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Juniperus turbinata Guss. Cone and Leaf Essential Oil Compositions with Morphological Characteristics and Altitude Interaction

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Abstract: This study investigates, the effects of elevation on cone morphological traits and on the volatile compounds of leaves and cones were investigated in *Juniperus turbinata* Guss. populations naturally distributed in Turkish Republic of Northern Cyprus. In cone and leaf samples collected from different altitudes, cone width, cone length, thousand seed weight, and dry matter rate were determined, while volatile compound analyses were performed using the HS-SPME technique coupled with GC–MS. The results revealed statistically significant negative relationships between altitude and the measured cone physical traits. A total of 64 volatile constituents were identified in the cone samples and 62 in the leaf samples, with α-pinene and myrcene emerging as the major components in both plant organs. Principal Component Analysis (PCA) demonstrated that volatile compounds differ markedly between plant organs and that certain major constituents exhibit altitude- specific variation. The findings indicate that morphological and chemical variability in *J. turbinata* is sensitive to environmental gradients, underscoring the need to consider altitude specific populations in the development of conservation and management strategies for the species.

Keywords: Altitudinal variation, cone physical traits, environmental factors, leaf and cone volatiles.

Juniperus turbinata Guss. Kozalak ve Yaprak Uçucu Yağ Bileşimleri, Morfolojik Özellikler ve Yükselti Etkileşimi

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Öz: Bu çalışmada, Kuzey Kıbrıs Türk Cumhuriyeti'nde doğal olarak dağılmış *Juniperus turbinata* Guss. popülasyonlarında rakımın kozalak morfolojik özellikleri ve yaprak ve kozalakların uçucu yağ bileşimi üzerindeki etkileri araştırılmıştır. Farklı rakımlardan toplanan kozalak ve yaprak örneklerinde kozalak genişliği, kozalak uzunluğu, bin tane ağırlığı ve kuru madde oranı belirlenmiş, uçucu bileşik analizleri ise HS-SPME tekniği ve GC-MS kullanılarak gerçekleştirilmiştir. Sonuçlar, rakım ile ölçülen kozalak fiziksel özellikleri arasında istatistiksel olarak anlamlı negatif ilişkiler olduğunu ortaya koymuştur. Kozalak örneklerinde toplam 64, yaprak örneklerinde ise 62 uçucu bileşen tanımlanmış olup, her iki bitki organında da α-pinen ve mirsen ana bileşenler olarak belirlenmiştir. Temel Bileşen Analizi (PCA), uçucu yağ bileşiminin bitki organları arasında belirgin şekilde farklılık gösterdiğini ve bazı ana bileşenlerin rakımla ilişkili varyasyon gösterdiğini ortaya koymuştur. Bulgular, *J. turbinata*'daki morfolojik ve kimyasal değişkenliğin çevresel değişimlere duyarlı olduğunu göstermekte olup, türün korunması ve yönetimi stratejilerinin geliştirilmesinde rakıma özgü popülasyonların dikkate alınması gerektiğinin altını çizmektedir.

Anahtar kelimeler: Çevresel faktörler, kozalak fiziksel özellikleri, rakım farklılığı, yaprak ve kozalak uçucu bileşikleri.

INTRODUCTION

Juniperus, a member of the Cupressaceae family, was first described in the literature by Linnaeus as *Juniperus phoenicea* L. (Linnaeus, 1973). This species is an evergreen plant that can attain a height of 8–12 meters, growing either as a tree or in a shrub form (Sanguin et al., 2016; You et al., 2016). It is a tree species primarily concentrated in the western Mediterranean Basin, particularly in the Iberian Peninsula and North Africa (the Atlas Mountains), with its westernmost distribution extending to the Macaronesian region (Madeira and the Canary Islands) (Christensen et al., 1997; Farjon, 2005). In the Middle East, the distribution of this species is characterized by regional discontinuities. Although there are no records of the species from countries such as Syria, Lebanon, and Palestine (Zohary, 1973), it is the only conifer species recorded in Egypt, where it exhibits a

highly restricted distribution (Waisel and Liphschitz, 1968; El-Bana et al., 2010). Its distribution extends from the Seir Mountains in southern Jordan westward into parts of western Saudi Arabia (Zohary, 1973; Touchan et al., 1999). Within this distribution range, in addition to pronounced ecological and geographical variation, several taxonomic (Farjon, 2005) and morphological studies (Mazur et al., 2016) have led to the initial recognition of two distinct subspecies within this taxon (*J. phoenicea* L. subsp. *phoenicea* and *J. phoenicea* subsp. *turbinata* (Guss.) Nyman). In recent years, several molecular studies have provided support for this taxonomic distinction (Boratyński et al., 2009; Dzialuk et al., 2011). However, more recent molecular phylogenetic analyses have reclassified this group at the species level, recognizing *J. phoenicea* s.str. and *J. turbinata* Guss. as two distinct species (Adams et al., 2013; Adams & Schwarzbach, 2013).

J. phoenicea, which is believed to have had a more extensive distribution in the past, has been subjected to intense anthropogenic pressure due to timber extraction as well as its use in traditional folk medicine and religious practices (El-Bana et al., 2010). Due to increasing anthropogenic pressure, along with habitat alteration and climatic changes, the species has declined considerably across much of its natural range, with many populations persisting today as remnant ecosystems (Zohary, 1973; Danin, 1999). Climate change in particular is projected to substantially disrupt the species' potential ecological niche across key areas of its distribution range (Salvà-Catarineu et al., 2021). These findings underscore the need to strengthen conservation measures across the species' distribution range and to implement targeted strategies to prevent local extinctions driven by anthropogenic pressure and climate change. Within this context, *J. phoenicea* is currently listed in the IUCN Red List under the LC (Least Concern) threat category (El-Bana et al., 2010; IUCN, 2025). This designation has represented an important step in shaping conservation and management strategies for the species.

Within Mediterranean maquis formations, this species occurs at low to mid elevations and typically favors sun-exposed slopes (Hammi et al., 2010), limestone (calcareous) bedrock (Miralles et al., 2007), and clay-rich soils (López-Bermúdez et al., 1998). Overall, this plant is a pioneer species with high light and temperature requirements and marked tolerance to drought and unfavorable site conditions (Quézel & Médail, 2003; Mathaux et al., 2016), possessing a strong capacity for soil stabilization in wind-eroded environments and thus considerable ecological value. In these habitats, *J. phoenicea* functions as a keystone species for numerous endemic, rare, vulnerable, and endangered plant taxa (Boulos & Gibali, 1993).

Within forest ecosystems across its distribution range, this species is recognized for the significant ecological roles outlined above also attracts attention due to its rich essential oil content. The leaves and cones of this aromatic plant are widely used in the production of essential oils (You et al., 2016). It has been reported that essential oils derived from the plant exhibit inhibitory activity against the enzymes α-amylase and pancreatic lipase, which are responsible for the breakdown of carbohydrates and lipids, suggesting their potential use in the management of obesity and diabetes (Keskes et al., 2014). Decoctions prepared from the leaves have been traditionally used for their antidiabetic and laxative effects (Boukef et al., 1982; Khalil, 1995), while the essential oils obtained from the cones and wood have been employed in folk medicine for the treatment of conditions such as leprosy, typhoid, and tapeworm infections (Loizzo et al., 2007). Considering these properties, numerous studies have been conducted to directly determine the volatile compounds of *J. Phoenicea* (Medini et al., 2009; Derwich et al., 2010; Fouad et al., 2011). In addition, several studies have compared the essential oil profiles of samples collected from different geographical regions (Achak et al., 2008). However, limited attention has been given to variations in essential oil composition among samples collected across different elevations and to the relationships between volatile constituents and the plant's morphological traits.

One of the principal distribution areas of *J. turbinata* within the Mediterranean Basin is the island of Cyprus. Across Cyprus, data on plant species have been systematically documented in accordance with scientific standards in *Flora of Cyprus* by Meikle (1977, 1985). In his study, Meikle divided Cyprus into eight phytogeographical regions, and subsequent floristic investigations have been conducted based on this regional classification. Within this framework, the taxon occurring in the region has been identified as *Juniperus turbinata* Guss. (Hand et al., 2011; Mazur et al., 2016). The species in question occurs in all of the eight defined phytogeographical regions, except for the second region. However, the variation in volatile compounds with respect to elevation has not been adequately investigated. Therefore, we aimed to determine the volatile compounds of the leaves and cones of J. turbinata distributed in the northern part of Cyprus and to examine the relationships between these constituents, elevation, and selected morphological characteristics of the plant. Through this research, we sought to generate baseline data that may contribute to the conservation and management strategies

of this species, which holds considerable ecological significance in forest ecosystems.

MATERIAL AND METHOD

In this study, leaf and cone samples of Mediterranean juniper were collected from natural forest stands located in the Turkish Republic of Northern Cyprus (TRNC) (Figure 1). The island of Cyprus is in the eastern Mediterranean, approximately 65 km south of Türkiye, 100 km west of Syria, and about 770 km southeast of Greece. It is the third largest island in the Mediterranean, following Sicily and Sardinia. The island extends 225 km from Cape Arnauti in the west to Cape Apostolos Vereas in the northeast, while its north–south width reaches approximately 100 km (Britannica, 2024).

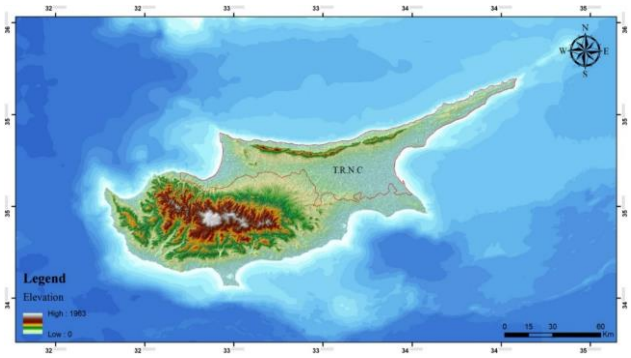

Figure 1. Map of the study area.

Morphological measurements of plant leaves and cones: From eight different elevations (98, 157, 257, 345, 430, 570, 610, 650 m) ten healthy, mature green cones were selected and measures were taken to ensure that the collected cone samples did not lose their moisture content prior to analysis. The width and length of the selected cones were measured in their fresh state using a digital caliper, with millimeter (mm) precision. In addition, the thousand-seed weight was measured. Subsequently, cone samples weighing 100 g from each elevation were placed in an oven at 105 °C and dried for 24 hours until reaching constant dry weight, after which they were reweighed. The difference between fresh and dry weights was then used to calculate the dry matter content (%).

HS-SPME/GC–MS analysis of volatile compounds: In addition to these laboratory measurements, analyses of the volatile constituents of *J. turbinata* cones and leaves were also conducted. The volatile constituents of *J. turbinata* cones and leaves were determined using the Headspace Solid-Phase Microextraction (HS-SPME) technique (Vichi et al., 2003; Risticevic et al., 2010). The analyses were performed using a Shimadzu gas chromatography–mass spectrometry system (GCMS-QP2010 SE; Shimadzu Corporation, Kyoto, Japan). For each analysis, 1 g of sample was weighed into 15 mL SPME vials and sealed airtight with silicone septum caps. The samples were equilibrated at 60 °C for 15 minutes. Subsequently, a 75 µm CAR/PDMS (Carboxen/Polydimethylsiloxane) fiber (Supelco, Bellefonte, USA) was exposed to the vial and left for 30 minutes during which the volatile compounds in the headspace were adsorbed onto the fiber. Following the extraction step, the fiber was inserted into the injection port of the GC system and held for 5 minutes to allow thermal desorption of the adsorbed volatile aroma compounds, which were then introduced into the capillary column (Restek Rx-5 Sil MS, 30 m × 0.25 mm i.d., 0.25 µm film thickness). The oven temperature program was initiated at 40 °C with a 2-minute hold, then increased to 250 °C at a rate of 4 °C per minute and maintained at this temperature for 5 minutes. The injector and detector temperatures were set at 250 °C. Ionization was carried out using the Electron Ionization (EI, 70 eV) method, and helium was employed as the carrier gas at a flow rate of 1.61 mL/min. Identification of the volatile compounds was performed with the aid of the Wiley, NIST, and FFNSC mass spectral libraries, and the results were expressed as relative abundance (%).

RESULTS AND DISCUSSION

Within the scope of the study, the thousand grain weight (g), cone width and length (mm), and dry matter rate (%) measured from physical cone samples collected from individuals of *J. turbinata* at different elevations were first evaluated in relation to elevation, latitude, and longitude (Fig. 2).

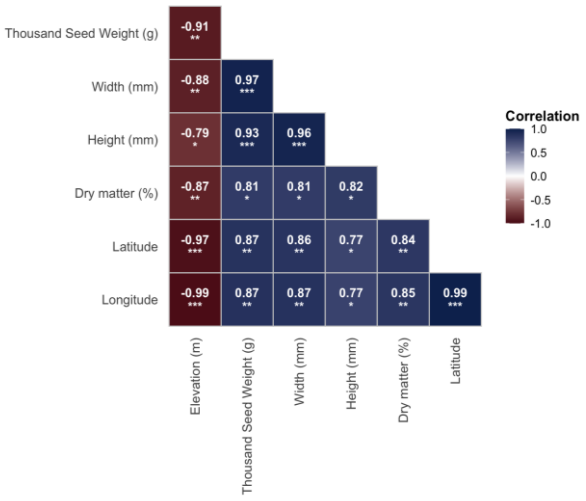

Figure 2. Correlation between the physical traits of cones and elevation, latitude, and longitude. (statistical significance at *p ≤ 0.05, **p ≤ 0.01, ****p ≤ 0.001*).

The correlation analysis revealed statistically significant negative relationships between elevation and the cone physical traits TSW, width, and DM at the p ≤ 0.01 significance level, and with height at the p ≤ 0.05

level. Moreover, statistically significant associations were also identified between the spatial coordinates of the sampling sites (latitude and longitude) and the measured cone physical characteristics.

A total of 64 different volatile compounds were identified in cone samples collected from different elevations, whereas 62 distinct volatile compounds were detected in the leaves (Table S1 and Table S2). Of these, 48 compounds were common to both cones and leaves. Conversely, fourteen volatile constituents were found to be unique to each cone and leave (Table S3).

According to the overall chemical profile of the species, examination of the mean values of volatile compounds identified across all elevations indicates that α-pinene (18.75%-41.09%–) and myrcene (9.73%–11.67%) are major volatile compounds shared by both cones and leaves. In the cones, these two major compounds were followed by germacrene-D (8.42%), limonene (5.54%), caryophyllene (4.56%), and terpinyl acetate (3.17%). In contrast, in the leaves they were succeeded by limonene (10.92%), β-phellandrene (8.16%), germacrene-D (5.55%), and terpinyl acetate (5.24%). Accordingly, due to the differences in ranking between cones and leaves, Principal Component Analysis (PCA) was performed in R Studio in the next step to determine the relationships between elevation and these major volatile compounds. The PCA results indicated that the first three principal components accounted for 86.81% of the total variance in the dataset (Table 1).

Table 1. Explained variance (%) of principal components for cone and leaf volatile compounds across elevations.

Component	Eigenvalue	Percentage of variance	Cumulative percentage of variance
PC1	3.25	40.67	40.67
PC2	2.56	32.03	72.7
PC3	1.13	14.11	86.81

The Pearson correlation coefficients between the first three principal components, the volatile constituents, and the elevation variable are presented in Table 2, while the positions of all these variables across the three principal components are illustrated in Fig 3.

Table 2. Pearson correlation coefficients between elevation, cone and leaf volatile compounds, and the principal component axes.

Variables	PC1	PC2	PC3
alpin	***-0.751***	-0.608	0.066
myrc	***0.705***	-0.562	0.21
gerd	***-0.817***	0.545	-0.036
cary	-0.312	***0.822***	0.204
limo	***0.719***	0.641	0.081
terace	0.282	0.581	***-0.62***
betphe	***0.908***	0.058	0.138
elvtn	-0.091	0.392	***0.792***

An examination of the axis loadings for the principal components reveals that, on PC3, elevation exhibits a negative association with one of the major volatile constituents, Terpinyl acetate (terace), at a level that may be regarded as statistically significant. In contrast, the strength of the relationship between elevation and the other major volatile constituents remained comparatively low. On the other hand, with respect to the proportions of the major volatile constituents, the cone and leaf samples of *J. turbinata* are separated from one another, as distinctly illustrated in the PCA ordination plot. The clustering of the samples in distinct regions along the ordination axes indicates a clear differentiation between the leaf and cone groups. A close inspection of the plot further shows that, among the volatile constituents, α-pinene (alpin) and germacrene-D (gerd) are more dominant in the cone samples, whereas myrcene (myrc), limonene (limo), and beta-phellandrene (betphe) appear to be more characteristic of the leaf samples. This separation appears to stem from the fact that certain volatile compounds are more strongly associated with specific plant organs. In the subsequent stage of the study, PCA was conducted to determine the relationships between the physical traits of cones collected from different elevations and their major volatile compounds. The results of the analysis showed that the first three principal components accounted for 92.47% of the total variance in the dataset (Table 3).

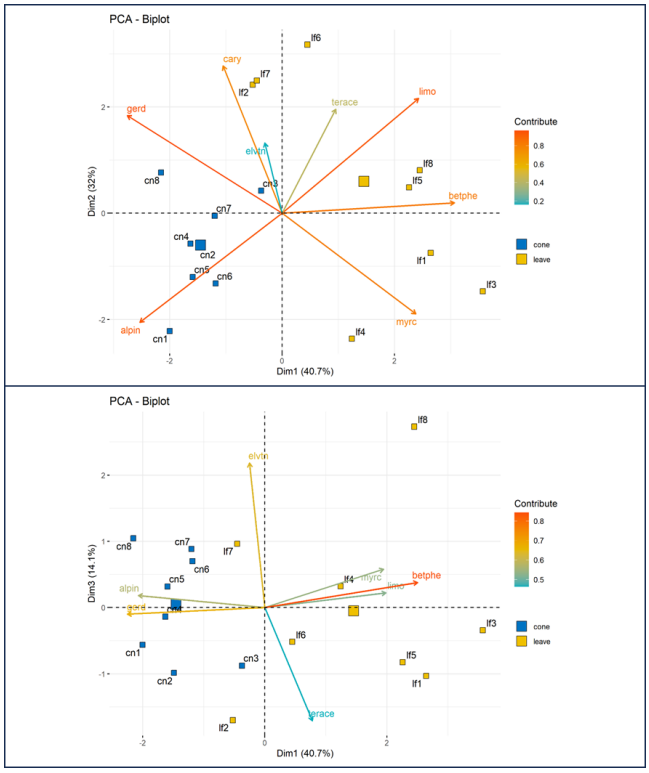

Figure 3. PCA biplot of major volatile compounds and elevation.

Table 3. Explained variance (%) of principal components (PCA) for cone volatile compounds and physical traits across elevations.

Component	Eigenvalue	Percentage of variance	Cumulative percentage of variance
PC1	6.67	55.62	55.62
PC2	2.47	20.60	76.23
PC3	1.95	16.25	92.47

The Pearson correlation coefficients between the first three principal components and the cone volatile constituents, physical traits, and elevation variable are

presented in Table 4, while the positions of all these variables within the three principal component planes are illustrated in Fig. 4.

Table 4. Altitude, cone physical traits, and volatile compounds with principal component axes and pearson correlation coefficients.

Variables	PC1	PC2	PC3
alpin	***0.695***	-0.505	-0.166
myrc	***0.736***	-0.356	0.503
gerd	-0.463	***0.659***	-0.46
cary	-0.434	***0.831***	-0.277
limo	***-0.684***	0.264	0.607
terace	-0.653	0.268	***0.685***
betphe	***-0.841***	-0.064	0.529
weight	***0.927***	0.222	0.296
width	***0.903***	0.342	0.176
height	***0.925***	0.288	0.03
dry	***0.762***	0.549	-0.022
elvtn	***-0.732***	-0.521	-0.376

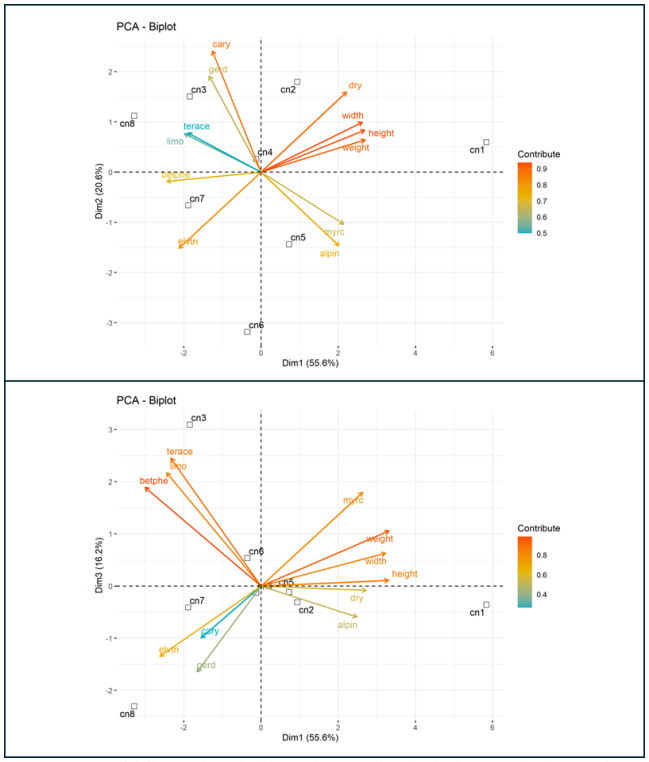

Figure 4. Multidimensional view of cone physical characteristics, major volatile compounds, and altitude relationships using PCA biplot.

When the PCA ordination is evaluated alongside the correlation coefficients of the variables along the principal component axes, elevation shows a negative correlation with all measured physical characteristics of the cone along the PC1 axis. Similarly, on PC1, elevation shows a statistically significant negative association with the volatile compounds α-pinene (alpin) and myrcene (myrc), whereas it is positively and significantly correlated with limonene (limo) and beta-phellandrene (betphe). This pattern also indicates that all cone physical traits are positively and significantly associated with α-pinene (alpin) and myrcene (myrc), while showing significant negative correlations with limonene (limo) and beta-phellandrene (betphe). Among the cone volatile compounds, germacrene-D (gerd) and caryophyllene (cary) are positively associated with one another on PC2. On PC3, terpinyl acetate (terace), which exhibits the highest correlation coefficient among the cone volatile compounds, does not show any other statistically significant associations with the remaining variables.

Finally, to evaluate independently the relationship between elevation and the volatile compounds of the leaf samples, a separate PCA was conducted. The results indicated that the first three principal components explained 88.72% of the total variance in the dataset (Table 5).

Table 5. The percentages of variance explained for the principal components as a result of PCA analysis applied to determine the relationships between volatile components of *J. turbinata* leaves and altitude.

Component	Eigenvalue	Percentage of variance	Cumulative percentage of variance
PC1	3.67	45.81	45.81
PC2	2.01	25.09	70.90
PC3	1.43	17.82	88.72

The Pearson correlation coefficients between the first three principal components and the volatile constituents of *J. turbinata* leaves, together with the elevation variable, are presented in Table 6, while the positions of all these variables across the three principal component planes are illustrated in Fig. 5.

Table 6. Altitude and principal component axes of leaf volatile compounds and Pearson correlation coefficients.

Variables	PC1	PC2	PC3
alpin	-0.471	***-0.695***	0.505
myrc	***-0.918***	0.106	0.353
gerd	***0.919***	-0.332	0.095
cary	***0.877***	0.028	0.309
limo	0.626	***0.669***	0.075
terace	0.442	-0.418	***-0.628***
betphe	-0.445	***0.796***	-0.292
elvtn	0.45	0.380	***0.675***

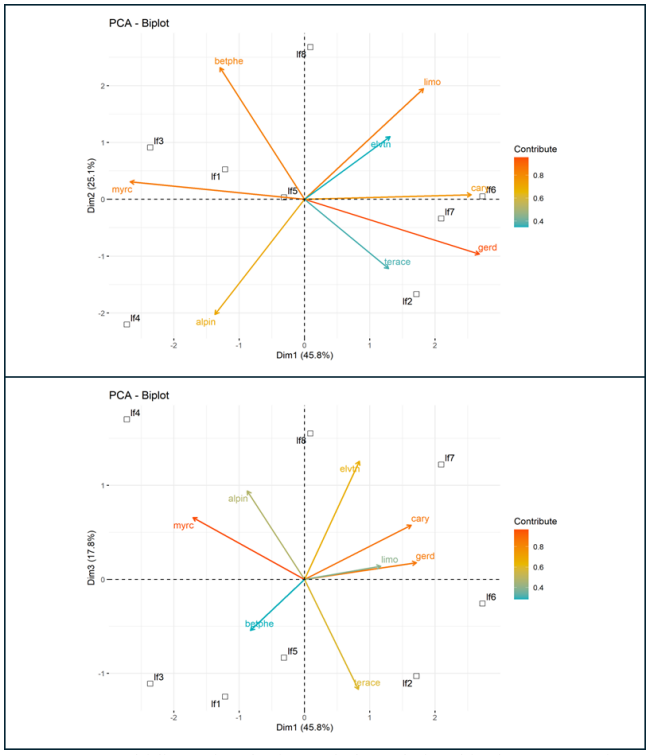

Figure 5. Multidimensional view of the relationship between major volatile components identified in *J. turbinata* leaves and altitude using PCA graph.

When the relationships between elevation and the major volatile compounds of *J. turbinata* leaf samples were examined independently through principal component analysis, elevation was found to exhibit a statistically significant association only with Terpinyl acetate (terace) on PC3. The relationships observed on PC1 and PC2 primarily reflect the internal associations among the leaf volatile compounds themselves.

Plants are influenced by environmental factors throughout all stages of their growth and development. From the onset of dormancy break and initial sprouting through the vegetative growth phase and into the reproductive stage, climatic variables particularly temperature and humidity along with other environmental factors, whether acting individually or in combination, influence plant dynamics (Charrier et al., 2015). These dynamics, defined as changes in plants across time and space, encompass fundamental processes such as growth, reproduction, dispersal, and competition. On the other hand, in many plant species, secondary metabolites such as volatile compounds, phenolic compounds, and antioxidant properties are recognised as important bioactive compounds. A portion of these dynamics, which may also be described as the chemical characteristics of plants, is shaped directly by hereditary factors, whereas another portion is reported to be influenced by ecological conditions that affect the plant's internal regulatory processes (Arslan & Aydemir, 2009; Gülsoy et al., 2013, 2014, 2017). Within this framework, the relationships between secondary metabolites and environmental variables in plants have become a significant focus of research in ecology.

Species within the genus *Juniperus* are distinguished by the diverse array of secondary metabolites present in their leaves, cones, bark, roots, and flowers. Widely distributed across forest ecosystems, junipers constitute an important group of plants classified among medicinal and aromatic species (Topçu et al., 2005). Species belonging to the genus *Juniperus* are particularly rich in volatile constituents, while also containing a range of other secondary metabolites, including tannins, flavonoids, resins, and triterpenes (Tavares et al., 2018). Consequently, owing to their pronounced medicinal and pharmacological properties, *Juniperus* species have found widespread applications across various sectors (Hegnauer, 1986; Tümen & Hafızoğlu, 2003). It is well established that the essential oils obtained particularly from the leaves and cones of the plant are utilised as active ingredients in cosmetic and medicinal products (Lemordant et al., 1978; Bellakhdar, 1991). *Juniperus* species, which stand out due to quality attributes such as wood durability, fine texture, pleasant aroma, and good workability, have been the subject of numerous studies addressing both their ecological roles in forest ecosystems (Yaltırık, 1993; Zeidler et al., 2009; Cano Ortiz et al., 2021) and their economic value from an industrial perspective (Özkan et al., 2025; Gross & Ezerietis, 2003). In contrast, studies addressing the variation in morphological traits and bioactive chemical composition of juniper species in response to changing ecological conditions remain relatively limited (Klimko et al., 2007; Gülsoy and Çıvğa, 2016; Fejér et al., 2018; Rajčević et al., 2023). In this context, research examining the relationships between the bioactive compounds of species within the genus and ecological factors holds considerable significance in the literature.

Situated within the Mediterranean Basin, the island of Cyprus harbours important forest areas in terms of juniper species. *J. turbinata*, which occurs naturally in the northern part of the island, represents one of the most characteristic tree species of these forests. In this study, volatile compounds and cone physical traits were determined in leaf and cone samples collected from *J. turbinata* across different elevations on the island. The analyses revealed that elevation exerts a significant influence on both the physical traits and the volatile compounds of the species' cones and leaves. A statistically significant negative association was observed between elevation and all measured cone physical traits in the species. This finding is consistent with expectations, as more favourable temperature regimes and growth conditions at lower elevations are likely to promote cone development. Indeed, previous studies have reported altitude-dependent changes in morphological traits, indicating a tendency for both cone width and length to decrease with increasing elevation (Yıldız, 2016; Üçler and Arpacı, 2017). This finding further suggests that more favourable environmental conditions at lower elevations may positively influence the development of reproductive organs in plants (Boulli et al., 2001). Moreover, it has been suggested that the effect of elevation on the weight and size of reproductive organs may be associated with enhanced photosynthetic efficiency and the support of developmental processes under conditions of adequate moisture availability and moderate temperatures (Boulli et al., 2001). Conversely, it has also been emphasised that this effect may vary depending on species-specific traits and prevailing climatic conditions, and that in colder regions increasing elevation may lead to adverse outcomes, such as flower damage, cone abscission, and impaired seed maturation (Turner et al., 2007; Messaoud et al., 2007). In addition to these findings, the observation that the highest mean dry matter rate in *J. turbinata* cones was recorded at lower elevations further indicates that the accumulation of storage compounds during cone development may have

occurred under the more favourable environmental conditions prevailing at these sites.

The chemical composition of the volatile profile of cone samples of *J. turbinata* is presented in Supplementary Table 1. A total of 64 volatile constituents were identified in the cone samples. However, not all of these compounds were detected at every elevation. Across all elevations examined, α-pinene was identified as the major constituent. In contrast, the relative ranking of the remaining components varied depending on elevation. It was determined that the volatile compounds profile of the cones consisted predominantly of monoterpenes, with the total monoterpene content varying between approximately 67% and 78% depending on elevation. Ennajar et al. (2009) reported that monoterpenes were major in the cone essential oils of *J. phoenicea*, with α-pinene identified as the major constituent (80.7%). Similarly, Mansouri et al. (2011) reported high levels of α-pinene in the essential oils of *J. phoenicea* ssp. *turbinata*, noting that its proportion reached 89.31% particularly in the cone volatile compounds. Accordingly, the results obtained in the present study for cone volatile compounds are generally consistent with previous findings on this taxon.

The chemical composition of the volatile compounds identified in J. turbinata leaf samples is presented in Appendix Table 2. A total of 62 volatile constituents were identified in the leaf samples. However, as observed in the cones, not all of these compounds were detected at every elevation. Across all sampled elevations, alpha -pinene was again identified as the major constituent. In contrast, the relative ranking of the remaining components varied with elevation. The compositional profile of the leaf volatile compounds was predominantly composed of monoterpenes, and the total monoterpene content was found to range approximately between 55-81% depending on elevation. Barrero et al. (2006) reported that monoterpenes constituted the major class of compounds (71.1%) in the volatile compounds of fresh *J. phoenicea* leaves, with α-pinene (45.5%) identified as the principal constituent. Similarly, in their study on *J. phoenicea*, Ennajar et al. (2009) found that monoterpenes represented the main component group of the essential oil (75.9%), with α-pinene (55.7%) occurring as the major compound. Moreover, Boumediene et al. (2026) demonstrated that the leaf essential oils of *J. turbinata* consist predominantly of monoterpene hydrocarbons (45.5–71.8%), with α-pinene identified as the most abundant constituent across all samples (38.2–55.8%). In another study, Adams et al. (1996) reported on the chemical composition of the leaf volatile compounds of *J. phoenicea* ssp. *turbinata*, indicating that α-pinene (28.3%), β-phellandrene (25.3%), β-myrcene (7.2%), and α-phellandrene (4.1%) were the dominant constituents, whereas limonene and δ-3-carene were not detected in the oil. In the present study, limonene was detected in all elevation groups, whereas δ-3-carene was identified at all elevations except within the 610–650 m range.

In this study, the α-pinene content of the leaf samples was found to be consistently lower than that of the cones across all elevations. Comparable results were reported by Angioni et al. (2003), who observed that α-pinene constituted 87.5% volatile compounds in cones and 48.9% in leaves. Moreover, Ennajar et al. (2009) likewise reported that the proportion of α-pinene in the leaves (55.7%) was lower than that determined in the cones (80.7%).

Finally, principal component analysis (PCA) was applied to correlate differences in volatile compounds with plant organs, altitude, and the physical properties of cones. In the PCA analysis conducted to evaluate the distribution patterns of volatile compounds in leaf and cone samples, it was found that the samples formed distinct clusters and exhibited different compositional trends in terms of their volatile compound profiles. An additional PCA analysis was subsequently conducted to independently assess the effect of altitude on the physical properties and major volatile compounds of the cones. The analysis revealed that while some physical traits and volatile compounds exhibited similar spatial patterns in relation to elevation, others deviated from these patterns by showing different trends. Examination of the PCA ordination indicated a negative association between elevation and α-pinene (alpin), myrcene (myrc), thousand seed weight, cone width, cone length, and dry matter. In contrast, limonene (limo) and beta-phellandrene (betphe) were positively correlated with elevation.

When the results of the PCA applied separately to the leaf samples were examined, the major volatile compounds were found to exhibit distinct directional patterns in relation to elevation. In this analysis, terpinyl acetate (terace) showed a statistically significant decreasing trend with increasing elevation, and this effect was more pronounced in the leaves than in the cone samples. No statistically significant relationships were detected between elevation and the other leaf volatile constituents.

In summary, the PCA analyses collectively demonstrate that volatile compounds of *J. turbinata* varies significantly with both plant organ and elevation. In addition, the findings indicate that physical traits likewise exhibit variation in response to elevational gradients. Indeed, these findings indicate that the chemical composition of essential oils can vary markedly within the same plant species, depending on the specific plant organ and the ecological conditions under which the samples occur. Abiotic factors such as climatic characteristics,

altitude, soil type, and geographical location have been reported as key ecological determinants capable of influencing the chemical profile of volatile compounds (Brada et al., 2007; Ghanmi et al., 2007). The literature emphasizes that differences in volatile compounds are not determined solely by genetic factors but may also be influenced by the plant's morphological characteristics, developmental stage, prevailing ecological conditions, and the analytical method used (Angioni et al., 2003; El-Sawi et al., 2007; Hojjati et al., 2009; Nacakcı, 2025). This underscores the importance of considering both intra-specific variation and environmental influences in chemical evaluations of volatile compounds, while also accounting for additional external factors that may contribute to compositional variability.

CONCLUSION

This study demonstrates that elevation may act as a key ecological determinant influencing both physical traits and volatile compounds in *J. turbinata* populations naturally distributed in the Turkish Republic of Northern Cyprus. The elevation-dependent variations observed in the major volatile compounds of cones and leaves further indicate that environmental gradients, in addition to inherited characteristics, contribute to shaping intraspecific chemical differentiation within the species. This finding carries ecological and evolutionary significance for *J. turbinata*, which is distributed across the Mediterranean Basin in fragmented and relict populations. Although the species is currently classified as "Least Concern (LC)" on the IUCN Red List, the pronounced morphological and chemical variability detected among populations clearly indicates that elevation-specific population units should be considered in conservation and management strategies. The conservation of populations occurring across different altitudes is critical for protect the species' long-term adaptive potential under climate change, as well as for maintaining its genetic diversity and chemically distinct ecotypes. Accordingly, conservation strategies that explicitly account for elevation-related physical and chemical differences are essential for the ecosystem-based management of the species' natural populations.

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SUPPLEMENTARY

Table S1 Cone volatile compounds.

Rt	Components	Code	cn1	cn2	cn3	cn4	cn5	cn6	cn7	cn8
8.683	alpha- Pinene	alpin	52.84	33.39	33.20	43.27	47.43	47.32	33.41	37.87
10.854	Myrcene	myrc	10.80	9.18	10.01	9.61	10.26	10.10	9.34	8.54
28.722	Germacrene-D	gerd	7.74	8.39	8.72	8.81	7.82	6.00	8.01	11.89
26.708	Caryophyllene	cary	4.27	4.81	4.90	4.85	4.13	3.41	4.59	5.56
12.379	Limonene	limo	3.38	4.27	9.56	5.27	4.69	5.00	5.99	6.18
27.878	alpha- Humulene	alphum	2.38	2.81	2.80	2.65	2.34	1.77	2.27	3.32
10.282	beta- Pinene	betpin	2.25	1.33	1.52	2.82	2.39	2.25	1.84	1.67
29.920	delta- Cadinene	delcad	1.88	2.10	1.90	1.75	1.71	1.31	1.71	2.06
24.320	Terpinyl acetate	terace	1.43	3.35	5.36	3.33	2.76	3.10	3.00	3.04
29.746	gamma- Cadinene	gamcad	1.38	1.56	1.28	1.25	1.25	0.99	1.28	1.54
29.475	Farnesene <(E,E)-, alpha->	feea	1.11	1.08	0.22	0.21	0.22	0.16	0.22	0.29
28.526	gamma- Muurolene	gammuu	1.09	1.31	1.17	1.03	0.97	0.84	1.07	1.33
29.209	Eudesma-3,7(11)-diene	euddie	0.91	1.02	0.89	0.82	0.82	0.69	0.86	1.07
12.404	beta- Phellandrene	betphe	0.86	1.93	3.94	2.59	2.26	2.87	2.85	2.68
28.091	(+)-Epi-bicyclosesquiphellandrene	epibic	0.81	0.84	0.71	0.68	0.68	0.58	0.72	0.91
25.695	beta- Elemene	betele	0.75	0.83	0.98	0.84	0.99	0.94	1.24	1.11
10.137	Sabinene	sabi	0.72	0.49	0.41	0.28	0.47	0.47	0.37	0.55
14.524	alpha- Terpinolene	alpter	0.64	2.52	0.77	0.85	0.58	1.19	2.42	0.94
9.271	Camphene	camp	0.50	0.24	0.27	0.48	0.45	0.44	0.28	0.32
27.555	Cadina-1(6),4-diene <10betaH->	cdb	0.37	0.38	0.32	0.30	0.30	0.26	0.32	0.40
11.415	alpha- Phellandrene	alpphe	0.35	0.52	2.19	1.10	0.96	1.32	1.49	0.03
29.291	alpha- Muurolene	alpmuu	0.35	0.42	1.07	1.65	1.01	0.67	0.98	1.50
8.275	Tricyclene	tric	0.30	0.15	0.15	0.22	0.25	0.25	0.14	0.20
27.034	gamma- Elemene	gamele	0.26	0.38	0.50	0.23	0.70	1.06	1.37	0.41
13.469	gamma- Terpinene	gamter	0.26	0.15	0.14	0.21	0.30	0.33	0.18	0.09
27.669	cis-Muurola-3,5-diene	cmd	0.22	0.24	0.22	0.21	0.19	0.17	0.21	0.28
25.217	alpha- Copaene	alpcop	0.21	0.26	0.24	0.22	0.21	0.17	0.21	0.28
16.852	Camphor	camph	0.20	0.21	0.23	0.45	0.20	0.30	0.16	0.19
9.812	(E)-2,6-Dimethyl-1,3,5,7-octatetraene	edo	0.19	0.00	0.05	0.18	0.14	0.12	0.00	0.18
12.143	o-Cymene	ocym	0.16	0.47	0.95	0.59	0.32	0.35	0.36	0.23
28.968	beta- Selinene (CAS)	bsc	0.15	0.21	0.23	0.17	0.20	0.22	0.28	0.20
20.138	(E)-2,3-Epoxycarane	eepo	0.14	0.00	0.00	0.16	0.10	0.08	0.00	0.08
14.719	1-Methyl-4-isopropenylbenzene	metiso	0.14	0.20	0.30	0.37	0.19	0.22	0.14	0.09
11.842	alpha- Terpinene	alphte	0.13	0.14	0.16	0.10	0.14	0.17	0.16	0.14
23.790	4-Terpinenyl acetate	terpac	0.12	0.47	0.00	0.21	0.00	0.00	0.00	0.00
9.195	alpha- Fenchene	alpfen	0.10	0.42	0.09	0.00	0.07	0.10	0.28	0.06
24.998	alpha- Ylangene	alpyla	0.10	0.11	0.10	0.00	0.09	0.07	0.09	0.11
11.150	2-Carene	care	0.08	0.00	0.22	0.10	0.07	0.09	0.11	1.66
13.060	Ocimene <(E)-, beta->	oeb	0.08	0.09	0.00	0.00	0.07	0.07	0.07	0.00
30.641	alpha- Calacorene	alpcal	0.08	0.10	0.15	0.00	0.18	0.29	0.38	0.07
20.791	Linalyl acetate	linace	0.06	0.00	0.00	0.00	0.08	0.05	0.00	0.00
6.035	Hex-2(E)-enal	hee	0.06	0.02	0.00	0.00	0.00	0.00	0.00	0.00
18.197	Terpinen-4-ol	terol	0.05	0.09	0.00	0.00	0.00	0.00	0.00	0.00
4.562	Hexanal	hexa	0.04	0.02	0.00	0.00	0.00	0.00	0.00	0.00
11.526	DELTA.3-Carene	delcar	0.03	12.26	1.66	0.02	0.05	0.78	8.00	1.69
1.355	Ethanol	etha	0.00	0.00	0.13	0.10	0.11	0.00	0.00	0.00
8.494	alpha- Thujene	alte	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.07
9.438	trans-Verbenol	alpthu	0.00	0.00	0.08	0.12	0.00	0.00	0.00	0.00
16.131	Campholaldehyde	traver	0.00	0.00	0.19	0.27	0.04	0.04	0.00	0.00
18.747	alpha- Terpineol	campho	0.00	0.00	0.00	0.00	0.06	0.24	0.35	0.44
18.758	Dihydrocarveol	dihy	0.00	0.20	0.35	0.43	0.00	0.00	0.00	0.00
19.195	Verbenone	verb	0.00	0.00	0.19	0.33	0.06	0.08	0.00	0.00
20.011	beta -Citronellol	betcit	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.16
20.554	Carvone	carv	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00
20.894	Piperitone	pipe	0.00	0.15	0.35	0.29	0.19	0.26	0.26	0.28
21.094	Methyl citronellate	metcit	0.00	0.41	0.00	0.00	0.00	0.33	0.00	0.00
21.544	Isopulegyl acetate	isoace	0.00	0.00	0.00	0.12	0.00	0.15	0.00	0.00
22.022	Bornyl acetate	borace	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00
22.442	(E,Z)-2,4-Decadienal	ezd	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.13
23.818	delta- Elemene	delele	0.00	0.00	0.34	0.08	0.41	0.50	0.66	0.12
30.881	alpha- Elemol	alpele	0.00	0.00	0.00	0.00	0.00	0.10	0.11	0.00
31.171	Germacrene B	gerb	0.00	0.17	0.41	0.00	0.90	1.62	2.13	0.00
31.918	Caryophyllene oxide	caroxi	0.00	0.00	0.25	0.19	0.05	0.05	0.00	0.00
32.715	alpha- Cedrol	alpced	0.00	0.00	0.11	0.12	0.03	0.02	0.00	0.06

Elevation (m) code: cn1:98, cn2:157, cn3:257, cn4: 345, cn5:430, cn6:570, cn7:610, cn8:650

Table S2 Leaf volatile compounds

Rt	Components	Code	lf1	lf2	lf3	lf4	lf5	lf6	lf7	lf8
8.683	alpha- Pinene	alpin	14.14	17.88	15.25	36.53	19.60	14.02	18.25	14.34
10.854	Myrcene	myrc	12.23	8.09	14.04	16.04	11.24	9.02	9.64	13.06
12.379	Limonene	limo	11.27	9.46	9.26	7.97	11.04	13.65	11.38	13.29
12.404	beta- Phellandrene	betphe	9.73	4.96	15.44	3.11	10.16	4.33	3.73	13.87
11.526	DELTA.3-Carene	delcar	8.31	0.00	2.54	1.23	1.97	2.17	0.00	0.00
6.035	Hex-2(E)-enal	hee	7.35	0.96	10.96	2.18	4.67	0.48	0.86	0.49
24.320	Terpinyl acetate	terpac	4.45	7.28	4.77	3.43	8.17	8.74	4.44	0.68
6.126	Hex-3(Z)-enol	hze	3.95	0.33	1.92	0.99	1.31	0.60	0.61	3.93
26.708	Caryophyllene	cary	3.20	7.54	2.07	2.89	3.39	6.31	7.74	6.80
11.415	alpha- Phellandrene	alpphe	2.65	2.48	4.21	1.16	3.30	3.49	2.66	3.53
14.524	alpha- Terpinolene	alpter	2.20	0.76	2.06	1.40	1.74	1.53	0.97	0.80
28.722	Germacrene-D	gerd	2.05	10.52	1.33	2.93	3.52	9.80	10.22	3.99
21.544	Isopulegyl acetate	isoace	1.98	0.83	0.27	0.16	1.76	0.18	0.46	0.00
27.878	alpha- Humulene	alphum	1.59	4.64	1.15	1.74	1.83	3.64	4.56	2.91
29.920	delta- Cadinene	delcad	1.50	3.62	1.01	1.70	1.62	3.15	4.01	2.39
20.791	Linalyl acetate	linace	1.47	0.88	0.29	4.99	0.17	1.71	0.35	0.00
12.143	o-Cymene	ocym	1.38	0.90	1.33	1.11	1.29	0.82	0.90	1.97
29.746	gamma- Cadinene	gamcad	0.97	2.32	0.67	1.18	1.06	2.09	2.61	1.28
28.526	gamma- Muurolene	gammuu	0.97	2.41	0.69	1.08	1.01	1.94	2.79	1.86
6.468	Hex-2(E)-enol	hexe	0.90	0.00	0.41	0.00	0.00	0.00	0.00	0.00
29.291	alpha- Muurolene	alpmur	0.68	1.94	0.84	0.85	1.53	1.71	1.88	1.12
29.081	alpha- Amorphene	alpamo	0.63	1.69	0.59	0.67	1.21	1.39	1.72	0.81
4.562	Hexanal	hexa	0.62	0.07	0.99	0.24	0.40	0.06	0.08	0.00
6.586	n-Hexanol	nhex	0.44	0.00	0.16	0.00	0.00	0.00	0.00	0.33
20.894	Piperitone	pipe	0.43	0.32	1.57	0.20	2.10	0.22	0.25	1.20
13.469	gamma- Terpinene	gamter	0.38	0.27	0.34	1.07	0.40	0.25	0.39	0.18
11.842	alpha- Terpinene	alphte	0.37	0.24	0.45	0.23	0.38	0.34	0.31	0.32
10.282	beta- Pinene	betpin	0.37	0.57	0.50	0.78	0.54	0.54	0.57	0.50
14.719	1-Methyl-4-isopropenylbenzene	metiso	0.36	0.28	0.26	0.23	0.40	0.25	0.17	0.00
28.091	(+)-Epi-bicyclosesquiphellandrene	epibic	0.34	1.14	0.16	0.36	0.36	0.66	1.27	0.46
25.217	alpha- Copaene	alpcop	0.27	0.82	0.38	0.26	0.39	0.43	0.60	0.49
23.818	delta- Elemene	delele	0.27	0.31	0.00	0.00	0.00	0.34	0.27	0.41
10.530	1-Octen-3-ol	oct	0.23	0.00	0.57	0.00	0.13	0.00	0.00	0.28
29.475	Farnesene <(E,E)-, alpha->	feea	0.23	0.46	0.00	0.00	0.19	0.40	0.52	0.00
27.034	gamma- Elemene	gamele	0.23	0.56	0.00	0.16	0.28	0.59	0.50	1.19
25.695	beta- Elemene	betele	0.22	1.09	0.12	0.14	0.24	1.02	1.02	0.87
18.747	alpha- Terpineol	alpterp	0.21	0.15	1.48	0.00	0.65	0.07	0.15	1.76
1.425	2-Propanone	pro	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.195	alpha- Fenchene	alpfen	0.20	0.03	0.07	0.09	0.06	0.07	0.03	0.01
27.555	Cadina-1(6),4-diene <10betaH->	cdb	0.20	0.54	0.12	0.19	0.19	0.47	0.59	0.18
13.060	Ocimene <(E)-, beta->	oeb	0.19	0.00	0.62	0.55	0.00	0.30	0.12	0.00
25.489	beta- Bourbonene	betbou	0.16	0.68	0.00	0.11	0.30	0.46	0.59	0.76
15.150	Linalool	linal	0.16	0.00	0.45	0.17	0.00	0.00	0.00	0.21
1.355	Ethanol	etha	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.27
11.150	2-Carene	care	0.10	0.23	0.16	0.00	0.19	0.29	0.30	0.26
9.271	Camphene	camph	0.09	0.11	0.11	0.24	0.12	0.08	0.12	0.07
10.137	Sabinene	sabi	0.04	0.09	0.09	0.08	0.07	0.07	0.04	0.11
26.860	beta- Cedrene	betced	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00
17.980	Isopulegon	iso	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00
30.641	alpha- Calacorene	alpcal	0.00	0.14	0.00	0.00	0.00	0.21	0.15	0.51
32.715	alpha- Cedrol	alpced	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00
24.998	alpha- Ylangene	alpyla	0.00	0.21	0.00	0.00	0.00	0.18	0.25	0.17
20.011	beta -Citronellol	betcit	0.00	0.33	0.00	0.00	0.32	0.00	0.10	0.00
28.968	beta- Selinene	betse	0.00	0.42	0.00	0.14	0.14	0.35	0.50	0.36
26.566	Cedrene	cedr	0.00	0.00	0.00	0.46	0.00	0.00	0.00	0.00
27.669	cis-Muurola-3,5-diene	cmd	0.00	0.51	0.12	0.00	0.00	0.30	0.38	0.14
12.652	cis-Ocimene	ciso	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00
31.634	Citronellyl propionate	citpr	0.00	0.13	0.00	0.00	0.00	0.28	0.06	0.00
29.209	Eudesma-3,7(11)-diene	euddie	0.00	0.81	0.20	0.36	0.32	0.68	0.90	0.53
31.171	Germacrene B	gerb	0.00	0.00	0.00	0.00	0.00	0.32	0.00	1.18
15.508	Rose oxide	rosoxi	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.16
8.275	Tricyclene	tric	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00

Elevation (m) code: lf1:98, lf2:157, lf3:257, lf4: 345, lf5:430, lf6:570, lf7:610, lf8:650

Table S3. Volatile compound specific to leaves and cones

Components	Code	cn1	cn2	cn3	cn4	cn5	cn6	cn7	cn8	lf1	lf2	lf3	lf4	lf5	lf6	lf7	lf8
Hex-3(Z)-enol	hze	ND	ND	ND	ND	ND	ND	ND	ND	3.95	0.33	1.92	0.99	1.31	0.6	0.61	3.93
Hex-2(E)-enol	hexe	ND	ND	ND	ND	ND	ND	ND	ND	0.9	0	0.41	0	0	0	0	0
alpha- Amorphene	alpamo	ND	ND	ND	ND	ND	ND	ND	ND	0.63	1.69	0.59	0.67	1.21	1.39	1.72	0.81
n-Hexanol	nhex	ND	ND	ND	ND	ND	ND	ND	ND	0.44	0	0.16	0	0	0	0	0.33
1-Octen-3-ol	octol	ND	ND	ND	ND	ND	ND	ND	ND	0.23	0	0.57	0	0.13	0	0	0.28
2-Propanone	prop	ND	ND	ND	ND	ND	ND	ND	ND	0.2	0	0	0	0	0	0	0
Linalool	lina	ND	ND	ND	ND	ND	ND	ND	ND	0.16	0	0.45	0.17	0	0	0	0.21
beta- Bourbonene	betbou	ND	ND	ND	ND	ND	ND	ND	ND	0.16	0.68	0	0.11	0.3	0.46	0.59	0.76
cis-Ocimene	cisoci	ND	ND	ND	ND	ND	ND	ND	ND	0	0	0	0.14	0	0	0	0
Rose oxide	rosoxi	ND	ND	ND	ND	ND	ND	ND	ND	0	0	0	0	0.15	0	0	0.16
Isopulegon	isop	ND	ND	ND	ND	ND	ND	ND	ND	0	0	0	0	0.12	0	0	0
Cedrene	cedr	ND	ND	ND	ND	ND	ND	ND	ND	0	0	0	0.46	0	0	0	0
beta- Cedrene	betced	ND	ND	ND	ND	ND	ND	ND	ND	0	0	0	0.13	0	0	0	0
Citronellyl propionate	citpro	ND	ND	ND	ND	ND	ND	ND	ND	0	0.13	0	0	0	0.28	0.06	0
Camphor	camph	0.2	0.21	0.23	0.45	0.2	0.3	0.16	0.19	ND	ND	ND	ND	ND	ND	ND	ND
(E)-2,6-Dimethyl-1,3,5,7-octatetraene	edo	0.19	0	0.05	0.18	0.14	0.12	0	0.18	ND	ND	ND	ND	ND	ND	ND	ND
(E)-2,3-Epoxycarane	eepo	0.14	0	0	0.16	0.1	0.08	0	0.08	ND	ND	ND	ND	ND	ND	ND	ND
4-Terpinenyl acetate	terpac	0.12	0.47	0	0.21	0	0	0	0	ND	ND	ND	ND	ND	ND	ND	ND
Terpinen-4-ol	terol	0.05	0.09	0	0	0	0	0	0	ND	ND	ND	ND	ND	ND	ND	ND
alpha- Thujene	alpthu	0	0	0	0	0	0	0.07	0.07	ND	ND	ND	ND	ND	ND	ND	ND
trans-Verbenol	traver	0	0	0.08	0.12	0	0	0	0	ND	ND	ND	ND	ND	ND	ND	ND
Campholaldehyde	campho	0	0	0.19	0.27	0.04	0.04	0	0	ND	ND	ND	ND	ND	ND	ND	ND
Dihydrocarveol	dihy	0	0.2	0.35	0.43	0	0	0	0	ND	ND	ND	ND	ND	ND	ND	ND
Verbenone	verb	0	0	0.19	0.33	0.06	0.08	0	0	ND	ND	ND	ND	ND	ND	ND	ND
Carvone	carv	0	0	0	0.1	0	0	0	0	ND	ND	ND	ND	ND	ND	ND	ND
Methyl citronellate	metcit	0	0.41	0	0	0	0.33	0	0	ND	ND	ND	ND	ND	ND	ND	ND
Bornyl acetate	borace	0	0	0	0	0.11	0	0	0	ND	ND	ND	ND	ND	ND	ND	ND
(E,Z)-2,4-Decadienal	ezd	0	0.22	0	0	0	0	0	0.13	ND	ND	ND	ND	ND	ND	ND	ND
alpha- Elemol	alpele	0	0	0	0	0	0.1	0.11	0	ND	ND	ND	ND	ND	ND	ND	ND
Caryophyllene oxide	caroxi	0	0	0.25	0.19	0.05	0.05	0	0	ND	ND	ND	ND	ND	ND	ND	ND

ND: not detected cn: cone lf: leaf.