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**ARAŞTIRMA MAKALESİ** **RESEARCH ARTICLE**

# Characterization of Volatile Compounds in Flowers of the Oleaster Tree (*Elaeagnus angustifolia* L.) from The Van Region, Türkiye

Van Bölgesi (Türkiye) İğde Ağacı (*Elaeagnus angustifolia* L.) Çiçeklerindeki Uçucu Bileşiklerin Karakterizasyonu

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## Abstract

This study investigates the volatile compounds in the flowers of *Elaeagnus angustifolia* L. from the Van province of Türkiye using Headspace Solid Phase Micro Extraction (HS-SPME) and Gas Chromatography-Mass Spectrometry (GC/MS). The objective was to identify and compare the volatile profiles of 12 different genotypes of this plant to assess differences in aroma. The results revealed the presence of 67 volatile compounds, including 6 aliphatic aldehydes, 2 aromatic aldehydes, 9 aliphatic alcohols, 3 aromatic alcohols, 19 aliphatic esters, 5 aromatic esters, 8 ketones, and 15 terpenes. Esters, which are the main contributors to the sweet and fruity fragrance, ranged from 19.09% to 87.65% across the genotypes. Genotype 8 exhibited the highest ester content (87.65%), producing a strong sweet aroma, while genotype 9 had the lowest ester content (19.09%). Aldehydes, contributing to fresh and sharp notes, were most abundant in genotype 3 (59.54%) and least in genotype 7 (5.35%). Alcohols were highest in genotype 11 (11.6%) and lowest in genotype 7 (2.75%). Ketones, which add complexity and longevity to the fragrance, were highest in genotype 1 (8.18%), while genotype 10 had no detectable ketones. Terpenes were found in smaller amounts, with genotype 5 having the highest content (8.18%) and genotype 9 the lowest (2.12%). These chemical differences among the genotypes highlight the potential for selecting specific genotypes for ornamental and medicinal applications. This study provides a foundation for breeding programs and the development of fragrance and pharmaceutical products from Oleaster. Furthermore, the clear variation in key aroma-contributing compounds suggests that certain genotypes may be particularly suitable for use in urban green spaces where pleasant and persistent floral scents are desirable. The findings also emphasize the ecological and cultural value of Oleaster, supporting its conservation and sustainable utilization in landscaping, traditional medicine, and aromatic product industries.

**Keywords:** Odour landscape, Oleaster tree, Urban green areas, Volatile profiles

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## Öz

Bu çalışma, Türkiye'nin Van ilinde toplanan *Elaeagnus angustifolia* L. çiçeklerindeki uçucu bileşikleri Headspace Katı Faz Mikro Ekstraksiyonu (HS-SPME) ve Gaz Kromatografisi-Kütle Spektrometrisi (GC/MS) kullanarak incelemektedir. Çalışmanın amacı, bu bitkinin 12 farklı genotipine ait uçucu bileşik profillerini belirlemek ve aroma özellikler bakımından ortaya çıkan farklılıkları değerlendirmektir. Analizler sonucunda 67 uçucu bileşik tespit edilmiştir. Bu bileşikler; 6 alifatik aldehit, 2 aromatik aldehit, 9 alifatik alkol, 3 aromatik alkol, 19 alifatik ester, 5 aromatik ester, 8 keton ve 15 terpen olmak üzere çeşitli kimyasal gruplara ayrılmıştır. Tatlı ve meyvemsi kokunun başlıca belirleyicileri olan esterler genotipler arasında %19.09 ile %87.65 arasında değişmiştir. En yüksek ester içeriği genotip 8'de (%87.65) bulunmuş olup bu genotip güçlü bir tatlı aroma sergilemiştir; en düşük ester içeriği ise genotip 9'da (%19.09) belirlenmiştir. Taze ve keskin koku notalarına katkı sağlayan aldehitler en yüksek genotip 3'te (%59.54), en düşük genotip 7'de (%5.35) saptanmıştır. Alkoller genotip 11'de (%11.6) ile en yüksek, genotip 7'de (%2.75) ile en düşük seviyede görülmüştür. Kokuya karmaşıklık ve kalıcılık kazandıran ketonlar genotip 1'de (%8.18) ile en yüksek düzeyde olup genotip 10'da keton tespit edilmemiştir. Terpenler ise daha düşük oranlarda bulunmuş; en yüksek genotip 5'te (%8.18), en düşük genotip 9'da (%2.12) olarak belirlenmiştir. Genotipler arasındaki bu kimyasal farklılıklar, süs bitkisi ve tıbbi kullanım açısından uygun genotiplerin seçilmesi için önemli bir potansiyel ortaya koymaktadır. Bu çalışma, iğde türüne yönelik ıslah programları ile koku ve farmasötik ürün geliştirme çalışmalarına bilimsel bir temel sunmaktadır. Ayrıca, aroma oluşturan temel bileşiklerdeki belirgin varyasyon, bazı genotiplerin hoş ve kalıcı çiçek kokusunun arzu edildiği kentsel yeşil alanlarda kullanım için özellikle uygun olabileceğini göstermektedir. Bulgular, iğdenin ekolojik ve kültürel değerini vurgulamakta; peyzaj düzenlemeleri, geleneksel tıp ve aromatik ürün endüstrilerinde korunması ve sürdürülebilir kullanımına destek sağlamaktadır.

**Anahtar Kelimeler:** İğde ağacı, Kentsel yeşil alanlar, Koku peyzajı, Uçucu bileşik profilleri

## 1. Introduction

Medicinal and aromatic plants, valued for their applications in food, pharmaceuticals, cosmetics, spices, and various industries such as dye production, landscaping, ornamental horticulture, and insecticide manufacturing, have been utilized since the earliest periods of human history (Gökduman and Yılmaz, 2025). *Elaeagnus angustifolia* L., commonly known as oleaster or Russian olive, is a fast-growing, short lived deciduous species native to regions including the Balkans, Iran, Central Asia, and Anatolia. Historically, it has been widely used as a hedge plant in vegetable and fruit gardens. Its distinctive oval-shaped fruits (14–16 mm long and 8–11 mm wide) have earned it the local name "bird's oleaster" in Anatolia due to their small size. This tree, typically reaching 5–6 meters in height with scattered branches, is highly valued for its light gray-green foliage and ornamental appeal, making it a common choice for parks, gardens, and roadside plantings. The bell-shaped flowers of *E. angustifolia* are among its most striking features. These flowers possess tubular sepals (3–4 mm long) with golden-yellow inner surfaces and white, gilded exteriors. Flowering occurs between May and June depending on ecological conditions, and the blossoms emit a strong, penetrating fragrance that is perceived as either pleasant or overly intense (Bartha and Csiszár, 2008; Thürkow et al, 2024). In the Van region of Türkiye, oleaster has long been incorporated into landscape design particularly in older gardens due to its calming fragrance and aesthetic value. Recent studies have identified 12 genotypes in the region with distinct fruit characteristics, highlighting its importance for urban green spaces (Bartha and Csiszár, 2008; Alp and Çığ 2022; Göral, 2024). Beyond its ornamental qualities, the oleaster holds considerable ecological and medicinal significance. Its adaptability and rapid growth allow it to thrive across diverse climates, making it a promising species for research and landscape use (Khan et al., 2016). Herbal products or herbal medicines defined as substances containing components derived from one or more plants, either in raw or processed form have long been recognized for their therapeutic properties and contributions to human health (WHO, 1998). In recent years, interest in medicinal and aromatic plants has increased markedly. This trend is particularly evident in developing countries, where limited economic resources and underdeveloped pharmaceutical industries make these plants valuable as accessible and low-cost treatment alternatives (Aslan and Velioglu, 2024). Pharmacological studies have demonstrated that different plant parts including flowers, leaves, and fruits exhibit anti-inflammatory, antioxidant, and antimicrobial activities (Esmaeili et al., 2013). The phytochemical profile of the oleaster, rich in bioactive compounds such as phenolic acids, flavonoids, and antioxidants, further underscores its medicinal potential (Saboonchian et al., 2014). One of the notable characteristics of the species is its volatile compound profile, particularly concentrated in its floral tissues. These volatile organic compounds not only define the plant's aromatic attributes but also contribute to its therapeutic mechanisms. Ethnobotanical studies indicate that these compounds may provide respiratory relief and calming effects (Liu et al., 2021). Despite this potential, critical knowledge gaps persist regarding variations in volatile compositions across genotypes, which may influence both therapeutic efficacy and aromatic characteristics (Qiao et al., 2011). Traditionally, oleaster flowers have been used in the treatment of chronic bronchitis, asthma, arthritis, and cough particularly in western China and are also utilized as flavor additives in beverages and wines (Liu et al., 2021). Research conducted in Malatya, Türkiye, has examined antimicrobial and antioxidant activities in various plant parts, identifying 53 volatile compounds using advanced HS-SPME/GC-MS techniques (İncilay, 2014). Furthermore, volatile compound profiles in oleaster flowers can shift significantly throughout the flowering season, influencing the quality of derived products (Liu et al., 2021). It was hypothesized that oleaster genotypes exhibit significant differences in floral volatile compound composition and relative abundance. Furthermore, these genotypic variations were expected to be associated with differences in aromatic intensity and the presence of bioactive volatile compounds with known therapeutic relevance.

## 2. Materials and Methods

### *2.1. Materials*

This study was conducted at the Zeve Campus of Van Yüzüncü Yıl University (Van, Türkiye; approximately 38°29′ N, 43°19′ E; 1700 m), located about 15 km from the city center of Van. Fresh flowers were collected from naturally grown *Elaeagnus angustifolia* L. plants during the full flowering stage. A total of 12 genotypes were selected based on distinct morphological characteristics, including flower color, inflorescence structure, flowering density, and plant growth habit. Species identification was carried out using standard taxonomic keys, and all genotypes were confirmed as *Elaeagnus angustifolia* L. These samples were promptly transported to the Horticulture Laboratory at the

Faculty of Agriculture, Çukurova University, for immediate flavor analysis.

### *2.2. Method*

One gram of flowers was weighed and extracted for 30 min by adding 1 mL of 5 M calcium chloride solution in standard headspace glass bottles (Supelco, 75 mm × 23 mm) using a magnetic stirrer at 40 °C. Each analysis was conducted in duplicate. Volatile compounds were absorbed using a Solid Phase Micro Extraction (SPME) Fiber Assembly (85 µm CAR/PDMS Stableflex 24Ga, manual holder, 3-pack, light blue SPME needle, Supelco, Bellefonte, PA) (*Figure 1*). The adsorbed aroma compounds were analyzed with a Shimadzu GC-2010 Plus Gas Chromatography-Mass Spectrometry (GC/MS) system. An HP-Innowax Agilent column (30 m × 0.25 mm i.d., 0.25 µm thickness) was used, with helium as the carrier gas. The GC oven was programmed to start at 40 °C and gradually increased to 260 °C at a rate of 5 °C/min, then held constant at 260 °C for 30 minutes. The injector temperature was set at 250 °C, and the mass spectrometer operated at 70 eV, scanning within the m/z range of 30–400. The volatile compounds were identified by comparing their mass spectra with those in the Wiley, NIST, and Flavor GC–MS libraries, and by comparing their linear retention index (LRI) values with those reported in the literature. No authentic standards were injected for confirmation (*Figure 1*). The relative of each volatile compound was calculated as the percentage of its peak area relative to the total peak area of all detected compounds in the GC–MS chromatogram (Kafkas et al., 2005).

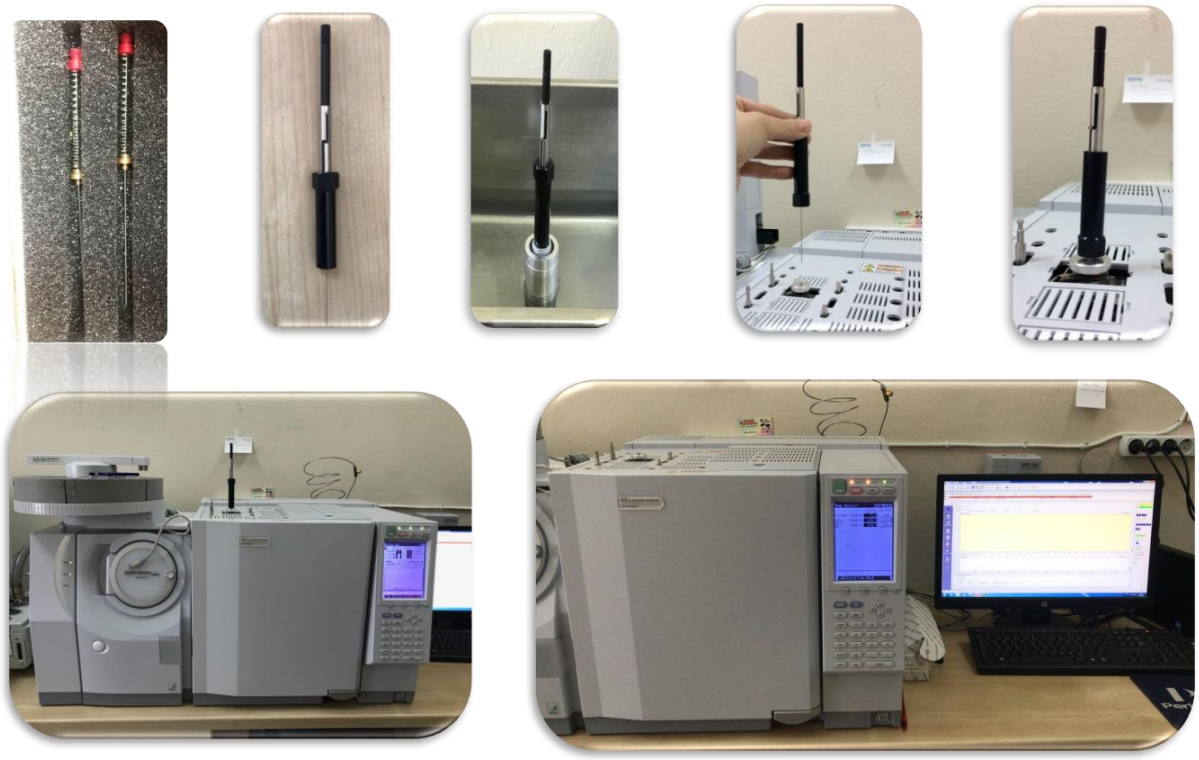

***Figure 1. Gas chromatography–mass spectrometry (GC–MS) system equipped with a solid-phase microextraction (SPME) fiber used for the analysis of volatile fragrance compounds in oleaster (Elaeagnus angustifolia L.) flowers. Volatile compound analysis was performed following the method described by Kafkas et al. (2005)***

### *2.3 Statistical analyses*

Calculating sample size for the survey: In a previous study (Yiğit et al., 2015), the rate of identification of the scent of oleaster was indicated as 12%. In relation to this identification rate, the sample size for the survey was calculated using the 12% identification or Oleaster fragnance likes. With a 95% confidence level or 5% type I error (Z value for 5% type error is 1.96), the effect size (d) was considered as 9%, and the sample size was calculated using the equation "$n = Z^2p(1\text{-}p)/d^2$". Accordingly, the minimum sample size was found ($n = 1.96^2$ x

0.12 x 0.88)/$0.09^2$ = 50). Considering the possibility of 8% losses during the survey process, the survey was conducted on 54 people.

Descriptive statistics for continuous variables are given as Mean ± Standard error, while for categorical variables, they are presented as count and percentage. For performing Multiple Correspondence Analysis, age of individuals was categorized into 2 groups. Then Multiple Correspondence Analysis was conducted to determine the relationship between age, education level, and gender with the questions. Thus, the configurations of variables categories were presented a two-dimensional space.

Peak areas/concentrations of volatile compounds were organized by genotype, with not determined "nd" values excluded. Due to positive skewness, concentrations were log10-transformed (log10(concentration + 0.001)) before analysis. Non detected (nd) observation were ignored completely in statistical analyses. Then One-way ANOVA or Kruskal-Wallis test was performed to compare genotypes. P-values from multiple tests were adjusted using the Benjamini–Hochberg method, and compounds with adjusted $p< 0.05$ were considered significantly different among genotypes. Significant compounds were visualized with boxplots, and a log-transformed Genotype × Compound matrix was used to generate a heatmap for overall aroma profile comparison. All data processing, statistical analyses, and visualizations were performed in SPSS (ver: 25) and Python (pandas, numpy, statsmodels, scikit-learn, matplotlib) on Google Colab.

## 3. Results and Discussion

### *3.1. Components of oleaster fragrance*

Headspace Solid Phase Micro Extraction (HS-SPME) is a widely employed method for identifying and analyzing volatile essential oils and aroma compounds, particularly when the target compounds distribute effectively on the fiber (Toci et al., 2012).

The comprehensive chemical profiling of oleaster flowers revealed a complex and diverse aromatic landscape that extends beyond mere identification of volatile compounds. Using blue SPME extraction, the major volatile groups detected in the juice included total aldehydes (4.44–59.54%), total alcohols (2.48–12.21%), total esters (17.23–189.14%), total ketones (0.10–8.18%), and total terpenes (1.04–6.67%). A total of 60 volatile compounds were tentatively identified, including six aliphatic aldehydes, two aromatic aldehydes, eight aliphatic alcohols, three aromatic alcohols, fifhteen aliphatic esters, five aromatic esters, seven ketones, seven terpenes, and seven compounds classified as others (*Table 1*). Among these, esters were the most dominant group, followed by aldehydes and ketones. These findings suggest that esters play a key role in defining the sweet and fruity notes of the oleaster flower's fragrance. For aliphatic esters, compounds such as 2-propenoic acid, 3-phenyl, ethyl ester (ethyl cinnamate), butanoic acid, 2-methyl-, ethyl ester, hexanoic acid, ethyl ester, and octanoic acid, ethyl ester were prominent in the aromatic ester category, benzoic acid, ethyl ester, benzenacetic acid, ethyl ester, and (Z)-3-phenyl-2-propenoic acid, methyl ester was the most abundant (*Table 1*). Ethyl cinnamate (Propenoic acid, 3-phenyl-ethyl ester) is an aromatic ester compound formed by the esterification of cinnamic acid with ethanol, and it occurs naturally in cinnamon, floral essential oils, and some fruits (Burdock, 2016). Due to its pleasant floral and fruity aroma, it is widely used in the food, cosmetic, and fragrance industries (Anonymous 2025a) In the food sector, ethyl cinnamate functions as a flavoring agent, enhancing the taste of confectionery, beverages, and baked products (Anonymous, 2025b). According to an assessment by the EFSA (Anonymous 2025c), the use of ethyl cinnamate in food is permitted within specific safety limits (Anonymous, 2025c).

Regarding aldehydes, the most significant compounds included (E)-2-Hexenal, Hexanal, and Acetaldehyde as aliphatic aldehydes, while Benzaldehyde was prominent among aromatic aldehydes. Aldehydes contribute fresh and green notes to the fragrance and are associated with antimicrobial and sedative properties, helping protect against infections and promoting better sleep (Farzaei et al., 2015).

For alcohols, aliphatic compounds like 1-hexanol, ethanol, and 3-methyl 1-butanol, were dominant, whereas aromatic alcohols such as Tetrahydro-2,5-dimethyl-2H-Pyranmethanol, and benzenemethanol were prevalent (*Table 1*). Alcohols are also significant antioxidants, helping protect against oxidative stress and free radical damage, while potentially offering antimicrobial effects as well (Farzaei et al., 2015; Hamidpour et al., 2017).

Ketones, such as dihydro 2(3H)-Furanone, were found in smaller amounts, but they are known for their pain management and anti-inflammatory properties, adding therapeutic value to the plant (Farzaei et al., 2015; Hamidpour

et al., 2017).

Terpenes such as l-Limonene, 3,7-dimethyl, (E)-1,3,6-Octatriene, and Styrene were also found in high amounts, contributing not only to the fragrance but also offering anti-inflammatory, antimicrobial, antioxidant, and respiratory benefits, which are useful in conditions such as asthma (Farzaei et al., 2015; Hamidpour et al., 2017).

These medicinal applications highlight the versatility of the volatile compounds in oleaster flowers, providing benefits that extend beyond their aromatic properties.The dominant ranges of specific compounds included 2-propenoic acid, 3-phenyl-ethyl ester (7.73–61.90%) for esters, hexenal (E) (2.50–56.06%) for aldehydes, ethanol (0.41–10.52%) for alcohols, 2(3H)-furanone, dihydro (1.27–7.24%) for ketones, and 3,7-dimethyl, (E)-1,3,6-Octatriene (0.51–4%) for terpenes(*Table 1*).

The intricate chemical composition of oleaster flowers suggests potential for applications beyond the traditional fragrance industry, extending to pharmaceutical and food preservation domains due to the antimicrobial and antioxidant properties of its volatile compounds (Farzaei et al., 2015; Hamidpour et al., 2017).

The findings of this study align closely with previous research. İncilay (2014), reported a total of 40 volatile compounds in oleaster flower extracts, with total volatile compound concentrations ranging between 10.304 and 19.412 µg/kg. Terpenes, such as L-limonene (6.240–13.077 µg/kg) and β-myrcene (902.5–1.767 µg/kg), constituted the majority (73.6–81.4%), while aldehydes were the second most abundant group (9.4–17.1%), with (E)-2-Hexenal being the dominant compound. Lanciotti et al., (1999), also highlighted the role of (E)-2-Hexenal in enhancing aroma and preserving color in packaged foods. Similarly, Liu et al. (2021) categorized the volatile compounds in oleaster flowers into four groups. Torbati et al. (2016) analyzed essential oils from oleaster flowers and leaves and found a total of 53 compounds in flowers and 25 in leaves, with esters being the most dominant group. The flower oils were rich in oxygenated compounds such as E-ethyl cinnamate (60.00%) and phytol (3.29%), contributing significantly to their aromatic profile. The consistent identification of esters across multiple studies underscores the significance of these compounds in defining the characteristic aroma of oleaster flowers. Moreover, the variations observed between different studies highlight the remarkable chemical diversity within the oleaster species, suggesting potential for targeted breeding or selection of genotypes with specific aromatic profiles.

### *3.1.1 Comparison of genotypes*

The analysis of volatile compounds in 12 oleaster flower genotypes revealed significant variations in their chemical composition (*Figure 2*). Esters were the dominant group across most genotypes, contributing to sweet and fruity top notes in the fragrance profiles. Genotype-8 exhibited the highest ester content (87.65%), while genotype-9 had the lowest (19.09%). Aldehydes were most abundant in genotype-3 (59.54%) and least in genotype-7 (5.35%). Alcohols were highest in genotype-11 (11.6%) and lowest in genotype-7 (2.75%). Ketones showed the highest concentration in genotype-1 (8.18%), while genotype-10 exhibited no detectable ketones. Terpenes, although less dominant overall, were highest in genotype-5 (8.18%) and lowest in genotype-9 (2.12%) (*Figure 2*).

This chemical variability not only highlights the aromatic diversity of the genotypes but also indicates their potential for medicinal applications. For example, Genotype-8, which exhibited a relatively high ester content, may be considered a potential candidate for anti-inflammatory applications, as several ester compounds have been reported to possess pain-relieving and anti-inflammatory properties in previous studies (Anonim 2025c). Genotype-3, with its high aldehyde content, could be valuable for antimicrobial and sedative formulations, while genotype-11, which exhibited the highest alcohol content, offers significant potential for antioxidant and antimicrobial products. Genotype-1, with its high concentration of ketones, may be useful for pain management products, further broadening the potential applications of oleaster in the pharmaceutical and healthcare sectors.

The pronounced chemical variability among genotypes offers promising opportunities for targeted selection and breeding programs aimed at developing cultivars with optimized aromatic profiles tailored to specific industrial or medicinal needs. Esters emerged as the predominant group of volatile compounds, imparting sweet and fruity characteristics to the fragrance. Meanwhile, aldehydes and terpenes, though present in smaller quantities, contributed to the complexity and persistence of the aroma. This diversity highlights the potential for further exploration of genotypes with unique aromatic and medicinal profiles, providing opportunities for expanding the use of oleaster in fragrance, food, and pharmaceutical industries.

***Table 1. Fragrance compounds and their concentrations in oleaster (Elaeagnus angustifolia* L.*) flowers from Van***

| R.time | Linear Retention Index | Compounds | Gen -1 | Gen -2 | Gen -3 | Gen -4 | Gen -5 | Gen-6 | Gen-7 | Gen -8 | Gen -9 | Gen -10 | Gen -11 | Gen -12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Aldehyde(-al)** | | | | | | | | | | | | |
| | | **Aliphatic Aldehydes** | | | | | | | | | | | | |
| 0.362 | 668 | 2-methyl Propanal | nd | nd | 0.23±0.00 | 2.72±0.32 | nd | 0.11±0.00 | 0.97±0.00 | nd | nd | nd | nd | 0.29±0.00 |
| 0.435 | 794 | 3-methyl Butanal | nd | 0.37±0.00 | 0.99±0.00 | nd | 0.43±0.00 | 0.12±0.00 | 0.85±0.00 | nd | 0.03±0.00 | 0.18±0.00 | nd | 0.36±0.00 |
| 0.798 | 612 | Acetaldehyde | nd | 1.12±0.20 | 0.76±0.00 | 0.25±0.00 | 0.65±0.00 | 0.42±0.00 | nd | nd | 0.07±0.00 | 0.11±0.00 | 0.84±0.00 | 0.56±0.00 |
| 1.335 | 786 | 2-methyl Butanal | nd | 0.55±0.00 | nd | nd | 0.64±0.00 | 0.09±0.00 | 0.71±0.00 | nd | 0.03±0.00 | 0.03±0.00 | nd | nd |
| 3.066 | 972 | Hexanal | 0.70±0.00 | 2.40±1.00 | 1.31±0.00 | 0.62±0.00 | 0.40±0.00 | 0.25±0.00 | nd | 0.10±0.00 | 0.22±0.00 | 0.56±0.00 | 0.21±0.00 | 0.25±0.00 |
| 5.412 | 1110 | (E)-2-Hexenal | 41.84±2.20 | nd | 56.06±3.21 | 22.52±3.30 | 17.72±1.32 | 11.69±3.34 | 2.50±0.92 | 5.36±1.90 | 9.77±3.63 | 34.30±2.00 | 6.55±2.09 | 6.78±1.05 |
| | | **Aromatic Aldehydes** | | | | | | | | | | | | |
| 13.219 | 1411 | Benzaldehyde | nd | nd | 0.19±0.00 | 0.16±0.00 | 0.29±0.00 | 0.24±0.00 | 0.32±0.00 | 0.11±0.00 | 0.13±0.00 | nd | 0.34±0.00 | nd |
| 16.178 | 1533 | Benzeneacetaldehyde | nd | nd | nd | 0.68±0.00 | nd | 0.51±0.00 | nd | nd | nd | nd | 1.14±0.00 | nd |
| | | **Total Aldehydes** | **42.54** | **4.44** | **59.54** | **26.95** | **20.13** | **13.43** | **5.35** | **5.57** | **10.25** | **35.18** | **9.08** | **8.24** |
| | | **Alcohol(-ol)** | | | | | | | | | | | | |
| | | **Aliphatic Alcohols** | | | | | | | | | | | | |
| 0.920 | 652 | 4-Penten-2-ol | nd | nd | nd | nd | nd | nd | 0.77±0.00 | nd | nd | 0.06±0.00 | nd | nd |
| 1.472 | 812 | Ethanol | 2.36±1.10 | 5.08±1.73 | 0.51±0.00 | 0.41±0.00 | 1.11±0.00 | 0.47±0.00 | 1.83±0.00 | 2.09±0.00 | 0.62±0.00 | 1.39±0.00 | 10.52± | 9.41±1.46 |
| 2.095 | 901 | Ethyl Pentanol | 0.20±0.00 | nd | 0.26±0.00 | 0.14±0.00 | nd | nd | nd | nd | 0.05±0.00 | 0.09±0.00 | nd | nd |
| 5.609 | 1106 | 3-methyl, 1-Butanol | 0.31±0.00 | nd | 1.16±0.07 | 0.32±0.00 | 0.61±0.00 | 0.09±0.00 | 1.02±0.00 | nd | nd | nd | nd | nd |
| 9.217 | 1253 | 1-Hexanol | nd | nd | 0.67±0.00 | 0.23±0.00 | 0.25±0.00 | 0.10±0.00 | nd | nd | 0.06±0.00 | 0.22±0.00 | nd | 0.19±0.00 |
| 10.506 | 1304 | (E)- 2-Hexen-1-ol | 0.35±0.00 | nd | 0.77±0.00 | 0.49±0.00 | 1.76±0.00 | 2.00±0.30 | nd | 0.28±0.00 | 1.52±0.00 | nd | 0.37±0.00 | 0.68±0.00 |
| 10.578 | 1307 | (Z)- 2-Hexen-1-ol | 3.90±0.30 | 2.13±0.44 | 8.20±1.05 | 3.19±0.00 | nd | 0.16±0.00 | 0.87±0.00 | nd | nd | 6.36±1.60 | nd | nd |
| 11.387 | 1309 | 1-Dodecanol | nd | nd | nd | nd | 0.60±0.00 | nd | 0.59±0.00 | nd | nd | nd | 0.56±0.00 | nd |
| | | **Aromatic Alcohols** | | | | | | | | | | | | |
| 10.411 | 1300 | Tetrahydro-2,5-dimethyl-2H-Pyranmethanol | 0.19±0.00 | 0.13±0.00 | 0.33±0.00 | 0.20±0.00 | 0.24±0.00 | | 0.88±0.00 | 0.13±0.00 | nd | nd | nd | nd |
| 21.563 | 1772 | Benzenemethanol | 0.79±0.00 | 0.46±0.00 | 0.31±0.00 | 0.22±0.00 | 0.63±0.00 | 0.44±0.00 | 1.33±0.00 | 0.15±0.00 | 0.17±0.00 | 0.16±0.00 | nd | nd |
| 22.234 | 1803 | Benzeneethanol | nd | nd | nd | nd | nd | nd | 1.34±0.00 | 0.10±0.00 | 0.06±0.00 | nd | 0.15±0.00 | nd |
| | | **Total Alcohols** | **8.10** | **7.80** | **12.21** | **5.20** | **5.22** | **3.26** | **8.63** | **2.75** | **2.48** | **8.28** | **11.6** | **10.28** |
| | | **Ester(-ate)** | | | | | | | | | | | | |
| | | **Aliphatic Esters** | | | | | | | | | | | | |
| 2.023 | 940 | Butanoic acid, 2-methyl- ethyl ester | 2.55±0.32 | 1.32±0.05 | 0.96±0.00 | 0.97±0.00 | 0.24±0.00 | 0.16±0.00 | 4.26±0.00 | 0.15±0.00 | 0.54±0.00 | 0.77±0.00 | 1.08±0.00 | 1.37±0.00 |
| 2.430 | 925 | Butanoic acid, ethyl ester | 0.38±0.00 | 11.56±0.00 | nd | 6.33±0.64 | nd | nd | 0.30±0.00 | 0.060.00 | 0.11±0.00 | nd | 0.21±0.00 | 0.18±0.00 |
| 2.433 | 926 | Butyrate 3-hydroxy- ethyl | nd | 0.12±0.00 | nd | 0.59±0.00 | 0.18±0.00 | nd | 0.34±0.00 | nd | nd | nd | 0.29±0.00 | nd |
| 5.100 | 1082 | Hexanoic acid, methyl ester | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | 0.22±0.00 |
| 5.181 | 1130 | Hexanoic acid, ethyl ester | 8.55±±1.22 | 1.57±±0.03 | 0.46±±0.00 | 0.59±±0.00 | 1.50±0.00 | 0.94±0.00 | 2.90±0.62 | 2.31±0.00 | 2.99±0.00 | nd | 6.24±1.30 | 14.06±0.00 |

***Table 1. Continued***

| R.time | Linear Retention Index | Compounds | Gen -1 | Gen -2 | Gen -3 | Gen -4 | Gen -5 | Gen-6 | Gen-7 | Gen -8 | Gen -9 | Gen -10 | Gen -11 | Gen -12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Ester(-ate)** | | | | | | | | | | | | |
| | | **Aliphatic Esters** | | | | | | | | | | | | |
| 7.814 | 1199 | 4D-methyl hexanoic acid ethyl ester | 1.10±0.00 | 1.08±0.00 | nd | 0.55±0.00 | 0.68±0.00 | 0.37±0.00 | nd | nd | 0.20±0.00 | 0.75±0.00 | nd | nd |
| 8.635 | 1231 | Heptanoic acid, ethyl ester | 0.50±0.00 | nd | nd | nd | nd | nd | nd | 0.17±0.00 | 0.07±0.00 | 1.57±0.00 | 1.27±0.04 | 0.79±0.00 |
| 11.185 | 1331 | Octanoic acid, ethyl ester | 2.14±0.21 | 0.73±0.00 | nd | 0.29±0.04 | 0.46±0.00 | 0.52±0.00 | 0.56±0.00 | 0.39±0.00 | 0.68±0.00 | 0.68±0.00 | 7.31±0.56 | 6.97±0.28 |
| 12.222 | 1372 | Ethyl cis-4-octenoate | 5.68±1.21 | 1.59±0.00 | 0.54±0.00 | nd | 1.12±0.15 | 0.40±0.00 | nd | 2.12±0.00 | 0.79±0.00 | 0.97±0.00 | 4.44±0.32 | 4.23±0.11 |
| 16.839 | 1562 | Ethyl E-4-decenoate | 0.78±0.02 | nd | nd | 0.38±0.01 | nd | 0.27±0.00 | nd | nd | nd | nd | 1.77±0.00 | 4.49±0.23 |
| 18.253 | 1622 | Methyl decadienoate | nd | 0.43±0.00 | nd | 0.16±0.00 | nd | 0.23±0.00 | 0.38±0.00 | 0.28 | 0.15±0.00 | 0.29±0.00 | 4.06±0.85 | 3.78±0.31 |
| 26.410 | 2010 | 1-methylethyl E-3-phenyl-2-propenoate | nd | 0.31±0.00 | 0.57±0.02 | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| 26.499 | 2015 | 2-Propenoic acid, 3-phenyl- ethyl ester | 7.73±1.36 | 55.49±2.54 | 11.90±2.01 | 45.96±2.62 | 38.72±3.70 | 61.90±2.46 | 38.09±1.75 | 40.19±2.30 | 46.82±3.22 | 37.87±2.30 | 36.02±3.04 | 21.17±0.32 |
| 28.288 | 2108 | Isobutylcinnammate | nd | 0.48±0.00 | nd | 0.45±0.00 | nd | 0.50±0.00 | nd | 0.22±0.00 | 0.36±0.00 | 0.19±0.00 | nd | nd |
| 40.616 | 2712 | Hexanedioic acid, dioctyl ester | 0.48±0.00 | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| | | **Aromatic Esters** | | | | | | | | | | | | |
| 15.626 | 1510 | Benzoic acid, methyl ester | nd | nd | nd | nd | 1.25±0.00 | 0.55±0.60 | 2.72±0.30 | 1.89±0.00 | 1.10±0.00 | nd | 0.35±0.00 | 0.52±0.00 |
| 16.682 | 1555 | Benzoic acid, ethyl ester | 3.22±0.42 | nd | 2.15±0.04 | nd | 19.08±1.64 | 11.05±3.06 | 21.62±1.12 | 39.15±2.30 | 29.39±2.63 | 5.78±0.30 | 9.80±0.82 | 11.26±0.03 |
| 18.730 | 1644 | Benzoic acid, pentyl ester | nd | nd | nd | nd | nd | nd | nd | 0.16±0.00 | 0.53±0.00 | nd | nd | nd |
| 19.530 | 1679 | Benzeneacetic acid, ethyl ester | 0.85±0.05 | 0.57±0.01 | 0.44±0.00 | 1.46±0.00 | 0.22±0.00 | 0.74±0.00 | 0.63±0.06 | 1.10±0.00 | 0.73±0.00 | 1.16±0.05 | 3.36±0.24 | 3.24±0.30 |
| 25.438 | 1960 | (Z)-3-Phenyl-2-propenoic acid, methyl ester | 2.48±0.12 | 1.04±0.00 | 0.21±0.00 | 2.53±0.20 | 1.21±0.00 | 1.60±0.00 | 1.82±0.00 | 0.95±0.00 | 0.59±0.00 | 0.89±0.00 | 0.52±0.00 | 3.93±0.20 |
| | | **Total Esters** | **36.44** | **75.29** | **17.23** | **60.16** | **64.66** | **79.23** | **73.62** | **89.14** | **85.05** | **50.92** | **76.72** | **76.21** |
| | | **Keton(-one)** | | | | | | | | | | | | |
| 0.983 | 672 | 2-Propanone | nd | 0.40±0.00 | nd | nd | nd | nd | nd | 0.08±0.00 | nd | nd | nd | nd |
| 7.353 | 1179 | 3-hydroxy-2-Butanone | nd | 0.21±0.00 | nd | nd | 0.25±0.00 | nd | nd | 0.06±0.00 | nd | nd | 0.16±0.00 | nd |
| 7.838 | 1199 | 4-Isobutoxy-2-butanone | nd | nd | nd | nd | nd | nd | 2.36±0.10 | 0.07±0.00 | nd | nd | nd | 0.38±0.00 |
| 8.064 | 1208 | 2-(1,1-dimethylethyl)-5-methyl-(2s-cis)1,3-Dioxan-4-one, | nd | nd | 0.27±0.00 | nd | nd | nd | nd | nd | 0.10±0.00 | nd | nd | nd |
| 8.554 | 1227 | 2,3-Octanedione | nd | nd | 0.46±0.00 | 0.52±0.00 | 0.18±0.00 | 0.10±0.00 | nd | 0.07±0.00 | 0.10±0.00 | 0.56±0.00 | nd | nd |
| 15.703 | 1513 | dihydro 2(3H)-Furanone, | 7.24±3.60 | 6.13±1.07 | 3.03±0.42 | 1.27±0.00 | 1.46±0.06 | nd | nd | nd | nd | nd | nd | nd |
| 27.353 | 2059 | 2-methyl-2-Hepten-4-one | 0.94±0.01 | nd | nd | nd | nd | nd | 0.32±0.00 | nd | nd | nd | nd | nd |
| | | **Total Ketones** | **8.18** | **6.74** | **3.76** | **1.79** | **1.89** | **0.10** | **2.68** | **0.28** | **0.20** | **0.56** | **0.16** | **0.38** |

***Table 1. Continued***

| R.time | R. Index | Compounds | Gen -1 | Gen -2 | Gen -3 | Gen -4 | Gen -5 | Gen -6 | Gen -7 | Gen -8 | Gen -9 | Gen -10 | Gen -11 | Gen -12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Terpen(ene-ane)** | | | | | | | | | | | | |
| | | **Monoterpenes** | | | | | | | | | | | | |
| 5.160 | 1084 | l-Limonene | nd | 0.28±0.00 | 0.48±0.00 | nd | 0.58±0.00 | nd | nd | 0.14±0.00 | nd | nd | nd | nd |
| 6.583 | 1147 | 3,7-dimethyl, (E)-1,3,6-Octatriene | 2.04±0.15 | 2.76±0.30 | 3.23±0.00 | 3.65±0.00 | 4±0.20 | 2.21±0.00 | 3.71±0.23 | 0.51±0.00 | 0.61±0.01 | 1.95±0.04 | 1.27±0.00 | 2.16±0.10 |
| 6.644 | 1149 | Styrene | 0.76±0.06 | 1.30±0.00 | 1.69±0.00 | 1.39±0.00 | 1.28±0.03 | 0.55±0.00 | 2.96±0.31 | 0.39±0.00 | 0.91±0.01 | 1.29±0.01 | 0.85±0.00 | 1.06±0.00 |
| 11.375 | 1338 | (Z)-3-Hexadecene, | 0.34±0.00 | 0.56±0.00 | nd | nd | nd | 0.30±0.00 | nd | nd | nd | nd | nd | nd |
| 11.390 | 1339 | 1-Tridecene | nd | nd | 0.39±0.00 | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| 16.345 | 1540 | 1-Hexadecene | nd | nd | nd | nd | nd | 0.12±0.00 | nd | nd | nd | nd | nd | nd |
| 22.981 | 1839 | Neophytadiene | nd | nd | nd | nd | nd | 0.10±0.00 | nd | nd | nd | nd | nd | nd |
| | | **Total Terpenes** | **3.14** | **4.90** | **5.79** | **5.04** | **5.86** | **3.28** | **6.67** | **1.04** | **1.52** | **3.24** | **2.12** | **3.22** |
| | | **Others Compunds** | | | | | | | | | | | | |
| 0.858 | 632 | Methane, thiobis | 1.38±0.00 | 0.31±0.00 | 0.94±0.00 | 0.39±0.00 | 1.34±0.04 | 0.34±0.00 | 1.95±0.00 | nd | nd | nd | 0.11±0.00 | 0.45±0.00 |
| 5.305 | 1092 | Hendecane | nd | nd | nd | nd | 0.28±0.00 | nd | nd | nd | nd | nd | nd | nd |
| 5.310 | 1092 | Dodecane | nd | nd | nd | nd | nd | nd | nd | nd | nd | 0.53±0.01 | nd | 0.65±0.06 |
| 10.261 | 1294 | Tridecane | 0.22±0.00 | 0.17±0.00 | 0.39±0.00 | 0.20±0.00 | 0.25±0.00 | 0.18±0.00 | 0.43±0.00 | 0.25±0.00 | 0.14±0.00 | nd | nd | nd |
| 10.261 | 1294 | Tetradecane | nd | nd | nd | 0.20±0.00 | nd | nd | 0.65±0.00 | nd | nd | nd | nd | 0.57±0.02 |
| 12.774 | 1394 | Pentadecane | nd | nd | nd | nd | nd | nd | nd | nd | nd | 0.14±0.00 | 0.19±0.00 | nd |
| 13.272 | 1294 | Octadecane | nd | nd | nd | nd | nd | nd | nd | nd | nd | 0.75±0.00 | nd | nd |
| | | **Total** | **1.60** | **0.48** | **1.33** | **0.79** | **1.87** | **0.52** | **3.03** | **0.25** | **0.14** | **1.42** | **0.3** | **1.67** |

nd: not detected
Gen: Genotype

The x-axis represents the twelve different *Elaeagnus angustifolia* L. genotypes analyzed in the study. Each genotype corresponds to a distinct plant material sampled and evaluated separately for its volatile compound composition (*Figure 2*). The y-axis indicates the relative proportion (%) of volatile compound groups obtained from GC–MS analysis. Values represent the percentage contribution of each chemical group (aldehydes, alcohols, esters, ketones, and terpenes) to the total volatile composition within each genotype. The total composition for each genotype sums to 100% (*Figure 2*).

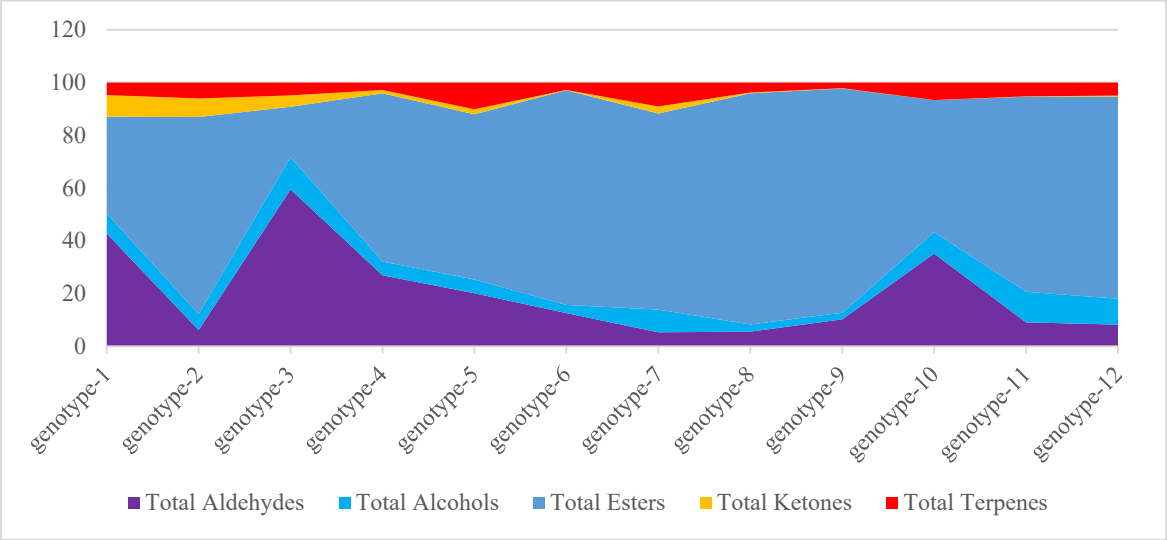


***Figure 2. Relative distribution (%) of volatile compound groups (aldehydes, alcohols, esters, ketones, and terpenes) among the studied genotypes (Genotype-1–Genotype-12). The x-axis represents genotypes and the y-axis shows the percentage contribution of each compound group to the total volatile profile***

### *3.1.2 Principal component analysis (PCA)*

The PCA analysis revealed a clear variation among oleaster flower genotypes based on their volatile compound composition. The first two principal components accounted for 53.3% of the total variance (PC1: 32.8%, PC2: 20.5%). Genotype 11 and Genotype 12 were clearly separated from the other genotypes along the PC1 axis. This separation was mainly associated with the higher relative abundance of aromatic esters, such as benzoic acid ethyl ester and benzeneacetic acid ethyl ester, in these genotypes. Genotype 2 and Genotype 3 were positioned on the negative side of the PC2 axis, suggesting a volatile profile relatively enriched in aldehydes**.** Genotypes 4, 5, 6, 8, 9, and 10 clustered closely together, indicating generally similar distributions of volatile compounds. Genotype 1 and Genotype 7 occupied distinct positions in the PCA space, reflecting differences in their overall volatile composition compared with the other genotypes. These results demonstrate that volatile compound composition constitutes a discriminative feature among oleaster flower genotypes (*Figure 3*).

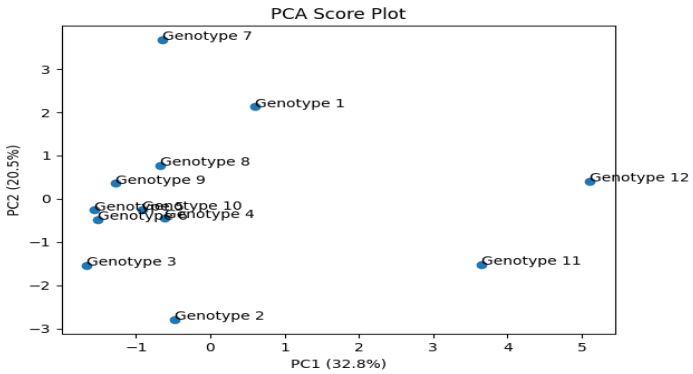


***Figure 3. Principal Component Analysis (PCA) biplot illustrating the distribution of (Elaeagnus angustifolia* L.*) Genotypes from based***

### *3.1.3 Correlation of genotypes volatile compounds*

The heatmap analysis visually illustrated the distribution patterns of individual volatile compounds across genotypes and supported the PCA findings. (E)-2-Hexenal exhibited high relative abundance particularly in Genotype 1 and Genotype 3. 2-Propenoic acid, 3-phenyl-ethyl ester was the dominant compound in several genotypes (Genotypes 2, 4, 6, 8, 9, and 10), indicating its strong contribution to genotype differentiation. Hexanoic acid ethyl ester and octanoic acid ethyl ester were notably concentrated in Genotype 11 and Genotype 12. While aliphatic aldehydes and alcohols occurred at relatively low levels in some genotypes, aromatic esters were predominant in specific genotypes (*Figure 4*). Overall, these distribution patterns indicate quantitative differences in volatile compound composition among genotypes, which can be effectively resolved using multivariate analytical approaches.

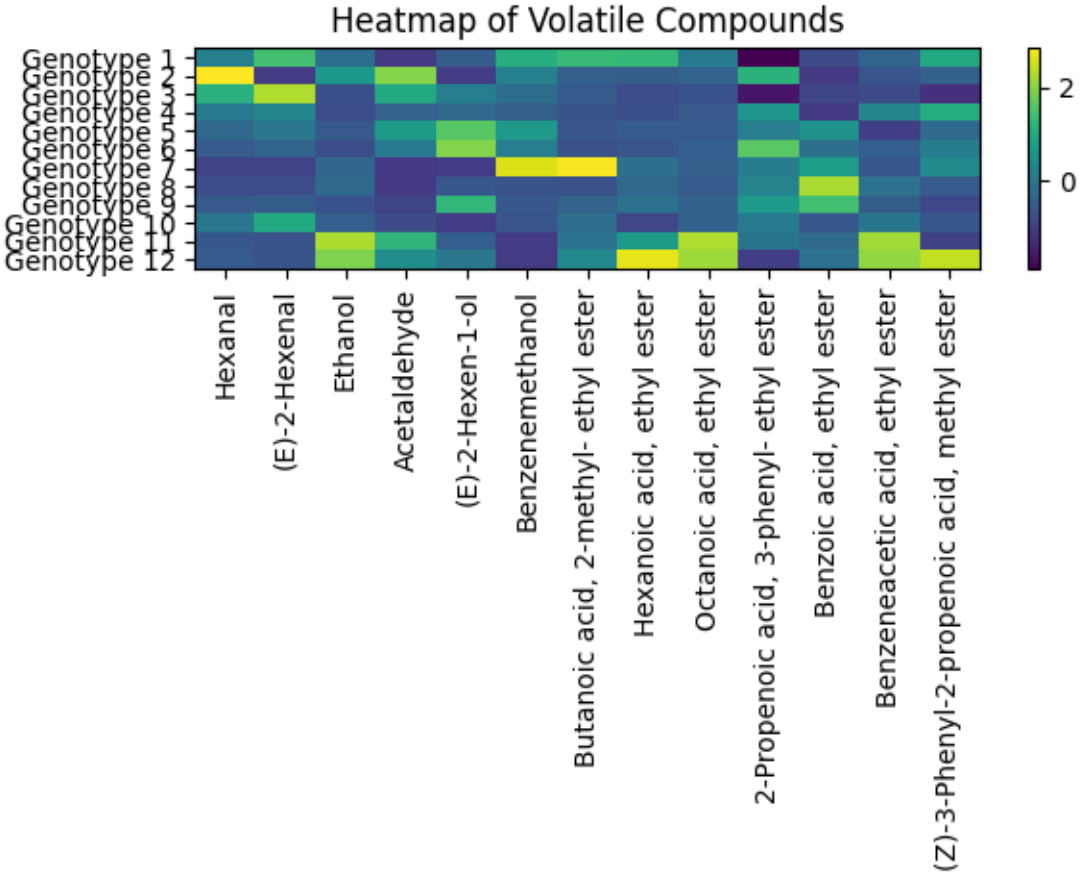


***Figure 4. Genotypes heatmap distribution volatile compounds according to cluster analysis***

### *3.2. Oleaster fragrance likes survey results*

The survey questions were designed to evaluate the perception, familiarity, and cultural memory of oleaster (*Elaeagnus angustifolia* L) fragrance among local residents, rather than the immediate sensory evaluation of fresh flowers or extracted essential oils. Since oleaster has been cultivated in the region for many years, participants assessed the fragrance based on their previous experiences and memory. Therefore, the responses reflect perceptual and associative judgments rather than direct olfactory measurements. Accordingly, the responses obtained from the questionnaire aimed to determine the place of oleaster fragrance in public memory, the level of satisfaction, and its potential areas of use are presented below.

### *3.2.1 Socio-demographic characteristics of participants*

The numbers and percentages for the demographic characteristics of age, gender and educational status are given in *Table 2*, while the numbers and percentages for each question are given in *Table 2*. As seen in *Table 2*. 46% of the 54 respondents were female and 53.7% were male. While 87% of these individuals were under 35 years of age, 13% were over 35 years of age. In terms of education level, 51.9% were university graduates, while 24.1% were middle and high school graduates.

***Table 2. Count and percent for demographic characteristics***

| **Gender** | n (%) | **Age** | n (%) | **Education** | n (%) |
|---|---|---|---|---|---|
| Female | 25 (46.3) | 18-35 | 47 (87.0) | Secondary | 13 (24.1) |
| Male | 29 (53.7) | 35> | 7 (13.0) | College | 13 (24.1) |
| Total | 54 (100.0) | Total | 54 (100.0) | University | 28 (51.9) |

When *Table 3* was evaluated based on the first question, "How much do you like the scent of oleaster flowers?", 5.6% of the participants reported that they did not like it at all, while 7.4% indicated that they liked it only slightly. The majority of respondents expressed positive attitudes toward the fragrance, with 38.9% selecting "I like it" and 38.9% selecting "I like it a lot." Additionally, 9.3% of the participants chose the neutral option.

These results indicate that more than three-quarters of the participants perceived the fragrance positively, demonstrating a generally favorable public perception of *E. angustifolia* scent. The second question asked to the participants was "Where do you prefer to use the oleaster fragrance?" and 14.8% of the participants stated that they preferred it as a perfume, 31.5% as a room fragrance, 16.7% as a candle and car fragrance, and 20.4% as a store fragrance. The third question was asked to the participants: "Where would you like the oleaster fragrance to be used?" and 29.6% of the participants preferred it to be used in parks, 33.3% in streets or avenues, 14.8% in homes, 18.5% on roads, while 3.7% did not express any opinion.

***Table 3. Count and percent for the questions***

| **Questions 1** | n (%) | **Questions 2** | n (%) | **Questions 3** | n (%) | **Questions 4** | n (%) | **Questions 5** | n (%) |
|---|---|---|---|---|---|---|---|---|---|
| I don't like it at all | 3 (5.6) | As perfume scent | 8 (14.8) | Park | 16 (29.6) | Peace | 23 (42.6) | Picnics | 14 (25.9) |
| I like it a little bit | 4 (7.4) | As room scent | 17 (31.5) | On the streets | 18 (33.3) | Nostalgia | 15 (27.8) | Family visits | 5 (9.3) |
| I like it | 21 (38.9) | As candle scent | 9 (16.7) | At homes | 8 (14.8) | Happiness | 5 (9.3) | Childhood memories | 9 (16.7) |
| I like it a lot | 21 (38.9) | Araba | 9 (16.7) | On the roads | 10 (18.5) | Sadness | 1 (1.9) | My hometown | 9 (16.7) |
| Undecided | 5 (9.3) | In stores | 11 (20.4) | No idea | 2 (3.7) | Longing | 5 (9.3) | Night walks | 12(22.2) |
| Total | 54 (100.0) | Total | 54 (100.0) | Total | 54 (100.0) | No idea | 5 (9.3) | No idea | 5 (9.3) |

***Table 4. Brief results of multiple correspondence analysis for q1 and demographic characteristics***

| **Model Summary** | | | | |
|---|---|---|---|---|
| Dimension | Cronbach's Alpha | Variance Accounted For | | |
| | | Total (Eigenvalue) | Inertia | % of Variance |
| 1 | 0.485 | 1.572 | 0.393 | 39.297 |
| 2 | 0.232 | 1.211 | 0.303 | 30.268 |
| Total | | 2.783 | 0.696 | |
| Mean | 0.375 | 1.391 | 0.348 | 34.783 |

The fourth question asked the participants was "What feelings does the smell of oleaster take you to?" 42.6% of the participants responded with peace, 27.8% with nostalgia, 9.3% with happiness and longing, 1.9% with sadness or grief, and 9.3% with no opinion. Finally, the fifth question asked, "What are the best memories with the smell of oleaster?" 25.9% of the participants responded with picnics, 9.3% with family visits, and 22.2% with night walks. While 16.7% responded with childhood memories and hometown, 9.3% with no opinion.

Multiple correspondence analysis was conducted to determine the relationship between the three demographic characteristics, “age”, “education” and “gender”, and the five questions separately. The summary results of the analysis conducted with the first question are given in *Table 4*. As seen in *Table 4*, the first dimension explained 39.3% of the total inertia or variance, the second dimension explained 30.3%, and the two dimensions together explained 69.6% of the total inertia (variance).

It represents the basic dimensions explaining the liking of the participants participating in the survey about the "oleaster fragrance " with 69.6%. The explanation rate of demographic groups and the configuration of the categories in two-dimensional space are given in *Figure 5*. As seen in *Figure 5*; while the female participants who are high school and university graduates over the age of 35 are positioned on the right side, which is the positive part according to the first dimension, the male participants who are secondary school graduates between the ages of 18-35 are positioned on the left side, which is the negative part according to the first dimension. Accordingly, it was observed that the female participants who are high school and university graduates over the age of 35 tend to "like it a lot" and "remain undecided" in response to the question "How much do you like the fragrance of oleaster?". In contrast, it was observed that the male participants who are secondary school graduates between the ages of 18-35 tend to "not like it at all", "like it a little" or "like it". It shows that the responses of the female participants who are high school and university graduates over the age of 35 about the oleaster fragrance are interpreted as clearly positive in the analysis. It shows that the responses of male participants aged between 18-35 who graduated from secondary school were evaluated more negatively about the oleaster fragrance.

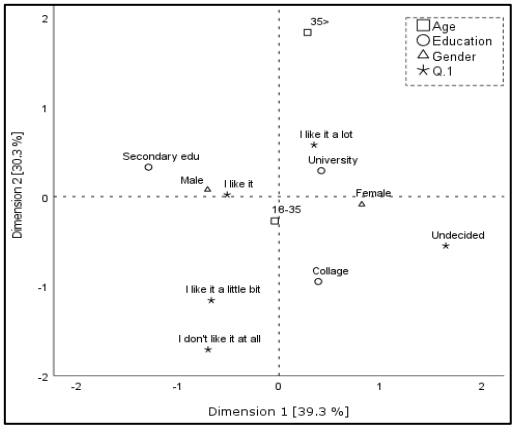


***Figure 5. Configuration of the relationship between demographic characteristics and the categories of the first question in two-dimensional space***

Similar to the relationship between the categories of features, the configuration of the relationship between the features in two-dimensional space is also given in *Figure 6*. As seen in *Figure 6*, the question “How much do you like the smell of oleaster?” was observed to be positively related to education status.

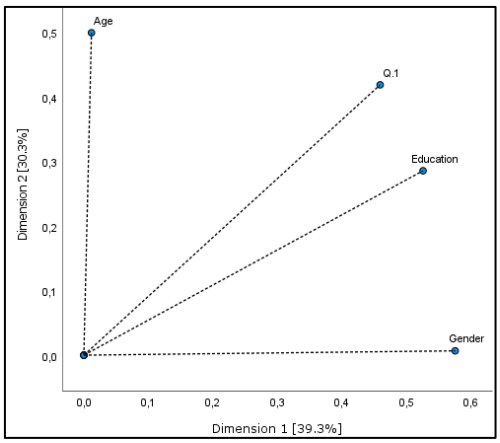


***Figure 6. Configuration of the relationship between demographic characteristics and the first question in two-dimensional space***

The summary results of the multiple correspondence analysis conducted to determine the relationship of the second question (Where do you prefer to use the smell of oleaster?) with age, education status and gender are given in *Table 5*. As seen in *Table 5*, the first dimension explained 39.8% of the total variance, while the second dimension explained 33.5%. The two dimensions together explained 73.3% of the total variance.

***Table 5. Brief results of multiple correspondence analysis for q2 and demographic characteristics***

| Model Summary | | | | |
|---|---|---|---|---|
| **Dimension** | **Cronbach's Alpha** | **Variance Accounted For** | | |
| | | **Total (Eigenvalue)** | **Inertia** | **% of Variance** |
| 1 | 0.495 | 1.591 | 0.398 | 39.767 |
| 2 | 0.338 | 1.340 | 0.335 | 33.505 |
| Total | | 2.931 | 0.733 | |
| Mean | 0.423 | 1.465 | 0.366 | 36.636 |

According to the first dimension, which explains 39.8% of the inertia (variance); male participants over the age of 35 are middle school graduates and the categories of "car" and "candle fragrance" are on the right side, which is the positive region according to the first dimension. Female participants between the ages of 18-35 are high school and university graduates and the categories of "perfume", "room" and "store" are on the left side. Accordingly, male participants over the age of 35 are secondary school graduates and they prefer oleaster fragrance more in cars and as a candle fragrance; female participants between the ages of 18-35 prefer oleaster fragrance as "store", "room" and "perfume" fragrance **(***Figure 7*).

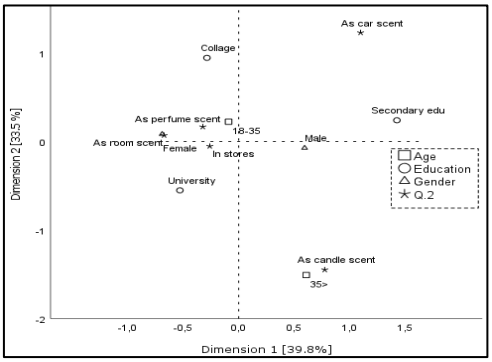


***Figure 7. Configuration of the relationship between demographic characteristics and the categories of the second question in two-dimensional space***

The two-dimensional space configuration of the relationship between the second question and age, education status and gender is given in *Figure 8*. Accordingly, similar to the first question, it was seen that the second question also has a high positive relationship with education status.

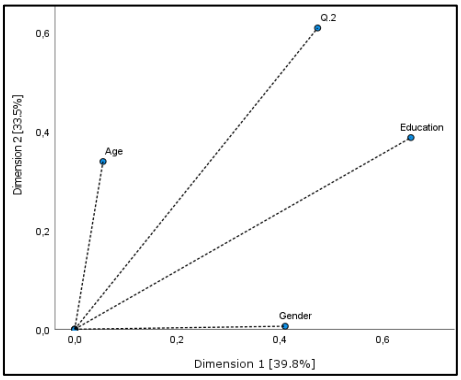


***Figure 8. Configuration of the relationship between demographic characteristics and the second question in two-dimensional space***

The summary analysis results regarding the relationship between the third question (Where would you like the fragrance of oleaster to be?) and age, gender and education status are given in *Table 6*. As seen in *Table 6*, the first dimension explained 37.2% of the total variance, the second dimension explained 30.9% and the variance explanation rate of both dimensions was 68.1%.

***Table 6. Brief results of multiple correspondence analysis for q3 and demographic characteristics***

| Model Summary | | | | |
|---|---|---|---|---|
| **Dimension** | **Cronbach's Alpha** | **Variance Accounted For** | | |
| | | **Total (Eigenvalue)** | **Inertia** | **% of Variance** |
| **1** | **0.437** | **1.487** | **0.372** | **37.179** |
| 2 | 0.253 | 1.234 | 0.309 | 30.853 |
| Total | | 2.721 | 0.680 | |
| Mean | 0.353 | 1.361 | 0.340 | 34.016 |

The categories of the third question and the configuration of gender, education status and age categories in two-dimensional space are given in *Figure 9*. Accordingly, it was observed that male participants who were secondary school graduates preferred the smell of oleaster to be more on “roads”, “parks” and “houses” and tended to be “undecided”. In contrast, female participants who were high school and university graduates tended to prefer the smell of oleaster to be more on “streets or avenues”.

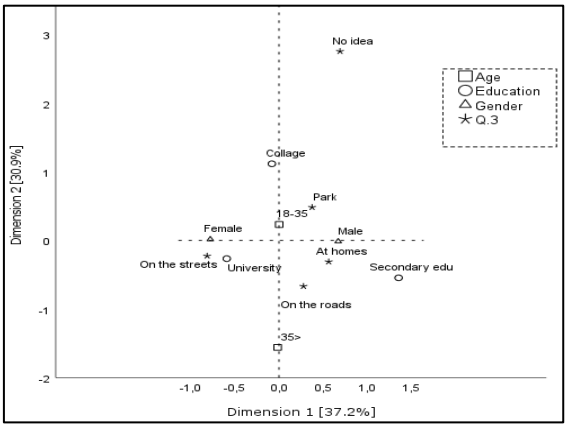


***Figure 9. Configuration of the relationship between demographic characteristics and the categories of the third question in two-dimensional space***

The relationship between the third question and gender, education status and age is given in *Figure 10*. As seen in *Figure 10*, it can be said that the third question is also closely and positively related to education status

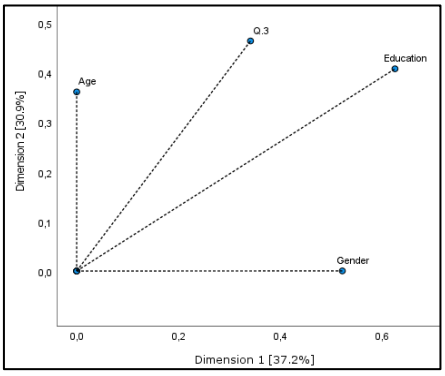


***Figure 10. Configuration of the relationship between demographic characteristics and the third question in two-dimensional space***

Summary results of the analysis for the relationships between the fourth question (What feelings does the fragrance of oleaster lead you to?) and age, gender and educational status are given in *Table 7*. In *Table 7*, the first dimension explained 42.0% of the total variance, the second dimension explained 34.9% and the variance explanation rate of its two dimensions together was 76.9%.

***Table 7. Brief results of multiple correspondence analysis for q4 and demographic characteristics***

| Model Summary | | | | |
|---|---|---|---|---|
| **Dimension** | **Cronbach's Alpha** | **Variance Accounted For** | | |
| | | **Total (Eigenvalue)** | **Inertia** | **% of Variance** |
| 1 | 0.539 | 1.679 | 0.420 | 41.966 |
| 2 | 0.378 | 1.395 | 0.349 | 34.874 |
| Total | | 3.074 | 0.768 | |
| Mean | 0.466 | 1.537 | 0.384 | 38.420 |

The two-dimensional space configuration of the categories of the fourth question and the categories of gender, education level and age are given in *Figure 11*. Accordingly, female participants who are high school and university graduates stated that the fragrance of oleaster reflects the feelings of "peace", "happiness" and "sadness" to them. In contrast, male participants who are secondary school graduates, although undecided, stated that the fragrance of oleaster reflects the feeling of "longing" to them.

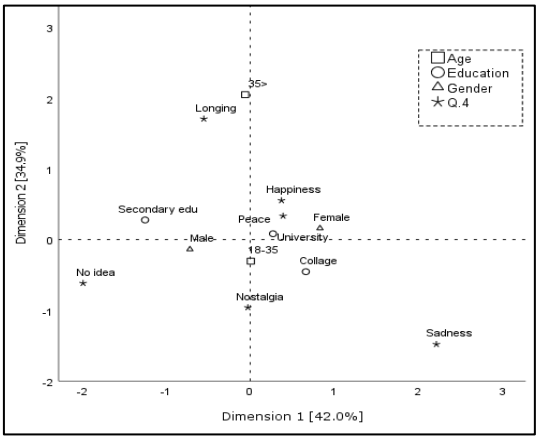


***Figure 11. Configuration of the relationship between demographic characteristics and the categories of the fourth question in two-dimensional space***

The relationship between the fourth question and gender, education level and age is given in *Figure 12*. As seen in *Figure 12*, it can be said that the fourth question is not related to demographic characteristics, but education level and gender are closely and positively related.

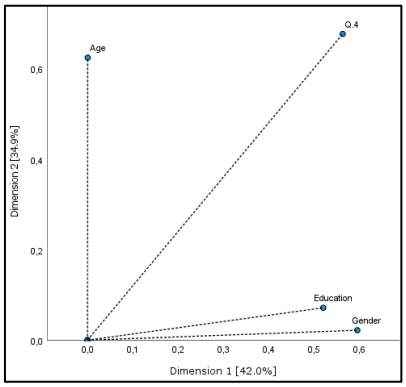


***Figure 12. Configuration of the relationship between demographic characteristics and the fourth question in two-dimensional space***

The summary analysis results regarding the relationship between the fifth question (What are your best memories of the fragrance of oleaster?) and age, gender and education level are given in *Table 8*. As seen in *Table 8*, the first dimension explained 45.5% of the total variance, the second dimension explained 38.0% and the variance explanation rate of both dimensions together was 83.5%.

***Table 8. Brief results of multiple correspondence analysis for Q5 and demographic characteristics***

| Model Summary | | | | |
|---|---|---|---|---|
| **Dimension** | **Cronbach's Alpha** | **Variance Accounted For** | | |
| | | **Total (Eigenvalue)** | **Inertia** | **% of Variance** |
| 1 | 0.600 | 1.818 | 0.455 | 45.458 |
| 2 | 0.455 | 1.519 | 0.380 | 37.968 |
| Total | | 3.337 | 0.834 | |
| Mean | 0.534 | 1.669 | 0.417 | 41.713 |

The categories of the fifth question and the two-dimensional space configuration of gender, education status and age categories are given in *Figure 13*. Accordingly, female participants aged 18-35, who are high school and university graduates, stated that their best memories related to the smell of oleaster are "picnics" and "night walks". In contrast, male participants aged over 35 and secondary school graduates were undecided, but their best memories related to the fragrance of oleaster are "family visits" and "childhood memories".

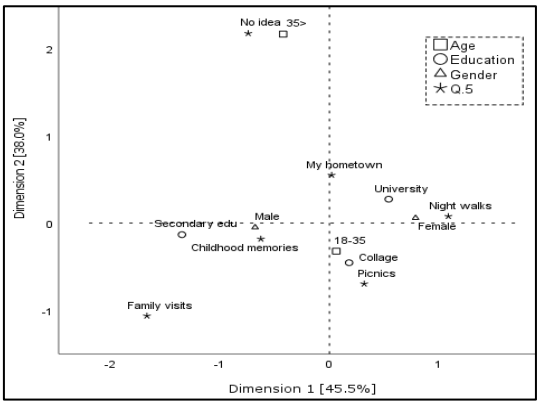


***Figure 13. Configuration of the relationship between demographic characteristics and the fifth question in two-dimensional space***

The relationship between the fifth question and gender, education status and age are given in *Figure 14*. As seen in *Figure 14*, it can be said that, similar to the fourth question, the fifth question is not related to demographic characteristics, but education status and gender are closely and positively related.

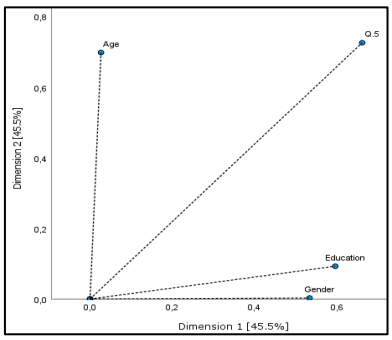


***Figure 14. Configuration of the relationship between demographic characteristics and the fifth question in two-dimensional space***

## 4. Conclusions

This study demonstrated considerable variation in the volatile compound composition of *Elaeagnus angustifolia* genotypes. Esters, aldehydes, alcohols, terpenes, and ketones were identified as the main chemical groups contributing to the aromatic profiles, with their relative proportions differing markedly among genotypes. Genotypes 1, 3, 4, and 10 showed more balanced distributions of these compound classes, whereas genotypes 2, 5, 6, 7, 8, 9, 11, and 12 were characterized by higher proportions of specific dominant groups, particularly esters and terpenes. These compositional differences indicate substantial aromatic diversity and suggest that certain genotypes may be preferable for specific fragrance-related or landscape applications. However, interpretations regarding fragrance persistence, sensory intensity, or biological and therapeutic effects require further investigation supported by sensory evaluation and bioactivity assays. Overall, the findings provide a chemical basis for the selection and breeding of *E. angustifolia* genotypes with distinct aromatic characteristics and contribute to the sustainable utilization of this species in landscape and fragrance-oriented applications.

### Ethical Statement

The survey conducted as part of the study was completed with 54 participants who participated on a voluntary basis.

### Conflicts of Interest

The authors state that they do not have any conflict of interest

### Authorship Contribution Statement

Concept: Alp, Ş.; Design: Polat, Y.; Data Collection or Processing: Polat, Y.; Statistical Analyses: Keskin, S.; Literature Search: Kafkas, N. E.; Writing, Review and Editing: Kafkas, N. E., Alp, Ş.

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