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# GENETİC DİVERSİTY AND GENERATİONAL SELECTİON İN BEES

# ARILARDA GENETİK ÇEŞİTLİLİK VE NESİL SEÇİLİM[1]

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## ÖZ

Bu çalışma, arılarda (Apis mellifera) genetik çeşitliliğin korunması ve nesil seçilim süreçlerinin arıcılığa etkilerini incelemektedir. Arılar, ekosistemlerde önemli bir tozlayıcı rolü oynarken, iklim değişikliği, habitat kaybı, hastalıklar ve parazitler gibi çeşitli tehditlerle karşı karşıyadır. Genetik çeşitlilik, arı popülasyonlarının çevresel değişimlere uyum sağlamasını, hastalıklara karşı direnç geliştirmesini ve genel koloninin sağlıklı kalmasını sağlayan temel bir faktördür. Çalışma kapsamında, arıların genetik yapısını korumak için doğal ve yapay seçilim süreçleri, hibritleme ve genetik belirteçler gibi modern ıslah teknikleri ele alınmıştır. Bal üretimi, koloni sağlığı, hastalıklara karşı direnç ve çevresel adaptasyon açısından, seçilim süreçlerinin sürdürülebilir arıcılık uygulamalarında kritik bir öneme sahip olduğu görülmüştür. Özellikle kontrollü çiftleşme, suni tohumlama ve genetik analizlerin, istenilen genetik özelliklerin aktarılmasında büyük bir avantaj sunduğu belirlenmiştir. Sonuç olarak, arıcılıkta genetik çeşitliliğin korunması ve dengeli nesil seçilim yöntemlerinin uygulanması, uzun vadeli sürdürülebilirlik açısından vazgeçilmez bir gereklilik olarak öne çıkmaktadır.

*Anahtar Kelimeler*:. Genetik Çeşitlilik, Nesil Seçilim, Arı Islahı, Hastalık Direnci, Sürdürülebilir Arıcılık, Kontrollü Çiftleşme, Yapay Seçilim

## ABSTRACT

*This study examines the effects of genetic diversity conservation and generation selection processes on beekeeping in bees (Apis mellifera). Bees play an important pollinator role in ecosystems and face various threats such as climate change, habitat loss, diseases and parasites. Genetic diversity is a key factor that enables bee populations to adapt to environmental changes, develop resistance to diseases and maintain the overall colony health. Within the scope of the study, modern breeding techniques such as natural and artificial selection processes, hybridization and genetic markers were discussed to preserve the genetic structure of bees. It was observed that selection processes have a critical importance in sustainable beekeeping practices in terms of honey production, colony health, resistance to diseases and environmental adaptation. It was determined that especially controlled mating, artificial insemination and genetic analyses provide a great advantage in transferring the desired genetic traits. As a result, the conservation of genetic diversity and the application of balanced generation selection methods in beekeeping stand out as an indispensable requirement for long-term sustainability.*

*Keywords*:. Genetic Diversity, Generation Selection, Bee Breeding, Disease Resistance, Sustainable Beekeeping, Controlled Mating, Artificial Selection

## INTRODUCTION

Bees (Apis mellifera) are pollinators of great importance for the sustainability of ecosystems and play a critical role in the continuity of agricultural production worldwide. However, in recent years, various environmental and biological threats such as climate change, habitat loss, pesticides, parasites and diseases have seriously affected bee populations (Van Engelsdorp & Meixner, 2010). These negativities endanger not only natural ecosystems but also honey production and agricultural productivity. In order for bee colonies to become

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resilient to these threats and to maintain their populations, preservation of genetic diversity and application of generation selection methods have become a great necessity (Panziera et al., 2022).

Genetic diversity is defined as the variety of genetic variations of individuals within a species and plays a critical role in the adaptation of organisms to environmental changes, development of resistance to diseases and maintenance of general population health (Frankham, Ballou, & Briscoe, 2010). In bees, colonies with high genetic diversity become more resistant to diseases, more productive, and more resistant to ecological stresses (Tarpy, 2003). In addition, reduced genetic diversity can accelerate the spread of diseases that can cause mass bee deaths, such as colony collapse (CCD) (Van Engelsdorp et al., 2009).

In beekeeping, generational selection and genetic breeding methods are the most important approaches used to ensure that desired traits are transferred from one generation to the next. These processes strengthen commercially and ecologically advantageous traits, such as high honey production, disease resistance, good wintering ability, and calm temperament (Brascamp, Uzunov, Bijma, & Du, 2024). While natural selection ensures that the most resistant individuals survive due to environmental pressures, artificial selection and controlled mating programs aim to produce and reproduce bees with specific genetic characteristics (Bienefeld, 2016). However, over-selection and breeding with a narrow gene pool can lead to a decrease in genetic diversity, making colonies more vulnerable to diseases and environmental stressors (Awodiran, Amoo, & Kehinde, 2021).

This study will discuss the genetic diversity of bees and the effects of generation selection processes on beekeeping. In particular, it focuses on why genetic diversity is important to preserve, how generation selection and breeding methods are applied, and how modern genetic analysis techniques contribute to beekeeping. Finally, it discusses the best strategies for the sustainable conservation of bee populations and the future development of beekeeping.

## GENETIC DIVERSITY IN BEES

Bees (Apis mellifera) are major pollinators that are of great importance for the sustainability of ecosystems (Goulson, Nicholls, Botías, & Rotheray, 2015). However, factors such as habitat loss, climate change, agricultural chemicals, and diseases threaten bee populations (Van Engelsdorp & Meixner, 2010). In order for bees to develop resistance to these environmental stress factors, genetic diversity must be preserved and increased.

Genetic diversity refers to the presence of genetic variation among individuals within a species and plays a critical role in the adaptation process (Frankham, Ballou, & Briscoe, 2010). High genetic diversity in bee populations supports colonies to be resistant to diseases and better adapt to environmental changes (Tarpy, 2003). In this article, a comprehensive assessment of the sources, importance, and conservation of genetic diversity in bees will be made.

One of the most important sources of genetic diversity in bee colonies is polyandry, which is achieved by the queen bee mating with multiple male bees (Tarpy, 2003). Queen bees collect sperm by mating with an average of 12 to 20 different male bees during their mating flights (Baudry, Kryger, Allsopp, & Koeniger, 2004). Multiple matings create genetically diverse worker bees in the same colony, which increases the colony’s adaptability (Seeley & Tarpy, 2007). For example, colonies with greater genetic diversity are more resistant to pathogens such as American foulbrood (Paenibacillus larvae) (Tarpy & Seeley, 2006). Genetic diversity can also be achieved through gene flow between different populations. Bee colonies can exchange genetic material with bees in different regions through natural dispersal or human intervention (Meixner, Pinto, Bouga, Kryger, & Ivanova, 2013). For example, the Buckfast bee is a breed with characteristics such as high resistance to diseases and good honey production, and was created by crossing different subspecies (Ruttner, 1988). Such artificial hybridization programs are an effective method for increasing genetic diversity.

Mutations are permanent changes in the DNA sequence that allow the formation of new genetic variations (Hartl & Clark, 2007). Mutations in bees can lead to the evolution of individuals resistant to parasites, especially varroa mites (Varroa destructor) (Locke, 2016). For example, some bee populations have developed natural resistance to varroa mites. Russian bees (Apis mellifera caucasica) are preferred in some breeding programs in Europe because they are resistant to varroa mites (Rinderer, Harris, Hunt, & de Guzman, 2010).

One of the most important advantages of genetic diversity is that it provides higher resistance to diseases and pests (Tarpy, 2003). For example, genetically diverse colonies may be more resistant to intestinal parasites such as Nosema ceranae (Huang, Solter, Yau, & Imai, 2013). When genetic diversity decreases, colonies become more vulnerable to pathogens. For example, mass colony losses, known as Colony Collapse Disorder (CCD), are more common in populations with low genetic diversity (Van Engelsdorp et al., 2009). Genetic diversity can also affect the honey production capacity of bees. Colonies with high genetic diversity can perform better in terms of working speed, nectar collection ability, and endurance (Garnery, Solignac, Celebrano, & Cornuet, 1993). For example, the Carniolan bee (Apis mellifera carnica) is a widely preferred subspecies in Europe due to its high honey yield and good wintering ability.

Factors such as increased temperature fluctuations and droughts due to climate change make it more difficult for bee populations to survive (Le Conte & Navajas, 2008). Genetically diverse colonies are better able to adapt to temperature changes. For example, Apis mellifera scutellata, which originates from Africa, is more resistant to high temperatures and is therefore widespread in Africa and some tropical regions (Whitfield et al., 2006).

## GENERATION SELECTION AND BREEDING METHODS IN BEES

Selection of generations is the process of selecting individuals with superior qualities in order to ensure that certain genetic traits are passed on to future generations (Frankham, Ballou, & Briscoe, 2010). In beekeeping, generational selection focuses on traits such as high honey production, disease resistance, good wintering ability, and calm temperament (Büchler, Berg, & Le Conte, 2010).

The first stage of the generation selection process is to decide which genetic traits need to be developed. In beekeeping, the preferred traits are usually factors such as high honey production, resistance to diseases, long-lived worker bees, calm and docile temperament, wintering ability and adaptation to hot weather conditions (Seeley & Tarpy, 2007). For example, the Carniolan bee (Apis mellifera carnica), which is widely raised in Europe, stands out in the selection process due to its calm temperament and good wintering ability (Ruttner, 1988). Similarly, Russian bees are used in many breeding programs because they have developed natural resistance to the Varroa mite. Colonies with the targeted traits are determined by genetic analyses, behavioral observations and productivity measurements (Tarpy & Seeley, 2006). At this stage, criteria such as the colony's honey production, resistance to diseases, the egg-laying capacity of the queen bee and the endurance of the worker bees are taken into account. For example, if a colony is not infected with the diseases specified, but provides high honey production, this colony can be considered a suitable breeding source for the next generation. In modern beekeeping practices, techniques such as genetic marker analysis (microsatellite and SNP tests) allow for more sensitive and efficient selection in the generation selection process.

- After colonies suitable for selection are determined, controlled mating programs are implemented to ensure the reproduction of individuals with increased genetic superiority. Three basic methods are used in this process (Collins & Pettis, 2001):
- Natural Mating: The queen bee is allowed to mate with male bees with superior genetic characteristics in the natural environment.
- Controlled Mating Areas: Only male bees with desired genetic characteristics are kept in certain areas, preventing the queen from mating randomly.
- Artificial Insemination: Sperm is collected from genetically selected male bees in a laboratory environment and injected into the queen.

Newly produced colonies are monitored to see if they meet the specified goals. During this evaluation process, analyses such as disease tests, honey production measurements, worker bee lifespan and behavioral observations are performed (Meixner et al., 2013). If the selection process is successful, new generations are included in the breeding program to ensure continuity in breeding. However, if it is seen that the targeted traits are not fully developed, the selection criteria are reviewed and the process is repeated.

In the process of genetic selection, the narrowing of the mating pool can lead to a decrease in genetic diversity and to colonies becoming vulnerable to diseases (Van Engelsdorp & Meixner, 2010). Therefore, the preservation of different genetic lines and controlled mixing of generations are of great importance in breeding programs. For example, some beekeepers prevent the decrease in diversity by increasing colonies resistant to the Varroa mite while at the same time preserving genetic lines from different ecological regions.

The breeding methods used in bees aim to improve important features of colonies such as honey yield, disease resistance, adaptation to climatic conditions and productivity by increasing genetic diversity. While breeding by natural selection encourages the survival and reproduction of individuals that are best adapted to the environment, the artificial selection method allows the beekeeper to control the breeding process by selecting individuals with certain genetic characteristics. Hybridization creates more resistant and productive generations by mating different species, while controlled mating and artificial insemination methods include fertilization techniques performed in special mating areas or laboratory environments to ensure the preservation of desired genetic characteristics. Genetic analyses and DNA markers are widely used in modern breeding studies to increase the resistance of colonies to diseases and to maintain genetic purity. Thanks to these methods, the beekeeping sector has the opportunity to grow healthier, more productive and sustainable colonies.

**EFFECTS OF GENETIC DIVERSITY AND SELECTION ON BEEKEEPING**

Genetic diversity is a critical factor in beekeeping in terms of colonies' disease resistance, adaptation to environmental changes, and productivity. The presence of individuals with different genetic structures makes colonies more resistant to pathogens and climate changes. For example, colonies with high genetic diversity can develop better immunity to diseases such as Nosema ceranae and American foulbrood (Paenibacillus larvae) (Panziera et al., 2022). However, when genetic diversity decreases, colonies become more vulnerable to the spread of certain pathogens and the risk of mass colony losses increases (Tarpy, Caren, & Delaney, 2023).

The selection process enables the development of advantageous factors for beekeeping, such as high honey production, good wintering ability, calm temperament, and resistance to pests, by ensuring that certain traits are passed on from one generation to the next (Brascamp, Uzunov, Bijma, & Du, 2024). While natural selection ensures that the most resistant individuals survive due to environmental pressures, artificial selection aims to produce and reproduce individuals with certain genetic traits in a controlled manner. For example, selectively producing bee colonies resistant to pests such as the Varroa destructor mite is a strategy widely applied in the beekeeping industry (Bienefeld, 2016).

However, excessive control of the selection process can lead to narrowing of genetic diversity. As genetic diversity narrows in artificial breeding programs, bees may become more vulnerable to certain stress factors. For example, African honey bees (Apis mellifera scutellata) have evolved resistance to hot climates and pests through natural selection, but Carniolan bees (Apis mellifera carnica), common in Europe, have been bred through controlled artificial selection and may be more sensitive to environmental changes (Awodiran, Amoo, & Kehinde, 2021).

In modern beekeeping practices, molecular biology techniques such as microsatellite analysis, SNP detection, and genetic markers are used to optimize the genetic selection process. Thanks to these methods, disease-resistant individuals can be detected more quickly and precisely, thus preserving genetic diversity and supporting sustainable beekeeping (Gritsenko et al., 2023). However, for genetic breeding programs to be successful, not only productivity and disease resistance but also the preservation of genetic diversity should be taken into account (Tarpy, Caren, & Delaney, 2023).

As a result, preserving genetic diversity in beekeeping and implementing a balanced selection process ensures that colonies become healthy, productive, and adaptable to environmental changes. While the balanced use of natural and artificial selection methods contributes to the creation of colonies that are resistant to diseases and provide high honey production, preserving genetic diversity stands out as a critical requirement for long-term sustainable beekeeping.

## 5. CONCLUSION

This study analyzed the effects of preserving genetic diversity in bees and generation selection processes on beekeeping. Genetic diversity has been evaluated as a critical element in terms of bee populations gaining resistance to diseases, adapting to environmental changes and increasing their productive capacity. The study found that the multiple mating (polyandry) strategy of the queen bee increases genetic diversity in colonies, making bees more resistant to diseases and pests. In particular, it was observed that colonies resistant to pathogens such as American foulbrood (Paenibacillus larvae) and Nosema ceranae were more common in populations with high genetic diversity. The study also detailed how generation selection processes are used to increase productivity in beekeeping. It has been shown that it is possible to develop desired traits in beekeeping, such as high honey production, wintering ability, calm temperament and resistance to pests, through natural and artificial selection methods. In particular, it has been determined that controlled mating and artificial insemination techniques are effective in transferring desired genetic traits from one generation to the next.

However, it has been emphasized that excessive artificial selection can narrow genetic diversity, making colonies more vulnerable to certain diseases and environmental stress factors.

It has been revealed that the use of molecular genetic analyses (such as microsatellite analysis, SNP detection and genetic markers) has increased in modern beekeeping practices and that these methods offer a great advantage in increasing disease resistance and productivity in bee colonies. The study concluded that increasing genetic diversity by preserving and using genetic material from different ecological regions is important in terms of ensuring sustainability in beekeeping.

As a result, it has been determined that genetic diversity should be protected and a balanced generation selection process should be implemented in order to protect bee populations in the long term and to continue beekeeping in a sustainable manner. While the balanced use of natural and artificial selection methods contributes to the creation of colonies that are resistant to diseases and provide high honey production, the preservation of genetic diversity stands out as a critical requirement for long-term sustainable beekeeping.

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