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FROM FLOWER TO FOOD: HONEY BEES AND THEIR ROLE IN CROP PRODUCTION

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ABSTRACT

Honey bees (*Apis mellifera*) are fundamental to the functioning of global agricultural systems, providing essential pollination services that significantly enhance crop yields, quality, and economic value. As key pollinators, honey bees facilitate the reproduction of many flowering plants and crops, making their role crucial for both biodiversity and agriculture. This review examines the multifaceted contributions of honey bees to agriculture, highlighting their critical role in the pollination of key crops including fruits, vegetables, nuts, and oilseeds. Empirical studies reveal that honey bee pollination can lead to substantial increases in agricultural productivity: up to 20% for apples, 80% for blueberries, and 33% for cucumbers. Additionally, honey bee activity is vital for high-value crops such as almonds and canola, with reported yield increases of 40% and 25% in nut set and oil content, respectively. Despite their importance, honey bee populations are under severe threat from a range of challenges including pesticide exposure, habitat loss, diseases, parasites, and climate change. These stressors compromise bee health and pollination efficiency, with potential negative repercussions for agricultural productivity and food security. Addressing these challenges requires a multifaceted approach encompassing improved agricultural practices, habitat restoration, and integrated pest management. This review underscores the urgent need for concerted efforts to support and sustain honey bee populations to ensure the continued provision of their vital pollination services, which are crucial for the stability and productivity of global agricultural systems.

Keywords: Honey Bees, Pollination Services, Agricultural Productivity, Crop Yields, Bee Health

ÇİÇEKTEN GIDAYA: BAL ARILARI VE ÜRÜN ÜRETİMİNDEKİ ROLÜ

ÖZET

Bal arıları (*Apis mellifera*), mahsul verimini, kalitesini ve ekonomik değeri önemli ölçüde artıran temel tozlaşma hizmetlerini sağlayarak küresel tarım sistemlerinin işleyişi için temel öneme sahiptir. Temel tozlaştırıcılar olarak bal arıları, birçok çiçekli bitki ve mahsulün üremesini kolaylaştırır ve rollerini hem biyolojik çeşitlilik hem de tarım açısından hayati hale getirir. Bu inceleme, bal arılarının tarıma çok yönlü katkılarını inceleyerek meyveler, sebzeler, kabuklu yemişler ve yağlı tohumlar gibi önemli mahsullerin tozlaşmasındaki kritik rollerini vurguluyor. Ampirik çalışmalar, bal arısı tozlaşmasının tarımsal üretkenlikte önemli artışlara yol açabileceğini ortaya koyuyor: elma için %20'ye, yaban mersini için %80'e ve salatalık için %33'e kadar. Ek olarak, badem ve kanola gibi yüksek değerli mahsuller için bal arısı faaliyeti hayati önem taşıyor; fındık tutumunda ve yağ içeriğinde sırasıyla %40 ve %25 oranında verim artışı rapor ediliyor. Önemlerine rağmen, bal arısı popülasyonları pestisit maruziyeti, habitat kaybı, hastalıklar, parazitler ve iklim değişikliği gibi çeşitli zorluklar nedeniyle ciddi tehdit altındadır. Bu stres etkenleri, arı sağlığını ve tozlaşma verimliliğini tehlikeye atıyor ve tarımsal üretkenlik ve gıda güvenliği açısından potansiyel olumsuz sonuçlar doğuruyor. Bu zorlukların üstesinden gelmek, gelişmiş tarım uygulamalarını, habitat restorasyonunu ve entegre zararlı yönetimini kapsayan çok yönlü bir yaklaşımı gerektirir. Bu inceleme, küresel tarım sistemlerinin istikrarı ve üretkenliği için hayati öneme sahip olan hayati tozlaşma hizmetlerinin sürekli olarak sağlanmasını sağlamak amacıyla bal arısı popülasyonlarını desteklemek ve sürdürmek için ortak çabalara duyulan acil ihtiyacın altını çiziyor.

Anahtar Kelimeler: Bal Arıları, Tozlaşma Hizmetleri, Tarımsal Verimlilik, Ürün Verimi, Arı Sağlığı

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1. INTRODUCTION

Honey bees (*Apis mellifera*) play an essential role in modern agriculture, providing crucial pollination services that underpin the productivity and diversity of many crops (Divekar et al., 2023). Their contribution extends beyond the production of honey, positioning them as vital agents in the pollination of a vast array of agricultural plants. Pollination, the transfer of pollen from the male anther to the female stigma of flowers, is a fundamental ecological process that enhances the reproductive success of flowering plants, thereby directly impacting fruit, vegetable, and nut yields (Osman and Shebl, 2020).

Approximately 75% of the world's leading crops benefit from animal pollination, with honey bees being the primary pollinators (Khalifa et al., 2021). The economic value of their pollination services is substantial, with estimates placing it in the range of hundreds of billions of dollars annually. For instance, crops such as apples, almonds, blueberries, and cucumbers rely heavily on honey bee pollination to achieve optimal yields and quality (Mashilingi et al., 2022). The dependency of these crops on honey bees highlights the bees' integral role in both agriculture and food security (Osman and Shebl, 2020; Requier et al., 2023).

However, honey bees are facing unprecedented challenges that threaten their populations and, consequently, agricultural productivity. Pesticide exposure, particularly from neonicotinoids, has been shown to impair bee health and foraging behaviour (Leska et al., 2021). Habitat loss due to urbanization, intensive farming practices, and climate change further exacerbates the decline in bee populations by reducing the availability of forage and nesting sites. Additionally, diseases and parasites such as *Varroa destructor* mites, *Nosema spp*., and the phenomenon known as Colony Collapse Disorder (CCD) pose significant threats to bee colonies, leading to high mortality rates and reduced pollination efficiency (Kline and Joshi, 2020; Leska et al., 2021).

This review aims to provide a comprehensive overview of the role of honey bees in crop production. It will examine the mechanisms of pollination, quantify the economic impact of pollination services, and explore the various challenges honey bees face. Additionally, it will highlight current and emerging strategies to support bee populations and ensure the sustainability of their pollination services. By synthesizing the latest scientific research, this review underscores the critical importance of protecting honey bee populations to maintain agricultural productivity and food security.

1.1.Mechanisms of Pollination by Honey Bees

Honey bees are highly effective pollinators due to their unique biological and behavioral characteristics. Their role in pollination begins with foraging behavior, where worker bees collect nectar and pollen from flowers to bring back to their hive (Khalifa et al., 2021). During this process, bees inadvertently transfer pollen from the anthers (male reproductive parts) of one flower to the stigma (female reproductive part) of another, facilitating cross-pollination, which is critical for genetic diversity and fruit set in many plants (Zariman et al., 2022).

1.2.Key Crops Dependent on Honey Bee Pollination

Honey bees are crucial to the successful cultivation of various crops, significantly impacting yield, quality, and economic value. Their role in pollination is essential across numerous agricultural sectors, with scientific studies highlighting their importance (Mashilingi et al., 2022).

1.2.1. **Fruits**

Honey bee pollination is vital for many fruit crops. For example, apple (*Malus domestica)* orchards show a marked increase in fruit set and quality with honey bee activity (Pardo and Borges, 2020). According to Weekers et al. (2022), apple yields can increase by up to 20% with the presence of honey bees. Stone fruits such as cherries (*Prunus avium*) and peaches (*Prunus persica*) also benefit significantly. Research by Joshi et al. (2021) showed that honey bees are responsible for up to 90% of the cross-pollination needed for these fruits. In blueberries (*Vaccinium spp.)*, honey bees can boost yields by up to 80% (Dufour et al., 2020). This is due to their efficient pollen transfer between flowers, enhancing fruit size and set.

1.2.2**. Vegetables**

Honey bees play a crucial role in the pollination of vegetables. Cucumbers (*Cucumis sativus),* for instance, produce better-shaped fruits with fewer deformities when pollinated by honey bees (Kumar et al., 2024). Ramello et al. (2024) reported that honey bee-pollinated cucumbers showed a 33% increase in yield compared to non-bee-pollinated crops. Pumpkins (*Cucurbita pepo*) and melons (*Cucumis melo*) also benefit from bee pollination, with research by Kiatoko et al. (2022) revealing a 25% increase in melon fruit weight and a 30% increase in sweetness.

1.2.3**. Nuts**

The almond industry (Prunus dulcis) heavily depends on honey bees. In California, over 2 million honey bee colonies are brought in annually to pollinate almond orchards, which produce about 80% of the world's almonds (Durant and Ponisio, 2021). Bommarco et al. (2012) found that honey bee pollination results in a 40% increase in almond nut set and a 30% increase in yield. Similarly, honey bee pollination enhances the production and quality of macadamia nuts (Macadamia integrifolia) and pistachios (Durant and Ponisio, 2021).

1.2.4**. Other Important Crops**

Honey bees are also essential for oilseed crops like canola (Brassica napus) and sunflowers (*Helianthus annuus*) (Sharma et al., 2023). Amro, (2021) found that honey bee pollination increased canola seed yield by 40% and oil content by 25%. For seed crops such as carrots (*Daucus carota*) and onions (*Allium cepa*), honey bees are critical for robust seed production (Negi et al., 2020).

1.3. Biological and Behavioral Aspects of Honey Bees

Honey bees possess specialized structures that make them efficient pollinators. Their bodies are covered with branched hairs that trap pollen grains, and they have pollen baskets (corbiculae) on their hind legs to transport pollen back to the hive (Wojcik, 2021). Additionally, bees exhibit flower constancy, a behavior where they visit the same type of flower repeatedly during a foraging trip. This behavior increases the likelihood of successful pollination as pollen is more effectively transferred between flowers of the same species (Yourstone et al., 2023).

1.4.Process of Pollination

When a honey bee visits a flower, it uses its proboscis to extract nectar, a primary energy source. While doing so, the bee's body comes into contact with the flower's anthers, and pollen grains adhere to the bee's hairs (Barberis et al., 2022). As the bee moves to the next flower, some of the pollen is deposited onto the stigma, enabling fertilization. This process is repeated as bees forage across multiple flowers and plants, ensuring widespread pollen distribution (Földesi et al., 2021).

1.4.1. Honey Bee-Plant Interactions

The relationship between honey bees and plants is mutually beneficial. Plants gain reproductive success through effective pollination, leading to fruit and seed production (Zarmin et al., 2022). In turn, honey bees obtain nectar and pollen, which are essential for their nutrition and hive sustenance. This mutualism is vital for the reproductive success of many agricultural crops, including apples, almonds, blueberries, and melons, which depend heavily on honey bee pollination for optimal yields (Khalifa et al., 2021).

1.4.2. Impact on Crop Yields

The efficiency of honey bees as pollinators directly affects crop yields and quality. Studies have shown that crops pollinated by honey bees produce more fruits and seeds, which are often larger and of higher quality compared to those resulting from wind or self-pollination (Khalifa et al., 2021). In addition to increasing the quantity of produce, honey bee pollination enhances the commercial value of crops by improving their quality attributes, such as size, shape, and shelf-life. In strawberries, honey bee-pollinated fruits have been found to be larger, more uniform, and have a longer shelf-life than those that are not pollinated by bees. Similarly, in the case of cucumbers, bee pollination has been linked to higher seed set and improved fruit shape (Anees et al.,2022).

Moreover, the presence of honey bees can lead to increased seed production in plants, which is essential for crops like sunflowers and canola that are grown for their seeds. Enhanced pollination by honey bees can also contribute to better oil content in crops such as oilseed rape, directly affecting the economic returns for farmers (Perrot et al., 2024). Additionally, the benefits of honey bee pollination extend to the cultivation of biofuel crops, thereby supporting renewable energy initiatives (Anees et al.,2022).

Understanding the mechanisms of honey bee pollination underscores their indispensable role in agriculture. Effective pollination not only enhances crop productivity but also maintains the genetic diversity and resilience of agricultural ecosystems. The synergistic effects of improved yield and quality underscore the necessity of protecting and promoting honey bee populations to sustain and enhance global food production (Khalifa et al., 2021).

1.4.3. Economic Impact of Honey Bee Pollination

Honey bee pollination has profound economic implications for agriculture, significantly influencing crop yields, quality, and overall profitability. The value of honey bee pollination services extends far beyond their contribution to honey production, playing a crucial role in the global agricultural economy (Khalifa et al., 2021).

1.4.4. Valuation of Pollination Services

The economic value of honey bee pollination services is substantial, with estimates suggesting that these services contribute hundreds of billions of dollars annually to global agriculture. For instance, the Pollinator Partnership (2021) estimates the annual economic value of honey bee pollination services in the U.S. alone at approximately $15 billion. This valuation encompasses a wide range of crops, including fruits, vegetables, nuts, and seeds, which benefit directly from honey bee activity (Khalifa et al., 2021).

1.4.5. Contribution to Agricultural Productivity

Honey bees enhance agricultural productivity by increasing crop yields and improving the quality of produce (Rollin and Garibaldi, 2019). This impact is evident across multiple crop categories, demonstrating the extensive influence of honey bee pollination on the agricultural sector.

1.4.5.1. Fruits

Honey bees play a vital role in the fruit industry. For instance, apple (Malus domestica) orchards benefit significantly from honey bee pollination (Khalifa et al., 2021). Mashilingi et al. (2022) reported that honey bee activity can increase apple yields by up to 20%, translating into significant economic gains for growers. Similarly, the blueberry (*Vaccinium spp*.) industry, which relies heavily on honey bees, sees a substantial boost in yield. Theimer et al. (2008) documented an 80% increase in blueberry yields with effective bee-mediated pollination, underscoring the economic value of these services (Mashilingi et al., 2022).

1.4.5.2.Vegetables

The impact of honey bees extends to vegetable crops. Cucumbers (*Cucumis sativus*), which require efficient pollination for optimal fruit development, benefit from honey bee activity. Ramello et al. (2024) found that honey bee-pollinated cucumbers produced a 33% increase in yield compared to those pollinated by other means. In pumpkins (*Cucurbita pepo*) and melons (*Cucumis melo*), honey bee pollination leads to improved fruit size and sweetness. Research by (Kumar et al. (2024) showed a 25% increase in melon fruit weight and a 30% improvement in sweetness due to honey bee pollination.

1.5.Challenges Facing Honey Bee Populations

Honey bees face numerous challenges that threaten their populations and, consequently, their essential pollination services. These challenges include pesticide exposure, habitat loss, diseases, parasites, and climate change, each of which has significant implications for bee health and agricultural productivity.

1.5.1. Pesticide Exposure

Pesticide use is a major factor contributing to honey bee declines. Neonicotinoids, a class of systemic insecticides, are particularly harmful (leska et al., 2021). Studies, such as those by Straub (2021), have shown that neonicotinoids can impair honey bee foraging behavior, reduce colony growth, and increase mortality rates. The sublethal effects of these chemicals, including altered navigation and memory, further disrupt bee health and productivity. Even non-neonicotinoid pesticides can have detrimental effects, as demonstrated by research from Lu et al. (2020), which found that pesticide exposure compromises honey bee immune systems and increases susceptibility to diseases.

1.5.2. Habitat Loss

Habitat loss is another critical issue affecting honey bee populations. Urbanization, agricultural expansion, and land use changes have led to a reduction in the availability of forage resources and nesting sites (Kline and Joshi, 2020). The decline in floral diversity and abundance reduces the nutritional options available to bees, as highlighted by studies such as those by Requier and Leonhardt (2020). This loss of habitat can lead to malnutrition and weakened immune responses, making bees more vulnerable to diseases and pests.

1.5.3. Diseases and Parasites

Honey bees are also threatened by various diseases and parasites. The Varroa destructor mite, a significant parasitic threat, infests honey bee colonies, feeding on bee blood and transmitting harmful viruses (Noël et al., 2020). Research by Morfin et al. (2023) demonstrated that Varroa infestations can lead to high colony losses and reduced honey production. Nosema spp., a group of microsporidian parasites, also adversely affects bee health by impairing digestion and reducing longevity (Galajd et al., 2021). Additionally, pathogens such as the deformed wing virus and the American foulbrood bacterium contribute to colony declines (Budge et al., 20215).

1.5.4. Climate Change

Climate change exacerbates these challenges by altering floral availability and synchrony with bee life cycles (Ali et al., 2023). Shifts in flowering patterns due to temperature changes can result in mismatches between the timing of flower availability and bee foraging periods. Research by Ali et al. (2023) indicates that climate-induced changes in floral resources can impact bee nutrition and colony health. Extreme weather events, such as droughts and floods, also affect habitat conditions and the availability of forage.

2. CONCLUSION

Honey bees are critical to global agriculture, providing indispensable pollination services that enhance crop yields, improve product quality, and bolster economic viability across numerous sectors. Their role in pollinating fruits, vegetables, nuts, and oilseeds significantly impacts agricultural productivity, as evidenced by substantial increases in yields and product quality. Scientific studies demonstrate that honey bee pollination can result in up to a 40% increase in nut set for almonds, a 25% increase in oil content for canola, and an 80% boost in blueberry yields.

However, honey bee populations face severe challenges, including pesticide exposure, habitat loss, diseases, parasites, and climate change. Addressing these issues is crucial to ensuring the sustainability of honey bee populations and, by extension, the stability of agricultural systems reliant on their pollination services. Strategic management practices, habitat restoration, and reduced pesticide use are essential to mitigate these threats and support bee health. The continued prosperity of global agriculture and food security depends on maintaining robust honey bee populations and their essential ecosystem services.

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