MICROMORPHOLOGICAL TRICHOMES DESCRIPTION, PHYTOCHEMICAL SCREENING, ANTIOXIDANT AND ANTIFUNGAL ACTIVITIES OF *Pelargonium graveolens* ESSENTIAL OIL

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Abstract: The aims of our study are to describe the chemical composition, trichomes morphology, leaves and petioles density of *Pelargonium graveolens* from Algiers. The light microscopy and scanning electron microscopy defined three kinds of trichomes; non-glandular, capitate and peltate trichomes. We determinate the essential oil profile by GC and GC-MS; results show that ester terpenoids are the most dominant group of total *P. graveolens* essential oil. The main compounds are geranyl formate (11.8 %), citronellyl formate (11.6%) and 10-*epi*-γ-eudesmol (10.0%). The antioxidant activity of pure essential oil was evaluate by the (DPPH) radical assay and ferric reducing antioxidant power. It exhibited an antioxidant activity with an IC50 value of 12.44 mg/mL. The antifungal screening showed that essential oil had a strong inhibitory effect against *Aspergillus carbonarius* and *Umbelopsis ramanniana.* These results indicate that this essential oil may serve as a potential source of antioxidants and antifungal compounds and for industrial uses.

Keywords: antifungal screening; antioxidant activity; essential oil profile; trichomes; *Pelargonium graveolens*.

INTRODUCTION

Currently, the use of medicinal plants in the treatment of pathologies has become one of the main pathways to healthcare. Most plant species have therapeutic virtues. The action of herbal medicine on human body depends on the composition of plants that constitute an inexhaustible reservoir of new secondary metabolites. Among these plants, *Pelargonium graveolens,* commonly named *Pelargonium roseum*, rose-scented pelargonium [33] is an aromatic plant belonging to the medicinal Geraniaceae family. The genus Pelargonium originates from “pelargos” that means “stork” in greek. The fruit form is similar to the stork’s spout [15]. Indigenous to South Africa, but largely cultivated in France, Spain, Algeria, Morocco and Tunisia [6, 8].

In Algeria, *P. graveolens* is mainly cultivated as an ornamental species in garden. In Africa, it has a long history of therapeutic usage. The main uses are for respiratory illnesses, wounds, and digestive problems. Mixtures of *Pelargonium graveolens* essential oil with others oils were found to be highly toxic to the maize weevil *Sitophilus zeamais* [25]. However, there are few reports of its usage for medicinal purposes outside of Africa [15]. This plant is used in traditional medicine due to its relaxant, anti-depressant and antiseptic effects, as well as to treat pre-menstrual and menopausal problems, nausea and poor circulation [8]. Geranium is highly valued due to its essential oil used as a flavouring agent, in skincare and aromatherapy [8]. This oil is secreted by glandular trichomes situated in the aerial parts, derived from epidermal cells. Generally they are considered as the location of essential oil biosynthesis and accumulation [17]. The type and distribution of trichomes are described in Tunisian *P. graveolens* [6] and in many species like, *Geranium dalmaticum*, *Geranium macrorrhizum* [17]; *Cannabis sativa* L. [19] and 14 solanum species [34].

Many essential oils might be utilized to prevent microbiological deterioration, maintain food quality and safety, extend the shelf life of foods due to their broad antioxidant and antimicrobial characteristics. Therefore, from the perspective of using the essential oil of *P. graveolens* in the food industry cosmetics and medical practice, we have proposed to observe the secretion site of the essential oil, determine its chemical composition and search for its antioxidant and antifungal activity.

MATERIALS AND METHODS

The plant material consisted of cultivated leaves harvested from a garden in Oued smar, Algiers, Algeria (36.70° N, 3.17° E) in April 2023, which were botanically identified by Dr. F Issiou botanist at a Faculty of Biology Science, USTHB. The essential oil was commercially procured from Sarl ZIPHEE BIO, having been extracted from the aerial parts of *P. graveolens* via industrial steam distillation, and was stored at 4°C in the dark until analysis.

Histological study of secretory gland of *P. graveolens*

For microscopic examination, the leaf surfaces were observed using Scanning Electron Microscopy (SEM) after being shade-dried, mounted, and carbon-coated. Complementary observations of the internal leaf and petiole structure were conducted using Light Microscopy (LM) on fresh, hand-cut sections that were stained with methyl green and congo red [3].

Gas Chromatography (GC-FID) and Gas Chromatography-Mass Spectrometry (GC-MS)

The analysis was performed using both Gas Chromatography with a Flame Ionization Detector (GC-FID) and Gas Chromatography-Mass Spec-

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trometry (GC-MS). The analyses utilized DB-5 capillary columns with identical temperature programs. Component identification was achieved by comparing their mass spectra with library data (Nist, Wiley) and by matching their linear retention indices (LRIs), determined using an n-alkane series, with those of authentic standards or literature values. Quantitative data were obtained from GC-FID area percentages [1, 18, 32].

Antioxidant activity

The antioxidant activity was evaluated using two methods. The **DPPH assay** measured the oil's free radical scavenging ability by the decrease in absorbance at 517 nm after reaction, with results expressed as an IC50 value and compared to ascorbic acid and α-tocopherol [31]. The **FRAP assay** determined the oil's reducing power by its ability to reduce ferric ions, indicated by an increase in absorbance at 700 nm, with activity quantified by the IC0.5 value and compared to the same standards [23].

Antifungal screening

Using a disc diffusion assay, the essential oil was tested for its ability to inhibit the growth of five phytopathogenic fungi: *Aspergillus carbonarius, Aspergillus westerdijkiae, Fusarium culmorum, Penicillium expansum* and *Umbelopsis ramanniana*. All tested fungi were obtained from LBSM (Laboratoire de Biologie des Systèmes Microbiens, Algiers, Algeria). Following 48-hour incubation, the antifungal effect was determined by measuring the inhibition zones and compared to the standard drug Nystatin.

Statistic assessment

Each experiment were carried in triplicate and presented as (mean±SD). Data were analysed by Student *t*-test and ANOVA one way with tukey's test. Statistics were done using Microsoft Excel.

RESULTS

Histological study of secretory gland of *P. graveolens*

Common in Geraniaceae species, glandular trichomes serve as a storage and manufacturing mechanism for essential oils [5]. In Lamiaceae, Solanaceae, Geraniaceae, and Phrymaceae plants glandular trichome can be divided into capitate glandular trichome and peltate glandular trichome [12, 30].

This study identified the secretory structures of *P. graveolens* essential oil through scanning and light microscopy. The leaf surface features two primary trichome types: non-glandular and glandular.

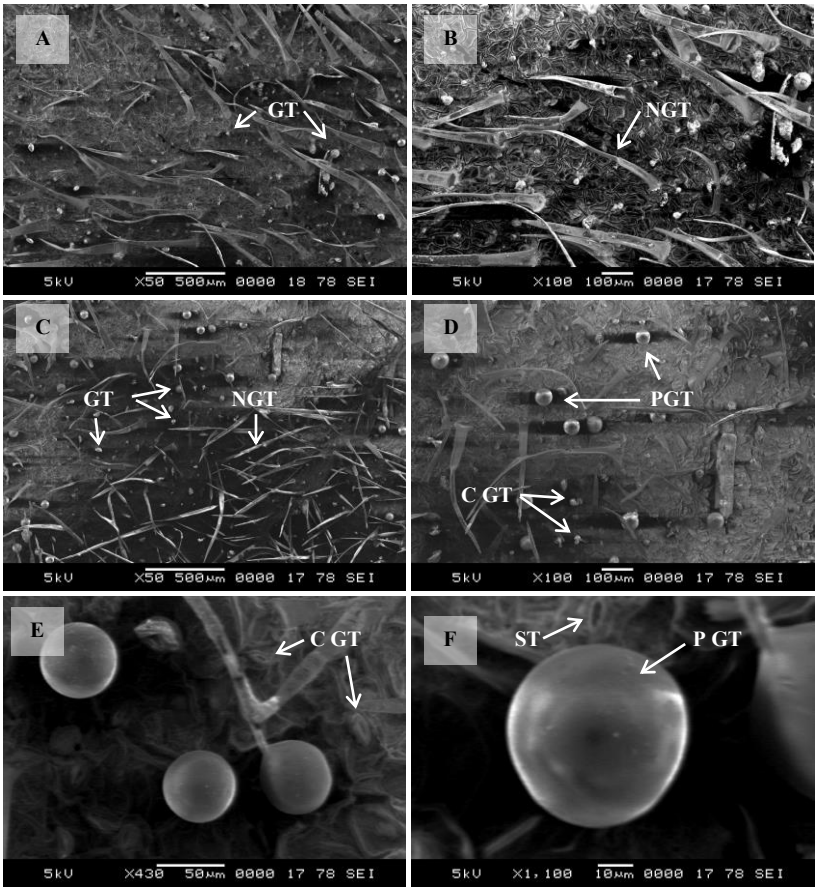

Figure 1. Scanning electron microscopy (SEM) micrographs of leaf lamina of *P. graveolens,* (A, B*)* adaxial (sup) leaf lamina surface, (C-F) abaxial (inf) leaf lamina surface. N GT: non glandular trichome, GT: glandular trichome, C GT: capitate glandular trichome, P GT: peltate glandular trichome, ST: stomata.

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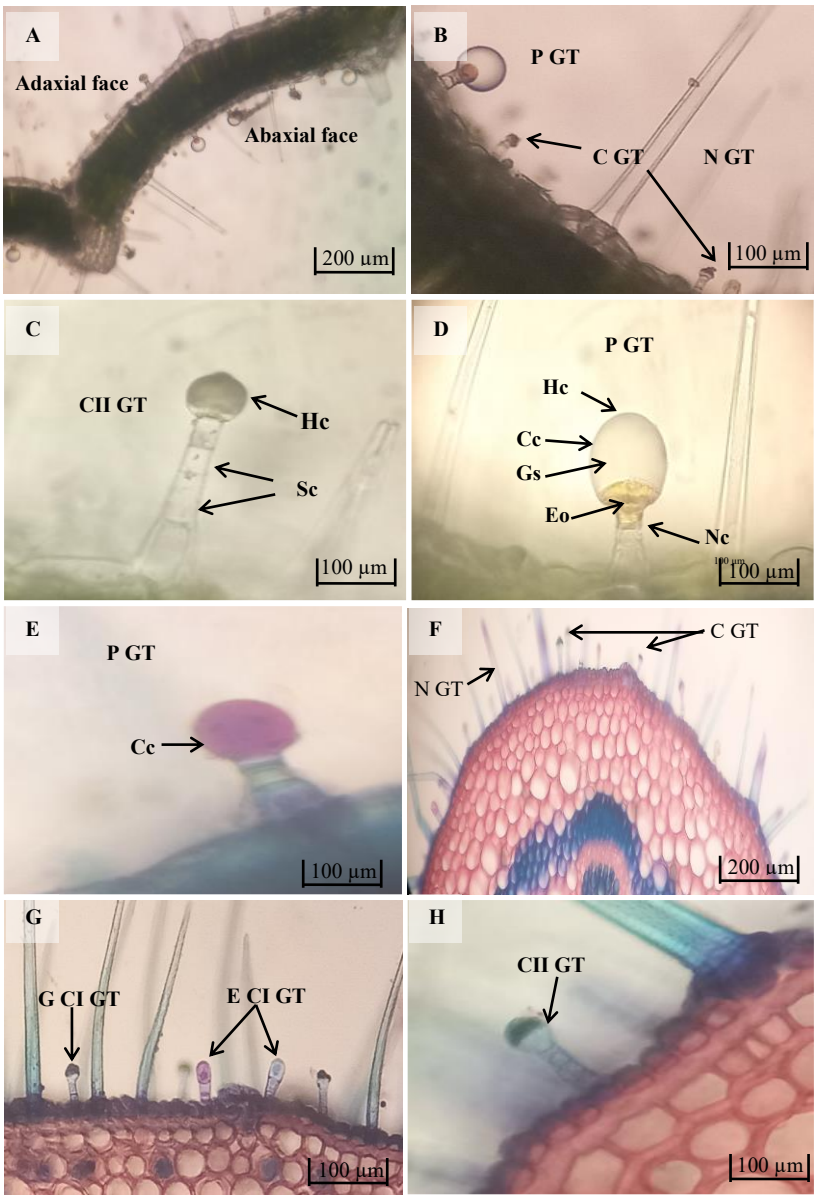

Figure 2. Light microscopy pictures showing different types of trichomes identified on the cross section without coloration (A-D) and after double coloration (E-H) of the leaf lamina (A-E) and petiole (F-H) of *P. graveolens,* under different magnification: A, F (G×40); B, C, D, E, G, H (G×100).N GT: non glandular trichome, C GT: capitate glandular trichome, P GT: peltate glandular trichome, CI GT: capitate glandular trichome type I, CII GT: capitate glandular trichome type II, Hc: head cell, Sc: stalk cell, Nc: neck cell, Bc: base cell, Cc: cuticle, Gs: glandular space, Eo: Essential oil, E CI GT: Elongated head cell in capitate glandular trichome type I, GCI GT: Globular head cell in capitate glandular trichome type I.

Non-glandular trichomes (NGTs) were found on both the adaxial and abaxial leaf lamina and the petiole. They appeared uniseriate, unbranched, and either unicellular or bicellular, with straight or folded shapes, pointed peaks, and granular or smooth surfaces (Fig. 1, 2).

Glandular trichomes were of two morphological types: **capitate and peltate**. Capitate trichomes were more abundant on the adaxial side and petiole. Two subtypes were identified: **Type I (C1):** A short stalk (1-2 cells) with a unicellular, globular, or elongated head, sometimes presenting a visible oil droplet (Fig. 2G). **Type II (C2):** A long stalk (3-4 cells) with a unicellular, pear-shaped head covered by a cuticle (Fig. 2C, H).

Peltate trichomes were predominantly located on the abaxial leaf surface. They consisted of a short stalk (1-2 cells) and a large head containing a storage pocket for essential oil. During secretion, a distinct glandular space formed from the extended cuticle and cell wall (Fig. 2B, D, E).

The distribution of glandular trichomes was similar across both leaf surfaces. However, those on the dorsal surface appeared fully charged with oil, while ventral glands often appeared empty.

Chemical composition

The essential oil of *P. graveolens* was extracted from the aerial parts by steam distillation and analyzed using Gas Chromatography (GC) and Gas Chromatography–Mass Spectrometry (GC-MS). The analysis revealed that 96.4% of the constituents were

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identified, comprising 36.6% esters, 30.2% alcohols, and 18.5% hydrocarbons.

The results presented in table 1 show that the main compounds are: geranyl formate (11.8%), citronellyl formate (11.6%), 10-*epi*-γ-eudesmol (10.0 %), *iso*-menthone (6.3 %), geraniol (6.0%), linaool (5.9 %) and citronellol (4.7%).

Table 1. Chemical composition of essential oil of *P. graveolens* from Algeria.

AI[a]	RI [b]	Compound [c]	% [d]	Methods of identification
0	**1**	**2**	**3**	**4**
932	934	α-pinene	0.8	RI, MS, Co-GC [e]
974	971	β-pinene	0.1	RI, MS, Co-GC
981	977	6-methyl 5-hepten 2-one	tr[f]	RI, MS
988	990,1	myrcene	1.4	RI, MS
1002	1005	α -phellandrene	0.2	RI, MS, Co-GC
1020	1023	*p*-cymene	0.1	RI, MS
1025	1028	β -phellandrene	0.6	RI, MS, Co-GC
1024	1030	limonene	1.0	RI, MS, Co-GC
1032	1046	*cis*-β-Ocimene	0.9	RI, MS
1044	1057	*trans*-β-Ocimene	tr	RI, MS
1083	1077	fenchone	tr	RI, MS
1086	1087	terpinolene	0.2	RI, MS, Co-GC
1095	1101	**linalool**	**5.9**	RI, MS, Co-GC
1106	1110	cis-rose oxide	1.0	RI, MS
1122	1126	trans-rose oxide	0.5	RI, MS
1141	1137	trans-verbenol	tr	RI, MS
1140	1145	camphor	0.1	RI, MS, Co-GC
1148	1151	menthone	0.5	RI, MS
1158	1164	***iso*-menthone**	**6.3**	RI, MS
1179	1182	*iso*-menthol	0.4	RI, MS
1186	1189	α-terpineol	0.4	RI, MS, Co-GC
1233	1233	**citronellol**	**4.7**	RI, MS, Co-GC
1249	1257	**geraniol**	**6.0**	RI, MS, Co-GC
1280	1274	**citronellyl formate**	**11.6**	RI, MS
1298	1299	**geranyl formate**	**11.8**	RI, MS
1322	1317	methyl geranate	0.2	RI, MS
1335	1332	δ-elemene	tr	RI, MS
1350	1347	citronellyl acetate	0.6	RI, MS
1357	1361	(2E)-undecanal	0.3	RI, MS
1374	1371	α-copane	1.1	RI, MS
1379	1378	geranyl acetate	0.9	RI, MS
1387	1387	β-bourbonene	0.3	RI, MS
1400	1405	longipinene	0.2	RI, MS
1414	1415	β-caryophyllene	1.5	RI, MS
1430	1424	β-copane	0.2	RI, MS
1439	1430	aromadendrene	tr	RI, MS
1442	1438	citronellyl propanoate	1.0	RI, MS
1442	1444	*cis* muurola 3,5-diene	0.3	RI, MS
1451	1449	*trans* muurola 3,5-diene	0.3	RI, MS
1452	1456	α-humulene	0.8	RI, MS
1452	1462	*allo*- aromadendrene	0.1	RI, MS
1458	1469	geranyl propanoate	1.9	RI, MS
1480	1477	germacrene D	1.9	RI, MS
1489	1482	β-selinene	0.1	RI, MS
1496	1491	**viridiflorene**	**2.5**	RI, MS
1500	1496	α-murolene	0.3	RI, MS
1513	1508	γ-cadinene	1.0	RI, MS
1514	1515	Z-γ-bisabolene	tr	RI, MS
1522	1519	*trans* calamenene	1.2	RI, MS
1522	1522	σ-cadinene	0.4	RI, MS
1530	1527	vitronellyl butanoate	0.1	RI, MS
1533	1532	*trans* cadina-1,4-diene	0.5	RI, MS
1544	1540	calacorene	0.6	RI, MS
1562	1554	**geranyl butanoate**	**2.8**	RI, MS
1577	1572	spathulenol	0.2	RI, MS
1582	1578	caryophyllene oxide	2.2	RI, MS, Co-GC
1590	1587	globulol	0.2	RI, MS
1602	1596	geranyl 2-mehyl butanoate	0.7	RI, MS
1607	1600	geranyl isovalerate	0.2	RI, MS
1621	1615	**10-*epi*-γ-eudesmol**	**10.0**	RI, MS
1627	1621	1-*epi*-cubenol	0.2	RI, MS
1630	1628	γ-eudesmol	0.3	RI, MS
1640	1635	hinesol	0.7	RI, MS
1649	1642	β-eudesmol	0.2	RI, MS
1652	1645	α-eudesmol	0.4	RI, MS

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0	1	2	3	4
1655	1656	geranyl valerate	0.4	RI, MS
1662	1664	7-*epi*-α-eudesmol	0.0	RI, MS
1666	1673	*trans* citronellyl tiglate	0.2	RI, MS
1684	1684	(2Z,6Z) farnesal	0.1	RI, MS
1696	1695	**geranyl tiglate**	**4.1**	RI, MS
1698	1706	(2E,6Z) farnesol	0.7	RI, MS
1716	1727	*trans* nerolidyl acetate	0.1	RI, MS
1742	1746	(2E,6E) farnesol	0.3	RI, MS
		Total	**96.4%**	

Notes: [a] Linear retention indices values from literature [10]; [b] Linear retention indices as determined on a DB5 column using the homologous series of *n*- alkanes; [c] Compounds listed in order of elution from a DB5-column; [d] Relative area was given according to FID area percentage data; [f] Trace (<0.1%); [e]Co GC ; identification was based on retention times of authentic compounds on DB5-capillary column.

Antioxidant activities

The antioxidant potency of *P. graveolens* essential oils was evaluated using 2,2-diphenyl-1-picrylhydrazyl (DPPH) and reducing power assay (FRAP). The antioxidant activity of *P. graveolens* essential oil was assessed at different concentrations with respect to the DPPH radical, by monitoring the reduction of this radical from violet (DPPH-) to yellow (DPPH-H), as measured at 517nm (fig.3). According to the results, the evolution of antioxidant activity is dose-dependent, increasing with increasing essential oil concentrations in the reaction medium.

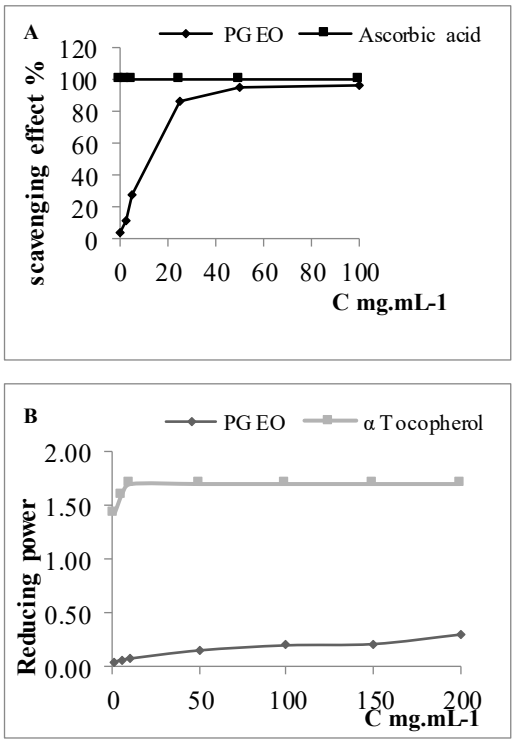

Figure 3. Antioxidant activity of *P. graveolens* essential oil (PG EO) determined by two methods: DPPH assay (A) and Ferric ion reducing antioxidant power (FRAP assay) (B) (Each value represents the mean of three trials ± SD).

Two standard antioxidants, ascorbic acid and α-tocopherol, were used for comparison. The antioxidant activity was expressed as IC_{50}, which represents the concentration of the compound needed to inhibit 50% of the radical absorbance. Lower IC_{50} values indicate higher antioxidant potency. As presented in Table 2, the IC_{50} values of the reference standards demonstrate markedly stronger free-radical scavenging and reducing activities compared to those observed for the essential oil.

Table 2. Antioxidant activities of *P. graveolens* essential oil and standards measured by DPPH radical scavenging capacity and reducing power assay in terms IC50 values.

C mg/mL	IC_{50} DPPH	$IC_{0,5}$ FRAP
P. graveolens essential oil	6.2 ± 0.42^{b}	$> 200^{c}$
Ascorbique acid	0.004 ± 0^{a}	0.047 ± 0^{a}
α-tocopherol	0.009 ± 0^{a}	0.507 ± 0.004^{b}

IC_{50}: sample concentration to inhibit 50% of the DPPH radical. $IC_{0,5}$: the sample concentration corresponding to an absorbance equal to 0.5. Results (means ± SD) in the similar column indicated by variable letters are significantly distinctive (P<0,05).

Antifungal screening

The in vitro antifungal activity of *Pelargonium* oil was investigated for a preliminary assay using a disc diffusion method against a pathogenic fungus. The results obtained from the inhibition zones, expressed in millimetres are presented in table 3. Results were classified according to the following scale [26]:

A zone of inhibition ≥20mm: strong inhibition; Zone of inhibition <20-12mm: moderate inhibition; Zone of inhibition <12mm: no inhibition.

So according to the previous scale, *P graveolens* essential oil showed a higher inhibition rate against all fungal strains tested especially against *Aspergillus carbonarius, Umbelopsis ramanniana* with Diameter of inhibition zones values 38.33 mm and 36.67 mm respectively. Moreover, the essential oil studied exerted an inhibitory activity on *Aspergillus westerdijkiae* similar to that of nystatin, with a non-significant difference at p<0.05.

Table 3. Antifungal activity of *P. graveolens* essential oil (PG EO).

Fungi/DIZ (mm)	PG EO	Nystatine
Penicillium expansum	31.67 ± 2.89^{a}	36^{b}
Umbelopsis ramanniana	36.67±2.89	ND
Aspergillus carbonarius	38.33±2.89	ND
Aspergillus westerdijkiae	20 ± 0^{c}	20^{c}
Fusarium culmorum	25 ± 5^{d}	22^{d}

DIZ (mm): Diameter of inhibition zones (mm) including sterile disc diameter of 5.5 mm and each value is presented as mean ± SD (n = 3) and indicated by variable letters are significantly distinctive (P<0,05); ND: not determined.

DISCUSSION

Glandular trichomes are specialized hair-like structures found on the surface of various plant species. These trichomes vary in several ways, in the chemical composition of secretions, in their structure, function

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and location. The differences in these aspects of glandular trichomes can be used in plant classification and identification [20]. The protective hairs are made up of dead cells so as a result, they only contain air. Their silky mass largely reflects the sun's rays and their dense tangle retains a layer of moisture-saturated air [4].

Hazzoumi *et al*. report that *Pelargonium* sp. leaves exhibit two types of secretory trichomes: peltate trichome (also known as long-term glands) and capitate trichome (also known as short-term glands) [15]. Additionally, they possess protective hairs, which are non-secretory trichomes. Our finding is in accordance with this research, which describe two categories of capitate trichomes and one type of peltate trichome. Besides Boukhris *et al.* observed 3 types of capitates trichomes in *Pelargonium graveolens* and peltate trichome present only on stems and calyx [6].

Two kinds of trichomes were found at the surface of all the vegetative and reproductive organs of *Pelargonium roseum* Wild. Tector trichomes formed of 2 cells and secretory trichomes with 2 sizes depending on the leaf ripening stage [11]. Capitate glandular trichomes are also observed in some other Geraniaceae species. Kremer *et al.* found C1 and C2 comparable with our finding in *Geranium macrorrhizum* and C3 composed with 2–6 stalk cells in *Geranium dalmaticum* [5].

Regarding the chemical composition of *P. graveolens* essential oil, the studied essential oil belongs to the African type which contains a significant amount of 10-epi-γ-eudesmol and lacks amount of guaia-6,9-dienne [27]. The 10-epi-γ - eudesmol is known to be one of the major constituents in some varieties of *P. graveolens* [29]. Our finding report a lower concentration of citronellol (4.7%) that is not consistent with other researches cited in the literature [5, 7]. Jaradat *et al.* reported that essential oil extracted from *P. graveolens* leaves growing in Palestine was composed predominantly of citronellol (24.44 %), citronellyl formate (15.63%), γ-eudesmol (8.6%), *iso*-menthone (7.43 %), geranyl formate (3.4 %) [16].

Other authors have reported different proportions of the major compounds in *P. graveolens* cultivated in Argentina, with geraniol (24.89%) and citronellol (19.5%) being the most abundant components [28]. In contrast, the essential oil extracted from the aerial parts of *P. graveolens* harvested in Morocco exhibited a markedly different chemical composition, with menthol (20.57%), isogeraniol (9.14%), and menthene (9.97%) identified as the main constituents [7].

Geraniol and citronellol compounds are originate from geranyl pyrophosphate. Their concentration variability is due to the biosynthesis which operated by different enzymes [10]. The variation in citronellol content could be explained by higher ratio during cold stress in geranium plants [28]. Moreover the difference of composition could be related to the difference in origin of samples and the extraction/distillation process [25]. In addition, during the development of *P. graveolens* it is possible that some metabolic reaction changes the chemical composition of the essential oil [7]. Oxygenated monoterpenes are generally formed more readily than sesquiterpenes because their production requires less enzymatic complexity and involves lower-molecular-weight precursors [7].

The assessment of the antioxidant effect through two different assays showed that *P. graveolens* essential oil presents a lower antioxidant activity (IC_{50} = 6.2 $mg{\cdot}mL^{-1}$) than ascorbic acid, as well as the reducing power effect of studied essential oil is not noteworthy compared to synthetic antioxidant α-tocopherol. However there is only one Moroccan study presented by Al-Mijalli *et al.* who measured the ferric reducing antioxidant power. They presented a considerable FRAP antioxidant power [2].

Our results are in accordance with these of Čavar and Maksimović [9]. They tested antioxidant capacity using the DPPH technique, and the results for essential oils varied from 63.70 $mg{\cdot}mL^{-1}$ for leaves to 64.88 $mg{\cdot}mL^{-1}$ for stems. In recent study antiradical activity of geranium essential oil was significantly higher than our results. The values of 50% effective concentration of the oils harvested in different growth stage (flowering, post flowering and vegetative) ranged from 83 $\mu g{\cdot}mL^{-1}$ to 138 $\mu g{\cdot}mL^{-1}$ [2], and from 1 $\mu g{\cdot}mL^{-1}$ to 2 $\mu g{\cdot}mL^{-1}$, with an IC_{50} = 2.5 $\mu g{\cdot}mL^{-1}$ for pure β-citronellol [10]. These findings demonstrate that flower oil of *Pelargonium* has the greatest antioxidant activity compared to the oils in the other stages [7]. This activity could be related to the major compounds such as geraniol and citronnellol (alcoholic monoterpenes) which are considered as antioxidant components [9].

Our results contradict this of Jaradat *et al*. [16] who asserted that *P. graveolens* essential oils exhibit a higher action in the scavenging of DPPH radicals. This difference may be due to the chemical composition of the essential oil. This variation can be attributed to the essential oil distillation method, seasonal and climatique variation as well as plant physiological conditions [16].

Our preliminary investigation of the antifungal activity is consistent with the findings of Džamić *et al.* [10], who reported that the antifungal efficacy of *P. graveolens* oil was considerably higher than that of bifonazole. Further research revealed that geranium oil provides a good inhibitory effect against *Candida* strains, for both *C. glabrata* and *C. albicans* and *Cryptococcus neoformans* [5, 13]. Recently, the inhibitory actions of *P. graveolens* essential oils and its three fractions (F1, F2 and F3) were determined against four wood decay fungi *Gloeophyllum trabeum, Poria placenta, Coniophora puteana* and *Coriolus versi* which are responsible for the brown and white rot wood [21]. This results showed that the essential oil and its fractions had an inhibitory effect against a tested fungal but the highest inhibitory effect was attributed to fraction 3 (F3); they confirmed that the efficacy of F3 might be due to its high levels of

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alcohols especially geraniol (30.87 %) and citronellol (27.42 %). Furthermore, the terpenes in essential oils may have antimicrobial properties due to their high lipophilicity and low molecular weight, which can disrupt cell membranes, kill cells or prevent the sporulation and germination of fungi that cause food spoilage [22].

These findings demonstrate that *P. graveolens* possesses diverse glandular trichomes, a distinct chemical profile, and notable antifungal activity, although its antioxidant potential is moderate. The observed variation in essential oil composition emphasizes the influence of plant origin, developmental stage, and extraction methods. Further studies, including determination of the minimum inhibitory concentration, are needed to quantify antifungal efficacy. Overall, *P. graveolens* essential oil shows promise as a natural preservative and antifungal agent, with potential applications in food preservation and various industrial sectors.

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Conflict of Interest: The authors declare that they have no conflict of interest.

REFERENCES

[1] Adams, R.P., (2007): Identification of essential oil components by gas chromatography/mass spectrometry, 4th Edition. Allured Publishing Corporation, Carol Stream, 804 p.

[2] Al-Mijalli, S.H., Mrabti, H.N., Assaggaf, H., Attar, A.A., Munerah, H., EL Baaboua, A., El Omari, N., El Menyiy, N., Hazzoumi, Z.A., Sheikh, R., Zengin, G., Sut, S., Dall'Acqua, S., Bouyahya, A., (2022): Chemical profiling and biological activities of *Pelargonium graveolens* essential oils at three different phenological stages. Plants, 11: 22-26.

[3] Belaid, F., Amrani, S., Bloem, E., Belkebir, A., (2020): Structures and chemical compounds causing integumentary inhibition of *Erythrina corallodendron* seeds in Algeria. Phyton, 60: 161-172.

[4] Boukhatem, M.N., Hamaidi, M.S., Saidi, F., Hakim, Y., (2010): Extraction, composition et propriétés physico-chimiques de l'huile essentielle du Géranium Rosat (*Pelargonium graveolens* L.) cultivé dans la plaine de Mitidja (Algérie). Nature et Technologie, 3: 37-45.

[5] Boukhatem, M.N., Kameli, A., Ferhat, M.A., Saidi, F., Mekarnia, M., (2013): Rose geranium essential oil as a source of new and safe anti-inflammatory drugs. Libyan Journal of Medicine, 8: 22520.

[6] Boukhris, M., Ben Nasri-Ayachi, M., Mezghani, I., Bouaziz, M., Boukhris, M., Sayadi, S., (2013): Trichomes morphology, structure and essential oils of *Pelargonium graveolens* L'Hér. (Geraniaceae). Industrial Crops and Products, 50: 604-610.

[7] Boukhris, M., Hadrich, F., Chtourou, H., Dhouib, A., Bouaziz, M., Sayadi, S., (2015): Chemical composition, biological activities and DNA damage protective effect of *Pelargonium graveolens* L'Hér. essential oils at different phenological stages. Industrial Crops and Products, 74: 600-606.

[8] Bown, D., (1995): Encyclopedia of herbs and their use. The Herb Society of America (1st Ed.), Dorling Kindersley Ltd, pp. 230-260.

[9] Cavar, S., Maksimovic, M., (2012): Antioxidant activity of essential oil and aqueous extract of *Pelargonium graveolens* L'Her. Food Control, 23: 263-267.

[10] Džamić, A.M., Soković, M.D., Ristić, M.S., Grujić. S.M., Mileski, K.S., Marin, P.D., (2014): Chemical composition, antifungal and antioxidant activity of *Pelargonium graveolens* essential oil. Journal of Applied Pharmaceutical Science, 4(3): 1-5.

[11] Gâlea, I.C., Ielciu, I., Crişan, G., Tămaş, M., (2017): Histo-anatomical studies on the vegetative and reproductive organs of *Pelargonium roseum* Willd. (Geraniaceae). Hop and Medicinal Plants, 1(2): 115-124.

[12] Gostin, I.N., Blidar, C.F., (2024): Glandular trichomes and essential oils variability in species of the genus *Phlomis* L.: A review. Plants-Basel, 13(10): 1338.

[13] Gucwa, K., Milewski, S., Dymerski, T., Szweda, P., (2018): Investigation of the antifungal activity and mode of action of *Thymus vulgaris, Citrus limonum, Pelargonium graveolens, Cinnamomum cassia, Ocimum basilicum,* and *Eugenia caryophyllus* essential oils. Molecules, 23(5): 11-16.

[14] Harzallah, A., Hachama, K., Fizir, M., Khadraoui, A., (2022): Traditional uses, botany, phytochemistry, and pharmacology of *Pelargonium graveolens*: a comprehensive review. Tropical Journal of Natural Product Research, 6(10): 1547-1569.

[15] Hazzoumi, Z., Moustakime, Y., Amrani Joutei, K., (2019): Essential oil and glandular hairs: diversity and role. In Essential Oils-Oils of Nature, IntechOpen, pp. 1-16.

[16] Jaradat, N., Hawash, M., Qadi, M., Abualhasan, M., Odetallah, A., Qasim, G., Awayssa, R., Akkawi, A., Abdullah, I., Al-Maharik, N., (2022): Chemical markers and pharmacological characters of *Pelargonium graveolens* essential oil from palestine. Molecules, 27(17): 5721.

[17] Kremer, D., Vitali Čepo, D., Dunkić, V., Müller, I.D., Kosalec, I., Bezić, N., Stabentheiner, E., (2013): Phytochemical and micromorphological traits of *Geranium dalmaticum* and *G. macrorrhizum* (Geraniaceae). Natural Product Communications, 8(5): 645-650.

[18] Konig, W.A., Hochmuth, D.H., Joulain, D., (2001): Terpenoids and related constituents of essential oils, Library of Mass Finder 2.1, Institute of Organic Chemistry, Hamburg.

[19] Lopez, C.P., Pekas, A., Stubsgaard, L., Sancho, B.G., Lütken, H., Sigsgaard, L., (2022): Glandular trichomes affect mobility and predatory behavior of two aphid predators on medicinal cannabis. Biological Control, 170: 104932.

[20] Marin, M., Koko, V., Duletić-Laušević, S., Marin, P.D., Rančić, D., Dajic-Stevanovic, Z., (2006): Glandular trichomes on the leaves of *Rosmarinus officinalis*: Morphology, stereology and histochemistry. South African Journal of Botany, 72: 378-382.

[21] Moutaouafiq, S., Farah, A., Ezzoubi, Y., Ghanmi, M., satrani, B., Bousta, D., (2019): Antifungal activity of *Pelargonium graveolens* essential oil and its fractions against wood decay fungi. Journal of Essential Oil Bearing Plants, 22(4): 1104-1114.

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[22] Nazzaro, F., Fratianni, F., Coppola, R., De Feo, V., (2017). Essential oils and antifungal activity. Pharmaceuticals, 10(4): 1-20.
[23] Oyaizu, M., (1986): Studies on product of browning reaction prepared from glucose amine. Journal of Nutrition, 44: 307-315.
[24] Peterson, A., Machmudah, S., Bhupesh, C.R., Goto, M., Sasaki, M., Hirose, T., (2006): Extraction of essential oil from geranium (*Pelargonium graveolens*) with supercritical carbon dioxide. Journal of Chemical Technology & Biotechnology, 81: 167-172.
[25] Popescu, I.E., Gostin, I.N., Blidar, C.F., (2024): An overview of the mechanisms of action and administration technologies of the essential oils used as green insecticides. AgriEngineering, 6(2): 1195-1217.
[26] Rusenova, N., Parvanov, P., (2009): Antimicrobial activities of twelve essential oils against microorganisms of veterinary importance. Trakia Journal of Sciences, 7(1): 37-43.
[27] Sharopov, F.S., Zhang, H., Setzer, W.N., (2014): Composition of geranium (*Pelargonium graveolens*) essential oil from Tajikistan. American Journal of Essential Oils and Natural Products, 2: 13-16.
[28] 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, 62(2): 145-152.
[29] Tabanca, N., Wang, M., Avonto, C., Chittiboyina, A.G., Parcher, J.F., Carroll, J.F., Kramer, M., Khan, I.A., (2013): Bioactivity-guided investigation of *Geranium* essential oils as natural tick repellents. Journal of Agricultural and Food Chemistry, 61: 4101-4107.
[30] Tang, H.M., Jiang, Q., Liu, H.Y., Zhang, F., Liu, Q., Pu, G.B., Li, J., Wang, L.N., Zhang, Y.Q., (2022): Glandular trichomes of medicinal plants: types, separation and purification, biological activities. Biologia Plantarum, 66: 219-227.
[31] Tepe, B., Daferera, D., Tepe, AS., Polissiou, M., Sokmen, A., (2007): Antioxidant activity of the essential oil and various extracts of *Nepeta flavida* Hub-Mor. from Turkey. Food Chemistry, 103(4): 1358-1364.
[32] Van Den Dool, H., Kratz, P.D., (1963): A generalization of the retention index system including linear temperature programmed gas-liquid partition chromatography. Journal of Chromatography A, 11: 463-471.
[33] Van der Walt, J.J.A.,Vorster, P.J., (1988): *Pelargoniums* of southern Africa (Vol.3). National Botanic Gardens, Kirstenbosch. Juta, Cape Town, pp 1-149.
[34] Watts, S., Kariyat, R., (2021): Morphological characterization of trichomes shows enormous variation in shape, density and dimensions across the leaves of 14 *Solanum* species. Annals of Botany plants, 13(6): 1-32.

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