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## WHAT ARE THE DIFFERENCES BETWEEN GERANIUM AND PELARGONIUM AS A REPRESENTATIVE OF *GERANIACEAE* FAMILY?

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### Abstract

In this investigation we collected and systematized the data known in the scientific literature about the specific valuable characteristics of *Geranium macrorrhizum* L. and the biological activity of geranium essential oil. We used information collected through systematic computer searches among the most reputable scientific databases, including PubMed, Science Direct, Web of Science, Google Scholar and Scopus. We found the differences between the representative geranium (Bulgarian geranium) and pelargonium. Both are aromatic plants, distributed throughout the world, mainly in subtropical and temperate climates. Only in Bulgaria are essential oils, concretes, and absolutes produced – aromatic products with valuable odor and fixing qualities. The geranium bouquet is still present in Bulgarian traditions and rituals today. The Bulgarian people have given the geranium the most expensive name for its most valuable gift – health. Herbalists even call it "the second Bulgarian rose" or "the poor man's rose". If a Bulgarian village had its own coat of arms, it would necessarily have a geranium on. Accordance to Lis Balchin (1996), the misunderstanding is coming from the mixing of the two species since the time of Carl Linnaeus at 1778. The differences between the chemical constituents and their biological activities of two representatives are in the primary uses - *G. macrorrhizum* L. is in phytotherapy, while pelargonium oil is in perfumery, cosmetics, and aromatherapy.

**Keywords:** *Geranium macrorrhizum* L.; pelargonium; geranium essential oil; phytochemical composition; biological activities

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### 1. Introduction

Since ancient times, people have relied on plants as a prophylactic or therapeutic means to restore and maintain health, as they are well known as an essential source of many biologically active compounds. In recent years, we have witnessed extensive research related to the study of various plant phytocomplexes and components of natural origin. They are a rich source of biologically active substances with medicinal and therapeutic value and find application in multiple spheres of life. Representatives of the *Geraniaceae* family are of interest to a large number of scientists around the world. Geranium species have been used in many conventional health systems around the world, such as Indian Ayurveda, traditional Chinese medicine, and various indigenous medical practices, through herbal formulas. [1]

Both the roots, leaves, and flowers of geranium have been used since ancient times in folk medicine to treat various diseases - stomach disorders [3], externally for wounds and for heavy bleeding [4], the cycle of the gallbladder and bile ducts, kidneys, bladder, and liver [5]. Anti-inflammatory, hemostatic, antibacterial, antiallergic, antihepatotoxic, anticancer, diuretic, tonic, etc. properties of alcoholic extracts of geranium are known [6, 7, 2]. The total phenolic and flavonoid content of essential oil and extracts often correlates well with antioxidant capacity [8, 9, 10]. Extracts of *Geranium macrorrhizum* L. have been studied for

hypotensive, antispasmodic, astringent, cardiotoxic, antioxidant, capillary-strengthening, and sedative effects [3].

In the scientific literature, the characteristics of *Geranium macrorrhizum* L. are often confused with representatives of the *Geraniaceae* family. There is no doubt that the botanical characteristics are similar, but the specifics of their phytochemical profile and biological properties are often confused.

Therefore, the aim of the present study was to collect and systematize the data known in the scientific literature about the specific valuable characteristics of *Geranium macrorrhizum* L. and the biological activity of geranium essential oil.

## 2. Materials and methods

To investigate the similarities and differences between Geranium and Pelargonium, we used information collected through systematic computer searches among the most reputable scientific databases, including PubMed, Science Direct, Web of Science, Google Scholar and Scopus. The keywords we applied were *Geranium macrorrhizum* L., geranium essential oil, phytochemical composition, biological activities

## 3. Results and Discussion

*Geranium macrorrhizum* L.: Native to the southeastern Alps and the Balkans. It is a perennial and hardy plant that is found in temperate climates and can withstand cold winters.

*Pelargonium*: Native primarily to South Africa. These plants are heat-loving and are usually grown as annuals in colder areas as they cannot survive frost.

### *Botanical and morphological characteristics of geranium*

Plants of the genus *Geranium* are mostly annual or perennial shrubs or herbs, distributed throughout the world, mainly in subtropical and temperate climates [11, 2]. The species of this family are categorized into six genera: *Geranium*, *Pelargonium*, *California*, *Monsonia*, *Hypseocharis*, and *Erodium*.

The petiolate leaves have toothed or lobed divisions, which have stipules, usually glandular or glandular-fibrous and palmately divided. The lower leaves may be successive; however, the stem leaves are usually opposite. The flowers are more often violet, pink, or bluish-pink and occur singly or in pairs, or in smaller umbels surrounded by bracts. Sepals are five-filiform and mucronate at the tip; the flowers are radially symmetrical. The size of the sepals usually increases as the fruit ripens. The nectary is near the base of the five equal petals, which may be clawed and sometimes have notches at the tips. In polyandrous flowers, there are ten stamens, grouped in two whorls, with the anthers of the outer whorl opening before those of the inner whorl.



**Fig. 1.** Botanical and morphological characteristics of pelargonium



**Fig. 2.** Botanical and morphological characteristics of geranium

*G. macrorrhizum* L., also known as "large-rooted geranium", "Bulgarian geranium" and "rock cranesbill", is widespread in the Southeastern Alps and the Balkans in the countries of Poland, Bulgaria, and Romania. It is a hardy flowering herbaceous perennial with a large rhizome, five-lobed aromatic leaves, and pale pink flowers. It is cultivated as an ornamental plant in temperate regions, with varieties being selected for their flowers.

Favorable climatic and soil conditions place Bulgaria in first place among the countries in Europe in the collection, cultivation, processing, and export of medicinal plants and herbs. Phytopharmaceutical products, including prescription and non-prescription products, represent 50% of the medicines on the market [12]. According to data from the World Health Organization, about 80% of the world's population relies on medicines of mainly plant origin for their primary health care [13]. The Bulgarian people have given the geranium the most expensive name for its most valuable gift – health. Herbalists even call it "the second Bulgarian rose" or "the poor man's rose". If a Bulgarian village had its own coat of arms, it would necessarily have a geranium on it.

Only in Bulgaria are essential oils, concretes, and absolutes produced – aromatic products with valuable odor and fixing qualities. The geranium bouquet is still present in Bulgarian traditions and rituals today.

In the scientific literature, there is a profound intertwining of the genera *Geranium* and *Pelargonium*, and this confusion existed before Linnaeus (1753) and his binomial classification system, where both genera were placed in the genus *Geranium*. Later, they were reclassified into two genera. Geranium oil is mainly extracted from the leaves of some species and varieties of *Pelargonium*. Still, its paramedical effects are often equated with those of the genus *Geranium*, e.g., *G. robertianum* and *G. maculatum* [14]. The medicinal properties of *Pelargonium* oil are largely unfounded, as they are based only on the properties of mainly water-soluble extracts (teas, decoctions, macerates, etc.). Additional confusion arises with the valuable oil of *G. macrorrhizum*, obtained from the species characteristic of Bulgaria, which is entirely different from commercial *Pelargonium* oil both in chemical composition and in medicinal properties, etc. [14]

The primary use of *G. macrorrhizum* L. is in phytotherapy, while *Pelargonium* oil is in perfumery, cosmetics, and aromatherapy.

#### *Geranium oil– valuable characteristics*

The International Organization for Standardization ISO defines geranium oil as "Oil obtained by steam distillation of fresh or slightly dried herbaceous parts" (International Standard 4731: 1972). The color is in various shades of amber yellow to greenish yellow. The odor is indicated as characteristic of the origin, similar to rose with a variable minty note.

The essential oil of *G. macrorrhizum* is highly valued in both perfumery and the food industry. The composition and biological activities of the essential oil and aqueous macerates of geranium from Bosnia and Herzegovina, France, Croatia, and Greece have been reported by Zeljković et al. (2020) [15]. Similar analyses of extracts of Bulgarian geranium have proven its valuable biological properties.

Geranium oil is mainly extracted from the leaves of some species and varieties of *Pelargonium*. Still, its paramedical effects are often equated with those of the genus *Geranium*, e.g., *G. robertianum* and *G. maculatum* [14]. The species *Pelargonium*, originating from South Africa, although introduced into European botanical gardens, is used only as an ornamental plant. The medicinal properties of *Pelargonium* oil, however, are largely unsubstantiated, as they are based solely on the properties attributed primarily to water-soluble extracts (teas, decoctions, macerates, etc.) of the geranium species.

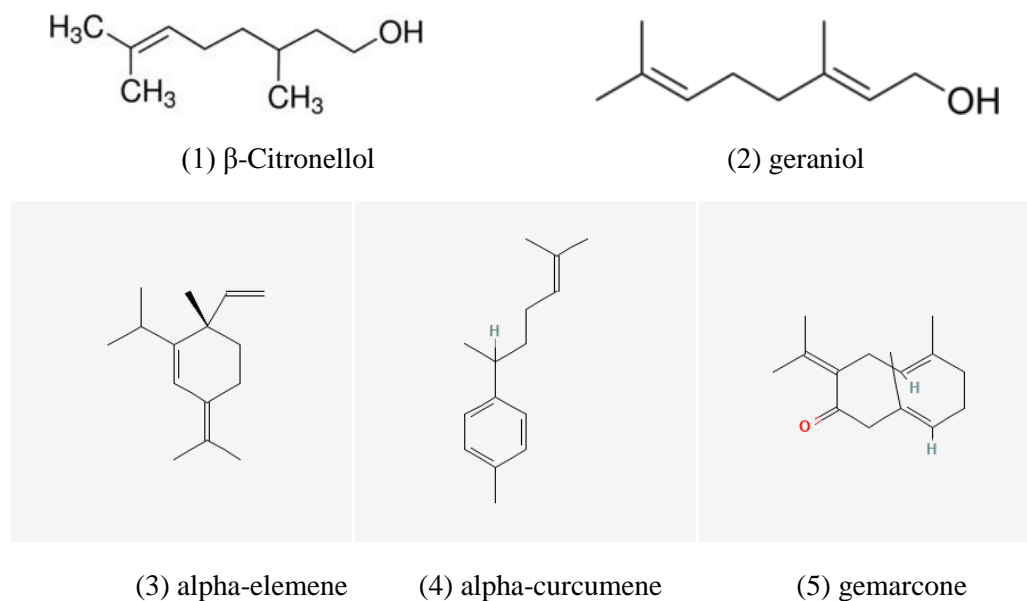
Additional confusion arises with the valuable oil of *Geranium macrorrhizum*, obtained from the species characteristic of Bulgaria, which is entirely different from the commercial geranium oil of the Pelargonium species, both in chemical composition and in medicinal properties, etc. [14].

The primary use of *Geranium macrorrhizum* L. is in phytotherapy, while the oil obtained from Pelargonium is in perfumery, cosmetics, and aromatherapy.

The high biological value of geranium oil is due to the presence of secondary metabolites in the leaves, stems, and rhizomes, which is a complex mixture of volatile phytochemicals, such as terpenes, esters, aldehydes, alcohols, ketones, and phenols. The main phytochemicals of the essential oil belong to the terpenoid group of metabolites, such as monoterpenes, sesquiterpenes, diterpenes, and their esters. Of these, geraniol, linalool, citronellol, and their esters (50–70%) usually constitute the central part of the essential oil, responsible for its aroma. The essential oil is biosynthesized in specialized tissues known as glandular trichomes, present in the leaves, green branches, and fresh flowers. Its valuable pharmacological properties have been proven, such as antifungal, anti-inflammatory, anticancer, antidepressant, antibacterial, antioxidant, antiseptic, antidiabetic properties. In addition, it improves blood circulation, treats congestion, cleanses the lymphatic system, strengthens the immune system, and is effective in combating nervousness, constipation, insomnia, anxiety, and high blood pressure.

The primary non-volatile secondary metabolites of *G. macrorrhizum* include gallic acid, ellagic acid, 4-galloylquinic acid, quercetin, quercetin-3- $\beta$ -glucopyranoside, quercetin-3- $\beta$ -galactopyranoside, and quercetin-4'- $\beta$ -glucopyranoside. The sesquiterpene germacrone is the primary volatile secondary metabolite of the essential oil.

The aerial parts of *G. macrorrhizum* produce an essential oil containing two known monoterpenoids, namely  $\beta$ -citronellol (1) and geraniol (2), in addition to many sesquiterpenes. These include  $\alpha$ -elemene (3),  $\alpha$ -curcumene (4), and germacrone (5), which together account for up to 50% of the oil. Figure 1 shows the typical composition of the essential oil of *G. macrorrhizum* L.



**Fig. 3.** Main compounds in the chemical composition of *G. macrorrhizum* L. essential oil.

#### Pharmacological properties and application

##### Cytotoxic/Anticytotoxic, Mutagenic/Antimutagenic and Genotoxic/Anti-Genotoxic Potential – to expand a little

The preservative properties of aromatic and medicinal plant volatile (essential) oils and extracts have been recognized since biblical times, while attempts to characterize these properties in the laboratory date back to 1900 (Martindale, 1910; Hoffman and Evans, 1911). Most of the Geranium species are used in folk medicine for their analgesic, antimicrobial, antioxidant, and hepatoprotective properties, while some species are ornamental plants [17]. Phytochemical analysis of this genus has shown the presence of hydrolyzable tannins, phenolic compounds, and flavonoids [18,19]. Geranium essential oil

is one of the most important essential oils obtained by steam distillation of the green leaves of Geranium. It has antibacterial, pesticidal, insect repellent, antioxidant, and anticancer properties [20].

#### *Antiviral activity*

Geranium is used in dysentery, as an antiviral agent, in diarrhea, gastrointestinal ulcers, as a hemostatic agent in hematuria and menorrhagia [21].

At higher concentrations, it exhibits vigorous extracellular virucidal activity. In a model of herpesvirus infection in guinea pigs in vivo, the extract delays the development of herpetic vesicles after primary infection with the HSV-1 strain Kupka. Good antiviral activity of water and alcohol extracts of geranium has also been demonstrated against other representatives of the so-called enveloped viruses - they contain a lipid bilayer on their surface and membrane proteins obtained from the host cell when they leave it. However, they have specific structural features and completely different mechanisms of replication. Herpesviruses contain a linear DNA genome that replicates in the cell nucleus, and the virion fully utilizes its transcriptional apparatus.

#### *Antimicrobial Activity*

Commercial geranium oil obtained from different sources and outlets showed significant variation in bioactivity against 25 different bacterial species, 20 different strains of *Listeria monocytogenes*, and three fungi, which was not correlated with chemical composition or stated country of origin [22]. Bioactivity against microorganisms was very strong for the main synthetic components, citronellol and geraniol, but low for authentic geranium oil, suggesting that differences in adulteration are responsible for the significant differences in bioactivity. These results are also consistent with previous studies of commercial essential oils, where differences in bioactivity between essential oils that were labeled similarly have been demonstrated.

The leaf extract has a significant bacteriostatic effect against Gram (+) strains, such as *S. aureus*, and a weakly pronounced bactericidal impact, even at the highest tested concentrations. The antifungal activity of the leaf extract of *G. macrorrhizum* has been established only against *Aspergillus niger* [23]. The essential oil of *G. macrorrhizum* L. inhibits the development of *Bacillus subtilis* [3]. The aqueous extract of the aerial roots of the Bulgarian medicinal plant *G. sanguineum* L. is the least toxic to cell cultures (Vero cells). It significantly inhibits the replication of HSV-1 and HSV-2.

#### *Antiradical and antioxidant activity*

Antioxidant potential is the most valued biological activity in the genus Geranium; there are about 30 species of Geranium studied in different geographical regions.

Radulović et al. (2012) used four types of solvents with ultrasound application on leaves and rhizomes of *G. macrorrhizum* L. Methanol and ethanol extracts were the richest in phenols, while acetone and ethyl acetate extracts were poorer. The presence of gallic acid in the methanol extract of rhizomes contributes to the high antiradical activity (DPPH and ABTS) and redox-modulating capacity (FRAP, CUPRAC).

Recent preliminary screening studies of some plants growing in Central and Eastern Europe have shown that *Geranium macrorrhizum* has distinct radical scavenging properties and is very effective in artificial radical model tests [24]. The active constituents were identified as polyphenolic compounds, such as glycosylated flavonoids (quercetin, kaempferol, rhamnetin) and some phenolic acids [24]. Several assays involving different reaction media (oil, oil-in-water emulsion, buffered aqueous solution), reactants, and reaction phases (monitoring primary or secondary oxidation products) were used to assess the antioxidant properties. The results of these assays varied from test to test. In general, *G. macrorrhizum* extracts are active in hydrophilic media or in emulsions, but less active in lipophilic media [24].

The composition of radical scavenging compounds from the leaves of *Geranium macrorrhizum* was analyzed, and the antioxidant activity of different extracts was determined. Seven compounds, namely gallic acid, ellagic acid, 4-galloylquinic acid, the flavonoid quercetin, and three of its glycosides, quercetin-3- $\beta$ -glucopyranoside, quercetin-3- $\beta$ -galactopyranoside, and quercetin-4'- $\beta$ -glucopyranoside, were isolated and identified in the different fractions. The radical scavenging activity of the isolated compounds was measured using DPPH<sup>•</sup> and ABTS<sup>•+</sup> scavenging assays and compared with the activity of rosmarinic acid. Quercetin-3- $\beta$ -glucopyranoside and quercetin-3- $\beta$ -galactopyranoside showed the highest antioxidant capacity. The antioxidant activity of all plant fractions was assessed by model system tests (superoxide anion and hydrogen peroxide

scavenging) and by oxidation tests ( $\beta$ -carotene bleaching, peroxide value, UV absorption, and hexanal determination by headspace gas chromatography).

#### 4. Conclusion

The confusion regarding geranium and pelargonium oils is due to commercial distribution principles. In the commercial network, when "geranium oil" or "Geranium oil" is sold, it is almost always obtained from the Pelargonium plant, most often from the species *Pelargonium graveolens*. The oil obtained from the true Bulgarian geranium (*Geranium macrorrhizum*) is not produced in large quantities and is very rarely found on the market.

As a classification, *Geranium macrorrhizum* L. is the true Bulgarian geranium, which is cold-hardy and is used primarily in traditional medicine and as an ornamental garden plant. Pelargonium, also called "mushkato" in Bulgarian, is the plant from which commercial geranium essential oil is most often obtained, and which is grown primarily as an ornamental in pots and gardens in the warmer months.

The differences between the essential oil of *Geranium macrorrhizum* and that of Pelargonium can also be felt during organoleptic analysis. *Pelargonium* oil (*Pelargonium graveolens*), which is called geranium oil on the market, has a sweet, pink, slightly herbal and citrus aroma. It is because of this pleasant, balanced aroma that it is so popular in perfumery, cosmetics and aromatherapy. Bulgarian geranium oil (*Geranium macrorrhizum*) has a very strong, sharp, earthy and specific aroma, which is quite different from that of geranium. Because of this strongly pronounced aroma, it is not popular in commercial aromatherapy, but it has many valuable biological activities that affect serious diseases.

#### Abbreviations

HSV-1: Herpes simplex virus type 1  
HSV-2: Herpes simplex virus type 2  
DPPH: 2,2'-diphenyl-1-picrylhydrazyl  
ABTS: 2,2'-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid  
FRAP: Ferric Reducing Antioxidant Power Assay  
CUPRAC: Cupric ion reducing antioxidant capacity

#### Conflicts of interest

The authors declare that they have no conflicts of interest.

#### Ethical approval

Not applicable.

#### Consent to participate

Not applicable.

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