Egypt. J. Chem. **Vol. 68,** SI: Z. M. Nofal, pp. 161 - 185 (2025)

Egyptian Journal of Chemistry
http://ejchem.journals.ekb.eg/

Unlocking the Therapeutic Potential of Limoniastrum Genus: Phytochemical Insights and Biological Activities

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Abstract
Halophytes have attracted the attention of the world recently. The world has become interested in wild plants, which are considered one of the finest and most significant therapeutic botanicals rich in phytochemical constituents and biological activities. This research clarifies the natural products in this halophyte and its therapeutic value for different species of *Limoniastrum*. The natural compounds found in *Limoniastrum* species, such as phenolic, phenolic sulfates, lignans, tannins, saponins, traces of alkaloids, and steroid compounds, have therapeutic effects as anti-cancer, anti-microbial, antioxidants, and anti-diabetic. This research aimed to overview the phytochemical and biological activities of *Limoniastrum* Family Plumbaginaceae in recent years.

Keywords: Plumbaginaceae, *Limoniastrum*; Phytochemical constituents; biological activities

1. Introduction

Halophytes are plants resistant to high salinity [1]. Different tolerance levels to salinity are observed among families of halophyte species. Some families, such as Potamogetonaceae, Zygophyllaceae, Tamaricaceae, and Plumbaginaceae, require high salinity for optimal growth, whereas others, like Araceae, Rosaceae, and Ericaceae, are salt-sensitive [2]. The three types of halophytes are glycohalophytes, euhalophytes, and crinohalophytes. Euhalophytes depend on the accumulation of salts in their tissues to be salt tolerant. Crinohalophytes, on the other hand, depend on eliminating hazardous ions such as Na+ and Cl- to expel salts from the plant's body. Glycohalophytes depend on mechanisms that keep excess salts from building up [3]. Many secondary metabolites, such as tannins, flavonoids, and proanthocyanidin, can be produced significantly by halophytes. Many nations, including Ghana, India, China, South Africa, Mexico, and Russia, use halophytes in their traditional medical practices, according to the WHO Global Report for 2019 [4]. These bioactive compounds scavenge ROS and lessen the consequences of oxidative stress in their capacity as antioxidants [5]. Approximately fifty-five species, or ten of the eleven genera, are included in the Plumbaginaceae [6]. Recently, Plumbaginaceae, which has 1138 species spread over 26 genera, has several plants that have evolved to live in salty environments [7]. The Plumbaginaceae family is found worldwide and is distributed as a weed throughout tropical and subtropical countries [8]. The Plumbaginaceae family includes lianes, herbs, shrubs, and flowering plants characterized by simple, whole to lobed, spirally arranged leaves that are occasionally auriculate, exstipulate, and rarely scaly [9]. There are therapeutic and ornamental uses for several Plumbaginaceae species [10]. The family, belonging to the monotypic order Plumbaginales, is closely related to the Caryophyllales order [11]. Limonioideae Reveal (formerly Staticoideae Burnett) and Plumbaginoideae Burnett are the two subfamilies that comprise the most commonly recognized taxonomy of the Plumbaginaceae family. In terms of morphology, the two subfamilies are clearly distinct [12]. Genera of the Plumbaginaceae in subfamily Plumbaginoideae include *Plumbago L.*, *Plumbagella Spach*, *Dyerophytum Kuntze*, *Ceratostigma Bunge*, while those in subfamily Staticoideae include *Aegialitis R. Br.*, *Acantholimon* Boiss, *Neogontscharovia* Lincz., *Gladiolimon* Mobayen, *Ghaznianthus* Lincz., *Dictyolimon* Rech. f., *Limoniastrum* Fabr., and *Limonium P.* Miller [13]. Currently, there are two species of halophytic shrubs in the genus *Limoniastrum* Heist. ex Fabr. (Plumbaginaceae): *L. guyonianum* Boiss. and *L. monopetalum* Boiss. These shrubs are primarily found in saline, arid areas and coastal regions of northern Saharan Africa and the Mediterranean [14]. In Algeria, *Limoniastrum guyonianum* (Plumbaginaceae) is used to cure anemia, headaches, constipation, hypertension, kidney problems, and snake and scorpion bites. In Tunisia, teas prepared from the leaves and galls of *Limoniastrum monopetalum* are used to cure parasites, bloody diarrhea, and infectious disorders [15]. A native of Mediterranean coastal sands and salt marshes, *Limoniastrum monopetalum* is an evergreen perennial shrub. It is employed in traditional medicine and as an attractive plant, and it has adapted to a range

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Received date 22 April 2025; Revised date 05 August 2025; Accepted date 16 August 2025
DOI: 10.21608/EJCHEM.2025.372064.11636

of environmental challenges [16]. Furthermore, given their extensive therapeutic potential, halophytes such as *Limoniastrum* species are increasingly being explored for novel antiviral applications, including respiratory infections, where medicinal plants have shown promise in mitigating viral diseases through immunomodulatory and phytochemical pathways [17].

Species of *Limoniastrum* contain various bioactive compounds that act as new anti-microbial agents, such as saponins, tannins, phenolic acids, lignans, traces of alkaloids, and steroid compounds. These compounds have therapeutic effects such as anti-diabetic, anti-inflammatory, anti-cancer, antioxidants, cytotoxic, and anti-microbial properties [18]. There is presently no detailed review that looks at all the phytochemical profiles and biological activity across the whole genus. The existing literature is still scattered and generally doesn't take a critical or comparative perspective, which makes it hard to see big patterns or the possibility for therapeutic growth. Also, most research have only looked at certain extracts or isolated chemicals without putting the results in the context of the genus's overall phytochemical makeup.

This review fills in this important gap by systematically gathering and analyzing what we know about the phytochemistry and biological activities of *Limoniastrum* species. It does this by creating a single framework that shows their potential as drugs, points out inconsistencies in the data, and suggests areas for further study.

2. Experimental

This review represents the first literature analysis conducted by Amaal. H. Zokalih, between May and August 2024, employing a computerized-based search such as Google Scholar, PubMed, ScienceDirect, Egyptian Knowledge Bank, Pub Chem, Sc Finder, books, theses, and official websites. "The Plant List" (www.theplantlist.org) was used to confirm the approved species number and names. ChemDraw professional 15.0 software was used to draw all chemical structures

3. Results and discussion:

3.1 Phytochemical constituents

Plumbaginaceae has different natural compounds and therapeutic values. In the genus *Limoniastrum*, different species have been isolated and identified. They have several bioactive compounds belonging to flavonoids, fatty acids, essential oils, sterols, phenolic acids and phenolic derivatives, saponins, and other compounds, as listed in Tables 1–6.

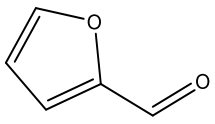
3.1.1 Essential oil components

Gas chromatography-flame ionization detector (GCFID) analytical technique and GC-MS were employed to investigate the oil obtained from the roots, leaves, flowers, and stem of *L. guyonianum*. There are numerous components in oil, and the main ones in each organ were found in the roots' essential oil, which makes up 87.28% of the volatiles overall. Conversely, the volatile fraction of seeds contained the highest amount of furfural (1) out of 31 components in total. The essential oils of leaves and flowers contained esters in nearly equal amounts. about 21.04% and 36.4% of the components were terpenes in flower oil leaf oil, respectively. The two main components were 3-phenylprop-2-enylpentanoate (3) (15.05%) and methyl-2,4-dimethylbenzoate (2) (14.70%) [19]. Using GC mass spectroscopy, numerous volatile components of the methanol (M) extracts of the leaves and stem of *L. guyonianum* were identified. Camphor was the primary compound in the leaves and stem, accounting for 96.98% and 94.65% of the identified components; other components were identified [20]. In the M-based preparations of *L. monopetalum* leaves, stems, and roots, the chemical structure of the volatile fractions and the recognition of multiple volatile constituents were determined using GC–MS and GC–FID [21]. Many volatile components were identified from the chloroform extract of *L. guyonianum* by GC-MS, and the major compounds were (21-22-23) (Table 1 and Figure 1) [22].

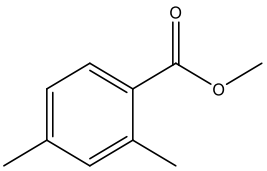
Table 1. Volatile components reported from genus *Limoniastrum*

No.	Compounds name	Plant parts	Species	Ref.
1	Furfural	S	*L. guyonianum*	[19]
2	Methyl-2,4-dimethylbenzoate	L	*L. guyonianum*	[19]
3	3-phenylprop-2-enylpentanoate	F	*L. guyonianum*	[19]
4	Camphor	L &St	*L. guyonianum*	[20]
		L&St&R	*L.monopetalum*	[21]
5	Fenchone	L&St	*L. guyonianum*	[20]
		St&R	*L.monopetalum*	[21]
6	Isopentylisovalerate	St	*L. guyonianum*	[20]
7	Karahanaenone	L	*L. guyonianum*	[20]
		St&R	*L.monopetalum*	[21]
8	Isoborneol	L	*L. guyonianum*	[20]
		St&R	*L.monopetalum*	[21]

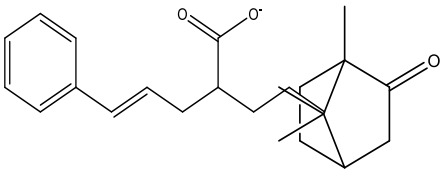
9	Cyclopent-2-enone-5-methylene-2,3,4,4-tetramethyl	L L	*L. guyonianum* *L.monopetalum*	[20] [21]
10	Nonanoic acid	St	*L. guyonianum*	[20]
11	Indole	St	*L. guyonianum*	[20]
12	Guaiacol	L	*L. guyonianum*	[20]
13	Geranyl acetone	St	*L. guyonianum*	[20]
14	Ionone	L &St	*L. guyonianum*	[20]
15	5,6,7,7-tetrahydro-4,4,7α-trimethyl -2(4h)-Benzofuranone	L	*L. guyonianum*	[20]
16	Dodecanoic acid	L	*L. guyonianum*	[20]
17	Nerolidylacetate	L	*L. guyonianum*	[20]
18	cis-Tujone	R	*L.monopetalum*	[21]
19	4-Methylene- isophorone	L	*L.monopetalum*	[21]
20	Trans-2-phenyl-1,3-diox	W	*L. guyonianum*	[22]
21	Olane-4-methyloctadec-9,12,15-trienoate	W	*L. guyonianum*	[22]
22	2-Pentanone,4-hydroxy-4-methyl	W	*L. guyonianum*	[22]
23	(3-Chlorophenyl) acetylene	W	*L. guyonianum*	[22]
	L:Leaves;St:Stem;F:Flowers;R:Root;	W:Whole Plant		



Furfural

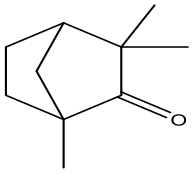


Methyl-2,4-Dimethylbenzoate

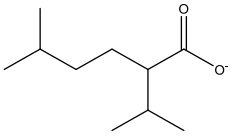


3-3-phenylpropenylpentanoate

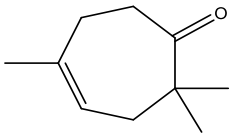
Camphor



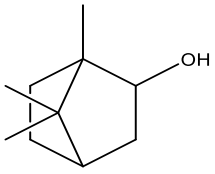
Fenchone



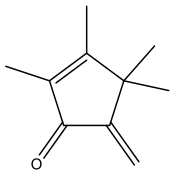
Isopentylisovalerate

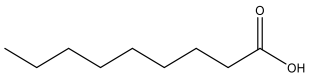


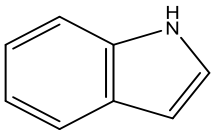
Karahanaenone

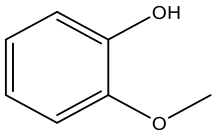


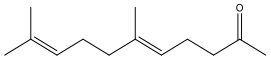
Isoborneol

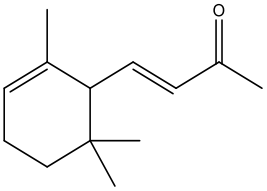

5-Methylene-2,3,4,4-tetramethyl- cyclopent-2-enone

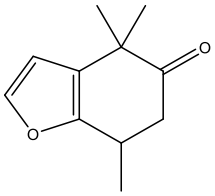

Nonanoic acid

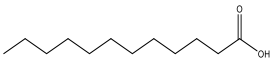

Indole

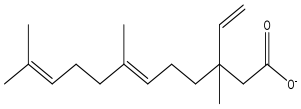

Guaiacol

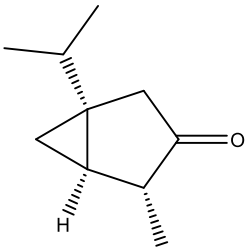

Geranyl acetone

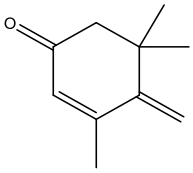

Ionone

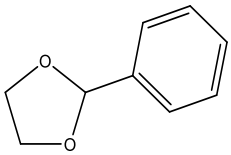

2(4h) Bernzofuranone,5,6,7,7 a-tetrahydro-4,4,7a-trimethyl

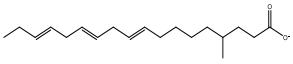

Dodecanoic acid

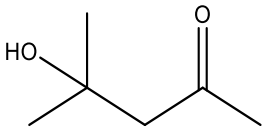

Nerolidylacetate.


cis-Tujone


4-Methylene- isophorone


Trans-2-phenyl-1,3-diox Olane


4-methyl octadec-9,12,15-trienoate,


2-Pentanone,4-hydroxy-4-methyl

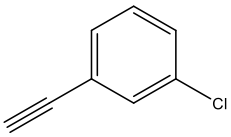

3-Chlorophenyl) acetylene

Figure 1. Structures of volatile components reported in genus *Limoniastrum*

3.1.2 Flavonoids

Limoniastrum species are rich in flavonoid compounds. These compounds have therapeutic values, such as maesopsin-6-*O*-glucoside (1), an aurone flavonoid. NMR identified this compound in methanolic extracts of *L. monopetalum* leaves [21]. Four flavonoids were isolated from water acetone extracts of *L. feei* twigs, as shown in Table 1 (2-5) [23]. By the HPLC–DAD–ESI-MS/MS analysis, five flavonoids glucoside from M-extracts of *L. guyonianum* aerial part were identified, as shown in Table 1 (6-10) [24]. From the aerial parts of *L. feei* extracts, glucosylated flavonoids (11-12) were isolated, identified by liquid chromatography, and elucidated by IR, UV, ^{1}H, and ^{13}C-NMR analysis [25]. Flavonoids were identified by RP-HPLC using 80% aqueous acetone extract of different organs of *L.monopetalum* (stems, flowers, and galls). Quercetin is present in all organs, amentoflavone in flower extract, flavone in stem and gall, and rutin in gall extract only [26]. Using QTOF–LCMS, many metabolites were detected from ethanolic extracts of *L. monopetalum* leaves (15-20) [27]. Hydro-alcoholic crude leaf extracts from *L. feei* were isolated, and many polyphenolic compounds were identified by NMR spectra (16-18-21-22-23) [28]. Phenolic compounds from leaves and stem extracts of *L. guyonianum* were identified by RP-HPLC as epicatechin, naringin, and myricetin (16-24-25) [29]. Seven new flavonoids were separated from *L. feei* aerial parts and identified by^{1}H-

NMR, ^{13}C, and RMN-1H (26-32) [30]. Two new flavonoid glycosides (33-34) were separated from *L. monopetalum* aerial parts. They were determined using the following methods: UV, ^{1}H and ^{13}CNMR, FAB-mass spectra, and acid hydrolysis to aglycone and sugar [31].

New phenolic compounds (19-21-24-35) were separated and clarified by ESI-MS analysis and 1D and 2D NMR investigations [32]. Gallocatechin (36) was isolated from *L.guyonianum* Bois roots using butanol extract, and its structure was identified using 1D and 2D NMR along with ES-MS [33]. Quercetin (13), amentoflavone, apigenin (37), and flavone were the four flavonoids found in *L. monopetalum* leaf extract using RP-HPLC chromatographic profiles of flavonoid standards and [34]. Quercetin (13) was identified in *L. guyonianum* aerial parts extract using HPLC-DAD in all fractions ($CHCl_3$, EtOAc, and n-BuOH) [35]. Flavonoid glucoside compounds (7-21-38-39-40), which are a myricetin derivative, were detected by HPLC-DAD-ESI/MS [36]. HPLC-TOF/MS was employed to identify many flavonoids (19-25-41-42) in the aqueous leaf extract of *L. guyonianum* [37].

By HPLC analysis of components extracted from aerial structures of *L. guyonianum*, different flavonoids (19-23-36) were identified, while in *L. monopetalum*, only gallocatechin was found in this extract according to retention time [38].

The chemical profiles of treated and untreated polyvinylpolypyrrolidone samples of *L.monopetalum* aerial parts (leaves and stem) acetone extracts were studied using HPLC and ESI (9-14-36-43) [39]. Different flavonoids were determined using HPLC chromatograms of macerated, microwave-assisted, and ultrasound-assisted ethanol extracts of *L. monopetalum* aerial parts (13-14-19-24-44) [40].

Many flavonoids were isolated from the aerial parts of *L. monopetatum* using Sephadex LH-20 columns (16-39-45) and identified using ^{1}-H-NMR, TLC, UV, and mass spectrum [41]. Different compounds, amentoflavone and (13-17-19-44-46-47), were identified by reversed-phase HPLC (RP-HPLC) from *L. guyonianum* roots extract [42].

HPLC analysis of the extracts of *L.guyonianum* Boiss showed catechin flavonoids (19) [43]. Eleven polyphenol compounds were isolated using column chromatography, prep-HPLC, and structural elucidation of the aerial parts of *L. feei;* six compounds were isolated from twigs, four from stems, and one from leaves (48-57) (Figure 2 and Table 2) [44].

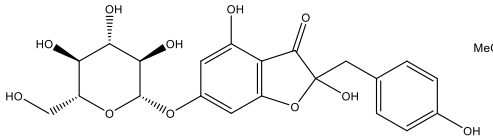
Table 2. Flavonoids reported from genus *Limoniastrum*

No.	Compounds name	Plant parts	Species	Ref.
1	Maesopsin-6-*O*-glucoside	L	*L.monopetalum*	[21].
2	6,3,4-tri-methoxy3,5,5-trihydroxy flavonol	T	*L. feei*	[23]
3	6,3',4'-tri-methoxy-5,5'-dihydroxyflavonol-3-(6"-malonyl-2"-rh-amnosylglucoside)	T	*L. feei*	[23]
4	7-hydroxy-4-methoxyisoflavone-8-*C*-β-glucopyranoside	T	*L. feei*	[23]
5	7,4'-dimethoxyisoflavone-8-*C*-β-glucopyranosyl (1'''→2'')glucopyranoside	T	*L. feei*	[23]
6	Myricetin-3-*O*-rhamnosylglucoside	AP	*L. guyonianum*	[24].
7	Myricetin-3-*O*-glucuronide	AP	*L. guyonianum*	[24].
			L. guyonianum	[36]
8	Myricetin-3-*O*- pentoside	AP	*L. guyonianum*	[24]
			L.monopetalum	
9	Quercetin-3-*O*-glucuronide	AP	*L. guyonianum*	[24]
			L.monopetalum	
			L.monopetalum	[39]
10	Eriodictyol-7-*O*- rutinoside	AP	*L. guyonianum*	[24].
11	6-(2,5-dimethyl hexyl)-5,7,3',4'-tetra hydroxy flavone -7-*O*-glucopyranosyl (1'''→6'')glucopyranoside	AP	*L. feei*	[25].
12	5,3',4'- trihydroxyl flavonol-3-*O*-(6"-ester 3-methyl hexan-1-one- 2,4-diene glucopyranoside) -7-*O*-(diglucouronoylmethyl ester(1''''→2'''), (1'''''→6''') glucopyranoside)	AP	*L. feei*	[25].
13	Quercetin	St	*L.monopetalum*	[26]
		F&G	*L. feei*	[28]
		L	*L.monopetalum*	[34]
		AP	*L. gyuonianum*	[40]
		AP	*L.monopetalum*	
		R	*L.guyonianum*	[42]
14	Rutin	St&F &G	*L.monopetalum*	[26]
			L.monopetalum	
		AP	*L. monopetalum*	[39]

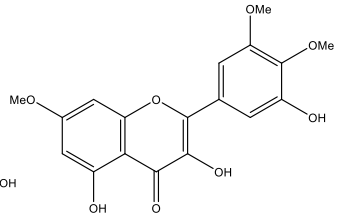
		AP	*L. monopetalum*	[40]
		AP		[41]
15	6-hydroxy luteolin	L	*L. monopetalum*	[27]
16	Myricetin	L	*L. monopetalum*	[27]
		L	*L. feei*	[28]
		St	*L. gyuonianum*	[29]
		AP	*L. monopetalum*	[41]
17	Isorhamnetin	L	*L. monopetalum*	[27]
		R	*L. guyonianum*	[42]
18	Quercetin-3-O-galactopyranoside	L	*L. monopetalum*	[27]
		L	*L. feei*	[28]
19	Catechin	L	*L. monopetalum*	[27]
		W	*L. feei*	[32]
		L	*L. gyuonianum*	[37]
		AP	*L. gyuonianum*	[38]
		AP	*L. monopetalum*	[40]
		R	*L.guyonianum*	[42]
		F	*L.guyonianum*	[43]
20	6,7-dihydroxy-5-methoxy 7-*O*-β-D-glucopyranoside	L	*L. monopetalum*	[27]
21	Myricetin-3-*O*-rhamnoside	L	*L. feei*	[28]
		W	*L. feei*	[32]
		AP	*L. gyuonianum*	[36]
22	Myricetin-3-*O*-β-galactopyranside	L	*L. feei*	[28]
23	Epigallocatechin-3-*O*-gallate	L	*L. feei*	[28]
		AP	*L. gyuonianum*	[38]
24	Epicatechin	St	*L. gyuonianum*	[29]
		W	*L. feei*	[32]
		AP	*L. monopetalum*	[40]
25	Naringin	St	*L. gyuonianum*	[29]
		L	*L. gyuonianum*	[37]
26	3-(3",4"-dimethyl-3"-pentenyl)-4',5-dihydroxyflavones7-*O*-(α-rhamnopyranosyl- (1’’’→6’’) -β-glucopyranoside)	AP	*L. feei*	[30]
27	4' - methoxyisoflavone 7-*O*-β-glucopyranoside	AP	*L. feei*	[30]
28	5,7,4'-trihydroxyflavones-6-C-β-(2"–O-β–glucopyranosyl glucopyranoside)	AP	*L. feei*	[30]
29	5-hydroxy3', 4' – methoxyisoflavone	AP	*L. feei*	[30]
30	5,4' - diméthoxy-3,6-dihydroxy flavonol	AP	*L. feei*	[30]
31	3-hydroxy-5,6,7,4' – tetraMethoxyflavone	AP	*L. feei*	[30]
32	7,8-(2'", 2'"–di-Methylchromeno)-6-prenyl-3,5,4'-trihydroxy-flavone	AP	*L. feei*	[30]
33	6,7 dihydroxy-5-methoxy-flavone 7-O-β-D-glucopyranoside	AP	*L. monopetalum*	[31]
34	6, 7-dihydroxy-5-methoxy flavanone 7-O-β-D-glucopyranoside	AP	*L. monopetalum*	[31]
35	Epigallocatechin	W	*L. feei*	[32]
		AP	*L. monopetalum*	[39]
36	Gallocatechin	R	*L. guyonianum*	[33]
		AP	*L. guyonianum*& *L. monopetalum*	[38]
37	Apigenin	L	*L. monopetalum*	[34]
38	Myricetin-3-*O*- galloyl hexoside	AP	*L. guyonianum*	[36]
39	Myricetin-3-*O*-glucoside	AP	*L. guyonianum*	[36]
		AP	*L. monopetalum*	[41]
40	Myricetin-*O*-acetylglucoronide	AP	*L. guyonianum*	[36]
41	Diosmin	L	*L. guyonianum*	[37]
42	Eupatorin	L	*L. guyonianum*	[37]
43	Isorhamnetin sulfate	AP	*L. monopetalum*	[39]
44	Kaempferol	AP	*L. monopetalum*	[40]
		R	*L.guyonianum*	[42]
45	kaempferol-7-*O*-glucoside	AP	*L. monopetalum*	[41]

46	isorhamnetin-3-*O*-rutinoside	R	*L. guyonianum*	[42]
47	Kaempferol-3-*O*-rutinoside	R	*L. guyonianum*	[42]
48	6,7,8,3',4'-Pentamethoxy5-hydroxy-flavone	T	*L. feei*	[44]
49	5,3',4'-Trimethoxy-7-hydroxy flavone	T	*L. feei*	[44]
50	5,7,8-Trihydroxy-3',4'-dimethoxy flavone	T	*L. feei*	[44]
51	5,6,7-Trihydroxy-3',4'-5-trimethoxy flavone	T	*L. feei*	[44]
52	7,4',5'-trimethoxy-5,3'-dihydroxy flavonol-3-*O*-(6"-malonyl- 2"-rhamnosyl glucoside)	T	*L. feei*	[44]
53	5,3'-Dihydroxy-7,4',5'-trimethoxy flavonol	T	*L. feei*	[44]
54	6,7,8,3',4'-Pentamethoxy 5-hydroxy isoflavone	St	*L. feei*	[44]
55	5,7-Dihydroxy 3',4'-dimethoxy isoflavone	St	*L. feei*	[44]
56	Hexacetate 8-hydroxy-4',7-dimethoxy isoflavone 8-*O*-[α-rhamnopyranosyl-(1→6)-β-glucopyranoside]	St	*L. feei*	[44]
57	Tetraacetate 7,8-dihydroxy-4'-methoxyisoflavone 8-*O*-β-glucopyranoside	St	*L. feei*	[44]

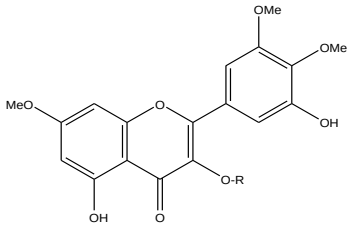
L:Leaves;St:Stem;F:Flowers;R:Root;T:Twig;G:Gall;W:Whole plant;AP:Aerial parts



Maesopsin-6-O-glucoside

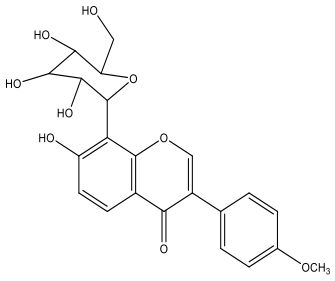


6, 3,4-Tri-methoxy3,5,5trihydroxy flavonol

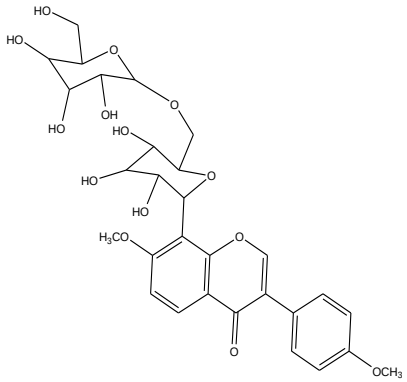


R= (6”-malonyl 2”-rhamnosyl glucoside)

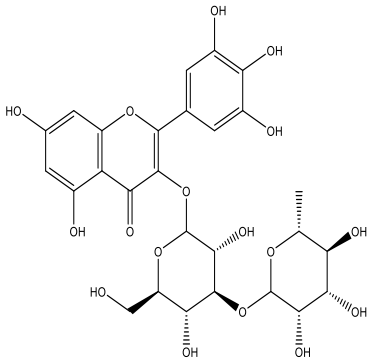
6,3',4'-tri-methoxy-5,5'-dihydroxyflavonol-3-(6"-malonyl-2"-rh-amnosylglucoside)



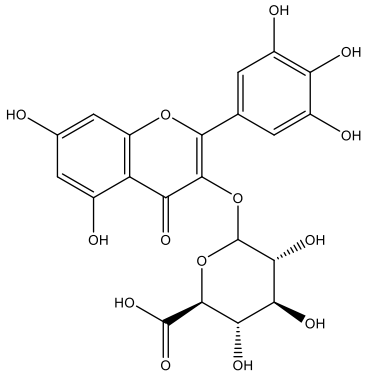
7-hydroxy-4’-methoxy isoflavone 8-C-β-glucopyranoside



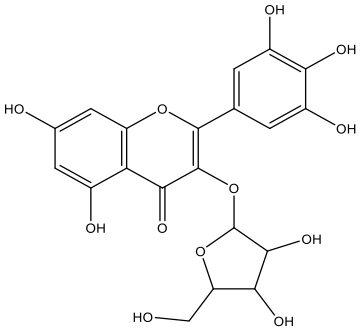
7,4’-dimethoxy isoflavone - 8-C-β glucpyranosyl (1’’’→2’’) glucopyranoside



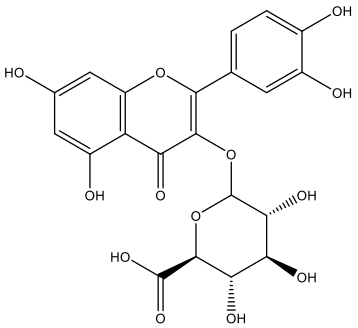
Myricetin-3-O-rhamnosylglucoside



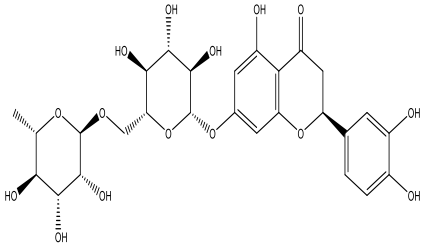
Myricetin-3-O-glucuronide



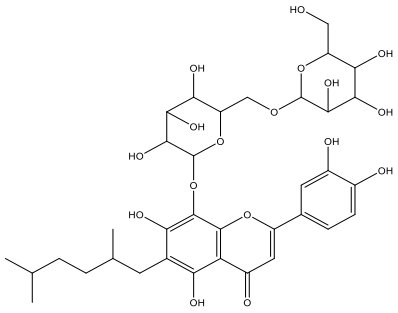
Myricetin-3-O- pentoside



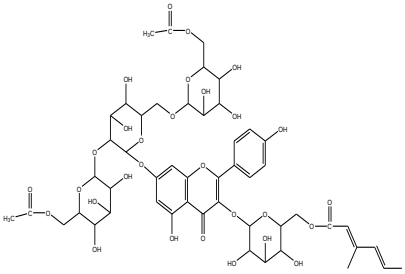
Quercetin-3-O-glucuronide



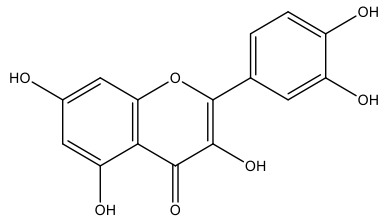
Eriodictyol-7-*O*- rutinoside



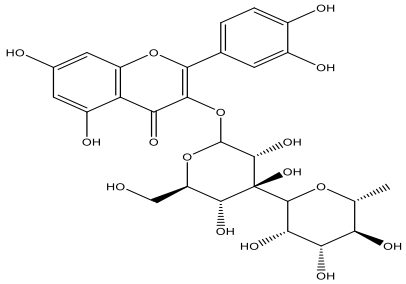
6-(2,5-dimethyl hexyl)-5,7,3’,4’-tetra hydroxy flavone -7-*O*-glucopyranosyl (1→6)glucopyranoside



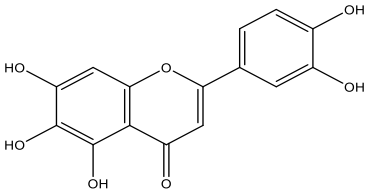
5,3’,4’- trihydroxyl flavonol-3-*O*-(6”-ester 3-methyl hexan-1-one-2,4-diene glucopyranoside) -7-*O*-(diglucouronoylmethyl ester(1→2), (1→6) glucopyranoside)



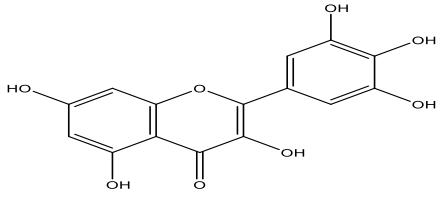
Quercetin



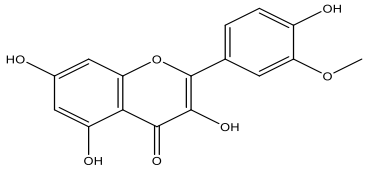
Rutin



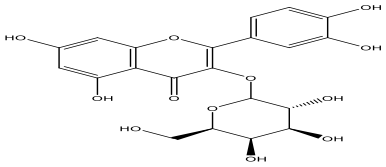
6-Hydroxy luteolin



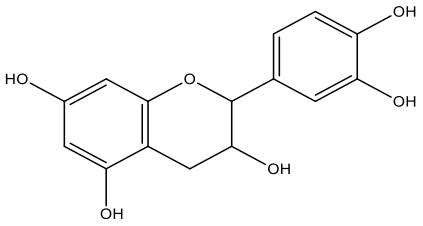
Myricetin



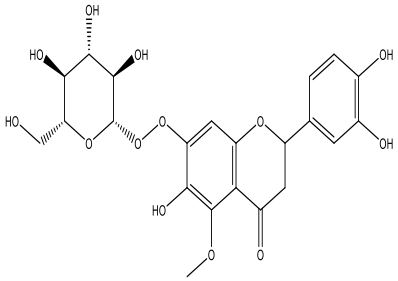
Isorhamnetin



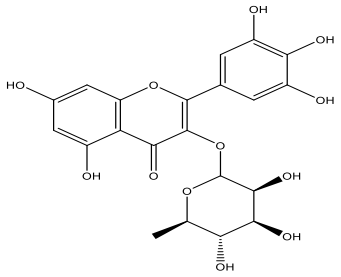
Quercetin-3-*O*-galactopyranoside



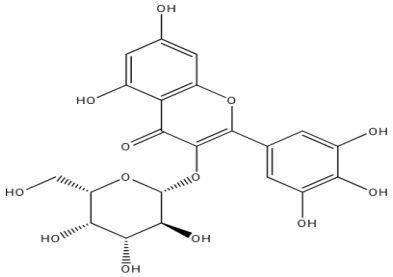
Catechin



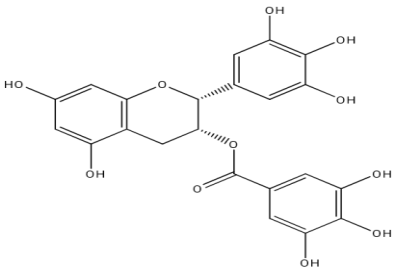
6,7-Dihydroxy-5-methoxy 7-O-β-D-glucopyranoside



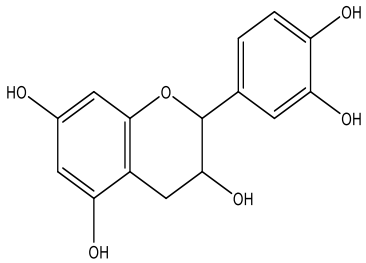
Myricetin-3-O-rhamnoside



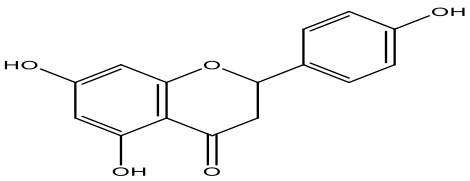
Myricetin-3-O-β-galactopyranoside



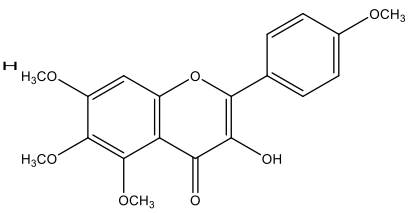
Epigallocatechin-3-O-gallate



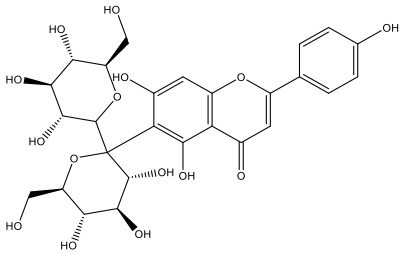
Epicatechin



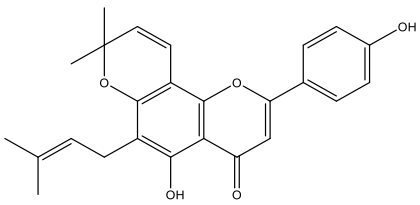
Naringin



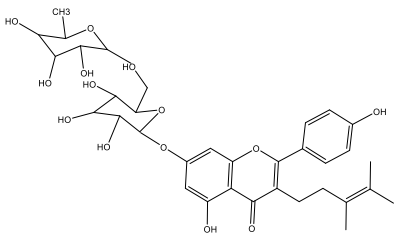
3-Hydroxy-5,6,7,4' – tetramethoxyflavone



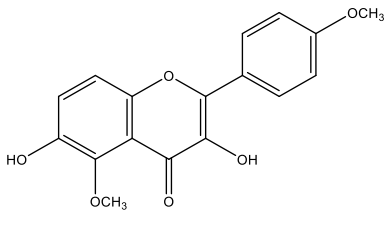
6-C-β- (2''–O- β– glucopyranosyl-glucopyranosyl) - 5,7,4' - trihydroxy flavones



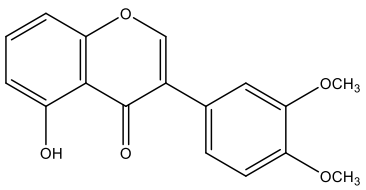
7,8- (2''', 2''' – di-Methylchromeno) -6-prenyl-3,5,4'-trihydroxy-flavone

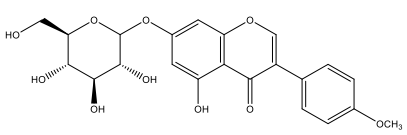


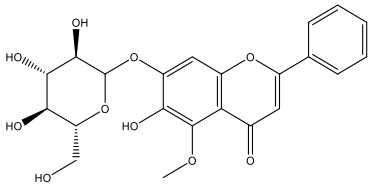
7-O- (α- rhamnopyranosyl- (1-6) - β-glucopyranosyl) - 3 (3'', 4'' dimethyl-3''-penténnyl) 4', 5-dihydroxy flavones



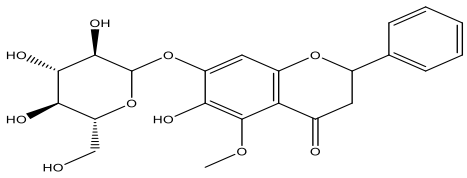
5,4' - Diméthoxy-3,6-dihydroxy flavonol



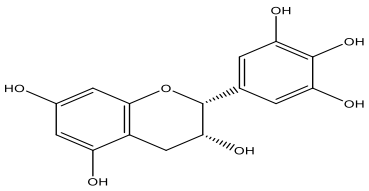




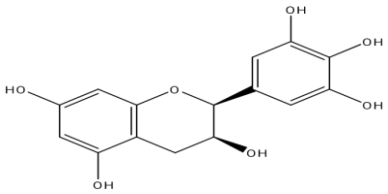
5-Hydroxy3', 4' – methoxyisoflavone



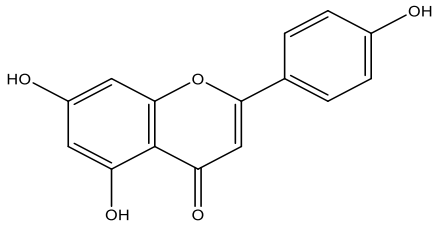
4' - Methoxyisoflavone 7-O-β-glucopyranoside



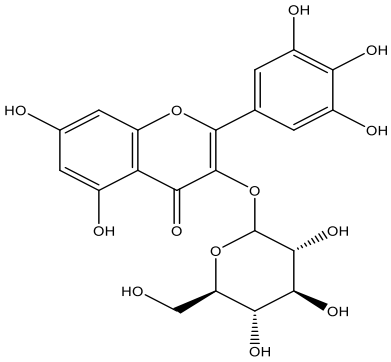
6,7 Dihydroxy-5-methoxy-flavone 7-O-β-D- glucopyranoside



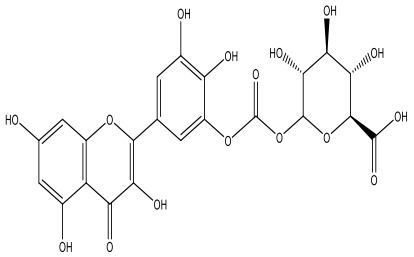
6,7-Dihydroxy-5-methoxyflavanone-7-O-β-D-glucopyranoside



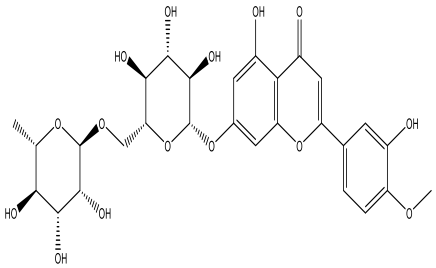
Epigallocatechin



Gallocatechin



Apigenin

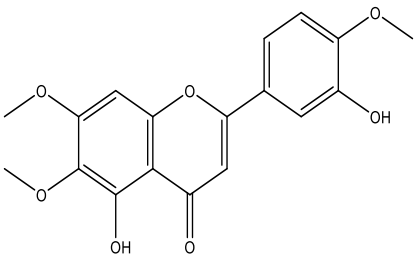


Myricetin-3-*O*-glucoside

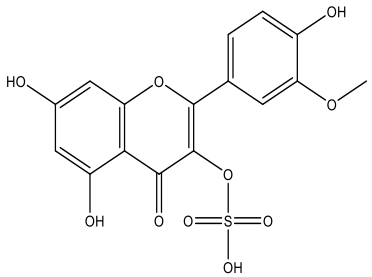
Myricetin-O-acetylglucoronide

Diosmin

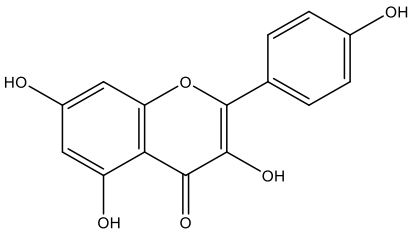
Eupatorin



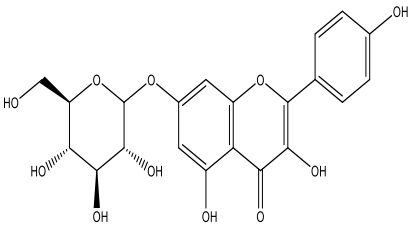
Isorhamnetin sulfate



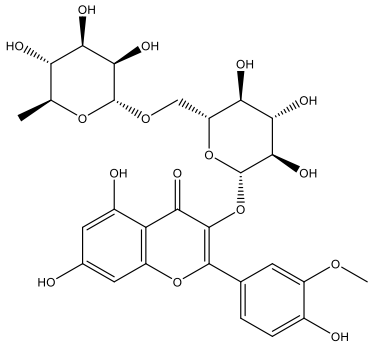
Kampferol

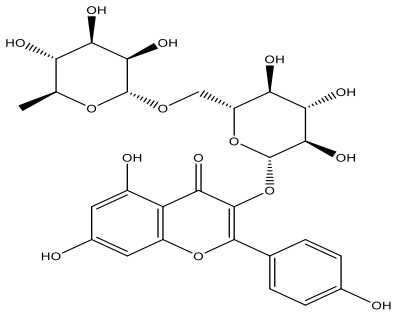


kaempferol-7-O-glucoside

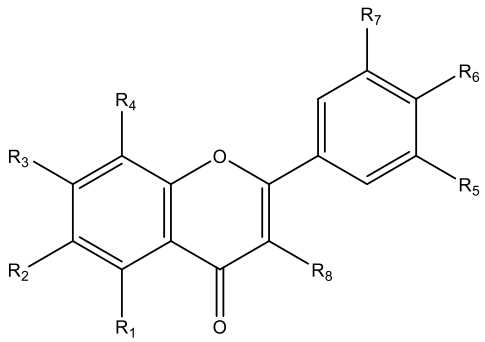


Isorhamnetin-3-*O*-rutinoside



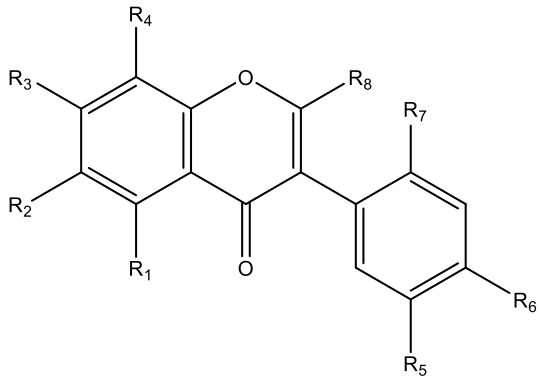


Kaempferol-3-*O*-rutinoside



	R1	R2	R3	R4	R5	R6	R7	R8
Pentamethoxy-6,7,8,3',4'-hydroxy-5 flavone	OH	OMe	OMe	OMe	OMe	OMe	H	H
5,3',4'-Trimethoxy-7-hydroxy flavone	OMe	H	OH	H	OMe	OMe	H	H
5,7,8-Trihydroxy-3',4'-dimethoxy flavone	OH	H	OH	OH	OMe	OMe	H	H
5,6,7-Trihydroxy-3',4'-5-trimethoxy flavone	OH	OH	OH	H	OMe	OMe	OMe	H
3-O-(Glucoside-6"-malonyl, 2"-ramnosyl)-7,4',5'-trimethoxy-5,3'-dihydroxy flavonol	OH	H	OMe	H	OH	OMe	OMe	OG1
5,3'-Dihydroxy-7,4',5'-trimethoxy flavonol	OH	H	OMe	H	OH	OMe	OMe	OH

G1= Glucoside-6"-malonyl, 2"-ramnosyl



	R1	R2	R3	R4	R5	R6	R7	R8
6,7,8,3',4'-Pentamethoxy 5-hydroxy isoflavone	OH	OMe	OMe	OMe	OMe	OMe	H	H

5,7-Dihydroxy 3',4'-dimethoxy isoflavone	OH	H	OH	H	OMe	OMe	H	H
8-hydroxy-4',7-dimethoxy isoflavone 8-O-[α-rhamnopyranosyl-(1→6)]-glucopyranoside	H	H	OMe	G2	H	OMe	H	H
7,8-dihydroxy-4'-methoxyisoflavone 8-O-β-glucopyranoside	H	H	OH	G3	H	OMe	H	H

G2= α-rhamnopyranosyl-(1→6)]-β-glucopyranoside, G3= β-glucopyranoside

Figure 2. Structure of flavonoids reported in genus *Limoniastrum*.

3.1.3 Phenolic acids and phenolic derivatives:

Different species of the genus*Limoniastrum* are rich in phenolic compounds that have strong therapeutic value, such as ferulic acid isolated from leaves of *L. monopetalum* (1)[27][34][35][43][37]. Gallic acid is the most prevalent phenolic acid found in different species of genus *Limoniastrum* from leaves and whole plants of *L.guyonianum*, *L. feei*, and *L. monopetalum* (2) [27][29][32][34][35][38] [39][40][42][43][37]. Chlorogenic acid was identified in leaves of *L. monopetalum* (3) [27][34] [35]. Methyl gallate was identified by QTOF–LCMS in ethanolic extracts of *L. monopetalum* leaves (4) [27]. Two naturally occurring monomers, N-E-feruloyl tyramine and N-E-caffeoyl tyramine, together with limoniastramide, a novel dimer of phenolic acid amide, were separated from *L. guyonianum* using centrifugal partition chromatography (CPC) (5-7) [45]. NMR spectra and liquid/liquid partition, using liquids of increasing polarity, were used to isolate and identify myrciaphenone A (8) [28]. Many phenolics (2-8-13) were detected using 1D and 2D NMR investigations and ESI-MS analysis [32]. RP-HPLC was used to identify several phenolic acids from *L. guyonianum* leaf and stem extracts (2-9-10-11-12) [29]. Identification of some phenolics (1-2-3-10-14-15-16) were conducted using RP-HPLC chromatographic profiles of phenolics standards of *L. monopetalum* leaf extract [32]).

In different extracts ($CHCl_3$, EtOAc, and n-BuOH) of *L. guyonianum* aerial parts, seven phenolics were identified using HPLC-DAD in different quantities in three fractions (1-2-3-18-19) [35]. HPLC-TOF/MS was used to identify many phenolic components (1-2-14-15-16) in the aqueous leaf extract of *L. guyonianum* [37]. Determination of phenolic acids in *L. guyonianum* and *L. monopetalum* was conducted by HPLC analysis, and many phenolic acid compounds (2-14-20) were found in *L. guyonianum*. At the same time, many phenolic acids (2-9-14-16-20) were found in *L. monopetalum* [38]. The chemical profiles of phenolic acids (2-21-22) in treated and untreated polyvinylpolypyrrolidone (PVPP) samples were examined using HPLC and ESI of *L. monopetalum* aerial parts (leaves and stem) acetone extracts [39].

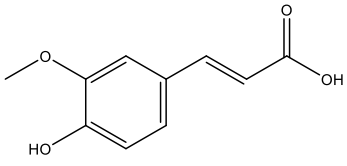
The phenolic acids (2-16-17) were identified by HPLC examination of ethanol extracts of the *L. monopetalum* aerial parts that were macerated, microwave-assisted, and ultrasound-assisted [40]. Gallic acid (2) was detected by reversed-phase HPLC from *L. guyonianum* root extract [42]. HPLC analysis of *L. guyonianum* Boiss showed three phenolic acids (1-2-16) [43]. (Figure 3 and Table 3).

Table 3. Phenolic acids and phenolic derivatives reported from the genus *Limoniastrum*

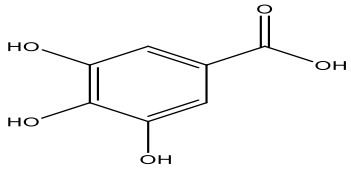
No.	Compounds name	Plant parts	Species	Ref.
1	Ferulic acid	L	*L.monopetalum*	[27]
		L	*L.monopetalum*	[34]
		AP	*L.guyonianum*	[35]
		F	*L.guyonianum*	[43]
		L	*L.guyonianum*	[37]
2	Gallic acid	L	*L.monopetalum*	[27]
		L	*L.feei*	[28]
		W	*L.guyonianum*	[29]
		W	*L.feei*	[32]
		AP	*L.guyonianum*	[34] [35]
		AP	*L.guyonianum& L.monopetalum*	[38]
		AP	*L.monopetalum*	[39]
		AP	*L.monopetalum*	[40]
		R	*L.guyonianum*	[42]
		F	*L.guyonianum*	[43]
		L	*L.guyonianum*	[37]

3	Chlorogenic acid	L	*L.monopetalum*	[27]
		L	*L.monopetalum*	[34]
		AP	*L.guyonianum*	[35]
4	Methyl gallate	L	*L.monopetalum*	[27]
5	Limoniastramide	AP	*L.guyonianum*	[45]
6	N-E-caffeoyl tyramine	AP	*L.guyonianum*	[45]
7	N-E-feruloyl tyramine	AP	*L.guyonianum*	[45]
8	myrciaphenone A	L	*L.feei*	[28]
		W		[32]
9	Procatechuic acid	AP	*L.guyonianum*	[29]
		AP	*L.monopetalum*	[38]
10	trans-cinnamic acids	AP	*L.guyonianum*	[29]
		L	*L.monopetalum*	[34]
		AP	*L.monopetalum*	
11	methyl-4-hydroxybenzoate	AP	*L.guyonianum*	[29]
12	n-propyl-3,4,5-trihydroxybenzoate	AP	*L.guyonianum*	[29]
	3,4-diihydroxyphenylthanol-8'-O-β-D-(6-sulphatoglucopyranoside	W	*L.feei*	[32]
13				
14	4-Hydroxybenzoic acid	L	*L.monopetalum*	[34]
		AP	*L.monopetalum&* *L.guyonianum*	[38]
		L	*L.guyonianum*	[37]
15	Syringic acid	L	*L.monopetalum*	[34]
		AP	*L.guyonianum*	[35]
		L	*L.guyonianum*	[37]
16	Vanillic acid	L	*L.monopetalum*	[34]
		AP	*L.monopetalum*	[38]
		AP	*L.monopetalum*	[40]
		F	*L.guyonianum*	[43]
		L	*L.guyonianum*	[37]
17	Caffeic acid	AP	*L.guyonianum*	[35]
		AP	*L.monopetalum*	[40]
18	*p*-coumaric acid	AP	*L.guyonianum*	[35]
		AP	*L.monopetalum*	
19	*O*-coumaric acid	AP	*L.guyonianum*	[35]
20	3,4-dimethoxybenzoic acid	AP	*L.monopetalum&* *L.guyonianum*	[38]
21	Sinapic acid sulfate	AP	*L.monopetalum*	[39]
22	Ferulic acid sulfate	AP	*L.monopetalum*	[39]

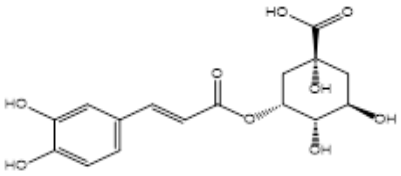
L:Leaves;F:Flowers;R:Root; W:Whole plant;AP:Aerial parts



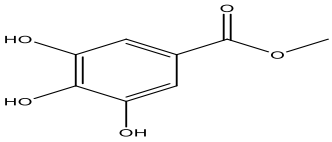
Ferulic acid



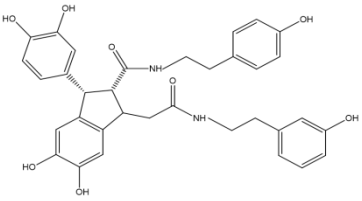
Gallic acid



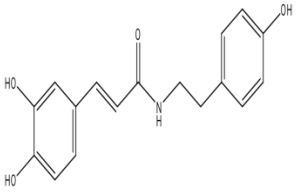
Chlorogenic acid



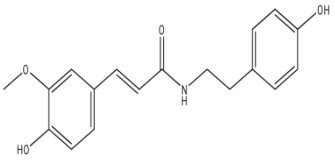
Methyl gallate



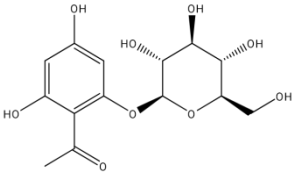
Limoniastramide



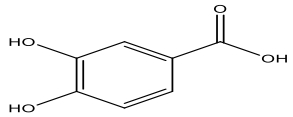
N-E-caffeoyl tyramine



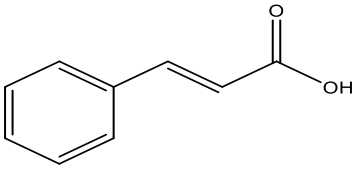
N-E-feruloyl tyramine



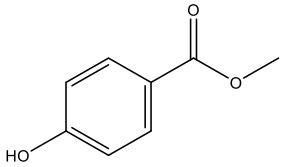
Myrciaphenone A



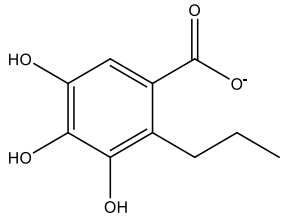
Protocatechuic acid



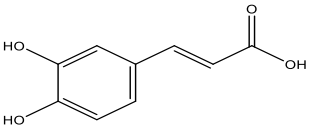
Trans-cinnamic acids



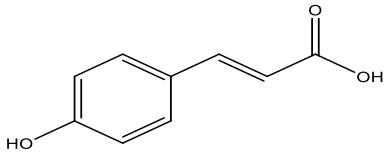
Methyl-4-hydroxybenzoate



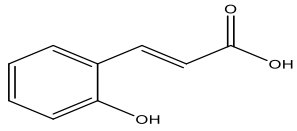
n-propyl-3,4,5-trihydroxybenzoate



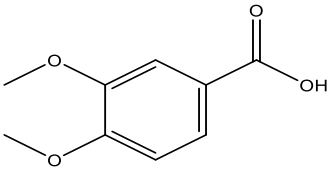
Caffeic acid



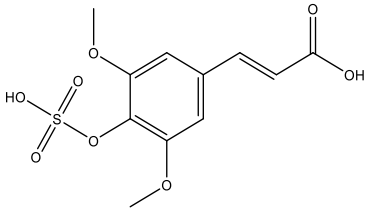
p-Coumaric acid



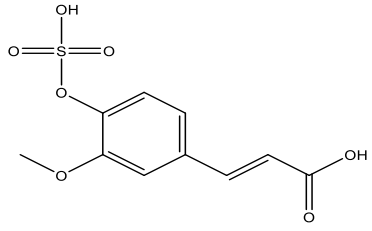
o-Coumaric acid



3,4-dimethoxybenzoic acid



Sinapic acid sulfate



Ferulic acid sulfate

Figure 3. Structures of phenolic acids and phenolic derivatives reported in the genus *Limoniastrum*.

3.1.4 Fatty acids:

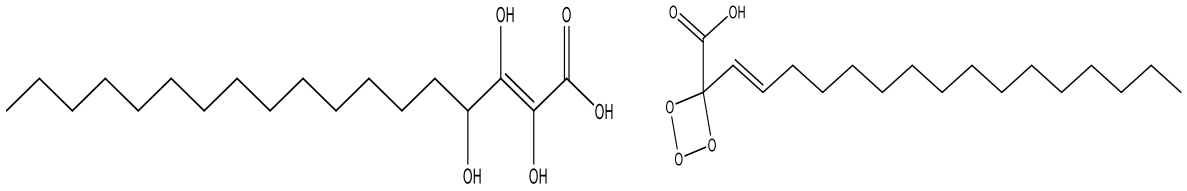
Trihydroxy-octadecenoic acid is a fatty acid (1) identified by LC–QTOF–MS analysis of M-extract leaves of *L. monopetalum* [27].

Trihydroxy-octadecenoic (1) acid and oxo-dihydroxy octadecenoic acid (2) were identified by HPLC and ESI of *L. monopetalum* aerial parts (leaves and stem) acetone extracts (Table 4 and Figure 4) [39].

Table 4. Fatty acids reported from the genus *Limoniastrum*

No.	Compounds name	Plant part used	Species	Ref.
1	Trihydroxy-octadecenoic acid	L	*L.monopetalum*	[27].
		AP	*L.monopetalum*	[39]
2	Oxo-dihydroxy octadecenoic acid	AP	*L.monopetalum*	[39]

L: Leaves; AP: Aerial parts



Trihydroxy-octadecenoic acid

Oxo-dihydroxy octadecenoic acid

Figure 4. Structures of fatty acid reported in the genus *Limoniastrum*.

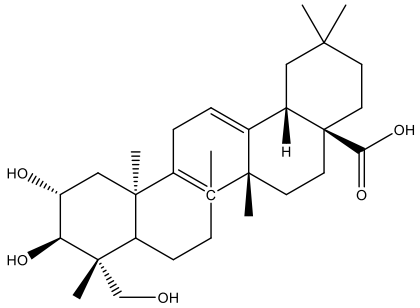
3.1.5 Saponins

Two major saponin compounds were isolated from *Limoniastrum feei* stems butanol extract and identified by ^{1}H NMR, IR, mass spectra, ^{13}C NMR, and comparative spectra (1-2) (Table 5 and Figure 5) [46].

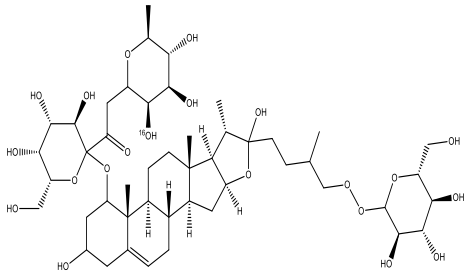
Table 5. Saponins reported from the genus *Limoniastrum*

No.	Compounds name	Plant parts	Species	Ref.
1	2α,3β,23-Trihydroxy-30-acetylolean-12-ene	St	*L. feei*	[46]
2	1-O-[α-L-rhamnopyranosyl-(1)-6-*O*-acetyl-β-D-galactopyranosyl]-1β,3β,22ξ-26-tetrahydroxyfurost-5(6)-ene26-*O*-β-D-glucopyranoside	St	*L. feei*	[46]

St:Stem



2α,3β,23-Trihydroxy-30-acetylolean-12-ene



1-*O*-[α-L-rhamnopyranosyl-(1)-6-*O*-acetyl-β-D-galactopyranosyl]-1β,3β,22ξ-26-tetrahydroxyfurost-5(6)-ene26-*O*-β-D-glucopyranoside

Figure 5. Structures of saponins reported in the genus *Limoniastrum.*

3.1.6 Other compounds:

Pinoresinol (1) is tetrahydrofuran lignan reported in the M-extract of *L. monopetalum* leaves and aerial parts and identified by LC–QTOF–MS analysis [27] [39]. Trans-syringin (2) was isolated from *L. guyonianum* Bois roots in a butanol extract. ES

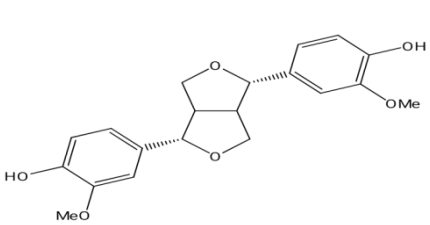
MS and 1 and 2D NMR were employed to elute their structures [33]. Salidroside (3) was isolated from *L. feei* whole plants, and its structure was identified by ESI-MS and 1D and 2D NMR analysis [32].

One tannin component (4) was isolated from leaves using column chromatography and prep-HPLC of the aerial section of *L. feei* (Table 6 and Figure 6) [44].

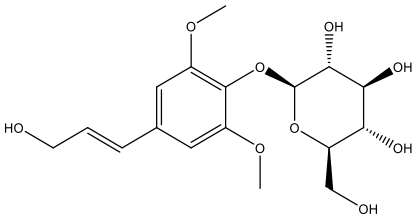
Table 6. Other compounds reported from the genus *Limoniastrum*

No.	Compounds name	Plant part used	Species	Ref.
1	Pinoresinol	L	*L. monopetalum*	[27]
		AP	*L. monopetalum*	[39]
2	Trans-Sryingin	R	*L. guyonianum*	[33]
3	Salidroside	W	*L.feei*	[32]
4	5,7-dihydroxy-4-oxo-2-(3,4,5-trihydroxyphenyl)-4H-chromen-3-yl 3,4,5-trihydroxybenzoate	L	*L.feei*	[44]

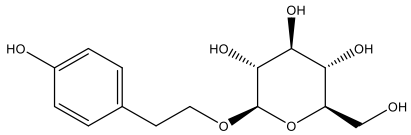
L: Leaves; R: Root; W: Whole plant; AP: Aerial parts



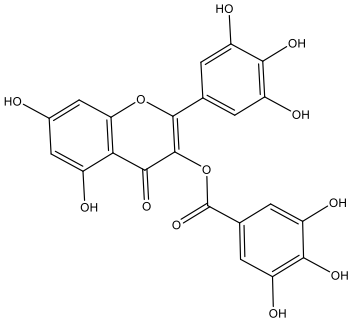
Pinoresinol



Trans-Sryingin



Salidroside



5,7-dihydroxy-4-oxo-2-(3,4,5-trihydroxyphenyl)-4H-chromen-3-yl 3,4,5-trihydroxybenzoate

Figure 6. Structures of other compounds reported in the genus *Limoniastrum*

3.2 Some reported biological studies of the constituents of *Limoniastrum*

Limoniastrum species have been ascribed numerous biochemical properties, including antioxidant, cancer prevention, anti-diabetic, anti-bacterial, anti-inflammatory properties, and neuroprotective activities, as determined by *in vitro* and *in vivo* studies. It is critical to highlight the medicinal value of these species.

3.2.1. Antioxidant activity:

The antioxidant properties of leaf extracts of *L. monopetalum* and *L. guyonianum* was assessed using several assays. While the DPPH free radical scavenging activity showed that there was no significant difference between the two *Limoniastrum* species, Comparing the IC_{50} for *L. guyonianum* and *L. monopetalum*, 14.90 ± 3 and 17.14 ± 2.4 µg/mL, respectively, *L. guyonianum* exhibited more than twice the ferrous ion chelating activity of*L. monopetalum*, with IC_{50}s of 191.63 ± 12 µg/mL and 90.15 ± 9 µg/mL, respectively. On the other hand, *L. monopetalum* displayed the highest decreasing power activity, with an IC_{50} of 42.33 ± 5 µg/mL. *L. monopetalum* has an enhanced integrity of the lipid membrane compared to *L. guyonianum*, according to thiobarbituric acid-reactive compounds (TBARS) tests. According to these findings, compared to *L. guyonianum*, *L. monopetalum* exhibited a less stressed state, which is linked to higher metabolite accumulation and declining

capacity [47]. The antioxidant potential of *Limoniastrum* species is not only attributed to the presence of phenolic compounds but also aligns with broader mechanistic frameworks by which natural antioxidants modulate oxidative stress and protect against chronic pathologies including cardiovascular, metabolic, and neurodegenerative diseases [48]

L. guyonianum Boiss. (Zita) pure extract, water-based, and ethyl acetate extracts were examined for their antioxidant properties. CPC generated ten fractions from the ethyl acetate fraction using n-heptane/ethyl acetate/methanol/water. These fractions exhibited substantial antioxidant properties, as evidenced by the total antioxidant activity, DPPH test, and reducing power. Using previous methods, the antioxidant activity of these fractions was assessed. Fraction 8 exhibited the strongest antioxidant power (1291.1 mg GAE/g DR), could halt DPPH radicals (IC_{50} = 2 µg/mL), and could diminish Fe^{3+} (EC_{50} = 65 µg/mL). Gallocatechin, epigallocatechin, and epigallocatechin-3-*O*-gallate were three prominent flavonoids in this section.These data indicate that *L. guynianum* possesses antioxidant capabilities. [49].

L. guyonianum aerial part extract was used to isolate phenolic amid by CPC. Various experiments examined the antioxidant properties of Limoniastrum amides. The findings revealed that the phenolics amid (N-E-feruloyl tyramine and N-E-caffeoyl tyramine) had the strongest DPPH value when compared to the dimer(limoniastramide) with IC_{50} = 0.5, 0.6, and 6.5 µg/mL, respectively,while the highest activity in preventing β-carotene bleaching was exhibited by limoniastramide with an IC_{50} value equal to 8 µg/mL. One of the phenolic amides (N-E-caffeoyl tyramine) had the greatest reducing capacity (EC_{50} = 26 µg/mL) among of all the compounds. This study proved that *L. guyonianum* amides had antioxidant activities [45].

Antioxidant evaluation of polyphenolic compounds isolated from leaves extract of *L. feei* had been approved through measuring the DPPH (0.94 ± 0.68) µg/mL and FRAP (0.83 ± 0.15) µg Fe^{2+}/mL tests; gallic acid had potent antioxidant activity. In contrast, in the superoxide nitro blue tetrazolium hypoxanthine/xanthine oxidase test (1.86 ± 0.12) µg/mL, myricetin was the most active product; it was determined to be a more selective superoxide radical scavenger [28].

The antioxidant capacity of *L. guyonianum* gall aqueous extract was assessed using both enzymatic (xanthine/xanthine oxidase assay) and the nonenzymatic (2,2-diphenyl-1-picrylhydrazyl) methods. Gall extract has high antioxidant properties [50].

The antioxidant properties of *L. guyonianum* Durieu ex Bioss aerial parts extract were assessed by many assays, such as DPPH, which reveals that methanolic extract is the best at stopping DPPH (EC_{50}=2.3 mg/mL), followed by chloroform extract (EC_{50}=2.4 mg/mL). The petroleum ether extract has the least ability to fight free radicals (EC_{50} = 4.5 mg/mL). The $ABTS^{\bullet+}$test showed that the methanolic extract had a substantial radical scavenging action (14 mmol TE/g DW). The chloroform and petroleum ether extracts, on the other hand, had effects of 21.1 and 21.7, respectively. The $ABTS^{\bullet+}$test and $FRAP^{++}$ results indicated that the methanolic extract was more effective (EC_{50}=0.2 mg/mL) than the chloroform and petroleum ether extracts, which had EC_{50} values of 0.32 mg/mL and 0.39 mg/mL, respectively. The findings indicated that the aerial parts of M-extract exhibited the highest polyphenol content and antioxidant activities against different assays. [29].

Aqueous extract of stems and leaves of *L. feei* was used to evaluate antioxidant activities using different chemical methods, The antioxidant capacity of extracts was assessed in the reducing power and total antioxidant tests using ascorbic acid equivalents. The aqueous extract showed equivalent capacities of 233.39 ± 4.23 µg and 112.4 ± 1.97 µg per 1 mg. The IC_{50} for the DPPH radical trapping assay was 0.58 ± 0.03 mg/mL. The extract's cyclic voltammetry reveals one irreversible oxidation peak at approximately 300-320 mV/(Ag/AgCl). *Limoniastrumfeei* aqueous extract demonstrated average superoxide scavenging activity of 61.46 ± 2.51% at 0.5 mg/mL.revealing the antioxidant properties of aerial parts of *L. feei* [51].

The antioxidant activities of *Searsia tripartita* and *L.guyonianum* aerial parts extracts were evaluated using $ABTS^{\bullet+}$, DPPH, and ORAC assays.In all assays, the crude extract has the maximum antioxidant activity, as measured by ORAC (1243.1 ± 46.4 µmol TE/g DR), $ABTS^{\bullet+}$(214.7 ± 5.2 µmol TE/g DR), and DPPH (551.9 ± 3.9 µmol TE/g DR). The values were 3–16 times higher than those in *L. guyonianum*(369.5 ± 85.7, 14.2 ± 1.0, and 33.0 ± 0.9 µmol TE/g DR, respectively). In *S. tripartita*, the ethyl acetate extract had the highest antioxidant capacity, followed by the butanolic and aqueous sections, whereas in *L. guyonianum*, the organic fractions had the lowest antioxidant capacity, the butanol fraction always having the lowest. [24].

Antioxidant activities of leaves and stems M-extracts of *L. feei* were assessed by two assays: free radical scavenging DPPH and reduction power. Both the leaves (IC_{50} = 4.75 µg. $mL^{-1)}$ and the stems (IC_{50} = 7.07 µg. mL^{-1}) methanolic extracts demonstrated the strongest free radical scavenging capabilities. For comparison, BHA and BHT had respective IC_{50} values of 2.38 and 7.53 µgmL^{-1}. The results proved that *L. feei's* different parts had potent antioxidant activities because of this plant's use of polyphenols and flavonoids [52].

In two regions of Algeria, the antioxidant activity of *L. guyonianum* of El Oued (LE) region and *L. guyonianum* of Ouargla (LO) region were assessed by using DPPH assay, phosphomolybdenum test, and reducing power assay (PM). The effective scavenging concentration (IC_{50}) on DPPH radical was between 0.11 and 0.16 mg/L in LO and between 0.18 and 0.25 mg/L in LE. In LO, the AEAC values of *L.guyonianum* varied from 1.8 to 2.16mM, while in LE, they ranged from 0.55 to 2.14mM. The plant extracts' Phosphomolybdate antioxidant activity ranged from 1.25 ± 0.07 to 7.94 ± 0.06 mM. The study found that *L. guyonianum* has massive free radical scavenging characteristics. The antioxidant capability of the LO ethyl acetate fraction was superior in all trials, with the exception of the phosphomolybdenum approach, where the LO butanol fraction exhibited the highest activity [53].

Different fractions (EtOAC, $CHCl_3$, and n-BuOH) of *L. guyonianum* aerial part extract were evaluated for antioxidant activity by using different tests such as ABTS•+ +° decolorization, radical scavenging activity, and cupric reducing power. With a concentration of 244.39±41.41 µg/mL, the EtOAc extract demonstrated the highest ability to neutralize DPPH radicals when compared to the positive control antioxidants, ascorbic acid (IC_{50} 13.94±2.82 µg/mL), BHA (IC_{50} 6.14±0.41 µg/mL), and BHT (IC_{50} 12.99±0.41 µg/mL). Comparing the EtOAc extract to the standards, BHA (IC_{50} 1.81±0.10 µg/mL), BHT (IC_{50}

1.29±0.30 µg/mL), and ascorbic acid (IC_{50} 1.74±0.10 µg/mL), the EtOAc extract showed the highest ABTS•+ $^{\circ+}$ scavenging activity, with the lowest IC_{50} value (41.97±1.05 µg/mL), followed by the n-BuOH extract (1984.44±19.39 µg/mL). The findings revealed that the fraction of EtOAc extract had the strongest antioxidant capacity *in vitro* [35].

Extract of *L.monopetalum* leaf using different solvents was evaluated for antioxidant activity by measuring DPPH test first, then superoxide scavenging activity, and finally, reducing power. The IC_{50} values were between 11 and 175 mg/mL. The leaf extract with acetone and water (8:2) (IC_{50} = 11 mg/mL) was the best in lowering DPPH. It was followed by methanol and water (8:2) (IC_{50}=26 mg/mL), ethanol and water (8:2) (IC_{50} =38 mg/mL), and pure methanol (IC_{50} =45 mg/mL). After that, the pure acetone and mixture (methanol-acetone-ethanol and methanol-HCl) extracts had similar effects, with IC_{50} values of about 80 mg/m. The most *L. monopetalum*-appropriate solvent extraction was used. When it investigated how well these three extracts could stop superoxide anion or lower iron levels, our findings showed that the IC_{50} or EC_{50} values were very varied. The first test showed that acetone/water (8:2) had the maximum activity (IC_{50} 120 mg/mL). The other two solvents (methanol/water, 8:2, and ethanol/water, 8:2) had virtually the same superoxide scavenging activity (IC_{50}> 165 mg/mL). Furthermore, the acetone/water (8:2) extract had the maximum reducing power, with an EC_{50} of 240 mg/mL The ethanolic extract came next, while the methanolic extract had the lowest activity (EC_{50} 280 and 330 mg/mL, respectively). The results revealed that acetone/water (8:2) leaf extract had the strongest antioxidant activity [34].

DPPH radical-scavenging, reducing power, and superoxide anion were employed to quantify the antioxidant capacity of various components of *L.monopetalum.* The results suggested that the antioxidant activity of all organs was characterized by varying IC_{50}. The DPPH test indicated that organ extracts had a wide range of effects on this radical. The IC_{50} values were actually between 2 and 6 µg/mL. Stem extracts have the highest antioxidant capacity of all the organs studied, with an IC_{50} value of 2 µg /mL. After that, floral and gall extracts were just as effective at getting rid of this radical (IC_{50} = 6 µg /mL). When it came to superoxide scavenging activity, the stem, flower, and gall extracts all had quite different O_2^- scavenging capabilities. Stem extracts had the most activity of all the plant parts (IC_{50} = 110 µg /mL). However, gall and floral extracts were not as effective in stopping this radical, with an IC_{50} of more than 150 µg/mL. further shows that various extracts from *L. monopetalum* have variable levels of reducing power. In fact, stem extracts were better at lowering Fe3 than the other organ extracts. The EC_{50} for stem extracts was 90 µg /mL, followed by gall (126 µg /mL) and flower (136 µg /mL). [26].

The scavenging activity of the plant extracts and the controls showed that all of the controls were more active than the plant extracts. The IC_{50} values for quercetin, ascorbic acid, and butylated hydroxy anisole were 9.54, 11.42, and 13.10 µg/mL, respectively. Anabasis articulate ethanol and ethyl acetate extracts had the most activity of all the plant extracts. Also, the chloroform extract of *Anabasis articulate* has an IC_{50} of 416.61 µg/mL, which is not found in the identical extract of the other two plants. on the other hand, gave comparative pars for the antioxidant activity of ethanolic, ethyl acetate, and chloroform extracts at 250µg/mL The results showed that *Anabasis articulata* extracts were more potent than other plant extracts at stopping DPPH color, with values of 71.83, 51.27, and 30.67 for the extracts, respectively. Also demonstrated that extracts of Mesembryanthemum crystallinum had moderate activity and lower activity was found or Extracts from *L. guyonianum*[54].

Antioxidant capacity was evaluated by measuring reduction power and radical-scavenging activity of *L. guyonianum* Boiss and *L. monopetalum* L aerial parts extract. The result revealed that total antioxidant activity varied significantly across provenances of the same species. The extracts of *L. guyonianum* from El Akarit show the highest activity, over 100 mg GAE g-1 DW, whereas those from Oued Ran contain approximately 82 mg GAE g-1 DW. The DPPH and decreasing power tests showed comparable results. Plant extracts from the El Akarit region exhibit higher antiradical activity (4.68 and 120 µg mL^{-1}, respectively) compared to those from Oued Ran (32 and 165 µg mL^{-1}). Additionally, there was intraspecific diversity between the two *L. monopetalum* provenances. Enfidha plant extracts outperformed Monastir extracts in terms of antioxidant activity (101.08 mg GAE g^{-1} DW), DPPH radical inhibition, and iron reduction, with lower IC_{50} and EC_{50} values (8 and 260 µg mL^{-1}, respectively) [38].

The antioxidant capacity of *L.monopetalum* aerial parts and root of *Echinops spinosus* in different solvent extracts such as chloroform, ethyl acetate, hexane, and ethanol were assessed by the radical-scavenging activity. The ethanol extract showed the highest ability to reduce DPPH radicals with IC_{50} values are 30 and 147 µg/mL for *Limoniastrum monopetalum* and Echinops spinosus extracts respectively the findings demonstrated that ethanol extract had the maximum antioxidant activity [55].

The antioxidant capacity of aerial parts of *L. monopetatum* extract and isolated flavonoids was measured by radical scavenging. The result showed that all the isolated flavonoids exhibited potent antioxidant ability with respect to Trolox [41].

The antioxidant capacity of five halophytes methanolic extracts of *L. pruinosum*, *A. macrostachyum*, *H. strobilaceum*, *T. nilotica* and *L. monopetalum* were studied by measuring scavenging DPPH. The results showed that SC_{50} values of 37.15, 27.79, 28.62, 33.13, and 35.72mg mL^{-1}, respectively. Based on the data of SC_{50} value, the ascorbic acid (standard antioxidant) showed about three-fold of the antioxidant activity than the MeOH extract of all plants, the of *H. strobilaceum* and *A. macrostachyum* MeOH extract had a higher antioxidant capacity but *L. monopetalum* and *L. pruinosum* have a *lower* antioxidant activity [5].

L. monopetalum ethanol-based and water-based extracts were assessed for their antioxidant effects by employing the DPPH assay. They used 23 wild plants and 24 ethanolic and aqueous extracts from spices and herbs and examined them. Of the 35 ethanolic plant extracts examined, four from *T. hirsute*, *A. stipularis*, *O. basilicum*, and *Atriplex* sp. had antioxidant activity greater than 70% (78.6, 72.7, 72.3, and 70.8%, respectively). Finally, the data showed that some plants' aqueous and ethanol extracts had strong antioxidant activity at a concentration of 100 µg/mL These plants included *M. nitens*, *L.monopetalum*, and *R. raetam.* But the aqueous extract of certain other plants, like *R. raetam*, *O. europaea*, and *Pituranthos tortuosus*, had stronger antioxidant activity than the ethanolic extract. Some plants' ethanolic extracts have greater antioxidant activity than their aqueous extracts, such as *Atriplex* sp., *S. nigrum*, and *Z. album*. The findings indicated that the ethanolic and water extracts demonstrate substantial antioxidant capabilities [56].

The antioxidant capacity of green-synthesized ZnO NPs in the aerial parts of *L. monopetalum* was evaluated using the DPPH assay. The result presented that IC_{50} was 148.43 and 475.7 μg mL^{-1} for the rod-shaped ZnO NPs and hexagonal ZnO NPs, respectively; thus, the ZnO NPs (rod-shaped) had a higher antioxidant than the hexagonal NPs [57].

The antioxidant activity of root extracts of *L. guyonianum* was assessed using different assays (DPPH, $ABTS^{\bullet+}$, and Fe^{2+}reducing power), DPPHradical dot Assay, IC_{50} = 1.6 μg/mL; $ABTS^{\bullet+}$radical dot+ test, IC_{50} = 27 μg/mL; Fe-reducing power, EC_{50} = 44 μg/mL The result showed that *L. guyonianum* root had a potent antioxidant capacity [42].

The antioxidant capacity in flowering and the vegetative stages in different solvent extracts of *L. guyonianum* Boiss, *Z. cornutum* Cossand, and *P. harmala* L. were examined using DPPH. The findings revealed that the crude extracts had a higher DPPH scavenging activity in the vegetative state (1.415 ± 0.068 mg/mL) than at the flowering stage (1.895mg/mL). Ethanol was the best solvent, with a concentration of 1.425 ± 0.066 mg/mL, whereas acetone had a concentration of 1.592 ± 0.067 mg/mL and methanol had a concentration of 1.948 mg/mL. The plant species *L. guyonianum* Boiss. had the most activity, with a value of 1.451 mg/mL. *Z. cornutum* Coss. (1.565 ± 0.066 mg/mL) and *P. harmala* L. (1.949 ± 0.067 mg/mL) came in second and third, respectively [43].

The antioxidant capacity of aerial parts of *L. guyonianum* different solvent extracts was measured using DPPH and $ABTS^{\bullet+}$ tests. The result showed that the ethanol extract had the maximum antioxidant capacity with DPPH than hydro M-extracts with IC_{50} =23.25± 0.62 and 31.10± 0.25 μg/mL, respectively, and the $ABTS^{\bullet+}$ radical of ethanolic extract of *L. guyonianum* had IC_{50} values that were somewhat lower than those of methanolic extracts (21.25± 0.42 and 22.71± 0.28 μg/mL, p=0.008). This shows that *L. guyonianum* was better at scavenging the $ABTS^{\bullet+}$ radical. But these activities were almost five times less than those of ascorbic acid (IC_{50} = 4.34 ± 0.08 μg/mL). [58].

The antioxidant activity of methanol, ethanol, and acetone extracts of *L. feei* was assessed by different methods, such as hydroxyl radical, DPPH, and *β*-carotene. The findings revealed that the methanolic extract has an IC_{50} of about 3.2 μg/mL in the DPPH scavenging method, which is similar to the IC_{50} of ascorbic acid (2.48 μg/mL). The same extract had a strong antioxidant effect against hydroxyl radical, with an IC_{50} of about 36.33 μg/mL, which is greater than the IC_{50} of ascorbic acid (61.83 μg/mL). The acetone extract showed a forceful antioxidant potential in the *β*-carotene bleaching test, similar to the positive control (IC_{50}: 5.85 μg/mL and 4.26 μg/mL, respectively) [59].

3.2.2 Anti-cancer activity

The cancer-preventing activities of *L. guyonianum* water gall extract and luteolin were evaluated in the HeLa cell line, which is a human cervical cancer (HCC) cell line. Exposing HeLa cells to gall extract or luteolin reduced cell growth in a dose- and time-dependent manner. The IC_{50} values were visually established, and inhibition percentages were derived. The G extract inhibited HeLa cell proliferation by 79.6% and 59.7% at 300 μg/mL concentrations after 48 and 24 hours of incubation, respectively. After 24 and 48 hours of treatment, G extract exhibited values of 170 μg/mL and 140 μg/mL. G extract exhibited no effect on normal human keratinocytes when administered at comparable quantities for 24 and 48 hours. This evidence indicates that G extract is particularly targeting cancer cells. Luteolin was found to cause cytotoxicity in HeLa cells with an IC50 of 21.8 μM after 24 hours. At 50 μM, luteolin reduced HeLa cell growth by 83.8% and 85.9% after 24 and 48 hours of incubation, respectively. The results indicate that both natural compounds suppress the proliferation of HeLa cells in a dose-dependent manner [60].

The aqueous gall extract of *L. guyonianum* was tested for anticancer qualities in vitro and in vivo, with a focus on elucidating its immunological mechanisms by examining its effects on tumor growth and immune response in mice. Mice were implanted with B16F10 mouse tumor cells and subsequently treated intraperitoneally with G extract (25 or 50 mg extract/kg B.W.) for 7, 14, or 21 days. At each timepoint, the extract's effects on tumor growth, splenocyte proliferation, NK cell activity, and CTL activity in mouse splenocytes were assessed. G extract-induced tumor growth inhibition was related to specific apoptotic alterations in tumor cells, such as nuclear condensation. The extract suppressed melanin formation and tyrosinase activity in melanoma cells in a concentration-dependent manner. G extract effectively inhibited tumor growth, boosted splenocyte proliferation, and increased NK and CTL activity in tumor-bearing animals. The extract increased lysosomal activity in macrophages and improved antioxidant activity in many cell types in mice. The findings indicated that the gall extract of *L. guyonianum* exhibited a strong anti-melanoma efficacy in both *in vitro* and *in vivo* [61].

In the BE cell line for human colorectal carcinoma, the antiproliferative and pro-apoptotic effectiveness of *L.guyonianum* water gall extract was assessed. An investigation was conducted into the possible cytotoxic impact of gall extract on a human colorectal cell line (BE). The MTT experiment demonstrated that gall extract may cause cytotoxicity in BE cells in a manner that was dependent on both time and dose, with an estimated IC_{50} value of 345.3 μg/mL following 48 hours of incubation. The results indicated that the gall extract of *L. guyonianum* functioned as a chemotherapeutic agent, suppressing the proliferation and apoptosis of BE colorectal tumor cells [62].

A study was conducted to assess the antiproliferative properties of the extract from the entire plant of *L. feei*. The n-BuOH isolate is potent when used against J774.A1, WEHI-164, and HEK293 cell lines.

This extract is active at IC_{50} = 27 μg/mL as shown by the results [32].

Different fractions of *L. guyonianum* aerial part ($CHCl_3$, EtOAC, and n-BuOH) extract were evaluated for their anti-cancer effects. The result showed that $CHCl_3$ extract proved its extremely potent efficacy towards HeLa cell lines (IC_{50}= 50.369±0.020μg/mL) [35].

In vitro tests were conducted on 23 wild plants extracted with ethanol and water, as well as 24 ethanolic and aqueous extracts from spices and herbs to assess their anticancer properties. The trypan blue method demonstrated antitumor efficacy against Ehrlich Ascites Carcinoma Cells (EACC), while The SRB method was employed against HepG2 cells. The results showed the ethanolic extracts from *S. nigrum*, *Atriplex* sp., and *A.spinosus* exhibited the highest inhibition (100%), followed by *A.palaestinum* (97.29%). The ethanolic extracts of *C. maritima*, *N. sativa*, and *Z. officinale* showed anticancer activity of

89.7%, 81%, and 80%, respectively. Ethanolic extracts from *O. basilicum*, *C. italica*, *P. quinquefolius*, and *Z.simplex* were found to have more than 60% anticancer activity (77.21, 66, 64.1, and 61%, respectively), while *T. hirsuta* and *L. monopetalum* showed more than 50% (54 and 53%). Twenty-two ethanolic extracts have weak anticancer activity (0.0 to 47.83%). *C. phelypaea*, *S. argel*, *C. italca*, and *C.maritima* extracts had the highest cancer inhibition (100, 95, 92, and 90.78%, respectively) among the studied water extracts. Extracts of *S. nigrum, C. sinensis*, and *G. glabra* had over 80% anticancer efficacy (89.7, 86.4, and 81%, respectively). Both aqueous and ethanolic extracts of *S. nigrum*, *C. maritime*, and *O. basilicum* showed significant anticancer action, inhibiting cell proliferation of EACC at 100 µg/mL concentration. Aqueous extracts from *A. palaestinum*, *N. sativa*, *P. quinquefolius*, *Z. simplex*, T. *hirsute*, and *L. monopetulm* outperformed ethanolic extracts in terms of anticancer activity. [56].

The monolayer breast cancer cell line (MCF7) was used to assess the anti-cancer properties of *L. monopetalum* towards normal (RPE1). Several tests were used to examine the extract's effects, including DNA fragmentation and apoptosis induction measured by cleaved cytokeratin-18 (CK18). Additionally, real-time PCR was used to quantify the expression of Bax and Bcl-2. Acute oral toxicity was used to calculate the median lethal dosage (LD_{50}), and ELISA was used to measure biomarkers linked to carcinogenesis, metastasis, and cell death. The Findings Among the examined extracts, B. variegata and *L. monopetalum* had the strongest anticancer effectiveness. With an IC_{50} of 100 µM, they showed strong cytotoxicity against MCF7 without having any discernible effect on hTERT RPE-1. The extract showed promise in killing cancer cells in 3D tumor-like structures, causing DNA fragmentation, up-regulating the tumor suppressor p53, down-regulating the anti-apoptotic Bcl-2 gene, and inducing death by caspase-3 activation and cytokeratin-18 cleavage. In a syngeneic mouse tumor model, the extract greatly suppressed tumor growth, indicating its potential for further development. Acute oral toxicity experiments in mice showed little toxicity [63].

Anti-cancer properties of aerial parts of *L. monopetalum* ZnO NPs was studied in vitro by the colorimetric and quantitative MTT (Methyl thiazolyl diphenyl-tetrazolium bromide) assay against the A-431 and HFB4 cell lines. The result exhibited that ZnO NPs (rod-shaped) with IC_{50} of 93.88 ± 1 µg -mL^{-1} had higher anti-cancer activity than hexagonal ZnO NPs [57].

The antiproliferative activity of chloroform extract of *L. guyonianum* (IC_{50}: 50.369±0.020µg/mL), was assessed towards HeLa cell lines. The findings revealed that chloroform extract has potent efficacy towards HeLa cell lines [22].

The antiproliferative and pro-apoptotic properties of *L. guyonianum* aqueous gall extract and M-extracts of stem were determined against U373 human glioma cancer cell line. The comet test demonstrated a correlation between DNA damage and the proliferation-inhibiting action of the gall and M- extracts with different concentrations (100 and 200µg/mL), for 24h. The experiment's findings showed that, when compared to G extract, M extract had the most anti-proliferative effect against U373 cells, with estimated IC_{50} values of 98.52µg/mL and 220µg/mL following 48 hours of treatment for M and G extracts, respectively. At a dosage of 400 µg/mL, the inhibition of U373 cell proliferation peaked at 94.15% and 92.22%, respectively, following 48 hours of incubation with M and G extracts. M-extracts and gall extracts might cause DNA damage and cytotoxicity depending on concentration and duration, and the two extracts are potent natural anti-cancer agents [64].

3.2.3. Antimicrobial activity

The bactericidal properties of various organs of *L. guyonianum* essential oil towards *Pseudomonas aeruginosa*, *Escherichia coli*, *Staphylococcus epidermidis*, *Staphylococcus aureus*, and *Micrococcus luteus* were assessed using both disc diffusion and dilution methods. The results demonstrated at a lower dose (MIC=0.02 mg.ml-1), antimicrobial testing revealed that *L. guyonianum* inhibited the visible growth of every tested bacterium.[19].

Using *L. monopetalum* leaf extract and AgNPs, the antibacterial properties towards Gram-positive and Gram-negative bacteria was evaluated. The study found that AgNPs and the plant extract had high activity towards all bacteria tested, with a stronger inhibitory impact against Gram-negative *K. pneumoniae* (36 ± 2.6; 19.7 ± 0.5 mm) and E. coli (37.3 ± 1.5; 25.3 ± 0.6 mm), respectively, than Gram-positive bacteria *S. aureus* (14.3 ± 1.5; 10.7 ± 0.6 mm) and *S. mutans* (17.0 ± 1.0; 13.3 ± 0.6 mm) for L-AgNPs. Significant variations were seen between the effects of the tested drugs on all strains. Ampicillin was used as a positive control. There were significant differences between the tested drugs and bacterial strains, with a significant interaction ($p < 0.0001$) [27].

Aerial parts of *L. guyonianum* Durieu ex Boiss. were evaluated as antibacterial and antifungal agents by using methanolic, chloroformic, and petroleum ether extracts and were tested against human fungal and bacterial pathogenic strains using micro dilution method in 96 multiwell microtiter plate. The result showed that three extracts demonstrated the highest antibacterial activity against *Pseudomonas aeruginosa* and *Staphylococcus aureus*, with MIC values of 23 and 46µg.mL-1, respectively. F13 and F16 show strong antifungal properties against *Candida glabrata, Candida krusei*, and *Candida parapsilesis* (MIC = 39µg.mL-1) [29].

Aqueous extracts of aerial parts of four species (*T.pallescens Noë, S. satureioides* Coss. et Dur., *L.guyonianum* Boiss., and *P.verticillata* Briq) were studied against pathogenic bacteria. According to the findings, the infusions had antibacterial activity that ranged from 2.5 to 20 mg mL^{-1} (MIC values). *Pseudomonas aeruginosa* and *Staphylococcus aureus* were the most susceptible and most resistant isolates, while *L. guyonianum* exhibited the greatest level of effectiveness towards all examined microbes [36].

L. feei extracts were assessed for their antibacterial and antifungal properties against a variety of bacteria (*E. coli*, *S. aureus*, *P. aeruginosa*, *K. pneumoniae*, and *E. fecalis*) and fungi (*C. albican and Saccharomyce cerevisiae*) using the disc diffusion method. In all bacterial tests, the M-extract of leaves and twigs exhibited superior antibacterial properties compared to both the water and acetone extract of leaves. Additionally, the M-extract of leaves and twigs performed exceptionally well in all fungal tests [65].

Ten leaf extracts of *L. monopetalum* were tested against pathogenic bacteria and yeast using pure and solvent mixtures. The antibacterial activity against a few food-borne pathogens, including *Escherichia coli*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, and *Micrococcus luteus*, was assessed using the disk diffusion method.Aqueous acetone extract of

leaves demonstrated a minor antimicrobial action towards *Micrococcus luteus,Staphylococcus aureus*, and *Candida holmii* [34].

Ten fractions were separated using CPC from the aerial section of *L. guyonianum*. To analyze antibacterial activity against the 5 tested strains, the results showed fractions 3 and 4 were the greatest and had comparable efficacy against these pathogens [66].

To evaluate antibacterial effect on *L. feei* aerial parts, we have found that methanolic and heptane extracts of the three parts of *L. feei* (leaves, stem, and twigs) have an interesting antibacterial effect [67].

The disc diffusion technique was used to assess antibacterial capacity against five human pathogenic bacteria, including Gram-positive bacteria, as well as the antifungal effect of *L. monopetalum* different organs extract was investigated. The results showed that stem and gall extracts have a high potential for antibacterial and antifungal action. Additionally, the results indicated that Candida species are more resistant to *L. monopetalum* organ extract. Gall extracts have limited action against *C. albicans, C. kefyr,* and *C. Glabrata*, whereas *C. holmii* are more resistant to the effect of gall extracts. The flower and stem extracts were less or not efficient against these Candida [26].

The antibacterial capacity of a diverse array of human disease-causing microbes was assessed using the disc diffusion method. The same method was employed to assess the antifungal activity of *C. glabrata, C. albicans, C. parapsilosis*, and *C.krusei*. The findings indicated that the two species possess disparate antibacterial and antifungal properties; however, *L. monopetalum* extracts demonstrated the most potent activity against *C. glabrata* and *C. krusei* [38].

Salt-tolerant plants' aerial parts of *L. monopetalum* acetone extract's in vitro anthelmintic activity against the parasites *Trichostrongylus colubriformis* and *Haemonchus contortus.* The results indicated that *L. monopetalum* has anthelmintic action [39].

The anti-microbial activity of aerial parts of *L. monopetalum* ZnO NPs was tested against bacteria and pathogenic fungi. The results demonstrated that hexagonal ZnO nanoparticles have excellent antibacterial and antifungal activities [57].

Various preparations of *L. feei* were assessed for their ability to regulate *Fusarium oxysporum* f. sp. *albedinis* (Foa) through antifungal assays and cellulase inhibition. The findings indicated that the antifungal and anti-cellulase activities of the various extracts were highly variable. The aerial part's M-extract exhibited the highest activity [68].

The disc agar diffusion method was employed to assess the antibacterial activity of acetic acid extracts of aerial portions of *L.guyonianum* Ouargla and El Oued regions (Algeria) against three bacteria: *Escherichia coli, Staphylococcus aureus*, and *Pseudomonas aeruginosa*. The findings indicated that the various extracts exhibited potent antibacterial properties [69].

Salt-tolerant plants' aerial parts of *L. monopetalum* acetone extract's *in vitro* anthelmintic activity against the parasites *Trichostrongylus colubriformis* and *Haemonchus contortus*. The results indicated that *L. monopetalum* has anthelmintic action [39].

3.2.4 Anti-diabetic activity

The anti-diabetic action of the water-based extract of *L. guyonianum* was examined in relation to fructose-induced metabolic syndrome. It was tested for its effects on fructose-induced metabolic syndrome (MetS) in Wistar rats. MetS groups were given a 10% w/v fructose solution to drink ad libitum during 9 weeks, while normal animals got regular water. LG extract was given to treated groups via gavage for the last 6 weeks of the experiment. Feeding fructose as a liquid solution led to weight gain, decreased insulin sensitivity, and elevated blood glucose levels. It also caused kidney oxidative stress and structural damage. MetS rats treated with LG extract at dosages of 100, 200, and 300 mg/kg b.w./day showed significant improvements in fructose-induced changes. This study concluded that the aqueous leaf extract of *L. guyonianum* contains hypoglycemic properties [37].

3.2.5 Anti-inflammatory activity

The M-extract of the *L.guyonianum* stem was used to investigate its anti-inflammatory action. The results indicated that it could enhance lysosomal enzyme activity and reduce nitrite oxide (NO) generation by mouse peritoneal macrophages, indicating a potential anti-inflammatory impact in situ [70].

The anti-inflammatory properties of *L.feei* aqueous leaf extract was evaluated and the results showed that mouse paw edema caused by a 25 mg/kg dose of an aqueous leaf extract resulted in an 85% and 95% reduction in inflammation, respectively [71].

3.2.6 Other activities

The immunomodulatory action of the M-extract of *L.guyonianum* stems on mouse immune cell function was assessed in vitro. These tests demonstrated that the extract suppressed mitogen-induced lymphocyte proliferation in a dose-dependent manner. Furthermore, the lectin-induced response appeared to be more susceptible to the extract's suppressive effects than LPS-stimulated responses. In experiments to investigate the possible effects of extract on innate immunity, the results indicated that the extract dramatically improved the killing activity of isolated NK cells [70].

The mutagenic and antimutagenic effects of an aqueous extract of *L. guyonianum* gall (G extract) were assessed in relation to Salmonella typhimurium bacteria. Upon evaluation with the S. typhimurium strains TA104 and TA100, the result showed the extract had weak antimutagenic potential against sodium azide in the presence of S. typhimurium TA100 and S. typhimurium TA1538 without metabolic activation (S9). However, in the presence of S. typhimurium TA104, we obtained a significant inhibition percentage (76.39%) against 3.25 µg/plate of methylmethanesulfonate. After metabolic activation, S. typhimurium TA100, S. typhimurium TA1538, and S. typhimurium TA104 strains inhibited aflatoxin B1, 4-nitro-o-phenylene-diamine, and 2-aminoanthracene with inhibition percentages of 70.63, 99.3, and 63.37%, respectively (S9) [50].

Gall aqueous extract from *L. guyonianum* Boiss was examined for its in vitro immunomodulatory properties. On cell proliferation, splenocytes were grown with extract alone, extract + lectin, and extract + LPS. In the absence of mitogen, extracts at 25, 50, and 75 mg/mL were effective in inducing splenocyte proliferation. In lectin assays, 75 and 100 mg/mL of G extract resulted in decreased cell growth. The extract had an inverse (dose-dependent) effect on LPS-induced proliferation.

The results indicated that the extract has the potential to significantly enhance the proliferation of splenocytes stimulated by LPS, which could lead to heightened humoral immune responses and B-cell activation in the host [72].

To assess the liver-protective properties of *L.monopetatum* in pet. ether and alcoholic extracts, the aerial portions were employed. It was determined that both extracts possess a hepatoprotective effect on hepatocytes in response to CCl4 cytotoxicity at concentration of 40µg/mL and 50µg/mL, respectively [41].

Several web-based in silico technologies were utilized to estimate quercetin, astragalin, and quercitin-7-O-β-D-glucopyranoside isolated from *L. feei*. Furthermore, the biological activity spectra were investigated. By inhibiting HPGDS, quercetin has been found to have potential antiallergic and anti-inflammatory benefits. It has been suggested that quercetin may be useful in treating muscular dystrophy and diabetic cataracts by inhibiting the enzyme chlordecone reductase. It was anticipated that astragalin's anti-cancer action would be mediated via suppression of FPPS. On the other hand, quercitin-7-O-*β*-D-glucopyranoside was suggested to possess hemostatic, antiviral, and anti-cancer properties through DCK inhibition [73].

The analgesic efficacy of an aqueous extract from the leaves of *L. feei* was tested in mice using acetic acid-induced writhing and varied doses. The results showed the aqueous extract from the leaves of *L. feei* at the doses assayed caused a significant inhibition on the writhing responses induced by acetic acid when compared with control, with values ranging from 33.39 to 35.38% of inhibition, being the AELF at a dose of 30mg/kg ip [74].

4. Conclusions

As previously reported, the Plumbaginaceae family contains several different bioactive components such as flavonoids, flavonoid sulfates, flavonoid glycoside, phenolic acids and phenolic acid derivatives, lignan and trace of lignan sulfates, and essential oil and fatty oils. These compounds play significant roles in therapeutic applications, such as antioxidant, anti-diabetic, anti-cancer, neuroprotective, anti-microbial, and anti-inflammatory activities. However, very few studies have been reported on *L.monopetatum* worldwide. A significant research gap exists in the lack of in vivo investigations, which are important for proving that these bioactive chemicals work and are safe in living systems. Addressing this gap could lead to a better understanding of the mechanisms by which these compounds exert their effects. Furthermore, it would pave the way for more informed decisions regarding their potential therapeutic applications in clinical settings. Most of the present results come from in vitro models; thus, there is a big need for more research in animal models and eventually in humans. Some species in the Plumbaginaceae family, like *L. feel*, have also not been studied much, which means there is still a lot of potential for finding new bioactive compounds.in the future More in vivo studies are needed to learn how these chemicals work and move through the body. Clinical trials are also important to find out how safe and effective they are in people. Also, looking at how different phytochemicals work together in*L. monopetalum* and related species could help us understand how they work and make them better candidates for therapies that target multiple targets. An interdisciplinary strategy that includes phytochemistry, molecular biology, and clinical research will be very advantageous in finding all the medical uses for these species that aren't being used enough.

5. Conflicts of interest

There are no conflicts to declare

6. Formatting of funding sources

No funding has been received for this study.

7. Acknowledgments

The authors would like to thank Prof. M. El-Ghazoly, Dean of the Faculty of Pharmacy at Pharos University. Special thanks are extended to the Faculty of Pharmacy, Pharos University in Alexandria, Faculty of Pharmacy, Cairo university, andNational Research Centre, Doki, Cairo, Egypt.

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