mating control is often a challenge for beekeepers. One reason is that the use of breeding values is more complicated than in farm animals. This is because controlled mating is a challenge (Uzunov et al., 2022b), and queens are mated to several drones from multiple queens. Moreover, traits like honey yield and varroa resistance are not measured on single bees but on colonies as a group of related individuals (known as superorganisms) from two generations (mother and daughters).

This paper starts by explaining the meaning of breeding values and finishes by discussing how to utilize estimated breeding values in honey bee breeding.

REVIEW ARTICLE

Breeding Values in Honey Bees

Aleksandar Uzunov, Evert W. Brascamp, Manuel Du, Piter Bijma and Ralph Büchler

Introduction
This article continues our series on the basics of honey bee breeding (Uzunov et al., 2017, 2022a, 2022b). Its purpose is to introduce the background and application of breeding values in honey bees to a reader that is not trained in quantitative genetics. Breeding values are currently not widely used in honey bee breeding. This is in contrast to farm animals, where nearly all breeding programs make use of breeding values. The limited use of breeding values in honey bees has various reasons. One reason is that many honey bee programs just aim at the multiplication of stock obtained from other breeders instead of gradually improving the population. However, for honey bee breeding programs that aim to improve the population, not using breeding values seems a missed opportunity. A second reason is that the use of breeding values is more complicated than in farm animals. This is because controlled mating is a challenge (Uzunov et al., 2022b), and queens are mated to several drones from multiple queens. Moreover, traits like honey yield and varroa resistance are not measured on single bees but on colonies as a group of related individuals (known as superorganisms) from two generations (mother and daughters).

Basics: TBV Meaning and Variability
The true breeding value of a queen is the genetic effect she transmits to her progeny for a certain trait, for example gentleness or suppressed mite reproduction. TBVs are typically defined relative to an average of zero. So, a TBV of 0.4 points for gentleness (scored from 1-4) means that one can expect the colony to score 0.4 points higher for gentleness than an average colony in the same environment. Correspondingly, a TBV of -0.2 points means that the expected gentleness of the colony is 0.2 points below average.

The TBV of a honey bee is the sum of the effects of many genes (Lynch & Walsh, 1998). These genes are distributed over the 16 chromosomes of honey bees. Because drones are haploid, they have only one copy of each of the 16 chromosomes and only one allele of each gene. Each drone inherits half of his mother's alleles. In contrast, queens and workers are diploid, and have 16 pairs of chromosomes, each of the two chromosomes of a pair carrying one allele. So, queens and workers have two alleles of each gene. Two chromosomes forming a pair (and thus containing information for the same genes) are called homologous chromosomes.

Each female egg produced by a queen contains one of her own alleles for each gene, the other allele comes from one of the drones she mated. Which of the two alleles of a queen is transmitted to her eggs is determined at random, as was discovered by Mendel (1866, random segregation). When a queen produces eggs, her contributing homologous chromosomes exchange material. This is called recombination. For this reason, all eggs consist of mixtures of homologous chromosomes. Because of random segregation and recombination, all eggs of a queen are genetically different. The transmitted alleles can be more or less beneficial for the traits they affect, leading to variability among progeny.

In queens and workers, this variability is further increased because the drones mating to a queen usually descend from multiple queens. Figure 2 shows the variability in TBV for gentleness among virgin queens raised from a single average colony (mean TBV = 0). The average TBV of the daughters is zero, but some will be better and others worse. The wide orange curve in Figure 2 shows TBV of virgin queens raised from a colony with a queen that was mated to drones produced by 10 sister queens. A substantial number of them will have a TBV over 0.2 points or under -0.2 points. The narrower blue curve shows the result for single drone insemination. Here the variation in TBV of virgin queens is smaller, and extreme TBVs are rare. However, there is still considerable variation because of the differences in the queen alleles transmitted to her eggs.