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SOME NECTARIFEROUS PLANTS FOR HONEY BEES AND THEIR SIGNIFICANCE

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Abstract

Honey bees (*Apis mellifera* L.) have played a crucial role throughout human history and continue to maintain their significance today. Their importance in ecosystem functioning and agricultural activities is indisputable, particularly as one of the most critical pollinators. Plant nectar resources are essential for both honey bees and the production of bee products. The quantity and diversity of nectar and pollen sources play a decisive role in colony development, honey production, and overall bee health. Nectar-producing plants not only constitute the foundation of bee product production but also meet the energy requirements of bees and support the life cycle of colonies. Recent studies have demonstrated that the decline in floral diversity, habitat loss, climate change, and pesticide use have seriously affected bee populations worldwide. In this review, recent studies indexed in major databases, including Web of Science, PubMed, DergiPark, Google Scholar, Scopus, and Springer Nature, were examined. Based on the available literature, nectar-producing plants of importance to honey bees, their melliferous characteristics, their effects on colony health, and their significance for sustainable beekeeping were evaluated. Furthermore, several important nectar sources within the Turkish flora were specifically assessed. The biological activities of nectar-producing plants were highlighted through findings reported in the literature. The reviewed studies indicate that honeys derived from different plant species may exhibit antioxidant, antimicrobial, antibacterial, and anticancer potential. In this context, the conservation and promotion of nectar-producing plants are of strategic importance not only for beekeeping activities but also for human health and the sustainability of biodiversity.

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BAL ARILARI İÇİN BAZI NEKTARLI BİTKİLER VE ÖNEMLERİ

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Özet

Bal arıları (*Apis mellifera* L.), insanlık tarihince çok önemli olmuş ve bu önemini sürekli devam ettirmektedir. Ekosistemdeki döngü ve tarımsal faaliyetlerdeki önemleri tartışılmazdır. Özellikle polinatörler arasında en kritiklerdendir. Hem bal arıları hem de arı ürünleri için bitki nektarları oldukça gereklidir. Nektar ve polen kaynaklarının miktarı ve çeşitliliği, koloni gelişimi, bal üretimi ve arı sağlığı üzerinde belirleyici rol oynamaktadır. Nektarlı bitkiler, arı ürünlerinin üretiminin temelini oluşturmasının yanı sıra arıların enerji gereksinimlerini karşılamakta ve kolonilerin yaşam döngüsünü desteklemektedir. Son yıllarda yapılan çalışmalar floral çeşitliliğin azalması, habitat kaybı, iklim değişikliği ve pestisit kullanımının arı popülasyonlarını ciddi şekilde etkilediğini ortaya koymuştur. Bu derleme çalışmasında, Web of Science, PubMed, DergiPark, Google Scholar, Scopus ve Springer Nature gibi indekslerde son yıllarda yapılan güncel çalışmalar incelenmiştir. Literatür temelli olarak bal arıları açısından önemli nektarlı bitkiler, bu bitkilerin mellifer özellikleri, koloni sağlığına etkileri ve sürdürülebilir arıcılık açısından önemi ele alınmıştır. Ayrıca özellikle Türkiye florasında önemli bir yere sahip olan bazı nektar kaynakları değerlendirilmiştir. Nektarlı bitkilerin biyolojik aktiviteleri yapılan çalışmalar ile vurgulanmıştır. Yapılan değerlendirmeler, farklı bitki türlerinden elde edilen balların antioksidan, antimikrobiyal, antibakteriyel ve antikanser potansiyel sergileyebildiğini ortaya koymaktadır. Bu bağlamda nektarlı bitkilerin korunması ve yaygınlaştırılması, yalnızca arıcılık faaliyetleri için değil, aynı zamanda insan sağlığı ve biyoçeşitliliğin sürdürülebilirliği açısından da stratejik önem taşımaktadır.

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Introduction

Bees play a critical role in maintaining biodiversity and ensuring the continuity of agricultural production by facilitating the pollination of plants in both natural and agricultural ecosystems. It has been reported that approximately 75% of globally cultivated crop species depend, either directly or indirectly, on animal-mediated pollination. This proportion clearly highlights the significant contribution of bees to food security and the sustainability of agricultural systems [1, 2].

The effective delivery of ecosystem services by bees depends on the availability of sufficient and high-quality nectar and pollen resources. Nectar serves as the primary energy source for bees and is essential for maintaining colony-level activities. Depending on the plant species, the sugar profile, amino acid composition, and phenolic constituents of nectar vary considerably, which directly influences both bee health and the physicochemical and biological properties of honey [3,4]. In addition, it has been demonstrated that different floral sources affect the bioactive chemical composition and biological activities of bee products such as propolis, pollen, royal jelly, bee bread, apilarnil, and even bee venom. In particular, secondary metabolites responsible for the biological activity of bee products, especially phytochemicals, are strongly influenced by the surrounding floral landscape.

Recent scientific studies have shown that bee products, particularly honey, pollen, bee bread, royal jelly, and propolis, are not only nutritious food sources but also natural products exhibiting functional properties. Monofloral honeys, in particular, have been reported to display varying levels of antioxidant, antimicrobial, and anti-inflammatory activities depending on their botanical origin. These biological activities are largely associated with the phenolic compound content of honey [5–13].

Moreover, studies have indicated that bee products may accumulate residues of pesticides used in agricultural practices as well as antibiotics applied for the control of bee diseases. Such residues can adversely affect product quality, food safety, and consumer health [14,15]. Therefore, the production of bee products should be carried out in areas distant from agricultural lands where intensive use of pesticides and other agrochemicals is common.

Nectar-producing plants are of great importance not only for honey production but also for the continuity and resilience of honey bee colonies. The coexistence of plant species with different flowering periods provides a continuous food supply for bees throughout the year and helps reduce colony stress. Therefore, increasing the diversity of nectar-producing plants is considered a fundamental requirement for the sustainability of beekeeping activities [16,17].

The aim of this study is to systematically examine nectar-producing plants that are important for bees, to classify these plants according to their botanical and ecological characteristics, and to evaluate them in line with their reported biological activities in the literature. The findings obtained within this scope are expected to provide a scientific basis for the planning of beekeeping activities and for conservation efforts targeting nectar-producing plant resources.

Material and method

This study is a literature review prepared through the examination of recent and original scientific articles, reviews, and book chapters published in recent years. Relevant studies were retrieved from databases including Web of Science, Scopus, PubMed, Google Scholar, and DergiPark using the keywords “nectar plants,” “bee forage plants,” and “*Apis mellifera* nutrition.” The selected studies were evaluated in terms of nectar yield, pollen content, colony development, and honey quality. The selected plants were chosen from among the most commonly used ones.

General Characteristics of Nectar-Producing Plants and Their Importance for Beekeeping

Nectar is primarily composed of glucose, fructose, and sucrose. In addition, it contains amino acids, phenolic compounds, and antioxidants. Nectar-producing plants provide a fundamental source of nutrition and energy for bees through the nectar secreted in their flowers. The quantity and composition of nectar vary depending on plant species, climatic conditions, soil characteristics, and flowering period. Plants with high nectar yield enhance the honey production capacity of bee colonies, whereas low nectar availability may limit colony development. Recent studies have shown that nectar with a high phenolic content can strengthen bee immunity and increase resistance to pathogens [18,19,27].

From a beekeeping perspective, ideal nectar-producing plants are those characterized by long flowering periods, wide spatial distribution, and abundant nectar secretion. These features not only meet the energy requirements of bees but also ensure continuity in honey production. Furthermore, nectar derived from different plant species contributes to the diversity of honey by influencing its taste, aroma, color, and biological properties [4,20].

Classification of Nectar-Producing Plants

Nectar-producing plants are generally classified in the beekeeping literature according to their botanical structure and life forms. The most commonly used classification includes tree-form plants, shrub-form plants, annual herbaceous plants, and perennial herbaceous plants. This classification provides a practical approach in terms of the continuity of nectar supply and the contribution of plants to beekeeping activities [4,21].

Tree and shrub-form plants generally provide abundant nectar during spring and summer periods, whereas herbaceous plants constitute an important food source for bees, particularly during summer and autumn. The coexistence of these plant groups contributes to the formation of a balanced and continuous nectar supply for bees throughout the year [4,21,22].

Structure of Nectar and Pollen Sources

The primary nutritional sources of honey bees are nectar and pollen. Nectar is a sugary liquid secreted by nectaries in plants. Depending on their location within the plant, two types of nectaries can be distinguished:

Floral nectaries: These are located in various parts of the flower, such as sepals, petals, stamens, or the ovary.
Extra-floral nectaries: These are found outside the flower, in plant organs such as stems, leaves, or petioles. Some plant species, such as cotton and cherry, are capable of secreting nectar from both types of nectaries.

Nectar guides, which are visual cues such as spots and stripes, facilitate the ability of pollinators to locate flowers and nectar sources more efficiently. Pollen, on the other hand, is a vital source of proteins, lipids, vitamins, and minerals for bees and is particularly essential for larval development [23–25].

Factors Affecting Nectar Yield and Quality

Climate change is one of the most important environmental factors directly influencing plant–pollinator interactions. Increasing temperatures, drought, and irregular precipitation patterns alter flowering periods and may reduce nectar production. While the genetic structure of the plant (intrinsic factors) determines its nectar production capacity, environmental conditions (extrinsic factors) shape the actual output. As temperature increases, nectar volume generally decreases, whereas sugar concentration tends to increase. High humidity levels may enhance nectar secretion but can reduce sugar concentration. In addition, wind and soil water availability also have direct effects on nectar secretion.

Therefore, the promotion of climate-resilient nectar-producing plants is considered an important component of sustainable beekeeping strategies [26,27].

Some Important Nectar-Producing Plants for Beekeeping

In this section, nectar-producing plants of importance to honey bees are discussed in terms of their botanical characteristics, flowering periods, significance for beekeeping, and reported biological activities in the literature. Each plant species is evaluated with regard to its contribution to apicultural activities as well as its potential effects on human health.

In Türkiye, the Eastern Anatolia Region, particularly the surroundings of Bingöl, is notable for its rich flora dominated by *Astragalus* spp. (milk vetch), *Thymus* spp. (thyme), and *Onobrychis sativa* (sainfoin). These species are considered strategically important for beekeeping due to their drought tolerance and extended flowering periods, which make them reliable nectar sources under variable climatic conditions [23,28–30].

1. Linden (*Tilia* spp.)

Linden (*Tilia* spp.), commonly known as “ihlamur,” is one of the most important nectar-producing tree species in temperate regions. It is widely distributed in Europe and Türkiye and plays a significant role in supporting honey bee foraging activities during the early to mid-summer period. Linden flowers are highly attractive to bees due to their abundant nectar secretion and characteristic aroma, which contributes to intensive foraging activity and substantial honey yields. From a beekeeping perspective, linden is considered a high-value nectar source because it produces light-colored honey with a distinctive flavor and high market demand. Linden honey is also reported to possess notable biological activities, including antioxidant, antimicrobial, and mild sedative effects, largely attributed to its phenolic and flavonoid content. The extended flowering period and high nectar productivity of *Tilia* species make them ecologically and economically important for sustainable apiculture. [25, 31, 32].

Figure **1.** Linden

2. Black Locust (*Robinia pseudoacacia*)

Black locust (*Robinia pseudoacacia*), commonly known as "akasya," is one of the most important nectar-producing tree species for apiculture due to its high nectar secretion and high sugar concentration. Native to North America but widely cultivated in many temperate regions, including Türkiye, this species blooms in late spring to early summer and provides a highly valuable nectar flow for honey bee colonies. From a beekeeping perspective, black locust is particularly significant because it produces light-colored, clear honey with mild flavor and slow crystallization properties, which is highly preferred in the market. The high sucrose content of its nectar contributes to the production of premium-quality monofloral honey. Additionally, black locust honey is reported to exhibit antioxidant and antimicrobial properties, mainly associated with its phenolic compound profile. Due to its strong nectar yield and adaptability to different ecological conditions, Robinia pseudoacacia is considered a key species in sustainable honey production systems. Black locust honey is characterized by its slow crystallization properties and low sucrose content. In the literature, it has been reported that acacia honey exhibits beneficial effects on the digestive system and possesses moderate antioxidant capacity. In addition, the leaves of the plant have been shown to exhibit antimicrobial and cytotoxic activities [17, 33-35].

Figure 2. *Robinia pseudoacacia*

3. Sweet Chestnut (*Castanea sativa*)

Sweet chestnut (*Castanea sativa*), commonly known as "kestane," is an important nectar- and pollen-producing forest tree species in temperate regions, particularly in Türkiye. It typically flowers in late spring to early summer, producing long male catkins rich in nectar and pollen, which are highly attractive to honey bees.

Chestnut honey is characterized by its dark color, strong aroma, and high mineral content. It is also reported to possess high antioxidant activity due to its rich phenolic composition. In the literature, chestnut honey has been associated with antimicrobial, anti-inflammatory, and vasoprotective effects, making it a functionally valuable bee product. In addition to honey production, C. sativa plays a significant ecological role by supporting forest biodiversity and providing a stable forage source for honey bee colonies. Due to its high phenolic and flavonoid content, it exhibits strong antioxidant and antibacterial activities. In addition, it has been reported to possess anti-inflammatory and anticancer potential [36-39].

Figure 3. *Castanea sativa*

4. *Eucalyptus* (*Eucalyptus* spp.)

Eucalyptus species provide a continuous nectar source for honey bees due to their long flowering periods. *Eucalyptus* honey is an important monofloral honey traded worldwide and is highly valued by consumers because of its medicinal properties attributed to the botanical origin of the plant. *Eucalyptus* honey is typically dark amber in color and is characterized by a strong aroma and distinctive taste. It has been reported to exhibit significant antioxidant, antimicrobial, and expectorant properties, largely attributed to its rich phenolic and volatile compound content. In addition, eucalyptus-derived bee products are frequently associated with respiratory health benefits in traditional medicine systems. Owing to its ecological adaptability and high nectar yield, *Eucalyptus* species are widely used in managed apiculture and habitat restoration programs. In addition, numerous studies have demonstrated that it has antioxidant and antibacterial activities [40, 41].

Figure 4. *Eucalyptus*

5. Citrus Species (*Citrus* spp.)

Citrus species, such as orange (*Citrus sinensis*), lemon (*Citrus limon*), and mandarin (*Citrus reticulata*), are important nectar-producing plants for honey bees, particularly in subtropical and Mediterranean climates. It is a genus belonging to the Rutaceae family that includes economically important fruit species. *Citrus* species such as orange, lemon, grapefruit, and mandarin flower intensively in the spring period and serve as important nectar and pollen sources for honey bees. Due to their characteristic floral aroma, light color, and high consumer demand, citrus honeys are among the globally important monofloral honey types. *Citrus* honeys are typically light-colored and pleasantly aromatic, and they are reported to possess stress-reducing and antioxidant properties. In addition, they have been suggested to exert a calming effect on the nervous system [42, 43].

Figure 5. *Citrus*

6. Lavender (*Lavandula angustifolia*)

Lavandula angustifolia Mill. (lavender) is a perennial aromatic plant belonging to the Lamiaceae family. It is considered an important honey plant due to its high nectar production, long flowering period, and frequent visitation by honey bees. The genus *Lavandula* includes many species; however, the most commonly used species in aromatherapy and those considered to have medicinal value include *Lavandula dentata, Lavandula angustifolia, Lavandula latifolia, Lavandula stoechas*, and *Lavandula hybrida*. Lavender honey is typically light amber in color with a distinctive floral aroma and is highly valued in international markets. Honey obtained from lavender flowers has high commercial value due to its characteristic aroma and biological activity. It has been reported that lavender honey exhibits antioxidant, antimicrobial, anti-inflammatory, antibacterial, antifungal, and calming effects, and has shown particularly positive outcomes against skin infections [44, 45].

Figure 6. *Lavandula angustifolia*

7. Thyme (*Thymus* spp.)

Thyme (*Thymus* spp.) is an important nectar-producing plant characterized by its high essential oil content. It is a perennial aromatic genus belonging to the Lamiaceae family and includes numerous species. Its flowers are rich in both nectar and pollen, making it an important food source for honey bees. Monofloral honeys obtained from thyme are of considerable interest to both consumers and researchers due to their characteristic aroma and high phenolic compound content. Thyme honey has been reported to possess strong antibacterial and antioxidant properties, particularly showing effectiveness against pathogenic microorganisms. Therefore, it holds an important place in the production of functional honey. In the literature, thyme honey has been associated with respiratory benefits and immune-modulating effects. Owing to its rich bioactive composition and high commercial value, *Thymus* species are considered key plants in sustainable beekeeping systems. [46, 47].

Figure 7. *Thymus*

8. Sage (*Salvia* spp.)

Sage (*Salvia* spp.) species are perennial aromatic and medicinal plants belonging to the Lamiaceae family. Their flowers are rich in nectar and are frequently visited by honey bees. Sage-derived honeys occupy an important place in apiculture and natural product research due to their characteristic aroma and high levels of biologically active phenolic compounds. Studies have reported that sage honey exhibits antimicrobial, antioxidant, and immune-supporting properties. In addition, *Salvia* species are widely recognized for their traditional medicinal uses, including antimicrobial and digestive system support effects. Due to its ecological resilience and high apicultural value, sage is considered an important plant species for sustainable beekeeping systems [48, 49].

Figure 8. *Salvia* spp.

9. Rosemary (*Rosmasrinus officinalis*)

Rosmarinus officinalis L. (rosemary), currently classified as *Salvia rosmarinus*, is an aromatic shrub belonging to the Lamiaceae family. It is a perennial plant native to the Mediterranean region and is characterized by its drought tolerance, extended flowering period, and nectar-rich flowers, making it an important source of nectar and pollen for honey bees. Due to its early flowering habit, it provides a valuable forage resource for bees during periods when other floral resources may be limited. Rosemary is rich in phenolic compounds such as rosmarinic acid, carnosic acid, and carnosol, which contribute to its antioxidant, antimicrobial, and anti-inflammatory properties. Additionally, it has been reported to exert beneficial effects on the circulatory system [50, 51].

Figure 9. *Rosmasrinus officinalis*

10. Sunflower (*Helianthus annuus*)

Helianthus annuus L., a member of the Asteraceae family, is an annual crop plant widely cultivated in agricultural areas and recognized for its high nectar and pollen production capacity. Due to its abundant pollen yield and extensive cultivation across large agricultural landscapes, it serves as an important forage resource for honey bees. Sunflower honey possesses significant economic value among apicultural products because of its characteristic color and crystallization properties. It ranges in color from light yellow to golden yellow and is known for its distinctive aroma and high nutritional value. Owing to its high nectar production, widespread cultivation, and substantial contribution to beekeeping, sunflower is considered one of the most important honey plants worldwide. Sunflower seeds are rich in phenolic compounds, tocopherols, and unsaturated fatty acids, which contribute to their antioxidant properties. In addition, their energy-rich composition has led to their recommendation as a component of sports nutrition [52, 53].

Figure 10. *Helianthus annuus*

11. Canola/rapeseed (*Brassica napus*)

Brassica napus L. (rapeseed), is an annual herbaceous plant belonging to the Brassicaceae family and is widely cultivated for oil production. Canola produces dense yellow flowers and blooms in early spring, providing an important source of nectar and pollen for honey bees. Extensive and uniform canola fields support honey bee colony development while also increasing honey yield. Canola honey is typically light in color, mildly flavored, and tends to crystallize rapidly due to its high glucose content. In addition, the plant is rich in glucosinolates, phenolic compounds, and unsaturated fatty acids, making it nutritionally and biologically significant [54, 55].

Figure 11. *Brassica napus*

12. Mustard (*Sinapis alba*)

The mustard plant, belonging to the Brassicaceae family, typically flowers between April and June and is an annual species that rapidly blooms while providing abundant nectar. It produces bright yellow flowers and, due to its early flowering period, serves as an important source of nectar and pollen for honey bees. Its dense flowering and high floral frequency support honey bee colony development and increase honey yield in agricultural areas. Mustard honey is characterized by its light color and tendency to crystallize rapidly due to its high sugar content. In addition, the plant is rich in glucosinolates, phenolic compounds, and various bioactive metabolites, making it nutritionally, medicinally, and agronomically important. Mustard honey has been reported to possess antibacterial properties and may have beneficial effects on the digestive system [56, 57].

Figure 12. *Sinapis alba*

13. Alfalfa (*Medicago sativa*)

The flowering period of alfalfa typically occurs between May and September, depending on cutting frequency and climatic conditions. *Medicago sativa* L., belonging to the Fabaceae family, is a perennial herbaceous forage plant and represents an important source of nectar and pollen for honey bees due to its long flowering period and extensive cultivation areas. Alfalfa fields are considered key ecosystem components that support colony development, especially in large-scale beekeeping operations. Alfalfa honey is generally light in color, mildly flavored, and rich in nutritional value, although it may crystallize relatively quickly. The plant is also rich in proteins, flavonoids, saponins, and various phenolic compounds, giving it high agricultural and apicultural importance. Studies have reported that alfalfa honey exhibits immune-supporting, antioxidant, anti-inflammatory, and antibacterial properties [58, 59].

Figure 13. *Medicago sativa*

14. Sainfoin (*Onobrychis sativa*)

Flowering between May and July, *Onobrychis sativa* L., a perennial forage plant belonging to the Fabaceae family, is considered an important honey plant due to its high nectar yield and bee-friendly floral structure. Its adaptability to rocky and semi-arid areas makes it a sustainable floral resource for beekeeping. Sainfoin produces nectar-rich flowers that are frequently visited by bees and contribute to high-quality honey production. Sainfoin honey is valued among monofloral honeys due to its light color, mild aroma, and slow crystallization properties. It is also considered nutritionally valuable and is rich in tannins, flavonoids, and various phenolic compounds, which have been reported to exhibit antioxidant and anti-inflammatory properties in the literature [60, 61].

Figure 14. *Onobrychis sativa*

15. Milk vetch (*Astragalus* spp.)

Flowering between May and August depending on the species, *Astragalus* spp. (milk vetch), belonging to the Fabaceae family, is a large genus comprising perennial herbaceous and shrub-like plants. Widespread in steppe and semi-arid ecosystems, milk vetch species are important sources of nectar and pollen for honey bees. Their high adaptability to harsh ecological conditions makes them a valuable component of natural flora and rangeland ecosystems for beekeeping. Honey derived from milk vetch is generally light to amber in color, with a distinctive aromatic profile, and in some species it may exhibit high viscosity and slow crystallization. The plant is also rich in bioactive compounds such as flavonoids, saponins, and polysaccharides, which contribute to its antioxidant and immune-supporting properties. Milk vetch honey has been reported to exhibit immune-boosting and antimicrobial effects [62, 63].

Figure 15. *Astragalus*

16. Vetch (*Vicia* spp.)

Belonging to the Fabaceae family, vetch species (*Vicia* spp.) are important forage crops consisting of annual or perennial herbaceous plants and are particularly significant for honey bees during the spring and summer periods. Among them, *Vicia sativa* L. typically flowers in spring and early summer, producing purple, blue, or white flowers that serve as a valuable source of nectar and pollen for honey bees. Due to its rapid growth and adaptability to various climatic conditions, it is widely cultivated in agricultural ecosystems and represents an important floral component supporting colony development in beekeeping. Vetch honey is generally light in color, mildly flavored, and exhibits a moderate tendency to crystallize. The plant is also rich in proteins, flavonoids, and various phenolic compounds, making it economically important both as a forage crop and for apicultural purposes. Vetch honey has been reported to have high nutritional value and antioxidant activity, and it is also suggested in the literature to support energy metabolism [64, 65].

Figure 16. *Vicia*

17. Clover (*Trifolium* spp.)

Belonging to the Fabaceae family and comprising a species-rich genus, *Trifolium* (clover) includes both annual and perennial species widely distributed in pastures and agricultural lands. Among the most common species are *Trifolium repens* (white clover) and *Trifolium pratense* (red clover). Clover species flower in spring and summer and, due to their dense floral structure and high nectar production, serve as highly valuable sources of nectar and pollen for honey bees. Their extended flowering period contributes to sustainable honey production and plays an important role in the composition of meadow honeys. Clover honey is generally light in color, mildly aromatic, nutritionally rich, and characterized by moderate crystallization. In the literature, clover honey has been reported to exhibit antioxidant and immune-supporting properties [66, 67].

Figure 17. *Trifolium*

18. Cotton (*Gossypium hirsutum*)

Belonging to the Malvaceae family, *Gossypium hirsutum* is a widely cultivated annual herbaceous and economically important industrial crop grown globally for fiber production. It flowers during the summer months and provides an important nectar source for honey bees. Cotton cultivation areas, due to their extensive coverage, contribute indirectly to the nutrition of bee populations and are considered agroecosystems that support pollinator activity. Although primarily grown for fiber production, it can also contribute to apiculture under suitable climatic conditions. Cotton honey is generally light to amber in color, mildly aromatic, and shows a relatively slow tendency to crystallize. Cotton plants are also biochemically significant due to their content of phenolic compounds and various secondary metabolites such as gossypol, and they are reported to have a relatively high mineral content. In addition, cotton has been reported in the literature to exhibit antibacterial activity [68, 69].

Figure 18. *Gossypium hirsutum*

19. Quince (*Cydonia oblonga*)

Belonging to the Rosaceae family, *Cydonia oblonga* is an important perennial fruit tree with a small-tree growth form, typically cultivated in temperate climates. It flowers in the spring, providing a short but valuable nectar source for honey bees. At the same time, quince orchards contribute indirectly to agricultural productivity and ecosystem services by supporting pollinator activity. Although quince nectar is available in limited amounts, it can contribute to high-quality honey production; the resulting honey is generally light in color, mildly aromatic, and delicately sweet. The plant is also rich in phenolic compounds, organic acids, and vitamins, and is notable for its antioxidant properties. Studies have also reported that quince honey may have beneficial effects on the digestive system [70, 71].

Figure 19. *Cydonia oblonga*

20. Apple (*Malus domestica*)

Belonging to the Rosaceae family, *Malus domestica* is a fruit species of high economic value widely cultivated in temperate climates. It produces abundant blossoms in spring, making it an important source of nectar and pollen for honey bees. Its flowers are heavily visited by bees during the blooming period, which is particularly crucial for effective pollination. Apple orchards represent important agroecosystems in integrated farming systems with beekeeping, enhancing both crop productivity and ecosystem services. Although apple nectar contributes only limited amounts to honey production, the resulting honey is generally light in color, mildly aromatic, and delicately sweet. Apple honey is also rich in phenolic compounds, flavonoids, and vitamins, and is noted for its antioxidant properties [72, 73].

Figure 20. *Malus domestica*

21. Pear (*Pyrus communis*)

Belonging to the Rosaceae family, *Pyrus communis* is a perennial fruit tree of high economic value widely cultivated in temperate climates. It shares similar flowering characteristics with apple and serves as an early-season nectar source for honey bees. Its blossoms are heavily visited by bees, playing an important role particularly as a pollen source. Although pear nectar contributes only limited amounts to honey production, the resulting honey is generally light in color, mildly aromatic, and delicately sweet. The plant is also rich in phenolic compounds, flavonoids, and various antioxidant constituents, which contribute to its biological activity. Pear honey is reported to have a mild aroma and may exhibit immune-supporting effects [74, 75].

Figure 21. *Pyrus communis*

22. Cherry (*Prunus avium*)

Prunus avium, a highly valuable perennial fruit species belonging to the Rosaceae family, blooms in early spring and contributes to the development of bee colonies. Its white blossoms in the spring period serve as an important source of nectar and pollen for honey bees, particularly supporting early-season pollination activities. Cherry orchards enhance bee activity during intensive flowering periods, thereby contributing significantly to agricultural productivity and ecosystem services. Although cherry nectar contributes only limited amounts to honey production, the resulting honey is generally light in color, mildly aromatic, and delicately sweet. The plant is also rich in phenolic compounds, anthocyanins, and flavonoids. Cherry honey has been reported in the literature to exhibit antioxidant and antimicrobial properties [76, 77].

Figure 22. *Prunus avium*

23. Plum (*Prunus domestica*)

Prunus domestica, a highly valuable perennial fruit species belonging to the Rosaceae family, supports colony development at the start of the season by providing both nectar and pollen to bees through its white flowers, which bloom in early spring. These flowers provide an essential early-season source of both nectar and pollen for honey bees, thereby contributing to the initial development and strengthening of colonies. The intensive visitation of bees during flowering not only enhances pollination efficiency but also directly improves fruit set. Plum orchards function as valuable agroecosystems that promote biodiversity within agricultural landscapes and, when integrated with apiculture, can significantly increase overall productivity. Plum-derived honey is typically light in color, with a mild aroma and smooth taste profile, and may exhibit moderate crystallization depending on nectar composition. Furthermore, plum honey has been associated with antioxidant potential, largely attributed to its phenolic and flavonoid constituents. [78, 79].

Figure 23. *Prunus domestica*

24. Apricot (*Prunus armeniaca)*

Prunus armeniaca, a highly valuable perennial fruit species belonging to the Rosaceae family, blooms especially in early spring, providing early-season pollen and nectar for bees. Increased bee activity during the flowering period enhances pollination efficiency and positively influences fruit set. Apricot orchards contribute to agricultural productivity and ecological balance, especially when integrated with beekeeping systems. Apricot-derived honey is generally light in color, mildly aromatic, and smooth in taste, and may exhibit moderate crystallization depending on its nectar composition. It has also been reported that apricot honey possesses immune-supporting and antioxidant properties due to its content of phenolic compounds, flavonoids, and carotenoids [80, 81].

Figure 24. *Prunus armeniaca*

25. Pomegranate (*Punica granatum*)

Belonging to the Lythraceae family, *Punica granatum* is a perennial fruit species of high economic value that produces striking red-orange flowers during the summer months. These blossoms serve as an important source of nectar and pollen for honey bees, particularly contributing to colony activity at the onset of the warm season. Pomegranate orchards, when integrated with beekeeping practices, enhance pollination efficiency while also supporting biodiversity. Pomegranate honey is reported to be rich in polyphenols, anthocyanins, and ellagic acid derivatives, and therefore possesses high antioxidant capacity, helping to reduce the effects of free radicals [82, 83].

Figure 25. *Punica granatum*

26. Blackberry (*Rubus fruticosus*)

The blackberry, a taxonomically complex species group within the Rosaceae family, plays a significant role in apicultural ecosystems by providing a prolonged and reliable source of nectar and pollen for honey bees. Its white or pink flowers, which bloom during the summer months, serve as an important forage resource for bees, particularly supporting colony activity in mid-summer. Its widespread occurrence in natural and semi-natural habitats ensures a consistent food supply for apiculture. Blackberry-derived honey is typically dark amber in color, with a strong aroma and a characteristic fruity flavor, and it may show moderate crystallization tendency. Studies have shown that blackberry honey exhibits both antimicrobial and antioxidant properties [84-86].

Figure 26. *Rubus fruticosus*

27. Raspberry (*Rubus idaeus*)

Rubus idaeus, a perennial semi-shrub fruit species within the Rosaceae family, is particularly important for honey bees during the summer period. Its flowers are frequently visited by bees and represent a rich source of both nectar and pollen. Its widespread presence in natural and cultivated areas provides a continuous forage resource for apiculture. Raspberry-derived honey generally ranges in color from light to amber tones and is characterized by a fruity aroma and a smooth taste profile, with a moderate tendency to crystallize. It has been reported that raspberry honey exhibits immune-supporting and antioxidant properties due to its content of anthocyanins, flavonoids, and phenolic compounds [86-87].

Figure 27. *Rubus idaeus*

28. Cornelian cherry (*Cornus mas*)

Cornus mas L., a perennial fruit species with shrub or small tree form in the Cornaceae family, flowers early between February and April, serving as an important early-season source of nectar and pollen for honey bees. Through this characteristic, it plays a significant ecological role by supporting colony development after winter. Its occurrence in natural forest ecosystems provides a sustainable floral resource for apiculture. Cornelian cherry-derived honey is generally light amber in color, mildly aromatic, and may exhibit characteristic sour taste notes, with a moderate tendency to crystallize. It has been reported in the literature that cornelian cherry honey exhibits antioxidant and anti-inflammatory properties due to its content of organic acids, phenolic compounds, and anthocyanins. [88-89].

Figure 27. *Cornus mas*

29. Mullein (*Verbascum* spp.)

The genus *Verbascum*, a taxonomically diverse group within the Scrophulariaceae family, flowers during the summer period and serves as an important source of nectar and pollen for honey bees. Mullein species, widely distributed in the flora of Türkiye, are regarded as valuable apicultural plants due to their extended flowering duration and high adaptability to harsh ecological conditions. These characteristics make them significant contributors to bee foraging resources, particularly during periods of limited floral availability. Honey derived from *Verbascum* species has been reported to exhibit beneficial effects on the respiratory system and to possess notable antimicrobial properties [90-91].

Figure 29. *Verbascum*

30. Fennel (*Foeniculum vulgare*)

Belonging to the Apiaceae family, *Foeniculum vulgare* is an aromatic perennial plant that flowers in late summer and early autumn, providing an important late-season source of nectar and pollen for honey bees. Its umbrella-shaped (umbel) inflorescences are easily accessible to bees, facilitating efficient foraging. Due to its extended flowering period, it serves as a valuable apicultural plant that supports colony activity, particularly during the summer season. Fennel-derived honey is generally light in color, characterized by a distinctive anise-like aroma, and shows a moderate tendency to crystallize. It has been reported that fennel honey may exert beneficial effects on the digestive system and exhibits antioxidant activity [92-93].

Figure 30. *Foeniculum vulgare*

31. Phacelia (*Phacelia tanacetifolia*)

Phacelia tanacetifolia (phacelia), a fast-growing annual species within the Hydrophyllaceae family (and in some classifications Boraginaceae), is widely regarded as one of the most valuable honey plants in apiculture due to its high nectar yield and dense flowering capacity. It is specifically cultivated to establish bee pastures as an annual crop. It flowers between March and May and remains in bloom for approximately 4–7 weeks, with a nectar yield of about 8–14 kg per decare. Its strong preference by honey bee populations provides a significant advantage, particularly in the production of monofloral honey. During the summer period, its dense purple-blue inflorescences are highly attractive to bees and offer an abundant source of both nectar and pollen. Its rapid flowering and prolonged blooming period make it one of the most effective plants for supporting colony development [94-95].

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Figure 31. *Phacelia tanacetifolia*

32. Lemon balm (*Melissa officinalis*)

Melissa officinalis, a medicinal and aromatic plant within the Lamiaceae family, is considered an important support species in apiculture due to its high attractiveness to honey bees and significant nectar production. It also holds a special role in beekeeping practices owing to its volatile compounds, which are associated with colony orientation and management. The plant is frequently visited by honey bees and is notable in apicultural ecosystems for its pleasant lemon-like aroma. It produces abundant nectar, and its white flowers are highly attractive to bees, which contributes to its high visitation rate. The plant has been reported in the literature to exhibit antioxidant properties due to its content of rosmarinic acid, flavonoids, and essential oils [96-97].

Figure 32. *Melissa officinalis*

33. Almond (*Prunus dulcis*)

Prunus dulcis (almond) is a cultivated crop that flowers in early spring and represents one of the important nectar and pollen sources for honey bees. Almond blossoms play a critical role in the development of colonies emerging from the winter period, and their pollen, which is rich in protein, supports brood-rearing activities and contributes to the rapid growth of colony populations. Bee pollination in almond orchards significantly increases fruit set and yield, establishing a mutually beneficial relationship between bees and the plant. Almond-derived honey is characterized by its light color, pleasant aroma, and nutritional properties. It has been reported that almond honey contains phenolic compounds, flavonoids, and various antioxidant substances, and may therefore contribute to the reduction of oxidative stress caused by free radicals. In addition, almond honey has been associated with antimicrobial, anti-inflammatory, and immune-supporting properties, with regular consumption suggested to have positive effects on overall health [98, 99].

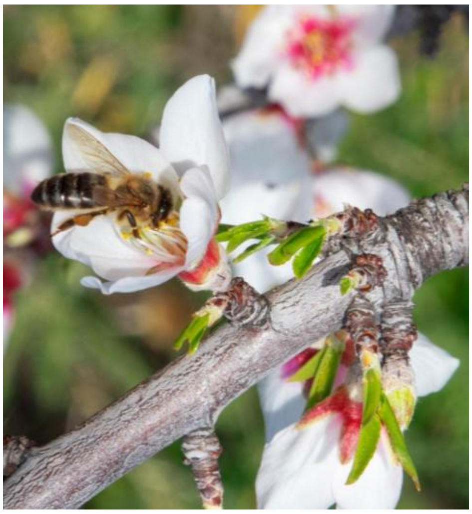

Figure 33. *Prunus dulcis*

The biological activities of honeys may vary depending on the production region, climatic conditions, botanical origin, and processing methods [5].

Some Important Studies

The literature indicates that nectar-producing plants are critical not only for honey production but also for ecosystem health. The Fabaceae and Lamiaceae families stand out due to their high melliferous potential.

In addition, it has been reported that as plant diversity increases, the chemical quality of honey also improves. This finding further enhances the importance of honey as a functional food.

In the study conducted by Mudrak and colleagues, the nectar-producing plants identified in Ukraine are presented in Table 1 [17].

Tablo 1. In the study conducted by Mudrak and colleagues, the nectar-producing plants identified in Ukraine are presented.

Scientific Name	Habitat / Growing Environment	Importance for Beekeeping	Flowering Period
Salix alba L.	Wetlands, riverbanks	Important early-season source of nectar and pollen	March
Acer platanoides L.	Parks, forest edges	Early spring nectar source for pollinators	April
Tilia cordata Mill.	Forests, urban areas	Major nectar source; honey potential up to 1000 kg/ha	May–June
Robinia pseudoacacia L.	Shelterbelts, field margins	High nectar productivity; honey potential around 800 kg/ha	May–June
Trifolium pratense L.	Meadows, pastures	Provides abundant nectar and pollen	May–July
Melilotus officinalis (L.) Lam.	Ruderal and disturbed areas	Produces profuse nectar flow; valuable forage plant	June–August
Echium vulgare L.	Dry and disturbed soils	High nectar yield and strong attractiveness to bees	June–August
Solidago canadensis L.	Ruderal sites, meadows	Important late-season nectar source; approximately 150 kg honey/ha	August–September
Brassica napus L.	Agricultural fields	Early-season mass-flowering nectar source	April–May
Helianthus annuus L.	Agricultural fields	Dominant summer nectar-producing crop	July–August
Fagopyrum esculentum Moench	Crop rotation fields	Specialty nectar plant producing distinctive honey	July–August
Phacelia tanacetifolia Benth.	Cover crops, field margins	Exceptional nectar producer with high pollinator attractiveness	June–August

This study indicates that nectar-producing plants in the flora of Ukraine constitute an important resource for beekeeping throughout the year. Early-flowering species support post-winter colony development, while mid- and late-season species ensure continuous nectar flow and enhance honey production. In particular, species such as *Tilia cordata*, *Robinia pseudoacacia*, and *Phacelia tanacetifolia* stand out due to their high nectar productivity. Overall, increased plant diversity improves both honey yield and quality, and the Fabaceae, Lamiaceae, and Asteraceae families are recognized as the most important melliferous plant groups in apiculture.

In the same study, important nectar-producing plant species for beekeeping are presented in Table 2.

Tablo 2. Most valuable nectar-producing species for beekeeping

Species	Key Characteristics
Tilia cordata	Very high nectar secretion; honey yield up to 1000 kg/ha.
Robinia pseudoacacia	One of the most productive honey plants; honey yield around 800 kg/ha.
Phacelia tanacetifolia	Outstanding nectar and pollen production; highly attractive to honey bees.
Helianthus annuus	Major summer nectar source in agricultural landscapes.
Fagopyrum esculentum	Produces dark, aromatic honey with high market value.

Species	Key Characteristics
Melilotus officinalis	Long flowering period and abundant nectar production.

This study evaluated the most valuable nectar-producing plant species for apiculture. In particular, *Tilia cordata* and *Robinia pseudoacacia* stand out due to their high honey yield potential, while *Phacelia tanacetifolia* was identified as a highly attractive species for pollinators owing to its strong nectar and pollen production. *Helianthus annuus* and *Fagopyrum esculentum* provide important nectar sources during the summer period, whereas *Melilotus officinalis* ensures resource continuity due to its extended flowering duration. Overall, the high melliferous characteristics of these species enhance both honey yield and quality, demonstrating their critical importance for sustainable beekeeping.

In the study conducted by Layek and colleagues, the pollen types identified in honey samples from the state of West Bengal, India, are presented in Table 3.

Tablo 3 Major nectar-producing plant species recorded in the Hadyach agroecosystems and their apicultural importance

Scientific Name	Habitat Type	Nectar/Pollen Importance
Salix alba L.	Wetlands, riverbanks	Early-season pollen and nectar source
Acer platanoides L.	Parks, forest edges	Important early spring nectar source
Tilia cordata Mill.	Forests, urban green areas	Major nectar source; honey potential up to 1000 kg ha^{-1}
Robinia pseudoacacia L.	Shelterbelts, field margins	High nectar productivity; honey potential about 800 kg ha^{-1}
Trifolium pratense L.	Meadows, pastures	Abundant nectar and pollen producer
Melilotus officinalis (L.) Lam.	Ruderal habitats, disturbed sites	Profuse nectar flow and extended flowering period
Echium vulgare L.	Dry grasslands, disturbed soils	High nectar yield and strong bee attractiveness
Solidago canadensis L.	Ruderal sites, meadows	Important late-season nectar source
Brassica napus L.	Agricultural fields	Early-season mass flowering nectar source
Helianthus annuus L.	Agricultural fields	Dominant summer nectar-producing crop
Fagopyrum esculentum Moench	Crop rotation fields	Specialty nectar plant producing aromatic honey
Phacelia tanacetifolia Benth.	Cover crops, field margins	Exceptional nectar and pollen producer
Glycine max (L.) Merr.	Agricultural fields	Moderate nectar source and beneficial preceding crop
Cucurbita pepo L.	Agricultural fields	Supplemental nectar source for pollinators
Zea mays L.	Agricultural fields	Primarily pollen source; limited nectar value
Onobrychis viciifolia Scop.	Grasslands, forage fields	High nectar productivity and excellent bee forage
Sinapis alba L.	Cover crop fields	Valuable nectar and pollen source
Medicago sativa L.	Forage fields	Rich pollen source with moderate nectar production

This study indicates that nectar- and pollen-producing plants in the Hadyach agroecosystems exhibit high diversity and are of significant importance for apiculture. Early-flowering species support colony development, while mid- and late-season species ensure continuous nectar flow and enhance honey production. In particular, *Tilia cordata*, *Robinia pseudoacacia*, and *Phacelia tanacetifolia* stand out due to their high melliferous potential. Agricultural crops also contribute to colony nutrition by providing both nectar and pollen resources. Overall, increased plant diversity is considered a critical factor for sustainable beekeeping and high honey yield.

In the study conducted by Bereke and colleagues, the nectar secretion potential of *Coffea arabica* L. was evaluated. *Coffea arabica* flowers produce an average of 3.3 μL of nectar and 3.6 mg of sugar per day, reaching the highest nectar volume in the morning and the highest sugar concentration in the afternoon. These plantations have a theoretical honey production potential of 125 kg per nectar source, and it has been reported that placing 2 to 4 colonies per nectar source, depending on the hive type, provides optimal productivity [100].

To protect honey bee colonies and increase honey yield, the following practices are recommended:

1. Bee pastures should be protected and restored.
2. Local plant species with high nectar potential should be promoted.
3. Flower strips should be established in agricultural areas.
4. Pesticide use should be carried out in a controlled manner.
5. Plants with different flowering periods should be cultivated together.
6. The cultivation of species belonging to the Fabaceae, Lamiaceae, and Boraginaceae families should be encouraged.
7. Practices that damage the natural flora should be restricted.

Conclusion

In this study, a wide range of nectar-producing plant species important for honey bees was comprehensively examined, and their effects on beekeeping activities and human health were evaluated in the light of existing literature. The findings revealed that nectar-producing plants are not only important for honey production but also play a determining role in the chemical composition, biological activity, and functional properties of honey.

Increasing plant diversity is of great importance for maintaining honey bee colony health, enhancing honey yield, and producing monofloral honeys with high biological activity. In particular, species such as chestnut, thyme, lavender, sage, and milkvetch have been identified as strategic plants for both apiculture and human health.

Nectar-producing plants for honey bees constitute a fundamental component of ecosystem sustainability. Recent studies have shown that increasing floral diversity is critical for both colony health and honey productivity. In particular, species such as linden, acacia, lavender, thyme, alfalfa, sainfoin, and milkvetch are of strategic importance.

In conclusion, to develop sustainable beekeeping practices, it is necessary to integrate nectar-producing plants into agricultural planning, conserve natural flora, and promote medicinal and aromatic plant cultivation. This study provides a scientific basis for future experimental and applied research by demonstrating the relationship between nectar-producing plants and the biological properties of honey.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this manuscript, the authors used artificial intelligence tools to correct grammatical errors and to assist in achieving an academic writing style. After using these tools, the authors carefully reviewed and revised the content as necessary and take full responsibility for the content of the publication.

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