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Changes of Essential Oil Content and Composition of Rose-Scented Geranium (*Pelargonium Graveolens* L'Her.) Cultivated at Different Province of Türkiye

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ABSTRACT

Pelargonium graveolens (rose-scented geranium) plants have been used since ancient times in food, cosmetics, perfumery, traditional medicine, and the pharmaceutical industries due to the pleasant fragrance of the essential oil obtained from its leaves. In this study, the essential oil content and components of rose-scented geranium cultivated in two different regions, Kırşehir in Central Anatolia and Adana in the Eastern Mediterranean, were investigated. The essential oil content of the plants from Kırşehir was determined to be 0.70%, while that of the plants from Adana was 0.34%. The main components of the essential oil of geranium cultivated in Kırşehir were citronellol (35.05%), geraniol (8.29%), and citronellyl formate (10.59%). In Adana, the essential oil components were citronellol (29.71%), geraniol (4.31%), and citronellyl formate (16.10%). The study shows that different locations significantly affect the essential oil content and chemical composition of rose-scented geranium.

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Introduction

Plants have been used for various purposes such as food and drug for centuries. The agricultural techniques developed have made the forms and techniques of using plants in various industrial fields have become more widespread with innovative methods and technologies. These advancements have increased the diversity and usage areas of seconder metabolites obtained from plants. Today, the constant addition of new active ingredients to the known active ingredients of medicinal and aromatic plants reveals additional new industrial uses such as medicines, cosmetics, perfumes, dyes, spices, bioactivators, biopesticides and herbal teas (Kırıcı et al. 2020). One of these, essential oils, is an important category of herbal products obtained from the aromatic components of plants and used in various industrial fields such as cosmetics, food, and medicine.

Essential oils are defined as natural raw materials and products obtained by methods such as distillation and pressing within the framework of standardization studies carried out by the International Organization for Standardization (ISO, 2021). Essential oils are used in many areas as natural products. Among these, aromatherapy, medicine, food, and perfumery are the most important ones.

Pelargonium graveolens L'Her. (scented geranium, geranium, rose-scented geranium) is a perennial, drought-resistant, important aromatic plant from the Geraniaceae family, which includes approximately 270 different species. *Pelargonium* species are also widely used in essential oil production due to their different properties and scent diversity (Blerot et al. 2016). Although the homeland of the plant is South Africa, it has been introduced to Europe from Zimbabwe and Mozambique (Miller, 2002). *Pelargonium graveolens* is commercially cultivated for its highly valuable essential oil. *Pelargonium graveolens* oil is among the top 20 essential oils worldwide. Due to its soothing rose-scented aroma, it is widely used in perfumery and aromatherapy, as well as in pharmaceuticals, cosmetics, and as a flavoring agent (Kumar et al, 2022; Ćavar and Maksimović, 2012). *Pelargonium graveolens* is widely used as a fresh or dried culinary herb. It is also known for its pharmacological properties in the treatment of fever, diarrhea, bronchitis, gastroenteritis, diabetes, gallbladder problems, liver problems, urinary stones, respiratory diseases, and asthma attacks (Tahan and Yaman, 2013; Tajkarimi et al. 2010; Mainardi et al. 2009; Thomas et al. 2001). Other beneficial properties of geranium essential oil include antibacterial, antifungal, anti-inflammatory, spasmolytic, antidiabetic and hypoglycemic effects. Additionally, the essential oil of

Pelargonium graveolens and its major components were recognized as generally safe by the Flavor and Extract Manufacturers Association (FEMA) in 1965. FEMA No. 2508 Geranium, Roseoil-*Pelargonium graveolens* L'Her flavoring ingredient usage levels have been documented, and it has been reported that it can be used in foods such as beverages, ice cream, candy, baked goods, gelatins and puddings, and chewing gum (FEMA, 1965). Furthermore, geranium essential oil is generally recognized as safe (GRAS) and approved by the American Food and Drug Administration (FDA) (Cebi, 2021). Rose-scented aromatic oil is obtained from the leaves of *Pelargonium graveolens* by hydrodistillation (Ćavar et al. 2012; Saxena et al. 2008). This aromatic oil has wide uses in the perfumery, cosmetics, food and pharmaceutical industries. According to ISO (International Organization for Standardization) 4371-2012, *Pelargonium graveolens* essential oil from different geographical origins should have citronellol (18-43%), geraniol (5–20%), linalool (2-–11%), citronellyl formate (4-12%), isomenthone (4-10%), geranyl formate (1–8%), (*Z*)-r*ose* oxide (0.4-3.5%), menthone (0.0-2.5%) and geranyl tiglate (0.7-2.0%) as the main components (ISO, 2012). Furthermore, *Pelargonium graveolens* essential oil has a fragrance profile similar to *Rosa damascena* essential oil due to its high content of citronellol and geraniol. Owing to these characteristics, it is used as an alternative to rose oil in industries such as cosmetics, perfumery, and aromatherapy. Additionally, compared to rose oil, it offers a more economical and sustainable option, which is one of the reasons for its preference in the industry (Rezaei Nejad and Ismaili, 2014).

It is known that cultivating the same species of medicinal and aromatic plants in different locations causes variations in the plant's essential oil content and essential oil components (Özgüven and Kırıcı, 1998, Katar and Aytaç, 2019, Maral and Kırıcı, 2023). The reason for selecting these regions is that they offer distinct ecological and climatic characteristics. Adana is influenced by the Mediterranean climate, characterized by mild winters, high temperatures, and high humidity. In contrast, Kırşehir exhibits the continental climate of Central Anatolia, with lower temperatures, low humidity, and significant seasonal temperature variations. These distinct ecological differences provide an important opportunity to understand the environmental effects on the essential oil yield and chemical composition of *Pelargonium graveolens*. The aim of this study is to examine the effect of two different locations (Kırşehir and Adana) on the essential oil content and essential oil components of *Pelargonium graveolens* plants. Thus, the influence of ecological factors on the essential oil composition of *Pelargonium graveolens* will be better explained, providing significant data for the cultivation and industrial utilization of this plant.

Materials and Methods

Plant Material

Pelargonium graveolens plants found in the AHIGETAM Medicinal and Aromatic Plants Research and Application Area of Ahi Evran University in Kırsehir and in the trial area of Medicinal and Aromatic Plants area of Field Crops Department, Çukurova University Faculty of Agriculture, in Adana were used as material in the research.

Kırşehir province is located in the Central Kızılırmak Section of the Central Anatolia Region. It is located at an altitude of 985 m above sea level. Kırşehir has a typical continental climate that is dominant in the Central Anatolia Region. Winters are cold and lightly rained, summers are hot and dry. The annual average precipitation is 383.3 mm. The winter average temperature is 0.8°C, the summer average temperature is 21.8°C, and the annual average temperature is 11.3°C (Kıymaz, 2011). Adana province is located in the Eastern Mediterranean Section of the Mediterranean Region. Adana, which has Mediterranean climate characteristics and has altitudes between 0 and 3756 meters from the Mediterranean coast to the central Taurus Mountain range, has hot and dry summers and mild and rainy winters (Aksu, 2016). The annual average precipitation is 668.2 mm. The lowest average temperature is 14.0°C, the highest average temperature is 25.4°C, and the annual average temperature is 19.3°C (MGM, 2024).

According to the analysis results made on the soil samples taken to determine the soil properties of the study locations. The texture structure of the locations is clayey-loamy for Kırşehir. It was observed that the pH values of the locations were 7.98 in Kırşehir and the soils of the study areas were slightly alkaline. Additionally, the amount of organic matter was determined to be 1.04% in Ankara Soil, Fertilizer and Water Resources Central Research Institute Directorate. The soils in the Adana location consist of flat and nearly flat topography and have young alluvial structure brought by the tributaries of the Seyhan River. They are soils with gravel deposits at various depths ranging from brown to pale brown, with a high amount of lime in the entire profile and a low amount of organic matter (Özbek et al. 1974). According to the analysis results of the sample taken from the trial area in Ç. Ü. Faculty of Agriculture, Department of Soil Science and Plant Nutrition laboratory, the soil pH is 7.49 and generally shows a slightly alkaline feature. The amount of organic matter was determined to be 1.4% in Adana.

The cultivated geranium plants during a one-year vegetative cycle were harvested at the beginning of flowering both locations. While the plants started to bloom in April in Adana ecological conditions, they bloomed in September in Kırşehir conditions. Fresh plants samples were separated into leaf and branch parts after harvesting. Leave samples were dried in the shade in the room conditions.

Essential Oil Yield (%)

Water distillation method was used to obtain the essential oil yield of the *Pelargonium graveolens* plant. 100 g dried leaves of the geranium were subjected to water distillation for 3 hours and essential oil was obtained. Volumetric (ml/100g) essential oil yield was determined with Clevenger type essential oil equipment. Essential oil analysis was carried out in 3 parallel studies. Essential oils were stored at 4±1°C until analyzed. The relative percentages of the separated compounds were calculated from the total ion chromatograms through GC-MS analysis. The identification of the oil components was based on the Wiley and NIST mass spectral libraries

Determination of Essential Oil Components

The chemical composition of the obtained *Pelargonium graveolens* essential oil was determined by GC-MS. GC/MS analysis was carried out on a Agilent 6890N

Network GC system combined with Agilent 5973 Network Mass with Agilent 19091N-136 (HP Innowax Capillary; 60.0 m x 0.25 mm x 0.25 mm). The oven temperature was programmed from 60 to 240°C at 4°C/min. Helium was used as carrier gas at a flow rate of 1.2 ml/min. The chromatography was coupled to a Agilent 5973 Network mass selective detector. The MS operating parameters were ionization voltage, 70 eV. Identification of essential oil components was made by comparing mass spectra with Wiley and Nist GC-MS libraries. The percentage amounts of essential oil components were calculated from GC peak areas using the normalization method.

Results and Discussion

Essential oils were obtained from dry leaves of the *Pelargonium graveolens* (rose-scented geranium) plant cultivated in Kırşehir and Adana ecological conditions. The ratio of essential oils was determined 0.70% and 0.34% (w/w) in Kırşehir and Adana, respectively. Kırşehir samples had high essential oil content that of Adana's. That is due to the different ecological conditions in the regions where the plants grow. The essential oil content of *Pelargonium graveolens* plant varies depending on the ecological conditions in which it is grown. *Pelargonium graveolens* essential oil content was 0.84 % in Tunisia (Mnif et al. 2011). In recent years, the increasing demand for phytochemicals from different industries has increased the interest in aromatic plants, especially essential oils. This has accelerated the production of aromatic plants (Pandey et al. 2020). Determining the yield and quality parameters of essential oils obtained from aromatic plants is an industrially important issue. The main factors that affect the essential oil content and compositions are different ecological conditions, harvest times and drying methods (Katar et al. 2020; Bağci et al. 2017; Çalışkan et al. 2017; Telci et al. 2006; Kothari et al. 2004). Studies have reported that essential oil yields and their components are related to genetics, climate factors, soil conditions, vegetative or flowering stages, organogenesis and the anatomical part of the plant (Gudaitytė and Venskutonis 2007; Nemeth 2005). All these results show that medicinal and aromatic plants should be tested in different ecologies to determine suitable growing regions.

The quantitative and qualitative composition of the oils is presented in Table 1. 16 components defined as common in the two provinces: alpha- Pinene, Linalool, Rose oxide cis, Rose oxide trans, Isomenthone, alpha- Terpineol, Citronellol, Geraniol, Citronellyl formate, Citronellyl acetate, gamma- Cadinene, Isoledene, Geranyl butyrate, Caryophyllene, Citronellyl tiglate, Geranyl butanoate. It was determined that there was difference in composition from the differences in the amounts of the main components of the essential oils: the highest amount of Citronellol was obtained from Kırşehir province with 35.05%, while it was obtained from Adana province as 29.71%. Geraniol, the other characteristic component of geranium oil, was obtained at the highest rate in Kırşehir at 8.29%, while it was obtained at 4.31% in Adana. While the highest amount of Citronellyl formate was obtained from Adana with 16.10%, it was obtained from Kırşehir with 10.59%. While the amount of linalool was highest in Kırşehir, 6.51%, it was found to be 2.78% in Adana. The amount of rose oxide cis was determined as 2.58% in Kırşehir and 3.82 in Adana. Variation in the percentage composition of the main constituents in Kırşehir and Adana may be due to the variation in agroclimatic and geographical conditions.

In a study conducted under the conditions of Türkiye, the essential oil components of *Pelargonium graveolens* were investigated. Essential oil components Geraniol 25.40%, Citronellol 56.90%, alpha- Pinene 2.09%, Linalool 65.80%, Citronellyl formate 84.10%, Rose oxide cis 12.25%, Isomentone 78.70%, It was found to be 7.33% (Aydınlık et al. 2021). Karimi et al. (2024), in their study in Azbeycan, determined the essential oil components as Citronellol 27%, Linalool 1.1%, Geraniol 25%, Citronellyl formate 8.4%. In a study conducted in Brazil, which has a tropical climate, the main active components of rose-scented geranium essential oil were found to be α-Pinene (0.35%), Rose oxide (0.33%), Citronellol (23%), Cis-Geraniol (21.33%), Citronellyl formate (9.74%), and Ledene (1.48%) (Dos Santos et al., 2024). The amount of Citronellol in the essential oil components of *Pelargonium graveolens* harvested at the beginning of flowering period in Morocco was determined. Geraniol was determined as 15.05%, Citronellyl formate as 2.06%, Menthol as 14.06%, alpha-Pinene as 5.64%, 3-Carene as 3.31%, Isoledene as 0.61% (Al-Mijalli et al. 2022). In another study, the essential oil components of *Pelargonium graveolens* in India were Geraniol 23.62%, Citronellyl formate 12.14%, Linalool 10.81%, p-menthan-3-one 6.76%, β-guaiene 5%, 68, geranyl propionate was reported as 3.12%, α-terpineol as 0.65% (Gauri Saxena et al. 2008). Stegmayer et al., (2022) reported that the main components of the essential oil obtained by steam distillation from *Pelargonium graveolens* cultivated in Esperanza were geraniol (24.89%) and citronellol (19.50%). In in vitro fungicidal tests, they determined that this essential oil completely inhibited the growth of the phytopathogen *Botrytis cinerea*, which was isolated from infected flowers. According to the GC-MS analysis results of *Pelargonium graveolens* collected from another region of Morocco with a different ecology, the main components were determined as epi-γ-Eudesmol (16.67%), Geraniol (12.54%), β-Citronellol (12.34%), Citronellyl formate (7.70%), and Geranyl tiglate (5.21%). Additionally, the essential oil and its fractions of this plant were reported to exhibit bactericidal effects against *Escherichia coli* and *Salmonella typhimurium* (Zakya et al, 2024). Jaradat et al. (2022) reported that the essential oil yield of *Pelargonium graveolens*, collected in Palestine and obtained using a Clevenger apparatus, was 1.01%. The major components of this oil were identified as citronellol (24.44%), geraniol (1.57%), citronellyl formate (15.63%), γ-eudesmol (8.6%), isomenthone (7.43%), and linalool (2.45%). Studies conducted in different locations show that the essential oil components of *Pelargonium graveolens* are significantly influenced by climatic and ecological conditions. While main components such as citronellol and geraniol are found in various geographical conditions, their proportions vary from region to region. These differences provide important insights into the plant's ecological adaptations and industrial applications. The studies suggest that the plant may exhibit different biological activities in different geographical areas, and as a result, these components may have various industrial uses. In

conclusion, the essential oil components and biological properties of *Pelargonium graveolens* can vary according to regional climatic factors, which provides valuable data for agricultural production strategies and industrial utilization planning.

According to ISO, when the essential oils of the *Pelargonium graveolens* (rose-scented geranium) plant are obtained from different geographical origins. The essential oils must contain certain components including citronellol, geraniol, linalool, citronellyl formate, isomenthone, geranyl formate, rose oxide cis and geranyl tiglate (ISO, 2012). In this study, it was observed that the two major components of *Pelargonium graveolens*, citronellol and geraniol were within the ranges specified by ISO in Kırşehir and Adana provinces. While citronellal is in the range of 18-43% according to ISO, it was detected as 35.05% in Kırşehir and 29.71% in Adana. While geraniol is in the range of 5-20% according to ISO. it was found to be 8.29% in Kırşehir and 4.31% in Adana. It was determined that the amounts of citronellyl formate, rose oxide cis, and geranyl tiglate detected in Kırşehir and Adana provinces were within the range determined by ISO; moreover, the amounts of these components exceeded the values specified by ISO. (Tablo 1).

The main components of geranium essential oil are citronellol, geraniol, citronellyl formate, and isomenthone, which constitute 65.54% of the essential oil in the Kırşehir region and 55.41% in the Adana region. The main component, citronellol, is an aromatic alcohol and is used as a fragrance ingredient or fragrance enhancer in creams, lotions, and bath products. It has less skin permeability and therefore lasts longer as a scent. It is also used as a mosquito repellent in various products (URL, 1). Citronellyl acetate, a terpene ester with a distinctive scent that is widely manipulated in a variety of perfumes with scents of rose, lily, lavender, carnation, apple, and lemon. Additionally, it is employed in producing food, medicine, and cosmetics. Because of this, there is a high demand for citronellyl acetate in the market, but the natural form obtained by directly extracting rose or other plants does not fulfill the specifications (Haq et al. 2024). Geraniol is a commercially important terpene alcohol occurring in the essential oils of several aromatic plants like geranium. It is one of the most important molecules in the flavour and fragrance industries and is a common ingredient in consumer products produced by these industries. In addition to its pleasant odour, geraniol is known to exhibit insecticidal and repellent properties (Chen and Viljoen, 2010).

Table 1. Common Essential Oil Compounds of *Pelargonium graveolens* from Two Locations

RT	RI*	Compounds	Contents according to locations (%)	
			Kırşehir	Adana
6.525	933	alpha- Pinene	0.55	0.85
14.052	1112	Linalool	6.51	2.78
14.581	1120	Rose oxide cis	2.58	3.82
15.518	1136	Rose oxide trans	1.07	1.63
17.775	1173	Isomenthone	11.61	5.29
19.717	1208	alpha- Terpineol	0.54	0.38
22.074	1239	Citronellol	35.05	29.71
23.518	1262	Geraniol	8.29	4.31
24.914	1275	Citronellyl formate	10.59	16.10
29.894	1361	Citronellyl acetate	0.59	3.32
39.920	1512	gamma- Cadinene	0.16	1.36
40.534	1528	Isoledene	0.26	1.24
43.953	1585	Geranyl butyrate	1.07	1.47
45.313	1606	Caryophyllene	0.11	0.38
49.018	1664	Citronellyl tiglate	0.35	2.38
50.957	1707	Geranyl butanoate	0.47	2.05

RI: Retention indices relative to C8 to C24 *n*-alkanes.

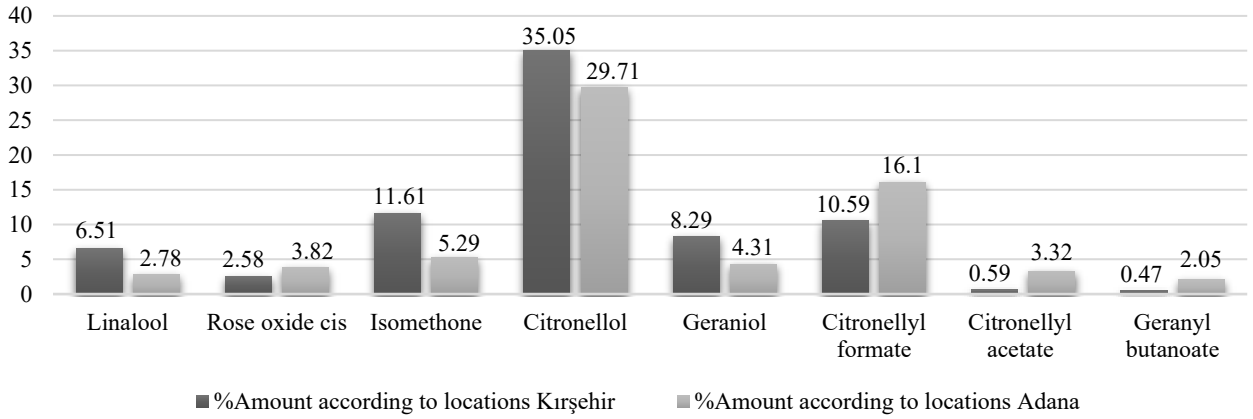

Figure 1. Common Essential Oil Components of the Two Location

Due to the main components contained in its essential oil, the geraniol plant is used in many areas, especially in the fragrance industry, and growing it in high quality in suitable ecologies is important for the country's economy. The components of plant essential oils are mainly terpenes and phenylpropanoids. Various factors, including growing conditions, altitude, climate, soil type, agricultural methods and practices, developmental stages, plant part used and harvest time are the most important factors in influencing the chemical composition and proportions of essential oil-bearing plants. Distribution modeling of medicinal aromatic plants in Nepal Himalaya due to climate change also supports these factors (Shrestha et al. 2022; Moghaddam and Mehdizadeh 2017). Studies have revealed that essential oil yields, chemical compositions and therefore biological activities vary depending on the maturity of the plant, harvest period, extraction process and geographical location (Elbali et al. 2018; Mohammedi et al. 2020).

Conclusion

Pelargonium graveolens essential oil has a similar scent profile to *Rosa damascena* essential oil due to its high content of citronellol and geraniol components. Additionally, it is preferred in the industry because it offers a more economical and sustainable alternative compared to rose oil. Due to its scent profile resembling *Rosa damascena* essential oil, it is used as an alternative to rose oil in industries such as cosmetics, perfumery, and aromatherapy. The quality of the commercially available *Pelargonium graveolens* essential oil varies depending on the ratios of its active components and several factors. Since the cultivation methods of *Pelargonium graveolens* have not been widely established, research on the plant is limited. This study aims to provide scientific findings on how the essential oil yield and chemical composition of the plant change under different ecological conditions, providing data for producers and establishing a foundation for agricultural production. Thus, it is intended to evaluate the industrial potential of the plant and contribute to the development of regional agricultural strategies. The study found that citronellol, geraniol, and citronellyl formate were the main components of *Pelargonium graveolens* essential oil at both locations. It was evaluated that the main components in the essential oil content profile were common, and the differences in their amounts were due to environmental factors and climatic conditions. When the essential oil composition of *Pelargonium graveolens* (rose-scented geranium) was examined in both ecological conditions, it was shown that the plant was suitable for cultivation in both Kırşehir and Adana conditions, as the major components met ISO standards. Although it was shown that both Kırşehir in Central Anatolia and Adana in the Eastern Mediterranean region are suitable for obtaining high-quality essential oil from rose-scented geranium, further research is needed to increase these values and determine leaf yields.

References

Aksu, H. H., (2016). Adana'nın Coğrafi Bilgi Sistemleri (CBS) Tabanlı Nem Dağılışı. TÜCAUM Uluslararası Coğrafya Sempozyumu *International Geography Symposium* 13-14 Ekim 2016 /*13-14 October 2016*. Ankara. Bildiri Kitabı: 845-858.

Al-Mijalli, S. H., Mrabti, H. N., Assaggaf, H., Attar, A. A., Hamed, M., Baaboua. A. E., ... & Bouyahya, A. (2022). Chemical profiling and biological activities of *Pelargonium graveolens* essential oils at three different phenological stages. *Plants*. *11*(17). 2226.

Aydınlık, P., & Yuceer, Y. (2021). Mikrodalga Destekli Hidrodistilasyon Yöntemiyle Elde Edilen *Pelargonıum Graveolens* (Itır) Esansiyel Yağının Karakteristik Bazı Özellikleri. *Gıda*, *46*(5), 1117-1131.

Bağci, Y., Kan, Y., Doğu, S., & Çelik, S. A., (2017). The essential oil compositions of *Origanum majorana* L. cultivated in Konya and collected from Mersin-Türkiye. *Indian J. Pharm. Educ. Res*. *51*(3). 463-469.

Blerot, B., Baudino, S., Prunier, C., Demarne, F., Toulemonde, B., & Caissard, J. C., (2016). Botany agronomy and biotechnology of Pelargonium used for essential oil production. *Phytochemistry Reviews*. *15*. 935-960. ının Karakteristik Bazı Özellikleri. *Gıda*. *46*(5). 1117-1131.

Ćavar, S., & Maksimović, M. (2012). Antioxidant activity of essential oil and aqueous extract of Pelargonium graveolens L'Her. *Food control*, *23*(1), 263-267.

Cebi N., (2021). Chemical fingerprinting of the Geranium (*Pelargonium graveolens*) essential oil by using FTIR. Raman and GC-MS techniques. *Avrupa Bilim ve Teknoloji Dergisi*. (25). 810-814.

Chen, W., Viljoen, A.M., (2010). Geraniol — A review of a commercially important fragrance material. South African Journal of Botany, Volume 76, Issue 4, October 2010, Pages 643-651 https://doi.org/10.1016/j.sajb.2010.05.008

Ćavar, S., & Maksimović, M., (2012). Antioxidant activity of essential oil and aqueous extract of *Pelargonium graveolens* L'Her. *Food control*. *23*(1). 263-267.

Çalışkan, T., Maral, H., Prieto, L. M. V. G., Kafkas, E., & Kırıcı, S., (2017). The influence of different drying methods on essential oil content and composition of peppermint (*Mentha piperita* L.) in Çukurova conditions.

Dos Santos, F. N., Fonseca, L. M., Jansen-Alves, C., Crizel, R. L., Pires. J. B., Kroning, I. S., ... & da Rosa Zavareze, E., (2024). Antimicrobial activity of geranium (Pelargonium graveolens) essential oil and its encapsulation in carioca bean starch ultrafine fibers by electrospinning. *International Journal of Biological Macromolecules*. *265*. 130953.

Elbali, W., Djouahri, A., Djerrad, Z., Saka, B., Aberrane, S., Sabaou, N., ... & Boudarene, L., (2018). Chemical variability and biological activities of *Marrubium vulgare* L. essential oil. depending on geographic variation and environmental factors. *Journal of Essential Oil Research*. *30*(6). 470-487.

FEMA (Flavoring Extract Manufacturer's Association), (1965). Survey of flavoring ingredient usage levels. No. 2508.

Gauri Saxena, G. S., Laiq-ur-Rahman, L. U. R., Verma, P. C., Suchitra Banerjee, S. B., & Sushil Kumar, S. K., (2008). Field performance of somaclones of rose scented geranium (Pelargonium graveolens L'Her Ex Ait.) for evaluation of their essential oil yield and composition.

Gudaitytė, O., & Venskutonis. P. R., (2007). Chemotypes of Achillea millefolium transferred from 14 different locations in Lithuania to the controlled environment. *Biochemical systematics and ecology*. *35*(9). 582-592.

Haq, N., Liaquat, M., Jahangir, M., Khan, A., Khan, AA., Haq, T., Aziz, T., Alharbi, M., (2024). Enzymatic synthesis and parameters affecting on citronellyl acetate ester by trans-esterification reaction. Polish *Journal of Chemical Technology, 26, **3**, 8—15, 10.2478/pjct-2024-0022.* DOI: 10.2478/pjct-2024-0022

Jaradat, N., Hawash, M., Qadi, M., Abualhasan, M., Odetallah, A., Qasim, G., ... & Al-Maharik, N. (2022). Chemical markers and pharmacological characters of Pelargonium graveolens essential oil from Palestine. *Molecules*, *27*(17), 5721.

Karimi, N., Hasanvand, S., Beiranvand, A., Gholami, M., & Birjandi, M., (2024). The effect of Aromatherapy with *Pelargonium graveolens* (*P. graveolens*) on the fatigue and sleep quality of critical care nurses during the COVID-19 pandemic: A randomized controlled trial. *Explore*. *20*(1). 82-88.

Katar, N. & Aytaç, Z., (2019). Sater (*Satureja hortensis* L.) genotiplerinin farklı lokasyonlarda agronomik ve kalite özelliklerinin belirlenmesi. Ziraat Fakültesi Dergisi. 14(2). 253-269

Katar, D., Can, M., & Katar, N., (2020). Farklı lokasyonların lavandin (Lavandula× intermedia Emeric ex Loisel.)'de uçucu yağ oranı ve kimyasal kompozisyonu üzerine etkisi. *Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi*. *6*(3). 546-553.

Kıymaz, S., (2011). Kırşehir İli Toprak ve Su Kaynaklarının Tarımsal Açıdan Değerlendirilmesi. Süleyman Demirel Üniversitesi Ziraat Fakültesi Dergisi 6 (2):76-85. 2011 ISSN 1304-9984.

Kothari, S. K., Bhattacharya, A. K., & Ramesh, S., (2004). Essential oil yield and quality of methyl eugenol rich *Ocimum tenuiflorum* Lf (syn. O. sanctum L.) grown in south India as influenced by method of harvest. *Journal of Chromatography A*. *1054*(1-2). 67-72.

Kumar, N., Ghosh, D., Chaudhary, N., & Chanotiya, C. S. (2022). Rainfall-induced premature senescence modulates biochemical and essential oils profiles in Pelargonium graveolens L′ Hér. under sub-tropical climate. *Industrial Crops and Products*, *178*, 114630.

ISO, (2012). ISO 4731. 2012. Essential oil of geranium (*Pelargonium × ssp.). International Standard. Third Edition 2012*–12–5. ISO Copyright Office. Switzerland **12**. 1–4.

ISO 9235, 2021. Aromatic natural raw materials.

Miller, D.M., The taxonomy of pelargonium species and cultivars. their origins and growth in the wild. Geranium and pelargoniums: the genera geranium and pelargo-nium. In: Medicinal and Aromatic Plants-Industrial Profiles. Edit. M. Lis-Balchin. pp. 49–79. Taylor and Francis. London, (2002).

Mainardi, T., Kapoor S., & Bielory, L., (2009). Complementary and alternative medicine: herbs. phytochemicals and vitamins and their immunologic effects. *Journal of Allergy and Clinical Immunology*. *123*(2). 283-294.

Maral, H., & Kırıcı, S., (2023). Some Yield and Quality Properties of Endemic Origanum husnucan-baserii Grown in Different Ecological Conditions. Tekirdağ Ziraat Fakültesi Dergisi. 20(2). 243-253. https://doi.org/10.33462/jotaf.1012619

MGM, 2024. T.C. Çevre Şehircilik Ve İklim Değişikliği Bakanliği Meteoroloji Genel Müdürlüğü. https://www.mgm.gov.tr/Veridegerlendirme/il-ve-ilceler-istatistik.aspx?m=ADANA. Erişim tarihi 21.08.2024.

Mnif, W., Dhifi, W., Jelali, N., Baaziz, H., Hadded A., & Naceur, Hamdi, N., (2011). Characterization of Leaves Essential oil of *Pelargonium graveolens* Originating from Tunisia: Chemical Composition. Antioxidant and Biological Activities. Journal of Essential Oil Bearing Plants 14 (6) 2011 pp 761 – 769.

Moghaddam, M. & Mehdizadeh. L., (2017). Chemistry of essential oils and factors influencing their constituents. In *Soft chemistry and food fermentation* (pp. 379-419). Academic Press.

Mohammedi H., Mecherara-Idjeri, S., & Hassani, A., (2020). Variability in essential oil composition. antioxidant and antimicrobial activities of Ruta montana L. collected from different geographical regions in Algeria. *Journal of essential oil research*. *32*(1). 88-101.

Nemeth, E., (2005). Essential oil composition of species in the genus Achillea. *Journal of essential oil research*. *17*(5). 501-512.

Özbek, H., Dinç, U., & Kapur, S., (1974). Çukurova Üniversitesi Yerleşim Sahası Topraklarının Detaylı Temel Etüt ve Haritası. *Ziraat Fakültesi Yayınları Bilimsel Araştırma ve İncelemeler*, 8.

Özgüven, M., & Kırıcı S., (1999). Research on Yield. Essential Oil. Contents and Components of Mint (Mentha) Species inDifferent Ecologies. Turkish Journal of Agriculture and Forestry. 23(5). 465-472.

Pandey, A. K., Kumar P., Saxena. M. J., & Maurya, P., (2020). Distribution of aromatic plants in the world and their properties. In *Feed additives* (pp. 89-114). Academic Press.

Rezaei Nejad, A., and Ismaili, A. (2014). Changes in growth, essential oil yield and composition of geranium (Pelargonium graveolens L.) as affected by growing media. J. Sci. Food Agric., 94, 905–910.

Shrestha, U. B., Lamsal. P., Ghimire, S. K., Shrestha, B. B., Dhakal S., Shrestha S., & Atreya K., (2022). Climate change-induced distributional change of medicinal and aromatic plants in the Nepal Himalaya. *Ecology and Evolution*. *12*(8). e9204.

Stegmayer, M. I., Álvarez, N. H., Sager, N. G., Buyatti, M. A., & Derita, M. G. (2022). Evaluation of Pelargonium graveolens essential oil to prevent gray mold in rose flowers. *Journal of Plant Protection Research*, 145-152.

Tahan, F., & Yaman M., (2013). Can the Pelargonium sidoides root extract EPs® 7630 prevent asthma attacks during viral infections of the upper respiratory tract in children. *Phytomedicine*. *20*(2). 148-150.

Tajkarimi, M. M., Ibrahim, S. A., & Cliver, D. O., (2010). Antimicrobial herb and spice compounds in food. *Food control*. *21*(9). 1199-1218.

Telci I., Bayram, E., Yılmaz G., & Avcı, B., (2006). Variability in essential oil composition of Turkish basils (Ocimum basilicum L.). *Biochemical Systematics and Ecology*. *34*(6). 489-497.

Thomas, K., J., Nicholl, J. P., & Coleman, P., (2001). Use and expenditure on complementary medicine in England: a population-based survey. *Complementary therapies in medicine*. *9*(1). 2-11.

Url, 1. https://www.lesielle.com/tr/citronellol-nedir-in-kozmetik-inci-448, erişim tarihi: 22.08.2024

Zakya, M., Bouymajane, A., Riffi O., Filali, F. R., Ettarchouch M., Elhorri, M., Amechrouq A., (2024). Chemical Composition and Antibacterial Activity of Essential Oil of *Pelargonium Graveolens* and İts Fractions. *Arabian Journal of Chemistry,*vol., 17, Issue 1.