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Review paper

ESSENTIAL-OIL COMPOSITION OF PLANT SPECIES OF THE GENUS *PELARGONIUM*

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Abstract. *The Pelargonium genus, comprising various flowering plants commonly known as geraniums, is renowned for its essential oils, which have gathered significant attention for their aromatic and therapeutic properties. In this review, we summarize the current knowledge on the essential-oil composition of plant species within the genus Pelargonium. The review includes available data on the chemical composition of essential oils isolated from various plant organs, oil yields, odor characteristics, and the percentage of identified components, with highlighted composition variations based on geographical origin, environmental conditions, and extraction methods. Tables comparing the chemical composition are included for essential oils that underwent multiple analyses, while the structures of the major essential oil constituents are provided.*

Key words: *Pelargonium, essential oil, chemical composition*

1. INTRODUCTION

Essential oils (EO; syn. essence, volatile oil, or etheric oil) are complex mixtures of volatile compounds that can be isolated from plant material by water, steam, dry distillation, or, in the case of citrus fruits, by expression (Başer and Demirci, 2007). Their occurrence and function in nature are still subjects of ongoing research; however, there is evidence that essential oils play a crucial role in the defense and interaction of plants with other organisms (Başer and Demirci, 2007). Essential oils are among the most used and thriving natural products in the industry, with their fractions and constituents utilized in the flavor and fragrance, food, pharmaceutical industries, and ethnomedicine (Başer and

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Demirci, 2007). Essential oils represent a mixture of a large number of structurally diverse compounds, typically divided into different classes based on their chemical structure and biosynthetic origin (terpenoids and other non-terpenoid constituents such as phenylpropanoids, fatty acids, fatty acid-related constituents, etc.) (Başer and Demirci, 2007).

The genus *Pelargonium*, commonly known as geraniums, comprises approximately 230 perennial plant species and countless hybrids that have captivated botanists and horticulturists for centuries, earning a place in gardens, balconies, and windowsills around the world (Roman et al., 2023). The name is derived from the Greek word "pelargos" due to the shape of the geranium flower, which resembles a stork's beak (Vinereanu, 2011). Originating primarily from the Cape area in South Africa, *Pelargonium* taxa have now spread globally, adapting to a wide range of climates and growing conditions (Roman et al., 2023). *Pelargonium* species can be categorized into three different clades: those with evergreen leaves, those with multi-colored leaves, and those with flowers and fruits (Courtier, 2003). From ancient civilizations to modern-day practices, these plants have been utilized for their aromatic oils, medicinal properties, and culinary enhancements, showcasing their remarkable versatility and significance (Roman et al., 2023).

To date, essential oils of various species of the genus *Pelargonium* have been chemically investigated, resulting in the detection of a large number of chemically diverse compounds (Roman et al., 2023). Based on the obtained essential oil composition, Couic-Marinier and Laurain-Mattar classified essential oil samples into three groups: the Chinese variant, with a high amount of citronellol; the African variant, containing 10-*epi*-eudesmol; and the bourbon variant, consisting of a significant amount of guaia-6,9-diene, geraniol, and linalool (Couic-Marinier and Laurain-Mattar, 2018).

Through a comprehensive review of the essential oil composition of *Pelargonium* species, we aim to collect in one place all the hidden treasures within these botanical gems and inspire further exploration of their chemical composition and industrial purposes.

2. Chemical Composition of the Essential Oil

Geraniaceae is one of the five plant families, alongside Hypseocharitaceae, Vivianiaceae, Francoaceae, and Melianthaceae, belonging to the order Geraniales. The family comprises approximately 830 species distributed among five different genera: *Geranium* (430 species), *Pelargonium* (280 species), *Erodium* (80 species), *Monsonia* (40 species), and *California* (1 taxon) (Lis-Balchin, 2002). The genera *Geranium* and *Pelargonium* have been confused for over 200 years, even after Linnaeus introduced his binomial system of classification in 1753. Initially, both genera were placed under the genus *Geranium*. Although Sweet reclassified them into two separate genera in 1820, this distinction has gained minimal acceptance among the general public and nurserymen (Lis-Balchin, 2002). However, it seems that the main usage of *Geranium* species is in herbal medicine, while *Pelargonium*-derived 'geranium' oil is primarily used in perfumery, cosmetics, and aromatherapy products (Lis-Balchin, 2002). Table 1 provides a summary of the research, detailing the analyzed *Pelargonium* species, the plant organs from which essential oils are isolated, the locations and collection times, as well as the yield and odor characteristics of the obtained essential oil samples.

Table 1 Data on the investigated *Pelargonium* taxa for the content of essential oils

Plant species	Plant parts	Location	Collection time	Yield	[%][a]	Odor	Reference
P. asperum	Aerial parts	Ndrondroni-Mvouni, Grande Comore	Full bloom phase	0.4	99.9	-	Hassane et al., 2011
	Aerial parts	Taounate. Morocco	March 2013	0.15-0.4	73.9		Btissam et al., 2015
P. betulinum	Aerial parts	Kirstenbosch, Western Cape, South Africa	-	0.04	73.0	Camphoreous	Lalli et al., 2006
P. capitatum	Aerial parts	Western Cape, South Africa	-	0.02	75.3	Rose	Lalli et al., 2006
P. citronellum	-	Garcias Pass, South Africa	-	0.1–0.3	91.6	Lemon	Demarne and Van der Walt, 1993
		Farm Langberg, South Africa			86.0		
		Waterkloof, South Africa			82.1		
		Garcias Pass, South Africa			95.8		
P. citrosum	Leaves	Maryland	November 1991	-	-	-	Matsuda et al., 1996
	Stem	Camden	September 1992	-	-	-	
P. crispum	-	Worcester, England	-	0.49	96.5	Lemon	Sadgrove and Van Wyk, 2018
P. cv. Rosé	Leaves	Reunion Island	May-June	0.43	98.0	Rosy, fruity, minty	Gauvin et al., 2004
P. endlicherianum	Aerial parts	Develi, Kayseri Province, Turkey	July 2015	0.012	92.5	-	Dumlupinar et al., 2020
P. exstipulatum	Leaves	Pebworth, UK	July	-	88.5	Balsamic	Lis-Balchin and Roth, 2000
P. fragrans	Aerial parts	Pantnagar, India	Flowering phase	0.18	90.2	-	Verma et al., 2012
P. glutinosum	Aerial parts	Stellenbosch, Western Cape, South Africa	-	0.02	59.2	Amber	Lalli et al., 2006
P. graveolens	Aerial parts	Francavilla al Mare, Italy	September 2014	-	97.5	Mint	Rosato et al., 2018
	Leaves	Tulkarem, Palestine	June 2020	1.01	99.5		Jaradat et al., 2022
	Flowers	Sakiet Ezzitin Sfax, Tunisia	April 2011	0.13	93.5		Boukhris et al., 2013
	Leaves			0.19	96.2		
	Stems			0.04	93.2		
	Stem	-	August 2010	0.1	96.3		Ćavar and Maksimović, 2012
	Leaves			0.7	92.3		
	Aerial parts	Agadir, Morocco	April 2015	-	99.8		Moutaouafiq et al., 2019

	Aerial parts	Sahel Boutaher, Morocco	Vegetative stage	-	92.9		Al-Mijalli et al., 2022
			Flowering stage	-	92.9		
			Full flowering stage	-	93.0		
P. hispidum	Aerial parts	Stellenbosch, Western Cape, South Africa	-	0.02	97.3	Fruity	Lalli et al., 2006
P. hortorum	Aerial parts	Peking, China	August 2011	0.11	97.7	-	Liu et al., 2012
P. inquinans	Leaves	Eastern Cape, South Africa	December 2015	0.44	97.2	-	Tambeni et al., 2019
	Stem			0.76	96.4		
	Leaves			0.42	92.3		
	Stem			0.56	82.9		
P. odoratissimum	Leaves	Pebworth, UK	July	-	-	Green apple, clove	Lis-Balchin and Roth, 2000
P. panduriforme	Aerial parts	Western Cape, South Africa	-	0.48	92.0	-	Lalli et al., 2006
P. papilionaceum	Aerial parts	Kirstenbosch, Western Cape, South Africa	-	0.17	98.1	Lemon	Lalli et al., 2006
P. peltatum	Fresh leaf	Grahamstown, Eastern Cape, South Africa	-	1.6	90.8	Apple	Rungqu et al., 2023
	Dry leaf			2.3	75.1		
	Fresh twig			2.0	92.2		
	Dry twig			2.5	87.7		
P. quercetorum	Aerial parts	Kurdistan, Iran	May 2005	0.28	80.8	Herbal-pine	Taherpour et al., 2007
P. radens	Aerial parts	Kirstenbosch, Western Cape, South Africa	-	0.69	95.1	Mint	Lalli et al., 2006
P. reniforme	Leaves	Staffort, Stutensee, Germany	October 1992	0.71	49.0	-	Kayser et al., 1998
P. roseum	Leaves	Kashan, Iran	Jun 2015	-	99.6	Rose	Tabari et al., 2017
	Leaves	Morocco	-	-	99.9		Marinkovic et al., 2021
P. scabrum	Aerial parts	Kirstenbosch, Western Cape, South Africa	-	0.12	83.3	Apricot, lemon	Lalli et al., 2006
P. sidoides	Leaves	Staffort, Stutensee, Germany	October 1992	0.52	65.0	-	Kayser et al., 1998
P. tomentosum	Aerial parts	Walter Sisulu, Western Cape, South Africa	-	0.21	97.9	Peppermint	Lalli et al., 2006
P. vitifolium	Aerial parts	Stellenbosch, Western Cape, South Africa	-	0.05	91.3	Lemon balm, lemongrass	Lalli et al., 2006
P. zonale	Leaves	Egypt	Flowering phase	2.0	98.1	-	Kotb et al., 2024

[a] [%] - The percentage of the total detected areas of the GC chromatograms.

Notably, from Table 1, the yield of essential oil ranged between 0.12% and 2.5%, depending on the plant species or the plant organ subjected to the EO isolation. The main components of the EO from species of the genus *Pelargonium* are oxygenated monoterpenoid compounds and their derivatives. The most abundant monoterpene hydrocarbons identified in the EO of plants from this genus include camphene, 3-carene, *p*-cymene, limonene, *p*-menthane, *β*-myrcene, *α*- and *β*-pinene, sabinene, *α*- and *β*-phellandrene, *α*- and *β*-thujene, etc. (Fig. 1). The most dominant oxygenated monoterpenes are citronellal, citronellol, geranial, geraniol, nerol, and linalool (Fig. 2). The main sesquiterpene hydrocarbons and oxygenated sesquiterpenes detected in the essential oils are presented in Figs. 3 and 4.

Among the more than one hundred different phytoconstituents identified in essential oil samples isolated from *Pelargonium* taxa, aliphatic esters (including propyl formate, 2-methylpropyl formate, butyl formate, 2-methylbutyl formate, 3-methylbutyl formate, 3-methylpentyl formate, hexyl formate, benzyl tiglate, and (*Z*)-hex-3-en-1-yl acetate), aromatic esters (such as 2-phenylethyl acetate, 2-phenylethyl propionate, 2-phenylethyl isobutyrate, 2-phenylethyl butyrate, 2-phenylethyl isovalerate, and 2-phenylethyl tiglate), and esters of monoterpenic alcohols (including geranyl formate, geranyl acetate, geranyl propionate, geranyl isobutyrate, geranyl butyrate, geranyl 2-methylbutyrate, geranyl 3-methylbutyrate, geranyl tiglate, geranyl valerate, geranyl 3-methylvalerate, geranyl 4-methylvalerate, geranyl hexanoate, geranyl heptanoate, geranyl octanoate, geranyl nonanoate, citronellyl formate, citronellyl acetate, citronellyl propionate, citronellyl butyrate, citronellyl isovalerate, citronellyl tiglate, citronellyl valerate, citronellyl 4-methylvalerate, citronellyl hexanoate, citronellyl heptanoate, citronellyl octanoate, citronellyl nonanoate, and neryl formate) represent more than 50% of the total essential oil constituents (Fig. 5) (Narnoliya et al., 2019).

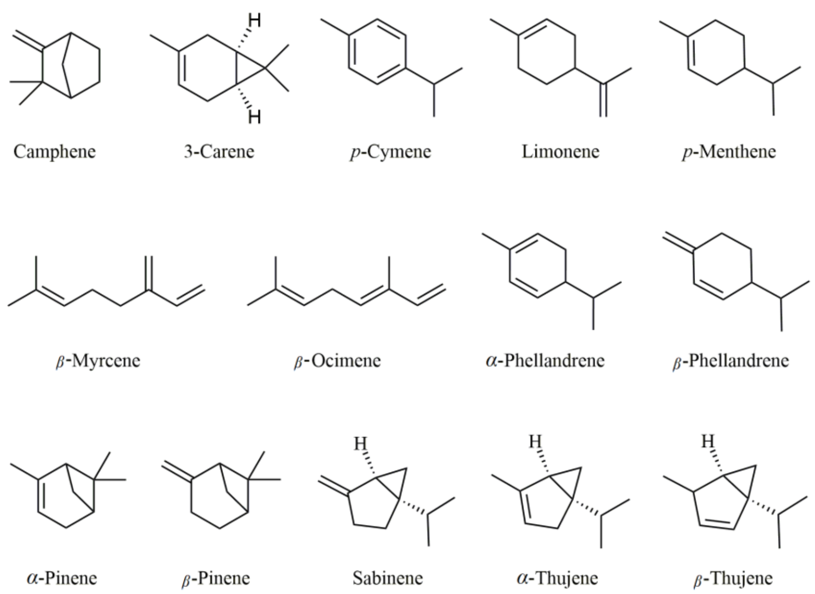

Fig. 1 Main monoterpene hydrocarbons found in the EO of *Pelargonium* species

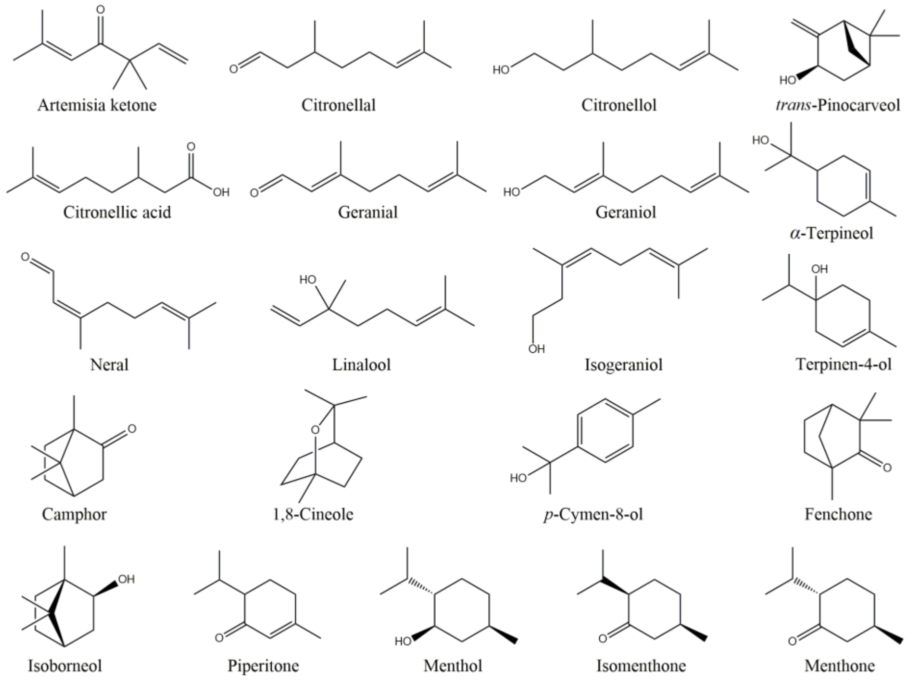

Fig. 2 Main oxygenated monoterpenes found in the essential oils of *Pelargonium* species

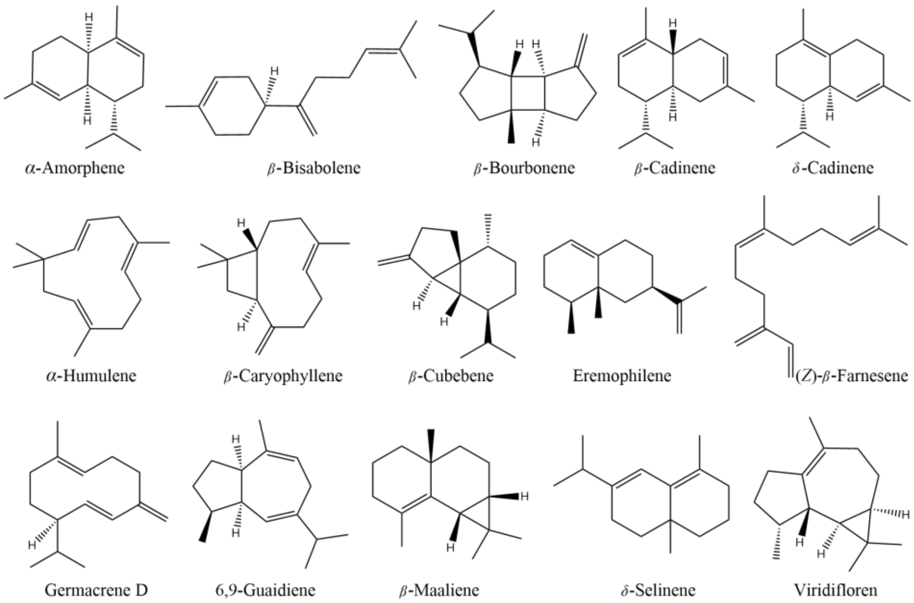

Fig. 3 Main sesquiterpene hydrocarbons found in the EO of *Pelargonium* species

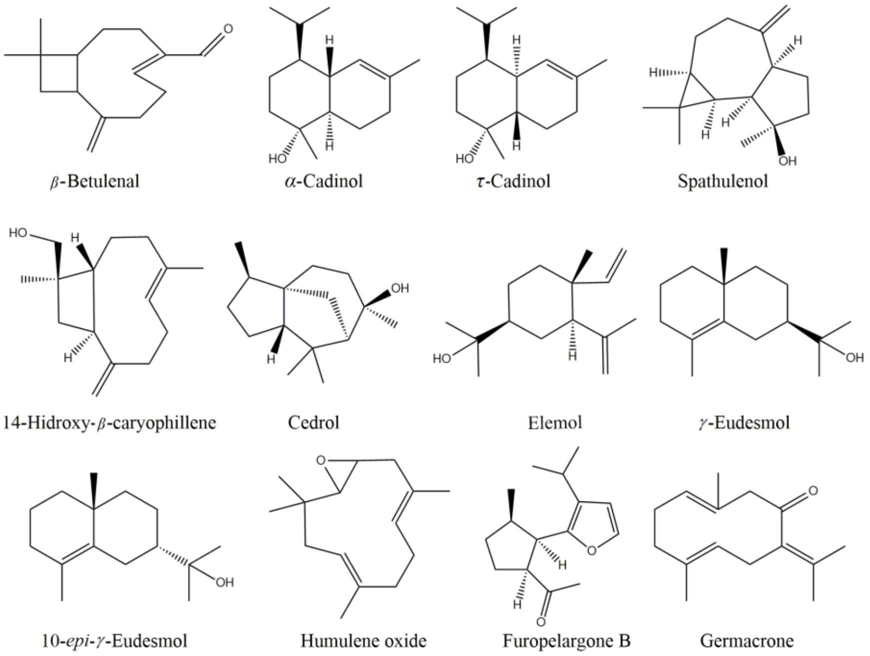

Fig. 4 Main oxygenated sesquiterpenes found in the essential oils of *Pelargonium* species

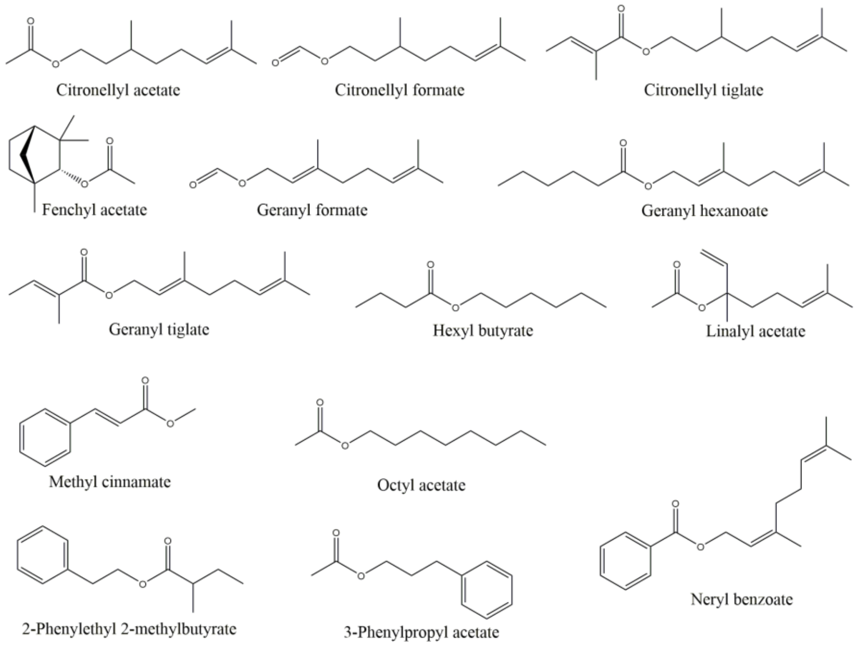

Fig. 5 Main esters found in the essential oils of *Pelargonium* species

The essential oil of *Pelargonium graveolens* has been extensively studied, revealing variations in its chemical composition depending on the analyzed plant part. Table 2 provides a comparison of the essential oils extracted from the aerial parts (Al-Mijalli et al., 2022; Moutaouafiq et al., 2019; Rosato et al., 2018), flowers (Boukhris et al., 2013), leaves (Boukhris et al., 2013; Jaradat et al., 2022; Ćavar et al., 2012), and stems (Boukhris et al., 2013; Ćavar et al., 2012). Rosato et al. (2018) identified citronellol (32.8%), 10-epi-γ-eudesmol (10.6%), and citronellyl formate (10.0%) as the major constituents in the essential oil from the aerial parts. Moutaouafiq et al. (2019) reported the presence of citronellol (25.2%), geraniol (23.4%), citronellyl formate (8.4%), and linalool (7.1%). In contrast, Al-Mijalli et al. (2022) found isogeraniol (15.1%), menthol (14.1%), and eremophilene (9.0%) as the dominant compounds in the aerial parts. Boukhris et al. (2013) analyzed the essential oils of flowers, leaves, and stems, finding citronellol (12.2-24.1%), geraniol (10.3-16.4%), and citronellyl formate (7.9-11.7%) as the major components.

Table 2 The major constituents in the essential oil of *P. graveolens*

Constituent	**Aerial parts**			**Flowers**	**Leaves**			**Stems**	
Citronellol	32.8	25.24±0.04		24.1	19.2	24.4	19.0	12.2	14.2
Citronellyl formate	10.0	8.35±0.06		11.7	8.4	15.6		7.9	
β-Cubebene			4.3	0.2	0.3			0.1	
Decanoic acid							3.4		1.2
Eremophilene			9.0	0.3					
γ-Eudesmol	0.3					8.6	0.2		0.4
10-*epi*-*γ*-Eudesmol	10.6			2.7	7.7		5.0	1.2	4.5
Geraniol	4.5	23.36±0.08		16.4	15.3	1.6	27.5	10.3	50.2
Geranyl formate	1.5	4.26±0.03	2.1	4.6	6.5	3.4	0.1	7.1	
Geranyl tiglate	1.0	2.06±0.01		1.8	4.0	2.4	3.9	5.4	3.2
Germacrene D	2.2	1.59±0.01	0.2	1.5	2.3	2.6		9.0	
Germacrone							0.1		6.1
6,9-Guaiadiene	0.1					0.5	4.6		1.4
Isoborneol			4.0						
Isogeraniol			15.1						
Isomenthone	6.3	3.37±0.01				7.4			
Linalool	2.9	7.11±0.04		8.0	4.8	2.4	3.6	2.5	0.4
Linalyl acetate			3.9						
p-Menthene			6.7						
Menthol			14.1	0.2			0.3		
Menthone	0.1	0.20±0.01	-	4.2	4.1		5.2	2.0	2.0
α-Pinene	0.5		5.6	1.2	0.5	0.2			
δ-Selinene					0.2	0.1		14.2	
Viridiflorene	1.4	0.3±0.01				2.2		3.9	
References	Rosato et al., 2018	Moutaouafiq et al., 2019	Al-Mijalli et al., 2022	Boukhris et al., 2013	Boukhris et al., 2013	Jaradat et al., 2022	Ćavar et al., 2012	Boukhris et al., 2013	Ćavar et al., 2012

Ćavar et al. (2012) identified geraniol (27.5% in leaves, 50.2% in stems) and citronellol (19.0% in leaves, 14.2% in stems) as predominant constituents. Jaradat et al. (2022) reported that the essential oil from leaves primarily contains citronellol (24.4%), citronellyl formate (15.6%), and *γ*-eudesmol (8.6%). These studies underscore the significant variability in the chemical composition of *P. graveolens* essential oils, influenced by the specific plant parts analyzed and the methodologies employed.

Comparative analyses of the major constituents of essential oils from various *Pelargonium* species are presented in Table 3, Table 4, and Table 5. The chemical compositions of the individual plant species are discussed below, based on the data from these tables. Hydrodistillation of aerial parts of *P. fragrans* from India resulted in the isolation of essential oil with a yield of 0.18% (Verma et al., 2012). Only 51 EO constituents were identified (Table 3), representing 90.2% of the peak areas in the GC chromatogram, with the major components being oxygenated monoterpene fenchone (10.7%), followed by phenylpropanoid methyl eugenol (9.9%), and the monoterpene hydrocarbons *α*-pinene (9.4%) and *α*-thujene (7.6%). It seems that the high amount of *α*-thujene is characteristic only for *P. fragrans* and *P. exstipulatum*.

The main *P. glutinosum* EO constituents (Table 3), identified by Lalli and co-workers (Lalli et al., 2006), were oxygenated sesquiterpenes viridiflorol (8.9%), spathulenol (6.9%), and caryophyllene oxide (6.3%). However, they only identified 59.2% of the peak areas in the GC chromatogram. Viridiflorol was also one of the major constituents (7.9%) in *P. panduriforme*, which predominately contains *p*-cymene (45.4%). Lalli and colleagues (2006) examined the essential oil of the aerial parts of *P. hispidum*, finding decanoic acid (47.0%), 2-decenoic acid (31.3%), and *β*-caryophyllene (8.6%) as the major EO constituents. In *Pelargonium hortorum* EO sample, Liu et al. (2012) identified 36 constituents, with 1,8-cineole (23.0%), *α*-terpineol (13.2%), *α*-pinene (8.1%), and camphor (8.1%) as predominant components (Table 3).

Tambeni et al. (2019) compared the composition of the essential oil samples isolated from leaves and stems of both cultivated and wild *Pelargonium inquinans*. The leaf essential oil samples were similar, with *α*-caryophyllene (17.2% cultivated, 25.8% wild), *β*-caryophyllene (16.3% cultivated, 25.2% wild), and phytol (20.5% cultivated, 14.2% wild) being most abundant. However, the stem EO differed significantly, with cultivated plants containing sabinene (27.8%), linalool (15.3%), and *α*-terpineol (8.7%), while stem EO from wild-grown plants contains a high amount of camphor (46.5%). Lis-Balchin and Roth (2000) identified 21 constituents of the EO from fresh leaves of *Pelargonium odoratissimum*, with predominantly methyl eugenol (31.2-79.8%) and isomenthone (4.6-16.9%). Surprisingly high amount of citronellic acid was found in the EO samples of *Pelargonium papilionaceum* and *P. vitifolium*, 96.2 and 74.7%, respectively (Lalli et al., 2006). Rungqu et al. (2023) analyzed the EO of fresh and dry leaves and twigs of *Pelargonium peltatum*. In fresh leaf oil, the main constituents were camphene (33.4%), *α*-terpineol (19.1%), piperitone (12.2%), and linalool (11.7%), while dry leaf EO had *β*-bourbonene (6.2%), phytone (5.0%), and *α*-terpineol (4.8%). Fresh twig EO was rich in *β*-myrcene (10.7%) and *β*-caryophyllene (9.5%), while dry twig oil contained *α*-thujone (15.6%), *α*-terpineol (13.1%), camphene (10.4%), and germacrene D (10.4%).

Taherpour et al. (2007) analyzed the essential oil from the aerial parts of *Pelargonium quercetorum*, identifying 80.8% of the total GC peaks area (Table 4). The most abundant compounds were *α*-pinene (25.3%), *α*-fenchyl acetate (20.6%), limonene (9.9%), and *trans*-*β*-caryophyllene (8.2%). The presence of *α*-fenchyl acetate is specific to *P.*

quercetorum. Lalli et al. (2006) compared the essential oils from the aerial parts of *Pelargonium radens*, *P. scabrum*, and *P. tomentosum*. The oil yield of *P. radens* was 0.69%, with 95.1% identified components, predominantly isomenthone (84.5%). In *P. tomentosum*, the main constituents were isomenthone (49.3%) and menthone (41.1%). The major EO constituent of the *P. scabrum* was 14-hydroxy-*β*-caryophyllene (27.9%). The chemical compositions of the essential oils of *Pelargonium roseum* from Iran and Morocco were analyzed. Tabari et al. (2017) and Marinkovic et al. (2021) found citronellol (35.9% and 30.7%), geraniol (18.5% and 16.3%) as the main components of the *Pelargonium roseum* EO from Iran and Morocco, respectively. Kayser et al. (1998) and Kotb et al. (2024) examined the leaf essential oils of *Pelargonium reniforme*, *P. sidoides*, and *P. zonale*. The oil yields ranged from 0.71 to 2.0%, with identified components being 49.0%, 65.0%, and 98.1%, respectively. *P. reniforme* EO was rich with *δ*-selinene (4.2%) and *δ*-cadinene (4.0%), *P. sidoides* EO with caryophyllene oxide (13.1%), and *P. zonale* EO with limonene (47.6%), myrcene (19.7%), and *α*-humulene (12.0%).

The essential oil from the aerial parts of *P. asperum* was analyzed from two different locations: Grande Comore and Morocco (Btissam et al., 2015; Hassane et al., 2011). Hassane et al. (2011) reported that the essential oil contained 30.0% citronellol, 14.1% geraniol, and 9.1% citronellyl formate (Table 5). In contrast, Btissam et al. (2015) found slightly lower concentrations of citronellol (25.1%) and geraniol (10.5%), but a slightly higher concentration of citronellyl formate (10.5%). In a study by Lally et al. (2006), the essential oils derived from *Pelargonium betulinum* and *P. capitatum* were analyzed. *P. betulinum* was notable for its high content of *τ*-cadinol, which accounted for 18.9% of the oil, a compound not found in significant quantities in other *Pelargonium* species. The major EO constituents of *P. capitatum*, with identified constituents that represent 75.3% of total GC peaks area, were citronellyl formate (31.1%) and citronellol (9.9%). Demarne and Van der Walt (1993) investigated the leaf EO of *P. citronellum*, identifying geranial (47.9%) and neral (37.4%) as the main components. Similarly, Sadgrove and Van Wyk (2018) found these compounds in *P. crispum*, albeit at lower percentages (24.3% for geranial and 14.9% for neral), along with a notable presence of linalool (12.1%). Matsuda et al. (1996) conducted a study on *P. citrosum*, cultivated both in a greenhouse in Maryland and outdoors in Camden. Table 5 compares the major components of the essential oils from the leaves and stems. In greenhouse-grown plants, the predominant components were citronellol (11.1%) and isomenthone (7.6%), while field-grown plants had higher levels of linalool (11.6%), isomenthone (11.5%), citronellol (8.8%), and 6,9-guaidiene (7.9%).

Gauvin et al. (2004) analyzed the leaf EO sample of *Pelargonium cv. Rosé* from Reunion Island, finding high amounts of citronellol (21.9%), geraniol (18.3%), linalool (16.0%), citronellyl formate (11.6%), and isomenthone (7.6%). In contrast, the leaf essential oil of *P. exstipulatum* from England, as analyzed by Lis-Balchin and Roth (2000), contained α-thujene (25.0%), limonene (18.5%), *α*-pinene (12.3%), and caryophyllene oxide (10.3%) as major components (Table 5). Dumlupinar et al. (2020) analyzed the essential oil from the aerial parts of *P. endlicherianum*, revealing *β*-bourbonene (15.5%) as the most abundant constituent. Additionally, significant amounts of 2-phenylethyl-2-methylbutyrate (10.5%) and hexahydrofarnesyl acetone (7.7%) were detected, compounds not typically present in essential oils from other *Pelargonium* species, except in trace amounts.

Table 3 The major constituents in the essential oils of *P. fragrans*, *P. glutinosum*, *P. hispidum*, *P. hortorum*, *P. inquinans*, *P. odoratissimum*, *P. panduriforme*, *P. papilionaceum*, and *P. peltatum*.

Sample	*P. fragrans*	*P. glutinosum*	*P. hispidum*	*P. hortorum*	*P. inquinans*				*P. odoratissimum*	*P. panduriforme*	*P. papilionaceum*	*P. peltatum*			
Constituent	Aerial parts	Aerial parts	Aerial parts	Aerial parts	Leaves	Stems	Leaves	Stems	Leaves	Aerial parts	Aerial parts	Fresh leaf	Dry leaf	Fresh twig	Dry twig
α-Amorphene														1.2	5.2
Artemisia ketone				3.0											
β-Bisabolene					2.7		3.2								
β-Bourbonene		0.3											6.2		4.2
β-Cadinene														3.4	6.7
Camphene	0.6		tr	0.5						tr	0.1	33.4	3.9	3.6	10.4
Camphor	0.6	tr	tr	8.1				46.5							
3-Carene						5.4				0.3					
α-Caryophyllene					17.2		25.8						0.8	5.5	
β-Caryophyllene	4.2	2.5	8.6	4.1	16.3	1.7	25.2	5.8	1.5-2.2		0.1	4.3	1.2	9.5	
Caryophyllene oxide	2.2	6.3	0.5		0.9	2.5		3.9	tr-1.7	0.1	tr		2.6	1.9	6.1
1,8-Cineole	1.8	0.1	0.2	23.0							tr				
Citronellal						3.2									
Citronellic acid			0.8								96.2				
Citronellyl tiglate									tr-3.7						
β-Cubebene		0.1												5.6	
p-Cymen	1.5	0.5	0.1			2.3			tr-3.5	45.4	tr				
p-Cymen-8-ol			tr							4.0	tr				
Decanoic acid			47.0												
2-Decenoic acid			31.3												

Elemol								3.7		0.6					
1,2-Epoxyhumulene														0.9	3.8
Fenchone	10.7								2.5-7.9						
Geranyl acetone		0.2	tr								tr		3.5		
Germacrene D	1.0			2.7										3.7	10.4
Hexyl butyrate		3.2													
Isomenthone		1.4	0.3						4.6-16.9		tr		0.8		
Isophytol					4.7		2.3								
Limonene	6.4	tr	tr	0.7		4.3			1.0-4.3	2.2	tr				
Linoleic acid					4.5			3.6					1.0		
Linolenic acid					6.1										
Linalool	4.2	0.1	0.7			15.3		2.6		4.4	tr	11.7	1.6	1.9	6.2
Methyl eugenol	9.9	0.3							31.2-79.8						
β-Myrcene	0.7			4.6		3.9					tr	5.2		10.7	
trans-*β*-Ocimene	0.1		tr			6.8				tr	0.1		2.2	0.9	
Palmitic acid					9.6		5.4							1.2	
α-Phellandrene	tr		0.1							4.3					
β-Phellandrene			tr	2.5						1.4				4.6	
α-Pinene	9.4		tr	8.1					tr-1.2	0.6	tr		1.2	3.0	
β-Pinene	2.9		tr	3.3		3.8		1.2	tr-0.3	0.1		4.9	1.4	4.4	6.0
trans-Pinocarveol				3.2						tr					
Piperitone			0.1						1.4-8.8		tr	12.2	0.9		
Phytol					20.5	0.7	14.2				tr				
Phytone													5.0	0.4	
Sabinene	4.3					27.8				0.5					
Spathulenol	4.7	6.9		0.2						3.8			2.6	0.7	
4-Terpineol	3.2			4.6						0.6					
α-Terpineol		0.2	0.5	13.2		8.7				0.5	0.3	19.1	4.8	5.4	13.1
α-Thujene	7.6										1.0				
β-Thujene					1.7		4.7								
α-Thujone						0.1							1.5		15.6
cis-Vaccenic acid								3.1							
Viridiflorol		8.9								7.9					
p-Xylene							5.2						1.6	0.8	
Reference	Verma et al., 2012	Lalli et al., 2006	Lalli et al., 2006	Liu et al., 2012	Tambeni et al., 2019				Lis-Balchin and Roth, 2000	Lalli et al., 2006	Lalli et al., 2006	Rungqu et al., 2023			

Table 4 The major constituents in the essential oils of *P. quercetorum, P. radens, P. reniforme, P. roseum, P. scabrum, P. sidoides, P. tomentosum, P. vitifolium* and *P. zonale.*

Sample	*P. quercetorum*	*P. radens*	*P. reniforme*	*P. roseum*		*P. scabrum*	*P. sidoides*	*P. tomentosum*	*P. vitifolium*	*P. zonale*
Constituent	Aerial parts	Aerial parts	Leaves	Leaves	Leaves	Aerial parts	Leaves	Aerial parts	Aerial parts	Leaves
β-Betulenal						5.6				
δ-Cadinene	3.3		4.0	2.5	1.1	0.7	1.5			
τ-Cadinol			1.9			6.1	2.9		0.9	
Camphene	4.3	tr				tr		0.1		0.7
trans-β-Caryophyllene	8.2		0.1	2.6		3.9	2.3	0.4	0.2	6.7
14-hydroxy-*β*-Caryophyllene						27.9				
Caryophyllene oxide		tr	3.5		0.2	4.2	13.1	0.2	0.6	
Citronellic acid								tr	74.7	
Citronellol		0.2		35.9	30.7				2.2	
Citronellyl acetate				3.5	0.6	0.1				
Citronellyl formate					16.2				0.1	
Decanoic acid		0.1	1.4			6.4				
Elemicin							3.6			
10-*epi*-*γ*-Eudesmol									7.1	
α-Fenchyl acetate	20.6									
Geraniol				18.5	16.3	0.1	0.6		tr	
Geranyl formate					8.1					
6,9-Guaiadiene		tr			5.6					
α-Humulene	0.8	tr			0.3	0.3		0.1		12.0
Isomenthone		84.5		4.2	1.8	tr		49.3		
Limonene	9.9	0.8	0.2	0.7	0.3	0.2	0.3	1.5		42.6
Linalool		0.6		5.7	4.4	0.7		tr	0.2	
Menthone		1.9		2.5	1.7			41.1		
Methyl decanoate						4.2				
Methyleugenol						0.3	4.3			
Myrcene	1.4	0.9	tr	0.1		1.4		0.8		19.7
Octadecanoic acid							3.5			
α-Pinene	25.3	0.3		0.7	0.5	0.1	tr	0.5		2.1
β-Pinene	3.2	0.1	tr	0.1		0.3		tr		3.7
δ-Selinene			4.2	5.5						
Reference	Taherpour et al., 2007	Lalli et al., 2006	Kayser et al., 1998	Tabari et al., 2017	Marinkovic et al., 2021	Lalli et al., 2006	Kayser et al., 1998	Lalli et al., 2006	Lalli et al., 2006	Kotb et al., 2024

Table 5 The major constituents in the essential oils of *P. asperum*, *P. botulinum*, *P. capitatum*, *P. citronellum*, *P. citrosum*, *P. crispum*, *P. cv. Rosé, P. endlicherianum* and *P. exstipulatum*.

Sample	*P. asperum*		*P. betulinum*	*P. capitatum*	*P. citronellum*	*P. citrosum*		*P. crispum*	*P. cv. Rosé*	*P. endlicherianum*	*P. exstipulatum*
Constituent	Aerial parts	Aerial parts	Aerial parts	Aerial parts	Leaves	Leaves and Stems[a]	Leaves and Stems[b]	-	Leaves	Aerial parts	Leaves
Benzaldehyde											4.3
β-Bourbonene	0.6		2.8	1.5	tr	0.1	0.5	2.3	0.5	15.5	
α-Cadinol			4.5							0.3	
τ-Cadinol			18.9	0.5							
Camphor											4.3
β-Caryophyllene	0.8		5.3			0.3	0.5		0.6	0.5	tr
Caryophyllene oxide			2.8	2.8						0.7	10.3
Cedrol			5.4								
Citronellol	30.0	25.1		9.9		11.1	8.8		21.9		
Citronellyl formate	9.1	10.5		31.1					11.6		
Decanoic acid				0.3		4.5	0.9				
10-*epi*-*γ*-Eudesmol	0.1					5.4					
β-Farnesene	4.3									0.6	
Fenchone	0.3										4.5
Furopelargone B				6.1		0.1	0.1		0.9		
Geranial	0.7				47.9	0.3	0.4	24.3	1.3		
Geraniol	14.1	10.5			1.0				18.3		
Geranyl formate	4.1	4.1		0.5	tr				4.0		
Geranyl hexanoate					tr			3.4			
Geranyl tiglate	0.1					3.8		1.6	1.3		
Germacrene D			0.2		tr	2.9	2.7		1.0	5.3	
6,9-Guaiadiene				0.5	tr	6.2	7.9		2.3	0.5	
Hexahydrofarnesyl acetone			tr	0.5						7.7	
Hydroxycitronellol								3.4			
Isomenthone	7.8			1.9		7.6	11.5		7.6		0.6
Limonen	0.2	0.3			tr	1.1	1.3		tr	1.7	18.5
Linalool	6.0	3.6		0.3	0.5	4.3	11.6	12.1	16.0		
Linalool oxide	0.5							3.0	0.3		
β-Maaliene		5.9									
Menthone		5.9				tr	0.3		0.1		0.2
(*E*)-Methyl cinnamate								5.5			
Neral					37.4			14.9	0.6		
Neryl benzoate								3.3			
Octyl acetate			5.7								

2-Phenylethyl-2-methylbutyrate									0.3	10.5	
3-Phenylpropyl acetate			3.0								
α-Pinene		1.2	0.1	0.2	tr	tr	0.1		0.1	5.8	12.3
β-Pinene		0.3								5.1	
p-Cymene	0.1		0.2	0.1	0.9			1.8	0.3	4.1	
Terpinen-4-ol								1.7			3.7
α-Thujene	0.5				tr						25.0
Viridiflorene		3.1									
Reference	Hassane et al., 2011	Btissam et al., 2015	Lalli et al., 2006	Lalli et al., 2006	Demarne and Van der Walt, 1993	Matsuda et al., 1996	Matsuda et al., 1996	Sadgrove and Van Wyk, 2018	Gauvin et al., 2004	Dumlupinar et al., 2020	Lis-Balchin and Roth, 2000

tr = trace amounts (<0.05%) [a] Greenhouse-grown; [b] Field-grown

In conclusion, a SciFinder search of the Chemical Abstracts Service (CAS) database revealed over 6,400 reports concerning *Pelargonium* species at the time of investigation. Further refinement of the search with the term "essential oils" resulted in approximately 800 reports. However, a detailed manual analysis of these reports indicated that only 130 included the chemical composition analysis of essential oils. This represents an alarmingly low percentage of chemically investigated essential oils from different *Pelargonium* species. Out of the 280 known *Pelargonium* species, essential oil samples from only about 30 taxa have undergone chemical analysis.

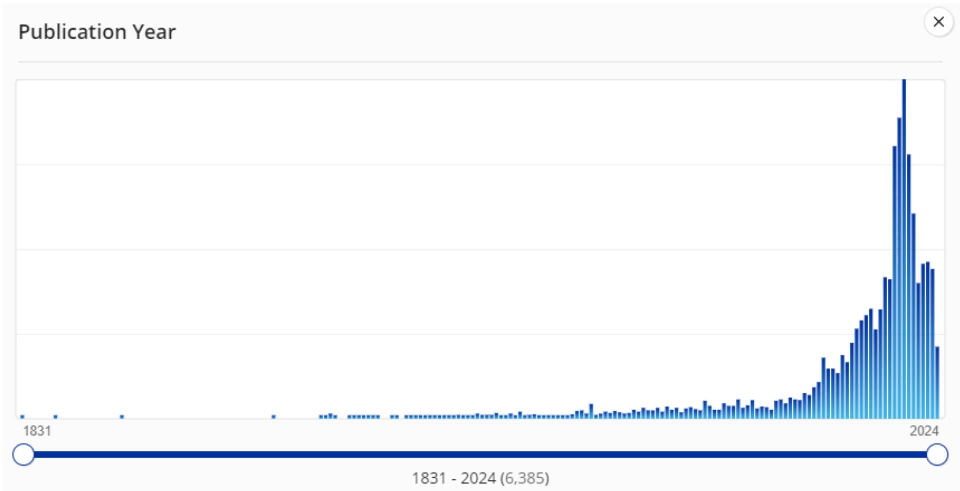

Fig. 6 Results from a SciFinder search of the Chemical Abstracts Service (CAS) database indicate a limited research interest in the plant taxa from the *Pelargonium* genus

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HEMIJSKI SASTAV ETARSKIH ULJA BILJNIH VRSTA RODA *PELARGONIUM*

Rod Pelargonium, koji obuhvata biljne vrste poznate kao geranijumi, poznat je po svojim etarskim uljima, koja su privukla pažnju zbog svojih aromatičnih i terapeutski svojstava. U ovom radu sumirana su trenutna saznanja o sastavu etarskih ulja biljnih vrsta unutar roda Pelargonium. Pregled uključuje dostupne podatke o hemijskom sastavu esencijalnih ulja izolovanih iz različitih biljnih organa, prinose ulja, karakteristike mirisa i procenat identifikovanih komponenti, sa naglašenim varijacijama sastava na osnovu geografskog porekla, ekoloških uslova i metoda ekstrakcije. Tabele koje upoređuju hemijski sastav uključene su za etarska ulja koja su podvrgnuta višestrukim analizama, dok su strukture glavnih sastojaka prikazane.

Ključne reči: *Pelargonium, etarsko ulje, hemijski sastav*