



From traditional use to modern phytochemistry – chemical composition and biological activity of cosmopolitan weed species: *Stellaria media*, *Galium aparine* and *Galinsoga parviflora*

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Abstract *Stellaria media* (L.) Vill., *Galium aparine* L., and *Galinsoga parviflora* Cav. are cosmopolitan species widely used in traditional medicine and as food sources. All three plants have been traditionally applied as anti-inflammatory agents and for the treatment of wounds and skin disorders. *S. media* has also been used as anti-arthritic remedy, while *G. parviflora* has been employed for protection against solar radiation. This review evaluates whether the traditional medicinal uses of these species are supported by contemporary phytochemical and pharmacological evidence and provides an updated overview of their chemical composition and biological activity. A comprehensive literature survey was conducted using major scientific databases, including Google Scholar, PubMed, ScienceDirect, Web of Science, SpringerLink, and Wiley Online Library. Phytochemical studies revealed high chemical diversity in all three species, including phenolic acids, flavonoids, iridoids, terpenoids, and phytosterols. Polar fractions were rich in phenolic compounds, whereas non-polar fractions were dominated by fatty acids, hydrocarbons, and terpenoids. Reported biological activities

include antimicrobial, anti-inflammatory, enzyme inhibitory, and antidiabetic effects. *S. media* additionally demonstrated anti-obesity, neuroprotective, and wound-healing activities, while *G. aparine* showed immunomodulatory and anticancer potential. Extracts of *G. parviflora* exhibited anti-biofilm, larvicidal, anti-arthritic, and photoprotective effects and inhibited enzymes such as α -amylase, α -glucosidase, urease, and hyaluronidase. Current evidence partially supports the traditional uses of these species. However, further studies employing standardized extraction procedures, bioactivity-guided fractionation, and detailed phytochemical characterization are necessary to clarify structure–activity relationships and support the development of evidence-based phytotherapy.

Keywords Caryophyllaceae · Rubiaceae · Asteraceae · Phytochemical composition · Pharmacological activity · Bioactive secondary metabolites

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Introduction

Researchers are particularly interested in topics related to the phytochemical analysis and therapeutic potential of exotic, often newly classified plants. However, the dynamic development of analytical techniques, in vitro and in vivo studies have broadened our understanding of plant species with long-standing

ethnomedicinal use, including those widely distributed taxa that are often regarded simply as weeds.

Among such species is *Stellaria media* (L.) Vill. (Caryophyllaceae). It is commonly found almost all over the globe, including Europe, Africa, Asia and North America (Singh et al. 2022). This plant was used both in folk medicine and as an edible plant (Cusumano et al. 2024). Traditional medicinal uses of *Stellaria media* include anti-inflammatory, diuretic, expectorant, digestive support applications, anti-arthritic, anti-cancer, anti-obesity and supportive in wound treatment and neurological conditions, as well as in relieving menstrual pain (Oladeji and Oyebamiji 2020; Singh et al. 2022). In addition to numerous nutrients – amino acids, vitamins and minerals (Oladeji and Oyebamiji 2020; Singh et al. 2022) – the plant also contains a rich array of secondary metabolites responsible for its biological activity – flavonoids (rutin, apigenin glycosides), phenols and phenolic acids, saponins, and phytosterols (Melnik et al. 2018; Rogowska et al. 2017).

Galium aparine L. (Rubiaceae) is also one of the weeds widespread throughout the world (Taylor 1999) with a wide range of applications in traditional medicine, including supporting the healing of wounds and injuries, skin lesions, as an anti-inflammatory, antimicrobial, immunity-boosting and anti-cancer remedies, diuretic and analgesic agent (Atmaca et al. 2016; Beirami et al. 2024; Ilina et al. 2020; Wu et al. 2025). *Galium aparine* contains numerous iridoids, phenolic compounds, including flavonoids responsible for biological activity (Ilina et al. 2019). This plant was also used as food (Defelice 2002).

Galinsoga parviflora Cav. (Asteraceae) is a cosmopolitan weed species (Santosa et al. 2020). It has been traditionally used in folk medicine to manage several ailments including malaria, cold, flu, yellow fever, inflammatory conditions and liver disorders, as well as in joint pain and pain generally, skin issues, and as protection against solar radiation with pharmacological activities attributed to diverse secondary metabolites (flavonoids, saponins, terpenoids, tannins) (Bharathi et al. 2021; Ripanda et al. 2023). This plant is also traditionally used as a food source, and studies indicate the presence of numerous nutrients, such as a range of amino acids, calcium, magnesium and vitamin C (Bharathi et al. 2021; Kazlauskienė et al. 2023). Despite their global distribution and traditional

use, these species have not yet been comprehensively compared in a single ethnopharmacological review.

The aim of this systematic, critical review is to link the traditional uses of these cosmopolitan plants with findings concerning their chemical composition and biological activity measured using modern instrumental techniques and in vitro and in vivo models. This approach provides a perspective on these species through the prism of evidence-based phytomedicine.

Review methodology

An in-depth review of the available literature on the chemical composition, total content of major classes of compounds – phenols, flavonoids, iridoids, saponins, alkaloids, biological activity and traditional use of *Stellaria media*, *Galium aparine* and *Galinsoga parviflora* was conducted. A systematic search was conducted in the following databases: Google Scholar (<https://scholar.google.com/>), Science Direct (<https://www.sciencedirect.com/>), PubMed (<https://pubmed.ncbi.nlm.nih.gov/>), Web of Science (<https://mjl.clarivate.com/>) and Wiley Online Library (<https://onlinelibrary.wiley.com/>). Key phrases included ‘*Stellaria media*/S. media’, ‘*Galium aparine*/G. aparine’, ‘*Galinsoga parviflora*/G. parviflora’, ‘Biological activity/activity’, ‘Chemical composition/composition/constituents’, ‘traditional use/ethnopharmacology’. Synonyms of the scientific names of plant species were also searched. The review includes texts covering aspects of the chemical composition, traditional use and biological activity of the plant species mentioned. Sources from 1995–2026 have been included. The data was reviewed and summarized in tables (in the case of chemical composition), with quantitative analysis results expressed in mass/mass or mass/volume units converted to a common unit. The compiled data on phytochemical analysis, traditional use and biological activity test results were subjected to critical discussion. ‘The World Flora Online’ (<https://www.worldfloraonline.org/>) was consulted for species botanical descriptions and scientific name verification.

Chemical composition

Stellaria media

A review of the available scientific literature revealed the presence of 60 chemical compounds in aqueous, alcoholic, aqueous-alcoholic and buffered (peptide extraction) extracts obtained from the herb, above-ground parts, whole plants, stems, flowers and seeds (Table 1). The phytochemical profile of *Stellaria media* is characterized by a high diversity of flavonoids, particularly C-glycosides and O-glycosides, as well as significant amounts of phenolic acids and specialized proteins with antimicrobial properties. The phenolic fraction of *S. media* contains substantial amounts of chlorogenic acid (up to 76 640 µg/g) and gallic acid (75 840 µg/g), accompanied by salicylic and vanillic acids and dihydroxybenzoic acid (Aleem et al. 2023; Miere et al. 2023). The species is particularly rich in **flavonoids**, with derivatives of luteolin and apigenin being the most prominent (Hu et al. 2009; Miere et al. 2023; Mikšátková et al. 2014; Rogowska et al. 2017). The plant also contains C-glycosides such as isovitexin and isoorientin (Rogowska et al. 2017). Notably, *S. media* exhibits a diverse profile of **isoflavones**, including genistin (0.99154 ± 0.00104 µg/g), sophoricoside, and ononin, along with **flavonols** like rutin and kaempferol (Aleem et al. 2023; Mikšátková et al. 2014).

A distinctive feature of *S. media* is its content of **antimicrobial peptides (AMPs)** and specialized proteins. These include stellamedin A and a series of defensin-like peptides such as SmAMP3, SM-AMP-D1, and SM-AMP-X, which contribute to the plant's defense mechanisms and potential therapeutic applications (Rogozhin et al. 2015; Shan et al. 2013; Slavokhotova et al. 2014, 2011). Additionally, the presence of oleanane type triterpenoid saponin, **stellarinpin A** (3β,16β,23,28-tetrahydroxyoleana-11,13(18)-dien-3-O-β-D-glucopyranosyl-(1→3)-β-D-glucopyranosyl-(1→2)-β-D-fuco-pyranoside), has been documented (Hu et al. 2009) (Fig. 1.). The lipophilic and volatile profile of the species includes: **coumarins**—coumarin (11 310 µg/g) and scopoletin (0.21 ± 0.04 µg/g) have been identified (Aleem et al. 2023; Mikšátková et al. 2014); **sterols and esters**: β-sitosterol and its glucoside are the primary phytosterols, accompanied by esters like hexacosanyl palmitate and methyl stearate (Pande et al. 1995).

Quantitative analysis of *S. media* constituents reveals an exceptionally wide spectrum of secondary metabolite concentrations, spanning seven orders of magnitude. Phenolic acids and flavonoids constitute the dominant fractions, with chlorogenic acid and kaempferol reaching the highest values (76 640 µg/g and 13 910 µg/g, respectively). Simultaneously, the use of sensitive analytical techniques allowed for the identification of trace compounds, such as isoflavones: genistin (0.99154 µg/g) and ononin (0.12285 µg/g), as well as salicylic acid at a level of only 0.00460 µg/g. Such significant concentration heterogeneity highlights the complexity of the plant's chemical matrix and suggests that its therapeutic potential may arise from both the action of macro-constituents and the high biological activity of compounds present in ultra-trace amounts. It is also important to emphasize the significant difference in the results of quantitative analyses for kaempferol and rutin content (No. 38 and 39 in Table 1). A complete list of identified compounds, along with their concentrations (in the case of quantitative analyses), is provided in Table 1. The units were standardized to µg/g. A table expanded to include information on the part of the plant from which the extract was obtained, the solvent used for extraction, and the extraction and analytical techniques has been included in the supplementary materials.

Galium aparine

A review of data available in the literature revealed the presence of over 150 compounds in alcoholic, alcoholic:aqueous, aqueous, chloroformic, and essential oil extracts (Table 2). The phytochemical profile of *Galium aparine* exhibits a high degree of chemodiversity, characterized by a significant concentration of **phenolic acids**, **flavonoids**, and a complex mixture of volatile **terpenoids** and aliphatic compounds. The phenolic fraction is dominated by **hydroxycinnamic acid derivatives**, particularly caffeoylquinic acids. Chlorogenic acid (5-O-CQA) is a major constituent, with reported concentrations reaching up to 2048 ± 3.52 µg/g in the plant material (Crişan et al. 2016) or even $163\,000 \pm 2\,000$ µg/g in specific extracts (Senio et al. 2018). Its isomers, cryptochlorogenic acid (4-O-CQA) and neochlorogenic acid (3-O-CQA), are also present in significant amounts (Ilină et al. 2019; Shynkovenko et al. 2018). Other phenolic acids identified include caftaric, gentisic, *p*-coumaric,

Table 1 Literature review of *Stellaria media* chemical composition

No	Compound name	Content	References
<i>Phenolic compounds</i>			
1	5-O-caffeoylquinic acid (chlorogenic acid)	76 640 µg/g	Aleem et al. (2023)
2	gallic acid	75 840 µg/g	
3	vanillic acid	5 330 µg/g	
4	salicylic acid	41 640 µg/g	
5	dihydroxybenzoic acid	1 760 µg/g	
		2 292 µg/g	Miere et al. (2023)
<i>Flavonoids</i>			
6	luteolin	0.34 ± 0.03 µg/g	Mikšátková et al. (2014)
7	luteolin-7-glucoside	49.11 ± 0.75 µg/g	
8	luteolin-8-C-β-D-glucoside	—	Hu et al. (2009)
9	luteolin-6-C-β-D-glucoside	—	
10	luteolin-rutinoside	3 137 µg/g	Miere et al. (2023)
		1 305 µg/g	
11	luteolin-rhamnoside	335 µg/g	
		233 µg/g	
12	luteolin-malonyl-glucoside	361 µg/g	
		264 µg/g	
13	luteolin-glucuronide	1 552 µg/g	
		1 116 µg/g	
14	apigenin	0.02 ± 0.01 µg/g	Mikšátková et al. (2014)
15	apigenin-7-glucoside	0.18 ± 0.02 µg/g	
16	apigenin-glucoside	933 µg/g	Miere et al. (2023)
		647 µg/g	
17	apigenin-glucuronide	1 065 µg/g	
		297 µg/g	
18	apigenin derivative	—	Rogowska et al. (2017)
19	apigenin-di-C-hexoside	—	
20	apigenin-di-C-glicoside(C-pentoside, C-hexoside)	—	
21	apigenin-tri-O,C,C-hexoside	—	
22	apigenin-apiosyl-glucoside	5 284 µg/g	Miere et al. (2023)
		2 749 µg/g	
23	apigenin-diglucoside	4 291 µg/g	
		3 559 µg/g	
24	apigenin-apiosyl-glucosyl-glucoside	1 048 µg/g	
		791 µg/g	
25	isovitexin	—	Rogowska et al. (2017)
26	isovitexin derivative	—	
27	isoorientin	—	
28	isoorientin hexoside	—	
29	formononetin	0.01119 ± 0.00006 µg/g	Mikšátková et al. (2014)
30	genistein	0.05180 ± 0.00029 µg/g	
31	genistin	0.99154 ± 0.00104 µg/g	
32	glycitein	0.00460 ± 0.00008 µg/g	
33	ononin	0.12285 ± 0.00036 µg/g	Mikšátková et al. (2014)

Table 1 continued

No	Compound name	Content	References
34	sophoricoside	0.26636 ± 0.00091 µg/g	
35	flavone	< Q	
36	naringenin	0.79 ± 0.03 µg/g	
37	quercetin	< Q	
38	kaempferol	13 910 µg/g	Aleem et al. (2023)
		0.04 ± 0.02 µg/g	Mikšátková et al. (2014)
39	rutin	3 940 µg/g	Aleem et al. (2023)
		12.07 ± 0.21 µg/g	Mikšátková et al. (2014)
40	chrysoeriol-apiosyl-glucoside	2 655 µg/g	Miere et al. (2023)
		556 µg/g	
<i>Coumarins</i>			
41	scopoletin	0.21 ± 0.04 µg/g	Mikšátková et al. (2014)
42	coumarin	11 310 µg/g	Aleem et al. (2023)
<i>Carboxylic acids</i>			
43	hydroxybutyric acid	9 580 µg/g	Aleem et al. (2023)
<i>Saponins</i>			
44	stellarinpin A	—	Hu et al. (2009)
<i>Alkanes</i>			
45	6,7-dimethylheptacosane	—	Pande et al. (1995)
46	hentriacontane	—	
<i>Esters</i>			
47	3-methyl-6-hydroxyheneicos-3-enyl acetate	—	Pande et al. (1995)
48	hexacosanyl palmitate	—	
49	methyl stearate	—	
<i>Alcohols</i>			
50	5-acetoxidotetracont-3-en-1-ol	—	Pande et al. (1995)
51	pentacosanol	—	
52	triacontanol	—	
<i>Fatty acids</i>			
53	triacontanoic acid	—	Pande et al. (1995)
<i>Phytosterols</i>			
54	β-sitosterol	—	Pande et al. (1995)
55	β-sitosterol-β-D-glucoside	—	
<i>Proteins</i>			
56	stellarmedin A	—	Shan et al. (2013)
57	SM-AMP-3	—	Rogozhin et al. (2015)
58	SM-AMP-D1	—	Slavokhotova et al. (2011)
59	SM-AMP-D2	—	
60	SM-AMP-X	—	Slavokhotova et al. (2014)

the symbol “—” indicates qualitative data only; < Q—below the limit of quantification

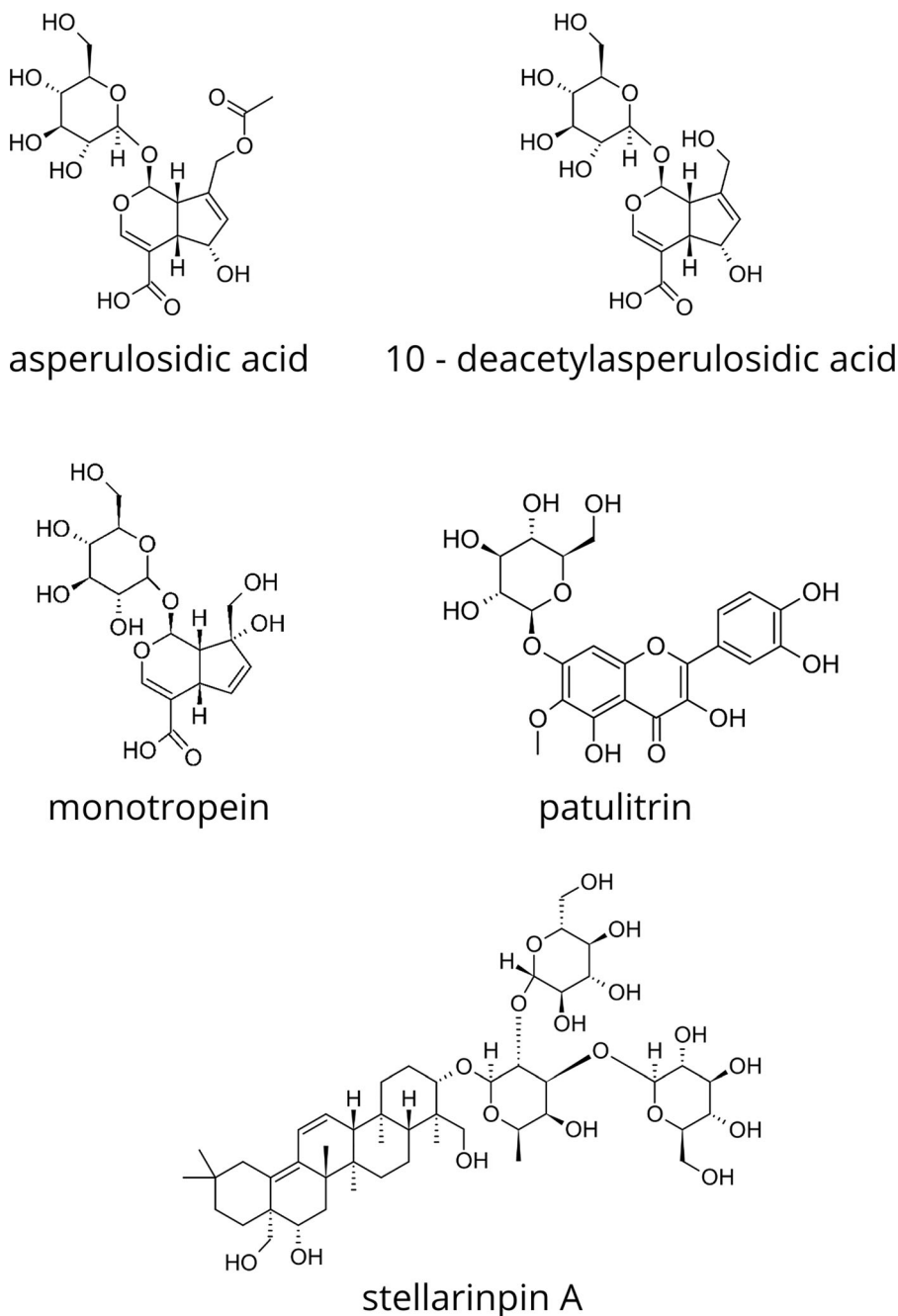


Fig. 1 Structures of selected compounds

and ferulic acids (Vlase et al. 2014). The species also contains various dicaffeoylquinic acid isomers (3,4-O-DCQA, 3,5-O-DCQA, and 4,5-O-DCQA) and cinnamoyl derivatives like 5-O-feruloylquinic acid (Ilina et al. 2019; Senio et al. 2018; Shynkovenko et al. 2018). The flavonoid profile consists mainly of

flavonols and their glycosides. Rutin (quercetin-3-O-rutinoside) is a prominent component (up to $6330 \pm 70 \mu\text{g/g}$), alongside quercetin, quercitrin, isoquercetin, and hyperoside (Ilina et al. 2019; Senio et al. 2018; Shynkovenko et al. 2018; Vlase et al. 2014). Additionally, luteolin and isorhamnetin

Table 2 Literature review of *Galium aparine* chemical composition

	Compound name	Content	References
<i>Phenolic compounds</i>			
1	caftaric acid	< 2.0 µg/g	Vlase et al. (2014)
2	gentisic acid	< 2.0 µg/g	
3	5-O-caffeoylquinic acid (chlorogenic acid)	2048 ± 3.52 µg/g	Crişan et al. (2016)
		780 µg/ml	Shynkovenko et al. (2018)
		< 2.0 µg/g	Vlase et al. (2014)
		163 000 ±	Senio et al. (2018)
		2 000 µg/g	
		158 000 ±	
		3 000 µg/g	
		157 000 ±	
		2 000 µg/g	
		145 000 ±	
		2 000 µg/g	
		18 440 ± 210 µg/g	Ilina et al. (2019)
		31 510 ± 190 µg/g	
		40 610 ± 120 µg/g	
4	4-O-caffeoylquinic acid (cryptochlorogenic acid)	8 120 ± 30 µg/g	Ilina et al. (2019)
		4 750 ± 80 µg/g	
		1 160 ± 20 µg/g	
5	3-O-caffeoylquinic acid (neochlorogenic acid)	110 µg/ml	Shynkovenko et al. (2018)
		8 910 ± 90 µg/g	Ilina et al. (2019)
		3720 ± 120 µg/g	
		530 ± 30 µg/g	
6	caffeoylquinic acid	12 500 ± 600 µg/g	Senio et al. (2018)
		10 500 ± 400 µg/g	
		9 200 ± 100 µg/g	
		5 200 ± 200 µg/g	
7	<i>p</i> -coumaric acid	14.04 ± 2.8 µg/g	Vlase et al. (2014)
8	ferulic acid	37.93 ± 3.1 µg/g	
9	caffeic acid	43.2 ± 1.02 µg/g	Crişan et al. (2016)
		30 µg/ml	Shynkovenko et al. (2018)
		< 2 µg/g	Vlase et al. (2014)
10	<i>p</i> -hydroxybenzoic acid	—	Ilina et al. (2019)
11	5-O-coumaroylquinic acid	2 100 ± 90 µg/g	Senio et al. (2018)
		3 300 ± 100 µg/g	
		2 220 ± 70 µg/g	
		2 800 ± 100 µg/g	
12	5-O-feruloylquinic acid	3 530 ± 50 µg/g	
		4 880 ± 60 µg/g	
		5 370 ± 40 µg/g	
		5 300 ± 200 µg/g	

Table 2 continued

	Compound name	Content	References
13	3,4-O-dicaffeoylquinic acid	—	Ilina et al. (2019)
14	3,5-O-dicaffeoylquinic acid	230 ± 20 µg/g 420 ± 80 µg/g 2 430 ± 110 µg/g 480 µg/ml	Shynkovenko et al. (2018)
15	4,5-O-dicaffeoylquinic acid	— 130 µg/ml	Ilina et al. (2019) Shynkovenko et al. (2018)
16	2-ethyl-4,5-dimethylphenol	< 1.0%	Laanet et al. (2023)
<i>Flavonoids</i>			
17	catechin	130 µg/ml	Shynkovenko et al. (2018)
18	quercitrin	20 µg/ml	
19	quercetin	30 µg/ml 56.79 ± 2.6 µg/g	Vlase et al. (2014)
20	luteolin	4.67 ± 0.7 µg/g	
21	isoquercetin	2 µg/ml 9.67 ± 1.3 µg/g	Shynkovenko et al. (2018) Vlase et al. (2014)
22	quercetin 3-O-rhamnoglucoside-7-O-glucoside	3 350 ± 100 µg/g 2 950 ± 50 µg/g 1 500 ± 20 µg/g	Ilina et al. (2019)
23	rutin (quercetin-3-O-rutinoside)	1 080 ± 50 µg/g 2 490 ± 30 µg/g 6 330 ± 70 µg/g 1 890 µg/ml 4 600 ± 100 µg/g 1 840 ± 40 µg/g 3 070 ± 60 µg/g 1 480 ± 10 µg/g 79.83 ± 3.0 µg/g	Shynkovenko et al. (2018) Senio et al. (2018)
24	Isorhamnetin-3-O-glucorhamnoside	—	Ilina et al. (2019)
25	hyperoside	310 µg/ml 3.00 ± 0.3 µg/g	Shynkovenko et al. (2018) Vlase et al. (2014)
<i>Iridoids</i>			
26	monotropein	—	Ilina et al. (2019)
27	deacetylasperulosidic acid	—	
28	asperulosidic acid	—	
<i>Monoterpenoids</i>			
29	eucalyptol	0.16%	Antoniak et al. (2019)
30	linalool	0.34%	
31	pulegone	0.24%	
32	carvone	0.35%	
33	carvacrol	0.55%	
34	10-(acetylmethyl)-3-carene	0.58%	
35	<i>p</i> -menthone	4.40%	Laanet et al. (2023)
36	thymol methyl ether	3.80%	
37	thymol	8.40%	

Table 2 continued

	Compound name	Content	References
38	α -terpineol	0.36%	Antoniak et al. (2019)
39	menthol	0.97%	
40	2,7-dimethyl-1,3,7-octatriene	0.38%	
41	dihydrocarveol	0.49%	
<i>Diterpenoids</i>			
42	trans-neophitadiene	3485.5 $\mu\text{g/g}$	Goryacha et al. (2014)
43	cis-, trans-neophitadiene	747.6 $\mu\text{g/g}$	
44	cis-neophitadiene	1237.5 $\mu\text{g/g}$	
45	phytol	3.08%	Antoniak et al. (2019)
<i>Triterpenoids</i>			
46	squalene	264.0 $\mu\text{g/g}$	Goryacha et al. (2014)
<i>Norisoprenoids</i>			
47	α -ionene	25.9 $\mu\text{g/g}$	Goryacha et al. (2014)
48	β -ionone	1.95%	Antoniak et al. (2019)
49	Hexahydropseudoionone	8.10%	Laanet et al. (2023)
50	β -damascenone	0.38%	Antoniak et al. (2019)
51	Dehydrodihydroionone	0.64%	
52	dihydroactinidiolide	218.3 $\mu\text{g/g}$	Goryacha et al. (2014)
53	loliolide	< 1.0%	Laanet et al. (2023)
		761.2 $\mu\text{g/g}$	Goryacha et al. (2014)
<i>Sesquiterpenoids</i>			
54	aromadendrene	0.84%	Antoniak et al. (2019)
55	bergamotene	0.18%	
56	β -farnazene	0.19%	
57	α -caryophyllene	0.39%	
		8.50%	Laanet et al. (2023)
58	α -gurjunene	0.40%	Antoniak et al. (2019)
59	γ -gurjunene	0.94%	
60	α -bisabolene	0.29%	
61	santalol	0.26%	
62	ledene oxide	0.22%	
63	spathulenol	1.72%	
64	trans- α -bisabolene epoxide	2.05%	
65	isoaromadendrene epoxide	0.67%	
66	humulene-1,2-epoxide	1.05%	
67	caryophyllene oxide	6.54%	
68	α -cadinol	1.65%	
69	cis-lanceol	3.27%	
70	β -bourbonene	< 1.0%	Laanet et al. (2023)
71	β -caryophyllene	3.00%	
72	β -acorenol	< 1.0%	
73	isobisabolone	< 1.0%	
<i>Phenylpropanoids and related compounds</i>			
74	anethole	1.77%	Antoniak et al. (2019)
		31.40%	Laanet et al. (2023)

Table 2 continued

	Compound name	Content	References
75	2-methoxy-2-vinylphenol	68.7 µg/g	Goryacha et al. (2014)
76	2-methoxy-4-vinylphenol	0.33%	Antoniak et al. (2019)
77	eugenol	0.39%	
78	4-ethenyl-1,2-dimethoxy-benzene	0.30%	
79	methyleugenol	1.05%	
80	2-propenylbenzene	0.20%	
81	phenylcoumaran hexoside	5 510 ± 40 µg/g 4 600 ± 100 µg/g 4 310 ± 70 µg/g 4 040 ± 80 µg/g	Senio et al. (2018)
<i>Toluenes</i>			
82	1-ethyl-2-methylbenzene	0.66%	Antoniak et al. (2019)
<i>Ketones</i>			
83	propiophenone	69.9 µg/g	Goryacha et al. (2014)
84	methylacetophenone	71.8 µg/g	
85	2,2,6-trimethylcyclohexanone	0.13%	Antoniak et al. (2019)
86	5-methyl-2-(1-methylethyl)-cyclohexanone	0.33%	
87	2-methylene-6-methylcyclohexanone	0.59%	
88	4-(1,3,3-trimethyl-7-oxabicyclo[4.1.0]hept-2-yl)-2-pentanone	0.16%	
89	6,10-dimethyl-5,9-undecadiene-2-one	0.52%	
90	4-(2,6,6-trimethyl-1-cyclohexen-1-yl)-3-buten-2-one	0.44%	
91	6,10,14-trimethyl-2-pentadecanone (Phytone)	3.16%	
92	2-Methyl-4-hydroxy-cyclobutanone	2.20%	Laanet et al. (2023)
<i>Keto acids</i>			
93	(-) 4-oxo-4-(p-tolyl)butanoic acid	1.03%	Antoniak et al. (2019)
<i>Alkyl aldehydes</i>			
94	pentanal	0.26%	Antoniak et al. (2019)
95	octanal	0.11%	
96	2-heptanal	0.14%	
97	2,6-nonadienal	0.23%	
98	2-nonenal	0.21%	
99	β-methylbutanal	1700%	Laanet et al. (2023)
100	2,4-decadienal	0.29%	Antoniak et al. (2019)
101	hexanal	2.40%	Laanet et al. (2023)
102	nonanal	4.10%	
<i>Aromatic aldehydes</i>			
103	benzaldehyde	0.80%	Antoniak et al. (2019)
		23.4 µg/g	Goryacha et al. (2014)
104	cinnamaldehyde	22.4 µg/g	
105	vanillin	16.8 µg/g	
106	salicylaldehyde	2.10%	Laanet et al. (2023)
<i>Cyclic aldehydes</i>			
107	2,6,6-trimethyl-1-cyclohexeneacetaldehyde	0.21%	Antoniak et al. (2019)
<i>Alcohols</i>			

Table 2 continued

	Compound name	Content	References
108	1-octene-3-ol	1.35%	Antoniak et al. (2019)
109	phenylethyl alcohol	1.57%	
110	2-octyn-1-ol	0.30%	
111	2-octen-1-ol	0.28%	
112	2-nonene-1-ol	0.89%	
113	2,6,6-trimethyl-1-cyclohexene-1-ethanol	0.21%	
114	3-decen-5-ol	0.45%	
115	3-(2,6,6-trimethyl-2-cyclohexen-1-yl)-2-propen-1-ol	1.29%	
<i>Ethers</i>			
116	5-(pentyloxy)-2-pentene	0.55%	Antoniak et al. (2019)
<i>Furans</i>			
117	2-pentylfuran	0.45%	Antoniak et al. (2019)
<i>Lactones</i>			
118	5,6,7,7a-tetrahydro-4,4,7a-trimethyl-benzofuranone	0.51%	Antoniak et al. (2019)
119	4,8,12,16-tetramethylheptadecane-4-olide	120.6 µg/g	Goryacha et al. (2014)
<i>Polycyclic aromatic hydrocarbons</i>			
120	1,2-dihydro-1,1,5-trimethylnaphthalene	31.4 µg/g	Goryacha et al. (2014)
121	1,2-dihydro-1,6,8,-trimethylnaphthalene	18.2 µg/g	
<i>Diazo compounds</i>			
122	9-diazo-9-fluorene	31.93%	Antoniak et al. (2019)
<i>Tocopherols</i>			
123	vitamin E	154.0 µg/g	Goryacha et al. (2014)
<i>Phytosterols</i>			
124	stigmasta-3,5-diene	127.0 µg/g	Goryacha et al. (2014)
125	γ-sitosterol	265.4 µg/g	
126	β-sitosterol	173.36 ± 9.25 µg/g	Crişan et al. (2016)
127	campesterol	12.7 ± 0.05 µg/g	
<i>Alkanes</i>			
128	tricosane	229.1 µg/g	Goryacha et al. (2014)
129	tetracosane	65.1 µg/g	
130	pentacosane	221.2 µg/g	
131	octacosane	788.5 µg/g	
132	heptacosane	300.4 µg/g	Goryacha et al. (2014)
133	nonacosane	3315.9 µg/g	
134	triacontane	248.5 µg/g	
135	untriacontane	297.9 µg/g	
136	nonadecane	0.71%	Antoniak et al. (2019)
137	hexatriacontane	1.34%	
138	n-hexatriacontane	1.97%	
<i>Alkenes</i>			
139	3,4-dimethyl-2-hexene	2.09%	Antoniak et al. (2019)
<i>Alkynes</i>			
140	2-pentadecene-4-yne	0.33%	Antoniak et al. (2019)
<i>Esters</i>			
141	ethyl linolenate	0.18%	Antoniak et al. (2019)

Table 2 continued

	Compound name	Content	References
<i>Cycloalkanes</i>			
142	1,5-Dimethylcyclopentene	0.39%	Antoniak et al. (2019)
<i>Monocarboxylic acids</i>			
143	phenylacetic acid	67.5 µg/g	Goryacha et al. (2014)
144	capric acid	95.5 µg/g	
145	α-methylpropanoic acid	2.00%	Laanet et al. (2023)
146	β-methylbutyric acid	7.50%	
147	α-methylbutyric acid	3.10%	
<i>Fatty acids</i>			
148	caprylic acid	52.5 µg/g	Goryacha et al. (2014)
149	tetradecanoic acid (myristic acid)	504.0 µg/g	
150	palmitoleic acid	436.4 µg/g	
151	palmitic acid	6.88%	Antoniak et al. (2019)
		13,742.2 µg/g	Goryacha et al. (2014)
152	heptadecanoic acid	220.2 µg/g	
153	linolenic acid	692.9 µg/g	
154	linoleic acid	18,937.3 µg/g	
155	dihomo-γ-linolenic acid	2.02%	Antoniak et al. (2019)

the symbol “-” indicates qualitative data only

derivatives have been documented (Ilina et al. 2019; Vlase et al. 2014).

A distinctive feature of *G. aparine* is the presence of iridoid glycosides, specifically monotropein, 10-deacetylasperulosidic acid, and asperulosidic acid (Fig. 1.), which serve as chemotaxonomic markers (Ilina et al. 2019). The terpenoid fraction is highly diverse. **Monoterpenoid** fraction consists of volatile constituents include thymol (8.40%), p-menthone (4.40%), and thymol methyl ether, as well as linalool, pulegone, and carvone (Antoniak et al. 2019; Laanet et al. 2023). **Sesquiterpenoids** contain caryophyllene oxide (6.54%), α-caryophyllene (up to 8.50%), cislanceol (3.266%) and β-caryophyllene (3.00%) are major components, accompanied by spathulenol and various sesquiterpene epoxides (Antoniak et al. 2019; Laanet et al. 2023). **Norisoprenoids** such as hexahydropseudoionone (8.10%), β-ionone (1.950%), and loliolide significantly contribute to the lipophilic profile (Antoniak et al. 2019; Goryacha et al. 2014; Laanet et al. 2023). The plant contains significant amounts of **phenylpropanoids**, notably anethole and methyleugenol (Antoniak et al. 2019). Interestingly, a high percentage of the diazo compound 9-diazo-9-

fluorene (31.934%) has also been reported in the volatile oil (Antoniak et al. 2019). However, this compound is not one of the known secondary plant metabolites, and its presence is most likely due to a misalignment with the database (see ‘6. Discussion’). A complete list of identified compounds, along with their concentrations (in the case of quantitative analyses), is provided in Table 2. The units were standardized to µg/g. A table expanded to include information on the part of the plant from which the extract was obtained, the solvent used for extraction, and the extraction and analytical techniques has been included in the supplementary materials.

Galinsoga parviflora

Based on the accessible literature, a total of over 170 chemical compounds present in the plant have been identified. The phytochemical profile of *Galinsoga parviflora* is characterized by a high diversity of phenolic compounds, particularly **phenolic acids** and **flavonoids**, which contribute to its biological activities. Most of the phenolic compounds, including flavonoids, identified in the extract were determined

Table 3 Literature review of *Galinsoga parviflora* chemical composition

No	Compound name	Content	References
<i>Phenolic compounds</i>			
1	4-hydroxybenzoic acid	—	Tariq et al. (2008)
2	3,4-dihydroxybenzoic acid	—	
3	gallic acid	—	
4	3,4-dimethoxycinnamic acid	—	Mostafa et al. (2013)
5	protocatechuic acid	—	
6	caffeoyl glucarate	—	Bazylko et al. (2015a)
7	caffeoylquinic acid	—	
8	dicaffeoyl glucarate	—	Bazylko et al. (2012)
9	dicaffeoylquinic acid	—	
10	tricaffeoyl glucarate	—	
11	caffeoyl derivatives	—	Dudek et al. (2016)
12	5-O-caffeoylquinic acid (chlorogenic acid)	—	
13	hydroxycinnamic acid	6 100 ± 200 µg/g	Ranilla et al. (2010)
		15 000 ± 1600 µg/g	
14	caffeic acid	—	Dudek et al. (2016)
		—	
15	1,3-O-dicaffeoylquinic acid	—	Bazylko et al. (2015a)
		—	
16	3,5-O-dicaffeoylquinic acid	—	Dudek et al. (2016)
17	1,5-O-dicaffeoylquinic acid	—	
18	2,4- or 3,5-dicaffeoylglucaric acid	—	Dudek et al. (2016)
19	2,4- or 3,5-dicaffeoylaltaric acid	—	
20	3,4,5-tricaffeoylglucaric acid	—	Dudek et al. (2016)
21	2,3,5- or 2,4,5-tricaffeoylaltaric acid	—	
22	2,3,4,5-tetracaffeoylglucaric acid	—	Dudek et al. (2016)
23	2,4,5-tricaffeoylglucaric acid	—	
24	2,3,4- or 3,4,5-tricaffeoylaltaric acid	—	Dudek et al. (2016)
25	2,3- or 4,5-dicaffeoylaltaric acid	—	
26	2,3,5-(2,3,5) tricaffeoylaltaric acid, 1(6)-O-methyl ester	—	Dudek et al. (2016)
27	2,3-(4,5-)-dicaffeoylaltaric acid, 1(6)-O-methyl ester	—	
<i>Flavonoids</i>			
28	quercetin	—	Surywanshi and Yadava (2015)
29	kaempferol	—	
30	3,5,3',5'-tetrahydroxy-7,4'-dimethoxyflavone-3-O-α-L-rhamnopyranosyl-(1->3)-O-α-L-arabinopyranosyl-3'-O-β-D-galactopyranoside	—	Surywanshi and Yadava (2015)
31	3,5,7,8,4'-pentahydroxy-3'-methoxyflavone-3-O-α-L-rhamnopyranosyl-7-O-β-D-glucopyranosyl-(1->4)-O-β-D-xylopyranoside	—	
32	galinsoside A	—	Ferheen et al. (2009)
33	galinsoside B	—	
34	7,3',4'-trihydroxyflavanone	—	Ferheen et al. (2009)
35	3,5,7,3',4'-pentahydroxyflavanone	—	

Table 3 continued

No	Compound name	Content	References
36	isoquercetin	—	Bazylko et al. (2012)
37	quercimeritrin	—	Bazylko et al. (2015a)
38	quercitagetrin	—	Bazylko et al. (2012)
		—	Bazylko et al. (2015a)
39	quercetagetin-7-O- β -glucoside	—	Dudek et al. (2016)
40	quercetin-3-O- β -glucuronide	—	
41	patulitrin	—	Bazylko et al. (2015a)
<i>Pyrimidine derivative</i>			
42	uracil	—	Mostafa et al. (2013)
<i>Sterol glycosides</i>			
43	β -sitosterol-3-O- β -D-glucoside	—	Tariq et al. (2008)
			Mostafa et al. (2013)
<i>Carboxylic acids</i>			
44	fumaric acid	—	Mostafa et al. (2013)
<i>Monoterpenoids</i>			
45	α -pinene	tr	Pino et al. (2010)
46	camphene	0.30%	
47	β -pinene	0.10%	
48	<i>p</i> -cymene	tr	
49	limonene	tr	
50	1,8-cineole	0.30%	
51	trans-linalool oxide	tr	
52	terpinolene	0.10%	
53	linalool	0.10%	
54	trans-sabinene hydrate	0.23%	Mostafa et al. (2013)
		0.60%	Govindarajan et al. (2018)
55	camphor	0.20%	Pino et al. (2010)
56	1,3,8-p-menthatriene	0.10%	Mostafa et al. (2013)
57	terpinen-4-ol	0.05%	
		0.10%	Pino et al. (2010)
		0.60%	Govindarajan et al. (2018)
58	<i>p</i> -cymen-8-ol	0.10%	Pino et al. (2010)
59	α -terpineol	0.10%	
60	safranal	tr	
61	β -cyclocitral	0.10%	
62	carvacrol	0.20%	

Table 3 continued

No	Compound name	Content	References
63	dihydrocarveol	0.15%	Mostafa et al. (2013)
		0.60%	Govindarajan et al. (2018)
64	exo-fenchyl acetate	0.12%	Mostafa et al. (2013)
		0.70%	Govindarajan et al. (2018)
<i>Diterpenoids</i>			
65	rimuene	2.40%	Pino et al. (2010)
66	phytol	4.39%	Mostafa et al. (2013)
		2.40%	Pino et al. (2010)
		3.70%	Govindarajan et al. (2018)
<i>Triterpenoids</i>			
67	squalene	2.40%	Pino et al. (2010)
68	ursolic acid	—	Tariq et al. (2008)
<i>Sesquiterpenoids</i>			
69	cyclosativene	0.10%	Pino et al. (2010)
70	α -copaene	0.10%	
71	α -longipinene	0.16%	Mostafa et al. (2013)
72	β -maaliene	0.37%	
		0.30%	Pino et al. (2010)
		1.10%	Govindarajan et al. (2018)
73	α -isocomene	0.31%	Mostafa et al. (2013)
		0.10%	Pino et al. (2010)
		0.90%	Govindarajan et al. (2018)
74	β -isocomene	0.25%	Mostafa et al. (2013)
		0.60%	Govindarajan et al. (2018)
75	β -caryophyllene	4.99%	Mostafa et al. (2013)
		12.40%	Pino et al. (2010)
		3.80%	(Govindarajan et al. 2018)
76	trans- α -bergamotene	0.20%	(Pino et al. 2010)
77	α -neo-clovene	0.32%	(Mostafa et al. 2013)
		1.20%	(Govindarajan et al. 2018)

Table 3 continued

No	Compound name	Content	References
78	α -humulene (α -caryophyllene)	0.51%	(Mostafa et al. 2013)
		1.80%	(Pino et al. 2010)
		1.40%	(Govindarajan et al. 2018)
79	(E)- β -farnesene	1.60%	(Pino et al. 2010)
80	α -acoradiene	1.00%	
81	cis-muurolo-4(14),5-diene	tr	
82	(Z,E)- α -farnesene	0.30%	
83	β -bisabolone	2.50%	
84	β -sesquiphellandrene	0.30%	
85	trans-calamene	tr	
86	(Z)-nerolidol	0.60%	
87	α -calacorene	tr	
88	(E)-nerolidol	0.30%	
89	spathulenol	0.70%	
90	sesquisabinene	0.23%	Mostafa et al. (2013)
		0.90%	Govindarajan et al. (2018)
		45.66%	Mostafa et al. (2013)
91	(Z)- γ -bisabolene	38.90%	Govindarajan et al. (2018)
		2.37%	Mostafa et al. (2013)
92	(E)- γ -bisabolene	3.20%	Govindarajan et al. (2018)
		0.24%	Mostafa et al. (2013)
93	α -cadinene	1.20%	Govindarajan et al. (2018)
		0.63%	Mostafa et al. (2013)
94	cis-sesquisabinene hydrate	0.25%	
95	germacrene B	0.90%	Govindarajan et al. (2018)
		2.42%	Mostafa et al. (2013)
96	(Z)-dihydro-apofarnesol	2.80%	Govindarajan et al. (2018)
		2.65%	Mostafa et al. (2013)
97	caryophyllene oxide	3.10%	Pino et al. (2010)
		3.40%	Govindarajan et al. (2018)

Table 3 continued

No	Compound name	Content	References
98	epi- α -muurolol	1.50%	Pino et al. (2010)
99	δ -cadinol	0.90%	
100	α -cadinol	3.10%	
101	cadalene	0.70%	
102	10-nor-calamenen-10-one	0.30%	
103	(Z)-bisabolol-11-ol	4.95%	Mostafa et al. (2013)
		3.90%	Govindarajan et al. (2018)
104	10-epi- γ -eudesmol	1.41%	Mostafa et al. (2013)
		2.60%	Govindarajan et al. (2018)
105	5-cedranone	0.75%	Mostafa et al. (2013)
		1.50%	Govindarajan et al. (2018)
106	valerianol	0.33%	Mostafa et al. (2013)
		0.90%	Govindarajan et al. (2018)
107	cedr-8(15)-en-10-ol	0.75%	Mostafa et al. (2013)
108	epi- β -bisabolol	0.98%	
		1.60%	Govindarajan et al. (2018)
109	α -bisabolol	0.53%	Mostafa et al. (2013)
		1.20%	Govindarajan et al. (2018)
<i>Norisoprenoids</i>			
110	(E)- β -ionone	tr	Pino et al. (2010)
<i>Phenylpropanoids and related compounds</i>			
111	eugenol	0.30%	Pino et al. (2010)
112	methyl eugenol	0.10%	
113	myristicin	tr	
<i>Lactones</i>			
114	cyclohexadecanolide	0.80%	Mostafa et al. (2013)
		1.80%	Govindarajan et al. (2018)
<i>Polyacetylenes</i>			
115	(Z)-falcarinol	1.40%	Pino et al. (2010)
116	(E)-falcarinol	2.90%	
<i>Phytosterols</i>			
117	β -sitosterol	—	Mostafa et al. (2013)
		—	Tariq et al. (2008)

Table 3 continued

No	Compound name	Content	References
118	stigmasterol	—	Mostafa et al.
119	7-hydroxy- β -sitosterol	—	(2013)
120	7-hydroxystigmasterol	—	
<i>Aromatic hydrocarbons</i>			
121	mesitylene	0.30%	Mostafa et al. (2013)
<i>Polycyclic aromatic hydrocarbons</i>			
122	naphthalene	0.06%	Mostafa et al. (2013)
<i>Coumarins</i>			
123	6-demethoxy-agerotochrome	14.00%	Pino et al. (2010)
<i>Unsaturated hydrocarbons</i>			
124	santolina triene	0.10%	Pino et al. (2010)
<i>Alkanes</i>			
125	n-decane	0.36%	Mostafa et al. (2013)
126	undecane	0.40%	Pino et al. (2010)
127	dodecane	0.20%	
128	tetradecane	0.50%	
129	heptadecane	0.50%	
130	heneicosane	0.10%	
131	n-tricosane	0.31%	Mostafa et al. (2013)
132	n-pentacosane	0.60%	
		1.20%	Surywanshi and Yadava (2015)
133	n-heptacosane	0.95%	Mostafa et al. (2013)
		1.80%	Govindarajan et al. (2018)
134	n-nonacosane	0.90%	Mostafa et al. (2013)
		2.10%	Govindarajan et al. (2018)
<i>Esters</i>			
135	3-hexenyl acetate	0.22%	Mostafa et al. (2013)
		tr	Pino et al. (2010)
		0.70%	Surywanshi and Yadava (2015)
136	methyl heptanoate	0.13%	Mostafa et al. (2013)
		0.90%	Govindarajan et al. (2018)
137	(Z)-hexenyl 2-methylbutyrate	tr	Pino et al. (2010)
138	bornyl acetate	0.10%	

Table 3 continued

No	Compound name	Content	References
139	ethyl 2-octynoate	0.09%	Mostafa et al. (2013)
		0.60%	Govindarajan et al. (2018)
140	phenylethyl isobutanoate	0.20%	Mostafa et al. (2013)
		0.60%	Govindarajan et al. (2018)
141	(Z)-3-hexenyl benzoate	0.20%	Pino et al. (2010)
142	8-hydroxy-isobornyl isobutanoate	0.58%	Mostafa et al. (2013)
143	galinisoate A	—	Afza et al. (2012)
144	galinisoate B	—	
145	galinisoate C	—	
<i>Fatty acids</i>			
146	nonanoic acid	tr	Pino et al. (2010)
147	hexadecanoic acid	2.10%	
148	octacosanoic acid	-	Tariq et al. (2008)
<i>Aliphatic ketones</i>			
149	3-heptanone	tr	Pino et al. (2010)
150	2-heptanone	tr	
151	6-methyl-5-penten-2-one	tr	
152	6-methyl-5-hepten-2-one (Sulcatone)	0.46%	Mostafa et al. (2013)
		1.20%	Govindarajan et al. (2018)
153	2-octanone	tr	Pino et al. (2010)
<i>Aromatic ketones</i>			
154	acetophenone	tr	Pino et al. (2010)
<i>Alkyl aldehydes</i>			
155	(E)-2-hexenal	2.70%	Pino et al. (2010)
156	heptanal	0.30%	Pino et al. (2010)
157	(E,E)-2,4-hexadienal	tr	
158	3-hydroxy-2-methylpentanal	tr	
159	octanal	0.10%	
160	(Z)-6-nonenal	0.60%	
161	nonanal	0.11%	Mostafa et al. (2013)
		0.20%	Pino et al. (2010)
		0.90%	Govindarajan et al. (2018)
162	decanal	0.20%	Pino et al. (2010)
<i>Aromatic aldehydes</i>			
163	benzaldehyde	0.10%	Pino et al. (2010)

Table 3 continued

No	Compound name	Content	References
164	phenylacetaldehyde	0.10%	Mostafa et al. (2013)
		0.20%	Pino et al. (2010)
		0.60%	Govindarajan et al. (2018)
165	4-methylbenzaldehyde	0.16%	Mostafa et al. (2013)
		0.70%	Govindarajan et al. (2018)
<i>Alcohols</i>			
166	(E)-3-hexenol	21.70%	Pino et al. (2010)
167	(E)-2-hexenol	tr	
168	1-hexanol	tr	Pino et al. (2010)
169	1-octen-3-ol	tr	
170	2-ethyl-1-hexanol	0.20%	
171	(Z)-3-octen-1-ol	0.20%	
172	n-undecanol	0.16%	Mostafa et al. (2013)
173	hexadecanol	0.54%	
		1.20%	Pino et al. (2010)
		1.40%	Govindarajan et al. (2018)
174	1-octadecanol	1.10%	Pino et al. (2010)
175	1-nonadecanol	0.50%	
176	triacontanol	—	Mostafa et al. (2013)

the symbol “-” indicates qualitative data only; tr – traces

only qualitatively (Table 3). The species is a rich source of **caffeic acid derivatives**. A significant group of these constituents includes **caffeoylglucaric acids** (e.g., caffeoyl glucarate, dicaffeoyl glucarate, and tricaffeoyl glucarate) and **caffeoylquinic acids**. Among them, chlorogenic acid (5-O-caffeoylquinic acid) has been quantified at a level of $6\,100 \pm 200\ \mu\text{g/g}$ dry mass (Ranilla et al. 2010). Detailed profiling has identified various isomeric forms, such as 1,3-O-dicaffeoylquinic, 3,5-O-dicaffeoylquinic, and 1,5-O-dicaffeoylquinic acids (Dudek et al. 2016). Furthermore, more complex structures have been reported, including tricaffeoylaltaric acids, tetracaffeoylglucaric acid, and their respective methyl esters (Dudek et al. 2016). Other simple phenolic acids identified in the extract include 4-hydroxybenzoic, 3,4-dihydroxybenzoic (protocatechuic), gallic, and 3,4-dimethoxycinnamic acids (Mostafa et al. 2013; Tariq et al. 2008). The flavonoid fraction of *G. parviflora*

consists mainly of **flavonols** and their glycosides. Quercetin and kaempferol are the primary aglycones identified in the herb (Surywanshi and Yadava 2015). Several glycosidic forms have been documented, including isoquercetin, quercimeritrin, and quercitagetrin (Bazylko et al. 2015a, 2012). Specialized studies have also reported the presence of **unique glycosides** such as Galinsoside A and B (Ferheen et al. 2009), and more complex structures involving rhamnopyranosyl and galactopyranoside moieties. Additionally, the presence of **flavanones** (e.g., 7,3',4'-trihydroxyflavanone and 3,5,7,3',4'-pentahydroxyflavanone) and methoxylated derivatives like patulitrin (Fig. 1.) and quercetagetin-7-O- β -glucoside further illustrates the chemodiversity of this plant (Bazylko et al. 2015a; Dudek et al. 2016).

The volatile and lipophilic fractions of *G. parviflora* are dominated by diverse terpenoids. **Sesquiterpenoids** constitute a major portion, with (Z)- γ -

bisabolene being the most abundant component (up to 45.66%) (Govindarajan et al. 2018; Mostafa et al. 2013). **Monoterpenoids** are represented by compound such as camphene, camphor, and 1,8-cineole, along with the apocarotenoid β -cyclocitral (Pino et al. 2010). The **diterpenoid** fraction includes phytol (up to 4.39%) and rimuene, while the **triterpenoids** are represented by squalene and ursolic acid (Mostafa et al. 2013; Pino et al. 2010; Tariq et al. 2008). The profile is complemented by **phenylpropanoids** (eugenol, myristicin) and **coumarins** (Pino et al. 2010). Furthermore, **unique esters** named Galinosoate A–C have been identified, further expanding the known chemical space of this species (Afza et al. 2012). A complete list of identified compounds, along with their concentrations (in the case of quantitative analyses), is provided in Table 3. The units were standardized to $\mu\text{g/g}$. A table expanded to include information on the part of the plant from which the extract was obtained, the solvent used for extraction, and the extraction and analytical techniques has been included in the supplementary materials.

Total phenolic content (TPC), total flavonoids content (TFC) and antioxidant activity:

Significant variation was observed in the total content of the analysed classes of secondary metabolites – total phenolic content (TPC), total flavonoid content (TFC), total iridoid content (TIC), total alkaloid content (TAC), total tannin content (TTC) and total saponin content (TSC). Significant variability was observed both between species and within the same species.

The highest TPC among the analysed extracts was found in the ethanolic extract from the aerial parts of *Galinsoga parviflora* collected in Brazil (133.04 ± 5.45 mg GAE/g of extract) (Feleti et al. 2020). *Galinsoga parviflora* 50% methanolic extract, prepared from herb harvested in Poland (June 2016), calculated as chlorogenic acid equivalent per gram of dry plant material, also showed a high TPC value of 98.30 ± 0.14 mg ChAE/g dry herb (Studzinska-Sroka et al. 2018). In the case of TPC analysis in another *Galinsoga parviflora* herb sample harvested in Poland, the values expressed as gallic acid equivalent per gram of dry plant material were lower and reached the following values: 38.25 ± 0.88 mg GAE/g dry herb

in decoction and 29.55 ± 0.57 mg GAE/g dry herb in hydromethanolic extract (70% methanol) (Chanaj-Kaczmarek et al. 2015). For *Stellaria media* extracts, the highest TPC result obtained was 68.12 ± 0.10 mg GAE/g extract, obtained in the analysis of a methanol macerate from the whole plant collected in Pakistan (Aleem et al. 2023). For the contract, the lowest TPC value was obtained in the analysis of ethanol macerate from edible, above-ground parts of *Stellaria media* subsp. *media* harvested in Turkey (4.44 ± 0.19 mg GAE/g extract) (Taskin and Bitis 2013). The TPC values obtained for the analyses of *Galium aparine* extracts were the lowest, ranging from 0.1458 ± 0.000012 mg GAE/g extract obtained by ultrasonic-assisted extraction of commercial plant material from Turkey in methanol (Bat Özmatara 2021) to 50 ± 0.036 mg GAE/g extract obtained by extraction of aerial parts of *Galium aparine* harvested in Turkey in ethyl acetate (Aslantürk et al. 2017).

Intra- and inter-species variability in total flavonoid content is also high. The highest were recorded for *Galium aparine* extract. The highest result was recorded for extract from commercial dried *Galium aparine* extracted with methanol in a Soxhlet apparatus (131.827 ± 0.008 mg QE/g extract) (Bat Özmatara 2021). The lowest TFC values were obtained in the analysis of extracts from *Galium aparine* plant material harvested at the full flowering stage in Ukraine, with values of 10.7 ± 0.1 , 10.2 ± 0.1 and 15.3 ± 0.1 mg RE/g of extract for extracts prepared in 20%, 60% and 96% ethanol (Ilina et al. 2019). For *Stellaria media*, the highest TFC result was 41.81 ± 0.07 mg CE/g extract, obtained in the analysis of a methanolic macerate from the whole plant collected in Pakistan (Aleem et al. 2023), and the lowest TFC value was 7.28 ± 1.18 mg QE/g extract, for hydroethanolic (70%) macerate of Romanian plant material (Miere et al. 2021).

The data found on total iridoid content (TIC) remain limited and refer only to Estonian *Galium aparine*. The TIC values obtained were 13.9 ± 1.2 , 20.3 ± 0.4 and 15.2 ± 0.2 mg asperuloside equivalent per gram of plant material for extracts prepared in 50% acetone, 50% ethanol and 80% ethanol, respectively (Laanet et al. 2023).

The total alkaloid content (TAC) was determined in a methanol extract from *Stellaria media* leaves collected in India and amounted to 0.7104 ± 0.0010 mg atropine equivalent per gram

Table 4 Total content of major secondary metabolites: phenols (TPC), flavonoids (TFC), iridoids (TIC), alkaloids (TAC) and saponins (TSC) in *Stellaria media*, *Galium aparine* and *Galinsoga parviflora*

S. media				G. aparine				G. parviflora			
Plant part	Content	References	Plant part	Content	References	Plant part	Content	Plant part	Content	References	References
<i>Total phenolic content (TPC)</i>											
wildgrowing plant material (Romania)	17.19±1.32 mg GAE/g extract	Miere et al., (2021)	aerial parts (Turkey)	41±0.280 mg GAE/g extract	Aslantürk et al., (2017)	Herb (Poland)	98.30±0.14 mg ChAE/g dry herb	Herb (Poland)	98.30±0.14 mg ChAE/g dry herb	Studzinska-Sroka et al., (2018)	Studzinska-Sroka et al., (2018)
edible aerial parts (Turkey)	4.44±0.19 mg GAE/g extract	Taskin and Bitis, (2013)	aerial parts (Turkey)	50±0.036 mg GAE/g extract	Aslantürk et al., (2017)	Wildgrowing plant material (Poland)	38.25±0.88 mg GAE/g dry herb	Wildgrowing plant material (Poland)	38.25±0.88 mg GAE/g dry herb	Chanaj-Kaczmarek et al., (2015)	Chanaj-Kaczmarek et al., (2015)
inedible aerial parts (Turkey)	8.00±0.00 mg GAE/g extract	Taskin and Bitis, (2013)	Commercial material	0.8254 ± 0.000015 mg GAE/g extract	Bat Özmatara, (2021)	Wildgrowing plant material (Poland)	29.55±0.57 mg GAE/g dry herb	Wildgrowing plant material (Poland)	29.55±0.57 mg GAE/g dry herb	Chanaj-Kaczmarek et al., (2015)	Chanaj-Kaczmarek et al., (2015)
whole plant (Pakistan)	68.12±0.10 mg GAE/g extract	Aleem et al., (2023)	Commercial material	0.1458 ± 0.000012 mg GAE/g extract	Bat Özmatara, (2021)	aerial parts (Brazil)	133.04±5.45 mg GAE/g of extract	aerial parts (Brazil)	133.04±5.45 mg GAE/g of extract	Feleti et al., (2020)	Feleti et al., (2020)
<i>Total flavonoid content (TFC)</i>											
wildgrowing plant material (Romania)	7.28±1.18 mg QE/g extract	Miere et al., (2021)	Seeds	6.36±0.03 %	Abbas et al., (2012)	Herb (Poland)	6.15±0.410 mg QE/g dry herb	Herb (Poland)	6.15±0.410 mg QE/g dry herb	Studzinska-Sroka et al., (2018)	Studzinska-Sroka et al., (2018)
			Commercial material	131.827±0.008 mg QE/g extract	(Bat Özmatara, 2021)	Wildgrowing plant material (Poland)	2.86±0.02 mg QE/g dry herb	Wildgrowing plant material (Poland)	2.86±0.02 mg QE/g dry herb	Chanaj-Kaczmarek et al., (2015)	Chanaj-Kaczmarek et al., (2015)
			Commercial material	30.8±0.009 mg QE/g extract	Bat Özmatara, (2021)	Wildgrowing plant material (Poland)	2.48±0.02 mg QE/g dry herb	Wildgrowing plant material (Poland)	2.48±0.02 mg QE/g dry herb	Chanaj-Kaczmarek et al., (2015)	Chanaj-Kaczmarek et al., (2015)
whole plant (Pakistan)	41.81±0.07 mg CE/g extract	Aleem et al., (2023)	Commercial material	32.47±0.10 mg QE/g extract	Bat Özmatara, (2021)						
			Herb at full flowering stage (Ukraine)	10.7±0.1 mg RE/g extract	Ilina et al., (2019)	aerial parts (Brazil)	96.02±1.45 mg RE/g of extract	aerial parts (Brazil)	96.02±1.45 mg RE/g of extract	Feleti et al., (2020)	Feleti et al., (2020)
			Herb at full flowering stage (Ukraine)	10.2±0.1 mg RE/g extract	(Ilina et al., 2019)						

Table 4 continued

S. media			G. aparine		G. parviflora			
Plant part	Content	References	Plant part	Content	References	Plant part	Content	References
Total iridoid content (TIC)								
			Herb at full flowering stage (Ukraine)	15.3±0.1 mg RE/g extract	(Ilina et al., 2019)			
			wildgrowing plant material (Estonia)	13.9±1.2 mg AE/g plant material	(Laanet et al., 2023)			
			wildgrowing plant material (Estonia)	20.3±0.4 mg AE/g plant material	(Laanet et al., 2023)			
			wildgrowing plant material (Estonia)	15.2±0.2 mg AE/g plant material	(Laanet et al., 2023)			
Total alkaloid content (TAC)								
Leaves (India)	0.7104±0.0010 mg ATE/g extract	Chak et al., (2021)	Seeds	2.76±0.03 %	(Abbas et al., 2012)			
Total tannin content (TTC)								
			Seeds	16.96±0.01 %	(Abbas et al., 2012)	whole plant (Saudi Arabia)	6.07±0.33 mg TAE/g dry plant	(Al-Robai et al., 2023)
			Commecial material	366.998±0.004 mg TAE/g extract	(Bat Özmatara, 2021)			
			Commecial material	318.7±0.001 mg TAE/g extract	(Bat Özmatara, 2021)	aerial parts (Brazil)	5.50±0.10 mg TAE/g of extract	(Feleti et al., 2020)
			Commecial material	293.27±0.013 mg TAE/g extract	Bat Özmatara, (2021)			
Total saponins content (TSC)								

Table 4 continued

S. media	G. aparine			G. parviflora		
	Plant part	Content	References	Plant part	Content	References
whole plant (India)	0.121 % w/w	Chidrawar et al., (2011)	Seeds	0.99±0.03 %	Abbas et al., (2012)	
whole plant (India)	0.108 % w/w	Chidrawar et al., (2011)				

GAE : Gallic acid equivalent; ChAE : chlorogenic acid equivalent; QE : quercetin equivalent; CE : catechin equivalent; RE : rutin equivalent; AE : asperuloside equivalent; AtE : atropine equivalent; TAE : tannic acid equivalent

of extract (Chak et al. 2021). In the case of *Galium aparine* seeds, the total alkaloid content was $2.76 \pm 0.03\%$ (Abbas et al. 2012). No data were found on the total alkaloid content in *Galinsoga parviflora*.

The total tannin content (TTC) in *Galium aparine* was high. Values found in the literature indicate the presence of $16.96 \pm 0.01\%$ tannins in the seeds of this plant (Abbas et al. 2012). Extract from commercial dried *Galium aparine* extracted with methanol in a Soxhlet apparatus showed TTC level at 366.998 ± 0.004 mg tannic acid equivalent per gram of extract (Bat Özmatara 2021). In the case of *Galinsoga parviflora*, TTC values of 5.50 ± 0.10 mg TAE/g of extract were recorded for the extract prepared from the aerial parts of the plant originating from Brazil (Feleti et al. 2020), and 6.07 ± 0.33 mg TAE/g dry plant for the extract prepared from the whole plant originating from Saudi Arabia (Al-Robai et al. 2023).

The total saponin content (TSC) was determined in *Stellaria media* at 0.121% (Chidrawar et al. 2011) and in *Galium aparine* seeds at $0.99 \pm 0.03\%$ (Abbas et al. 2012). No data were found on the total saponin content in *Galinsoga parviflora*. A complete summary of the total compound content in *Stellaria media*, *Galium aparine* and *Galinsoga parviflora* is presented in Table 4. The table, expanded to include information on the solvent used and extraction techniques, is included in the supplementary materials.

Biological activity

Biological activity of *Stellaria media*

There are a number of reports in the literature concerning the **antimicrobial activity** of *Stellaria media*. The results indicate moderate inhibitory activity against both Gram-positive (*Staphylococcus aureus*) and Gram-negative (*Escherichia coli*) bacteria. The inhibition achieved was dependent on the concentration of *Stellaria media* extract, but in no case was it comparable to the antibiotics used as controls (Miere et al. 2021, 2023). Chloroform extracts also showed moderate activity against bacteria: *E. coli*, *S. aureus*, *Proteus mirabilis*, *Klebsiella pneumoniae*, *Shigella dysenteriae* and *Salmonella typhi*, as well as fungi: *Fusarium solani*, *Alternaria alternata* and

Candida albicans (N. Ahmad et al. 2022a, b). Defensins isolated from plant seeds showed significant antifungal activity against phytopathogenic fungi of the genus *Fusarium* (*F. oxysporum*, *F. graminearum*, *F. avenaceum*) and *Botrytis cinerea*, reaching IC₅₀ values in the range of 0.35–1.00 µM (Slavokhotova et al. 2011). *Stellaria media* has also demonstrated anti-hepatitis B virus activity in in vitro tests (Ma et al. 2012).

Hexane, chloroform and ethyl acetate fractions of *Stellaria media* extract showed **anti-inflammatory** activity in in vitro tests through COX-2 inhibition, but the values obtained were an order of magnitude weaker than those obtained with the control indomethacin (Chak et al. 2025). Studies covering both in vitro and in vivo components also indicate a reduction in inflammatory markers in both tissue culture tests and patients diagnosed with polyarticular inflammatory **arthritis** (Babu et al. 2025). However, it should be noted that both the duration of the study and the population participating in it were limited. In in vitro studies on rats with albumin-induced paw oedema, *Stellaria media* extract showed anti-inflammatory effects comparable to those of the control group treated with indomethacin, also demonstrating an **analgesic effect** (Oyebanji and Saba 2012).

In vitro studies have demonstrated a significant **anti-diabetic** effect of methanolic extract from *Stellaria media* in reducing hyperglycaemia in rats with alloxan-induced type 2 diabetes. A significant decrease in blood glucose levels was observed after administration of the extract at the highest concentration tested (400 mg/kg b.w.). The effect was comparable to that induced by the standard antidiabetic drug glibenclamide at a dose of 5 mg/kg b.w. (Ahmad et al. 2019). Studies conducted on rats with streptozotocin-induced type 2 diabetes showed that oral supplementation with *Stellaria media* aqueous extract reduced blood glucose levels compared to the control group, but over time the anti-diabetic effect disappeared and blood glucose levels in both groups almost equalised (Demján et al. 2020). An in vivo experiment demonstrated the potential of freeze-dried *Stellaria media* juice as **anti-obesity** agent – the extract inhibited the absorption of fat and carbohydrates by inhibiting digestive enzymes in a dose-dependent manner (Rani et al. 2012). *Stellaria media* methanolic extract also had an anti-obesity effect in a mouse model of progesterone-induced obesity – it reduced white

adipose tissue gain, obesity index and liver weight compared to the group with induced obesity without administration of extracts (Chidrawar et al. 2011). A significant degree of inhibition of enzymes has been demonstrated: amylase and glucosidase, involved in the aetiology of **diabetes**, as well as acetylcholinesterase, butyrylcholinesterase and tyrosinase, associated with the development of **neurodegenerative diseases**, in particular Alzheimer's and Parkinson's (Cusumano et al. 2024). Methanolic extract of *Stellaria media* demonstrated **neuroprotective** properties and reduced lipid peroxidation in an in vivo model (W. Ahmad et al. 2022a, b). The methanolic extract also showed significant anxiolytic effects (Arora and Sharma 2012). The extract has also been shown to have **anti-tumour** activity against breast cancer cells (Eftekhari et al. 2025) and **wound healing** potential (Miere et al. 2021).

Biological activity of *Galium aparine*

Galium aparine has been shown to have **antibacterial** activity against *E. coli* and *S. aureus* and to accelerate **wound healing** in in vitro tests (Beirami et al. 2024). The lipophilic extract of *Galium aparine* showed antibacterial and antifungal activity against *S. aureus*, *E. coli*, *Pseudomonas aeruginosa*, *Bacillus subtilis*, *Proteus vulgaris*, and *C. albicans* (Goryacha et al. 2014; Tatyana Vasilevna et al. 2016). Moderate activity of *Galium aparine* extracts against filamentous fungi of the genus *Aspergillus* and *Penicillium* has also been demonstrated (Senio et al. 2018).

An **immune-enhancing** effect was demonstrated in an animal model of cyclophosphamide-induced immunodeficiency (Lee et al. 2024). In vitro studies also indicate immunomodulatory potential of this plant (Irina et al. 2019). The **anti-inflammatory** effect of *Galium aparine* has also been demonstrated by decreased mRNA expression levels of IL1α, IL1β, IL6, and TNFα (in vitro) (Shim 2018).

Galium aparine demonstrated concentration-dependent inhibitory effect on HNO210 human laryngeal carcinoma cells viability (Kubilay et al. 2026). The extracts also showed **cytotoxic activity** against MCF-7 breast cancer and Caco-2 colon cancer cells, as well as **apoptotic activity** (Aslantürk et al. 2017). The extract showed cytotoxicity, anti-proliferative and apoptotic effects towards breast cancer cell lines: MCF-7 and MDA-MB-231, however, it did not show

cytotoxicity towards MCF-10A breast epithelial cells (untransformed) (Atmaca 2017; Atmaca et al. 2016). The extract also showed strong inhibitory activity against α -amylase, indicating its potential **anti-diabetic** effect (Bat Özmatara 2021). Anthraquinone aldehyde, which has **insect antifeedant** properties, has also been identified in the plant (Morimoto et al. 2002).

Biological activity of *Galinsoga parviflora*

Galinsoga parviflora extracts showed moderate **antibacterial** activity against the following bacteria: *P. aeruginosa*, *P. mirabilis*, *Ralstonia solanacearum*, *S. aureus* and *Xanthomonas oryzae*, but in each case the activity of the extract was lower than that of the control antibiotic, ampicillin (Negi et al. 2025). The extract showed significant activity, comparable to the control nystatin, in inhibiting the growth of *Aspergillus niger* (Mostafa et al. 2013). The antibacterial activity of *Galinsoga parviflora* fiber extract against *S. aureus* and its **anti-biofilm** properties have also been demonstrated (Raja et al. 2024). Extracts from this plant and compounds isolated from it: β -sitosterol, ursolic acid, 4-hydroxybenzoic acid and β -sitosterol-3-O-, β -D glucopyranoside have shown **anti-nematocidal** activity (Ferheen et al. 2011). (Z)- γ -bisabolene, present in significant amounts in *Galinsoga parviflora* essential oil, has demonstrated **larvicidal** and oviposition deterrent properties against mosquito vectors (Govindarajan et al. 2018).

Galinsosides A and B, bioactive flavanone glucosides isolated from *Galinsoga parviflora* show significant urease and α -glucosidase inhibitory activity (Ferheen et al. 2009). *G. parviflora* silver nanoparticles showed **antidiabetic** activity by inhibition of α -amylase and α -glucosidase stronger than control substance – acarbose (Bhat and Ahmed 2024). Antidiabetic activity has also been demonstrated in animal models (Dhakad et al. 2024; Mostafa et al. 2013). The extract also inhibited hyaluronidase strongly than the control compound kaempferol and exhibited **anti-inflammatory** activity (Studzinska-Sroka et al. 2018). *Galinsoga parviflora* methanolic extract showed significant, dose-dependent, **anti-arthritic** and **anti-platelet** activity compared to standard drug acetyl salicylic acid in in vitro models (Katiyar et al. 2020). Caffeic acid derivatives from *G. parviflora* showed protecting activity for dermal

fibroblasts against UVA-induced oxidative stress (Parzonko and Kiss 2019). Aqueous extract from *G. parviflora* showed **photoprotective** activity due to their ability to inhibit ROS generation (Bazylko et al. 2015b). There are also reports of **anticancer** activity in in vitro models (Feleti et al. 2020).

Discussion

The available data indicate that the phytochemical profile of the polar fraction of the analyzed species is dominated by phenolic compounds, like structurally diversified flavonoids, simple phenolic compounds and their derivatives. The non-polar fraction consists predominantly of fatty acids, alcohols and hydrocarbons, as well as numerous biologically active components, primarily belonging to the classes of terpenoids (monoterpenoids, norisoprenoids, sesquiterpenoids, di- and triterpenoids) and phytosterols. The presence of long-chain n-alkanes and fatty alcohols in the nonpolar fractions can be attributed to cuticular wax constituents, which are primarily composed of very-long-chain fatty acid derivatives, including alkanes, primary alcohols, aldehydes, and esters (Samuels et al. 2008; Yeats and Rose 2013). In the case of the chemical composition analysis of the phenolic fraction of *Galinsoga parviflora*, most of the results are only qualitative data – quantitative analyses seem to be necessary. Overall, the phytochemical distribution clearly reflects solvent polarity, with polar fractions enriched in phenolic constituents and non-polar fractions dominated by lipidic and terpenoid compounds. However, significant variability in reported contents is observed, which may result from differences in geographical origin, plant part, extraction procedure, and analytical methodology.

A major limitation of the current literature is the predominance of studies based on crude extracts without detailed phytochemical standardization. In many cases, biological activity is attributed broadly to “phenolic compounds” or “flavonoids” without identification of specific active constituents. This makes mechanistic interpretation difficult and limits reproducibility. Another issue is the heterogeneity of experimental models. Most studies rely on in vitro assays, particularly enzyme inhibition and antioxidant tests (in vitro antioxidant activity not included in the overview), whereas in vivo studies remain scarce and

clinical data are lacking. The few data available on activity in human models depend on limited sample size. Therefore, the translational relevance of the reported biological effects remains uncertain. Moreover, data on bioavailability, metabolism, and potential toxicity are largely unavailable, which further limits the assessment of therapeutic applicability.

The methodology for determining phytochemical composition also remains imprecise. Analyses of the total content of major classes of compounds (TPC, TFC, etc.) are inconsistent and non-standardized in terms of the composition of the reaction mixture, incubation time, wavelength during spectrophotometric analysis, and reference compound. It should be emphasized, however, that high total phenolic or flavonoid content does not necessarily translate into strong biological activity. The lack of correlation analysis and bioactivity-guided fractionation in most studies prevents reliable structure–activity interpretation. Furthermore, spectrophotometric assays such as Folin–Ciocâlteu are non-specific and may respond to various reducing agents, which can lead to overestimation of total phenolic content.

The methodology for qualitative and quantitative determinations also remains imprecise, which is particularly evident in the case of screening analyses of volatile extracts using GC–MS, as shown in Table 2. No. 122. The dominant compound in *Galium aparine* essential oil was reported as 9-diazo-9-fluorene, a structure that is not recognized as a typical plant secondary metabolite. This assignment may require further verification, as GC–MS identification based solely on library matching can occasionally lead to misannotation, particularly for polycyclic aromatic structures with similar fragmentation patterns. In such cases, structurally related naturally occurring compounds, such as fluorenone derivatives or anthraquinones (e.g. alizarin), could potentially generate comparable fragmentation profiles, emphasizing the need for complementary analytical confirmation (e.g., retention index comparison, co-injection with standards, or NMR verification). The Rubiaceae family is known for producing anthraquinones, which have historically been used as dyes (e.g. in *Rubia tinctorum*). It also seems necessary to standardize the system for reporting the results of quantitative analyses in phytochemical studies. The analysed data, both in the case of data on the total content of compound classes and the results of quantitative composition, included

data reported in terms of dry weight of plant, dry weight of extract, liquid extract, and the entire range of units— $\mu\text{g}/\text{mg}$, mg/g , and even $\text{mg}/100\text{ g}$. Standardizing the system for reporting results, for example to a value expressed in $\mu\text{g}/\text{g}$ of dry plant material, would enable direct comparison of results.

Despite these limitations, consistent evidence indicates that cosmopolitan weed species – *Galium aparine*, *Stellaria media* and *Galinsoga parviflora* – exhibit interesting biological activity, potentially representing a valuable and widely available source of therapeutic compounds. These species represent underexplored but chemically rich medicinal resources, particularly considering their global availability and historical ethnomedicinal relevance. The traditional use of *S. media* as an anti-inflammatory and anti-rheumatic agent has been confirmed in the literature, both in vitro and in vivo studies. The potential of this plant to accelerate wound healing in an in vitro model has also been demonstrated. Its traditional use in neurological diseases may be related to its inhibitory activity on enzymes: acetylcholinesterase, butyrylcholinesterase and tyrosinase, which are involved in neurodegenerative diseases. Its traditional use against obesity has been confirmed by a series of studies using in vitro and in vivo models, concerning the reduction of hypoglycaemia, weight loss, reduction of fat and carbohydrate absorption through inhibition of digestive enzymes, and reduction of liver weight in a mouse model of progesterone-induced obesity. Regarding its traditional use as a menstrual pain reliever, *S. media* has also shown an analgesic effect in in vivo studies. *Stellaria media* has also demonstrated anti-tumor activity against breast cancer cells.

The traditional anti-inflammatory and immunity-enhancing effects of *G. aparine* have also been confirmed in in vitro and in vivo tests involving an animal model of cyclophosphamide-induced immunodeficiency and decreased mRNA expression levels of IL1 α , IL1 β , IL6, and TNF α in a cell line model. Anticancer activity has been demonstrated—*G. aparine* exhibited cytotoxic effects against the MCF-7 and Caco-2 cell lines, as well as apoptotic and antiproliferative effects, while showing no toxicity to the untransformed MCF-10A cell line. The plant also showed antimicrobial and wound-healing properties in in vitro tests, which is also consistent with its traditional use.

G. parviflora has traditionally been used as an anti-inflammatory agent and for pain relief, including joint pain. This corresponds with the results obtained in in vitro tests regarding anti-inflammatory and anti-rheumatic activity. Traditional use also included protection against harmful UV radiation, and this activity has also been confirmed. Its use in folk medicine also includes anti-malarial and anti-yellow fever activity. Although no evidence of anti-protozoal and antiviral activity has been found, (Z)- γ -bisabolene, present in large quantities in the essential oil, has shown larvicidal and oviposition deterrent properties against mosquito vectors, which may be helpful in protecting against mosquito-transmitted diseases.

The available data indicate that solvent polarity strongly influences both phytochemical composition and biological activity, emphasizing the need for extract standardization. There appears to be a clear need to standardize measurement and analytical methodologies to enable direct comparison of results. It seems necessary to place greater emphasis on the analysis of fractions and specific phytochemicals contained in plant extracts. This would translate into increased repeatability of results, better understanding of the structure–activity relationship (SAR) and better mechanistic reasoning – deeper understanding of activity at the molecular level and identification of molecular targets. Only such an approach will allow these widely distributed species to move from ethnopharmacological relevance toward evidence-based phytotherapy. Without such methodological rigor, further accumulation of descriptive phytochemical and in vitro data will not substantially advance the pharmacological credibility of these species.

In summary, this cosmopolitan weed species mentioned above are non-toxic, have a long history of use as a food source and in traditional medicine, and available in vitro and in vivo studies indicate considerable potential for their use in therapeutic agents. However, despite numerous empirical evidence confirming the traditional use of *Stellaria media*, *Galium aparine* and *Galinsoga parviflora*, further research is needed to identify molecular targets and the structure–activity relationship of their components.

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I.J.-M.; investigation, B.R. and I.J.-M.; resources, B.R. and I.J.-M.; data curation, I.J.-M. and B.R.; writing—original draft preparation, B.R.; writing—review and editing, B.R. and I.J.-M.; visualization, B.R.; supervision, I.J.-M.; funding acquisition, I.J.-M.

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Declarations

Competing interest The authors declare no competing interests.

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