BEE and PLANT

EDITORS
Prof. Dr. Nuray ŞAHİNLER
Assoc. Prof. Dr. Ayşen Melda ÇOLAK

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Prof. Dr. Nuray ŞAHİNLER[1]
Assoc. Prof. Dr. Ayşen Melda ÇOLAK[2]

AUTHORS
Prof. Dr. Nuray ŞAHİNLER
Assoc. Prof. Dr. Ayşen Melda ÇOLAK
Assoc. Prof. Dr. Aziz GÜL
Assoc. Prof. Dr. Gonca ÖZMEN ÖZBAKIR
Assoc. Prof. Dr. Mahir Murat CENGİZ
Assoc. Prof. Dr. Rahşan İVGİN TUNCA
Assoc. Prof. Dr. Sibel ALAPALA
Assist. Prof. Dr. Alaeddin YÖRÜK
Assist. Prof. Dr. Dilek KABAKCI
Lecturer Dr. Fatma ALAN

İKSAD
Publishing House

[1] Uşak University, Faculty of Agriculture, Department of Animal Science, Uşak, Türkiye, nuray.sahinler@usak.edu.tr, Orcid ID 0000-0003-4999-773X
[2] Uşak University, Faculty of Agriculture, Department of Horticulture, Uşak, Türkiye. aysenmelda.colak@usak.edu.tr, Orcid ID: 0000-0003-0113-2104

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TÜRKİYE TR: +90 342 606 06 75
USA: +1 631 685 0 853
E mail: iksadyayinevi@gmail.com
www.iksadyayinevi.com

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PREFACE

Nowadays, when the world population is rapidly increasing and food resources and agricultural areas are decreasing, agriculture is at the forefront among strategic areas. Beekeeping is an important branch of agricultural activity that provides pollination in plant production and increases productivity and quality, as well as producing products important for our nutrition and health. For all these reasons, beekeeping activities and scientific studies have gained significant momentum.

In recent years, beekeeping has been faced with a number of problems such as climate change, environmental pollution, intensive and unconscious use of pesticides, mass colony losses, and decreased productivity.

We know very well that beekeeping activities are important for the continuity of our world and humanity. In this sense, the book "Bee and Plant" covers different topics of beekeeping such as honey bee behavior, molecular studies in beekeeping, artificial insemination and productivity.

The chapters in the Bee and Plant Book are written in a simple, understandable manner by scientists who are experts in their fields, and are prepared for academicians, undergraduate and graduate students, and beekeepers in the sector.

We would like to thank all the chapter authors who prepared the book with great care and meticulousness to contribute to the beekeeping industry.

EDITORS

CHAPTER 1

GENE EXPRESSION STUDIES IN HONEY BEES

(*Apis mellifera* L.)

Assist. Prof. Dr. Dilek KABAKCI[1]
Prof. Dr. Nuray ŞAHİNLER[2]

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[1] Muş Alparslan University, Faculty of Applied Sciences, Department of Animal Production and Technologies, Muş, Türkiye. d.kabakci@alparslan.edu.tr, Orcid ID: 0000-0002-3296-0394

[2] Uşak University, Faculty of Agriculture, Department of Animal Science, Uşak, Türkiye, nuray.sahinler@usak.edu.tr, Orcid ID 0000-0003-4999-773X

INTRODUCTION

Pollination is important for the continuity of the ecosystem. Insects, and bees in particular, are considered the most important living group that plays a role in pollination. Therefore, the ecosystem is crucial for maintaining a high level of agricultural production and the persistence of many plant species (Klein et al., 2007; Rader et al., 2014; Ollerton et al., 2011). According to data, 75% of the agricultural products produced worldwide are supplied by pollinator insects (Klein et al., 2007; Chaplin-Kramer et al., 2014). Honey bees (*Apis mellifera*) are economically important pollinators of plants and plant products in nature (Schulte et al., 2013). The honeybee plays an important role in people's access to honey and other foods and is considered the most suitable pollinator (Kadiroğlu and Çetin, 2021; Alberoni et al., 2016). Over the course of their lives, animals exhibit various behaviors related to feeding, reproduction and care of offspring. Behavior as a function of morphological traits shows great flexibility in real time and variability over the course of evolution (Wcislo, 1989; West–Eberhard, 1989). The behavior of living organisms is variable because it is both stable and flexible. While animals exhibit a certain behavior at all times, they can switch to different behavioral states as needed. Both hereditary and environmental factors are known to interact to influence behavior (Anholt et al., 2004; Robinson, 2008; Robinson, 2004). Pheromones, which are effectively used by honeybees, are very important chemical compounds in animal communication.

It has been reported that the effect of brood pheromones on behavioral traits causes changes in the expression of one hundreds genes in bee brain (Alaux et al., 2009). Pheromones produce behavioral effects by inducing changes in the brain's neuronal response thresholds to environmental conditions, and they are very important for understanding the effects of environmental conditions on behavioral mechanism (Wyatt, 2003). There are also genetic differences between honey bees in their ability to tolerate the Varroa parasite. Microarray analyzes of different in *Apis mellifera* gene expression due to genotypic different in both mite parasitism and bee tolerance have been reported (Navajas et al., 2008). Any researchers around the world have determined the metabolic effects of synthetic acaricides on honey bees in beekeeping (Pareja et al., 2011; Orantes-Bermejo et al., 2010; Mullin et al., 2003; 2010; Chauzat and Faucon, 2007; Martel et al., 2007; Maver and Poklukar, 2003; Lodesani et al., 2003; Bogdanov et al., 1997).

1. Studies on Behavioral Mechanism

Behavioral genetics clearly reveals the genetic differences in the natural behavior of living beings. In the last 20 to 30 years, some geneticists have succeeded in determining the number of genomic regions associated with behavioral differences, while other researchers have identified differences in the effects of specific genes, such as neuropeptides, on behavior (Hoekstraa and Robinson., 2022). The honeybee (*Apis mellifera*) is considered to be the most suitable creature for carrying out the standard study protocol under controlled conditions (Denton, 2021; Giurfa, 2012). While traits such as viability, overwintering ability, adult bee development, brood area development, weight gain during the nectar period in the hive, flight efficiency and honey yield are defined as physiological traits in honey bees, traits such as pugnacity tendency, scavenging tendency, swarming tendency and propolis collection tendency are defined as behavioral traits (Ruttner, 1988). In their study, Fahad Raza et al. (2022) investigated the sense of smell and learning ability of Apis mellifera ligustica honeybees using the PER protocol. The researchers compared the difference in learning ability between learning and non-learning bees in an RNA-Seq transcriptome analysis. The study identified 57 regulated genes in the brains of learning bees and 17 genes and a total of 74 gene regions in non-learning bees. As a result of the study, genes regulating brain storage proteins, brain development, sensory learning and neurodegenerative disorders were found to cause brain shrinkage in non-learning bees. In this way, the learning mechanism in honey bees was determined using molecular methods. In their research, Lutz and Robinson (2013) found that field bees make exploratory flights to discover the hive and the flowering area. They found that the Egr-1 gene is active in honeybees from an early age and that this gene makes learning in bees more effective. Rittschof and Robinson (2013) conducted a study to determine colony development and expression levels of genes that regulate fighting ability in African honeybee species. As a result of the study, it was found that 4 gene regions are effective in regulating aggressiveness in honey bees and that there is a statistical increase in expression levels. Later, Richard et al. (2012) In their study, they found that social insects such as honeybees show physiological and behavioral responses to parasites and pathogens. They also reported that they use behavioral responses to defensive their hives against parasites and pathogens. These behaviors are hygiene behavior and grooming behavior. They found that immune stimulation in honey bees leads to changes in the cuticular hydrocarbon profile of worker bees and that this alters the social interactions of worker bees. These cuticular hydrocarbons enable the worker bees to recognize sick bees and regulate their behavior accordingly. The study found chemical and genomic differences in the behavioral responses to different immunostimulants. As a result, the study identified changes in hundreds of genes involved in immune stimulation and many nominee genes that may play a role in the biosynthesis of cuticular hydrocarbons. Alaux et al. (2009) Look over the effects of the environment on the aggressive behavior of various honey bee species. They reported that African honey bees and European honey bees differ in terms of their aggressiveness. In the study, they also found that the level of aggressiveness varies among bees of different age groups. Using molecular methods, they found that aggressive behavior in honey bees is controlled differently by genes depending on species and age. Alaux et al.

(2009) conducted a study with forager and brood care bees to determine the level of gene expression in the brain during the regulation of brood pheromone in honey bees. Alaux et al. (2009) conducted a study with forager and brood care bees to determine the level of gene expression in the brain during the regulation of brood pheromone in honey bees. In the study, an increased expression level was found in a total of 96 gene regions in 227 gene regions in bees of different age groups exposed to brood pheromone for 5 days, while a decreased expression level was found in 131 gene regions. The study found an increase in 122 gene regions and a decrease in 106 gene regions out of a total of 228 genes in bees exposed to brood pheromone for 15 days. As a result of the study, a statistically significant expression level was found in 19 gene regions at 5 and 15 days of exposure. Sen Sarma et al. (2007) also investigated the expression level of genes related to honeybee functions within the colony and their communication behavior in the species *A. cerana, A. florea* and *A. dorsata*. In the study, the difference between gene expression in the brains of field bees and one-day-old worker bees was determined. The result of the study was that although differences were found in 1772 gene regions between field bees and one-day-old bees, no differences were found in 218 genes. Grozinger et al. (2003) found in their study that the queen bee's pheromone regulates the behavior of worker bees. The researchers created living conditions in the incubator by placing 35 worker bees in cages. Bees of different age groups, including nurse bees and field bees, were used for the study. The study found a statistically significant expression level between the kr -h1 genes that regulate the behavior of nurse and field bees.

2. Studies on Ectoparasites and Pesticide

Following the sequencing of its genome, honey bee (*Apis mellifera* L.) has become very important a model organism for genetic studies (Consortium HGS, 2006). As it is a important pollinator insect in the world, its economic value is also increasing. Varroa destructor are ectoparasites of honey bees that parasitize larva land adult bees and breed in brood cells (Burget et al., 2004; Griffiths and Bowman, 1981). There are genetic different in the ability of honey bees to tolerate the Varroa *destructor*. Some honey bee colonies tolerate the Varroa parasite and survive despite the present of the mite in the hive. Several factors are thought to be responsible for these differences, as brood nurse and hygienic behavior, as well as different in the timing of larval and pupal development, which influence parasite reproduction (Le Conte et al., 2007; Sammataro et al., 2000; Fries et al., 1994; Moritz, 1985). In the study conducted by Yıldız and Karabağ (2022), gene the expression levels of neuroxin-1, ataxin-3 and atlastin genes, which are thought to be related to grooming behavior in five different honey bee breeds (*Apis mellifera anatoliaca*, *Apis mellifera caucasica*, *Apis mellifera carnica*, *Apis mellifera ligustica*, *Apis mellifera syriaca*), were examined and statistical data were obtained. Significant differences were found. However, the study reported that the expression levels of neurexin-1, ataxin-3 and atlastin genes were similar in Syrian and Anatolian bees having grooming behavior. Morfin et al. (2020) compared the characteristics of the grooming behavior of Indian bees and Italian bees on the basis of their degrees of expression. The study also found that the AmNrx1 gene region had a higher gene expression level in Indian bees than in Italian bees and that AmNrx1 gene expression was positively associated with the proportion of fragmented mites in the selected colony. n their study, Hamiduzzaman et al. (2017) found that bees with strong grooming behavior showed high expression in the AmNrx1 gene region compared to bees that showed little or no grooming behavior. In their study, Boncristiani et al. (2012) used 5 different chemicals: Apiguard (thymol), Apistan (tau-fluvalinate), Checkmite (coumaphos), Miteaway (formic acid) and ApiVar (amitraz) to control varroa in honey bee colonies. The study found that 4 gene regions of detoxification genes (cytochrome p450 and protein kinases) were affected and the expression level of some of the Cyp gene regions increased and the expression level of others decreased. Increased expression of protein kinase genes was detected. Navajas et al. (2008) conducted the study by taking samples from a group of mite-infected pupae and from non-mite -infected pupae. The researchers determined the expression level in a total of 32 gene regions. While an increase was found in 15 of those exposed to Vaaro, a decrease was found in 17 gene regions. The only exception in the study was EST in varroa-infected bees. While this gene region was found to have a 20-fold increase in expression, it was found to be consistent with deformed wing virus, which is a honey bee virus.

CONCLUSION

Varroa destructor has a negative effect on the health of bee colonies and its control is necessary to prevent colony losses. However, there is no consensus on the best control method to avoid effects that reduce the mite but cause minimal damage to the host in the future. The studies conducted by many researchers show that the behavior of honey bees in controlling the Varroa mite changes over time and depending on the methods used. Breeding studies on honey bees in the world and in our country should focus on the hygienic behavior of bees that have developed tolerance to protect against Varroa, as well as bees with pupal cleansing abilities

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CHAPTER 2

MOLECULAR GENETIC BREEDING STUDIES IN BEEKEEPING

Assist. Prof. Dr. Dilek KABAKCI[1]
Prof. Dr. Nuray ŞAHİNLER[2]

DOI: https://dx.doi.org/10.5281/zenodo.13152275

[1] Muş Alparslan University, Faculty of Applied Sciences, Department of Animal Production and Technologies, Muş, Türkiye. d.kabakci@alparslan.edu.tr, Orcid ID: 0000-0002-3296-0394
[2] Uşak University, Faculty of Agriculture, Department of Animal Science, Uşak, Türkiye, nuray.sahinler@usak.edu.tr, Orcid ID 0000-0003-4999-773X

INTRODUCTION

Although the exact date of the emergence of honeybees is not known, it is assumed that they first appeared on the African continent around 80 million years ago. In recent years, genetic studies have been carried out which show that the emergence of honeybees coincided with the emergence of flowering plants, and it has been reported that honeybees reached their present form around 30 million years ago. Of the approximately 1.2 million known insect species, the honey bee (*Apis mellifera* L.) is one of the insect species on which the most scientific research has been carried out. The honey bee (*Apis mellifera*) is considered to be the species with the greatest economic and ecological value among the 11 species of the genus Apis. Honey bees, which are the most important group among beneficial insect species, not only provide income to many farmers by breeding them for their valuable products, but also make an important contribution to the agricultural sector due to their role in pollination. Honey bee (*Apis mellifera* L.); In addition to its products such as honey, beeswax, royal jelly and propolis (Güler, 2017), it is produced in agriculture for human consumption or in nature due to its contribution to the pollination of other plants in nature (Williams, 1996; Richards, 2001; Steffan-Dewenter et al., 2005; Klein et al., 2007; Wright et al., 2018), it is an indispensable living being for agricultural production and thus for human nutrition and life (Maggi et al., 2016). Honey bees also play an important role in maintaining the ecological balance thanks to their role in pollination and the survival of many plant species. It is known that many plant species pollinated by honeybees are of great importance for human and animal nutrition (Bilgi, 2023; Tautz, 2008; Güler, 2017). Honey bees (*Apis mellifera* L.) are social organisms and a colony consists of individuals, including a single queen bee that can lay eggs, worker bees and drones (Tautz, 2008). Honey bees have attracted the attention of humans because they have developed surprising abilities and behaviors (Hunter and Kole, 2008; Tautz, 2008; Güler, 2017).

Honey bees have been able to survive on earth for thousands of years and have survived for centuries due to their high adaptability and the survival skills associated with this adaptation. Despite this adaptability and survivability, honeybees (*Apis mellifera* L.), like any living species, also have diseases and pests that cause a decrease in viability and low productivity, leading to economic losses and high levels of colony mortality if precautionary measures are not taken (Rinderer et al., 2010; Güler, 2017). These diseases and pests have been extensively controlled with pesticides worldwide over the last 65-70 years. With the use of pharmaceuticals against diseases and pests, pathogens and parasites resistant to pharmaceuticals have emerged and the efficacy of pharmaceuticals used against diseases and pests has decreased, leading to significant problems for human health due to drug residues in the products (Milani, 1999; Wallner, 1999; Mutinelli, 2000; Lodesani and Costa, 2005; Rinderer et al., 2010; Bıyık, 2019). Despite global disasters, some European honey bee populations have survived without being attacked. It has been reported that these populations have undergone natural selection against diseases and parasites and have shown one or more behaviors to resist them thanks to some physiological traits they possess (Seeley and Tarpy, 2007). Since the interaction between the host and the parasite is quite complex, it has been predicted that tolerance to the Varroa parasite may take the form of different behaviors. At this point, hygiene behavior (behavioral tolerance) has come to the fore. This term is used not only for the individual, but also for the bee colony (Boecking and Spivak 1999). Hygienic behavior is a social immunity trait in honey bees (*Apis mellifera* L.); in this way, workers recognize and remove unhealthy offspring and improve disease resistance within the colony (Guarna et al., 2017). This is economically valuable for beekeeping (Nganso et al., 2017). Hygienic behavior, a behavioral response of worker bees to infection, describes the process of opening the wax covering the cells of the combs with parasite-infected, diseased or dead offspring and rapidly removing the bees from the hive. Hygienic honey bee workers can recognize infected broods in closed brood cells and tend to quickly remove these broods from the hive. This behavior protects the bee colony from infections such as Varroa, American foulbrood (Paenibacillus larvae larvae) (Boecking and Spivak 1999) and chalk disease (Gilliam et al., 1988; Harbo and Harris, 2009; Alemli, 2019). Varroa is considered one of the many stress factors (Goulson et al., 2015) that lead to high bee losses worldwide. If Varroa is not combated, this represents a major economic burden for beekeepers, considering the colony losses caused by the pest and the financial resources required for the medication used to combat it. While healthy bee colonies and the bee products they produce make an important contribution to the pollination of plants and to the country's economy, the positive effect on the economy disappears with the increase in the number of weak, sick bee colonies or the collapse of bee colonies (İvgin Tunca et al., 2018).

The aim of this study is to provide information on breeding studies at the molecular level in colonies that have developed hygienic behavior and tolerance to Varroa parasites in honey bees.

1. Mechanism of Hygienic Behavior and Breeding Studies in Honey Bees (*Apis mellifera* L)

Eusocial insects represent the highest level of social organization in the animal kingdom. In a honeybee colony, a system has evolved in which the division of labor is carried out by the individual responsible for reproduction (queen bee) and all tasks such as brood care and feeding, honeycomb construction, field work and protection of the colony are carried out by worker bees. The harmony between all individuals in this system also explains the success of social insects (Hamilton, 1964). However, it can also reduce the fitness of individuals in the colonies, as the constant contact between closely related individuals also favors the transmission of diseases and parasites. In eusocial insects, the individual immune system is supported by a collective immune defense to reduce the risk of transmission (Wilson et al., 2009). For example, hygienic behavior in honey bees is an important behavior that contributes to the social immunity of colonies (Cremer et al., 2007). Hygienic behavior is defined as the detection of sick or dead offspring by the workers and their cleaning by throwing them out of the hive. Early studies on this behavior were limited to its effects on the transmission of bacterial foulbrood, American foulbrood (Rothenbuhler, 1964). However, later studies have shown that this behavior also limits the growth of fungal brood diseases (Gilliam, Taber, Lorenz, & Prest, 1988) and even to some extent the populations of invertebrate parasites (Boecking & Drescher,1992; Ellis et al., 2004). Hygienic behaviors can be genetically detected by bee individuals by sensing cues such as the odor of dead or dying individuals (Spivak and Gilliam 1993; Masterman et al., 2000; Spivak and Reuter 2001a; Gramacho and Spivak 2003). Hygienic behavior is important in eusocial insects because it reduces the transmission and multiplication of pathogens within a colony (Trumbo and Robinson 1997; Evans and Spivak 2010). The susceptibility of bees to diseases can be genetically determined. Different bee genotypes and ecotypes within different breeds: Ascosphera apis (Gilliam et al., 1988), American foulbrood (Rothenbuchler et al., 1956), Varroa destructor (Guzman et al., 1996), Acarapis woodi (Gary and Page, 1987), They have been found to have different susceptibility to parasites and pathogens such as Nosema apis (Woyciechowski et al., 1994). One of the many elements that determine the resistance of bees to disease is their hygienic behavior. Therefore, it is important to control this trait by using different methods to evaluate it (Olszewski et al., 2007; Olszewski et al., 2013). This trait is highly heritable and can be selected from many bee populations (Rotenbuchler, 1964; Büchler, 1996; Spivak and Reuter, 1998).

This resistance mechanism plays an important role in determining the extent of pathogens such as scion diseases and varroasis (Gilliam et al., 1983). The effectiveness of this resistance mechanism is determined by the bees developing hygienic behavior in the colony. Very hygienic bees were 25% more likely to increase the percentage of dead larvae from 26% to 46% than unhygienic bees (Arathi and Spivak, 2001). In addition to genetic variation in the population, which affects phenotypic diversity, there is also natural variation in the genotypes of the bees in the colonies. This natural diversity is a result of evolutionary developed multiple mating. Mating with multiple drones is important for natural selection. Without it, colonies cannot easily adapt to changing environmental conditions (Page and Robinson, 1991). In a genetic diversity theory, it has been reported by various researchers that genetic diversity in a honey bee colony increases resistance to disease (Sherman et al., 1988; Shykoff and Schmid-Hempel, 1991; Schmid-Hempel, 1998; Baer and Schmid-Hempel, 1999; Tarpy, 2003; Tarpy and Seeley, 2006; Seeley and Tarpy, 2007). Studies on hygienic behavior have reported that honey bee colonies that can remove 95% or more of dead offspring within 48 hours are considered hygienic (Toy, 2013). In the world and in our country, research has been conducted on the breeding of hygienic behavior of honey bees. Bilgin (2023) investigated the status of genetic diversity of Caucasian bee, Black Sea bee and Caucasian-Black Sea hybrid populations created by their hybridization, selected for hygienic behavior and bred in the Bee Breeding Research and Application Unit of Ondokuz Mayıs University Faculty of Agriculture. The SNPs related to hygienic behavior investigated in the study were found to be SNPs associated with both high and low hygienic behavior performance and were predominantly heterozygous in the populations. In his study, Gül et al., (2023) examined some breeds and ecotypes in Turkey according to their hygienic behavioral characteristics. In the study, the results of the hygienic tests performed between 2019 and 2021 were 96.47±2.52% and 96.88±3±66% for the Anatolian bees; 95.21±17.32 and 95.77% for the Gökçeada bee; 93.53±15.01% and 96.11±8.64% for the Hatay bee; 97.18±1.77% and 97.86±2.88% for the Kırklareli bee and 79.85±17.54% and 92.30±8.45% for the Düzce bee. The study of Bıyık (2019), aimed to determine the degree of change in this behavior in the fourth and fifth generations of the parent colonies of the Caucasian bee breed, to which three generations of selection were previously applied in terms of the phenotype of hygienic behavior. For this purpose, colonies of the Caucasian bee breed (*Apis mellifera caucasica Gorbatcshev*) were used, whose hygienic behavior was improved in three generations. It was found that the average number of dead pupae in the fourth and fifth generations was 158.30±0.63 and 159.90±0.71 pieces/pupa/colony, respectively. It was reported that the heritability coefficients calculated using mother-daughter regression and analysis of variance were 0.112±0.096, 0.032±0.024 and 0.60±0.25, 0.98±0.36 for the fourth and fifth generations, respectively. The broad significance (BSC) of heritability (h2) across generations was determined to be 0.33 and 0.12. In these two generations, a selection superiority (I) of 7.16 and 6.02 and a genetic improvement (ΔG) of 2.37 and 0.71 were determined. It was found that the average amount of dead pupae eliminated in the fourth and fifth generations was over 95%. Facchini et al. (2019) conducted a study in 2016 to determine the effects of killing brood by freezing in uncapped brood chambers and diseased colonies in colonies at the University of Milan on cleaning behaviour.

In the study, data was collected from 56 and 95 colonies in 2017 and 2018. The result of the study was that the young animals killed by freezing with liquid nitrogen were cleared in a shorter time and a correlation of 0.93 was established between the colonies. The correlation for single-year data is 0.64. They reported that the heritability (h2) for one-year data was 0.23 and 0.24, while the heritability (h2) for two-year data was 0.37. In their study, Gerula et al. (2015) mated queen bees conceived as sisters with sperm from male colonies that exhibited high hygienic behavior by artificial insemination. The aim of this study was to increase the rate of hygienic behavior by mating queen bees with low hygienic behavior and queen bees with high hygienic behavior. As a result of the study, it was found that the hygiene behavior rates of the colonies reached 52%, 47% and (63%). In the study conducted by Waith (2015) to determine the hygienic behavior of honey bees in England and Wales, 41 colonies were studied. In the research. They reported that 8 colonies showed 10% hygienic behavior, while most colonies showed largely hygienic behavior.

2. Mechanism of Varroa Tolerance in Honey Bees and Breeding Studies

Honey bees have great economic value as they contribute to the pollination of plant products as well as providing products that can be consumed directly (Greenleaf & Kremen, 2006; VanEngelsdorp & Meixner, 2010). For efficient pollination, it is important that the bee colony is healthy, but like other pollinator insects, honey bees also have a variety of parasites and pathogens (Genersch et al., 2010). Varroa, an ectoparasite of the honey bee, is deadly and poses the greatest threat to beekeeping. With this harmful effect, Varroa caused the death of millions of bee colonies and caused great economic losses (Ryabov et al., 2014). Varroa destructor is a parasite that can survive with a host in the eye of the offspring. Varroa females and their offspring feed on the hemolymph of pupae and adult honey bees, which usually leads to fluid loss in the body, shortening the life span of the colonies and largely leading to colony death (Amdam et al., 2004; Sammataro et al., 2000). Genetic breeding studies in honey bees are one of the most important topics in beekeeping. In the USA and EU countries, breeds and lines have been bred that are resistant to Varroa pests, European and American foulbrood, lime and nosema diseases, have a high honey yield and a low tendency to swarm. Economically important genetic characteristics of honey bees can be improved with the help of breeding methods (Khoei, 2012). Breeding efforts to improve these traits are continuing. In her research, Gülbin Gökdemir (2023) selected 50 colonies with a similar number of colonies and brood area from an apiary with 200 colonies to determine the selection difference in terms of Varroa destructor in Caucasian honey bee (*Apis mellifera caucasica)* colonies. The Varroa load in these selected colonies was determined using the powdered sugar shaking method, and colonies with three or fewer Varroa loads were classified as resistant and the others as non-resistant. In the study, 25 of 46 colonies were classified as resistant to the Varroa parasite and 21 as non-resistant. According to the research results, the selection success rate was 54.3%. In the study conducted by Roberts et al. (2020) in Papua New Guinea, the survival of bee colonies that were not sprayed in any way by local beekeepers suggests that the local bees may have developed a tolerance to varroa. The researchers identified high-yielding colonies and used the PCR method to determine whether they had developed tolerance. During the tests, *Apis mellifera* and *Apis cerena* honeybees were found to be contaminated with Sac-Brood virus and black queen cell virüs. As a result of the research, findings regarding Dwv could not be detected in all colonies. As a result, it was determined that honey bees in the region developed tolerance to varroa. In his research, Yıldız (2019) found that among the honey bee races commonly found in our country; Anatolian (*Apis mellifera anatoliaca*), Caucasian (*Apis mellifera caucasica)*, Carniolan (*Apis mellifera carnica*), Italian (Apis mellifera ligustica) and Syrian (*Apis mellifera syriaca*) breeds were determined as material. It was aimed to determine the grooming behavior responses of 20 worker bees representing these honey bee races against Varroa destructor under in vitro conditions.

The expression levels of 3 candidate genes (Neuroxin-1, Ataxin-3 and Atlastin) reported in the literature to be associated with grooming behavior in honey bees were investigated. According to the results of the study; No statistical difference was found between 5 phenotypic honeybee races in terms of grooming behavior. It was found that there are significant differences between breeds in the expression levels of the neuroxin-1, ataxin-3 and atlastin genes, which are candidate genes for grooming behavior. İvgin Tunca et al. (2018) The Muğla Beekeepers Association identified beekeepers who had not practiced migratory beekeeping for ten years and had not imported queen bees from outside and selected 100 colonies representing Muğla province. To determine the varroa load of the colonies used as breeding material in the study: 1. the varroa load per adult bee was counted using the powdered sugar method, 2. the varroa load per brood was determined by opening the eyes of the brood, 3. the varroa load was counted on the bottom board of the hive. In addition, the colonies were evaluated based on the number of frames with bees and the number of frames with brood. The breeding colonies were determined by calculations based on the results of 5 criteria. The measurements for each criterion were carried out in the fall and spring. The analyzes were performed in the mtdfREML software according to the following model using the BLUP-based animal model. Artificial inseminations were performed by selected breeders according to the results of the BLUP analysis. At the end of the study, it was found that there was genotypic progression in the number of progeny frames, powdery sugar and progeny eyes. The increase in the number of frames with progeny across generations was found to be statistically significant (P<0.001). The average number of frames with progeny was found to be 2.37 in 2016, 2.89 in 2017 and 3.54 in 2018. In 2016, 4.55% of the hives were selected for breeding using the powdered sugar method; in 2017, the figure was 4.49. The lowest Varroa count of 1.63 was recorded in 2018. The decrease in Varroa numbers was statistically significant between years according to the analysis of variance (P<0.01). The number of Varroa counted in the brood cells of the colonies in the initial flock of the study was 12.94 in 2015; it was observed to be 10.25 in 2016, while it was lowest in 2017 at 1.73. In 2018, the number of Varroa colonies in the eyes of the offspring was determined to be 3.09. In the selection study carried out using the brood eye method, the genotypic progress of the first generation was-0.03 in 2016-2017, but reached +0.05 in the second generation. The heritability was calculated at 0.10. According to the powdered sugar method used in the breeding study, the genotypic progress in the first generation 2016-2017 was 0.048, while it reached 0.055 in the second generation. The genotypic variance was reported to be 0.44. It was reported that the genetic progress in the number of progeny frames increased from-0.015 to +0.002 in two generations. Mondet et al. (2014) investigated the relationship between varroa-sensitive hygienic behavior and the antennae, which are important for varroa detection. According to the research results, the antennae are an important factor for VSH behavior. It was reported that the antenna profiles of nurse bees are close to each other and a high varroa rate was found in bees without VSH.

In this study, brief information on the mechanism and breeding of hygienic behavior in honey bees and studies on varroa tolerance are provided.

CONCLUSION

Honey bees are an important agricultural animal, both for the products they produce and for their role in pollinating many agricultural products. Increasing the resistance of honey bees to diseases and parasites is important both economically and ecologically. A permanent method of controlling the Varroa parasite, which is a major threat to honey bee breeding, has not yet been found. Therefore, the only effective method to control this mite is to breed honey bee lines that are tolerant to this mite. The Varroa parasite will continue to be a problem for beekeeping in the future. Hygienic behavior is also an important behavior that honey bees have developed against American foulbrood. The presence of these two behaviors in honey bees is the most effective way to control both varroa and foulbrood. Breeding studies using molecular techniques are increasing in the world and in our country, so that results can be obtained in a short time.

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CHAPTER 3

FORAGING IN HONEY BEES

Assoc. Prof. Dr. Rahşan İVGİN TUNCA[1,2]
Assoc. Prof. Dr. Gonca ÖZMEN ÖZBAKIR[3]

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[1] Muğla Sıtkı Koçman University, Ula Ali Koçman Vocational School, Muğla, Türkiye.
[2] Muğla Sıtkı Koçman University, Beekeping and Pine Honey Application and Research Center, Muğla, Türkiye. rahsantunca@mu.edu.tr, Orcid ID: 0000-0003-0745-6732
[3] Harran University, Faculty of Agriculture, Department of Animal Science, Şanlıurfa, Türkiye. gozmenozbakr@harran.edu.tr, Orcid ID: 0000-0003-1695-4012

INTRODUCTION

Honey bees are social insects called super organisms because of properties of them such as living in a common nesting area, the coexistence of overlapping generations in the colony, the division of labor including brood care, and the presence of a morphologically distinct caste of sterile worker bees (Seeley, 1989a; O'Toole & Raw, 1991; Özmen Özbakır & Alişaroğlu, 2019). Because of these features, it is a social insect that continues to attract the attention of researchers working in many fields such as evolution, ecology, behavior, breeding and nutrition.

The social structure in the hive is constructed by the queen bee responsible for laying eggs, worker bees working inside and outside of the colony, drones, eggs and larvae. While the existence of the colony is sustained by the magnificent communication networks that provide social order such as division of labor in the colony, this order is provided with the extraordinary discipline and coordination in order to adapt to constantly changing environmental conditions (Güler, 2017; Özmen Özbakır & Alişiroğlu, 2019). Like other social insects, honey bees search for food to provide the nutrients necessary for the nutrition of colony individuals, including growth, development and reproduction (Hölldobler & Wilson, 2009; Ghosh et al., 2020). Specialized sterile female worker bees carry nectar, pollen, water and propolis in order to sustainability of the colony and perform vital activities in search of food (Oswald et al., 2016; Wright et al., 2018; Ghosh et al., 2020). Honey bees provide the carbohydrates, proteins, fats, vitamins, and minerals required in their diet from nectar, pollen, and water collected by them. In general terms, flower nectar and insect secretions can be considered as the main energy source energy for honey bees (Özmen Özbakır & Alişiroğlu, 2019). The source of lipids, proteins, sterols and microelements necessary for the hive is pollen. (Herbert & Shimanuki, 1978; Ghosh & Jung 2017; Wright et al., 2018).

1. Foraging Behaviors

Under normal conditions, the outside duties of worker bees begin on the 21st day in the colony and foraging behavior is carried out by these worker bees (Abou-Shaara, 2014). Foraging activities require division of labor. Middle-aged and forager bees in the colony contribute equally to food collection and both of them have flexible responses in foraging (Seeley, 1989a; Seeley, 1989b; Johnson, 2023). Indeed, researchers have summarized the division of labor, which includes collecting food, storing it in the hive and using it, under a series of main activities that must be kept in balance in the colony. The first one is that forager bees find the source of food and the forager bees coordinate best on this food source. Later, the forager bees collecting nectar transfer the collected food to the bees inside the hive. These bees in the hive transform nectar into honey and store it. And last main activity requires the middle-aged bees inside the hive to provide adequate storage space for the food source coming from outside and this involves energically costly activities such as wax secretion, comb cells building, and others (Seeley et al., 1991; Seeley, 1992; Johson, 2023). Factors which are genes and environment have an impact on the foraging behavior (Robinson, 2002; Wright et al., 2018; Abou-Shaara, 2014; Hunt et al., 1995; Özmen Özbakır & Alişiroğlu, 2019). Particularly, the subfamily composition of the colony (queen and worker bee paternal lineage) affects pollen-nectar collection behavior and division of labor in forager bees as well as in young workers (Robinson & Page, 1989; Pankiw et al., 2002). It has also been reported that there is an increase in juvenile hormone titer and changes in the octopamine level in the transition of the worker bee from inhive to outside work (Knoll et al., 2022; Schulz et al., 2002; Elekonich et al., 2001).

Honeybee foragers use information from time, place memory, sugar concentration, previous experience, and also use knowledge about the quality and location of the resource through the waggle dance to decide whether to continue collecting or end the foraging (vonFrisch, 1967; Seeley & Towne, 1992; Wainselboim et al., 2002; Grüter & Farina 2009; Al Toufailia et al., 2013; vanNest & Moore, 2012; Rivera et al., 2015; Dong et al., 2023).

Honeybee foraging behavior is a complex admixture of both high level of collective behavior and individual level decision. The forager bees are mainly responsible for nectar collection. In the forager groups, there are different groups that are scout bees looking for the most profitable food source and foragers waiting in the hive until the scout bees return (Seeley, 1986; 1995). In general, these bees waiting in the hive constitute 40-90% of the total forager population (vanNest & Moore, 2012; Abou-Shaara, 2014). Even if environmental conditions change, scout bees explore and scan the area around the colony within a radius of several kilometers. Scout bees evaluate the nectar source according to high or low quality (Seeley, 1986; 1989b). Their decision about the nectar quality is informed to other waiting bees in the hive via waggle dance on the dance floor. They perform the more waggle dance in the hive for the location having high quality nectar (Seeley et al., 1991). The whole process inside and outside the hive construct an information pool that could be get the knowledge for the novice foragers. In this way, the distribution of the foraging bees to different nectar sources will be provided. Johnson (2023), stated that in this case, if there are three different nectar areas and these areas are ranked between one and three, this is showed in the number of dance performed to each categorical area in the hive. It is also emphasized that the allocation of bees according to foraging areas does not reflect the entire foraging system for a colony. In another way, the dance decision to signal food location is determined by rules that led the foragers to the most gainful locations, and variations in the responses of recipients can qualitatively change collective outcomes (Detrain & Deneubourg, 2008; Schürch & Grüter, 2014; Lemanski et al., 2019). In a study, Hasenjager et al. (2022) found little evidence that contrary to expectations, recruitment bees' responses to dance commands depended on target distance over the foraging distances considered (100-500 m). They also noted that this study provides experimental support for the long held conjecture that the self organized foraging activities of honeybee colonies are largely based on signal performance rules with limited input from the receiver (Hasenjager et al., 2022). It has been determined that this organization is important for foragers to save energy and time. An experimental study of how field conditions affect the foraging distribution of forager bees in a colony has shown that dance communication acts on crucial role in thespatial distribution of foraging and is potentially useful in reducing the costs of searching to and from nectar collection by directing recruited bees to closer foraging locations (Shackleton et al., 2023). On the other hand, it has been revealed that bees have information about dried areas in which not having nectar flow currently, and they use this information to go to old or new areas. In other words, previous experience at a foraging location plays a crucial role during foraging behavior (Beismeijer & Seeley, 2005; Fernandez & Farina, 2005; Johnson, 2023). In the molecular level study, major differences were found between scout foragers and other foragers in terms of gene expression, including glutamate, catecholamine, and γ-aminobutyric acid signaling in their brains (Liang et al., 2012).

In foraging activity, it has been reported that it is important for forager bees to sleep at night, otherwise their navigation memory is affected (Beyaert et al., 2012; Abou-Shaara, 2014). The sucrose response threshold is crucial for foraging and the division of labor of forager bees. Pankiw & Page (2000), found differences in sucrose threshold values among honey bee workers in their study. They found that the workers with the lowest response thresholds were water foragers, followed by increased response thresholds for pollen foragers, nectar foragers, bees collecting both pollen and nectar, and finally those returning to the colony empty. The study finally demonstrated that variable response thresholds of a sensory physiological process, namely sucrose perception, are causally connected to the division of foraging labor (Pankiw & Page, 2000). In addition, another study reported that resin foragers had lower sucrose response thresholds than pollen foragers (Simone-Finstrom et al., 2010).

The amount of load carrying is also important in foraging activity and provides a clue as to whether the colony's nutritional needs will be met or not, depending on the foraging capacity of the colony. The amount of load carried by forager bees after pollen and nectar collection activities varies depending on the load carried by the bees (Wright et al., 2018). It has been reported that the pollen load of pollen foragers collecting pollen weighs nearly 10 mg, while bees collecting both nectar and pollen weigh less than half of this, and the nectar load of only nectar foragers weighs approximately 18 mg (Drezner -Levy et al., 2009). It has been reported that the average pollen and nectar load of foragers in the colony is 15 mg and 30 mg, respectively (Seeley, 1995).

2. Nectar and Nectar Collection

The raw material of nectar is plant sap, and after processing at the cellular level by the plant, it turns into nectar, which is raw sap. The preference of the nectar-providing plant by bees depends mainly on the sugar content, amino acid and fatty acid content and quality it provides during flowering. Although it changes from plant to plant, nectar contains 50-70% water, 10-50% sugar, 1-4% aromatic compounds, enzymes and mineral substances. Many plant related factors can be listed in the production of nectar, such as the number and size of the plant's nectar glands, the position of the flower on the plant, and the age of the plant. Environmental factors (such as the amount of moisture, soil structure, amount of precipitation, temperature, wind, light intensity and duration) are also important in the nectar production of the plant (Güler, 2017). For bees, nectar is the main energy source and the basic raw material for producing honey in honeycombs (Wright et al., 2018). Although the presence of odor and fatty acids in the flower is easily perceived sensually by the bee, the presence and quality of nectar in the flower cannot be determined until the bee lands on the flower. The main factor that guides the bee to the plant is the odors secreted by the flower. The worker bee determines the presence of nectar by extending its proboscis inside the flower. If there is nectar, it extends its proboscis and sucks. If there is no nectar, it folds the proboscis, moves away from the flower and flies to a new flower. It is known that every time a worker bee goes on a foraging activity, they bring different amounts of nectar to the hive depending on the flower type, nectar potential and the distance of the flower source from the nest (Güler, 2017). Factors such as the bee genetic structure, the distance of the nectar secreting plant to the hive, and the amount of nectar determine the number of flights to nectar and the amount of nectar carried to the hive daily. It has been reported that one worker makes an average of 10-12 nectar collection trips per day, and each trip takes about 30-45 minutes and the average time spent in the hive during these visits is about 4 minutes (Güler, 2017). Foraging activity takes 7.5-10 hours a day to collect nectar depending on weather conditions (Genç & Dodoloğlu, 2011).

Proboscis extension reflex test results, which include both antennal and proboscis responses in honey bees, have shown that they have great sensitivity to sucrose (Waller et al., 1972; Simcock et al., 2017; Wright et al., 2018).

Studies have shown that sucrose is preferred because it is metabolically more valuable per unit weight and sucrose is digested quickly by bees and nectar sugars are efficiently assimilated (Gmeinbauer & Crailsheim, 1993; Wright et al., 2018). The studies show that the nectar foragers generally prefer essential amino acids and the most preferred amino acid is phenylalanine, which is a phagostimulatory amino acid. It is this amino acid that usually has the highest concentration in the nectar of plants visited by bees (Petanidou et al., 2006; Hendriksma et al., 2014; Wright et al., 2018). It has been shown that minerals, other micronutrients and secondary metabolites present in nectar affect bee behavior (Søvik et al. 2014; Wright et al., 2013 Wright et al., 2018). After the nectar has been collected by the foragers, the unloading of nectar at the colony level is another important part of foraging. It has been determined that honey bees, which pre-concentrate nectar during foraging, provide very different concentrations than those in the nectar, and this has effects on information exchange (Nicolson et al., 2022). When the bee search the nectar away from the nest, the benefit of evaporating nectar for the colony is much greater than the cost of flight benefit for the individual forager. Nicolson et al. (2022), have suggested that the ability to evaporate nectar outside the nest has a strong evolutionary benefit and shapes decision making during foraging at both the individual and colony level.

3. Pollen and Pollen Collection

Pollen is the male reproductive gamete cells of flowering plants. The diameter of the pollen grain is between 6 and 200 micrometers, and the grain varies greatly in shape and color depending on the plant species. Each plant pollen has a distinctive shape, color and its content varies from plant to plant. It contains different substances such as protein, fats, carbohydrates, vitamins, minerals, enzymes, flavonoids, vitamins and growth regulators in different quantity and quality depending on the plant species. While the protein content of pollen varies between 8-35%, the sugar content is between 15-50% and the starch content is 18% (Güler, 2017). Pollen quality depends on the crude protein level as well as the amino acid composition. Protein is vital for the proper development and function of body tissue, glands, membranes and muscles (Avni et al., 2014). It plays a crucial role in colony homeostasis, especially in both development of brood and the the colony developmental process. It has been found that forager honeybees collect pollen with higher protein content (Ghosh et al., 2020). Other macronutrients supplied by pollen are carbohydrates and lipids (Wright et al., 2018). Lipids in pollen are used as an important source of energy for honey bees and as a structural component of cell membranes. Fatty acid content of pollen varies between 1% and 20% depending on the plant species (Brodschneider & Crailsheim, 2010; Avni et al., 2014). Palmitic, alpha-linolenic (omega-3) and linoleic (omega-6) acids are the most common in its content (Avni et al., 2014; Wright et al., 2018). Pollen contains a variety of sterols (Stigmasterol, β-sitosterol, avenasterol and 24-methylene cholesterol) and is rich water soluble vitamins (e.g. B vitamins) than fat soluble vitamins (Wright et al., 2018).

The forager bees collect the pollen on their body with the help of their legs and place it in the pollen basket on the hind leg with enzymes and some honey. A colony can collect 15-75 kg of pollen per year under suitable environmental conditions (Dreller et al., 1999). In order to rear one larva, 25-37.5 mg of protein is required, which is equivalent to 125-187.5 mg of pollen (Hrassnigg & Crailsheim, 2005). Since pollen is a very important food needed for the sustainability of the honey bee colony and the production of offspring due to its rich content, factors such as bee genotype, season, and the presence of larvae in the hive affect the collection and storage of pollen (Camazine, 1993; Ghosh et al., 2020). One of the main factors is the number of offspring. Brood pheromones released from both old and young larvae stimulate pollen collection to foraging bees (Pankiw et al., 1998; 2008; Traynor et al., 2015; Ghosh et al., 2020). It has been observed that colonies given externally synthetic brood pheromone increased foraging activity and pollen collection (Jung & Burgett 2011; Jung et al., 2011; Ghosh et al., 2020). In the colony, young larvae require less food than older larvae, so the pheromonal signal triggers pollen collection, even if it is thought that the young larval signal should be weaker. Empty cells in the comb also trigger more pollen collection, but this effect is smaller than that associated with brood, and the excess of pollen in the nest suppresses foraging (Johnson, 2023). How foragers perceive the amount of pollen and empty combs is still not fully understood. It has been reported that foragers attempting to deposit their pollen loads do quite extensive work around the comb cell where they will deposit their pollen (Calderone & Johnson, 2002; Johnson., 2003).

4. Pollen or Nectar?

The nectar or pollen needs of the colony vary depending on the season and the colony conditions. Studies illustrate that there are differences in pollen and nectar collection both at the colony level and in the foraging behavior of individuals. The issue of whether to collect pollen or nectar depends on the plant responsible for the resource, and bees have a preference for those that produce pollen or nectar, or both (Johnson, 2023). Nectar requirement and tendency to collect nectar are high throughout the season. It is necessary to build a food stock for the colony in the winter, so if there is enough space for storage, nectar collecting behavior is high during the main season. Pollen collection tendency will increase if the number of offspring is high, especially during the brood production period (Scheiner at al., 2004; Genç & Dodoğlu, 2011). As the number of larvae increases in the hive, the increase in the concentration of brood pheromone produced by the larvae creates a pollen collection signal for forager honeybees. According to the response threshold model within the hive, the increase in the brood pheromone will exceed the response thresholds of field workers within the hive and will be directed towards this foraging behavior. Pheromones cause changes in individual or collective foraging behavior (Pankiw et al., 1998; Dreller et al., 1999; Dreller & Tarpy, 2000; Barron et al., 2002. Scheiner et al., 2004). On the other hand, it should be noted that individual response threshold levels vary (Scheiner et al., 2004). The most important point is that honey bee colonies organize their foraging activities in a way that the best balances their nutrition and thus colony sustainability, provided that suitable floral resources are available (Hendriksma & Shafir, 2016).

5. Water Collection

Water is used by bees to keep the temperature and humidity inside the hive at the desired level, to keep the adult honey bee's body fluid homeostasis in balance, to produce glandular secretions, to continue brood rearing activities uninterruptedly, to consume crystallized honey, to dilute honey and use it for brood feeding, to maintain the moisture required for brood rearing in very hot weather. In short, it is the most important element for the sustainability and individual needs of the hive (Nicolson, 2009; Genç & Dodoloğlu., 2011; Oswald et al., 2016). Honey bees generally do not store the water in the comb cells (Genç & Dodoloğlu, 2011). Because water collection is regulated according to current demand and honey bees, especially in temperate regions, can reach water sources as they do not change (Seeley, 1995; Nicolson, 2009). When the water consumption is high in the hive, it is likely to rapidly increase the amount of water collection. The behavior of foragers to carry water to the hive can either be rapidly activated or deactivated when conditions change within the hive. Water foragers may be activated as the fluid demands of middle aged bees in the hive change, or they may be activated by colony thirst (Seeley, 1995; Oswald et al., 2016). If the need for water continues, they should continue collecting and perhaps even perform waggle dances to involve others in the water collection. However, if the need decreases, collection is stopped. In other words, the number of bees around the water-collecting bee to get water and the waiting time until the water-collecting bee unloads its load reliably indicate the colony's need for water (Seeley, 1995; Kühnholz & Seeley, 1997; Oswald et al., 2016; Johnson, 2023). When a water collector returns to hive with a water load, bee transfer it to the middle-aged bees who have positioned themselves near the nest entrance. If the colony's water needs are high, the water collector quickly (within 30 seconds) finds a bee to unload. But if the colony's water needs are low, it struggles to find a bee willing to accept its load. When it takes more than 5 minutes for a water forager to find a nestmate willing to take the water load, or even if forager cannot find a bee to give the water to and is rejected, the water foragers stop collecting water and rest inside the hive. It is reported that the change in the ease with which a water collector can unload its load and the change in the number of water receivers determine the change in water needs of the colony. After middle-aged bees take in the water, they move it deeper into the hive and finally spread it onto the walls of the cells or give it to other bees, or both. In addition, when forager bees in a colony are busy collecting nectar and the need for water increases (when a colony starts to overheat) and other workers (and possibly non-working bees or middle-aged bees who are not foragers) switch to water collection duty, the number of water receivers increases. Thus, it have been showed that the nectar receiver numbers in a colony is not drastically reduced by activating additional water receivers (Kühnholz & Seeley, 1997; Johnson, 2023).

CONCLUSION

As a result, general categories on the foraging activities of bees: Colony and individual behaviors and other factors affecting these behaviors should be taken into consideration. So far, the behavior of forager bees has been tried to be summarized in general. However, it is necessary to take into consideration the effects of parasites, pathogens, and chemicals used in agricultural control on both individual and colony foraging behavior. Because these factors may cause the foragers not to return to their colonies, the return period to be prolonged, and start of foraging activities early (Abou-Shaara, 2014). In this chapter, an attempt has been made to make a general compilation about the foraging behavior of bees, which attracts attention with their dances in the mysterious world of bees and later attracted the great attention of scientists working in the forager bees.

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CHAPTER 4

OPTIMIZING HONEY BEE (*Apis mellifera* L.) COLONY PRODUCTIVITY: STRATEGIES FOR POPULATION CONTROL AND SUSTAINABILITY

Assoc. Prof. Dr. Mahir Murat CENGİZ[1]
Assoc. Prof. Dr. Aziz GÜL[2]

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[1]Atatürk Üniversitesi, Teknik Bilimler Meslek Yüksekokulu, Bitkisel ve Hayvansal Üretim Bölümü Erzurum, Türkiye. mahirmuratcengiz@gmail.com, Orcid ID: 0000-0002-9844-4229
[1]Hatay Mustafa Kemal Üniversitesi, Ziraat Fakültesi Zootekni Bölümü, Antakya, Hatay, Türkiye. agul25@gmail.com, Orcid ID: 0000-0003-1158-5019

INTRODUCTION

Honey bee (*Apis mellifera* L.) colonies are not only integral to the natural ecosystem but also vital contributors to global agriculture (Mashilingi et al., 2022; Phiri et al., 2022). Their remarkable pollination services ensure the reproduction of numerous plant species, including many crops essential for human consumption (Mashilingi et al., 2022). Moreover, honey bees produce honey, beeswax, royal jelly, and other valuable hive products that have been utilized by humans for centuries (Güler, 2017; Genç and Dodoloğlu, 2017). However, sustaining high productivity levels in honey bee colonies requires careful management of various factors, with population control playing a pivotal role.

The population dynamics within a honey bee colony are complex, influenced by factors such as the presence and productivity of the queen bee, availability of resources, environmental conditions, and interactions with pests and diseases. Optimal colony productivity is achieved when these factors are balanced effectively, allowing for robust colony growth, efficient resource utilization, and maximum output of pollination services and hive products (Nganso et al., 2024).

This article explores the multifaceted approach of enhancing productivity in honey bee colonies through population control strategies. It delves into a range of techniques and practices employed by beekeepers and researchers to regulate colony size, composition, and behavior. These strategies encompass aspects such as queen bee management, drone population control, brood management, selective breeding, nutrition management, integrated pest management (IPM), and data-driven monitoring.

By understanding and implementing these population control strategies, beekeepers can optimize colony health, productivity, and sustainability. Moreover, the promotion of effective population management contributes to the conservation of honey bee populations and the maintenance of biodiversity in both natural and agricultural ecosystems. As such, this article aims to provide insights into the importance of population control in honey bee management and its implications for global food security, environmental conservation, and sustainable agriculture.

Success in beekeeping is possible by knowing and fulfilling the technical beekeeping conditions. Technical beekeeping is a beekeeping model in which all the possibilities of modern technology are used and as a result, it provides the producer with as much profit as possible above the economic efficiency level.

Factors that play a role in reaching this level; strong, healthy colonies of suitable bee breeds, modern equipment, rich nectar resources, availability of natural conditions and sufficient knowledge and experience in beekeeping. Population regulation should be done correctly and on time to increase productivity in colonies. For this, it is necessary to know the life cycle and life-related characteristics of the colony individuals well.

Population Regulation

The purpose of population control; It is to keep the power of the colony at the desired level regardless of the season of the year. The strength of the colony is represented by the number of worker bees that make up the colony. The amount of honey to be obtained in colonies with different population levels will also be different. The production amount per worker bee obtained by dividing the honey yield by the population size is called "Production Efficiency".

Table 1. The relationship between population level and honey yield and production efficiency.

Population Level	Honey Yield	Production Activity
40.000	20 kg	20 kg/40.000 = 0.5 gr
80.000	80 kg	80 kg/80.000 = 1 gr
160.000	120 kg	120 kg/160.000= 075 gr

(Doğaroğlu 1999).

In the study, it is seen that the population level with the maximum production efficiency is 80 thousand. This represents a population of 20 frames tightly covered with bees in the Langstroth hive. The beekeeper needs to bring his colonies to the population level of 80 thousand. For this, while combining two colonies with a population of 40 thousand, it can also divide a colony with a population of 160,000 into two colonies of 80 thousand and get maximum honey.

Another important point to be considered is that the production and consumption balances within the hive should be established before the nectar flow. The population consists of young bees, who are in the hive service, and forager that provide the needs of the colony from the outside. The honey accumulated in the hive is the amount left after consumption in the hive from the nectar brought by the forager. This indicates productivity in the colony and is called "population dynamics". Colonies with high population dynamics produce honey according to population levels and forager ratios, while low ones tend to brood production. In other words, while one of the colonies of the same strength is making honey, the other focuses on brood production. The more forager there are in the population, the higher the production will be; otherwise, even if the population is strong, honey cannot be obtained at the desired level.

Brood Period	In-Hive Service	Forager
3 Week	3 Week	1-2 Week
← Total 42 days →		

Figure 1. Life cycle of worker bees

All the studies carried out to bring the populations to the level of 70-80 thousand at the beginning of the nectar flow are called "population regulation studies". Various colony management systems can be used while performing these studies. These;

1. Two-queen colony management
2. Colony support system
3. Package bee system (bee supplement)
4. Queen bee confinement

Purposes of Use of Different Colony Management Systems	
Management System	**Aim**
Two Queen Bee Colony Management System	Increasing the colony population, Renewing the queen bee
Colony Support Management System	Increasing the colony population and the ratio of producers to consumers in the population, increasing the population dynamics and increasing the chance of collecting honey,
Package Bee System (Bee Supplement)	Increasing the colony population in favor of forager, increasing the population dynamics and increasing the chance of collecting honey
Queen caging in the frame	Increasing the ratio of producer bees (forager) to consumers within the existing colony population, increasing the population dynamics and increasing the chance of collecting honey, being able to fight Varroa

1.Two-Queen Colony Management System

Generally, the presence of a queen in each bee colony is considered normal. However, beekeepers can sometimes observe in the same colony that an old queen and one of her offspring lay eggs in the same or nearby frame. When queen bee inspections are made at the end of the big honey flow, approximately 5% of the colonies are encountered with a mother-daughter union (Farrar 1953). Some bee lines are more prone to this condition than others. This trend seen in the colonies aroused the opinion that with some precautions, two queens could be found in the same colony at the same time, and trials were started. In all methods applied by various researchers, the presence of two queens laying eggs at the same time significantly increased honey production (Walton 1974). The reason for this is the linear increase in honey yield as the population increases (Woyke 1984; Wilde et al., 2009).

Colony management with two queens is an intensive management system based on population reproduction in order to obtain high yield from colonies. On the one hand, the other purpose of the system, which is to achieve high efficiency; It is the presence of a second queen that continues to lay eggs in the colony against the inefficiency caused by the loss of a queen. The important thing in the system is to make good timing. It is not correct to think that every production region will be successful. The producer must first determine the suitability for his own conditions by starting with a small number of colonies according to his own production conditions.

For this purpose; strong overwintered colonies reach a high level of population by adding pollen in early spring. Queen bees to be placed in the upper sections should have been captured approximately 2 months before the start of the honey flow (20 April - 5 May). After the queens are provided, the overwintered queen is left in the lower brood body of the young brood. Other glazed and emerging brood frames are placed in the upper brood with the bees on them. In addition, most of the bees are shaken to this new unit and balance is achieved in both units due to the currents that will occur towards the lower brood. The two brood chamber units are completely separated by a cover board or double- fly wire. Thus, two brood chamber bodies are used for each lower and upper queen bees. The new queen bee is placed between the frames in the top brood with a sugar plug. After it is seen that newly introduced queens lay plenty of eggs, the cover board is removed and a queen exculuder is put in place (Moeller, 1976).

In cases where the weather conditions are not suitable and there is not enough nectar, additional feeding should be given to both colonies. When there is 1 month left before the end of the nectar flow, there is no need to have a second queen bee. Because eggs laid after this period are required 3 weeks to become adult bees and at least 2 weeks to collect honey. However, it is not easy to confuse the hatching in the middle of the honey flow, to search for the queen and to combine the hatching. Therefore, the colony is left with two queens until the end of the honey flow.

Consolidation is done after the honey harvest. Most of the honey can be lost with early joining of hatchings, and some of it can be lost by being late. After the removal of the queen exculuder, in the colonies that are brought to the position with a single queen, the next thing to be done is the same as in the colonies with a single queen until the spring of the year. The system allows high yields with strong populations (Duff and Furgala 1989). Honey production increases by at least 20 kg compared to single-storey colonies. Since the pre-winter colonies are strong, they spend the winter without any problems. If the queen in the colony is unproductive, naturally the colony gains a productive queen. Another issue is the presence of a second queen in the colony against queen bee loss. In the implementation of the system, a large number of assistants are needed in some periods. Large-scale applications without gaining experience bring along difficult problems (Dunham, 1953).

According to the conditions of our country, in the two-queen colony management system, good care and feeding should be applied to the strong colonies that emerge in the spring, and a large part of the existing queen, young brood and population should be in the sub-brood chamber.

2. Colony Support System

This system is a colony management system that aims to improve the colony's chance of collecting honey by increasing the ratio of producers (forager bees) to consumers in the population, in other words, by increasing the population dynamics, in order to obtain high yields.

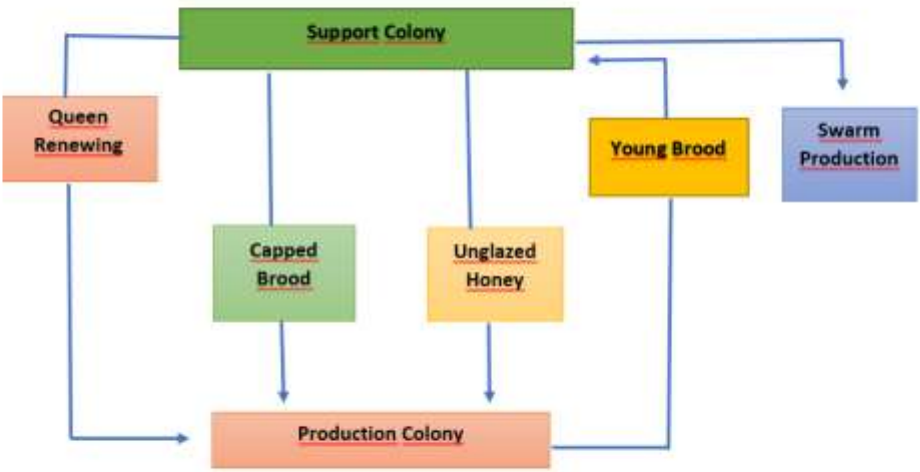

Figure 3. The basis of the colony support system (Dogaroğlu, 1999).

Thus, it is aimed to get more honey by directing certain colonies to honey in the apiary. For targeted honey production, approximately 6 weeks before the nectar flow, brood and egg laying areas are provided in all colonies in order to achieve excessive laying. At the beginning of the nectar flow after six weeks, the effective honey collection power will be obtained from the individuals who will be field farmers from the eggs laid for this period. Plenty of nutrients can be given to encourage colonies to lay eggs.

When the eggs laid in this period enter the pupal stage after 3 weeks, the colonies are divided into 2 equal parts according to the population strength as the very strong ones and the less strong ones. Strong colonies are production colonies and are called group A and numbered as A1, A2 The less strong colonies are support colonies and are called B1, B2 by giving the name of group B. For example, the support colony near the production hive A1 is the support hive of that colony and is numbered B2.

The pupae frames, which are about to emerge from the support colonies about 3-4 weeks before the nectar flow, are transferred to the production colonies. In addition, honeyed frames are transferred to the production colonies to be glazed. Frames with larvae (young brood) that cause consumption in production colonies are transferred to support colonies. Thus, by increasing the ratio of producers to consumers in the population, the population dynamics and the chance of collecting honey are also increased, and the production efficiency in the colony is improved. Meanwhile, swarm production and queen bee can be raised from the support colony. The most important issue in the implementation of the system is timing.

3. Package Bee System (Bee Supplement)

The frameless transport of bees in small packages is called the "Package Beekeeping" system. Honey bees, which are offered for sale according to their weight in boxes, which are covered with sieve wire on both sides, wooden on the other surface, and recently made of plastic, which allow ventilation during transportation, are called "package bees".

Package bees can be with or without a queen. In package bee production, which is an important beekeeping activity, it can improve the yield potential by increasing the ratio of producer bees (field bees) to consumers, that is, population dynamics in colonies. The most important thing to note here is that the supplement is done at the right time and little by little. Because there is a risk of killing the queen bee of the existing colony. Considering that package bees are composed of young individuals approximately 5-15 days old, supplements to be made approximately 1-2 weeks before the nectar flow, depending on the duration of the nectar flow, will increase the colony population in favor of the producers and will contribute positively to honey production (Karacaoğlu et al., 1998).

Figure 4. Package bees

1. Queen Imprisonment in The Frame

The important thing here is timing as in other systems. Another important benefit of the system is the biological control method in the fight against Varroa. The queen bee is covered with a queen exculuder, which is prepared approximately 4 weeks before the nectar flow. This grill can be opened and closed on one side, its four laths can be prepared from a frame of equal thickness (4 cm) and an embossed honeycomb is placed inside. The queen bee is also placed in this frame so that she lays her eggs only in this frame. Once the brood is glazed, this comb can be destroyed and replaced with another comb (Calderone 2005; Giacomelli et al., 2016).

Thus, the honey yield potential of the colony is increased by increasing the percentage of field worker bees that do not give the consumer a chance to live in the colony during the nectar carrying period. At the same time, adult varroa use only this comb to reproduce, as there is no brood in other combs during this period. Since the honeycomb will be destroyed when the brood is glazed, an effective fight against varroa, which is an important bee pest, will be made.

Success in beekeeping, as in every production branch, is to know the production material well and to manage it well. This is only possible with technical beekeeping. Getting more honey or producing other bee products is only possible with population control. For high honey yield, the producer should arrange his colonies at a level that will maximize the production efficiency (ie 70-80 thousand) at the beginning of the honey season. The important factor determining the productivity in the colonies is the high number of field bees during the nectar flow period. For this, about 6 weeks before the nectar flow, queens should be encouraged to lay eggs in all colonies, and spawning areas should be provided in hatching and honeydew. Producers increase and regulate the populations in their colonies for more honey production; Two-queen colony management system, colony support management system, bee supplement and queen bee trap can be used.

APPLICATIONS TO SUPPORT COLONY MANAGEMENT SYSTEMS

1. Drone Population Control

Drone population control is a crucial aspect of honey bee colony management aimed at optimizing resources and promoting productivity. Drones, or male bees, play a significant role in colony dynamics, but excessive drone populations can strain colony resources and impede productivity.

Implementing effective drone population control strategies involves managing drone numbers without compromising colony health or genetic diversity (Wharton et al., 2007). Here are several methods for achieving drone population control:

a. **Drone Congregation Area Management:** Identify and monitor areas where drones congregate for mating flights, typically known as drone congregation areas (DCAs) (Utaipanon et al., 2019). Implement management practices to influence drone mating behavior and reduce congregation size. For example, strategic placement of pheromone traps or deterrents near DCAs can disrupt mating flights and limit drone numbers.
b. **Drone Trapping:** Utilize specialized drone trapping devices placed within the hive to capture and remove drones. Traps are designed to allow drones to enter but prevent their exit, effectively reducing drone populations within the colony. Regular monitoring and emptying of traps are essential to prevent overcrowding and maintain trap efficacy.

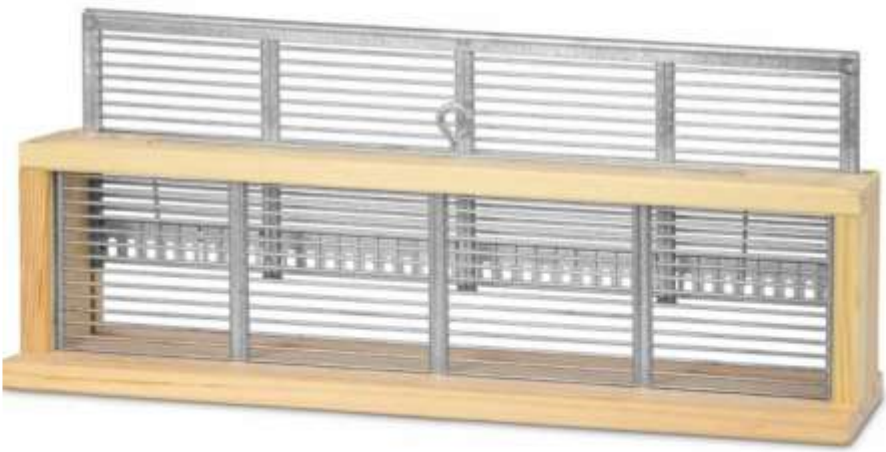

Figure 5. Drone Trap

c. **Colony Manipulation:** Adjust colony dynamics through manipulation techniques such as brood removal or queen excluder placement. Removing drone brood frames from colonies can limit drone population growth by reducing the number of emerging drones (Odemer et al., 2022). This method also provides an effective fight against Varroa destructor (Charrière et al., 2003; Güneşdoğdu and Şekeroğlu., 2021). Effect of using drone brood cells as traps against Varroa destructor (Varroa mite). Turkish Journal of Agriculture-Food Science and Technology, 9(6), 1226-1231.). Installing queen excluders can restrict the queen's access to drone comb, resulting in fewer drones being produced.

Figure 6. Drone brood removal

d. **Queen Management:** Control the rate of drone production by managing the queen bee within the colony. Techniques such as queen caging, queen rearing, or queen replacement can influence the queen's egg-laying behavior and subsequently affect drone population size. Selective breeding for queens that produce fewer drones or implementing protocols to limit drone brood production can also help regulate drone populations.

e. **Natural Controls:** Encourage natural mechanisms of drone population control within the colony. Worker bees may exhibit behaviors such as drone eviction or supersedure of the queen in response to overcrowding or resource limitations. Providing colonies with adequate space, ventilation, and forage resources can support natural regulatory mechanisms.

f. **Monitoring and Adjustment:** Regularly monitor colony populations and drone numbers to assess the effectiveness of population control measures. Adjust management practices based on seasonal variations, colony needs, and observed outcomes. Continuously evaluate the balance between drone populations and colony productivity to optimize management strategies. Effective drone population control requires a comprehensive understanding of colony dynamics and the ability to implement targeted management techniques. By employing a combination of these strategies, beekeepers can regulate drone populations while maintaining healthy and productive honey bee colonies. Additionally, promoting genetic diversity and sustainable beekeeping practices ensures the long-term viability of honey bee populations and supports ecosystem health.

Figure 7. Queen caging

2. Brood Management

Brood management is a fundamental aspect of honey bee colony management aimed at optimizing population dynamics and enhancing productivity. The brood, consisting of eggs, larvae, and pupae, represents the future workforce of the colony. Effective brood management involves manipulating brood development to regulate population size, promote colony health, and maximize resource utilization. Here are several methods for implementing brood management techniques

a. Brood Inspection: Regularly inspect hive frames to assess the distribution and health of brood within the colony. Observe brood patterns, including the presence of drone and worker brood, brood cell density, and overall brood health. Identify any signs of brood diseases or pests that may require intervention (Lee et al., 2019).

b. Brood Removal: Remove excess brood frames to control population size in the nectar flow and prevent overcrowding within the hive. Excess brood frames may contain surplus drone brood or unnecessary worker brood, which can strain colony resources and impede productivity. This application, performed during intense nectar flow, increases production in colonies (Doğaroğlu, 1999). Utilize brood frames for purposes such as swarm prevention, population management, or selective breeding programs.

c. Drone Brood Management: Monitor and manage drone brood production to regulate drone population size within the colony. Cull drone brood frames or selectively remove drone cells to control the number of emerging drones. Adjust drone brood management based on colony needs, seasonal variations, and breeding objectives. This will also reduce honey consumption within the colony (Doğaroğlu, 1999).

d. Queen Excluder Placement: Install queen excluders within the hive to restrict the queen's access to certain areas, such as honey supers or drone comb. By preventing the queen from laying eggs in designated areas, beekeepers can control the distribution of brood within the hive (Cengiz, 2018). Utilize queen excluders strategically to manipulate brood patterns and optimize resource allocation. This application in the nectar flow prevents swarm production and increases honey yield.

e. Brood Frame Rotation: Rotate brood frames within the hive to promote even brood development and maintain colony balance. Moving frames containing brood and emerging bees to different positions within the hive encourages efficient use of hive space and resources. Rotate frames periodically to prevent brood chamber congestion and facilitate optimal brood rearing conditions. This is necessary for a more regular brood area that expands in an elliptical shape.

f. Brood Boosting: Introduce frames of brood from strong, healthy colonies to bolster populations in weaker or queenless hives. Brood boosting helps replenish colony numbers, stimulate population growth, and mitigate the risk of colony decline. On the other hand, significant positive relationships were determined between brood production efficiency and honey yield in honey bee colonies (Genç & Aksoy, 1993; Cengiz & Dülger, 2018). Select brood frames with healthy, capped brood and nurse bees to ensure successful integration into recipient colonies.

3. Integrated Pest Management

Integrated pest management is a holistic approach to pest control that aims to minimize the impact of pests while maximizing the sustainability and health of honey bee colonies. By integrating multiple strategies, including cultural, biological, physical, and chemical control methods, integrated pest management promotes effective pest management while reducing reliance on conventional pesticides. Here are the key components and practices involved in implementing integrated pest management for honey bee colonies:

a. Pest identification and Monitoring: Begin by identifying common pests and diseases that affect honey bee colonies, such as Varroa mites, Nosema spp., wax moths, and hive beetles. Establish regular monitoring protocols to assess pest levels, colony health, and disease prevalence (Morawetz et al., 2019). Utilize sampling techniques, such as sticky boards, alcohol washes, and visual inspections, to monitor pest populations and detect early signs of infestation (Jack et al., 2021).

b. Cultural Practices: Implement cultural practices that create unfavorable conditions for pests and promote colony health. Examples include maintaining clean and well-ventilated hive equipment, minimizing stressors such as overcrowding and poor nutrition, and providing access to clean water sources.Promote colony vigor through proper nutrition, adequate hive space, and queen management to enhance resilience against pests and diseases (Dequenne et al., 2022).

c. Biological Control: Utilize biological control agents to manage pest populations and maintain ecological balance within honey bee colonies. Examples include introducing beneficial organisms such as predatory mites (e.g., Stratiolaelaps scimitus) or entomopathogenic fungi (e.g., Metarhizium anisopliae) to control Varroa mites (Hamiduzzaman et al., 2012; Rangel & Ward, 2018). Encourage natural predators and beneficial microorganisms that contribute to pest suppression and colony health.

d. Physical Control: Employ physical barriers and traps to prevent pest entry into hives and reduce population levels.Install screened bottom boards, entrance reducers, or hive stands with oil traps to exclude pests and prevent hive infiltration. Use sticky traps, drone brood trapping devices, or queen excluders to capture pests such as Varroa mites, wax moths, or small hive beetles (Jack & Ellis, 2021).

e. Chemical Control: As a last resort, consider targeted chemical treatments to manage pest populations when other control methods are insufficient. Selective acaricides, organic acids, essential oils, and biopesticides may be used judiciously to control Varroa mites and other pests (Cengiz, 2012; Ahmed et al., 2021). Follow label instructions carefully, rotate chemical treatments to mitigate resistance development, and minimize exposure to bees and the environment.

f. Education and Training: Educate beekeepers and stakeholders on the principles and practices of integrated pest management. Provide training on pest identification, monitoring techniques, and best management practices for minimizing pest impacts while maintaining colony health. Foster a culture of proactive pest management and continuous learning within the beekeeping community. Integrated pest management offers a comprehensive and sustainable approach to pest control in honey bee colonies. By incorporating diverse strategies and emphasizing prevention, monitoring, and ecological balance, Integrated Pest Management helps beekeepers effectively manage pests while promoting the long-term health and productivity of honey bee populations.

4. Selective Breeding

Selective breeding is a powerful tool utilized by beekeepers and researchers to enhance desirable traits within honey bee populations, ultimately leading to improved productivity, health, and resilience. This method involves intentionally mating honey bee colonies with specific genetic characteristics to selectively propagate traits such as honey production, disease resistance, gentle behavior, and foraging efficiency. Here are several steps involved in implementing selective breeding programs

a.Trait Selection: Identify the desired traits to be improved or maintained within the honey bee population. Traits may include honey production, resistance to pests and diseases (e.g., Varroa mites, Nosema), hygienic behavior, gentleness, winter hardiness, and pollination efficiency. Prioritize traits based on their importance to beekeeping goals, environmental conditions, and regional challenges (Maucourt et al., 2020).

b. Breeding Stock Selection: Evaluate potential breeding stock based on their genetic background, performance history, and observed traits. Choose colonies or queen bees with the desired traits to serve as breeding stock for the program. Consider factors such as genetic diversity, pedigree, and known lineage when selecting breeding stock to avoid inbreeding depression and maintain vigor (Genç & Cengiz, 2019).

c. Breeding Methods: Implement controlled mating techniques to ensure that selected breeding stock pass on desired traits to future generations. Options include instrumental insemination, artificial insemination, and controlled mating in isolated mating yards. Maintain careful records of mating outcomes to track the transmission of desired traits and assess breeding program success (Genç & Cengiz, 2019).

d. Selection Criteria: Establish criteria for evaluating the performance of breeding stock and their offspring. Monitor traits such as honey production, brood viability, disease resistance, behavior, and colony strength. Use quantitative metrics and subjective assessments to measure trait expression and overall performance (Güler, 2017).

e. Pedigree Tracking: Keep detailed records of breeding lines, parentage, mating outcomes, and trait expression. Pedigree tracking enables the identification of superior breeding lines and facilitates informed breeding decisions. Utilize pedigree information to optimize mating strategies and minimize the transmission of undesirable traits (Genç & Cengiz, 2019).

f. Continuous Evaluation and Improvement: Regularly assess the performance of breeding stock and their progeny to refine breeding goals and strategies. Incorporate feedback from field observations, colony inspections, and performance data into breeding decisions. Continuously select for the most desirable traits while maintaining genetic diversity and colony vigor (Güler, 2017).

g. Collaboration and Information Sharing: Collaborate with other beekeepers, researchers, and breeding programs to exchange knowledge, resources, and genetic material. Participate in breeding networks, queen rearing cooperatives, and research initiatives to collectively advance selective breeding efforts. Share breeding successes, challenges, and best practices to foster innovation and support the broader beekeeping community.

Selective breeding holds great potential for improving the resilience and productivity of honey bee populations in the face of evolving challenges such as pests, diseases, and environmental stressors. By systematically selecting for desirable traits and responsibly managing genetic diversity, beekeepers can cultivate colonies better adapted to their specific needs and environmental conditions. Additionally, ongoing research and collaboration are essential for advancing selective breeding programs and ensuring the long-term sustainability of honey bee populations.

5. Nutrition Management

Nutrition management is a crucial aspect of honey bee colony management aimed at providing bees with adequate and diverse food sources to support colony growth, health, and productivity. A well-balanced diet is essential for bees to perform their various tasks within the colony, including brood rearing, foraging, and hive maintenance. Here's how to implement effective nutrition management for honey bee colonies

a. Assessing Nutritional Needs: Understand the nutritional requirements of honey bee colonies at different stages of development, including brood rearing, overwintering, and peak foraging periods. Consider factors such as colony size, brood production, available forage resources, and environmental conditions when assessing nutritional needs.

b. Forage Resources: Identify and promote diverse forage resources within the foraging radius of honey bee colonies. Encourage the planting of bee-friendly flowering plants, trees, and shrubs that provide nectar and pollen throughout the growing season. Utilize native vegetation, cover crops, and wildflower to supplement natural forage resources and enhance nutritional diversity.

c. Supplemental Feeding: Provide supplemental feeding when natural forage resources are limited or insufficient to meet colony nutritional needs (Ahmad et al., 2021). Use sugar syrup or sugar water solutions as a carbohydrate source to supplement nectar during periods of nectar dearth or when colonies require additional energy (Güler, 2017). Offer protein supplements such as pollen substitute patties or pollen powder to support brood rearing and adult bee nutrition during times of pollen scarcity (Topal et al., 2022).

d. Feeder Management: Utilize various feeder types, including top feeders, frame feeders, and entrance feeders, to deliver supplemental food to honey bee colonies. Position feeders strategically within the hive to minimize disturbance and reduce the risk of robbing by other bee colonies or pests.

Monitor feeder activity and food consumption to assess colony needs and adjust feeding strategies accordingly.

e. Water Sources: Ensure access to clean, fresh water sources near the hive to meet the hydration needs of honey bee colonies. Provide water sources with landing platforms or floating materials to prevent drowning and facilitate easy access for bees. Consider installing water features such as birdbaths, ponds, or shallow containers with rocks or floating vegetation to attract bees and minimize water competition with other animals.

f. Monitoring and Adjustment: Monitor colony health, population dynamics, and foraging activity to evaluate the effectiveness of nutrition management strategies. Assess colony weight, brood development, and overall vitality to determine if supplemental feeding or forage enhancement is necessary. Adjust feeding schedules, feeder types, and supplemental food offerings based on seasonal variations, colony requirements, and observed outcomes.

g. Environmental Considerations: Consider environmental factors such as weather conditions, landscape characteristics, pesticide exposure, and habitat quality when managing colony nutrition. Minimize pesticide use near bee forage areas to avoid contamination of nectar and pollen sources. Advocate for sustainable land management practices that support pollinator-friendly habitats and ensure access to diverse and abundant forage resources.

h. Education and Outreach: Educate beekeepers, farmers, landowners, and the public about the importance of nutrition management for honey bee colonies and pollinator health. Provide resources, workshops, and outreach programs to promote bee-friendly landscaping practices, habitat restoration, and sustainable agriculture.

Foster collaboration between beekeepers, researchers, policymakers, and stakeholders to address challenges and develop solutions for improving honey bee nutrition and colony health.

By implementing these nutrition management practices, beekeepers can support the health, productivity, and resilience of honey bee colonies while contributing to pollinator conservation efforts and sustainable agriculture. A proactive approach to nutrition management ensures that honey bees have access to the essential nutrients they need to thrive and fulfill their vital roles within ecosystems and food systems alike.

6. Data-Driven Monitoring

Data-driven monitoring is a critical aspect of modern beekeeping, enabling beekeepers to make informed decisions based on quantitative analysis of colony performance, health, and productivity metrics. By collecting, analyzing, and interpreting data from hive inspections, environmental sensors, and other sources, beekeepers can gain valuable insights into colony dynamics and identify trends, patterns, and anomalies. Here's how to implement data-driven monitoring in honey bee colonies:

a. Data Collection Tools and Techniques: Utilize a variety of tools and techniques to collect data on colony parameters, including hive inspections, hive scales, temperature and humidity sensors, entrance monitors, and digital hive cameras(Braga et al., 2020). Adopt standardized data collection protocols to ensure consistency and accuracy across multiple colonies and beekeepers. Record key data points such as hive weight, brood development, population size, foraging activity, pest and disease prevalence, and environmental conditions (Meikle & Holst, 2015).

b. Data Management and Organization: Establish a centralized system for storing, organizing, and managing data collected from honey bee colonies. Utilize digital platforms, spreadsheet software, or specialized beekeeping apps to track and manage data efficiently. Implement standardized naming conventions and data formats to facilitate data retrieval, analysis, and sharing.

c. Regular Monitoring and Sampling: Conduct regular hive inspections and sampling to collect data on colony health, population dynamics, and resource utilization. Establish a monitoring schedule based on seasonal variations, colony development stages, and specific management objectives. Incorporate random sampling techniques to obtain representative data and minimize bias in monitoring efforts (Meikle& Holst, 2015).

e. Data Analysis and Interpretation: Analyze collected data using statistical methods, visualization tools, and data analytics software to identify trends, patterns, and correlations. Look for deviations from expected norms or thresholds that may indicate potential issues or opportunities for intervention. Interpret data in the context of beekeeping goals, environmental factors, and colony-specific characteristics to inform decision-making.

f. Benchmarking: Compare data from individual colonies within a beekeeping operation or across multiple beekeepers to establish benchmarks and identify outliers. Evaluate colony performance relative to predefined metrics, industry standards, or historical data to assess progress and identify areas for improvement. Share data and insights with other beekeepers, researchers, and stakeholders to facilitate collaborative learning and benchmarking efforts.

g. Data-Driven Decision-Making: Use data analysis and interpretation to guide decision-making in hive management, pest and disease control, nutrition supplementation, and other aspects of beekeeping. Implement targeted interventions and management strategies based on data-driven insights to address specific challenges or capitalize on opportunities for improvement. Continuously monitor the outcomes of management interventions and adjust strategies as needed based on ongoing data analysis.

h. Continuous Learning and Improvement: Foster a culture of continuous learning and improvement by leveraging data-driven insights to refine beekeeping practices and techniques. Document and share lessons learned, successful strategies, and best practices within the beekeeping community to facilitate knowledge exchange and collective improvement. Embrace innovation and experimentation in data collection methods, analysis techniques, and management approaches to drive continuous improvement in data-driven monitoring and beekeeping practices.

Data-driven monitoring empowers beekeepers to optimize colony health, productivity, and sustainability by leveraging quantitative data to inform decision-making and management strategies. By adopting a systematic and proactive approach to data collection, analysis, and interpretation, beekeepers can enhance their ability to effectively manage honey bee colonies and support the long-term viability of beekeeping operations.

CONCLUSION

In conclusion, the applications of population control techniques in honey bee colonies offer valuable strategies for beekeepers to enhance productivity, sustainability, and overall colony health. By carefully managing population dynamics, beekeepers can optimize resource utilization, reduce stressors, and mitigate risks associated with colony overcrowding and disease transmission.

Throughout this article, we have explored various applications of population control, including queen bee management, colony splitting, drone population control, brood management, selective breeding, nutrition management, integrated pest management, and data-driven monitoring. Each of these techniques plays a crucial role in regulating colony size, composition, and behavior to maximize productivity and support sustainable beekeeping practices.

Furthermore, the integration of these population control methods contributes to the resilience and adaptability of honey bee populations in the face of environmental challenges, pest and disease pressures, and changing agricultural landscapes. By adopting a holistic approach that considers the interplay between biological, ecological, and management factors, beekeepers can effectively balance colony health and productivity while minimizing negative impacts on honey bee populations and the surrounding environment.

As we look to the future of beekeeping, continued research, innovation, and collaboration will be essential for refining population control techniques, developing sustainable management practices, and addressing emerging threats to honey bee health. By leveraging the collective expertise of beekeepers, researchers, policymakers, and stakeholders, we can cultivate thriving honey bee colonies that contribute to food security, biodiversity conservation, and ecosystem resilience.

In essence, the applications of population control in honey bee colonies represent a cornerstone of modern beekeeping, providing beekeepers with the tools and knowledge needed to nurture healthy, productive colonies that play a vital role in our agricultural systems and natural ecosystems alike. Through proactive management and a commitment to sustainable practices, we can ensure the continued success and well-being of honey bee populations for generations to come.

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CHAPTER 5

SWARMING and NEST-BUILDING BEHAVIORS of HONEYBEES (*Apis mellifera* L.)

Assoc. Prof. Dr. Gonca ÖZMEN ÖZBAKIR[1]
Assoc. Prof. Dr. Rahşan İVGİN TUNCA[2,3]

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[1]Harran University, Faculty of Agriculture, Department of Animal Science Şanlıurfa, Türkiye. gozmenozbakr@harran.edu.tr, Orcid ID: 0000-0003-1695-4012
[2]Muğla Sıtkı Koçman University, Ula Ali Koçman Vocational School, Muğla, Türkiye.
[3] Muğla Sıtkı Koçman University, Beekeping and Pine Honey Application and Research Center, Muğla, Türkiye. rahsantunca@mu.edu.tr, Orcid ID: 0000-0003-0745-6732

INTRODUCTION

Honey bees are insects having both economic and ecological importance and living in colonies within a social organization. Western honey bees (*Apis mellifera*) build their nests in their natural habitats by constructing many honey combs parallel to each other in appropriate volume rock crevices, tree hollows, and similar dark cavities. As a result of the observations and investigations made after the relationship between man and honeybees began, the existence of a fixed distance between these combs was determined and movable frame hives were developed with the common features of the nests. Just as in the design inside of the nest, there is an order in the each honey comb using in the nest. Although the combs constituting the nest are used primarily for food storage and brood rearing, they are important to colony communication, defense, and as an expression of colony identity. In generally, swarming behavior is the division of a honey bee colony as a result of reproduction. Swarming is a complex behavior that involves the collective action of many individuals and is a vital importance for the colony. When the decision to swarm is made in a colony, a vital process begins because the process of moving to the new nest must be completed in a short time. During this period, many potential nest sites should be investigated comprehensively by a small group of workers and the most appropriate nest site must be determined. Thousands of individuals in the swarm must be safely transported to this nest, covering varying distances for each swarm. In this behavior, thousands of bees move as one body, one mind. Like the departed swarm, the vital process continues in a different way in the parental colony. Swarming behavior, which means loss of both bees and products for the beekeeper, must be understood in all its aspects and the process must be managed.

In this chapter; it is aimed to give detailed information about the preparations of a honey bee colony for swarming, leaving the hive by swarming, forming a swarm cluster, searching for a new nest, and nest construction after the swarm moves to the new nest.

1. Factors Cause Swarming

A honey bee colony has a queen who ensures the continuity and integrity of the colony by laying eggs and secreting pheromones. Worker bees, developing from fertilized eggs and constitute the most populous group of the colony, perform tasks inside and outside the hive, depending on their physiological age. This social organization among worker bees is called age-related division of labor. Drones, changing their numbers depend on the seasonal cycle, develop from infertile eggs and are the carriers of the genetic material of the colony (Winston, 1987; Seeley, 1995). The combined behavior of colony individuals determines the development and survival of the colony. For the western honey bee (*Apis mellifera*), it is necessary to examine nest construction, swarming, foraging, food storage, brood care, temperature regulation, hygiene and defense behaviors as a whole, like a colony (Siefart et al., 2021). The rate and amount of egg laying by the queen bee varies seasonally. In a healthy colony coming out of winter, as the weather warms up and the first flowers appear, the queen bee increases egg production, the development of the colony population increases with the abundance of pollen and nectar resources, and the colony population gradually decrease towards autumn in temperate climates. Colonies may enter winter at different sizes depending on differences in honey bee genotypes, climate characteristics and their health status.

As organisms develop, they use their resources primarily in growth and survival, but after reaching a certain state, they begin to invest the resources in reproduction. Similarly, superorganisms such as honeybees first invest in growth and survival and then allocate resources to reproduction when the number of worker bees in the colony exceeds the reproductive threshold (Smith et al., 2017).

Swarming is the separation of a group of worker bees from the hive with one or more queen bees as a result of the rapid reproduction of a honey bee colony during a period of their annual life cycle. The cluster of bees that leave the colony is called a swarm (Gençer, 1999).

Swarming usually occurs in strongly populated colonies and occurs in late spring to early summer. The colony's preparations for swarming begin approximately one month before the swarm departs. Swarming is caused by several factors including an increase in the number of adults and broods in the colony, a decrease in the space required for brood rearing and food storage, a change in the internal balance of the hive in terms of temperature and humidity, and a reduction in the transmission of queen pheromones. However, some genotypes have more tendency to swarm (Winston, 1987; Güler, 2006; Seeley, 2010). Swarming is a complex, multistep process mediated by environmental, physiological, social and molecular factors, a collective behavior that requires communication and coordination (Grozinger et al., 2014).

As a result of the abundance of nectar and pollen resources and the increase in the queen's laying rate, the brood area and food storage areas begin to diminish, and there is not enough working space left. However, due to rapid population growth and lack of ventilation, the temperature-humidity balance inside the hive is disrupted. The queen and the drones she mates with are of a genotype that is genetically prone to swarming, as well as the decrease in the transmission of the queen's pheromones due to old age or an increase in the colony population, and especially the numerical increase in the young worker population, are multiple reasons for the colony to swarm. The factors that cause swarming can be summarized as follows:

- Genetic structure
- Lack of brood and food storage area
- Increase in colony population
- Imbalance in the workers age distribution (increase in the number of young worker bees)
- Decrease in the amount of queen pheromone available and insufficiency in its distribution within the hive
- Change in homeostasis within the hive; combination of sounds, temperature and humidity

2. Preparations for Swarming and The Departure of Swarm

The reproductive investment of a honey bee colony is to increase the number of drone cells to produce drones and to reproduce by swarming (Boes, 2010). A study reports that reaching a critical number of workers in the colony is the basic parameter for spending colony resources on reproduction. It has been assumed that the critical threshold is when colonies with more than four thousand worker bees begin to build drone eyes, regardless of other parameters (Smith et al., 2014). The proportion of drone cells built in a colony also depends on the number of available drone cells**.** The amount of drone offspring and the number of adult drones in a colony are positively related to the number of worker bees (Free and Williams, 1975). The emergence of drones as adults reaches its peak just before swarming, when unmated young queens are present (Lee and Winston, 1987).

The initial visible step of the colony's preparation for swarming is the initiation of rearing dozens of new queens. The mother queen lays eggs in these cups prepared on the lower edges of the honeycombs, or worker bees carry eggs from other cells. The queen produces a series of chemical signals that serve to inform colony members about her existence and quality, and these signals have a significant impact on worker bee physiology and behavior. It is thought that the populous of workers limits the transmission of the queen's mandibular glands pheromones and encourages the rearing of new queens in preparation for the mother queen's departure. The main factors that trigger the raising of new queen bees are the increase in the number of young worker bees and especially the fact that more than 90% of the combs with broods are in use (Winston, 1987; Winston et al., 1981; Kocher and Grozinger, 2011, Rangel and Seeley 2012). During the swarming season, there is a relationship between the population density of a hive and the number of queen cells built. It has been determined that in an overcrowded colony, the tarsal pheromonal traces of the mother queen are almost absent on the lower edges of the comb where new queen cells are built (Lensky and Slabezki, 1981). However, it has also been reported that the existing queen bee occasionally examines new queen cells that have not yet been sealed and tries to damage them. In weather conditions that are not suitable for swarming, the destruction of some new queen cells can postpone swarming in order to increase the chances of survival of both the swarm and the swarming colony (Winston, 1987).

Pheromones, sounds, vibrations and dances play an important role in inside colony communication. The swarming process also requires sharing a lot of information through multiple signals. It has been reported that the queen produces two different sounds in intra-colony communication, in addition to pheromones. During the swarming process, when the newly reared young queens emerge from their cells, the second or subsequent swarms can also leave the colony. The sound (tooting) produced by the young queen 7-11 days after the departure of the first swarm, just before the departure of the following swarm, is a sound that can be heard outside the hive. The distinct and distinguishable sound of the newly hatched queen is explained as announcing its presence to the colony and rival queens. It has been reported that in response to this sound produced by the virgin queen, the queens still waiting in their cells (imprisoned) respond with a different sound 'quacking'. In intra-colony communication, these signals between the virgin queens, the worker bees and the queens waiting in their cells ready to emerge play a role in preventing many queens from emerging at the same time and also in regulating the duel between rival queens (Wenner,1964; Michelsen et al., 1986; Kirchner 1993; Hrncir et al., 2006; Hunt and Richard 2013).

Approximately 10-14 days before swarming, workers dramatically limit the amount of food they feed to the mother queen (Seeley and Fell, 1981), which allows the queen to fly long distances with the departed swarm. Despite the decrease in nutrition, the queen continues to lay eggs at almost the preswarm rate until five to seven days before swarming, when egg production decreases rapidly. Approximately 10 days before the swarm departs, worker bees begin to fill their crops with honey in preparation for searching for and establishing a new nest. Swarm do not leave a colony until the pupa period of newly reared queens begins, and swarm departure is determined on the day the cell is sealed or the day after (Allen, 1956; Comb, 1972). One study reported that approximately 75% of the worker population of a swarming colony leaves the parental nest with the mother queen, while only 25% remains behind with the young queen. (Rangel and Seeley, 2012). There is an advantage in the majority of young worker bees leaving the hive with the mother queen. The period from the swarm to the discovery of the new nest and from the construction of the combs in the new nest to the production of the new generation of worker bees ensures the existence of a sufficient worker bee population. The ages of the majority of workers in a swarm correspond to the ages of worker bees that typically engage in brood care-nursing behavior in established colonies (Winston, 1987; Seeley, 1995). However, scout bees are inclined to be older than other bees in a swarm, within the age range of young foragers (Gilley, 1998). Changes in worker bee behavior are also observed when the swarm leaves the nest. For the swarm to lift off, worker bees must increase their body temperature to be ready for flight. For this task, excited worker bees were observed producing sounds by pausing every second while mingling with the swarm. The harsh behavior of these excited workers, such as pushing, shaking and biting the queen, in order to prepare her for flight, encourages her to move. Some drones also join the group that will leave with the swarm, but their numbers are very few. Although swarming usually occurs in the late morning or afternoon (10.00-14.00), it may happen during the day depending on weather conditions. Although the preparations for the swarming take a long time, the departure of this group of bees from the hive is completed quickly, within minutes. Although a new era begins for the bee group that leaves the nest, the swarming process still continues in the parent colony. In the parent colony, there are still open and sealed queen cells, worker bee brood area, some honey and pollen storage, and approximately 40% of the adult worker bees. In this process, due to lack of care and feeding, mortality rates in the larval and egg stages of worker bees are high in the brood area. The process is similar for the second and consecutive swarms, and the number of swarms given is related to the amount of worker bee brood area in the hive. In the second and subsequent swarms, the queens are unmated and more than one queen may join the swarm. If the second swarm does not occur, one of the virgin queens eliminates her rivals and becomes the head of the colony, and all remaining queen cells are destroyed. (Winston, 1987).

3. Swarm Cluster and Nest Hunting

After leaving the parental hive, the swarm usually lands on a tree branch for several days and begins a decision-making process that will have huge consequences for the survival of the swarm. Some of the workers perform scouting duties, flying around the surrounding areas to find suitable cavities for their colony. The scout who returns to the swarm after examining a quality nest site, informs this knowledge to other bees through waggle dances on the surface of the cluster. These dances inform the direction and distance to the new nest. Various forms of physical, acoustic, and visual communication are used to ensure the movement of all bees together and to coordinate departure times for departure from the swarm cluster. Among this information; waggle dance to indicate the direction and distance of possible nest sites, shaking/vibration signals to activate scout bees, buzz runs to prepare the swarm for take-off, fast flights and pheromones to mark the way to the new nest are in effect. While most individuals in the swarm cluster are inactive, a small minority (scouts) are mobile in the selection of the swarm's future nest site. In order to move from the swarm cluster to the new nest, all bees on the swarm surface are ready for action by warming their flight muscles to 35 °C in ten minutes before take-off. All bees in the swarm cluster, which contains approximately ten thousand bees, begin to fly in about 60 seconds and begin to move together, forming a rotating cloud of bees (Visscher and Camazine,1999; Seeley et al., 2003; Seeley, 2010; Grozinger et al., 2014).

Suitable nest areas for the swarm are hollow trees or cracks between rocks in nature. During the swarming season, empty hives with combs left by beekeepers or some other suitable man-made spaces (electrical panels, under-roof spaces, etc.) can also be determined as suitable nesting places by scout bees. Although honeybees can design the inside of their nests, they cannot cavity the necessary holes for the nest. In particular, nests large enough to accommodate the swarming bee colony must also have some other characteristics. Tree hollows preferred by bees are generally long and cylindrical, consistent with the shape of tree trunks. As a result of observations, it was determined that the average nest cavity has a volume of approximately 40 liters. It is preferred that the entrance to the nest cavity be small (10-20 cm^2), oriented towards the south, and that the entrance be high from the ground (3-5 m) but near to the bottom of the nest hole. A small entry is easily protected and helps insulate the nest from the outside environment. An entry from the bottom of the nest chamber rather than the top may assist in minimizing heat loss from the colony. When the bees come out to defecate on sunny days the southern orientation is important during the winter months In addition, the empty honeycombs left over from the previous residents in the new nest cavity also positively affect the selection. The distance of the new nest site from the parent colony is also a factor. Although there are differences according to subspecies, they generally prefer nest sites within 500-600 meters. It takes approximately 40 minutes for a scout bee to examine the nest site. The basic behavior of the scout when inside a cavity is to walk quickly around the interior surfaces of the nest. The scouts who identify potential new nest sites return to the swarm cluster, and start their dances. Other scouts examine the determined nest location and when the decision is made to move, they ensure the swarm is moved with excited dances on the swarm cluster. The nasanov pheromone of worker bees in front of the new nest entrance invites the swarm to the nest (Seeley 1977; Camazine et al., 1999; Seeley, 2010).

4. Built a New Nest After Swarming

After arriving to their new nest, beeswax production is started immediately by the worker bees. When necessary the inner walls of the cavity are flattened by removing wood splinters with the worker bees mouthparts. When this is not possible, walls and airflow gaps are closed with propolis. After all these are completed, new honeycombs are started to be built using the storage in the honey stomachs. The wax glands of worker bees, located in the abdominal segments, convert the sugar content of honey into beeswax and produce small wax scales. Wax glands develop slowly, reaching their peak performance in worker bees between approximately the 12th and 18th day of their lives, and then degenerate. However, if necessary, older bees can also start secreting beeswax again. There are more than 300 chemicals in the beeswax composition. This mixture is a substance that has the physical properties of a liquid, even though it appears solid at lower temperatures. Wax scales are collected by the bee through a special part of the hind leg and transmitted to the middle and front legs and mouth parts. Here, the wax scales are shaped by the mandibles, mixed with the secretions of the mandibular glands, and brought to a consistency that the bees can work with. A colony's beeswax production is especially high after moving to a new home and requires a significant energy input. A worker bee needs approximately four minutes to complete the preparation of each wax scale. Approximately 8000 honeycomb cells are made from 100 g of wax, and approximately 125000 wax scales are required for this. Immediately after swarming, the honey in the honey stomach of worker bees provides enough energy for the construction of approximately 5000 initial cells. First, the foundation is formed by attaching wax lumps to the roof or side walls of the nest with the help of mouth parts. For each new honeycomb, they can start construction work in several places at the same time. Each worker bee adds a lump of wax onto this thick wax puddle. In an advanced stage of honeycomb construction, many worker bees connect their legs together and form chains. Bees have gravity receptor organs in all their leg joints, between the head, thorax, and abdomen. They use the data from these receptors to orient honeycombs vertically in the dark hive. Bees use their bodies as stencil as they start to form cell walls and create cylindrical tubes around themselves. Initially cylindrical, tube-like cells, but when the bees boost the temperature of the wax to 37-40°C they take on their typical hexagonal shape. In this way, the side walls between the firmly packed wax cylinders are also strained in a straight line, gaining a completely flattened surface and a thickness of 0.07 mm, an angle forming exactly 120° relative to each other. They also add propolis to the honeycomb content. Propolis has antibacterial and antifungal properties, therefore it prevents or reduces the risk of infection and increases the resistance of the beeswax. Bees also leave large stores of propolis inside the nest that can be accessed when needed. In western honey bee combs, the average width of the workers' cell is 5.2 mm and the depth is 11 mm on average, while the average width of the drone's cell is 6.2 mm and the depth is 12.5 mm on average. The hexagonal cells of the comb are used to store nectar and pollen, as well as to raise the brood. Honeycombs are also used as a line of defense against pathogens, where the colony's unique identity is stored, and as a dance floor especially in communication. Even forager bees that leave the hive to search and gather food spend more than 90% of their lives in or on the honeycomb. The positions of the honeycombs within the nest and the way each honeycomb is used are similar. The brood area is in the middle part of the comb and is also in a protected area within the nest and in the combs in the middle. The outermost combs are basically the combs where honey is stored, and on a single comb, honey begins to be stored from the upper part. Pollen is stored around the brood area. Larger cells prepared for raising drones are built on the lower edges of the comb, and queen cells are built in different parts of the honeycomb depending on the purpose of rearing (Winston, 1987; Güler, 2006; Tautz, 2008; Karihaloo et al., 2013).

CONCLUSION

Swarming in honey bees presents a fascinating example of collective behavior that contains thousands of individuals in a range of different physiological and behavioral states collaborating to drive a complex behavioral process that can spread over multiple days, locations, and stages. Swarming, or reproduction by colony fission, is a remarkable example of a behavior that necessitates the simultaneous coordination of thousands of worker honey bees and queen. The efficient operation of this group behavior depends on members of the swarm responding appropriately to various cues generated by workers and queens to coordinate nest departures, nest location searches, and nest site migration (Grozinger et al., 2014).

In this chapter, both the factors causing honey bee colonies to swarm and the vital behaviors of the swarming bees resulting in the new nest construction are explained.

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CHAPTER 6

BEE DISEASES COMMONLY OBSERVED IN TURKIYE

Assoc. Prof. Dr. Sibel ALAPALA[1]

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[1] Uşak University, Faculty of Agriculture, Department of Animal Science, Usak. Turkey
sibel.alapala@usak.edu.tr. ORCİD ID: 0000-0001-7677-5919.
(Corresponding Author)

INTRODUCTION

Bees are social insects that live in highly organized colonies with a strict hierarchy. Therefore, beekeepers must have a deep understanding of bee behavior and biology to effectively manage their colonies. A colony typically consists of a single queen bee, thousands of female worker bees, and several hundred male bees. While the queen bee is responsible for laying eggs, worker bees perform a variety of tasks such as foraging for nectar and pollen, caring for the brood, and defending the hive. The primary role of drones is to mate with the queen (Cengiz and Arslan, 2023).

Beekeeping, also known as beekeeping, is the practice of maintaining honeybee colonies by humans, usually in hives. This activity is primarily carried out for the production of honey, beeswax, propolis, royal jelly and the pollination of crops. The history of beekeeping dates back thousands of years, and there is evidence that ancient Egyptians kept bees for honey and wax (Crane, 1999).

1. General Situation of Beekeeping in Our Country

In addition to its contribution to plant production, honey bee breeding enables the production of products that improve human health with honey and other beekeeping products (royal jelly, pollen, propolis, bee venom and apiair). On a national basis, Turkey is the third country in the world with 8,179,085 hives after India and China, leaving behind many countries in terms of bee presence and amount of honey produced (Anonymous 2021; Kutlu et al., 2022). Despite this great potential, the amount of honey obtained from a unit hive cannot provide product diversity and the desired success in the world market. The number of hives and honey production in Turkey is increasing every year, but it does not have a production that will be subject to world trade in both the yield per colony and the production of non-honey products. The reasons for this include many factors such as honeybee diseases and pests, mistakes made in cultivation and non-compliance with sanitation rules (Kutlu et al., 2022).

2. Bee Diseases Commonly Observed in Our Country

One of the important problems in beekeeping activities is bee diseases. Parasites, bacteria, viruses and fungi can cause diseases in both the development and adult stages of honey bees. These disease-causing factors enter the colony in various ways and spread rapidly from colony to colony, apiary to apiary and region to region. There is a need to develop control and combat strategies to minimize these problems.

2.1. .Viral Diseases Seen in Honey Bees

2.1.1. Chronic Bee Paralysis Virus

Genetic analysis has shown that chronic bee paralysis virus should be classified as a new group of viruses due to its similarity to Nodaviruses (Nodaviridae). The majority of bee colonies exposed to chronic bee paralysis virus may not exhibit symptoms. Type 1 and Type 2 syndromes have been defined in colonies with disease symptoms (Ribiere et al., 2010).

The main symptoms of type 1 syndrome are tremors, drooping wings, and swollen abdomen. Abnormal trembling movements are observed in the wings, bodies and legs of these bees, which are mostly seen at the entrance of the hive (Ribiere et al., 2010). The most typical clinical findings seen in type-2 syndrome are loss of body hair and darkening of the body color, turning bright black. Because of this appearance, it is also called 'hairless black syndrome' (Ribiere et al., 2007; Ribiere et al., 2010). Affected bees appear smaller than others. However, their abdomens are swollen. In some cases, Type 1 and Type 2 syndromes may occur simultaneously in the same colony, but one is seen to be more dominant than the other (Ribiere et al., 2010).

2.1.2. Chronic Bee Paralysis Satellite Virus (CBPV)

Chronic bee paralysis satellite virus has a diameter of approximately 12-17 nm and a structure with cubic symmetry. The virus is a non-enveloped virus carrying a three-piece RNA genome and is serologically completely different from the chronic bee paralysis virus. The agent is a typical satellite virus that necessarily requires chronic bee paralysis virus to multiply. This virus is mostly seen in queen bees. The virus has not been found to cause any disease symptoms in bees (Allen and Ball, 1996; Doğanay and Aydın, 2017).

2.1.3. Acute Bee Paralysis Virus (ABPV)

Acute bee paralysis virus was discovered accidentally during laboratory work to identify the agent that initially caused bee paralysis (chronic bee paralysis virus). Acute bee paralysis virus, located in the Dicistroviridae family, is an RNA virus found in the Aparavirus genus (Doğanay and Aydın, 2017). The agent is transmitted from infected worker bees without disease symptoms to larvae feeding on royal jelly, or to pupae and larvae by the varroa parasite (Moore et al., 2015). Until the spread of the Varroa parasite in the world, this virus was not directly detected serologically in dead adult bees or in breeding bee breeding. The longer the feeding period of the varroa mite on the honey bee, the greater the amount of virus transmitted. Contamination with acute bee paralysis during the pupa period causes pupal deaths (Aubert et al., 2008).

2.1.4. Cashmere Bee Virus (KBV)

The causative agent is an RNA virus in the Aparavirus genus in the Dicistroviridae family (Aubert et al., 2008; Doğanay and Aydın, 2017). Cashmere bee virus was discovered accidentally as a contaminant during the administration of Apis iridescent virus extracts obtained from Apis cerena (Asian honey bee) found in Northern India to Apis mellifera (European honey bee). The disease occurs through direct contact with infected bees or transmission of the agent to the cuticle from contaminated environments. Infected worker bees can transmit viruses to larvae during honeycomb cleaning. It is possible for cashmere bee virus to be transmitted via transovarial-vertical route. The disease mostly progresses as persistent infection in adult bees. The appearance of varroa parasites in colonies parallels the appearance of disease symptoms (Allen and Ball, 1996; Aubert et al., 2008).

2.1.5. Israeli Acute Bee Paralysis Virus (IAPV)

These viruses, which have the greatest impact on honey bee populations, are smaller than viruses in the Dicistroviridae and Iflaviridae families. (Chen and Siede, 2007). It is observed that many cases of Israeli acute bee paralysis infection proceed without clinical symptoms. In bees with clinical symptoms, signs of paralysis and wing tremors may be detected. Additionally, dead bees are encountered outside the hive (Meeus et al., 2014).

The Nosema apis parasite acts as a vector in the transmission of the virus and causes diarrhea in adult bees. During the pupa period, the virus multiplies rapidly and causes the death of the offspring. The larvae in the honeycomb cells have a light yellow appearance and a hard sac-like structure like sacbrood.

2.1.6. Deformed Wing Virus (DWV)

Deformed wing virus is an RNA virus belonging to the Iflavirus genus of the Iflaviridae family. Varroa destructor is the main vector of deformed wing virus. Observations and experiments show that in a bee colony infested with the varroa parasite, a bee infected with the virus may die at a certain developmental stage (pupa stage), the virus multiplies slowly, and clinical symptoms such as wrinkled/vestigial wings, abdomen shortening and weight loss appear in infected adult bees. It was found to occur. The agent has been detected in honey bees in Europe, Africa, Asia, England, North and Central America. During a study on virus infections in bee colonies in the Scandinavian countries, serological detection of deformed wing virus was associated with colony collapse (Aubert et al., 2008; Martin et al., 2012).

2.1.7. Varroa Destructor Virus-1 (VaDV-1)

Genetically, varroa destructor virus-1 (VaDV-1) is also genetically similar to deformed wing virus. These often occur together and exchange (recombination) occurs between them. They have the ability to reproduce in both varroa and bees. VaDV-1 can be found in different tissues of bees and in high titer (Ongus et al., 2004).

2.1.8. Tulum foulbrood virus (SBV, Bag disease)

Tubular foulbrood can affect both larvae and adult honey bees, but it causes more serious consequences in larvae. In the disease, the color of the larvae changes from white to dark and they are found in the comb chamber with their heads turned up and to the side. This appearance is most clearly detected in the head and chest area of the larva. Since the agent disrupts the molting structure of the larva, the old skin cannot be separated from the head and some fluid accumulates between the two skin layers. As a result, the head becomes swollen and looks like a jumpsuit (Uygur and Girişgin, 2008).

2.1.9. Black queen cell virus (BQCV)

This disease is characterized by the presence of dead queen bees, pupae and prepupae that have turned dark brown in the cells of the comb. It is the main cause of death of queen bee larvae. During the larval and pupal stages, the virus becomes active and blackening of the cell wall occurs. Afterwards, the pupa dies inside the eye. In adult bees, it causes diarrhea, jerky movements and death. Nosema apis is cultivated to spread this disease in adult bees. Black queen cell virus occurs in the intestines and ovaries of queen bees. Infection occasionally occurs in worker bee larvae. However, since adult bee larvae feed for a shorter period of time, their chances of encountering the virus are low or they do not encounter a lethal dose of the agent (Allen and Ball, 1996; Aubert et al., 2008).

Transmission in Viral Diseases Knowing the transmission process of viruses enables the determination of the appropriate control program. Transmission of viruses generally occurs through horizontal, vertical transmission, or a combination of both. Horizontal transmission occurs in two ways: direct and indirect. Direct transmission occurs through airborne, foodborne, contact and sexual intercourse. Indirect transmission occurs through a biological vector such as mites (Varroa, Nosema). In vertical transmission, viruses are transmitted vertically from the mother to her offspring, either on the surface of the egg shell or within the egg. It is thought that the transmission of most bee diseases occurs through food exchange. The disease spreads through the feces of sick or asymptomatic bees and when food contaminated with the virus is eaten by healthy bees and their offspring. Susceptibility to some diseases may vary among bee lines. Infected worker bees can transmit viruses to larvae during honeycomb cleaning. Transmission through contact is an important means of transmission, especially for CBPV. It can also be seen in KBV. Vector-borne transmission; Varroa is an obligate parasite of honeybees and accompanies most viral infections. Studies have reported that it plays a role in the transmission of all the mentioned diseases (ABPV, CBPV, DWV, KBV, BQCV). Studies have also shown that the combination of the virus and this mite causes high deaths in the colony. Infection with Nosema is frequently seen in viral diseases, and is especially important for BQCV (Anonymous, 2022).

2.2. Bacterial Diseases Seen in Honey Bees

Unlike other animals, which veterinarians treat one by one, a beehive is treated as a superorganism consisting of thousands of individuals with developing larvae and adult honey bees. In this super organism, which includes the queen, worker and drone bees, the larvae are generally the most worrying and need to be treated (Applegate and Petritz, 2020). Paenibacillus larvae, Melissococcus plutonius, Serratia marcescens, Spiroplasma apis and Spiroplasma melliferum are the factors shown to be the primary cause of bacterial diseases in honey bees (Burritt et al., 2016). Among these, the most important ones in terms of economic losses due to the diseases they cause are P. larvae and M. plutonius, which mostly affect larvae (Fünfhaus et al., 2018). Common bacterial diseases in our country are as follows;

2.2.1. American Foul Rot (AYF)

The causative agent of the disease is Gram-positive and spore-forming Paenibacillus larvae, which causes serious losses in colonies in temperate and subtropical regions (Genersch, 2010). Since P. larvae spores are pathogenic for the larvae, they do not cause disease in adult bees (Uygur and Girişgin, 2008). Young bee larvae ingest P. larvae spores orally and are more prone to infection during the first 12 to 36 hours after hatching (Hoage and Rothenbuhler, 1966). P. larvae spores become vegetative in the midgut lumen and, after penetrating the intestinal epithelium, disrupt the epithelium locally and proliferate massively in the hemocoel (Yue et al., 2008). After the infected larva dies, P. larvae continues to develop and decompose until the dead larva becomes fully decomposed. More than a billion endospores can be found in a single dead larva in a diseased comb cell. As the course of the disease progresses at the colony level, more larvae become infected and die. Thus, as the number of offspring decreases, the continuation of the lineage cannot be ensured, and this causes the colony to disappear (Genersch, 2010).

2.2.2. European Foul Rot

European Foulbrood disease is an economically important disease of honeybee colonies, and severe cases can cause severe damage or even complete loss of beehives (Tomkies et al., 2009). The causative agent of the disease, Melissococcus plutonius, is Gram-positive and generally has a spindle-shaped and sometimes pleomorphic and rod-like appearance.

European Foebrood affects honeybee larvae, usually 4-5 days old, in unsealed brood cells and causes death (Forsgren, 2010). The larva emits a foul or sour odor due to secondary factors such as Enterococcus faecalis and Paenibacillus alvei (Arai et al., 2012). While the incidence of the disease is low in winter and spring, it increases in summer. The first step in infection is asymptomatic colonization. M. plutonius ingested through contaminated food multiplies in the midgut of larvae. Routine beekeeping practices also result in M. plutonius being easily transported between colonies. For this reason, European foulbrood generally spreads rapidly and is difficult to eradicate unless urgent action is taken (Thompson and Brown, 2001).

2.2.3. Septicemia

Serratia marcescens, the causative agent of the disease, is a Gram-negative opportunistic pathogen of a variety of animals, including humans and insects. In most animals, S. marcescens is lethal only when present in the bloodstream (Grimont and Grimont, 1978). The Serratia genus are rods that generally produce prodigiosin, the characteristic red or pink pigment. Additionally, S. marcescens was isolated from diseased honey bee larvae (El Sanousi et al., 1987).

2.3. Parasitic Diseases Seen in Honey Bees

2.3.1. Varroa

Varroa destructor is a dangerous parasite that lives by sucking blood on the larvae, pupae and adults of honey bees (Apis Mellifera L.). Its main host is Apis Cerena, known as the Indian bee. This parasite was transmitted to Apis

Mellifera through unconscious migratory beekeeping for the purpose of producing more honey (Kaftanoğlu, 2003). Varroa destructor first spread to Russia and then to Eastern European countries, and then spread to all continents, causing the extinction of hundreds of thousands of colonies. It first entered Turkey in 1977 and spread throughout the country in a short time. Although many precautions have been taken, it still poses a great danger to colonies (Kaftanoğlu et al., 1990).

Adult Varroa is brown or dark brown and its body is covered with a transverse layer of chitin. Adult females 1.1-1.2 mm. in length and 1.5-1.6 mm. width (Kaftanoğlu et al., 1992; Şahinler and Alapala Demirhan, 2023)

Female Varroa are not normally capable of reproduction. In order to gain the ability to lay eggs, the larvae must be fed with the Juvenile hormone in their hemolymph. For this, Varroa enters the honeycomb cell where the larva is located shortly before the larva is sealed and begins to lay eggs 60 hours after receiving enough Juvenile hormone. 5 female Varroa can become adults from the male bee's eye and 3 female Varroa from the worker bee's eye of the honeycomb. After Varroa come out of the honeycomb, they attach to any bee in the hive and feed on its blood (Kaftanoğlu and Yeninar, 2000).

As a result of Varroa destructor feeding by sucking blood, bees lose protein, and bacteria, fungi and other pathogens can easily enter the body. Microbial infection and protein loss shorten the lifespan of bees and greatly increase wintering losses. In those that survive, flight activity is very low. Bees affected by the Varroa mite during the pupa period are more damaged; It can complete its development with deformations such as wingless, single-winged, small abdomen and small feet (Kaftanoğlu et al., 1990).

Biological control methods are also used to control Varroa parasites. These are limiting the production of male brood eyes, carrying brood eyes and trapping method, trapping method by taking artificial swarms, wire cage and drawer base application method, method of applying electricity to honeycomb wires, method of using young queen bees, utilizing heat applications, using pollen traps, worker bees. These can be listed as changing eye size and limiting male offspring eye production (Kaftanoğlu et al., 1992).

2.3.2. Nosema

Nosematosis is one of the most common diseases seen in adult honey bees. The causative agent of the disease is microsporidia called Nosema apis and N. ceranae (Somerville and Hornitzky, 2007). The disease spreads via fecal-oral route in honey bee colonies. Adult bees contract the disease through water and food contaminated with spores or when removing contaminated feces during hive cleaning. Once ingested, the spores germinate and multiply in the midgut. A few weeks after infection, millions of spores are formed and these spores are excreted in the feces (Fries, 1997). In infected colonies; Digestive system disorders, shortening of lifespan, inability to fly, dirty white and dull intestines, collection of dead bees at the entrance of the hive, decrease in colony population and honey production, and even extinction in colonies may occur (Bailey and Ball, 1991). Nosema apis is the first described microsporidian. It is one of the parasites. In the past, it was thought that only N. apis was the cause of nosematosis in European honey bees (*Apis mellifera*), and N. ceranae was thought to parasitize only Asian honey bees (*Apis cerana*). However, N. ceranae, a species added to the definitions; It is seen in four continents: Asia, Europe, North America and South America, is rapidly spreading among European honey bees, and is replacing *N. apis* worldwide (Williams, 2008).

2.3.3. Bee Lice (Braula coeca)

Bee Lice is not actually a lice, but Braula coeca, a member of the Diptera order, is a brown-colored insect that is 1.5 mm long and 1 mm wide. It has no wings or eyes. Although adults are similar to Varroa, they can be distinguished by having three pairs of legs and their licking-sucking mouthparts (Zeybek, 1991). It lives on worker and queen bees and is very rare in male bees. During the adult period, they are found in the chest and mouth parts of the bee and steal food from its mouth. They feed on royal jelly, pollen and honey, not by sucking blood like other bee pests (Zeybek, 1991). After mating, adult females of the bee louse lay their eggs on the upper part of the honeycomb cells. The emerging larvae consume honey by opening tunnels in the honey secrete. They can consume all the honey inside the eye during the larval period, which lasts 45-50 days. When the larva matures, it turns into a pupa at the base of the eye. Pupae are white in color. Adults emerge after the pupa period, which lasts 12-16 days (Öncüer and Benlioğlu, 1998). The most suitable conditions for larvae and adults are environments with a temperature of 32-35 °C and 50-60% relative humidity. Bee lice cause queen bees to weaken, their ability to lay eggs to decrease, bee larvae to be malnourished, and the market value of honey to decrease significantly by damaging the secrets of the honeycombs in the hive (Zeybek, 1991). Bee lice cannot reproduce during winter and early spring. It spends the winter as an adult insect. It begins to multiply as the weather warms in spring.

2.4. Fungal Diseases Seen in Honey Bees

2.4.1. Lime Disease

Lime disease is a juvenile disease caused by the fungus called Ascosphaera apis (Betts, 1932). There are three subspecies of the fungus: Ascosphaera apis alvei, Ascosphaera apis minor and Ascosphaera apis major (Zeybek, 1991). Ascosphaera apis is a fungus with a heterothallic structure (mycelia having different sexes as male (+) or female (-)). Hyphae from two different sexes combine to form spore sacs approximately 47-140 μ in length. The inside of these sacs is filled with spores of the fungus (Öncüer and

Benlioğlu, 1998). The larva ingests Ascosphaera apis with food (Flores et al. 1996). Larvae are more susceptible to diseases when they are 4-5 days old and a few hours after the honeycomb eyes close (Flores et al. 1996). Spores are very durable. They can maintain their disease-causing ability for 15 years. It is most common in spring and autumn. Strong colonies can overcome the disease during the summer months. Spores that remain alive on the honeycombs for years without causing disease become active again when they find suitable conditions for reproduction. The most suitable temperature for the growth of the fungus is around 30 °C. In the advanced stages of the disease, white mummified larvae are seen in the middle parts of the incubation area and in the middle of the combs with broods (Genç and Dodoloğlu, 2002). If the larvae are infected with only (+) or (-) sexual mycelia, they are white as chalk. If infected with both (+) and (-) sexual mycelia, the color of the diseased larva becomes grayish black (Flores et al., 1996). Environmental pollution, intensive use of antibiotics, feeding bees with artificial nutrients, excessive humidity, and the use of adulterated wax are effective in the formation of the disease. During the colony checks carried out by beekeepers in early spring, especially on days when the weather is overcast and cold, the temperature of the brood in the hive decreases, the resistance of the brood decreases, and the development of the fungus is activated as more oxygen penetrates into the larval tissues with cold (Yeninar and Kaftanoğlu, 1992). No chemical treatment is recommended to treat and control arthritis. The method of replacing calcareous colonies with queens produced in colonies without lime is also very effective in the control (Sanford, 2003).

2.4.2. Stone Disease

The main cause of stone disease is Aspergillus flavus. Sometimes the fungus called A. fumigatus or other Aspergillus species are the causative agent (Shimanuki et al., 1993). Diseased larvae can die at any age. However, most deaths occur in the period before pupation. Adult bees can also get sick at any age. Especially old adult bees remaining from the summer are more sensitive to the disease (Öder, 1983). Stone disease occurs due to insufficient ventilation of the hive, high moisture content and disruption of the bees' normal intestinal flora due to the use of antibiotics (Öncüer and Benlioğlu, 1998). Since honey from diseased hives will have a carcinogenic effect when consumed by humans, these honeys and honeycombs must be destroyed (Zeybek, 1991). Best method; destruction of sick bees and honeycombs, thorough disinfection of hives and replacement of queen bees.

3. Bee Death and Fight Against Diseases

Today, it is known that many factors infect honeybees (*Apis mellifera*). As a result of the transmission of these viruses to honey bees in different ways, some of them show high pathogenicity, while a significant part of them are found in colonies without causing disease, but under certain special conditions, they cause disease symptoms and losses. Therefore, in the pathogenesis of honey bee viruses, virus, host (life stage of the honey bee) and environmental factors must be considered together.

In the fight against bee diseases and pests, some measures can be taken to prevent the transmission and spread of diseases. Chief among these are;

1-Pillaging should be prevented and hives should be placed 3-4 meters apart from each other to prevent entering the wrong hive.

2- Queen bees must be changed in hives infected with the disease.

3-If the source of honey is unknown, it should not be used in nutrition.

4-Old diseased honeycombs should not be used

5- Do not work with queen bees that carry disease agents.

6- If possible, young bees should be added to sick hives and the hives should be strengthened.

If the specified conditions are complied with, bee diseases and pests will not be able to shelter in the hives, and even if they do, there will be a chance to be treated as quickly and easily as possible. This will save our beekeepers from using excessive amounts of pesticides. In the fight against bee diseases and pests, chemical substances used in high amounts and without proper timing will increase the resistance of microorganisms, fungal spores and bee mites to the drug. This situation reduces the benefit from spraying over time. In the fight against diseases and pests, spraying at the exact dose and at sufficient frequency will eliminate the residue problem.

CONCLUSION

One of the most important factors that prevent the development of our beekeeping is bee diseases and pests. Therefore, beekeepers need to have information about the symptoms and characteristics of the most common viral, bacterial, fungal and parasitic diseases in bees and the methods of combating them. Unconscious and incorrect practices cause both economic losses and the spread of diseases to healthy colonies.

Care should be taken to combat diseases on time, with the appropriate medication and in the appropriate dosage. It should not be forgotten that unnecessary and excessive use of drugs will leave residues in honey and beeswax, which will negatively affect human health. Beekeepers should be careful about bee diseases and pests, and in case of doubt, they should seek help from expert veterinarians and technical staff working in the provincial and district Directorates of Agriculture.

In order to be protected from some diseases, it is necessary to apply continuous treatment at certain periods. For this, physical, biological, genetic and chemical control methods must be used together in harmony. Among these methods, the least labor intensive, cheapest and easiest to apply method is chemical control. In this study, it is necessary to popularize the use of natural products instead of chemical control and to raise awareness of growers about natural treatment methods. Unconscious use of drugs leaves residues in bee products and poses a danger to human health.

More studies are needed on the applicability of the researched methods in the field. The development of new methods in these diseases, where detection is difficult, especially due to hygienic behavior, will provide data for studies to prevent diseases.

The most important way to combat bee diseases is to prevent the disease. Regular hive inspection should be carried out, and attention should be paid to cleaning and hygiene rules. Preparing bee colonies for harsh winter conditions and eliminating stress factors (climate changes, environmental pollution, base stations, harmful pesticides, etc.) is an important method of protecting against infections.

The use of immune system boosters in the nutrition of bees in addition to cakes and sherbet in appropriate proportions can be effective in the fight against bee diseases.

Identifying and using infection-resistant bee lines and replacing the queen bee in colonies showing clinical symptoms with a queen bee obtained from healthy colonies in areas where the disease is intense will help eliminate the disease.

Parasites that are virus vectors must be combated. There is a parallelism between the amount of parasites and the density of viruses. Chemical control should be carried out especially against Nosema apis and Varroa.

In populations where bee deaths due to infectious microorganisms occur, necessary places should be consulted for disease diagnosis and control and control programs should be implemented (Anonymous, 2022).

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CHAPTER 7

ARTIFICIAL INSEMINATION IN HONEYBEES

Assoc. Prof. Dr. Aziz GÜL[1]
Assoc. Prof. Dr. Mahir Murat CENGİZ[2]

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[1] Hatay Mustafa Kemal Üniversitesi, Ziraat Fakültesi Zootekni Bölümü, Antakya, Hatay, Türkiye. agul25@gmail.com, Orcid ID: 0000-0003-1158-5019
[2] Atatürk Üniversitesi, Teknik Bilimler Meslek Yüksekokulu, Bitkisel ve Hayvansal Üretim Bölümü Erzurum, Türkiye. mahirmuratcengiz@gmail.com, Orcid ID: 0000-0002-9844-4229

INTRODUCTION

Beekeeping, as a tradition of the Anatolian people, has been practiced in our country since ancient times. Although it has a very old history, beekeeping has developed in recent centuries due to advances in science and technology. In today's technical sense, beekeeping, which is an agricultural endeavor and production branch in itself, can be defined as "the art of using and managing honey bees" for certain purposes. As in other branches of production, the aim of beekeeping is to provide the highest income with the least expense (Güler, 2006). Beekeeping has been practiced in Anatolia since ancient times and 5 of the 27 honey bee races in the world are in Türkiye. However, these genetic resources have been changed due to high migratory beekeeping activities, and high uncontrolled colony and queen selling. So Türkiye has to save all these genetic resources through setting up instrumental insemination substructures. Queen bee is a genetic key of the honey bee colony. It is impossible to control the genetic structure of colony as the queen mates with many drones at the outside of the colony. In this case the genetic resources of honey bee should be protected by restricted area, mating station or arinstrumental insemination. Stock, pure and hybrid line rearing which necessitate controlled mating can be performed by artificial instrumental insemination technique. Artificial insemination (AI) of honey bees is a specialized technique used primarily in scientific research and selective breeding programs to control and enhance specific genetic traits within honey bee colonies (Kaftanoğlu, 2005; Güler, 2006). The development of artificial insemination for use in honey bees in the early half of the 20th century was a turning point for bee breeding programs. Artificial insemination has since become integral to both breeding and research programs globally. The last overarching review of artificial insemination in honey bees was published in 1987. Since then, research has focused on semen storage and handling (Gillard and Oldroyd, 2020). Although, the technique of instrumental insemination, developed in 1920's and perfected in the 1940's and

1950's, provides a method of complete genetic control. Today, with improvements in instrumentation, the technique is highly repeatable and highly successful (Cobey, 1983; Laidlaw, 1987).

1. Importance Of Artıficial Insemination Of Honey Bee

Artificial insemination of honey bees plays a significant role in advancing honey bee genetics, health, and productivity, thereby supporting sustainable beekeeping practices and contributing to global agricultural stability. Artificial insemination of honey bees is an important technique in beekeeping and scientific research for several reasons:

Genetic Improvement: It allows beekeepers and researchers to control the genetic diversity of honey bee populations. By selectively breeding queens with desired traits (such as disease resistance, productivity, or gentleness), artificial insemination ensures that these traits are passed on consistently.

Research and Study: It enables scientists to study specific genetic traits and their effects on honey bee behavior, physiology, and overall health. This research contributes to understanding and improving honey bee management practices and addressing challenges like colony collapse disorder.

Preservation of Genetic Diversity: In regions where certain bee populations are threatened or endangered, artificial insemination can help preserve genetic diversity by maintaining stocks that might otherwise be lost.

Mitigation of Disease: Artificial insemination allows for the selective breeding of honey bees that are resistant to diseases and parasites. This can help reduce the reliance on chemical treatments and promote sustainable beekeeping practices.

Efficiency in Breeding Programs: It accelerates the breeding process compared to natural mating, where the queen mates with multiple drones with varying genetic backgrounds. This efficiency is crucial for commercial beekeepers who need to maintain productive and healthy colonies.

Controlled Breeding Environment: Artificial insemination provides a controlled environment where factors such as temperature, humidity, and the quality of sperm can be carefully managed, ensuring higher success rates compared to natural mating.

2. History of Artificial Insemination

After the aerial mating behavior of honey bees was learned, many different practices and methods were tried by researchers in the process of controlling queen and drone mating for the improvement of bee populations. Reaumur (1740) tried to mate the queen bee and the male bee by placing them in a glass of water. Similarly, Françis Huber (1814) attempted to inseminate the queen bee by applying it to the needle circle after collecting the semen of the male bee. Following these researchers, Kohler (1868) attempted artificial insemination by pouring the liquid from the male bee larva onto the queen bee larva, and McLain (1885) attempted artificial insemination by dropping semen liquid onto the queen bee pupa and the adult queen bee (Harbo, 1985; Cobey, 1983, 2004).

3. Artificial Insemination Process

3.1. Equipments

Development of artificial insemination in honey bees was mostly driven by improvements in instrument design, and in the care of queens and drones. First instruments, such as that of Watson (1927), were basic to say the least. Watson physically restrained conscious queens to an angled wooden board with multiple loops of silk thread. This was in turn placed upon the stage of a dissecting microscope, to which was clamped an insemination pipette. To introduce the pipette into the queen's sting chamber, the sting. Necessary Tools and Equipment Before starting artificial insemination, the tools and equipment listed below are needed (Figure 1) (Schley, 1988; Cobey and Schley, 1989**;** Cobey, 1995).

- Insemination device with injector
- Sterio microscope with Lighting mechanism
- Anesthesia mechanism (CO_2 tube and mechanism)
- Queen bee marker and glue
- Antibiotic (streptomycine etc.)
- Ethyl Alcohol (70%)
- Pure water, Paper towel
- NaCl (9% sodium chloride)
- Scissors, Cotton swab, Glass
- Drone trap
- Queen bee application cage

Figure 1. Instrumental Insemination Unit

3.2. Queen and Drone Rearing

Almost all queens to be artificially inseminated must be breeding material or genetic stocks. Queen bees to be artificially inseminated are specially raised. For this purpose, strong, dominant colonies with a large number of young worker bees that produce large amounts of royal jelly are used (Laidlaw, 1979; Harbo, 1986; Ruttner, 1988; Morse, 1994). A small number of larvae (average 30) are transferred to the prepared starter colony (Figure 2). Starter colonies should have ample stocks of honey and pollen and be fed with sugar syrup. Queen bees and drones are raised and inseminated during the best period of the season (Moritz, 1984; Kaftanoğlu and Peng, 1982; Güler and Alpay, 2005). In order to raise quality queen bees, 0-24 hour old larvae are used and older larvae are not used for transfer purposes.

Naturally, a virgin queen is about 6 days old, she flies out of her colony and locates a nearby drone congregation area, an area in the landscape where drones gather. A drone congregation area is typically an open space of 100–400 m radius surrounded by trees. At the drone congregation area, drones circle in flight at a height of 10–50 m (Cobey, 2007). Drone congregation areas are frequented by drones from colonies within the surrounding 3.75 km radius (44 km^2) (Güler, 2006). Queen bees to be artificially inseminated must be 6-15 days old. Since the reproductive organs and tissues of queen bees younger than six days old are very weak; Some difficulties occur in artificial insemination of queen bees older than 15 days of age, as the elasticity of their tissues decreases. For example, it has been determined that queens older than 15 days of age store less sperm when artificially inseminated (Güler, 2006).

Figure 2. Queen cells

Breeding and selection of male bees is as important as queen bee breeding. Because the offspring that will be formed will receive all the characters they will have from these two parents at an equal and random half (1/2) level. Male bee breeding depends on the season and it is difficult to raise male bees old enough to be used at any time in any season (Figure 3). For this reason, queen bee breeding and drone breeding should be planned together. The incubation period of male bees is 24 days and they reach sexual maturity in 14 days after emerging from the honeycomb. Therefore, drone breeding should be started at least 38-40 days before the date of artificial insemination (Harbo, 1985; Güler, 2006). For this purpose, a raised honeycomb with drone eyes should be given to the colony where males will be raised, and the queen bee should be trapped on this honeycomb with a cage. 24 days after unfertilized eggs are deposited in the drone cells, the male bees complete the incubation period and emerge from the honeycomb cells. These drones are marked and used in artificial insemination studies. The best drones to use in artificial insemination are those between 10 and 21 days old. Drones younger than 10 days of age are not used in artificial insemination because they have not reached sexual maturity, and those older than 21 days of age cannot be used in artificial insemination because they carry diseases or leave residue in the queen oviduct (Cobey, 1983; Harbo, 1985).

Figure 3. Drone Collection

3.3. Syringe Preparation And Sperm Collection

Various physiological fluids are used in the preparation of the syringe. The most basic solution used in insemination is physiological saline solution. However, known solutions other than physiological saline are Ringer's and Kiev's solutions. Ringer's solution (NaCl, 0.85 g; KCl, 0.025 g; CaCl, 0.030 g; glucose, 0.50 g and distilled water, 100 ml), and Kiev's solution (Trisodium citrate-2 hydrate, 2.43 g; NaHCO3, 0.01 g; KCl, 0.30 g; glucose, 0.30 g and distilled water, 100 ml) contain chemicals that will not harm sperm and regulate pH optimally. After these solutions are prepared, they should be sterilized or bacterial growth should be prevented by adding an antibiotic such as 0.25% streptomycin (Cobey and Schley, 2002; Güler, 2006). The diluent used is more critical when semen is diluted, mixed or held in storage. The syringe adapter is filled with this prepared liquid and the syringe needle is mounted on the adapter and the syringe is prepared for sperm collection. With the vacuum created by using the liquid taken in the syringe, drone semen is drawn into the syringe and artificially transferred to the queen bees.

Figure 4. Partial and full eversiyon

The thorax of the collected drones is caressed between the index and thumbs of the right hand and squeezed slightly. By the reproductive organ (endophallus) of the male bee is removed from the urogenital mouth, the first eversion is achieved (Figure 4). Full eversion is achieved by gently squeezing the tip of the abdomen again with the index and thumbs of the left hand (Figure 4). On the endophallus, semen fluid is distributed or aggregated in a thin film layer along with the mucus. With the prepared syringe, the semen fluid of the drone is drawn into the syringe under the microscope. While collecting sperm, care should be taken to ensure that the syringe tip does not touch the mucus layer and that mucus and semen are not mixed into the syringe. During sperm collection, the tip of the syringe should be kept wet to prevent residue from forming at the syringe mouth and to prevent clogging of the syringe tip. There should be a connection between the semen fluid taken from male bees and there should be no gap. Sperm collection continues until the required amount of semen is reached (Figure 5). A male bee produces an average of 10 million spermatozoa, and approximately 7.5 million spermatozoa are contained in a volume of semen fluid of 1 μl (Harbo, 1985; Cobey and Schley, 2002; Güler, 2006).

Figure 5. Semen Collection

3.4. Artificial Insemination of Queen Bees

At this point, it is necessary to provide a brief synopsis of the process of artificial insemination in bees. The goal of artificial insemination is simple: transfer semen from the seminal vesicles of selected drones into the median oviduct of the selected queens (Figure 6). Queens are reared using standard methods (Harbo, 1986), and introduced to individual nuclei as queen pupae (Mackensen and Roberts, 1948), or maintained as virgins in a queen bank until inseminated. Naturally, queen bees go on a mating flight 6-10 days after they become adults. Queen bees to be artificially inseminated must be 6-15 days old. Since queen bees younger than six days old have not reached sexual maturity, their reproductive organs and tissues are very weak and are not suitable for insemination. Likewise, some difficulties occur in the insemination of queen bees older than 15 days of age. For example, it has been determined that queens older than 15 days of age store less sperm when artificially inseminated (Woyke and Jasinski, 1976).

The number of sperm cells stored in th normal mated queen spermatheca is variable. Among drones, the number and viability of sperm is also variable (Lodesani et al., 2004; Cobey, 2007). As discussed, environmental conditions as well as the pre and post insemination treatment of queens can effect the number of sperm cells stored. The dosage, quality and handling of semen are also contributing factors. To obtain results similar to natural mating, the standard semen dosage for instrumental insemination is 8 to 12 µL (Mackensen, 1964; Cobey, 2007). An increase can be gained by multiple inseminations of small doses. Smaller semen doses migrate faster (Bolten and Harbo, 1982; Cobey, 2007).

Figure 6. Insemination posses

Carbon dioxide treatments, used to anesthetize the queen during the insemination procedure. CO_2 treatments stimulate the neurosecretory production of juvenile hormone, which contributes to the initiating of oviposition (Mackensen, 1947). Two CO_2 treatments stimulate young Quenns to begin oviposition in a similar time period as Normal mated queens. One treatment is given during the insemination; another is given either before or after the insemination. The timing and dosage of CO_2 treatments are variable in practice and may influence queen performance (Cobey, 2007). CO_2 gas should be sufficient during artificial insemination. Otherwise, it will cause the queen bee to move and may cause serious injury. It is possible to determine this amount by the number of bubbles that will form by dipping the carbon dioxide hose into a glass of water. If bubbles can be counted, this indicates that the amount of CO_2 passing through is sufficient. Before CO_2 gas reaches the queen bee, it must be heated either in water or in another chamber. The temperature of the gas reaching the queen bee should be close to room temperature. Cold CO_2 can cause unsuccessful insemination and subsequent problems with ovulation. The main reasons for CO_2 application are to prevent the queen from moving during insemination, to relax the tissues and muscles to facilitate the passage of the semen needle through the vaginal ring, and to enable the queen to lay eggs in a short time. With the help of ventral and dorsal hooks, the queen's sting circle is opened under the microscope. During the opening process, the needle circle is first entered with the help of the ventral hook and grasped at the last sternum of the ventral (Figure 6-7) (Güler, 2007).

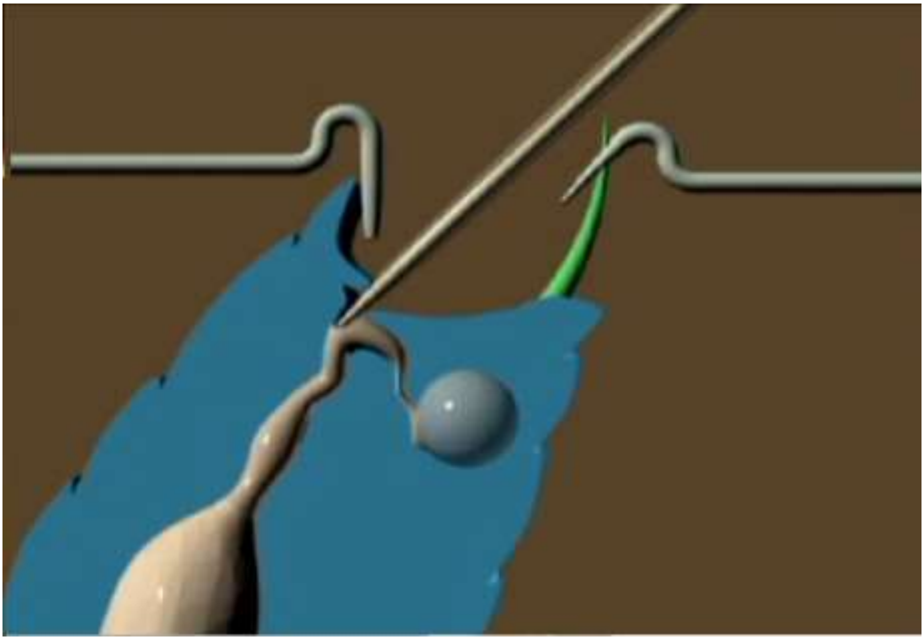

Figure 7. Passing walfehood and transferring sperm inside the oviduct

After entering the oviduct, 8-10 microliters of sperm fluid is injected into the queen by slowly turning the control knob of the syringe to the right. After this process, the syringe is withdrawn and removed from the queen bee's reproductive organ. The queen bee is removed from the tube and returned to the hive from which it was taken when the effect of anesthesia (CO_2) wears off and the queen becomes fully conscious. If the semen fluid does not flow or flows out during injection, it should be understood that the median oviduct (vaginal) valve cannot be passed and it should be tried again. With the injection of semen, semen fluid flows into the lateral oviduct canals and within the next 24 hours, semen fluid passes into the spermatheca and is stored there (Figure 8).

Figure 8. Mated (b) and unmated (a) queens spermatheca

As seen in Figure 8 (a), the spermatheca of a queen bee that has not yet mated is filled with a transparent liquid. However, after the queen mates, approximately 7-8 million sperm are transferred into the spermatheca and its color changes to cream as seen in Figure 8 (b).

In conclusion, artificial insemination of honeybees plays a crucial role in modern beekeeping by optimizing genetic selection, enhancing colony health, and producing queen bees with desired traits. This technique aims to increase resistance to diseases, improve overall bee performance, and provide beekeepers with tools to mitigate challenges such as environmental changes and colony collapse disorder. Therefore, artificial insemination of honeybees represents a significant strategy in the beekeeping industry to enhance sustainability and productivity.

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CHAPTER 8

ORGANIC BEEKEEPING AND BEE HEALTH

Assoc. Prof. Dr. Sibel ALAPALA[1]

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[1] Uşak University, Faculty of Agriculture, Department of Animal Science, Usak. Turkey sibel.alapala@usak.edu.tr. ORCİD ID: 0000-0001-7677-5919.

INTRODUCTION

In parallel with the rapid population growth in the world, efforts to increase production, called the green revolution in agriculture, were accelerated in the 1960s and 1970s in order to provide adequate nutrition for people. In order to increase production, the use of synthetic chemical pesticides, mineral fertilizers, growth regulators and hormones has been encouraged. However, environmental pollution caused by these inputs, disruption of natural balance, and chemical residues in food reaching levels that threaten the food chain and human health have directed producers and consumers to the production and consumption of natural, organic and healthy agricultural products (Kaftanoğlu, 2003).

Organic beekeeping is generally based on the principle of obtaining the product without being exposed to any nutrients or chemicals other than organic honey, growing it in pristine and pollutant-sensitive areas, and inspecting all stages with control and certification. Organic beekeeping, which increases the income from beekeeping and allows consumers to supply products with desired features, is developing as a new model in Turkey.

Our country is very rich in terms of natural structure and nectar resources and has a great potential in terms of beekeeping (Genç and Dodoloğlu, 2017; Murray et al., 2009) Beekeeping has a great importance among organic agriculture activities. Characterization of beekeeping products as organic production; It depends on the characteristics of the hives, environmental quality, careful obtaining and storage conditions of beekeeping products. By training beekeepers on organic beekeeping activities and implementing more effective colony management, our country will take its place among the few countries in the world in organic honey production, as in conventional honey production.

1.Current Situation of Organic Beekeeping in Turkey

Beekeeping and dairy farming were among the firsts in organic animal husbandry in our country (Şahinler et al., 2019). Organic beekeeping is the beekeeping activities carried out in areas with an intact natural structure or in organic farming areas, without using any artificial feeding or chemical pesticides in all processes from production to consumption of beekeeping products.

In our country, colonies are traditionally fed with sugar and sugar syrup, the amount of honey produced per hive is low due to deficiencies in colony management and therefore the cost is high, the prevalence of bee diseases and pests and the chemical drugs used to combat them leave residues in the colony and bee products, the difference between traditionally produced honey and organic honey. Organic honey production can be made at a limited level in Turkey because the price difference between the honey produced varies between 10% and 20% and this difference is not considered sufficient by the beekeeper (Yücel, 2005; Yalçın and Büyükbay, 2015).

Data on honey production by years in the country where organic beekeeping is considered to have started in 2003 (Köseoğlu et al., 2008) are included in Table 1.

Table 1. Organic Honey Production in Türkiye

Year	Number of Provinces	Number of Producers	Number of Hives	Production Amount (Tons)
2004	7	159	27.839	737.26
2005	11	127	24.475	572.71
2006	16	110	25.706	636.48
2007	12	143	23.308	497.38
2008	17	93	11.207	180.11
2009	17	147	14.917	201.13
2010	21	191	14.699	204.61
2011	25	190	19.177	216.18
2012	31	355	47.065	513.08
2013	33	279	32.342	335.53
2014	38	321	36.391	277.00
2015	34	322	38.296	667.08
2016	34	276	40.371	349.00
2017	30	305	45.848	391.08
2018	37	334	51.742	494.9
2019	31	249	50.100	576.76
2020	36	387	70.385	1028.39
Toplam	430	3988	573.868	7878.68

Source: Anonymous, 2022.

When the organic honey production data in the table is evaluated, it is seen that 2004, which was taken as the beginning, was the second year with the highest production after 2020; It turns out that the small declines experienced until 2007 accelerated after this year, and fluctuating changes were experienced until recent years. However, there is a general upward trend in both the number of provinces where organic beekeeping is practiced and the number of producers, except for the sudden decrease in 2008 (Demir et al., 2023).

2. Basic Principles of Organic Beekeeping

If we want to offer healthier and higher quality bee products to the consumer by making organic production in beekeeping, we have to comply with the "Organic Beekeeping" rules specified in Article 23 of Chapter 3 of the Regulation on the Principles and Implementation of Organic Agriculture issued by the Ministry of Agriculture and Forestry. Some rules that must be followed for organic beekeeping are given below (Anonymous, 2024).

-According to the relevant regulation, the apiaries to be established for organic production should not be at least 3 km away from the nectar and pollen sources, and there should be no adverse effects on the organic nature of the nectar and pollen sources, and they should also be away from urban centers that are likely to cause pollution (Anonymous, 2024).

-In organic beekeeping, where hives must be made of materials that will not pose a risk to the environment and bee products, physical applications such as direct fire and steam are allowed for disinfection. In addition, hives cannot be painted with chemical dyes; Instead, propolis, beeswax and vegetable oils should be used (Anonymous, 2024).

-The transition period in organic beekeeping is one year. Beekeeping products can be marketed as organic products, provided that the provisions of this Regulation are implemented for at least one year (Anonymous, 2024).

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-In this production model, where every stage is controlled, if the colonies are under threat due to climatic conditions, the authorized organization may allow them to be fed with organic honey or organic sugar. In addition, while it is essential to work with resistant genotypes adapted to local conditions against honey bee diseases and pests, in case of disease and pests despite protective measures, phytotherapeutic or homeopathic treatment methods should be used instead of chemically compounded drugs (Anonymous, 2024).

Bee products obtained after complying with the specified general rules and completing the transition period can be sold as organic products after certification approval.

3. Health Protection and Control in Organic Beekeeping

As a general expression, "Bee Health" means that honey bees living in colonies, that is, in a community order, can maintain the order they have established in different types of hives or suitable shelters without external intervention. In cases where external intervention occurs, for example, when very valuable products such as pollen, nectar, propolis and honey accumulated by bees are taken from the hives by humans in abnormal ways and at times, bee health is directly intervened. Because bees ensure their survival by collecting bee products to ensure the continuation of their own colonies. In order to stay healthy, they produce swarms that vary in duration and frequency against increasing parasitic infestations. Different problems arise in bees whose swarming behavior is constantly inhibited (Muz et al., 2019).

Like all living things, honeybees are under threat from various parasites and microorganisms around them. These parasites and microorganisms cause bees to get sick, colonies to weaken or die out, and thus their productivity to decrease. While chemicals are generally used to control diseases and pests in conventional beekeeping, in organic beekeeping the necessary precautions are either taken to prevent diseases or products or methods that will not harm organic production are preferred. The priority for this work is to take protective measures to prevent honey bees from contracting diseases. For this;

-When veterinary medicinal products are applied; The type of product, including the active pharmacological substance, diagnosis, dose, method of application, duration of treatment and residual elimination period of the drug are recorded and the authorized organization is informed before the products are marketed as organic products.

-Stable breeds and lines should be selected, queen bees should be renewed regularly

-Materials used in apiaries should be disinfected regularly using organic methods,

-Hives should be systematically inspected and male offspring should be checked,

-Contaminated materials or resources should be destroyed harmlessly,

-Honeycombs should be renewed regularly,

-A sufficient amount of pollen and honey should be left in the hives (Gökçe, 2002).

-If chemically synthesized allopathic products are applied for therapeutic purposes, during this period the colonies under treatment are placed in isolated hives and all beeswax is replaced with wax from organic beekeeping. A one-year transition period is applied to these colonies (Anonymous, 2022).

In addition to these measures taken, disinfection of the hives should be done by burning them with purifier. Other beekeeping equipment should be disinfected in boiling water. In order to disinfect the hives and equipment used in beekeeping; potassium and sodium soap, water and steam, lime cream, lime, quicklime, sodium hypochlorite (e.g. bleach), caustic soda, caustic potash, hydrogen peroxide, natural plant extracts, citric, paracitic acid, formic acid, lactic acid, oxalic acid, acetic acid, alcohol, formalin and sodium carbonate can be used (Lodesani et al., 2003; Anonymous, 2002b).

If colonies become sick despite all the precautions taken, they should be treated immediately and pesticides should be applied in accordance with organic production rules. A transition period is applied to the treated colonies or they are transferred to organic honeycomb frames. If the use of chemical drugs is unavoidable, it should be done under veterinary control. After the treatment, all honeycombs in the colonies where the pesticide was applied should be replaced with new honeycombs. In case of the Varroa destructor parasite, one of the biggest problems in beekeeping, products such as formic acid, lactic acid, acetic acid, oxalic acid, menthol, thymol, eucalyptol and camphor should be used. When these products are used, a one-year transition period is not applied to the colonies. (Anonymous 2002a; Gökçe 2002; Imdorf, 2003; Livia et al., 2003).

Examples of drug use in organic honey production include the use of salt instead of naphthalene against wax moth, as well as the use of formic acid against varroa and lime disease (Kumova and Korkmaz, 2000). Formic acid stands out as a preparation that can be used against varroa and lime disease because it is an organic acid naturally found in honey, the dose given does not leave a residue in the honey, and the formic acid rate decreases to natural limits shortly after application and does not adversely affect human health (Kaftanoğlu et al.,1992).

Apart from this, frames with drone eyes can be used as a biological method. Another method of struggle is the heating method. In this system, the hive is kept at 45 ^{0}C for 5 minutes is heated. Varroa that fall under the hive are collected and destroyed (Gökçe, 2000).

4. Natural Fight Against Diseases in Beekeeping (Varroa Examples)

In organic beekeeping, it is recommended to use natural treatment methods first to protect bee health. Below, the results obtained with natural methods used in the treatment of Varroa disease are mentioned.

In a study conducted to determine the effectiveness of Tobacco leaves, Bay oil, Thyme leaves or oil in the fight against Varroa, the effect of tobacco leaves (35.55%), thyme oil (12.30%) and laurel oil (21.90%) in the fight against Varroa in the autumn period was higher than the control group. It was determined that. In the spring period, it was determined that tobacco leaf (28.48%), thyme oil (17.90%) and bay oil (0.52%) levels were higher than the control group. It has been stated that the application of tobacco leaves in the autumn and spring periods is more effective than other applications in the fight against Varroa, followed by the application of thyme oil (Şahinler and Alapala Demirhan, 2022).

As a result of the study in which eucalyptus bark and leaves and orange peel were used against Varro control, it was reported that it was 94% effective in the eucalyptus bark and leaf group and 99% in the orange peel application group (Çetin, 2010).

The effects of formic acid plates on lime disease caused by Varroa destructor and Ascosphera apis were examined, and their bioactivity against Ascosphera apis was determined in vitro. Formic Acid application to the colonies was made 4 times with 4-day intervals in the spring of the same year. Its effectiveness against Varroa destructor was found to be 93.3% on average, and its effect against lime disease was 45.28%. It has been reported that the doses of Formic Acid applied to colonies do not have a negative effect on queen bees, worker bees and colony development (Kaftanoğlu et al., 1990).

In another study, it was reported that the effectiveness of juniper tar smoke against Varroa destructor was 3.61% (±4.51) on average, and the effectiveness of cardboard tobacco was 2.64% (±0.78) on average. According to the analysis of variance test applied to investigate the numbers of varroa falling into the drawer after tobacco applications, trial and control It was reported that there was no significant difference between the groups ($p>0.05$), and as a result, juniper tar tobacco was ineffective against Varroa destructor (Girişkin et al., 2007).

The European Union has monitored the drugs and various chemicals used in the fight against varroa in order to ensure unity among member countries while establishing organic agricultural production standards. As a result of scientific studies on these substances, the use of formic acid, lactic acid and oxalic acid has been recommended. In addition, it has been reported that the use of drugs alternately (for example, formic acid in spring, oxalic acid in autumn and lactic acid in the other spring) is also important in preventing varroa from gaining resistance to chemicals (Akyol and Özkök, 2005).

In a study conducted in Erzurum, the effectiveness of oxalic acid, tymol and lactic acid in combating Varroa destructor infestation and their effects on colony development were investigated. As a result of the trial, the effectiveness of oxalic acid, tymol and lactic acid groups against Varroa destructor infestation was determined as 84.90±5.60%, 90.10±3.03%, 79.50±3.78%, respectively. According to the results obtained; The difference between the effectiveness levels of the organic compounds used for Varroa destructor was found to be statistically significant ($P<0.05$). Additionally, it was determined that the number of adult bees dying after spraying in the oxalic acid group was significantly different ($P < 0.05$) from the thymol and lactic acid groups (Cengiz, 2012).

The effectiveness of Apivar (Amitraz) was investigated in honeybee colonies (in pollen trap hives) naturally infested with Varroa destructor in the Bursa region. In the Apivar group, a total of 8838 Varroa fell into the pollen drawers in 42 days, and 57% of them fell in the first 48 hours. In the control group, a total of 1923 Varroa fell into the pollen drawers in 42 days, and 13% of them fell in the first 48 hours. The effectiveness of Apivar was determined firstly by Henderson–Tilton's formula and secondly by the percentage change method, which is based on comparing the average percentage of mites on bees before and after treatment. Accordingly, the effect of Apivar was found to be 99.43% and 99.36%, respectively. No side effects caused by the drug were observed (Aydın and Girişkin, 2010).

In a study conducted in Hatay, orange peel, eucalyptus leaves and eucalyptus bark were applied against the varroa parasite, and it was determined that the orange peel application was more effective than other applications in the autumn and spring periods, followed by the application of a mixture of eucalyptus peel and leaves. It was determined that the effectiveness of the applications made in the autumn period was higher than in the spring period (Şahinler, 2010).

As seen in the studies, natural control methods have yielded positive results in Varroa disease, and results have emerged that encourage the application of natural methods in other bee diseases.

5. Factors Affecting the Efficiency and Quality of Organic Bee Products

As a result of beekeeping activities, many products such as honey, beeswax, pollen, royal jelly, bee venom and propolis are obtained. These products are widely used both as foodstuffs and in the treatment of many diseases. Achieving the expected benefits from bee products is only possible with the production and consumption of organic bee products (Kaftanoğlu, 2003).

Beekeeping requires attention to the seasonal needs of the bee colony. During the spring and summer months when flowers are abundant, bees are busy collecting nectar and pollen to feed the colony and produce excess honey. Beekeepers must ensure that there is enough space in the hive for bees to store honey and raise brood. During autumn and winter, bees reduce their activity and form a winter cluster to maintain heat and survive cold weather. Beekeepers may need to supplement the bees' food source with sugar syrup, cake or honey syrup during the winter months (Seven and Tatlı Seven, 2018).

Nutrition plays a very important role in the well-being of bee colonies. Proper nutrition is essential for bee physiology, biochemistry, immunity and larval development. Nutritional stress resulting from habitat loss is associated with the collapse of honeybee colonies. Therefore, effective nutritional management is crucial to ensure the survival and productivity of bee colonies.

The organic beekeeping sector in Turkey faces several challenges that affect its growth and sustainability. These include problems such as low honey yield, problems in the management of diseases and pests, limited production diversity, price instability and export restrictions. These problems prevent the best results from organic beekeepers in Turkey. Potential solutions to address the challenges faced by beekeepers in Turkey include promoting sustainable organic beekeeping, improving disease management, preserving genetic diversity, and supporting research and education.

CONCLUSION

Organic production is an alternative agricultural system that preserves the ecological balance in nature, aims to obtain healthy and reliable products by optimizing the use of natural resources and energy and prioritizing quality rather than production quantity. Nowadays, there are increasing opinions and findings that foods produced with the excessive and unconscious use of synthetic chemicals threaten human health. Because the undesirable residue content of honey produced in Turkey is increasingly becoming a problem for export. The problem of chemical residues in bee products can be minimized by raising awareness of our beekeepers about the negative effects of chemicals used in the production of bee products on bee products and humans, the way and time of use of chemicals.

In addition to its large pasture areas, Turkey has a rich vegetation with forest trees such as linden, chestnut and pine. There is no doubt that our country, which ranks 3rd in the world after India and China in conventional honey production, will achieve the same success in organic honey production in this rich vegetation. However, organic beekeeping within the framework of certain rules will cause production losses for the producer. By making the prices paid for organic bee products more attractive, these losses can be eliminated, and organic beekeeping can become more widespread. In addition, encouraging the production of other bee products and providing the necessary state support during difficult times in the beekeeping sector can prevent the decline in organic honey production.

Undoubtedly, bee health and protection in the production of bee products is very important in organic beekeeping. In the treatment of diseases, natural methods should be used first, then drug treatments should be used, and all records should be kept. These practices will also guide growers when similar diseases are observed.

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CHAPTER 9

THE EFFECT OF BEES ON PRODUCTIVITY AND QUALITY

Lecturer Dr. Fatma ALAN[1]
Assoc. Prof. Dr. Ayşen Melda ÇOLAK[2]

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[1] Ankara University, Kalecik Vocational School, Horticulture Program Ankara, Türkiye.falan@ankara.edu.tr, Orcid ID: 0000-0001-5266-6339
[2] Uşak University, Faculty of Agriculture, Department of Horticulture, Uşak, Türkiye. aysenmelda.colak@usak.edu.tr, Orcid ID: 0000-0003-0113-2104

INTRODUCTION

In terms of fruit growing, Türkiye is the homeland of many fruit species and the cradle of vineyard and garden culture. Although there are both wild and cultivated fruit species in our country (Ağaoglu, 1987), apples, pears, quinces, hazelnuts, pistachios, sour cherries, plums, walnuts, almonds, figs, grapes, pomegranates, strawberries and blackberries have gained importance today. Many fruit species grow in these lands (Özbek, 1975).

In addition to climatic factors in the cultivation of fruits, pollination, which is the first condition of fertilization, is important for the functioning of ecosystems and protection of plant diversity, ensuring the continuity of species, fruit formation and the formation of seeds in flowering plants. The product obtained as a result of pollination by insects, especially bees, constitutes a large part of human food (Buchmann and Nabhan, 1996). In this context, fruit species pollinated by insects that help pollination are called entomophilous plants, and plants pollinated by insects are called entomophilia. In these species, the petals of the flowers are large and of various colors, fragrant, showy, and in most of them, there are glands that produce nectar between the male organs and the petals.

The process of transporting the pollen produced in the male flowers of flowering plants to the pistil of the flower of the same flower or the same individual or a different individual of the species, through an intermediary, is called pollination (Beram and Aday, 2022). Depending on the flower structure, pollination in plants is carried out by wind or nature-friendly pollinator insects, which transport pollen from the anther to the stigma.

There are great differences in pollination in pome and stone fruit species and grape fruits, depending on the species and varieties. Some species and varieties are self-pollinated, while others require foreign fertilization. In self-pollinated fruit species; Although pollination occurs with their own pollen, in self-sterile ones, fertilization only occurs with the help of pollen from other varieties of the same species (Özbek, 2008). This pollination event that occurs between two plants or plants with different genetic structures is called allogamy (Özçağıran, 2002), and in plants that require foreign pollination, pollination is especially done by bees (Gregor, 1976; Goodwin, 1986; Free, 1993; Özbek, 1979, 2003, 2008).

While pollination in fruit species occurs with the help of wind, in later years it was determined that this was done by insects, especially bees, which are known as one of the rare creatures that do not harm plants in any way, although they feed on flowers (Free, 1964). It was noted in the late 1800s that pollination of fruit flowers was done by insects, especially honeybees, and its importance in pollination was understood in the early 1900s and it was determined that fruit yield increased when beehives were placed in orchards (Auchter, 1924; Menke, 1950). However, in many fruit varieties of different species, flowers fall off when pollination does not occur and fertilization occurs, and fruit drop is observed in those that form fruit. On the other hand, in some fruit species and varieties, deformities are observed in the fruits due to insufficient fertilization in the flowers (Free, 1993). This shows that these tiny creatures, perhaps without even realizing it, are as important as fertilizer and water in agricultural activities.

The Importance of Bees in Pollination of Fruit Species

Wind, known as the main pollinator of flowering plants, is not sufficient for pollination in many plant species because it cannot provide homogeneous pollination and cannot carry heavy pollen. For this reason, it is known that honey bee colonies make significant contributions to increasing productivity in orchards and when their effective use is ensured, the productivity of existing gardens will increase. However, if farmers neglect the pollination process by applying all cultural procedures, they will fail to obtain a good harvest (McGregor, 1971). For this reason, honeybees have been preferred as primary pollinators because they have large colonies and can be easily transported and managed.

The climatic conditions, topographic structure and geographical location of our country and the richness of the vegetation allow the bee fauna to be abundant (Özbek, 2002; Anonymous, 2019), and the pollination event called pollination in plants is of vital importance in ensuring the continuity of species. This is largely achieved by living creatures called pollinators. Bees, which are an important part of the natural ecosystem and economically agricultural products worldwide, are the most active pollinators and play a critical role in the pollination of plants (Kekillioğlu and Kunduracı, 2022; Anonymous, 2023).

Bees are included in the *Insecta* (insects) class, *Hymenoptera* (membrane winged) order, *Apidea* (bees) family, *Apis* (honeybees) genus and *Apis mellifera* (honeybee) species. In *Hymenoptera* taxonomy, classification is generally made based on morphological, anatomical, molecular and behavioral features (Kekillioğlu and Bostan, 2023).

In pollination, which is a very important process in the fruit and seed production of the plant, pollen from the male organs of the flower is carried to the female organs by pollinators. This process is vital for the reproduction of plants and ensures the efficient growth of fruits, vegetables and other plant products (Kekillioğlu and Bostan, 2023). In order to benefit from honey bees in pollination at the highest level, bees should not be more than a certain distance from the plants they want to pollinate (Kuvancı, 2022).

Bees have an excellent performance in terms of pollination and it is easy for them to enter flowers that provide plenty of pollen and nectar. They also convey the location, direction, type, abundance and scent of flowers to other bees. Flower colors, pollinated by bees, are generally blue, purple, lavender or white. In addition, by pollinating various wild plants in nature, bees help many plant species continue their lineage, spread throughout the earth, and help the continuity of other plants that form communities with these plants.

With pollination, the continuity of nature is ensured, the quality and quantity of the product increases, an earlier and more uniform product is obtained, the oil content of the seeds increases, the fruit shape does not deteriorate, quality hybrid seeds are obtained, the harvest is done at the same time in the parcel, diversity in bee products and population increase in bee colonies are provided.

Studies on Pollination in Fruit Growing

In Özbek's study; It has been stated that 45-90% of the bees visiting pome fruit species and 81-97% of stone fruit species are honeybees (Özbek, 1979, 1980a, 1980b).

Melnichenko reported in his study that effective pollination increased the yield by 50-60% in apples and pears, by 75-90% in cucumbers, and by 95-100% in melons and watermelons (Melnichenko, 1977).

Malerbo et al. in their studies conducted in orange groves in Brazil, found that honeybees are the first among the pollinators that visit orange flowers the most, and that when attractants such as sugar sherbet and lemon extract are added to the trees, they increase the yield and quality with their positive effect on fertilization. (Malerbo et al., 2004).

Most fruit trees such as apples, pears, plums, almonds and cherries are self-incompatible and completely dependent on cross-pollination and are known to be pollinator honeybees. While there was a significant positive correlation in the relationship between bee-tree number in pears and apples, the percentage of fruit set and fruit set rate were found to be high in Japanese plum. It has been determined that honey bees play an important role especially in cross pollination (Altunoğlu, 2017; Stern et al., 2007).

Kuvancı et al. in 2010, determined that the highest efficiency of the contribution of bees to pollination in strawberry plants was obtained from the unit area free for bee access, and this was determined by the efficiency obtained in the area where wind and morphologically small insects such as honeybees were effective. They determined that the least yield was obtained in the area where the wind was effective. They also reported that honey bees accelerate the fruit ripening period, providing earliness of 3-4 days. In another study conducted on strawberries, Klatt et al. (2014) reported that a high proportion of pollinators (98.5%) were bees, and the remainder consisted of honey bees (33.9%) and wild pollinators (64.6%).

In the study conducted by Canverdi in 2016 in a closed apple garden with Granny Smith and Jersey Mac varieties grafted on M9 rootstock in Ulubey district of Ordu province, the average fruit weight of Granny Smith and Jersey Mac varieties, respectively, in the area where honey bees are effective, was 97.6 and 211.2 on the closed tree with a net and 63.3, respectively, 150.1 and 47.3, 128 g in the tree covered with tulle (Canverdi, 2016). In addition, in the studies of Kuvancı et al. in 2013, the number of seeds and shelf life of fruits were determined as 66.78 days and the average shelf life of fruits obtained from areas open to honeybees as 1497, and the average shelf life of fruit trees closed to bees as 58.15 days and 1497 days, respectively. They determined the number of seeds as 153 (Kuvancı et al., 2013). Again, in the study conducted by Kuvancı et al. in 2010 to determine the effect of honey bees on the vitamin C content of kiwi fruit; They determined it to be high in fruits taken from areas open to honey bees and low in fruits that are closed to bee access, and stated that honey bees make a positive contribution to fruits in terms of quality and quantity (Free, 1993).

In 2017, Akdeniz and his colleagues concluded that honey bees are completely effective on fruit set and yield in almond trees, but their effect on the parameters of yield, number of empty fruits and number of twin fruits is not statistically significant (Akdeniz et al., 2017).

Kuvancı et al. in their study on the effects of honey bees and other insects on the pollination of strawberry plants, stated that the effect of honey bees on the yield of strawberry plants comes first, followed by wind and insects that are morphologically smaller than bees (Kuvancı et al., 2010).

Klatt et al. In 2014, they examined the effect of bee activity on yield and fruit quality and found that as a result of bee pollination in strawberries, fruit quality, size and market value improved according to wind or self-pollination, and that the redness increased, the sugar/acid ratio decreased, the fruits were harder and their shelf life increased.

In a study in which the amounts and types of volatile compounds in the flowers of three strawberry varieties were determined by gas chromatography, Klatt et al. in 2013. They reported that similar volatile compounds were found in different amounts in the varieties and, in line with the results, they determined that the density of these compounds determined the pollination preference of the female bee *Osmia bicornis*. According to the results they obtained; They argued that flower scent is more important in attracting bees and flower morphology has a more minor effect (Klatt et al., 2013). In another study conducted, Ceuppens and his colleagues examined the effect of the aroma released by the flowers on the duration and number of visits of *B. Terrestris* to the flowers and observed that pollinators visited the flowers of the 'Sonata' variety more than the 'Elsanta' variety and the visit times were twice as long. In their study results, Ceuppens and his colleagues determined that the repellent compounds were less and the attractive compounds were more in the 'Sonata' variety compared to the 'Elsanta' variety (Ceuppens et al., 2015).

In the study conducted by Çöçen et al. in 2019 on the effect of honey bees and other insects on fruit set and fruit quality of the '0900 Ziraat' cherry variety in Malatya ecology, they determined that honey bees are the most effective factor in pollination of cherries and that they greatly increase fruit set (Çöçen et al., 2019). In a similar study conducted on sour cherry, Hansted et al. (2012) reported that honey bees and bumble bees increased productivity.

In his study conducted on 0900 Ziraat variety in Eğirdir conditions, Sarısu (2017) reported that the fruit set rate under free pollination conditions varied between 15.62% and 27.65%, while in another study conducted on cherry, Topal et al. (2017) found that fruit set was 14.12% and that the honey bee significantly increased fruit set.

In their study on the effect of honey bee pollination on fruit and seed yield in plum in 2021, Kutlu and Kılıç determined that the average amount of seeds in flowers that are open to bees is higher than the average amount of seeds in flowers that are closed to bees. They stated that they needed bees to provide food.

In his study, Vithanage found that the average number of fruits per tree was 788 as a result of the use of honey bees in pollination in the avocado plant, and in the absence of honey bees, the number of fruits was 227 (Vithanage, 1990).

Sapir et al. (2017) stated that introducing bumble bees to the honey bee garden improved foreign pollination, increased the number of seeds and fruit size, and concluded that introducing bumble bees to the orchard improved the foraging behavior of honey bees. In another study, Isaac and Kirk. While they concluded that bumblebees are effective in pollinating small areas and honeybees are effective in pollinating large areas, and that competition is important in pollination, Garratt and his colleagues stated in their studies conducted in an apple garden in England that the use of honeybees in pollination is effective on fruit quality parameters and regulates the level of mineral substances.

According to the results obtained in the research conducted in previous years, it has been stated that many berries, especially strawberries, and kiwis have a high number of seeds, so frequent bee visits ensure that the number of seeds is sufficient, which allows the fruits to have smooth shapes and high taste and aroma (Woyke and Bronikowska, 1984; Cervancia and Bergonia, 1991; Shrivastava and Shrivastava, 1991; Banda and Paxton, 2000).

Malformed fruits in strawberries occur as a result of the achene on the fruit losing their functions due to the temperature being below 7^{o}C during pollen formation and development (Ariza, 2011), and the amount of malformed fruits varies among strawberry varieties (Carew, 2003; Ariza, 2011). In a study, according to the results obtained, it was determined that the yield values were high between Medina and Camarosa strawberry varieties, while most of the malformed fruit formation occurred in the early period, it was observed that the Camarosa variety produced more malformed fruits within the scope of the trial, and the amount of malformed fruits was reduced with the use of pollinators. It was determined that the amount of malformed fruits was decreased and thus, it was stated that the amount of malformed fruits depended on environmental factors and genetic effects (Ariza, 2012).

Çolak et al. 2017, according to the data obtained from a study conducted in order to determine the effect of honeybees on pollination and fecundation of strawberry in Usak province between 2014 and 2016, a considerable increase in quality and a homogeneity in strawberry fruit were observed and 1248.6 g of productivity was obtained in strawberries with bee pollination, while 970.33 g of productivity was obtained in strawberries without bee pollination

According to the results obtained in the study conducted by Güler in 2022 on the importance of solitary bees in fruit production, which are the most basic plant pollinators of agricultural ecosystems and play a key role in increasing the yield of many agricultural products, they visit more flowers and start flying activity earlier in the morning and late in the morning. It has been determined that it lasts for hours and plays a role in increasing productivity.

CONCLUSION

The data showing the flowering periods of important plants for beekeeping in fruit cultivation and their distribution by province at the regional level will constitute an important database for beekeepers and future scientific studies.

In particular, the protection of natural life and the popularization of the use of honey bees as pollinators in case of need are important in terms of economy and honeybee-fruit flower benefits in plant production. Attention should be paid to the use of pesticides during the flowering period in fruit growing, beekeepers in the region should be informed and the use of chemical pesticides should be avoided unless necessary in order to protect natural life.

Pollination carried out by bees will ensure the continuity and diversity of the natural flora, and in addition, earlier, uniform and quality products will be obtained in plant production, fruit shapes will be smooth, storage life will increase, and high-quality hybrid seeds with high germination ability will be obtained.

The use of bees as pollinators will increase the fruit setting rate of plants, fruit size, number of seeds in the fruit and fruit characteristics. In addition, the flowers of many plants pollinated by bees will be less damaged by late spring frosts.

In many cultivated plants that require foreign pollination, there will be increases in quality and quantity in fruit and seed yield with the use of honey bee colonies. The number of seeds will be sufficient, the fruits will be properly shaped, and their taste and aroma will increase.

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CHAPTER 10

BEEKEEPING SUPPORTS IN THE EUROPEAN UNION AND TURKEY

Assist. Prof. Dr. Alaeddin YÖRÜK[1]

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[1] Osmaniye Korkut Ata University, Faculty of Applied Sciences, Department of Organic Agriculture Management Osmaniye, Turkey. alaeddinyoruk@osmaniye.edu.tr Orcid ID: 0000-0003-2098-4468

INTRODUCTION

Nowadays, with the honey and other products they produce, as well as the pollination services they provide, honey bees offer both economic and societal benefits. According to FAO's 2022 data, with a presence of 100,996,303 colonies and 1,830,768 tons of honey production worldwide, they are considered an important branch of agriculture. Beekeeping is practiced all over the world for different reasons, ranging from hobby beekeeping to balcony beekeeping in cities, from beekeeping as a source of livelihood for poor rural communities to beekeeping as a source of production for professional enterprises, and with the number of hives ranging from one hive to thousands of hives.

Beekeeping is practiced worldwide. When evaluated based on colony presence, honey production quantity, different production conditions, yields, and beekeeping practices, China, India, Turkey, and the European Union countries as a region stand out as leading places for beekeeping. Beekeeping is defined as obtaining honey, royal jelly, beeswax, pollen, propolis, and bee venom from bee colonies as bee products (Tutkun and Boşgelmez, 2003).

In addition to bee products, the necessity of bees and other pollinators (honey bees, bumblebees, and solitary bees) as important pollinators for agricultural activity, the continuation of plant production, and natural plant habitats is well known. There is no doubt that honey bees play a significant role in the agricultural sectors. Approximately one-third of human food is pollinated by honey bees, and more than 66% of the 1,500 crops worldwide are directly or indirectly pollinated by honey bees (Kremen et al., 2002). Pollination contributes approximately 215 billion USD per year to ecosystem services (Tutkun and Boşgelmez, 2003; Smith et al., 2013).

However, bees and pollinators worldwide face many threats. Numerous interacting and complex factors, such as habitat loss and pesticide use, combined with the effects of the climate crisis and pollution, are leading to the decline of pollinators. Bee health and sustainable beekeeping are seen as the key to sustainable agriculture globally. The honey bee, an important pollinator of flowering plants and various crops managed by humans (Anonymous, 2019), has shown a decline in health despite the stable number of western honey bee (*Apis mellifera*) colonies, according to numerous reports and publications from different parts of the world over the past two decades (Anonymous, 2019a; Anonymous, 2022; Anonymous, 2023a). It has been observed that multiple biotic and abiotic factors, such as pests, parasites and pathogens, pesticides, habitat changes, poor nutrition, and lack of genetic diversity, contribute to poor colony health (Anonymous, 2024; Anonymous, 2019b). Some scientists also suggest that the combination of these factors may be behind the cases of Colony Collapse Disorder, where increasing numbers of honey bees inexplicably abandon their hives, leaving the queen bee behind (Anonymous, 2019b).

Bees are highly sensitive to environmental factors (Abrol, 2010). Temperature, humidity, light intensity, and pesticide residues in crops are all considered potential causes of Colony Collapse Disorder (CCD). The invasion of ectoparasitic mites (Varroa destructor) (Ziegelmann et al., 2018; Hillayová et al., 2022) and attacks by invasive species such as killer hornets (Vespa mandarinia) also result in significant losses in honey bee colonies (Zhu et al., 2020). However, honey bee colonies can regulate their composition to overcome environmental threats by adding worker bees, forager bees, and drones. Colonies strive to keep the number of forager bees above a minimum threshold to maintain productivity; otherwise, colony failure will occur (Khoury, 2011).

The loss of honey bee colonies and the current threats to their health are major concerns for both beekeepers and biologists. For bees, a significant portion of the threatened wild bee species are known to be endemic to Europe (20.4%, or 400 species) or the EU-27 (14.6%, or 277 species). Approximately 30% of the threatened species at the European level are specific to Europe.

The risk of honey production depletion threatens beekeepers' livelihoods and affects more than just beekeepers. The reduction in the pollination power of struggling bee colonies threatens overall agricultural production and impacts the entire population. In recent years, maintaining bee colonies in the face of annual colony losses has become crucial for the profitability of beekeeping operations, which are traditionally labor-intensive. Challenges related to honey production, combined with the ongoing increase in consumer demand, have led to sharp rises in honey prices. Additionally, since the 1990s, the growth rate in pollinator-dependent agriculture has shown a sharp increase, surpassing the average growth in the number of hives. This rise in demand for pollination services, combined with ongoing and growing colony loss crises, has created a serious shortage of bees for pollination. Bees are highly effective pollinators with an annual global contribution to crop yields valued at 147 billion euros (Anonymous, 2020).

Beekeeping plays a very important role in agriculture. In Europe, pollinators contribute not only an annual added value of 1 billion euros to the sector's agricultural production but also to a total amount of at least 22 billion euros. The most significant impact of beekeeping is its support for the agricultural sector in the EU, thereby promoting sustainable development, and contributing to the development of rural areas and the preservation of biodiversity.

Increasing the resilience of beekeeping to abiotic stresses such as climate change, habitat loss, and hazardous chemicals is achievable through support and grants provided to beekeepers. Honey bee colonies have been observed to generally be weak in coping with stresses due to modern beekeeping practices. The key to resilient beekeeping lies in harnessing the power of nature to restore harmony and balance within the honey bee colony and between the colony and its environment (both of which are disrupted by human activities) by developing locally adapted colonies.

Abandoned colonies and wild colonies that survive in nature will be leading examples of regional adaptation. However, such colonies often lack many of the positive traits important in modern beekeeping. The solution here is to understand the processes and mechanisms that are effective in nature and adapt modern beekeeping practices and decisions accordingly, while also leveraging the benefits of advanced technologies when appropriate. Implementing this new approach in beekeeping management will involve close cooperation with relevant stakeholders.

Restoring harmony and balance should occur at three levels: the environment, the honey bee, and beekeeping practices. The value that will enable all of this lies in supporting beekeeping. This study will examine the support and grants available for beekeeping in the EU and Turkey.

General Status of Beekeeping

According to FAO's 2024 data, while there were approximately 80 million bee colonies worldwide in 2010, this number has continuously increased to around 101 million by 2022. However, the same cannot be said for honey production. FAO's 2024 data shows that global honey production peaked at approximately 1.88 million tons in 2017. However, due to a series of adverse factors, honey production began to decline after 2017. Particularly in 2019, the climate crisis and bee losses impacted production, leading to a decrease in honey production to 1.76 million tons.

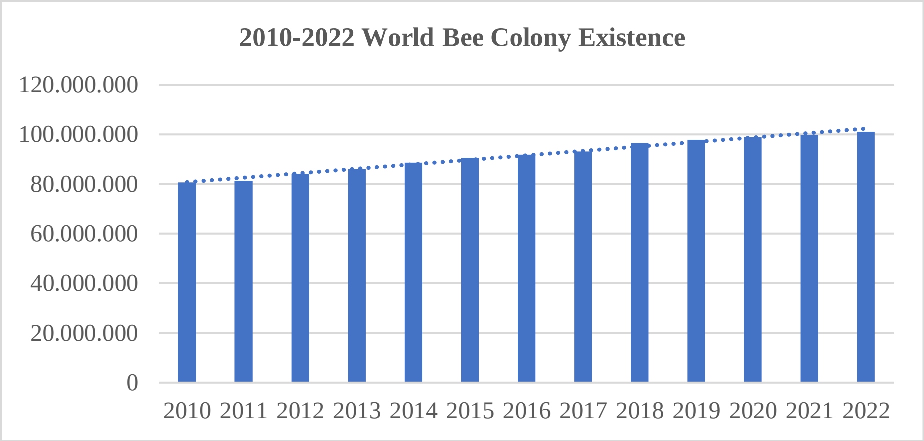


Figure 1. Number of Bee Colonies Worldwide (FAO, 2024)

As of 2022, India has the highest number of bee colonies with approximately 12.614 million, followed by Mainland China and Turkey. According to Figure 2, data from 2022 shows that five countries (India, China, Turkey, Iran, and Ethiopia) account for approximately 45% of the global colony presence.

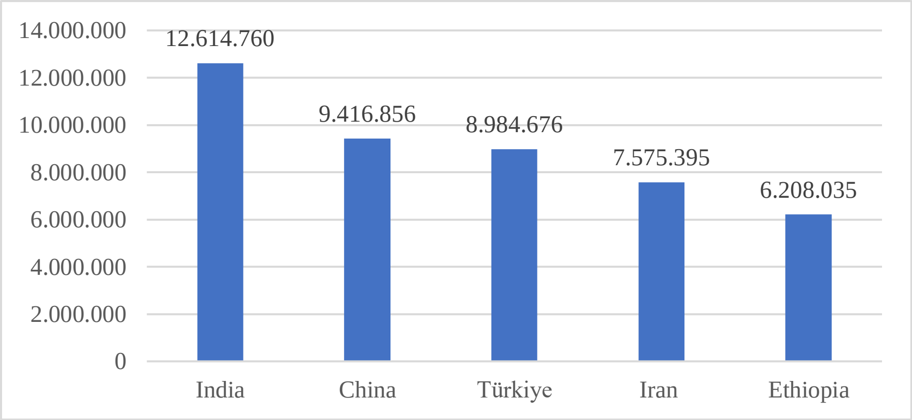


Figure 2. Countries Holding Approximately Half of the World's Bee Colonies (FAO, 2024)

Table 1 shows that Asia is the continent with the highest number of colonies, holding 45,341,060 colonies. The twenty-seven member states of the

European Union have a total of 19,881,604 colonies, while Turkey has approximately 9 million bee colonies.

Tablo 1. Number of Beehives in the World (2022)

Alan	**2022**
World	100.996.303
Asia	45.341.068
European Union (27)	**19.881.604**
Americas	11.711.294
India	12.614.760
China	9.416.856
Türkiye	**8.984.676**
Iran (Islamic Republic of)	7.575.395
Ethiopia	6.208.035
United Republic of Tanzania	3.077.056
Argentina	2.975.530
Russian Federation	2.789.983
United States of America	2.667.000
Mexico	2.319.393
Republic of Korea	2.125.326
Central African Republic	1.659.185
Kenya	1.416.489
Angola	1.191.158
Brazil	1.017.158

Source: (FAO, 2024)

According to FAO's 2024 data, EU countries rank second in terms of colony presence. The number of bee colonies in the EU has been steadily increasing. In 2022, there were approximately 19 million bee colonies in the EU, managed by 615,000 beekeepers.

Although the global number of colonies has increased over the past decade, fluctuations in honey production have been observed. These fluctuations can be attributed to various factors, including climate change and the Varroa mite.

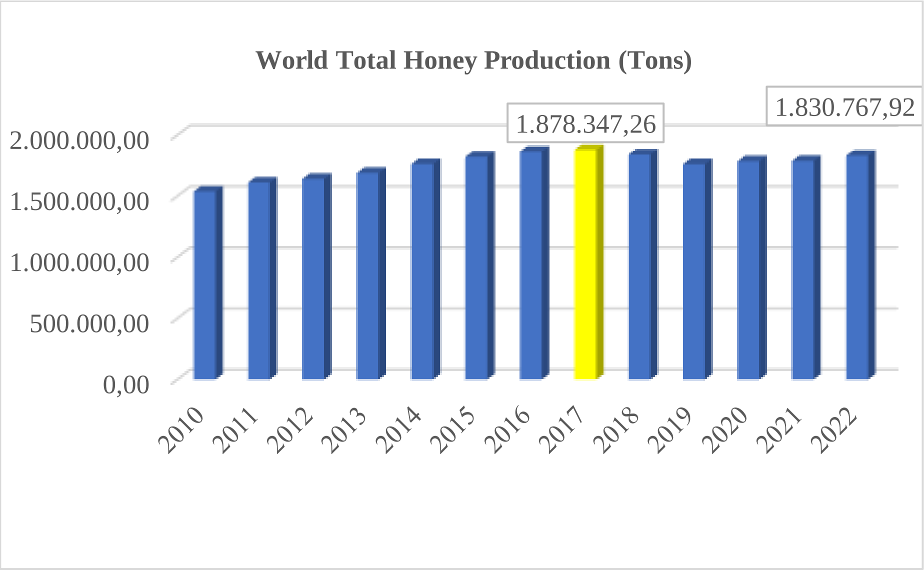


Figure 3. Global Total Honey Production from 2010 to 2022 (FAO, 2024)

According to FAO's 2022 data, despite having the highest number of colonies, India is surpassed by China in terms of honey production volume. In 2022, China produced approximately 473,000 tons of honey. Turkey follows as the second-largest producer, with honey production amounting to 118,000 tons, roughly one-fifth of China's production.

According to FAO's 2024 data, EU countries are ranked second in terms of colony presence. The number of bee colonies in the EU has been steadily increasing. In 2022, approximately 20 million bee colonies were managed by 710,825 beekeepers across the 27 EU countries.

According to FAO's 2024 data, the EU produces approximately 240,288 tons of honey, making it the second-largest honey producer after China, which produces 474,106 tons. Although EU-supported initiatives have increased honey production in recent years, the EU still produces enough honey to meet only about 60% of its own consumption needs, indicating a self-sufficiency rate of approximately 60%.

Table 2. Honey Yields of the World, Some Continents and Leading Countries in 2022

Area	**2022**
World	1.830.767,92
Asia	882.455,35
China	**474.106,88**
Europe	418.330,38
Americas	340.173,62
European Union (27)	**240.288,80**
Türkiye	**118.297,00**
Iran	79.534,90
India	74.204,35
Argentina	70.437,09
Russian	67.014,00
Mexico	64.320,37
Ukraine	63.079,00
Brazil	60.966,00
ABD	56.849,00
Canada	33.745,00
Tanzania	31.345,26
S.Korea	29.951,18
Romania	29.760,00

Source: (FAO, 2024)

According to 2022 data, 564,706 tons of honey are used for export, with a total trade value of 2,047,876,000 USD. China, as the leading producer, also holds the highest natural honey export value, with 154,965 tons of honey exported and approximately 280 million USD, accounting for 10.5% of the total export value. In 2022, the EU emerged as the world's leading honey importer, purchasing honey worth approximately 162,551 million USD from other countries.

Table 3 shows beekeeping data related to Turkey. An examination of Table 3 reveals a consistent increase in colony numbers since 2013, although honey production has not shown the same level of growth.

Honey production has experienced fluctuations in yield due to colony losses and climate change in various years.

Despite being among the leading countries in the world in terms of colony numbers and honey production, Turkey has not yet reached the desired level in honey product trade.

Table 3. Turkey Apiculture Data for 2013-2023

Apiculture (Türkiye)					
Year	**Number of beekeeping enterprises (Quantity)**	**New Hive (Quantity)**	**Old Hive (Quantity**	**Honey (tons)**	**Beeswax (tons)**
2013	79 934	6 458 083	183 265	94 694	4 241
2014	81 108	6 888 907	193 825	103 525	4 053
2015	83 475	7 525 652	222 635	108 128	4 756
2016	84 047	7 679 482	220 882	105 727	4 440
2017	83 210	7 796 666	194 406	114 471	4 488
2018	81 830	7 904 502	203 922	107 920	3 987
2019	80 675	7 929 368	198 992	109 330	3 971
2020	82 862	7 956 933	222 152	104 077	3 765
2021	89 361	8 456 305	277 089	96 344	3 766
2022	95 386	8 734 938	249 738	118 297	4 165
2023	100 399	8 969 387	255 494	114 886	3 971

Source: (TÜİK, 2024)

In Turkey, honey production increased by 22.8% in 2022 compared to the previous year, reaching 118,000 tons. However, in 2023, honey production experienced a decline of 2.88%, with a total of 114,886.43 tons produced.

According to honey production data for 2023, Ordu is the leading province with 19,006.52 tons of honey, followed by Adana with 12,279.98 tons, and Muğla with 8,081.51 tons.

In addition to honey production, beekeeping in Turkey also contributes to the production of beeswax, and, although not in significant quantities, to pollen, propolis, royal jelly, and bee venom. Preparing bee colonies for trade is also an important source of income for beekeepers.

Tablo 4. Turkey's Honey Production and Top Ten Honey Producing Provinces According to 2023 Data

	2018	**2020**	**2021**	**2022**	**2023**
Türkiye	**107.920,10**	**104.076,65**	**96.344,20**	**118.297,46**	**114.886,43**
Ordu	16.993,50	17.212,74	11.377,03	19.098,34	19.006,52
Adana	10.941,22	12.171,54	12.336,38	12.645,91	12.279,98
Muğla	14.777,07	6.103,76	3.820,11	6.577,76	8.081,51
Sivas	5.047,98	5.470,62	5.744,12	6.078,82	6.382,76
Kocaeli	624,39	561,08	555,04	4.725,86	4.239,88
İzmir	2.776,58	1.493,07	3.056,07	3.515,55	3.626,22
Mersin	2.416,00	2.149,58	3.191,64	3.295,27	3.420,23
Aydın	4.227,04	3.643,03	3.253,86	3.143,38	3.412,09
Siirt	710,92	2.400,82	2.322,99	2.497,73	2.798,92
Şanlıurfa	1.909,12	2.119,93	2.107,15	2.199,13	2.370,14

Source: (TÜİK, 2024)

Beekeeping Support

Worldwide, habitat shifts, climatic weather events, pesticide use, diseases and parasites, improper land use, and reductions in biodiversity have led to colony losses and declines in beekeeping. In response to these losses, efforts have been made to protect honey bees through scientific and managerial initiatives. As a result, many countries and some non-governmental organizations are providing support to improve beekeeping practices. The goal is to protect honey bees for the future. This section discusses some of the support measures implemented in the EU and Turkey.

EU Support for the Beekeeping Sector

While support varies by country within the EU, the Common Agricultural Policy (CAP) has provided direct support for beekeeping since 1997. Starting from 2017, CAP support has been divided into three-year periods (2017-2019, 2020-2022). Until the end of 2022, support was provided through voluntary national beekeeping programs developed and implemented by EU countries, aimed at improving the production and marketing of beekeeping products. The support program for 2023-2027 has now been announced (Anonymous, 2015).

These support programs and funding amounts have been increasing and evolving. In June 2019, the European Commission raised the funding for national beekeeping programs for the 2020-2022 programming period from €108 million (USD 121 million) during the 2017-2019 period to €120 million (USD 134 million) (EC, 2019) (Anonymous, 2023a).

This funding has been matched by Member State contributions and used to support training, research, improvements in honey quality, business support, and combating parasites that damage hives. Consequently, several Member States launched and completed new beekeeping programs in 2019 (Anonymous, 2020). For example, Bulgaria completed its national beekeeping program for 2020-2022, which was approved by the European Commission in June 2019. This program included funding for mobile beekeeping expenses, training, trade fairs, pesticide residue inspections, and research to combat specific diseases affecting bees. Similarly, Estonia's national beekeeping program for 2020-2022 was approved in July 2019. Estonia's program focuses on preserving biodiversity and product yields and includes measures for registering bee colonies in the national livestock registry and a new beekeeping market monitoring initiative (Anonymous, 2013a).

The scope of support for the beekeeping sector during the 2023-2027 period has been expanded with two additional measures. The interventions that Member States can offer to farmers now include actions aimed at:

- Helping to mitigate damage caused by adverse climatic events and adapting to changing climate conditions.

- Actions aimed at preserving or increasing the existing number of bee colonies in the EU, including the maintenance of beehive
- Reproduction

Furthermore, Member States should increase national co-financing rates from a minimum mandatory 50% to 70% of public expenditure (from EU and national funds).

This increases the budget allocation available for the beekeeping sector.

From 1 January 2023, support to the sector is provided through beekeeping interventions, which are a mandatory part of the CAP Strategic Plans for the period 2023-27. These plans are designed at national level and set out how each EU country will channel support to achieve the economic, environmental and social objectives of the CAP.

The total planned public expenditure (EU+MS) for the beekeeping sector is expected to amount to €610.1 million in 28 CSPs for the period 2023-2027, corresponding to an EU financial contribution of €285.6 million in the period 2023-2027 (Anonymous, 2013).

The EU allocation of €60 million for the 2023 financial year has been utilized.

Tablo 5. Funding and utilization rate of the Union for beekeeping programs

EU funds can be used for	2019	2020	2021	2022	2023
Allocated Fund	36 000 000	40000000	60000000	60000000	60000000
Amount of EU funds used by Member States in EUR*	33 757 308	35 947 262	46 772 973		
Execution rate	0,94	0,91	0,78		

Source: (Anonim, 2024 f)

Allocation of EU contribution per Member State

As laid down in Article 4 of Commission Delegated Regulation (EU) 2015/1366, the rules for calculating the allocation of EU contributions to beekeeping schemes are based on the proportion of beehives notified by each Member State participating in the scheme and a minimum EU contribution of €25,000 per scheme. However, if a Member State claims less than its entitlement on the basis of the apiary rate, the remaining EU funding can be distributed to other Member States that claim more than their theoretical share of the fund.

Actions Supported Through CAP Strategic Plans

The scope of actions eligible for support through beekeeping interventions under the CAP Strategic Plans has been improved and expanded as per Regulation (EU) 2021/2115, Article 55(1). The expanded scope now includes the following seven types of interventions (Anonymous, 2021):

- Consultancy Services for Beekeepers and Beekeeping Organizations: Providing technical assistance, training, information, and networking opportunities to share best practices.
- Investments in Material and Non-Material Assets: This includes financial support for various activities such as:
    - Combatting Bee Colony Pests and Diseases: Including specific measures against invasive pests and diseases such as Varroosis.
    - Mitigating Damage from Adverse Climate Events: Developing and promoting management practices to prevent damage from negative climate events and adapting to changing climate conditions.
    - Restocking Bee Colonies in the EU: Efforts to restock bee colonies, including support for bee breeding and hive management practices.
    - Rationalizing Beekeeping Practices;

- Supporting Laboratories: Funding for laboratories to analyze bee products, assess bee losses or productivity declines, and evaluate substances potentially toxic to bees;
- Maintaining or Increasing Bee Colonies: Actions to preserve or increase the number of bee colonies within the EU, including efforts to boost bee breeding and colony management;
- Research Collaboration: Implementing research programs in the field of beekeeping and bee products, in cooperation with specialized organizations;
- Promotion and Consumer Awareness: Actions aimed at increasing consumer awareness about the quality of beekeeping products through market monitoring, promotion, communication, and marketing activities;

Improving Product Quality: Measures to enhance the quality of beekeeping products, ensuring they meet high standards and consumer expectations.

EU countries, in collaboration with beekeeping organizations, are free to choose which of the available interventions to include in their CAP plans to address the specific needs and challenges of beekeeping in their country. These are summarized as follows (Anonymous, 2022 a)

These are summarized as follows:

• Overview of Beekeeping Sector and Selected Interventions: Provides a general overview of the beekeeping sector in the relevant EU country, along with the selected interventions as outlined in Section 3.5.2 of the CAP Strategic Plan.

• Detailed Description of Beekeeping Interventions: Section 5.2 of the CAP Strategic Plan details the specific beekeeping interventions planned for the 2023-27 period. This includes the support provided, the regional scope, the design of the interventions, eligibility criteria, types and rates of support, as well as planned outcomes and financial allocations.

- Information exchange, consultancy, training, technical assistance
- Investments and other actions, including:
  - Control of apiary diseases and invasives
  - Climate mitigation and adaptation to climate change
  - Restocking of beehives, bee breeding
  - Rationalization of transhumance
- Analysis of beekeeping products, bee losses, toxic substances for bees
- Protecting beehives and increasing the number of beehives
- Cooperation for research in beekeeping and its products
- Promotion, communication, marketing and market
- monitoring Improving product quality

Beekeeping Support in Turkey

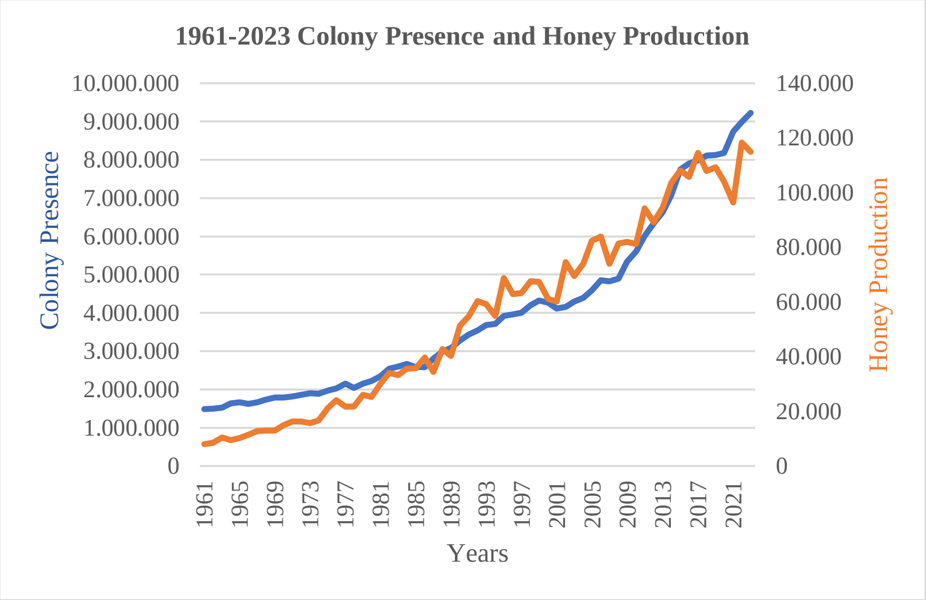
During the second quarter of the Republic, beekeepers, like many other agricultural activities, received support from various state institutions. In the 1950s and 1960s, the General Directorate of Forestry and the Turkish Agricultural Equipment Institution produced 10,000 modern hives annually at some of their facilities, benefiting from the timber allocation by the General Directorate of Forestry. This allowed beekeepers to obtain hives at a more economical price (Gönenç, 1987). During the same period, interest-free hive loans were provided to beekeepers. However, difficulties in finding bee colonies led to the discontinuation of this practice (Ulu, 1987).

From the 1950s to the 2000s, beekeeping support in Turkey primarily focused on transitioning beekeepers from traditional hives to modern ones. This support was provided by state institutions such as Orköy, which offered hive subsidies, and certain farmer loans through Ziraat Banks.

Since the 2000s, various forms of support and credit for beekeeping have been introduced (Anonymous, 2012a). As shown in Table 5, these government supports have significantly increased the number of hives, from approximately 1.5 million in 1961 to about 10 million by 2023. Additionally, honey production rose from around 8,000 tons to 115,000 tons during the same period. These efforts have enabled Turkey's beekeeping industry to achieve a significant position in global beekeeping regarding colony numbers and honey production.

Beekeeping State Support and Credits have evolved over time. Initially, support was provided through hive subsidies. Later, this expanded to include product support, colony support, queen bee support, and support for beekeeping tools and equipment, as well as various types of credits.

Table 6. Increases in Number of Hives and Honey Production (1961-2023)



Source: (FAO; TÜİK 2024)

When examining beekeeping support

The General Directorate of Forestry supports beekeeping and contributes to the national economy through both equipment and flora support.As of 2012, there were 116 honey production forests (Şanal and Yılmaz, 2012). With the implementation of the 1st and 2nd Honey Forest Action Plans by the General Directorate of Forestry, the number of honey forests increased to 846 by the end of the 2013-2017 and 2018-2023 periods, covering approximately 100,000 hectares and supporting around 1 million colonies.

As part of livestock support, in 2003, a support program for queen bees was initiated. Union member beekeepers who purchased breeding queen bees received a 6 TL incentive per queen, while other beekeepers received 4 TL per queen. Although this support faced interruptions in 2007, it resumed in 2024 with enhanced incentives: 200 TL per breeding queen bee and 200 TL per hive under the Bee Protection (On-site Conservation of Genetic Resources) project.

The Ministry has prepared laws and regulations to continue the development of the beekeeping sector and to facilitate the organization of producers. Subsequently, producers have completed their organization efforts nationwide (Anonymous, 2012a).

In 2008, to support the active beekeeping sector, the Ministry of Agriculture and Forestry introduced the Beekeeping Registration System (AKS) (Anonymous, 2012a). A support of 5 TL per hive was provided to associations and businesses registered in the beekeeping registration system, encouraging organized beekeepers to participate in the system (Anonymous, 2012). By the end of 2009, approximately 40,000 businesses and 4,350,000 colonies were registered in the AKS system (Özcan and Köksal, 2010). By 2023, 100,399 businesses and 9,224,881 bee colonies were recorded. For 2024, the support for beehives is set at 60 TL for registered beekeepers and 40 TL for others.

Between 1980 and 2000, public resources provided 600,000 beehives through grants, interest-free, and low-interest loans. During this period, 30,000,000 TL was allocated to develop beekeeping in underdeveloped regions (Topçu, 2000). In the 2000s, these types of credits continued to be available at various times.

Under the supervision of the Ministry of Agriculture and Forestry, the Low-Interest Investment and Operating Loan Program started on January 31, 2024, as per the presidential decree, with the final application date set for December 31, 2026. The rates related to beekeeping are provided in Table 6 of the decree.

Under the beekeeping loans section, as detailed in Table 7, the support includes;

- Construction of Facilities: For processing, packaging, and storage of bee products.
- Purchase of Equipment: Related to beekeeping.
- Processing and Packaging Lines: Acquisition of new lines or modernization of existing ones for processing and packaging honey within the farm.
- Breeding Stations: Establishment and equipping of stations for the production of queen bees by licensed producers.
- Renewable Energy Production: For self-consumption in processing and packaging facilities, including construction and acquisition of machinery and equipment.

These supports aim to enhance various aspects of beekeeping operations and infrastructure (Anonymous, 2024).

Tablo 7. Beekeeping Loans and Discount Rates 8038 Presidential Decree

	Discount rate %		
	Investment Credit	Business Credit	Financing Upper Limit
Apiculture	**50**	**50**	**10.000.000**
Organic farming/good agricultural practices	–	+15	
Mobile beekeeping	+10	+10	
Young farmer/entrepreneur (<=40 years)	+10	+10	
Women farmer/entrepreneur	+10	+10	
Maximum applicable discount rate	**85**	**100**	

Source: (Anonymous, 2024)

The Northeast Anatolia Development Agency has announced a feasibility support call for 2024, targeting non-profit organizations. The initiative has a total budget of 4,000,000 TL, with 750,000 TL available as 100% grant support. This support aims to prepare feasibility studies to increase the income and added value in the beekeeping sectors. The final application date is December 24, 2024 (Anonymous, 2024a).

Both experienced and new beekeepers can benefit from rural development grants. Investments aimed at developing beekeeping are supported, including the purchase of beekeeping materials, hives, and the construction of processing and packaging facilities for honey and other beekeeping products, as well as the acquisition of machinery and equipment. Eligible expenditure amounts range from 5,000 to 250,000 Euros (Öztürk and Gülpınar, 2012).

Under the "Diversification of Farm Activities and Business Development (302)" IPARD III 2nd Application Call Period III, for the production, processing, and packaging of beekeeping and bee products, individuals who have no other economic activity besides agriculture and are registered in the beekeeping registration system must have at least 30 and a maximum of 500 hives to produce and package honey and bee products. However, for the processing and packaging of honey and bee products and the production of hives, the hive number limitation will not be considered (Anonymous, 2024b).

Individuals producing queen bees must hold a valid breeding license.

For the processing and packaging of honey and bee products, applicants must possess the necessary production and registration certificates in accordance with Law No. 5996 on Veterinary Services, Plant Health, Food, and Feed at the time of application. For new businesses, this procedure must be completed by the final payment request (Anonymous, 2024b).

For investments, there is a minimum limit of 5,000 Euros and a maximum limit of 500,000 Euros. For investments made by organic certified farmers and young farmers, the public contribution is 70% of the total expenditure. For others, the public contribution is 60% of the total expenditure (Anonymous, 2024b).

Projects Eligible for Support in Beekeeping:

1. Production, Processing, and Packaging of Beekeeping and Bee Products:
    - Construction of garages and outbuildings for the storage or processing of honey and bee products.
    - Purchase of work equipment for the production, management, and maintenance of beehives.
    - Purchase or modernization of processing and packaging lines for honey within the farm.
    - Establishment and equipping of breeding stations for the production of queen bees by licensed producers.

Orköy Loans: Support and loans provided to forest villagers include interest-free loans for beekeepers, with a 2023 upper limit of 80,000 TL for standard hives and 90,000 TL for imported hives (Anonymous, 2024c).

Beekeeping Insurance: Under TARSİM, 50% of the insurance premium for beekeeping and 66% of the frost coverage premium for plant products are covered by the State (Anonymous, 2024d).

Damages to registered hives with official plates, as determined by the Ministry of Agriculture and Forestry, are covered by insurance. Risks that require an inspection and are deemed unsuitable for insurance coverage by the Agricultural Insurance Pool will not be covered (Anonymous, 2024d).

This insurance covers damages to hives caused by:

- Storms
- Tornadoes
- Fires
- Landslides
- Earthquakes
- Vehicle collisions
- Floods and water damage
- Wild animal attacks
- During transportation: impact, collisions, tipping, burning, etc.

The coverage is provided in accordance with the General Conditions, Tariffs, and Instructions (Anonymous, 2024d).

Currently, beekeeping support provided by state institutions in Turkey is offered under various categories, aiming to maximize benefits for beekeepers. For information and assistance regarding beekeeping incentives and support in Turkey, one can consult the Provincial Directorates of Agriculture and Forestry, branches of Ziraat Bank, and Agricultural Credit Cooperatives (Sağlam, 2012).

CONCLUSION

According to FAO data from 2024, the European Union, ranked 2nd, and Turkey, ranked 3rd in terms of colony numbers, demonstrate that beekeeping remains an integral part of agriculture. Beyond producing honey, honeybees, along with wild bees and other pollinators, play crucial roles in ecosystem and agricultural services. They are essential for crop pollination, particularly for entomophilous plants.

Concerns about increasing mortality rates and the decline in both honeybees and wild pollinators highlight the profound negative impacts on agriculture, food production and security, biodiversity, environmental sustainability, and ecosystems. Given the importance of beekeeping for sustaining biodiversity and ensuring ecological balance, the significance of grants and support for beekeeping becomes even more evident. These measures are critical for promoting the sustainability of beekeeping and strengthening biodiversity.

Despite the agricultural and environmental measures and support to promote the establishment of bee colonies, urgent and large-scale strategies are necessary to protect and restore wild bee populations. Ensuring the health and well-being of bees requires maintaining biodiversity, which provides them with permanent pastures, foraging areas, and natural and semi-natural habitats.

Key issues impacting bee populations include:

- Improper Use of Plant Protection Products: The misuse of pesticides and other chemicals can be harmful to bees and their habitats.
- Decline in Forage Plants: The reduction in pastureland and the increased use of land for hay production have led to a gradual disappearance of plants that are crucial for bee feeding.

- Monoculture Agriculture: Farming practices that rely on monocultures reduce biodiversity and pose risks such as inadequate pollination and the loss of plant cover.

Addressing these challenges requires implementing comprehensive and long-term strategies to support wild bees, enhance their habitats, and promote diverse and sustainable agricultural practices.

In Turkey, the emphasis on protecting wildflowers and pollinator-friendly species through projects such as the "Bal Ormanı" (Honey Forest) initiative, as well as the development of ecological focus areas (EFA) and strategies for planting nectar-rich plants on unused land in Europe, highlights the need for comprehensive environmental measures.

Organic beekeeping operations, due to their unique requirements and the increased environmental impacts they face compared to conventional operations, indeed require appropriate financial incentives. Given the additional challenges and the need for compliance with stricter environmental and organic standards, it is crucial to enhance support measures for these businesses.

In Turkey and across the EU, it is crucial to provide the necessary incentives to promote locally developed practices for the preservation of honeybee ecotypes and their breeding. These incentives should focus on: Conserving Genetic Heritage: Enhancing Adaptation Capacity Local Adaptation: Combating Invasive Species

By fostering local practices and supporting the conservation of local honeybee ecotypes, we can enhance their resilience and contribution to biodiversity and ecosystem health.

With support measures, it is crucial to use all available tools to:

Protect Local and Regional Honeybee Species, Rebuild Populations,

Manage Invasive Species,

These actions will help maintain the health and diversity of local honeybee populations, support ecosystem balance, and ensure effective pollination services.

In Turkey, it is crucial to establish centers dedicated to the breeding and preservation of local bee species. These centers would focus on:

Breeding and Preservation

Enhancing Valuable Traits

Supporting Local Populations

Credit and subsidies should provide appropriate basic and vocational training programs for beekeepers, ensuring that beyond the agricultural and other economic aspects of beekeeping, the teaching material provides information on pollination and other environmental practices, such as maintaining ecological balance and preserving biodiversity and improving the survival conditions of pollinators on farmlands.

Considering the urgent need for intergenerational renewal in the sector, it is considered necessary to further develop the potential of the beekeeping sector in ways tailored to the needs of all beekeepers, enabling the preparation of projects that will encourage new young people to enter the beekeeping profession, as well as young farmer supports

While the positive effects of subsidies on the production, packaging and marketing of beekeeping products cannot be ignored, as in the EU's 'School fruit, vegetable and milk program', beekeeping and bee products promotion programs in our country should include producers as well as consumers; The nutritional value of bee products, their health effects, their use in food products, their use in beauty and dermatology should be promoted and while encouraging producers to produce bee products other than honey such as pollen, propolis, beeswax, bee venom and royal jelly, consumers should be encouraged to recognize and consume bee products.

Although ecotourism and beekeeping, which are new versions of hobby beekeeping that have been developing in our country in recent years, can be projected in support and loans, urban beekeeping has gained popularity in the EU and the USA and has the potential to raise awareness of the nature and benefits of beekeeping among a wider circle of citizens, including children, but beekeeping has no place among beekeeping support issues.

In the fight against bee diseases and parasites, synchronization of subsidies by preparing joint regional projects through unions will make the fight against diseases and pests more effective. In this case, it will be useful in solving the residue problem in foreign trade by increasing the quality of bee products.

It is known that consumers all over the world have the right to know the place of origin of all foodstuffs. The production of high-quality products based on GI schemes should be encouraged through subsidies, especially through rural development programs.

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