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ARAŞTIRMA MAKALESI / RESEARCH ARTICLE

POLLEN ANALYSIS OF HONEYS FROM TRABZON (TÜRKİYE)

Trabzon (Türkiye) Ballarında Polen Analizi

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ABSTRACT

This study presents the results of pollen analysis on honey samples collected from 85 different locations across all districts of Trabzon, Türkiye, during the months of June to October between 2009 and 2012. A total of 50 pollen taxa were identified, including 23 families, 25 genera, and 2 species. The most dominant pollen type was *Castanea sativa*, found in 65 samples, reflecting the regional floral characteristics. Lamiaceae was dominant in only one sample. Secondary pollen types commonly observed included Apiaceae, Asteraceae, Brassicaceae, *Carduus*, *Cistus*, *Cynoglossum*, Fabaceae, *Hedysarum*, *Laurus nobilis*, *Rhododendron*, and Rosaceae. Four samples were classified as monofloral honeys, all identified as *Castanea sativa* honey. *Rhododendron*, known for its toxic effects when present above a certain threshold in honey, was detected in 48 samples, indicating the necessity of evaluating these honeys in terms of consumer health. TPN-10 ranged from 2,845 to 1,525,683 per 10 g of honey. Correlation analysis showed that floral diversity increased with altitude, while cluster analysis indicated that total pollen count was the most influential factor in sample classification. These findings underline both the rich botanical diversity of Trabzon honeys and the impact of ecological variables on honey composition.

Keywords: Botanical origin, *Castanea sativa*, Melissopalynology, *Rhododendron,* Total pollen number

ÖZ

Bu çalışmada, 2009-2012 yılları arasında Trabzon ilinin tüm ilçelerinde, Haziran-Ekim aylarında 85 farklı bölgeden toplanan bal örnekleri üzerinde polen analizi gerçekleştirilmiştir. Yapılan analizler sonucunda, 23 familya, 25 cins ve 2 tür düzeyinde olmak üzere toplam 50 taksona ait polen varlığı tespit edilmiştir. Bölgenin karakteristik türlerinden *Castanea sativa*, 65 örnekte dominant polen olarak en yüksek orana ulaşmıştır. Lamiaceae familyası ise yalnızca bir örnekte dominant olarak saptanmıştır. Sekonder polen grubunda ise Apiaceae, Asteraceae, Brassicaceae, *Carduus*, *Castanea sativa*, *Cistus*, *Cynoglossum*, Fabaceae, *Hedysarum*, Lamiaceae, *Laurus nobilis*, *Rhododendron* ve Rosaceae taksonları öne çıkmıştır. İncelenen örneklerin 4'ü monofloral bal olarak sınıflandırılmış ve tamamı *Castanea sativa* balı olarak tanımlanmıştır. Balda belli bir miktarın üzerinde bulunduğunda zehirleme etkileriyle bilinen *Rhododendron* cinsine ait polenler 48 örnekte belirlenmiş, bu durum balın tüketici sağlığı açısından değerlendirilmesi gerektiğini göstermiştir. TPS-10 g değerine göre polen sayıları 2.845 ile 1.525.683 arasında değişmiştir. Korelasyon analizleri, rakım yükseldikçe balın floristik çeşitliliğinin arttığını ortaya koyarken; kümeleme analizinde örneklerin sınıflandırılmasında en belirleyici unsur toplam polen sayısı olmuştur. Bu bulgular, Trabzon balının floristik zenginliğini ortaya koyarken, aynı zamanda ekolojik değişkenlerin bal kompozisyonu üzerindeki etkilerini de net bir şekilde gözler önüne sermektedir.

Anahtar kelimeler: Botanik köken, *Castanea sativa*, Melissopalinoloji, *Rhododendron,* Toplam polen sayısı

GENİŞLETİLMİŞ ÖZET

Giriş: Balın polen içeriği, üretim alanının floristik kompozisyonuyla doğrudan ilişkilidir. Türkiye, iklimsel çeşitliliği ve 12.000'i aşkın bitki türüyle arıcılık açısından son derece yüksek bir potansiyele sahip bir ülkedir. Ancak, bitki çeşitliliğinin bilinmesine rağmen, bu bitkilerden hangilerinin bal üretimine ne ölçüde katkı sağladığı konusunda yeterli düzeyde detaylı ve bölgesel temelli bilimsel çalışmalara ihtiyaç duyulmaktadır. Bitki çeşitliliğinin bal üretimindeki rolünü değerlendirmede en etkili yöntemlerden biri melissopalinolojik analizlerdir. Son yıllarda Türkiye'de üretilen ballar üzerine yapılan palinolojik araştırmaların sayısında artış gözlemlenmekte; bu çalışmalar sayesinde, nektar kaynağı bitki türlerinin belirlenmesi ve üretilen balların kalite standartlarının yükseltilmesi amaçlanmaktadır. Bu çalışmanın temel amacı, Trabzon il merkezi ve bağlı ilçelerden toplanan 85 adet bal örneğinin polen içeriklerini analiz ederek, bölge ballarının botanik kökenini ve kalite düzeyini ortaya koymaktır.

Gereç ve Yöntem: Bal örnekleri, Trabzon il merkezinden ve tüm ilçelerinden 2009-2012 yılları arasında Haziran-Ekim ayları arasında üreticilerden temin edilmiştir. Toplanan bal örneklerinden kalitatif ve kantitatif melissopalinolojik analizler için preparatlar hazırlanmıştır (Louveaux et al. 1978). Homojenize edilmiş stok baldan alınan 10 gram alınarak steril tüplere konulup üzerine 20 mL distile su eklenmiş ve balın suda çözünmesi için 45°C'de su banyosunda bekletilmiştir. Numuneler 3500 rpm'de 45 dakika santrifüj edilerek tüplerin dibinde oluşan polen tortusu, kalıcı bir preparat hazırlamak amacıyla bazik fuksinli gliserin jelatin kullanılarak hazırlanmıştır. Hazırlanan preparatlarda polenlerin ait olduğu bitki taksonları belirlenmiş ve yüzde oranları hesaplanmıştır. İncelenen bal örnekleri, eser (3%'ten az), minör (3-15%), sekonder (16-44%) ve dominant (>45%) olmak üzere 4 grupta incelenmiştir. Bal örneklerindeki toplam polen sayısı (TPS-10 g), *Lycopodium* spor tabletleri kullanılarak hesaplanmıştır (Moar 1985). Polenler, TPS'ye göre kategori I (< 20 000), kategori II (20 000-100 000), kategori III (100 000-500 000), kategori IV (500 000-1 000 000), kategori V (>1 000 000) olmak üzere 5 kategoriye sınıflandırılmıştır (Jose et al. 1989). Elde edilen parametreler arasındaki ilişkiyi belirlemek amacıyla bulgulara korelasyon analizi, polen spektrumu analizi ve hiyerarşik kümeleme analizi uygulanmıştır.

Bulgular: Yapılan analizler sonucunda, 36 familyaya ait 50 takson tespit edilmiştir. 65 örnekte *Castanea sativa*'ya, 1 örnekte ise Lamiaceae familyasına ait polenlerin dominant miktarda bulunduğu belirlenmiştir. Sekonder miktarda polen bulunan taksonlar ise 10 örnekte *Castanea sativa*, 9 örnekte Fabaceae, 8 örnekte *Cistus*, 7 örnekte *Rhododendron*, 5 örnekte Lamiaceae ve *Hedysarum* L., 3 örnekte Apiaceae ve Brassicaceae, 2 örnekte Rosaceae ve 1 örnekte ise Asteraceae, *Cynoglossum* L., *Carduus* L. ve *Laurus nobilis* L. olmuştur. İncelenen bal örneklerinde belirlenen bitki taksonlarının sayısının 2 ile 24 arasında değiştiği gözlemlenmiştir. Ayrıca yapılan analizler sonucunda belli bir miktarın üzerinde tüketildiğinde zehirlenmeye neden olduğu bilinen *Rhododendron* (Ericaceae) polenlerine de 48 adet bal örneğinde çeşitli miktarlarda rastlanmıştır. Bal örnekleri, toplam polen sayısı (TPS-10 g) miktarına göre sınıflandırıldığında; 19 tanesi kategori I (% 22.3), 39 tanesi kategori II (% 45.9), 23 tanesi kategori III (% 27), 2'şer tanesi ise kategori IV (% 2.4) ve kategori V (% 2.4) olarak belirlenmiştir. 10 gram baldaki TPS-10 değerleri 2845 ile 1 525 683 arasında hesaplanmıştır**.**

Tartışma-Sonuç: Yapılan palinolojik analizler, Trabzon yöresine ait bal örneklerinin botanik kökenine ışık tutarak bölgenin arıcılık potansiyelini ortaya koymuştur. Çalışma sonucunda, Fagaceae familyasına ait *Castanea sativa* yöre balları için başlıca nektar ve polen kaynağı olarak belirlenmiştir. Bal örneklerinde en fazla tespit edilen ikinci polen taksonu Lamiaceae, üçüncü ise Rosaceae familyası olmuştur. Toplamda analiz edilen 85 bal örneğinin 4'ü, unifloral (tek çiçek türüne dayalı) bal olarak sınıflandırılmıştır. Bu unifloral balların tamamı kestane balıdır. Geriye kalan 81 örnek ise çok sayıda bitki türünden polen içermesi nedeniyle multifloral (çok çiçekli) bal olarak tanımlanmıştır. Analizler sonucunda, Trabzon ballarında 23'ü familya, 25'i cins ve 2'si tür düzeyinde olmak üzere toplam 50 farklı taksonun polenine rastlanmıştır. Bu polenlerin büyük çoğunluğu Apiaceae, Asteraceae, Brassicaceae, Cistaceae (*Cistus*), Ericaceae (*Rhododendron*), Fabaceae, Fagaceae, Lamiaceae, Poaceae ve Rosaceae familyalarına aittir. İstatistiksel değerlendirmeler, bal kalitesinin belirlenmesinde en önemli faktörün toplam polen sayısı olduğunu ortaya koymuştur. Bu araştırma, yalnızca Trabzon bölgesinin nektar bitkileri potansiyelini belirlemekle kalmayıp, aynı zamanda

Türkiye nektarlı bitkileri listesine de katkı sunmayı hedeflemektedir. Bölgesel bitki çeşitliliğini yansıtan bu veriler, arıcılık faaliyetlerinin yönlendirilmesinde, coğrafi işaretleme çalışmalarında ve bal kalite kontrol süreçlerinde önemli bir referans niteliği taşımaktadır.

INTRODUCTION

The floristic composition of the production area determines the pollen content of honey. With its climatic features and 11 707 plant species (Güner et al. 2012), Türkiye has a very high potential in beekeeping. However, Türkiye's rich plant diversity is known, so detailed studies on which plant contributes to honey production are needed. For this reason, the most important method to help determine the contribution of plant diversity to honey production is pollen analysis in honey. Therefore, with the increasing number of studies on the palynological examination of honey produced in Türkiye in recent years, the aim is to determine the nectar-producing plant species and to increase product quality.

Honey has been a valuable nutrient for humans since ancient times. However, the quality of honey varies depending on the geographical structure and herbal characteristics of the place where it is produced. Honey is a natural product that can be produced anywhere in the world without any preparation and can be used in human nutrition. The increasing understanding of honey's composition has made it a more preferred food product among consumers. The market value of honey varies depending on its floral source; in some Northern European countries, honeydew honey is preferred and valued more highly than blossom honey, while in other countries, monofloral blossom honeys may be preferred (Bogdanov et al. 2004, Kenjeric et al. 2008, Prodolliet and Hischenhuber 1998). Monofloral honeys are considered more valuable because they are easier to market and consumers can more easily find the type of honey they want; therefore, they are commercially important and are generally sold at higher prices than polyfloral honeys (Atanassova et al. 2012, Deodikar 1965, Oddo et al. 1988, Oddo and Bogdanov 2004,). This price variability based on consumer preference is likely one of the main reasons honey is a frequent target for food fraud, particularly concerning its botanical origin. Melissopalynological analyses are conducted to determine the botanical origin of honey. Thus, it is accepted that honey is sourced from pollen-producing plants in proportion to the pollen ratio (Sorkun 1985). To identify the plant source and geographical indication of honey, pollen analysis must be conducted on honey from that region (Güzel 2014). No honey produced is the same as the other since the herbal resources used by the bees are very diverse and obtained in different climatic conditions. Therefore, honeys show significant differences, especially in taste and aroma (Crane 1990).

Pollen analysis in honey was first performed by Pfister in 1845. Pollen analysis in Turkish honey was first studied by Quistani in 1976 (Sorkun et al. 1989). Sorkun and İnceoğlu (1984), one of the Turkish researchers, conducted pollen analysis in honey for the first time between 1979-1981. In recent years, melissopalynological studies have gained importance worldwide (Barth and Luz 2022, Giorgi et al. 2011, Makhloufi et al. 2010, Matthew et al. 2018, Samrat et al. 2023, Sanz et al. 2005) and in Türkiye (Bağcı and Tunç 2006, Bayram 2019, Özler 2015, Silici and Gökceoglu 2007). In the Eastern Black Sea Region, where our study area is located, pollen analysis studies on honey are carried out, albeit in small numbers (Bayram et al. 2019, Sorkun et al. 1989, Sorkun and Yuluğ 1985, Tosunoğlu et al. 2023, Uzunca et al. 2023). These studies positively affect honey's quality and increase honey's value in marketing.

Beekeeping has been done in Trabzon province for many years. In order to clarify the current state of beekeeping in Trabzon province, official data regarding the number of enterprises and colonies, as well as production figures, were taken into consideration. According to the most recent statistics, there are 2,629 registered beekeeping enterprises in the province, with a total of 155,829 colonies. Annual honey production is recorded at 781 tons, corresponding to an average yield of 5.01 kg per colony (Tarım ve Orman Bakanlığı 2025). In line with the "Development of Modern Beekeeping" project studies by the Provincial Directorate of Food, Agriculture and Livestock, many beekeeping courses, technical meetings and symposiums were organized and technical information about modern beekeeping was given to people engaged in beekeeping. Trabzon region has important beekeeping potential, unique climate and vegetation, and different nectar plants. Botanical origin analyzes have been carried out on the honeys of the neighboring provinces (Gümüşhane, Rize, Bayburt) of the region and this research conducted

in the Trabzon region is complementary (Bayram et al. 2019, Sorkun et al. 1989, Sorkun and Yuluğ 1985, Tosunoğlu et al. 2023). For this reason, Trabzon was chosen as the study area.

The aims of the research are to identify the botanical origins of honeys and to explore the diversity of pollen types present, to provide information on the relationship between the flora of the region and the characteristics of local honeys, and to understand the relationships between the number of plant taxa in honey, altitude, pollen spectrum, and total pollen count through correlation analysis, pollen spectrum analysis, and hierarchical clustering analysis. Additionally, this study contributes to the authenticity and quality of honey, which are of critical importance for consumers and producers in the honey industry.

MATERIALS AND METHODS

Study area

Trabzon province; in the Eastern Black Sea Region, it covers 0.6% of the country's territory with a surface area of 4685 km², between 40° 30' and 41° 07' north latitudes and 39° 07' and 40° 30' east longitudes. Starting from the sea level and increasing towards the south, the altitude reaches 3000 meters in the region (Haldizen Mountain 3325 m).

In the province of Trabzon, the annual precipitation amount is 820.60 mm, the maximum temperature average of the hottest month is 26.80 °C, the minimum temperature of the coldest month is 4.30 °C, the summer precipitation is 133.50 mm, the precipitation-temperature equivalent (Q) is 126.39, and the Emberger drought index is 4.98, and there is a Transitional climate, which is considered as the Submediterranean bioclimate type, between the Ocean-Mediterranean climates (Kurt 2014).

Trabzon province, is in the Europe-Siberian phytogeographic region (Davis 1965-2000). A few flora studies of vascular plants were carried out in Trabzon (Palabaş-Uzun and Anşin 2006, Palabaş-Uzun and Terzioğlu 2019, Uzun and Terzioğlu 2008). Uzun and Terzioğlu (2008) investigated the vascular flora of forest vegetation in Altındere Valley (Maçka-Trabzon) in 2001-2002. 383 vascular taxa belonging to 246 genera and 84 families were identified. The richest family was Asteraceae 35 taxa (9.1%), followed by Lamiaceae 27 taxa (7.0%) and Fabaceae 23 taxa (6.0%). Additionally, the richest genus was *Campanula* L. 7 taxa (1.82%), followed by *Trifolium* L. 6 taxa (1.56%) and *Acer* L. 6 taxa (1.56%). Palabaş-Uzun and Terzioğlu (2019) studied Flora of Sisdağı (Şalpazarı/Trabzon) and Environs, and 472 vascular plant taxa belonging to 84 families and 254 genera were determined. Depending on determined vascular taxa, the richest plant families are as follows; Asteraceae 52 taxa (11.02%), Rosaceae 38 taxa (8.05%), Poaceae 29 taxa (6.14%), Fabaceae 27 taxa (5.72%), Lamiaceae 26 taxa (5.51%), Apiaceae 18 taxa (3.81%), Ranunculaceae 14 taxa (2.97%), Plantaginaceae 13 taxa (2.75%), Brassicaceae 12 taxa (2.54%), Orchidaceae 10 taxa (2.12%), Polygonaceae 10 taxa (2.12%).

Honey sampling

85 honey samples, for which pollen analyses were made, were collected from Trabzon city center and all its districts in June-October between 2009 and 2012 with the help of the Trabzon Beekeepers Association (Figure 1). While collecting honey samples, the distance between the villages and their altitudes was considered, and special attention was paid to the fact that the hives were settled (fixed) in the province of Trabzon, where migratory beekeeping is quite common. Honey samples taken by opening the hive with bee producers were placed in transparent and sterile jars and labeled. Different honey samples taken from the same village or neighborhood of the district are numbered 1, 2, 3 etc. to avoid confusion. In the region where the hives are located, the plants that the bees can go to were collected and identified, and reference pollen preparations were prepared from these plants according to the Wodehouse method (Wodehouse 1935).

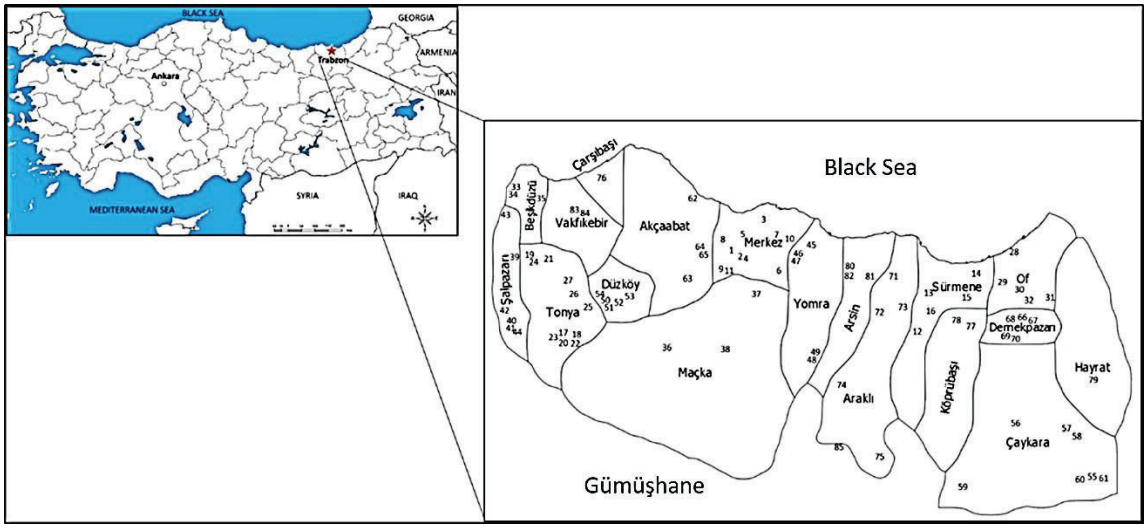

Figure 1. Locations of the collected honey samples

Melissopalynological analyses

Qualitative analysis: The method Louveaux et al. (1978) suggested for the qualitative analysis was followed. To prepare pollen slides, 10 grams of honey taken from the homogenized stock honey into sterile tubes was added to 20 mL of distilled water and kept in a water bath at 45 ˚C to dissolve the honey in water. After the samples were centrifuged at 3500 rpm for 45 minutes, the pollen precipitate formed at the bottom of the tubes was smeared with some basic fuchsin glycerin gelatin to prepare a permanent slide. In the prepared slides, the plant taxa to which the pollen belonged and the number of pollen were calculated. The investigated honey samples were examined in 4 groups as trace (<3%), minor (3-15%), secondary (16-44%), and dominant (>45%) (Louveaux et al. 1978).

Quantitative analysis: The total pollen number (TPN in 10 g honey) in honey samples was calculated according to Moar (1985) by using tablets of *Lycopodium* spores (Stockmarr 1971). Based on the TPN-10 g value, the pollen grains were classified into 5 categories; Category I (<20 000 pollen grains per 10 g honey), Category II (20 000-100 000 pollen grains), Category III (100 000-500 000 pollen grains), Category IV (500 000-1 000 000 pollen grains), and Category V (>1 000 000 pollen grains) (Maurizio 1979).

Pollen slides were examined with a Leica ICC50 HD imaging system connected to a Leica DM 750 microscope, and pollen counts and identifications were made. An immersion lens (×100) was used to identify pollen and take microphotographs. The entire lamella area of 22×22 mm was scanned in the examinations, and the pollen in this area was identified. Two slides were prepared from each sample for microscopic analysis of pollen taxa of honey samples. Pollen averages and pollen % of taxa were determined. While identifying the pollens, those that could be identified at the species and genus levels were diagnosed accordingly, while those that could not be classified at these levels were identified at the family level. The occurrence rates and percentages of pollens identified at the genus level within the same family were calculated separately from those at the family level. The contribution of pollen belonging to these taxa in the honey studied was determined. When describing pollen types, palynological literature (Aytuğ 1971, Blackmore and Ferguson 1986, Erdtman 1969, Faegri and Iversen 1989, Kapp 1971, Pehlivan 1995, Punt 1976, Punt and Clarke 1980, Sawyer 1988, Sorkun 2008) and reference pollen slides prepared from plants collected from the research area, and the collection of pollen preparations in the Palynology Laboratories of Gazi and Hacettepe University Biology Department were used.

Statistical analyses

For statistical data analysis, Python's Pandas and NumPy libraries were used, while Matplotlib & Seaborn and Scikit-learn libraries were used for visualization (Harris et al. 2020, Hunter 2007, McKinney 2010, Pedregosa et al. 2011, Wascom

2021). The analysis process consists of four main parts: data preparation, correlation, pollen spectrum, and hierarchical clustering analysis. The correlation matrix is a fundamental statistical tool used to examine linear relationships between variables. Correlation coefficients (ranging from -1 to +1) indicate the direction and strength of the relationship between variables (Pearson 1896). Based on the data distribution, a linear relationship was found between the variables, so Pearson Correlation was calculated and visualized in the heatmap. Hierarchical Clustering analysis is a clustering method that groups data based on their similarities or differences. Each data point initially belongs to its own cluster, and then clusters are merged based on the distance between similar data (Everitt 2011).

RESULTS

As a result of pollen analysis of Trabzon honey, a total of 50 taxa were identified, 23 at the family, 25 at the genus, and 2 at the species level (Figure2-4, Table 1,). Percentage rates of the most abundant taxa in the samples; *Castanea sativa* (95.2%), Lamiaceae (87%), Rosaceae (83.5%), Apiaceae (74.1%), Fabaceae (74.1%), *Cistus* L. (70.5%), *Rhododendron* L. (56%), Poaceae (54.1%), Brassicaceae (40%) and Asteraceae (36.4%). The taxon whose pollen is most frequently found in honey samples is *Castanea sativa*, one of the region's natural plants. As a result of the pollen analysis, it was observed that the highest number of taxa was found in the trace group, followed by the minor, secondary, and dominant groups (Table 1). 4 of the honey samples (40, 59, 78, 81) were defined as unifloral and *Castanea sativa* pollen was determined to be dominant in these honeys, and they were named as chestnut honey. The remaining 81 honey samples were named multifloral honey. Although the honey collected from the Trabzon region is generally seen to be of multi-plant origin, the majority of honeys called multifloral contain not only dominant and trace amounts of pollen, but also low amounts of minor pollen. For example, the presence of *Castanea sativa* pollen in 24 honey samples is over 80%. However, low amounts of minor pollen from other taxa were detected in these honey samples, these honeys were named multifloral honey.

As a result of melissopalynological analysis, it was determined that *Castanea sativa* pollen was dominant in 65 samples, and Lamiaceae pollen was found in dominant amounts in one sample. Taxa with secondary quantities of pollen were *Castanea sativa* in 10, Fabaceae in 9, *Cistus* in 8, *Rhododendron* in 7, Lamiaceae and *Hedysarum* L. in 5, Apiaceae and Brassicaceae in 3, Rosaceae in 2 samples, and Asteraceae, *Cynoglossum* L., *Carduus* L., and *Laurus nobilis* L. in 1 sample. It was observed that the total number of plant taxa whose pollen was encountered in the honey samples examined varied between 2 and 24 (Table 1).

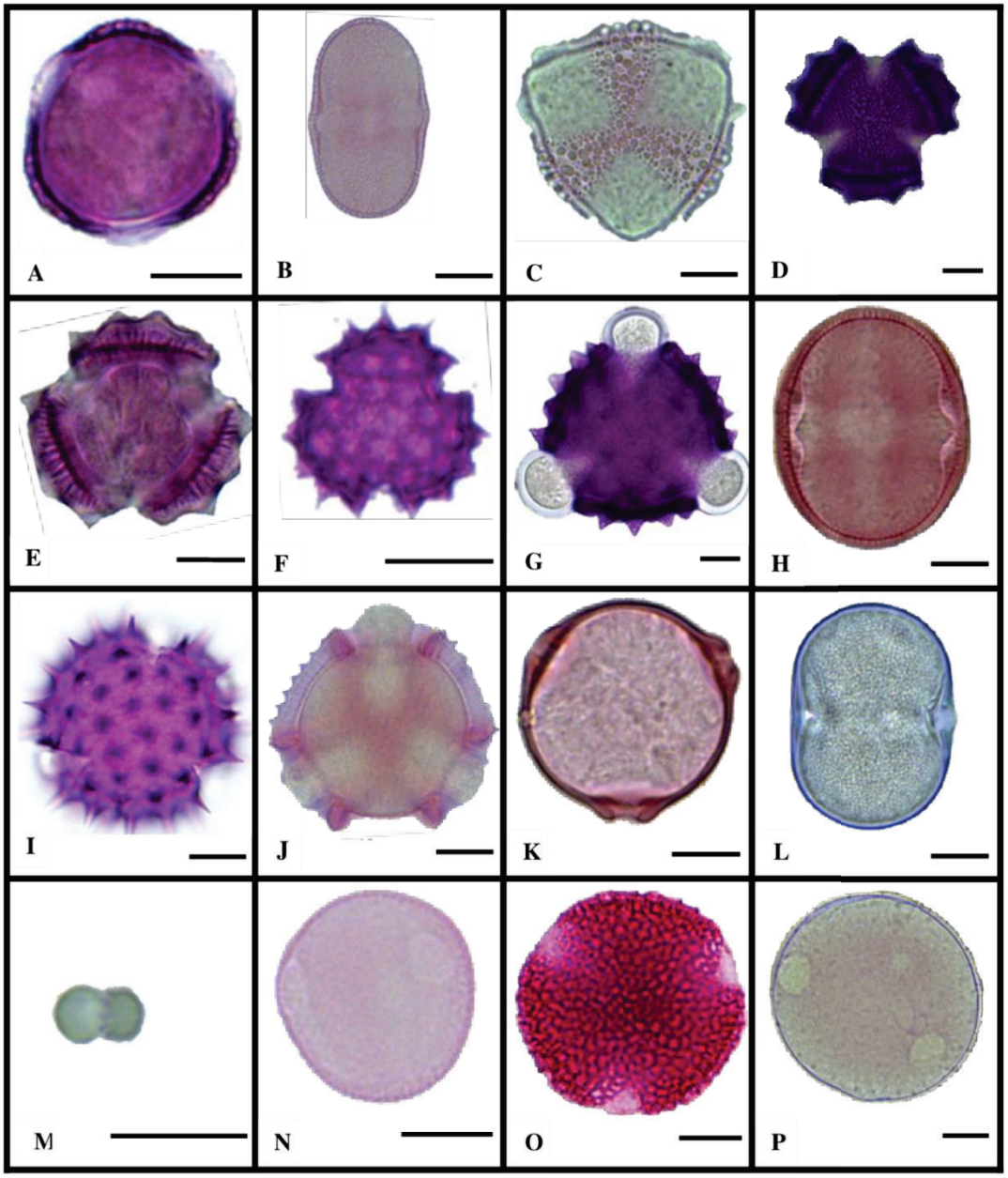

Figure 2. A- Adoxaceae-*Sambucus* sp. B- Apiaceae C- Aquifoliaceae-*Ilex* sp. D- Asteraceae E- Asteraceae-*Anthemis* sp. F- Asteraceae-*Bellis* sp. G- Asteraceae-*Carduus* sp. H- Asteraceae-*Centaurea* sp. I- Asteraceae-*Helianthus* sp. J- Asteraceae-*Taraxacum* sp. K- Betulaceae L- Boraginaceae M- Boraginaceae-*Cynoglossum* sp. N- Boraginaceae-*Echium* sp. O- Brassicaceae P- Campanulaceae Scale bars-10 µm.

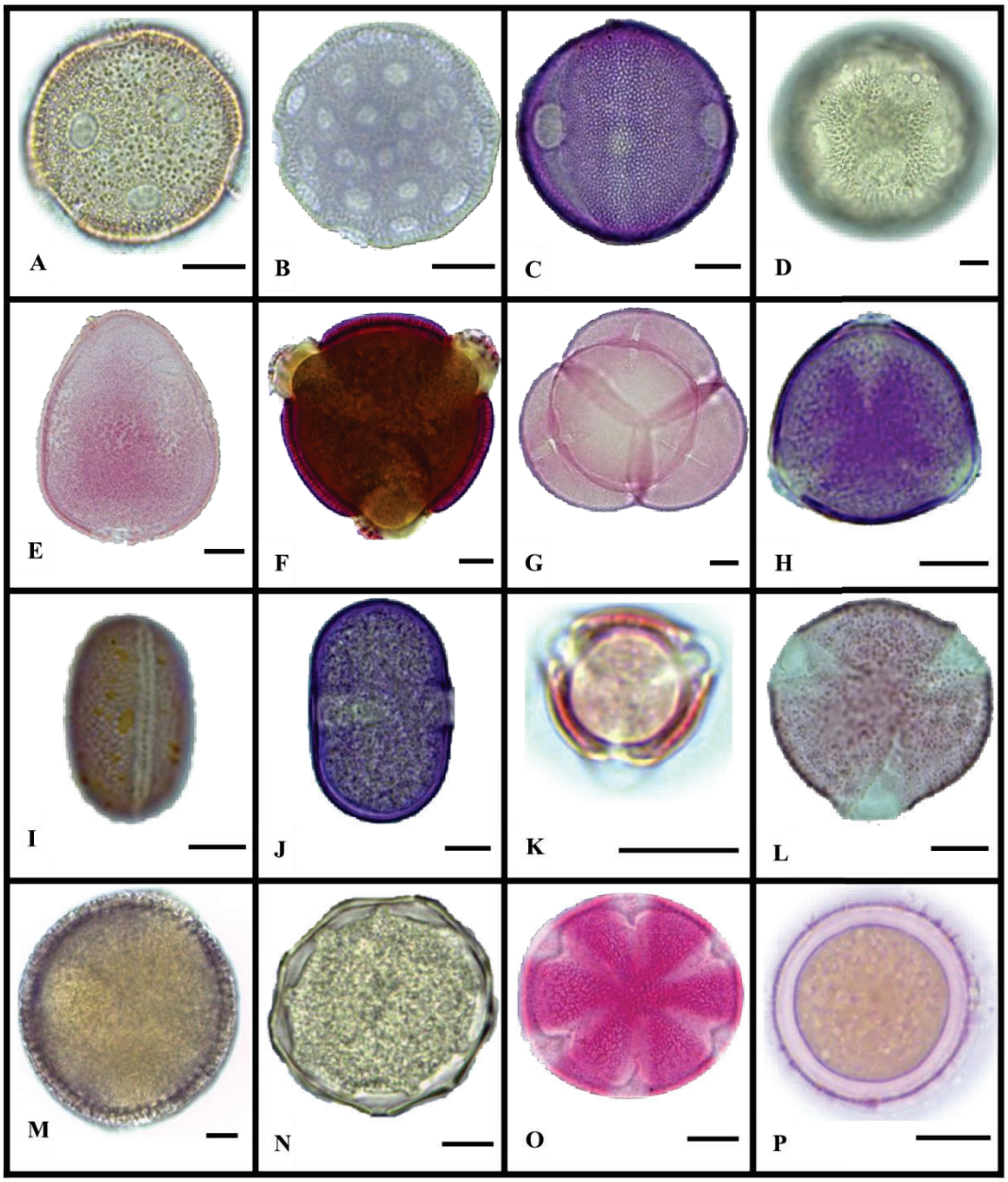

Figure 3. A- Caryophyllaceae B- Amaranthaceae (=Chenopodiaceae) C- Cistaceae-*Cistus* sp. D- Convolvulaceae E- Cyperaceae-*Carex* sp. F- Dipsacaceae G- Ericaceae-*Rhododendron* sp. H- Fabaceae I- Fabaceae-*Hedysarum* sp. J- Fabaceae-*Vicia* sp. K- Fagaceae-*Castanea sativa* L- Fagaceae-*Quercus* sp. M- Geraniaceae N- Juglandaceae O- Lamiaceae P- Lauraceae- *Laurus nobilis* Scale bars-10 µm

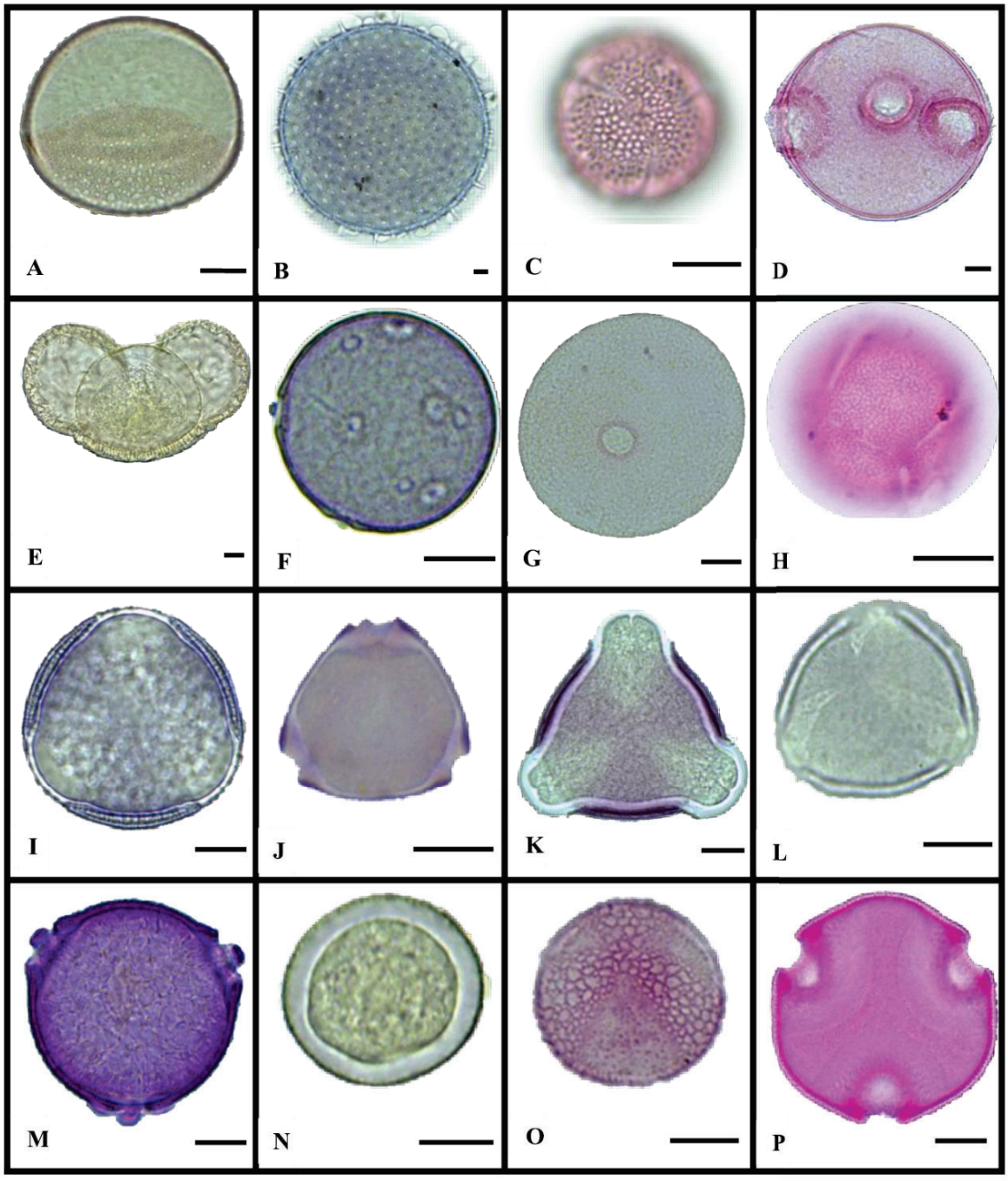

Figure 4. A- Liliaceae B- Malvaceae C- Oleaceae D- Onagraceae-*Epilobium* sp. E- Pinaceae F- Plantaginaceae-*Plantago* sp. G- Poaceae H- Polygonaceae-*Rumex* sp. I- Ranunculaceae J- Rhamnaceae K- Rosaceae L-Rosaceae-*Rubus* sp. M-Rosaceae-*Sanguisorba* sp. N- Salicaceae–*Populus* sp. O- Salicaceae-*Salix* sp. P- Tiliaceae-*Tilia* sp. Scale bars-10 µm

Table 1. Number of samples, location and altitudes, TPN-10 g values, number of taxa in each sample, pollen spectrum, and percentages for the Trabzon honey samples (* Dominant pollen, ** secondary pollen, *** minor pollen, ****trace pollen)

Sample number	Locations/ Altitude (m)	TPN-10 g /Pollen status	Number of taxa	Pollen spectrum and percentage (%)
1	Ortahisar - Akkaya 550	16.853 Category I	8	* *Castanea sativa* (81.5) *** Fabaceae (6), Rosaceae (5) ****Apiaceae (2.5), Lamiaceae (1), Poaceae (1.5), *Rumex* (1), Ranunculaceae(1.5)
2	Ortahisar - Geçit (1) 500	95.156 Category II	13	* *Castanea sativa* (63) ** Apiaceae (19) *** Fabaceae (8.5) **** Brassicaceae (1), Lamiaceae (2.5), Rhamnaceae (0.5), Rosaceae (1.5), *Rubus* (0.5), *Rumex* (0.5), *Sambucus* (1.5), *Taraxacum* (0.5), *Tilia* (0.5), *Vicia* (0.5)
3	Ortahisar - Başkurt 600	112.316 Category III	23	* *Castanea sativa* (44) ** Brassicaceae (26.5) *** *Cistus* (4), Juglandaceae (4), *Rhododendron* (5), Rosaceae (3.5) **** Apiaceae (1), *Carduus* (0.5), *Carex* (0.5), Caryophyllaceae (0.5), *Echium* (0.5), Fabaceae (2.5), *Hedysarum* (1.5), Lamiaceae (1.5), *Laurus nobilis* (0.5), Malvaceae (0.5), Oleaceae (0.5), Pinaceae (0.5), *Plantago* (0.5), Poaceae (0.5), *Rubus* (0.5), *Rumex* (0.5), *Sanguisorba* (0.5)
4	Ortahisar - Geçit (2) 600	147.610 Category III	12	* *Castanea sativa* (65) ****Cistus* (8), Fabaceae (10.5), Rosaceae (9) ****Apiaceae (0.5), *Taraxacum* (0.5), *Rhododendron* (1.5), *Hedysarum* (1), Poaceae (1), *Rubus* (0.5), *Rumex* (2), *Vicia* (0.5)
5	Ortahisar - Bengisu 50	102.164 Category III	9	* *Castanea sativa* (65.5) *** Apiaceae (7.5), Fabaceae (11.5), Rosaceae (3), *Tilia* (8) **** Campanulaceae (0.5), *Cistus* (0.5), Lamiaceae (2), Rhamnaceae (1.5)
6	Ortahisar - Yeşilyurt 250	42.112 Category II	7	* *Castanea sativa* (84.5) ***Apiaceae (6.5), Lamiaceae (4) ****Cistus* (2), Fabaceae (2), Oleaceae (0.5), Rosaceae (0.5)
7	Ortahisar- Yanyamaç 500	61.485 Category II	12	* *Castanea sativa* (73.5) *** *Cistus* (5.5), Fabaceae (5), *Rhododendron* (3), Rosaceae (5) **** Apiaceae (2.5), Geraniaceae (0.5), Juglandaceae (0.5), Lamiaceae (1), Oleaceae (2), Poaceae (0.5), *Tilia* (1)
8	Ortahisar- Karakaya 150	7.506 Category I	8	* *Castanea sativa* (88) *** Apiaceae (5), Lamiaceae (3) **** Pinaceae (0.5), Poaceae (0.5), Ranunculaceae (0.5), Rhamnaceae (1), Rosaceae (1.5)
9	Ortahisar- Ağıllı (2) 400	200.257 Category III	7	* *Castanea sativa* (83) *** Apiaceae (7.5), Lamiaceae (4.5) **** Asteraceae (0.5), *Cistus* (0.5), Fabaceae (2), Rosaceae (2)
10	Ortahisar- Kendirli 450	24.129 Category II	8	* *Castanea sativa* (63.5) ** *Cistus* (24) *** Fabaceae (3), Rosaceae (5) ****Amaranthaceae (1), *Hedysarum* (1), *Plantago* (2), Scrophulariaceae (0.5)
11	Ortahisar- Ağıllı (2) 500	109.757 Category III	17	* *Castanea sativa* (69.5) *** Apiaceae (3), *Cistus* (6), Fabaceae (5.5), *Rhododendron* (3.5), Rosaceae (3) ****Ailanthus* (0.5), Brassicaceae (2), Campanulaceae (0.5), *Centaurea* (0.5), *Hedysarum* (0.5), Lamiaceae (2), *Laurus nobilis* (1), Malvaceae (0.5), Oleaceae (0.5), Poaceae (0.5), *Rumex* (1)
12	Sürmene- Yeşilköy 930	48.407 Category II	6	* *Castanea sativa* (65) ** Lamiaceae (22) *** Apiaceae (5), *Rhododendron* (6) **** *Cistus* (0.5), Poaceae (1.5)

Table 1. Continued

Sample number	Locations/ Altitude (m)	TPN-10 g /Pollen status	Number of taxon	Pollen spectrum and percentage (%)
13	Sürmene-Gültepe 350	301.616 Category III	14	* *Castanea sativa* (58.5) *** Apiaceae (10.5), Asteraceae (3.5), Oleaceae (5.5), Poaceae (3), Rosaceae (4), *Taraxacum* (3), *Vicia* (3.5) **** *Bellis* (1.5), Brassicaceae (2.5), *Centaurea* (2), Fabaceae (1), Lamiaceae (1), *Rhododendron* (0.5)
14	Sürmene-Yeniay 500	25.732 Category II	7	* *Castanea sativa* (63) ** *Rhododendron* (17), Rosaceae (16) ***** Brassicaceae (0.5), *Ilex* (0.5), *Laurus nobilis* (2.5), Rhamnaceae (0.5)
15	Sürmene-Ormanseven 410	118.522 Category III	7	* *Castanea sativa* (84) *** Fabaceae (5), *Rhododendron* (7.5) **** Boraginaceae (1), *Helianthus* (0.5), Lamiaceae (1), *Salix* (1)
16	Sürmene-Aşağıovalı 430	33.298 Category II	4	* *Castanea sativa* (93) *** Apiaceae (4) **** Fabaceae (1), Rosaceae (2)
17	Tonya-Kalınçam (1) 1.100	369.710 Category III	13	* *Castanea sativa* (70.5) *** *Cistus* (4), Fabaceae (4), *Hedysarum* (7), Poaceae (4), Rosaceae (3) **** Apiaceae (0.5), Boraginaceae (1.5), Amaranthaceae (0.5), Geraniaceae (0.5), Lamiaceae (2), *Rhododendron* (2), *Sanguisorba* (0.5)
18	Tonya-Kalınçam (2) 1.100	26.459 Category II	10	* *Castanea sativa* (84.5) ****Rhododendron* (8) **** Asteraceae (1), Boraginaceae (1), *Cistus* (2), Caprifoliaceae (1), Fabaceae (1), Pinaceae (0.5), Poaceae (0.5), Rosaceae (0.5)
19	Tonya-İskenderli (1) 750	72 164 Category II	12	* *Castanea sativa* (67) ** *Hedysarum* (16) *** Apiaceae (3), Fabaceae (5.5), Poaceae (3) **** Boraginaceae (0.5), *Centaurea* (0.5), Amaranthaceae (0.5), Lamiaceae (1.5), *Populus* (1), Rosaceae (1), *Rumex* (0.5)
20	Tonya-Kalınçam (3) 1.100	46.425 Category II	11	* *Castanea sativa* (79.5) *** Apiaceae (3), *Rhododendron* (5), Rosaceae (5) **** Betulaceae (0.5), Brasicaceae (0.5), *Cistus* (0.5), Fabaceae (2), *Hedysarum* (0.5), *Plantago* (1.5), Poaceae (2)
21	Tonya-Hoşarlı 755	65.210 Category II	11	** *Castanea sativa* (25), *Hedysarum* (30) *** Apiaceae (7.5), *Centaurea* (4), *Cistus* (5), Fabaceae (13.5), Lamiaceae (9), Rosaceae (3) ****Amaranthaceae (0.5), Geraniaceae (1), *Vicia* (1.5)
22	Tonya-Erikbeli 1.500	10.855 Category I	11	** *Carduus* (19.5), *Cistus* (22.5), Fabaceae (18) *** Apiaceae (3), *Castanea sativa* (14.5), *Hedysarum* (4.5), Lamiaceae (6), *Plantago* (3), Rosaceae (6) ****Poaceae (1.5), *Salix* (1.5)
23	Tonya-Zevon 1.200	52.489 Category II	15	* *Castanea sativa* (68.5) *** Fabaceae (5), Poaceae (3.5), *Rhododendron* (12.5) **** Asteraceae (1), *Centaurea* (0.5), *Cistus* (1), *Cynoglossum* (0.5), Caprifoliaceae (2), *Ilex* (0.5), Lamiaceae (2.5), Pinaceae (0.5), *Plantago* (0.5), *Populus* (0.5), Rosaceae (1)
24	Tonya-İskenderli (2) 750	2.845 Category I	12	** *Castanea sativa* (16.5), Fabaceae (30), Lamiaceae (32.5) *** Asteraceae (6), Brassicaceae (4) **** *Anthemis* (1), Apiaceae (2), Boraginaceae (2), *Centaurea* (1), Poaceae (2), Rosaceae (2), *Taraxacum* (1)
25	Tonya-Biçinlik 1.100	6.408 Category I	9	** *Castanea sativa* (16), Fabaceae (31), *Hedysarum* (20), Lamiaceae (18) *** Rosaceae (6.5) **** Brassicaceae (2.5), Campanulaceae (2,5), *Rhododendron* (2.5), Scrophulariaceae (1)
26	Tonya-Kadıralak 1.800	21.926 Category II	14	*** *Cistus* (25), Lamiaceae (26) *** Asteraceae (3.5), *Castanea sativa* (7.5), Fabaceae (10.5), *Hedysarum* (10), Rosaceae (5), Scrophulariaceae (3.5) **** Apiaceae (2.5), Campanulaceae (0.5), Convolvulaceae (0.5), *Cynoglossum* (0.5), Geraniaceae (2.5), Poaceae (2.5)

Table 1. Continued

Sample number	Locations/ Altitude (m)	TPN-10 g / Pollen status	Number of taxon	Pollen spectrum and percentage (%)
27	Tonya-Zere 1.850	26.494 Category II	16	** *Cistus* (20), *Hedysarum* (22.5) *** Asteraceae (12), Fabaceae (8.5), Geraniaceae (5), Lamiaceae (6), Rosaceae (12.5), *Sanguisorba* (4) **** Apiaceae (0.5), Brassicaceae (2), *Castanea sativa* (2.5), Caryophyllaceae (0.5), Poaceae (0.5), Rhamnaceae (2.5), *Taraxacum* (0.5), *Vicia* (0.5)
28	Of- Sulaklı 500	77.014 Category II	9	* *Castanea sativa* (73) *** Boraginaceae (6), Lamiaceae (12), *Tilia* (3) **** Apiaceae (1), *Cistus* (2), Pinaceae (1), Poaceae (1), Rhamnaceae (1)
29	Of-Yazlık 350	46.576 Category II	12	** Apiaceae (26.5), *Castanea sativa* (21.5), *Rhododendron* (26.5) *** *Cistus* (7.5), Fabaceae (4.5), *Hedysarum* (5) **** Campanulaceae (2.5), Caprifoliaceae (0.5), *Ilex* (0.5), Lamiaceae (2), *Laurus nobilis* (0.5), Rosaceae (2.5)
30	Of-Ballıca 400	38.032 Category II	10	* *Castanea sativa* (79) *** *Cistus* (3), Lamiaceae (3.5), *Rhododendron* (10) **** Campanulaceae (0.5), Fabaceae (0.5), Poaceae (1), Rosaceae (1.5), *Rumex* (0.5), *Vicia* (0.5)
31	Of-Ağaçseven 500	159.218 Category III	6	* *Castanea sativa* (92.5) *** *Rhododendron* (3) **** Boraginaceae (0.5), Fabaceae (1), Lamiaceae (1), Rosaceae (2)
32	Of-Uğurlu	94 179 Category II	2	* Castanea sativa (93) *** Lamiaceae (7)
33	Beşikdüzü-Oğuz (1) 302	274.863 Category III	12	* *Castanea sativa* (72.5) *** Apiaceae (7.5), Lamiaceae (4.5), Poaceae (4) ****Amaranthaceae (0.5), *Cistus* (1), Fabaceae (2), *Rhododendron* (2.5), Rosaceae (2), *Rumex* (2), Scrophulariaceae (0.5), *Vicia* (1)
34	Beşikdüzü-Oğuz (2) 470	439.580 Category III	9	* *Castanea sativa* (81) *** Apiaceae (3), *Cistus* (9) **** Brassicaceae (0.5), Fabaceae (1), Lamiaceae (0.5), Poaceae (1), *Rhododendron* (2), Rosaceae (2)
35	Beşikdüzü-Ağaçlı 300	96.960 Category II	11	* *Castanea sativa* (68) *** Boraginaceae (3.5), Amaranthaceae (8), *Cistus* (4.5), Lamiaceae (6.5), Poaceae (4) **** Apiaceae (0.5), *Epilobium* (1.5), *Hedysarum* (1), *Plantago* (1), Rosaceae (1.5)
36	Maçka-Ormanüstü 1.000	7.956 Category I	5	* *Castanea sativa* (55) *** Campanulaceae (7.5), *Cistus* (15), *Echium* (7.5), *Rhododendron* (15)
37	Maçka-Temelli 650	15.985 Category I	6	* *Castanea sativa* (62.5) ** *Rhododendron* (32.5) **** Apiaceae (1), Boraginaceae (1), Malvaceae (2), Poaceae (1)
38	Maçka-Yazlık 800	16.217 Category I	11	** *Laurus nobilis* (16), *Rhododendron* (43) *** Brassicaceae (6), *Cistus* (13), Geraniaceae (5), Lamiaceae (5), Pinaceae (3), Poaceae (3), Rosaceae (4) **** *Ilex* (1), Liliaceae (1)
39	Şalpazarı-Kasımağzı 800	75.873 Category II	7	* *Castanea sativa* (82.5) *** Apiaceae (6), Boraginaceae (4.5) **** *Cistus* (1.5), Lamiaceae (2.5), *Rhododendron* (2.5), *Tilia* (0.5)
40	Şalpazarı-Gökçeköy 1 900	38.611 Category II	9	* *Castanea sativa* (92.5) **** Apiaceae (1), Boraginaceae (2.5), *Cistus* (0.5), Lamiaceae (0.5), Oleaceae (0.5), Pinaceae (1), *Rhododendron* (1), Rosaceae (0.5)
41	Şalpazarı-Gökçeköy 2 900	345.648 Category III	11	* *Castanea sativa* (56) ** *Rhododendron* (29.5) *** Rosaceae (7) **** Apiaceae (1), Brassicaceae (0.5), *Cistus* (1), Lamiaceae (0.5), Oleaceae (1), Pinaceae (1), *Plantago* (2), Poaceae (0.5)

Table 1. Continued

Sample number	Locations/ Altitude (m)	TPN-10 g / Pollen status	Number of taxon	Pollen spectrum and percentage (%)
42	Şalpazarı-Yeşilyurt 900	10.147 Category I	15	* *Castanea sativa* (56) ** *Rhododendron* (27.5) *** Rosaceae (4) **** Apiaceae (2.5), Asteraceae (0.5), Boraginaceae (0.5), Brassicaceae (1), Fabaceae (2), Lamiaceae (0.5), Malvaceae (0.5), Oleaceae (0.5), *Plantago* (2.5), Poaceae (0.5), *Rumex* (1), *Salix* (0.5)
43	Şalpazarı-Akkiriş 700	10.092 Category I	9	*** *Castanea sativa* (21.5), Fabaceae (37.5) *** *Ailanthus* (4), Asteraceae (5), Lamiaceae (11.5), Pinaceae (7.5), *Plantago* (4), Rosaceae (5), Scrophulariaceae (4)
44	Şalpazarı-Gökçeköy-3 900	95.575 Category II	21	** Brassicaceae (33) *** Apiaceae (3), Asteraceae (6), *Cistus* (15), Fabaceae (6.5), *Hedysarum* (6), Lamiaceae (8.5), *Quercus* (3), Rosaceae (5) **** *Castanea sativa* (1.5), *Centaurea* (0.5), Amaranthaceae (0.5), *Echium* (1.5), *Laurus nobilis* (1.5), Malvaceae (0.5), Oleaceae (1.5), Poaceae (0.5), Rhamnaceae (1.5), *Rumex* (0.5), *Salix* (2.5), *Vicia* (1.5)
45	Yomra-Çınarlı 20	214.760 Category III	14	* *Castanea sativa* (69.5) *** Apiaceae (6), *Cistus* (5), *Rhododendron* (10.5) **** Asteraceae (1.5), Brassicaceae (0.5), Fabaceae (2.5), Lamiaceae (0.5), *Laurus nobilis* (0.5), Oleaceae (0.5), *Plantago* (0.5), Poaceae (1), Rhamnaceae (0.5), Rosaceae (1)
46	Yomra-İkisu (1) 350	114.159 Category III	5	* *Castanea sativa* (88) *** Apiaceae (4), *Cistus* (3), *Rhododendron* (4) **** Lamiaceae (1)
47	Yomra-İkisu (2) 350	194.237 Category III	21	* *Castanea sativa* (52) *** Apiaceae (6), Brassicaceae (3.5), Fabaceae (7), Lamiaceae (5.5), Poaceae (3.5), Rosaceae (7.5) **** Asteraceae (1.5), *Cistus* (2.5), Caprifoliaceae (0.5), *Echium* (1), Geraniaceae (0.5), *Hedysarum* (0.5), Malvaceae (1.5), Oleaceae (1.5), Rhamnaceae (1), *Salix* (0.5), *Sanguisorba* (0.5), Scrophulariaceae (2), *Taraxacum* (0.5), *Vicia* (1)
48	Yomra-Çamlıyurt 1.200	10.398 Category I	9	* *Castanea sativa* (70) *** Asteraceae (4), Campanulaceae (5), Lamiaceae (6), *Rhododendron* (10) **** Brassicaceae (2), *Cistus* (1), Fabaceae (1), Malvaceae (1)
49	Yomra-Çamlıyurt -2 750	27.512 Category II	8	* *Castanea sativa* (66) *** Apiaceae (7.5), Fabaceae (7.5), *Rhododendron* (12.5), Rosaceae (3.5) **** Lamiaceae (1.5), *Plantago* (0.5), Rhamnaceae (1)
50	Düzköy-Çayırbağı (1) 1.150	20.932 Category II	18	** *Castanea sativa* (41), *Rhododendron* (16.5) *** Campanulaceae (3), Caryophyllaceae (10), Lamiaceae (4.5), Malvaceae (3), Rhamnaceae (3.5), Rosaceae (11) **** Apiaceae (0.5), Asteraceae (0.5), *Cistus* (0.5), *Epilobium* (1.5), Fabaceae (0.5), Geraniaceae (1.5), *İlex* (0.5), Pinaceae (0.5), Scrophulariaceae (1), *Taraxacum* (0.5)
51	Düzköy-Çayırbağı (2) 1.100	64.416 Category II	11	* *Castanea sativa* (65) *** Apiaceae (7), *Cistus* (3), Lamiaceae (5), *Rhododendron* (13.5) **** Asteraceae (1.5), Fabaceae (1), Liliaceae (0.5), Malvaceae (1), Rhamnaceae (0.5), Rosaceae (2)
52	Düzköy-Çayırbağı (3) 1.100	535.995 Category IV	13	* *Castanea sativa* (70.5) *** Lamiaceae (15) **** Apiaceae (1), Asteraceae (2), Brassicaceae (0.5), *Cistus* (2), Fabaceae (0.5), Geraniaceae (0.5), Malvaceae (2.5), Rhamnaceae (1.5), *Rhododendron* (2), Rosaceae (1.5), *Tilia* (0.5)
53	Düzköy-Mezere 2.000	94.848 Category II	15	* *Castanea sativa* (49.5) *** Apiaceae (13), Brassicaceae (3.5), Fabaceae (7), Lamiaceae (12.5), Rosaceae (4.5) **** Asteraceae (1), Boraginaceae (1.5), *Cistus* (1.5), Convolvulaceae (0.5), Geraniaceae (2.5), Oleaceae (0.5), *Plantago* (0.5), Poaceae (1.5), Ranunculaceae (0.5)

Table 1. Continued

Sample number	Locations/ Altitude (m)	TPN-10 g /Pollen status	Number of taxon	Pollen spectrum and percentage (%)
54	Düzköy-Çayırbağı (4) 1.100	75.371 Category II	7	* *Castanea sativa* (78) *** Apiaceae (12), Rhamnaceae (4) **** Asteraceae (1), Fabaceae (1), Malvaceae (2), *Rhododendron* (2)
55	Çaykara-Demirkapı (1) 1.150	12.341 Category I	11	** Brassicaceae (24.5), *Cistus* (22) *** Apiaceae (5), *Cynoglossum* (14.5), Fabaceae (5.5), Lamiaceae (12), Poaceae (12.5) **** Asteraceae (0.5), *Hedysarum* (0.5), Pinaceae (0.5), Rosaceae (2.5)
56	Çaykara-Taşkıran 1.000	26.583 Category II	5	* *Castanea sativa* (93) *** *Rhododendron* (3) **** Apiaceae (2), Asteraceae (1), *Cistus* (1)
57	Çaykara-Çayıroba (1) 2.200	4.629 Category I	11	* *Castanea sativa* (62.5) *** Campanulaceae (3), *Cistus* (7.5), Fabaceae (6), Lamiaceae (7.5), Rosaceae (6) **** Apiaceae (1.5), Caryophyllaceae (1.5), Geraniaceae (1.5), Oleaceae (1.5), *Rhododendron* (1.5)
58	Çaykara-Çayıroba (2) 2.000	10.504 Category I	12	* *Castanea sativa* (72) *** Brassicaceae (7), *Cistus* (5), *Hedysarum* (3), Lamiaceae (3), *Rhododendron* (3) **** *Cynoglossum* (1), Campanulaceae (2), Fabaceae (1), Liliaceae (1), Rosaceae (1), *Taraxacum* (1)
59	Çaykara-Merkez 300	6.083 Category II	11	* *Castanea sativa* (91.5) **** Apiaceae (2), Brassicaceae (0.5), Fabaceae (1), Lamiaceae (1), Malvaceae (0.5), Pinaceae (0.5), Poaceae (0.5), *Rhododendron* (1), Rosaceae (1), *Tilia* (0.5)
60	Çaykara-Demirkapı (2) 1.150	20.708 Category II	12	** Asteraceae (16), Fabaceae (39.5) *** Apiaceae (12.5), Brassicaceae (3.5), *Cistus* (3), Oleaceae (8), Rhamnaceae (6.5), Rosaceae (5) **** *Echium* (1.5), Geraniaceae (1.5), *Plantago* (1.5), *Vicia* (1.5)
61	Çaykara-Demirkapı (3) 1.150	3.485 Category I	14	** Fabaceae (27) *** Apiaceae (4), Boraginaceae (4), *Castanea sativa* (8.5), *Centaurea* (6.5), *Echium* (8), *Hedysarum* (12), Lamiaceae (9), *Plantago* (4), Rosaceae (9) **** Brassicaceae (2), Malvaceae (2), Oleaceae (2), Poaceae (2)
62	Akçaabat-Yıldızlı 50	63.404 Category II	13	* *Castanea sativa* (45) ** *Cynoglossum* (23.5) *** Apiaceae (14), Lamiaceae (3), Rosaceae (4) **** Boraginaceae (1), *Cistus* (1.5), Fabaceae (1), *Hedysarum* (2), Poaceae (1.5), Rhamnaceae (1), *Rumex* (2), Scrophulariaceae (0.5)
63	Akçaabat-Uçarsu 250	45.110 Category II	8	* *Castanea sativa* (60.5) *** Apiaceae (7.5), *Cistus* (6.5), Lamiaceae (7.5), Poaceae (4.5), Rhamnaceae (3), *Rhododendron* (6), Rosaceae (4.5)
64	Akçaabat-Akçaköy (1) 200	1.525.683 Category V	9	* *Castanea sativa* (67) ** Lamiaceae (18) *** *Cistus* (5), Rosaceae (4.5) **** Apiaceae (1), Betulaceae (0.5), Fabaceae (2), Geraniaceae (0.5), Poaceae (1.5)
65	Akçaabat-Akçaköy (2) 200	5.564 Category I	12	** Fabaceae (30), *Hedysarum* (17.5) *** Brassicaceae (9), *Castanea sativa* (7.5), *Echium* (11), Lamiaceae (9), Rosaceae (8.5) **** Asteraceae (1.5), *Centaurea* (1.5), *Cistus* (1.5), *Cynoglossum* (1.5), *Salix* (1.5)
66	D.pazarı-Kondu (1) 650	120.583 Category III	6	* *Castanea sativa* (94) *** Lamiaceae (3.5) **** *Plantago* (0.5), Poaceae (0.5), *Rhododendron* (1), Scrophulariaceae (0.5)
67	D.pazarı-Kondu (2) 550	178.166 Category III	9	* *Castanea sativa* (81) *** Lamiaceae (4.5), *Rhododendron* (5) **** Apiaceae (1), *Carduus* (0.5), *Cistus* (2.5), *Plantago* (1), Poaceae (2.5), Rosaceae (2)
68	D.pazarı-Kondu (3) 600	107.508 Category III	5	* *Castanea sativa* (78) ** *Cistus* (18) **** Fabaceae (0.5), Lamiaceae (1), *Rhododendron* (2.5)

Table 1. Continued

Sample number	Locations/ Altitude (m)	TPN-10 g /Pollen status	Number of taxon	Pollen spectrum and percentage (%)
69	D.pazarı-Yenice (1) 2.000	50.190 Category II	5	* Lamiaceae (82) *** Asteraceae (6), Brassicaceae (5), *Cistus* (6) ****Rosaceae (1)
70	D.pazarı-Yenice (2) 2.000	38.571 Category II	18	** *Castanea sativa* (28.5), Rosaceae (36) *** Apiaceae (4.5), Fabaceae (7.5), Lamiaceae (8), *Rhododendron* (3.5) **** Asteraceae (1), Brassicaceae (0.5), Campanulaceae (1), Caryophyllaceae (0.5), *Cistus* (2), *Cynoglossum* (0.5), *Hedysarum* (0.5), *İlex* (1.5), Pinaceae (0.5), Poaceae (2), Scrophulariaceae (1.5), *Vicia* (0.5)
71	Araklı-Yeşilce 220	61.633 Category II	11	* *Castanea sativa* (64.5) *** Apiaceae (5), Fabaceae (8.5), Lamiaceae (12.5), Poaceae (3.5) **** Asteraceae (2), Brassicaceae (0.5), Rhamnaceae (0.5), *Rhododendron* (0.5), Rosaceae (2), *Salix* (0.5)
72	Araklı-Değirmencik 1.200	136.103 Category III	9	* *Castanea sativa* (89.5) *** *Cistus* (3.5) **** Apiaceae (1.5), Asteraceae (0.5), Lamiaceae (1.5), Poaceae (1), *Rhododendron* (1.5), Rosaceae (0.5), *Vicia* (0.5)
73	Araklı-Yoncalı 350	1.096.031 Category V	12	* *Castanea sativa* (50) ** Apiaceae (30) *** Lamiaceae (3), Rosaceae (4.5), *Rhododendron* (6.5) **** Asteraceae (1), Brassicaceae (1), *Centaurea* (0.5), *Cistus* (2), Fabaceae (0.5), Geraniaceae (0.5), Rhamnaceae (0.5)
74	Araklı-Merkez 100	85.392 Category II	7	* *Castanea sativa* (58) ** Fabaceae (18) *** *Cistus* (10), Rosaceae (9) **** Apiaceae (2), Lamiaceae (2), Scrophulariaceae (1)
75	Araklı-Bahçecik 1.550	6.266 Category I	11	** *Castanea sativa* (27.5), *Cistus* (37) *** Fabaceae (10), *Hedysarum* (4.5), Lamiaceae (9), Rosaceae (4) **** Apiaceae (2.5), Brassicaceae (1.5), Geraniaceae (1.5), Oleaceae (2), Scrophulariaceae (0.5)
76	Çarşıbaşı-Kavaklı 211	27.342 Category II	8	* *Castanea sativa* (80) *** Lamiaceae (6), Rosaceae (4) **** Asteraceae (2), Brassicaceae (2), *Cistus* (2), Fabaceae (2), Poaceae (2)
77	Köprübaşı-Çifteköprü 530	102.708 Category III	4	* *Castanea sativa* (93.5) *** *Rhododendron* (5) **** Lamiaceae (0.5), *Plantago* (1)
78	Köprübaşı-Gündoğan 350	145.933 Category III	6	* *Castanea sativa* (93) **** Apiaceae (2), Fabaceae (1), Lamiaceae (1), Poaceae (1), Rosaceae (2)
79	Hayrat-Sarmaşık 2.500	6.057 Category I	9	** *Castanea sativa* (30), *Cistus* (20) *** Asteraceae (5), Brassicaceae (4), *Cynoglossum* (3), Fabaceae (10), Lamiaceae (12), Rosaceae (7), Scrophulariaceae (9)
80	Arsin-Harmanlı -1 150	49.039 Category II	8	* *Castanea sativa* (80) *** Apiaceae (4), *Tilia* (6) **** *Cistus* (2), Lamiaceae (2), Oleaceae (2), Poaceae (2), Rosaceae (2)
81	Arsin-Yolüstü 200	245.498 Category III	11	* *Castanea sativa* (90.5) **** Apiaceae (1), Brassicaceae (0.5), *Cistus* (0.5), Convolvulaceae (0.5), Fabaceae (1.5), Lamiaceae (1), Poaceae (0.5), *Rhododendron* (2.5), Rosaceae (1), *Taraxacum* (0.5)
82	Arsin-Harmanlı (2) 150	278.474 Category III	8	* *Castanea sativa* (78) *** Apiaceae (4), Fabaceae (9), Rosaceae (5) **** Asteraceae (0.5), *Cistus* (2), *Quercus* (0.5), Lamiaceae (1)
83	Vakfıkebir-Deregözü (1) 600	832.896 Category IV	7	* *Castanea sativa* (68) *** Apiaceae (12.5), Fabaceae (5.5), *Rhododendron* (9.5) **** Asteraceae (1.5), Lamiaceae (1.5), Rosaceae (1.5)
84	Vakfıkebir-Deregözü (2) 700	43.099 Category II	4	* *Castanea sativa* (92) *** Rosaceae (5) **** Apiaceae (1), Lamiaceae (2)
85	Gümüşhane Yağmurdere 2.000	11.175 Category I	11	** *Castanea sativa* (20), Fabaceae (24), Lamiaceae (32) *** Brassicaceae (4), *Cistus* (8), *Hedysarum* (6), Rosaceae (4) **** Geraniaceae (0.5), Oleaceae (0.5), Poaceae (0.5), Scrophulariaceae (0.5)

Honey samples according to total pollen count (TPN-10 g) amounts are grouped; 22.3% Category I (19 samples), 45.9% Category II (39 samples), 27% Category III (23 samples), 2.4% Category IV (2 samples) and 2.4% Category V (2 samples) (Figure 5, Table 1). The total number of pollen in 10 grams

of honey (TPN-10 g) has been determined to be at least 2845 (sample 24) and at most 1 525 683 (sample 64) (Table 1). The graph showing the grouping of honey samples according to the amount of TPN-10 g is given below (Figure 5).

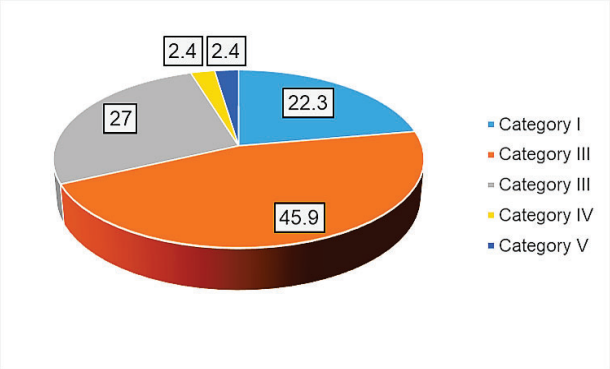

Figure 5. Percentage distribution of honey samples according to total pollen number (TPN-10 g)

Correlation analysis was performed to examine linear relationships between variables. This analysis used altitude, TPN-10 g, number of taxa, and pollen status variables. The correlation matrix was calculated, and the heat map was visualized. The map expresses correlation coefficients with color tones; dark colors indicate high correlation, and light colors indicate low correlation.

When the correlation between altitude and both TPN-10 g and pollen status was calculated, it was determined that there was a negative relationship between them. As the altitude increases, there is a decrease in TPN-10 g value and pollen status. However, there is a positive relationship between altitude and the number of taxa. In other words, as the altitude increased, the number of taxa contained in honey also increased. Similarly, it was determined that there was a positive relationship between the total pollen count and the pollen status. On the other hand, when the relationship between the number of taxa and both the total pollen number and the pollen status was examined, almost no connection was found between these characters. It was determined that the results of the correlation analysis were compatible with the results of the research. Pearson correlation coefficients of the analyses are given in Figure 6.

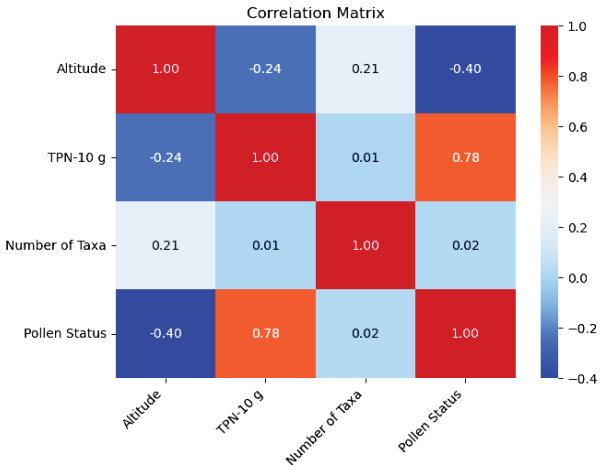

Figure 6. Correlation matrix heat map made with altitude, TPN-10 g, number of taxa, and pollen status characters

Pollen spectrum analysis examined the percentage distribution of plant taxa found in honey. By defining the relevant columns, the percentages of occurrence in honey samples were calculated for each plant taxon, and these data were visualized using a polar plot. Color intensity indicates the abundance of taxon types in honey (Figure 7).

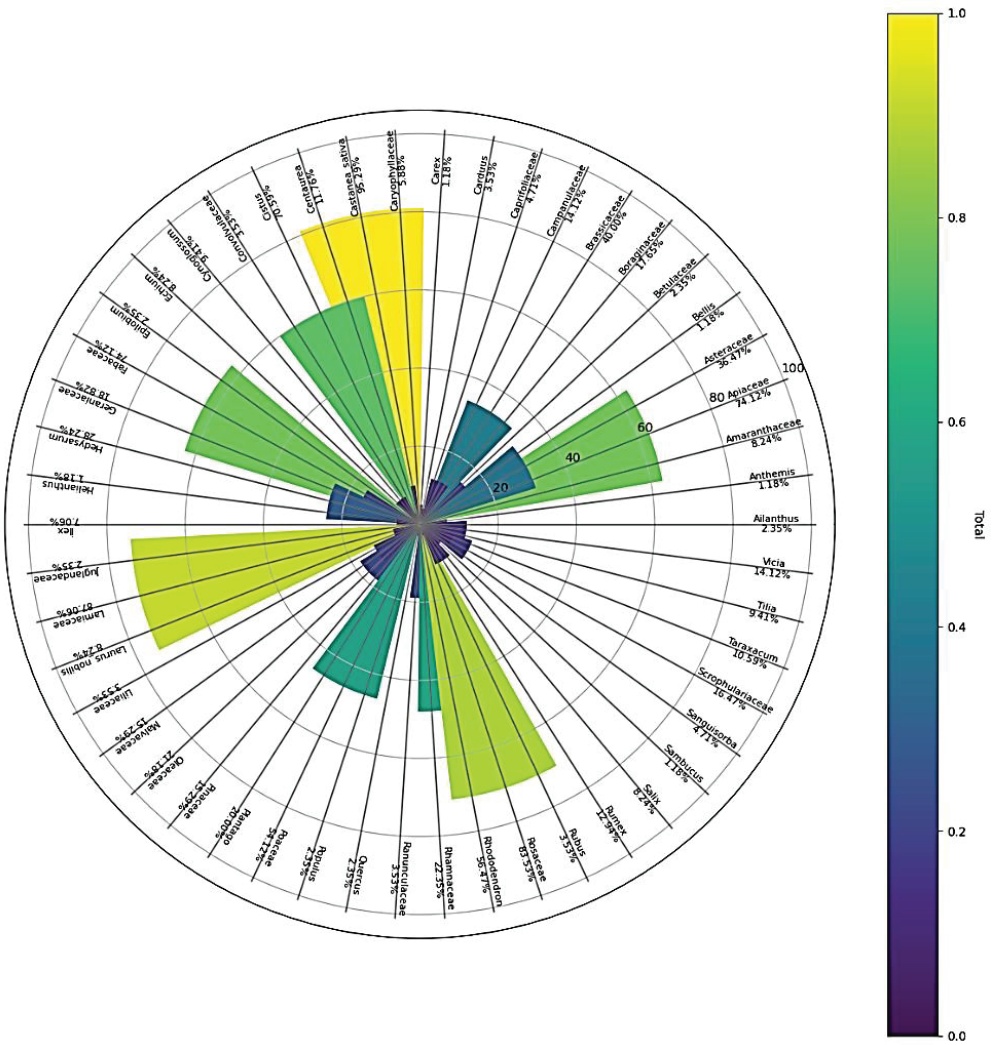

Figure 7. Polar graph resulting from pollen spectrum analysis

A cluster analysis was performed on all the data (altitude, TPN-10 g, pollen spectrum, and pollen status) characteristics of the 85 honey samples produced in Trabzon (Türkiye). When the hierarchical clustering method was applied, the samples were grouped in a tree structure, and a dendrogram was drawn. While each node represents an example, the distances between nodes show the similarity or distance between these examples. There are 2 main groups, each with 2 subgroups of honey samples according to the hierarchical clustering dendrogram. Samples in the green and orange subsets have similar characteristics and converge at small distances. The same situation is observed in the red and purple clusters. When the subclusters are examined, the closest similarity is the red subcluster, while the examples in the green subcluster converge at larger distances, and these clusters show more significant differences (Figure 8).

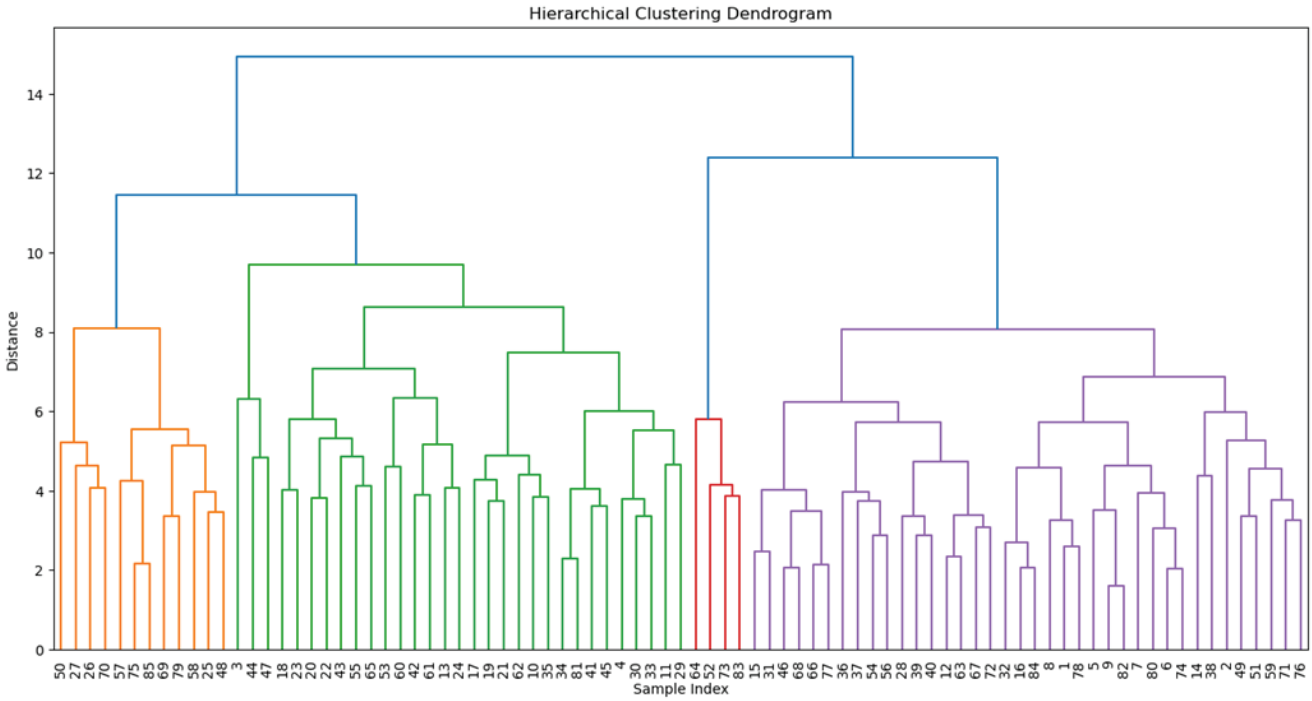

Figure 8. Cluster dendrogram of the honey samples investigated using all data (altitude, TPN-10 g, pollen spectrum, and pollen status)

DISCUSSION

To develop beekeeping in a region and obtain high efficiency from beekeeping, along with the colony strength, nectar and pollen must be diverse and abundant (Bijev 1958). Therefore, knowing what honey plants are necessary to make beekeeping activities more efficient.

As a result of pollen analysis of Trabzon honey, 50 taxa belonging to 36 families were identified. Most of these taxa belong to Apiaceae, Asteraceae, Brassicaceae, Cistaceae, Ericaceae, Fabaceae, Fagaceae, Lamiaceae, Poaceae and Rosaceae. Similarly, it is known that the plant taxa that the source of flower honey produced in Türkiye are Asteraceae, Brassicaceae, Fabaceae, Fagaceae, Lamiaceae, Malvaceae, Myrtaceae, Oleaceae, and Scrophulariaceae families (Sorkun et al. 1999). Sorkun and Doğan (1995), reported in their study that the diversity of taxa in the dominant group is always less, and the diversity of taxa in the trace group is always greater. In this study, as a result of pollen analysis, it was observed that the trace group had the highest number of taxa, followed by the minor, secondary, and dominant groups (Table 1).

The dominance of *Castanea sativa* pollen in the honey samples clearly indicates that this species is one of the most important nectar and pollen sources in the region. The presence of *Castanea sativa* pollen in 81 out of 85 honey samples (Figure 9), and its classification as dominant in 65 of them, secondary in 10, minor in 4, and trace in 2 samples (Table 1), underlines its pivotal role in local honey production. This dominance is closely related to Trabzon's unique geography and vegetation. Located along the Black Sea coast, the province has a humid and mild climate that supports the growth of broad leaved moist forests where *Castanea sativa* is widespread. Naturally growing at elevations of 300-1000 meters, chestnut trees bloom in June, providing abundant nectar and pollen for honeybees (Dalgıç 1994, Sorkun and Yuluğ 1985).

Accordingly, four honey samples were identified as unifloral and labeled as chestnut honey. However, in many multifloral honey samples, *Castanea sativa* remained the dominant pollen source. In our research, several samples with over 80% *Castanea sativa* pollen were still classified as multifloral due to the presence of minor amounts of other taxa. This

reflects both the foraging behavior of bees and the botanical richness of the region.

From both floristic and apicultural perspectives, chestnut has a high value. In our study, 65 samples with dominant *Castanea sativa* pollen also had high total pollen counts (TPN-10 g), confirming that this species is dominant not only floristically but also in terms of pollen production. Particularly in the red cluster subgroup, samples had notably high TPN values, supporting their chestnut origin. The widespread presence of chestnut pollen is attributed not only to the tree's abundance but also to its preference by bees. Its small sized pollen grains are easily collected, its flowering is intense, and its fragrance is highly attractive to bees (Dalgıç 1994, Sorkun and Doğan 1995).

Samples 64 and 73 had the highest total pollen counts (1.525.683 and 1.096.031), placing them in Category V, which is typically associated with additive honey. In both samples, *Castanea sativa* was the dominant taxon. According to the study by Sorkun and Doğan (2002), total pollen count (TPN-10 g) is an important parameter for distinguishing natural from artificial honey. In line with their findings, these two samples could be interpreted as not being natural. However, considering the high prevalence of *Castanea sativa* pollen in our samples and the fact that the chestnut tree is a highly attractive, nectar and pollen rich source for bees, these high pollen count samples are likely to be natural as well. It is also important to note that TPN-10 g alone is not sufficient to determine the authenticity of honey; chemical and physical analyses are also required. Supporting findings from neighboring provinces with similar ecological characteristics such as Rize, Sinop, Adapazarı and Kastamonu have also reported dominant levels of *Castanea sativa* pollen in honey samples (Erdoğan et al. 2006; 2009, Özler 2015, Sorkun et al. 1989, Sorkun and Yuluğ 1985, Uzunca et al. 2023). These consistent results reinforce the significant potential of the Black Sea region in chestnut honey production.

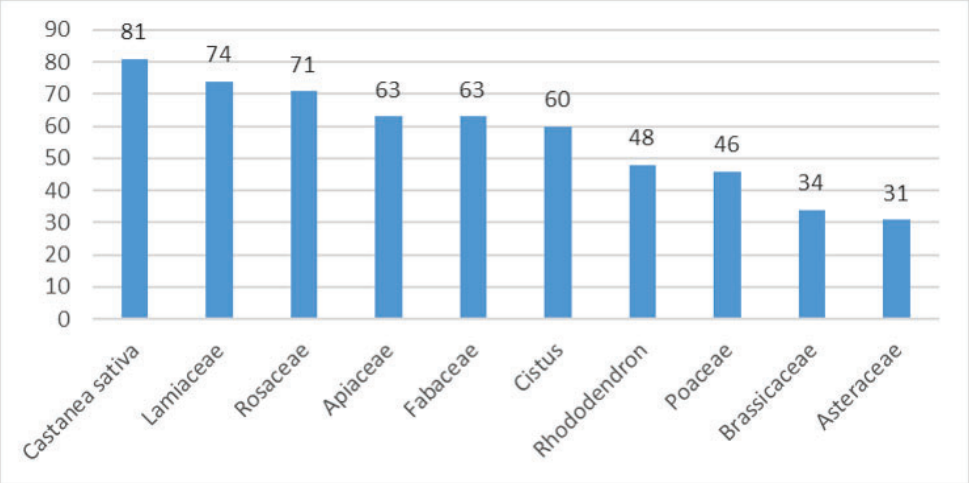

Figure 9. The most common taxa in honey samples

Lamiaceae and Rosaceae were identified as the second and third most frequently encountered pollen families in Trabzon honey, respectively. Lamiaceae pollen was detected in 74 out of 85 samples, being dominant in 1, secondary in 6, minor in 35, and present in trace amounts in 33 samples. Due to their long flowering periods, aromatic nature, and rich nectar content, members of the Lamiaceae family constitute an important source for beekeeping (Sorkun 1986). Rosaceae pollen was identified in 71 samples, mostly in minor (39 samples) and trace (30 samples) amounts. The prevalence of this family's pollen is likely due to its early spring blooming, high pollen production, and the abundance of fruit orchards in the region. The presence of pollen from both families has been frequently reported in studies conducted in various regions of Türkiye (Dalgıç 1994, Erdoğan et al. 2006, 2009, Sabuncu et al. 2002, Sorkun et al. 1999, Sorkun ve İnceoğlu 1984).

The detection of pollen from the *Rhododendron* genus, belonging to the Ericaceae family, in honey holds particular significance. It has been reported that honey produced by bees collecting nectar from *R. ponticum* L. and *R. luteum* Sweet, both species of this taxon, may cause poisoning when consumed in excess due to its high grayanotoxin content. These types of honey have also been shown to affect the cardiovascular system (Ergun et al. 2005). *Rhododendron* pollen contains an alkaloid called andromedotoxin (Grayanotoxin I), and excessive exposure to such honey has been associated with symptoms of hypotension, including vomiting, dizziness, visual disturbances, and tinnitus (Tutkun 2000). *Rhododendron* pollen was detected in 48 out of 85 honey samples. Among these, it was found as a secondary pollen type in 7 samples, as a minor pollen in 24 samples, and in trace amounts in 17 samples. Pollen of this taxon has also been identified in studies conducted in provinces neighboring Trabzon (Erdoğan et al. 2006, 2009, Sorkun et al. 1989). In the present study, *Rhododendron* pollen was detected in 16 of Trabzon's 18 districts. Notably, the amount of pollen increased in honey samples collected from districts such as Düzköy, Maçka, Of, Sürmene, and Şalpazarı, where this taxon is known to be densely distributed.

In this study, statistical analyses conducted on 85 honey samples produced in Trabzon provide significant insights into the relationship between the pollen content of honey, its floristic diversity, and environmental factors. The results of the Pearson correlation analysis revealed meaningful relationships between altitude and certain variables. A positive correlation was found between altitude and the number of taxa, indicating that a greater diversity of plant taxa was observed at higher elevations, and these taxa were reflected in the honey samples. This suggests that certain plant species may be more dominant at higher altitudes or that bees in these regions may utilize a broader range of floral sources. However, the lack of a significant correlation between the number of taxa and both the total pollen count and pollen status indicates that diversity does not necessarily correlate with abundance. In other words, a honey sample may contain pollen from many different plant taxa, but each taxon may be represented in small quantities.

In the pollen spectrum analysis, the percentage distributions of plant taxa present in the honey samples were examined. This analysis enabled the identification of the botanical origins of the honey and their relative abundances. The polar plot served as an effective tool for understanding the floristic composition, with taxa shown in more intense colors representing dominant plant sources in the honey.

The hierarchical clustering analysis grouped the honey samples based on their similarities and identified two main clusters, each consisting of two subgroups. These subgroups were differentiated based on the floristic composition, total pollen count, and environmental characteristics of the samples. The red subgroup, which includes the most similar samples, is noteworthy for containing honey samples with the highest total pollen counts. This finding highlights the total pollen count (TPN-10 g) as the most influential variable in the clustering process. In contrast, the green subgroup, which showed greater distances between samples, reflects higher variability among its samples, indicating a more heterogeneous set of characteristics.

Conclusion: The findings of this study reveal the significant potential of the Black Sea Region particularly Trabzon province for the production of high-quality chestnut honey. This highlights the importance of regional branding, improvement of quality control processes, and the development of sustainable beekeeping practices. In this context, expanding floristic mapping studies and supporting them with chemical analyses will facilitate science-based progress in the apiculture sector.

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Ethics: Not applicable.

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