

A Review of the Pharmacological Activities and Therapeutic Compounds of Invasive Plants in Polish Protected Areas

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Abstract

Invasive plants pose threats to the environment. However, their role in ethnomedicine and ethnoveterinary medicine should not be underrated, as their therapeutic compounds can serve as drugs, drug precursors, and drug prototypes. Poland is one of the countries in central Europe that continues to battle with invasive plants, especially in its protected areas. Despite numerous studies on Polish invasive plants, few or no studies have focused on the pharmacological activity and therapeutic compounds of invasive plants. This review thus aimed to compile a single study on the pharmacological activity and therapeutic compounds of Polish invasive plants in 23 national parks. The review examined 5 studies on invasive plants in 23 Polish national parks, and this was guided by a PRISMA flowchart. 68 Polish invasive plants from 29 families were recorded, with most species being herbaceous plants and belonging to the Asteraceae family. Antimicrobial activity topped among the pharmacological activities in Polish invasive plants and was followed by antioxidant, antiinflammatory, anticancer, antidiabetic, and antitumor activities. Among the different antimicrobial activities, antibacterial activity was highly prevalent, followed by antifungal activity. Quercetin and kaempferol had a pronounced rate of occurrence among the different therapeutic compounds in invasive plants. The possession of diverse pharmacological activities and therapeutic compounds in invasive plants highlights the need for their consideration as drug sources, drug precursors and drug prototypes.

1. Introduction

Protected areas hold an immense role as they aid in biodiversity conservation and preserving ecosystems which are particularly valuable for nature conservation (Braun et al., 2016). Protected areas (PAs) such as national parks and biosphere reserves have significant benefits for conservation and can be regarded as the foundation of the global protected area network (Le Saout et al., 2013). Despite the paramount importance of PAs, they face several pressures, such as climate change (Hannah et al., 2002), wildfire management, poaching, and illegal harvesting of resources (Rands et al., 2010). Another factor that has received global attention due to its negative effects on PAs is biological invasion by plants. Biological invasions are one of the five primary drivers of global biodiversity loss (Diagne et al., 2021).

The magnitude of biological invasions confronts PAs with the challenge of prevention and management (Foxcroft et al., 2017). Moreover, there is still an increasing body of information containing numbers of invasive plants in the flora and addressing the impacts of invasive plants on PAs: in Europe (Lapin et al., 2019), Asia (Kudo et al., 2014), North America (Abella et al., 2015), South America (Becerra & Simonetti Zambelli, 2013), Africa (McConnachie et al., 2015), Australia (Setterfield et al., 2013), and New Zealand (West & Thompson, 2013). Invasive plant species (IPS) also known by terms like alien plant species, can be defined as plants that have disturbing impacts on ecosystem functioning and become naturalized and rapidly spreading (Tokarska-Guzik et al., 2021). According to statistics from the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, there are over 37,000 established IPS globally, and with approximately 3,500 causing significant ecological harm (Roy et al., 2024).

The spreading of IPS makes it difficult to achieve the basic objectives of PAs of protection of biodiversity (Braun et al., 2016). Managing IPS is pertinent in continents such as Europe since most Europe's PAs have a long history of anthropogenic usage, including the introduction of IPS (Branquart et al., 2016; Braun et al., 2016). Some of the extensive evidence of a negative impact of invasive aliens on native species and their ecosystems on a global scale suggests that plant invasions may ultimately decrease the potential of PAs to conserve nature (Rands et al., 2010).

Many agents drive the spread of IPS in the areas they are introduced and some of these include humans who are vectors for spreading IPS (Kowarik & von der Lippe, 2011). IPS are considered biological pressures as they fuel changes which threaten native biodiversity, economy, and/or human health (Tokarska-Guzik et al., 2012).

Regarding biodiversity loss, recently, 70, 80, and 67% declines in species richness, alpha diversity, and macrofauna density, respectively, due to invasion by *Spartina anglica* were reported (Shin et al., 2022). To the economy, IPS cause losses in the global biodiversity, with an estimated \$423 billion in annual economic damages worldwide (Diagne et al., 2021). To humans, the allergenic pollen of IPS like *Ambrosia artemisiifolia* causes seasonal respiratory ailments in adults and children (Kim et al., 2012). According to Monaco (2014), 378 invasive plant species in total were distributed in various types of European PAs, and the share of alien species in some PAs in Europe reached almost 40% (Pyšek et al., 2013). Countries in central Europe, and particularly Poland, have been affected by IPS based on the findings of Bomanowska et al., (2019).

The devastating effects of IPS in central Europe may be attributed to the effects of human activity that were increasingly visible in the second half of the 20th century (Jackowiak, 2023). In Poland, some studies report that IPS are a serious threat to natural and seminatural plant communities as well as native plant species in PAs (Najberek & Solarz, 2011). To this, there is a plethora of studies on invasive plants in Poland as seen in the studies of Bomanowska et al., (2019), Tokarska-Guzik et al., (2021), Zajac & Zajac (2009), Gucwa-Przepióra et al., (2016), Popiela et al., (2015), Wrzesień & Denisow, (2017), Dajdok & Wuczyński (2008), Tokarska-Guzik et al., (2014), Tokarska-Guzik et al., (2010), Denisow et al., (2017), and Tokarska-Guzik (2005). However, none of these studies have taken into account to document the pharmacological properties and therapeutic compounds. The present study thus found it indispensable to compile a single study of IPS, their pharmacological activities, and therapeutic compounds, in 23 national parks (NP) in the whole territory of Poland.

2. Materials and Methods

2.1 Literature search strategy

A systematic literature search was conducted from January 1970 to January 2026, and included published scientific literature, theses, and dissertations. The following databases, Google Scholar, ScienceDirect, and Research Gate were searched for research articles on IPS in the 23 national parks situated in Poland. During the review process, the following search terms were included: invasive plant species, alien plants, Białowieża NP, Biebrza NP, Kampinos NP, Tuchola NP, Wigry NP, Drawa NP, Narew NP, Roztocze NP, Ojców NP, Wielkopolska NP, Babia Góra NP, Bieszczady NP, Gorce NP, Karkonosze NP, Magura NP,

Pieniny NP, Polesie NP, Słowin NP, Stołowe Góry NP, Święty Krzyż NP, Tatra NP, Ujście Warty NP, and Wolin NP. Study titles and abstracts were critically reviewed for retrieval and were saved to a reference management tool (Mendeley V1.19.8) together with details of where the reference had been found.

2.2 Study selection and data extraction

For any article to be considered in this review, it had to meet certain criteria. First of all, the study had to document any IPS in Białowieża NP, Biebrza NP, Kampinos NP, Tuchola NP, Wigry NP, Drawa NP, Narew NP, Roztocze NP, Ojców NP, Wielkopolska NP, Babia Góra NP, Bieszczady NP, Gorce NP, Karkonosze NP, Magura NP, Pieniny NP, Polesie NP, Słowin NP, Stołowe Góry NP, Święty Krzyż NP, Tatra NP, Ujście Warty NP, and Wolin NP. It must have been published or made available from 1970 up to January 2026. Articles that were excluded were review articles (systematic or literature), unpublished articles, articles published in languages other than English and Polish, and articles on IPS in protected areas other than national parks. The selection of the articles was done in four steps, and this was possible using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart (Fig. 1).

The first step involved checking the relevance of the studies based on their title. The second step involved evaluating the abstracts to make sure that they matched the inclusion criteria. If the primary inspection of an abstract of a paper did not give adequate information to make an informed judgment, the full paper was looked for in the third step and reviewed by the authors prior to making a decision concerning inclusion in the review. Lastly, those that appeared to meet the inclusion criteria were retrieved for extra appraisal. All the scientific names of the plants were re-checked and named according to the kew database <http://powo.science.kew.org>, and the plant families were verified using the Angiosperm Phylogeny Group IV <https://www.gbif.org/dataset/fa8ab13c-52ed-4754-b838-aeff74c79718>.

Only IPS meeting the following criteria: (i) species listed as invasive plants in Poland at the national, regional or local levels (Tokarska-Guzik et al., 2012) and (ii) invasive species in Poland according to the Regulation of the Minister of the Environment of 9th September 2011 on the list of alien plant and animal species whose introduction into the environment may threaten indigenous species or natural habitats (Regulation of the Minister of the Environment, 2011) were considered.

2.3 Data Analysis and Visualization

Descriptive statistics were conducted using MS Excel Version 2013 to analyse the data collected. Graphical data visualization was performed on GraphPad Prism 8.0.2 program (GraphPad Software, Inc., San Diego, CA) while the word cloud was produced using a word cloud software.

3. Results

3.1 Study characteristics

A total of 168 publication records were identified, and all were assessed. Only 5 passed the selection criteria for review and data extraction (Fig. 1). All the reviewed studies were from Poland and had information on IPS in national parks.

3.2 Location of the selected protected areas in Poland

Studies on invasive plant species, taking into consideration the number of IPS in each studied protected area, have been conducted in different regions of Poland, as shown in Fig. 2. Some of the selected PAs such as Drawa NP in north-western Poland, Kampinos NP in central Poland, and Ojców NP in southern Poland, harbor extremely high numbers of IPS based on surveys by other researchers (Fig. 2). However, other PAs such as Stołowe Góry NP in western Poland and Babia Góra NP in southern Poland, have extremely low numbers of IPS (Fig. 2).

Table 1
Invasive plant species in Polish National Parks

Scientific Name & family	Location (National Park)	Common name	Life form	Pharmacological activities	Therapeutic compounds
1. <i>Acer negundo</i> L. [Aceraceae]	2, 3, 5, 6, 10, 13, 14, 15, 17, 20, 21, 22	Ash-Leaf Maple/ Ashleaf maple/ Boxelder/ Box elder	Tree	Significant inhibitory activity against sarcoma 180 in mice (Kupchan et al., 1967)	Acerotin, acerocin (Kupchan et al., 1971), rutin, catechin,, apigenin, gallic acid, ferulic acid, and 2.5 dihydroxybenzoic acid, caffeic acid, quercetin-3- β -glucoside and isorhamnetin (Salgado-Garciglia et al., 2021)
2. <i>Ailanthus altissima</i> (Mill.) Swingle [Simaroubaceae]	21	Tree of heaven	Tree	Analgesic, antipyretic and antiulcer activities (Rashed et al., 2012), antituberculosis, antimalarial, antitumor and antiherpes activities (Hwang et al., 2002), antioxidant, antimicrobial (Poljuha et al., 2022)	Quassinoids (Kubota et al., 1996), indole alkaloids (Souleles & Kokkalou, 1989) lipids and fatty acids (Kucuk et al., 1994), phenolic derivatives (Abd El-Baky et al., 2000), 3-caffeoylquinicacid, 4-caffeoylquinicacid, 5-caffeoylquinicacid, Kaempferol-galloyl-hexoside, gallic acid (Poljuha et al., 2022)
3. <i>Alopecurus myosuroides</i> Huds.[Poaceae]	11	Black-grass/ slender foxtail	Herb	**	**
4. <i>Amaranthus retroflexus</i> L. [Amaranthaceae]	3, 5, 7, 10, 11, 15, 17, 21	Red amaranth/ tumbleweed/ pigweed amaranth	Herb	Antioxidant activity (Mihaela et al., 2025), antimicrobial efficacy, anticancer, haemostatic, and wound-healing and antiinflammatory effects (Bs, 2024)	Polyphenols (Mihaela et al., 2025), flavonoids (e.g. rutin and quercetin) (Kalinova & Dadakova, 2009), alkaloids (e.g. amaranthine) (Fiorito et al., 2017), sesquiterpenes (Fiorentino et al., 2006), phenolic acids (Sokołowska-Woźniak, 1996)
5. <i>Ambrosia artemisiifolia</i> L. [Asteraceae]	11	Ragweed	Herb	Antihelminthic, cardiotonic, antiinflammatory, analgesic, sedative, antimalarial (Rybalko, 1978), antimicrobial, and antiproliferative effects (Kovács et al., 2024)	Coronopilin, dihydropartenolide, psilostachyin, cumanin, peruvín, artemisiifolin, isabelin, psilostachyins C and B (Rybalko, 1978), 8 acetoxyl-3-oxopseudoguaian-6,12-olide, ambrosin, cumanin diacetate, 4-oxo-3,4-secoamrosan-6,12-olidic acid and its methyl ester, 4-oxo-6 hydroxypseudoguai-11(13)-en-6,12 olide, 8-angeloyloxy-10-acetoxylguai-3-en-6,12-olide (Milosavljević et al., 1999), 3-hydroxy-11 H,13-dihydrodamsin, 3-acetoxyl-11 H,13 dihydrodamsin (Błoszyk et al., 1992), paulitin, and isopaulitin (David et al., 1999)
6. <i>Amelanchier lamarckii</i> F.G. Schroed [Rosaceae Juss.]	2	Romanian juneberries	Shrub	Antioxidant activity, enzymatic inhibitory potential against tyrosinase, α -glucosidase, and acetylcholinesterase (Dăescu et al., 2024)	Anthocyanins (cyanidin), flavonols (quercetin), proanthocyanidins, and phenolic acids (Fang, 2021), cyanidin-galactoside, 3,4-dihydroxy-5-methoxybenzoic acid, feruloylquinic acid, and kaempferol (Dăescu et al., 2024)
7. <i>Amelanchier spicata</i> (Lam.) K.Koch [Rosaceae]	5, 7, 14, 21	Dwarf serviceberry	Shrub	Antioxidant activity (Saunoriūtė et al., 2025)	Chlorogenic acid, neochlorogenic acid, quercitrin, rutin, and hyperoside (Saunoriūtė et al., 2025), isofucosterol and taraxerol (Saunoriūtė et al., 2026)
8. <i>Anthoxanthum aristatum</i> Boiss. [Poaceae]	7, 15, 21	Annual Vernal Grass	Herb	**	**

Scientific Name & family	Location (National Park)	Common name	Life form	Pharmacological activities	Therapeutic compounds
9. <i>Aronia x prunifolia</i> (Marshall) Rehder [Rosaceae]	15, 23	Purple chokeberry	Shrub	Antioxidant effects (Szopa et al., 2017)	Cyanidin glycosides, chlorogenic acid, neochlorogenic acid, quercetin, quercitrin, rutin,, and rosmarinic acid (Szopa et al., 2017), hydroxycinnamic acids, and Proanthocyanidins (Taheri et al., 2013)
10. <i>Aster novi-belgii</i> L. [Asteraceae]	5, 7, 11, 15, 17, 21	New York Aster	Herb	Molluscicidal activity against <i>Biomphalaria alexandrina</i> snails (Hassan et al., 2011)	Triterpenoid saponins, oleanolic acid 3-O- β -D-galactopyranosyl (1 $\rightarrow$ 3)- α -L-arabinopyranoside; 3-O- β -D-glucopyranosyl- 3 β , 16 adihydroxyolean- 12-en- 28-oic acid-28-O- α -L-arabinopyranoside; {3-O- β -D-glucouronopyranosyl- 3 β ,16 adihydroxyolean- 12-en- 23-oic acid 28-O- β -D-xylopyranosyl- (1 $\rightarrow$ 3)- β -D-xylopyranosyl- (1 $\rightarrow$ 4)- α -L-rhamnopyranosyl-(1 $\rightarrow$ 2)- α -L-arabinopyranoside} ester and {3-O- β -D-glucouronopyranosyl-3 β ,16 adihydroxyolean- 12-en- 23-oic acid 28-O- β -D-xylopyranosyl- (1 $\rightarrow$ 3)- β -D-xylopyranosyl (1 $\rightarrow$ 4)- [α -L-arabinopyranosyl- (1 $\rightarrow$ 3)] - α -L-rhamnopyranosyl- (1 $\rightarrow$ 2)- α -L-arabinopyranoside} ester, and kaempferol, quercetin, kaempferol 3-O- β -D-glucopyranoside and quercetin 3-O- β -D-glucopyranoside (Hassan et al., 2011)
11. <i>Aster x salignus</i> Willd. [Asteraceae]	3, 11	Grass aster/ purple loosestrife	Herb	**	Terpenoids (spatuenol, aromadendrenoxyde, aromadendren, germakren D-1,10-epoxyde) (Trzhetsinsky et al., 2015)
12. <i>Avena fatua</i> L. s.l. [Poaceae]	5, 7, 10, 11, 14, 15, 21	Wild oat/ spring wild oats	Herb	Antibacterial and anti-fungal activities (Aziz et al., 2023), antioxidant activity (Saeed et al., 2018)	Alkaloid, saponin and phenolic contents (Aziz et al. 2023)
13. <i>Bidens frondosa</i> L. [Asteraceae]	2, 3, 5, 6, 7, 10, 17, 20, 21, 23	Common beggar-ticks	Herb	Antibacterial (Rahman et al., 2011), antioxidant (Venkateswarlu et al., 2004), antimalarial (Brandão et al., 1997) and antidiarrheal (Zhao & Wang, 1999), antiinflammatory activities (J. Le et al., 2015), anticancer, antiviral (Shawon et al., 2025), antidiabetic (Shawon et al., 2025), tyrosinase inhibitory activities (Abbas et al., 2017)	Acetylene (Brandão et al., 1997), polyenic D-glucosides (Pagani & Romussi, 1971), chalcones and aurones (Venkateswarlu et al., 2004), flavones and terpenes (J. M. Le et al., 2014)
14. <i>Bromus carinatus</i> Hook. & Arn. [Poaceae]	3, 5, 7, 11, 15, 21	California brome	Herb	**	**
15. <i>Bunias orientalis</i> L. [Brassicaceae]	3, 4, 6, 10, 11, 18, 21	Turkish cabbage	Herb	Antioxidant and antibacterial potential (Vergun, 2018)	Phenolic compounds (Vergun, 2018)
16. <i>Clematis vitalba</i> L. [Ranunculaceae]	5, 11, 15, 21	Traveller's Joy	Shrub	Antimycotic activity against <i>Prototheca zopfii</i> (Shahan &	Vitalboside, n-triacontan, n-nonacosan, ginnon, ginnol, β -sitosterol, chlorogenic acid,

Scientific Name & family	Location (National Park)	Common name	Life form	Pharmacological activities	Therapeutic compounds
				Pore, 1991), antibacterial (Khan et al., 2001), antiinflammatory, antinociceptive and antipyretic effects (Yesilada & Küpeli, 2007)	caffeic acid, colneleic acid, colnelenic acid (Ulubelen, 1970)
17. <i>Conyza canadensis</i> (L.) Cronquist [Asteraceae]	2, 3, 4, 5, 6, 7, 10, 11, 13, 15, 17, 20, 21, 23	Horseweed/ Canadian fleabane	Herb	Antifungal activity (Phuong et al., 2015), cytotoxic, antibacterial, anti-inflammatory, antioxidant, and antiagregant (Csupor-Löffler et al., 2011; Lenfeld et al., 1986; Olas et al., 2006; Shakirullah et al., 2011), antiviral effects (Edziri et al., 2011), antidiarrhoeal and antihaemorrhoidal activities (Chevallier, 1996; Chiej, 1984; Sastri, 1952)	Monoterpenes, sesquiterpenes and acetylene derivative constituents (Liu et al., 2010; Ogg et al., 1975; Veres et al., 2012), flavonoids, benzoic acid derivatives, alkaloids, essential oils, sphingolipids, fatty acids and sterols (Ding et al., 2010; Xie et al., 2007)
18. <i>Cornus sericea</i> L.emend. Murray [Cornaceae]	3, 6, 7, 10, 15, 21	Red Osier Dogwood/ Dogwood	Shrub	Antidiarrheal activity (Turner, 1990)	**
19. <i>Digitalis purpurea</i> L. [Plantaginaceae]	5, 14, 15, 18, 23	Foxglove/ purple foxglove	Herb	Cardiovascular, hepatoprotective, insecticidal and antioxidant, antidiabetic, antiproliferative effects (Zahid & Rizwani, 2016), antiinflammatory, anticancer, neuroprotective, and antimicrobial properties (Karakoti et al., 2025).	Digitoxin, digoxin, gitoxin and gitaloxin (Zahid & Rizwani, 2016), Luteolin, digicitrin and hesperidin, Apigenin, Dinatin (= Hispidulin), and Nepetin (Kartnig et al., 1977), digitolutein, 4-hydroxydigitolutein, and digitopurpone (1,4,8-trihydroxy-2-methylantraquinone), 1,6-dihydroxy-3-methylantraquinone (phomarin) and and isochrysophanol (1,8-dihydroxy-2-methylantraquinone) (Brew & Thomson, 1971), jaitoxin, and jatitalin (Jan et al., 2024) gitonin, and tigonin (Singh & Panda, 2005)
20. <i>Diplotaxis muralis</i> (L.) DC. [Brassicaceae]	11, 21	Annual wall rocket/ mustard rocket	Herb	Antioxidant activity (Ressurreição et al., 2025)	Mono-, di-, and/or triglycosides of kaempferol, quercetin, and isorhamnetin (3-O; 7-O; and/or 3-O,7-O-glycosides) (Bennett et al., 2006; Cartea et al., 2010), quercetin-3-O-β-D-galactopyranosyl-7-O-α-L-rhamnopyranosyl-(2→1)-O-β-D-xylopyranoside and isorhamnetin-3-O-β-D-galactopyranosyl-7-O-α-L-rhamnopyranosyl-(2→1)-β-D-xylopyranoside (Alaniya et al. 2012)
21. <i>Echinochloa crus-galli</i> (L.) P.Beauv [Poaceae]	3,5,7,10,11, 14,15,17,21	Barnyard grass	Herb	Antidiabetic (Yumnam et al., 2012), antioxidant (Mehta & Vadia, 2014), cytotoxic activities against breast carcinoma, colon carcinoma, cervical carcinoma and liver carcinoma (El Molla et al., 2016).	5,7-dihydroxy-3 ¹ ,4 ¹ ,5 ¹ -trimethoxy flavone, 5,7,4 ¹ -trihydroxy3 ¹ ,5 ¹ -dimethoxy flavone (tricin), quercetin, flavone, apigenin-8-C-sophoroside, 2-methoxy-4-hydroxycinnamic acid, p-coumaric acid and quercetin-3-O-glucoside (El Molla et al., 2016).

Scientific Name & family	Location (National Park)	Common name	Life form	Pharmacological activities	Therapeutic compounds
22. <i>Echinocystis lobata</i> (F.Michx) Torr. & A. Gray [Cucurbitaceae]	1,2,5,7,9,10,11,14,15,17,19,22,23	Wild cucumber or balsam apple	Herb	Antioxidant (Ielciu et al., 2018; Vinogradova et al., 2021) and antitumor effects (Vinogradova et al., 2021)	Isoquercitrin, rutin, quercitrin, kaempferol, p-coumaric and ferulic acid (I. Ielciu et al., 2018), cucurbitacins (Sokolov, 1986), hispidulin, apigenin, sinapic acid (I.-I. Ielciu et al., 2017)
23. <i>Elodea canadensis</i> Michx. [Hydrocharitaceae]	1,2,5,7,10,14,15,17,20,21,23	Canadian pondweed	Herb	**	**
24. <i>Epilobium ciliatum</i> Raf. [Onagraceae]	1,5,6,7,17,18	American willowherb/ fringed willowherb	Herb	Antioxidant property (Granica et al., 2014)	Macrocyclic ellagitannins oenothetin A and oenothetin B (Vlase et al., 2024), flavonoids quercetin (Granica et al., 2014), isoquercetin, myricetin (Ivanauskas et al., 2023), isomyricetin, kaempferol and their glycosides (Comalada et al., 2005), sterols β -sitosterol (Jariene et al., 2020)
25. <i>Erigeron annuus</i> (L.) Pers [Compositae]	2,3,4,5,6,7,11,14,17,21	Annual fleabane, daisy fleabane or eastern daisy fleabane	Herb	Antifungal, antiproliferative (Nazaruk et al., 2010), antiatherosclerosis (Kim et al., 2005), antiinflammatory (Jo et al., 2013), antidiabetic (Jang et al., 2010), antiobesity (Zheng et al., 2021), cytoprotective, antioxidant (Kim & Kim, 2003), and neuroprotective effects (Yoon MiSo et al., 2014)	β -sitosterol, coumarins, flavonoids (Mohamed & Abd, 2006), terpenoids-monoterpenes, sesquiterpenes, diterpenoid; polyacetylenic compounds; γ pyrone derivatives, sterols (Iijima et al., 2003)
26. <i>Fraxinus pennsylvanica</i> Marshall [Oleaceae]	5,7,14,17,19	Green Ash/ Red Ash/ Swamp Ash	Tree	Antibacterial activity (Omar et al., 2000)	Quercetin, pinorensinol-derived hexosides, laricresinol and apigenin (Eyles et al., 2007)
27. <i>Galinsoga ciliata</i> (Raf.) S.F. Blake [Astraceaea]	3,4,5,6,7,11,12,14,15,17,21,23	Shaggy soldier	Herb	**	**
28. <i>Galinsoga parviflora</i> Cav. [Astraceaea]	3,5,7,10,11,15,16,17,21,23	Gallant soldier/ quickweed/ waterweed/ potato weed/ yellow weed	Herb	Alphaglucoosidase inhibitor & hypoglycemic, antioxidant, antiinflammatory, anti-cancer (Ali et al., 2017), antifungal, hepatoprotective (Mostafa et al., 2013), antibacterial (Surywanshi & Yadava, 2015), nematocidal (Ferheen et al., 2011), antiscavenging, anti-hyaluronidase (Bazylko et al., 2012), antiarthritic (Pandey, 2010), antiplatelet (Kiritikar, 2009), and analgesic effects (Tolossa et al., 2013)	Flavonoids, patulitrin, quercimeritrin, quercitagratin and caffeoyl derivatives (Bazylko et al., 2012), Sinapic acid, Syringic acid, Vanillic acid (Al-Robai et al., 2023)
29. <i>Helianthus tuberosus</i> L. [Asteraceae]	3,5,7,9,10,11,13,14,17,19,21,23	Jerusalem artichoke or topinambour	Herb	Aperient, cholagogue, diuretic, stomachic and tonic effects, antibacterial, anti-inflammatory, antifungal and anticancer activities (Pan et al., 2009), antioxidant	3-O-caffeoylquinic acid, caffeic acid, 3,5-dicaffeoylquinic acid (3,5-DiCQA), 1,5-dicaffeoylquinic acid (1,5-DiCQA), 4,5-dicaffeoylquinic acid (4,5-DiCQA) and 3,5-dicaffeoylquinic acid methyl ether (3,5-DiCQAME) (Yuan e

Scientific Name & family	Location (National Park)	Common name	Life form	Pharmacological activities	Therapeutic compounds
				properties (Yuan et al., 2012) and antiviral effects (Cornescu et al., 2023)	al., 2012), desacetyleupaserrin, hymenoxin, nevadensin, kaempferol gluconate, kaempferol-3-o- glucoside, kaempferol, rutin, andrographin, nobiletin, silymarin, puerarin, rhamnazin, Δ7-stigmastenol, Δ7-campestenol (Y. Wang et al., 2020)
30. <i>Heracleum mantegazzianum</i> Sommier & Levier [Apiaceae]	3,4,7,16,22	Giant hogweed	Herb	Antibacterial, antifungal (Walasek et al., 2015), and antiviral effects (Tkachenko, 2007)	Xanthotoxin (Walasek et al., 2015), coumarins (Jakubaska-Busse et al., 2013)
31. <i>Heracleum sosnowskyi</i> Manden. [Apiaceae]	3,8,9,12,14,16,18,22	Sosnowsky's hogweed	Herb	Antibacterial (Borska et al., 2025), antioxidant, cytotoxic, antitumor (Hosseinzadeh et al., 2019), antifungal, and bone health-promoting properties (Pynam & Dharmesh, 2018), antiviral effects (Tkachenko, 2007)	Alkaloids, triterpene saponins, flavonoids and furanocoumarins (Osipova & Gladkov, 2024)
32. <i>Hordeum murinum</i> L. [Poaceae]	5,11,21	Wall barley	Herb	**	**
33. <i>Impatiens capensis</i> Meerb. [Balsaminaceae]	23	Jewelweed	Herb	Antimicrobial effects (Yang et al., 2001)	Impatienol, kaempferol, quercetin and lawsone (Oku & Ishiguro, 2002) and phenolics, flavonols, anthocyanins, quinones, (Yang et al., 2001), and saponins (Motz et al., 2015)
34. <i>Impatiens glandulifera</i> Royle [Balsaminaceae]	1,3,4,5,6,7,8,9,10,11,12,15,16,17,18,19,22	Indian balsam, Gnome's hatstand,	Herb	Neuroprotective, antidepressant-like and anxiolytic, antinociceptive, anti-inflammatory, antioxidant effects and moderate cytotoxicity against human leukaemia cells HL-60 and HL-60/MX2 (Žafran et al., 2025)	α-spinasterol, chondrillasterol, and Δ7-sitosterol (Žafran et al., 2025), naphthoquinones (Cimmino et al., 2016), phenolic acids (Szewczyk & Olech, 2017), flavonoids (Szewczyk et al., 2019), phytosterols, triterpenoids and fatty acids (Szewczyk et al., 2018)
35. <i>Impatiens parviflora</i> DC. [Balsaminaceae]	1,2,3,5,6,7,9,10,11,12,13,14,15,17,19,20,21,22,23	Small balsam	Herb	Antioxidant, antiinflammatory, antimicrobial, alleopathic, insecticidal (Grabowska et al., 2016), and antimelanoma effects (Grabowska et al., 2017)	3-O-([b-D-glucopyranosyl-(1!3)]-[b-D-glucopyranosyl-(1!2)])- b-D-glucuronopyranoside 16-O-acetyl-3b,22a,28-trihydroxy-olean-12-ene and 3-O-([b-D-glucopyranosyl-(1!3)]-[b-D-glucopyranosyl-(1!2)])-bD-glucuronopyranoside 3b,16a,22a,28-tetrahydroxy-olean-12-ene (Grabowska et al., 2020), naphthoquinones (Pavela et al., 2009), mono- and digalactosyldiacylglycerols (Grabowska et al., 2016), caffeoylmalate, 1,2,4-trihydroxynaphthalene-1-O-glucoside, feruloylmalate, quercetin – 3-O-hexoside, kaempferol-3-Oglucoside (4) (Hromádková et al., 2014)
36. <i>Juglans regia</i> L. [Juglandaceae]	3,5,11,17,23	Persian walnut, white walnut, English walnut	Tree	Antibacterial, antifungal, antioxidant (Pereira et al., 2008), antihelmintic, astringent, keratolytic,	Pyrogallol, p-hydroxybenzoic acid, vanillic acid, ethyl gallate, protocatechuic acid, gallic acid, 3,4,8,9,10-pentahydroxydibenzo pyran-6-one, tannins, glansrins

Scientific Name & family	Location (National Park)	Common name	Life form	Pharmacological activities	Therapeutic compounds
				antidiarrhoeal, hypoglycaemic (Mouhajir et al., 2001), antiatherogenic, osteoblastic (Papoutsi et al., 2008) and antiviral effects (Mei-zhi et al., 2006)	(Fukuda et al., 2003; Zhang et al., 2009)
37. <i>Juncus tenuis</i> Willd. [Juncaceae]	2,4,5,6,7,10,11,15,17,18,21,23	Path rush, poverty rush	Herb	Antiproliferative effects (Bús et al., 2020)	Juncusol, effusol, and 2,7-dihydroxy-1,8-dimethyl-5-vinyl-9,10 dihydrophenanthrene (Bús et al., 2020), luteolin, 5,7-dihydroxy-4-chromone, p-hydroxybenzoic acid, vanillic acid, and trans-p-coumaric acid (Barta et al., 2025)
38. <i>Lemna turionifera</i> Landolt [Lemnaceae]	10	Red duckweed	Herb	**	**
39. <i>Lolium multiflorum</i> Lam. [Poaceae]	6,10,11,15,17	Italian ryegrass	Herb	Antioxidant, antiseptic, antiinflammatory (Choi et al., 2017), antitumor and antibacterial effects (K. D. Lee et al., 2018)	α -linolenic acid, docosahexaenoic acid, oleic acid, docosatetraenoic acid and caprylic acid (Valan Arasu et al., 2014)
40. <i>Lupinus polyphyllus</i> Lindl. [Fabaceae]	3,4,5,6,7,8,11,14,15,17,19,21	Garden lupin	Herb	Antiradical activity (Purmalis et al., 2025)	Gallic acid, catechin, epigallocatechin, ellagic acid, epicatechin, catechin gallate, and epicatechin gallate (Boinik et al., 2015)
41. <i>Lycium barbarum</i> L. [Solanaceae]	3,5,7,11,15,21	Chinese wolfberry/ goji berry/ wolfberry/ barbary matrimony vine/ red medlar/ and matrimony vine	Shrub	Hepatoprotective (Sevindik et al., 2025), anticancer, antitumor, cytotoxic (Georgiev et al., 2019), anti-diabetic, hypoglycemic (Ma et al., 2022), antiinflammatory (S. R. Lee et al., 2020), antimicrobial (Ilić et al., 2020), antioxidant (Shang et al., 2022), antiviral (Li et al., 2023), antiradiation, antifatigue, antiaging, antistress, antiyeast, cardio protective and wound healing effects (Kwok et al., 2019; Leontopoulos, Skenderidis, Kalorizou, et al., 2017; Leontopoulos, Skenderidis, Anatolioti, et al., 2017)	Caffeic acid, chlorogenic acid, p-coumaric acid, ferulic acid, isoquercitrin, gentsic acid, kaempferol, rutin (Dong et al., 2011; Mocan et al., 2014), salicylic acid, sinapic acid (Mocan et al., 2015; Pollini et al., 2020), syringic acid, quercitrin, quercetin, vanilic acid, vanilin (Dong et al., 2011; Mocan et al., 2014, 2015; Pollini et al., 2020), acetic acid, hexadecanoic acid, ethyl lactate, 3-hydroxy-2-butanone, linoleic acid, 1-methoxy-2-propanone, β -elemene, myristic acid, ethyl hexadecanoate (Altintas et al., 2006), hexanal, (E)-2-hexenal, nonanal (F. Chen et al., 2015), isoamylol, 1-hexanol, 1-octen-3-ol (Lu et al., 2017), hexyl acetate, methyl salicylate, ethyl octanoate, o-cymene, d-limonene, linalool, β -cyclocitral, 2-pentylfuran (Altintas et al., 2006; F. Chen et al., 2015; Lu et al., 2017)
42. <i>Lysimachia punctata</i> L. [Myrsinaceae]	18	Spotted loosestrife	Herb	Antioxidant (Toth et al., 2014) and cytotoxic effects (Podolak et al., 2005)	Myricitrin, quercetin-hexoside (Toth et al., 2014), hydroxycinnamic acid (Toth et al., 2012), embelin (Podolak et al., 2005)
43. <i>Mimulus guttatus</i> DC. [Phrymaceae]	5,8,15	Yellow monkeyflower	Herb	**	Caffeic acid esters (Mølgaard & Ravn, 1988), mimulosides, verbascoside, conandrosides, calceolariosides A and B (Keefover-Ring et al., 2014)

Scientific Name & family	Location (National Park)	Common name	Life form	Pharmacological activities	Therapeutic compounds
44. <i>Onobrychis viciifolia</i> Scop. [Fabaceae]	11	Sainfoin/ St. Foin	Herb	Antimalarial (Bowers et al., 1995) and antioxidant effects (Ince et al., 2012)	Polyphenols, condensed tannins, arbutin, kaempferol, quercetin, rutin, afzelin, the branched quercetin-3-(2 G - rhamnosylrutinoside), the amino acid l-tryptophan, the inositol (+)-pinitol (Marais et al., 2000; Regos et al., 2009)
45. <i>Oxalis corniculata</i> L. [Oxalidaceae]	2	Creeping wood sorrel	Herb	Anthelmintic, antiinflammatory, analgesic, astringent, depurative, diuretic, emmenagogue, febrifuge, relaxant, lithontripic, stomachic and styptic, cardio relaxant, antibacterial, antiamebic, antiimplantation and abortifacient (Badwaik et al., 2011), wound-healing (Taranalli et al., 2004); anticancer (Kathiriya et al., 2010); antifungal (Verma et al., 2008), antioxidant (Reddy et al., 2010), antiepileptic (Sharma & Kumari, 2014); antiulcer activity (Patil et al., 2011), and antidiabetic effects (Dutta et al., 2016)	Flavonoids, iso vitexine and vitexine-2"- O- beta – D- glucopyrunoside, palmitic acid,oleic, linoleic, linolenic and stearic acids (Badwaik et al., 2011); oleanolic acid, eburicoic acid, squalene, and phytol (Karimzadeh et al., 2019); trigonelline (Feng et al., 2023); quercetin, kaempferol, and gallic acid (Nashipudi et al., 2025)
46. <i>Oxalis fontana</i> Bunge [Oxalidaceae]	4,6,7,10,11,14,17,21	Common yellow woodsorrel	Herb	**	**
47. <i>Padus serotina</i> (Ehrh.) Borkh. [(Rosaceae)]	3,7,10,13,14,17,19,22,23	American black cherry	Tree	Antioxidant (Luna-Vázquez et al., 2013), cardiovascular (Luna-Vázquez et al., 2016), vasodilating (Luna-Vázquez et al., 2013), and antibacterial properties (Telichowska, Kobus-Cisowska, Ligaj, et al., 2020)	5-caffeolquinic acid 2 (Mikulic-Petkovsek et al., 2016), gallic acid (Donno et al., 2018), prunazine and amygdalin (Telichowska, Kobus-Cisowska, & Szulc, 2020), vanillic acid, rutin, kaempferol hexoside pentoside, quercetin hexosyl pentoside 3, quercitrin, Uvaol and ursolic acid (Luna-Vázquez et al., 2013)
48. <i>Parthenocissus inserta</i> (A. Kern.) Fritsch [Vitaceae]	2,3,7,11,14,17	Thicket creeper	Creeper	**	**
49. <i>Quercus rubra</i> L.[Fagaceae]	2,3,5,7,9,10,11,13,14,15,17,19,21,22,23	Northern red oak	Tree	Antioxidant, antibacterial, antifungal potential, α-glucosidase, and tyrosinase inhibitory (Tanase et al., 2022)	Tannins (Tanase et al., 2022) gallic and ellagic acids, flavan-3-ols and flavonols (Cantos et al., 2003; Oracz et al., 2022; Rakić et al., 2007; Vinha et al., 2016), rutin, quercetin-3-β-glucoside, luteolin, neohesperidin; catechins: catechin, epicatechin, epicatechin gallate, gallocatechin; hydroxycinnamic acids: chlorogenic, caffeic, trans-ferulic, trans-cinnamic, p-coumaric, hydroxyphenylacetic, benzoic, syringic, sinapic acids (Konovalova et al., 2023)

Scientific Name & family	Location (National Park)	Common name	Life form	Pharmacological activities	Therapeutic compounds
50. Reynoutria xbohemica Chrtek et Chrtková [Polygonaceae]	7,11	Bohemian knotweed	Herb	Antioxidant, antidiabetic, and antimicrobial against yeast (Pogačnik et al., 2020)	Stilbenes (e.g., resveratrol and polydatin) (Chen et al., 2013) and emodin (Kovárová et al., 2010), as well as different catechins (Vrchotova et al., 2010) and carotenoids (Metličar et al., 2019)
51. Reynoutria japonica (Houtt.) Ronse Decraene [Polygonaceae]	2,3,5,6,7,9,11,12,13,14,15,16,17,21,22,23	Japanese knotweed	Herb	Antimicrobial against yeast (Pogačnik et al., 2020), antiallergic, antimutagenic, antioxidant, antibacterial, antiviral (Bralley et al., 2008; Goc et al., 2015; Zahedi et al., 2013), and antiinflammatory effects (Jo et al., 2024)	Stilbenes (e.g., resveratrol and polydatin) (Chen et al., 2013) and emodin (Kovárová et al., 2010), as well as different catechins (Vrchotova et al., 2010) and carotenoids (Metličar et al., 2019)
52. Reynoutria sachalinensis (F. Schmidt) Nakai [Polygonaceae]	5,7,8,11,12,13,16	Knotweed	Herb	Antibacterial, antioxidant (Abdulrazzaq Yasir Alrikabi, Viktoriia Protska, Nadiia Burda*Zhuravel & Kuznetsova, 2021), skin-whitening, antiinflammatory, anticancer (Lee et al., 2025), neuroprotective, and Acetylcholinesterase inhibitory effects (Eom et al., 2017)	Gallic acid, chlorogenic acid, trans-cinnamic acid, rutin, hyperoside and isoquercitrin (Abdulrazzaq Yasir Alrikabi, Viktoriia Protska, Nadiia Burda*Zhuravel & Kuznetsova, 2021), quercetin 3-O-glucoside and quercetin 3-O-(6'-acetyl-glucoside) (H. Lee et al., 2025), 1-decanol, b-amyrin, dammaran-3b-ol, campesterol, daucosterol, ergosterol peroxide, emodin 8-O-b-D-glucopyranoside, anc isoquercitrin (Eom et al., 2017), vanicoside A and vanicoside B (Nawrot-Hadzik et al., 2020), emodin glucoside, emodin-8-O-(6'-O-malonyl)-d-glucoside, hydropiperoside, physcion-8-O-β-d-glucoside, quetin, emodin (Suprun et al., 2024)
53. Rhus typhina L.[Anacardiaceae]	5,7,11,14,19,23	Staghorn Sumac	Shrub	Antihaemorrhoidal, antiseptic, diuretic (Moerman, 1998), antiinflammatory, hemostatic, and antihaemorrhoidal (Kossah et al., 2010), antioxidant (Kossah et al., 2011), interferon-inducing and antitumor (Islambekov et al., 1994), antiprotease (Jedinak et al., 2010), antibacterial, fungicidal (Zazharskyi et al., 2020), antidiabetic activity (Fereidoonfar et al., 2019) and antiviral effects (Antov et al., 2023)	Gallic acid, gallotannin (Werner et al., 2004), sumafllavone, and trigallic acid (Nazir et al., 2025)
54. Robinia pseudoacacia L. [Fabaceae]	3,5,6,7,9,10,11,13,14,15,17,19,20,21,22,23	Black locust	Tree	Antispasmodium, febrifuge, antioxidant; diuretic, emollient, antitumor, sedative, anti-inflammatory effects, hypotensive, laxative, anticoagulant, and α-glucosidase inhibitory (Lukash et al., 2024), antibacterial (Marinas et al., 2014), antifungal	Catechin, kaempferol glucuronyl rhamnosyl hexosides, luteolin dirhamnosyl hexosides and vescalagin (Lukash et al., 2024), acacetin, apigenin, diosmetin, luteolin, and quercetin (H. S. Kim et al., 2019), epigallocatechin, ferulic acid, hyperoside, and rutin (Savic Gajic et al., 2019) robinlin (Tian et al., 2001), dihydrobinetin and robinetin (Rudman, 1963), secundiflorol, mucronulatol,

Scientific Name & family	Location (National Park)	Common name	Life form	Pharmacological activities	Therapeutic compounds
				(Hosseinihashemi et al., 2015), and antimelanogenic effects (Chung et al., 1999)	isomucronulatol, and isovestitol (Tian & McLaughlin, 2000)
55. <i>Rosa rugosa</i> Thunb.[Rosaceae]	3,4,5,6,10,11,15,18,19,21,22,23	Rugosa rose, Japanese rose	Shrub	Inhibitory effects on acetylcholinesterase, antihypertensive (Xie & Zhang, 2012), astringent (Youwei & Yonghong, 2007), inhibitory activity against HIV reverse transcriptase (Fu et al., 2006), antioxidant, anticancer, antiinflammatory (Kim et al., 2022), and antidiabetic effects (Chen et al., 2015)	Quercitrin, tannin, fatty oil, organic acids (gallic acid), β -carotene, citronellol, geraniol, nerol, eugenol, phenethyl alcohol (Xie & Zhang, 2012), linalool, phenylethyl alcohol, citronellol, α -bisabolol, anthocyanins, procyanidins, proanthocyanidins (Ren et al. 2018), triterpenoid saponins (pulsatilloside F, hederacolchiside F, patrinia saponin H3, hederasaponin B, and cussosaponin C) (Thao et al., 2014)
56. <i>Rudbeckia laciniata</i> L. [Asteraceae]	2,3,4,5,7,9,11,14,15,17,21	Cutleaf coneflower	Herb	**	Prelacinan-7-ol, igalan, and lacinan-8-ol (Fukushi et al., 1998)
57. <i>Rumex confertus</i> Willd. [Polygonaceae]	2,3,4	Asiatic dock	Herb	Wound healing, antibacterial (Umarov et al., 2024), antifungal (Shermatova, 2021), antioxidant (Saoudi et al., 2021), and anticancer effects (Gülüm et al., 2025)	Hydroxycinnamic acids, and anthraquinones (Sun & Shahrajabian, 2023), tannins (ellagic acid, phloroglucinum and caffeic acid), flavonoids (nepodin, chrysophanoic acid, emodin) (Eshbakova et al., 2022), flavone glycosides (hyperoside and rutin) (Eisenman et al., 2012)
58. <i>Setaria pumila</i> (Poir.) Roem. et Schult. [Poaceae]	2,5,7,10,15,17,21	Yellow foxtail, Summer-grass, golden foxtail, wild millet	Herb	**	**
59. <i>Setaria viridis</i> (L.) Beauv. [Poaceae]	2,3,5,7,10,15,17,	Green foxtail	Herb	Antiinflammatory, antioxidant, hepatoprotective (Kwon et al., 2025), and antibacterial effects (Fan et al., 2014)	Tricin, p-hydroxycinnamic acid, vitexin 2"-O-xyloside, orientin 2"-O-xyloside, triclin-7-O-beta-D-glucoside and vitexin 2"-O-glucoside (Kwon et al., 2002), naphthol rhamnosides (8-O- α -L-rhamnosyl- β -sorigenin, 6-hydroxy-8-O- α -L-rhamnosyl- β -sorigenin, and 6-methoxy-8-O- α -L-rhamnosyl- β -sorigeni) (Fan et al., 2014)
60. <i>Solidago canadensis</i> L. [Asteraceae]	5,6,7,8,10,11,12,13,14,15,17,20,21,22,23	Canada goldenrod	Herb	Antioxidant, antiinflammatory, spasmolytic, diuretic (Wang JianFang et al., 2011), antibacterial (Deng et al., 2015), antimutagenic (Hayder et al., 2005) and analgesic effects (Mishra et al., 2011)	Triterpenoids (lupeol, lupeyl acetate, ursolic acid, cycloartenol, cycloartenyl palmitate, α -amyrin acetate, and stigmaterol, 3 β -(3R-acetoxyhexadecanoyloxy)-lup-20(29)-ene, 3 β -(3-ketohexadecanoyloxy)-lup-20(29)-ene, 3 β -(3R-acetoxyhexadecanoyloxy)-29 nor-lupan-20-one, and 3 β -(3-ketohexadecanoyloxy)-29 nor-lupan-20-one) (Chaturvedula et al., 2004)
61. <i>Solidago gigantea</i> Aiton . [Asteraceae]	2,3,4,5,6,7,8,9,10,11,12,13,14,15,17,21,22	Giant goldenrod	Herb	Antioxidant, antiinflammatory, antifungal, antiviral, insecticidal (Čerevková et al., 2020; Kołodziej et al., 2011; Lenda et al., 2013), and antimutagenic effects (Chekir-ghedira, 2011)	Flavonoids (quercetin, kaempferol, and rutin); terpenoids (limonene, α -pinene, and β -caryophyllene; saponins); and phenolic acids (chlorogenic, caffeic, and rosmarinic acids) (Gębarowska et al., 2026)

Scientific Name & family	Location (National Park)	Common name	Life form	Pharmacological activities	Therapeutic compounds
62. <i>Solidago graminifolia</i> (L.) Elliott . [Asteraceae]	5,8	Grass-leaved goldenrod	Herb	Antioxidant, antibacterial, and antifungal activities (Toiu et al., 2019)	Acetylenes (Lam et al., 1992) di-C-glycosylflavones (schafatoside, isoschafatoside) (Budzianowski, 1990), flavonoid glycosides (hyperoside, rutin, quercitrin), flavonoid aglycones (quercetin, luteolin, kaempferol), and phenolic acids (caftaric, gentisic, chlorogenic, p-coumaric, ferulic, gallic, protocatechuic, vanillic, syringic, rosmarinic acids) (Toiu et al., 2019)
63. <i>Spiraea tomentosa</i> L. [Rosaceae]	5	Hardhack	Shrub	Antibacterial and antioxidant activities (Fulcher, 2008)	**
64. <i>Telekia speciosa</i> (Schreb.) Baumg. [Asteraceae]	4,5,18	Heartleaf oxeye	Herb	Cytotoxic (Réthy et al., 2007), antiproliferative activity against human cancer cell lines (Spiridonov et al., 2005), antiinflammatory, anticancer and antibacterial effects (Čilović-Kozarević et al., 2021)	Eudesmane-type sesquiterpene lactones (Stojakowska et al., 2011), xanthanolides, terpenoid cyclopropanone derivatives, polyacetylene, thymol and nerol derivatives (Bohlmann et al., 1981), geraniol, α-humulene, cameroonan-7α-ol fukinone (Čilović et al., 2019) 6-O-(E)-caffeoyl-glucopyranose, and 3-O-caffeoylquinic acid (chlorogenic acid), violaxanthin, lutein 5,6-epoxide and antheraxanthin,, β-carotene 5,6-epoxide and β-carotene 5,6,5',6'-diepoxide (Varga et al., 2023)
65. <i>Veronica filiformis</i> Sm. [Plantaginaceae]	4,6,11	Slender speedwell	Herb	**	Anthocyanidin delphinidin, isoscutellarein 4'-methyl ether 7-O-β-(6'''-O-acetyl-2''-O-allosylglucoside) (Salehi et al., 2019)
66. <i>Veronica persica</i> Poir. [Plantaginaceae]	3, 4, 5, 6, 7, 10, 11, 14, 15, 17, 18, 21	Common field speedwell/ Persian speedwell	Herb	Antibacterial, scolicidal, and inhibitory potential on acetylcholinesterase, tyrosinase, lipoxigenase and xanthine oxidase (Sharifi-Rad, Tayeboon, et al., 2018), antioxidant (Sharifi-Rad, Sharifi-Rad, et al., 2018), antifungal, mitodepressive, and antiinflammatory effects (Fierascu et al., 2018)	Calendin, tyrosol, and two benzoic acid derivatives (Sarker et al., 2000), persicoside, acteoside, isoacteoside, and lavandulifolioside (Salehi et al., 2019), hexitol, dulcitol, aucubin, veronicoside, amphicoside, 6-O-veratroyl-catalpol, catalposide, verproside, and verminoside (Harput et al., 2002)
67. <i>Vicia grandiflora</i> Scop.[Fabaceae]	21	Large yellow vetch	Herb	**	Behenic acid (Cacan et al., 2016)
68. <i>Xanthium albinum</i> (Widder) H. Scholz [Asteraceae]	7, 20, 21	Riverside Cocklebur	Herb	**	**

Key: Sh=Shrub; H=Herb; L=Leaves, F=Flowers, Fr=Fruits, Se=Seeds, Tw=Twig, R=Roots, St=Stem, Tr=Tree;

1 = Białowieża NP, 2 = Biebrza NP, 3 = Kampinos NP, 4 = Tuchola NP, 5 = Wigry NP, 6 = Drawa NP, 7 = Narew NP, 8 = Roztocze NP, 9 = Ojców NP, 10 = Wielkopolska NP, 11 = Babia Góra NP, 12 = Bieszczady NP, 13 = Gorce NP, 14 = Karkonosze NP, 15 = Magura NP, 16 = Pieniny NP, 17 = Polesie NP, 18 = Słown NP, 19 = Stołowe Góry NP, 20 = Święty Krzyż NP, 21 = Tatra NP, 22 = Ujście Warty NP, and 23 = Wolin NP

**= Not documented

3.3 Invasive plants in Polish national parks

68 invasive plant species belonging to 29 families were recorded (Table 1). The family with the most species was Asteraceae (n = 14), followed by Poaceae, according to Fig. 3. Regarding life forms, the majority of the IPS were herbs (n = 51) according to Fig. 4.

3.4 Pharmacological activities of invasive plant species

Various pharmacological properties possessed by IPS were recorded (Fig. 5) and among these, antimicrobial activity had the highest frequency of mention (n = 70) in IPS followed by antioxidant, antiinflammatory, anticancer and antitumor activities.

Figure 6 shows the different antimicrobial activities in Polish alien plants. Antibacterial activity had the highest frequency of mention (n = 27) followed by antifungal activity.

3.5 Therapeutic compounds in Polish invasive plants

Different therapeutic compounds belonging to classes such as alkaloids, terpenoids, phenolic compounds and sulfur containing compounds, were documented in Polish invasive plants (Table 1). Kaempferol, rutin, and quercetin were common in many IPS (Fig. 7).

4. Discussion

4.1 Invasive plant families in Polish National Parks

The family with the most IPS was Asteraceae, followed by Poaceae. These findings are similar to the study of Weidlich et al., (2020) where Poaceae and Asteraceae were the most frequently controlled invasive plant families. The studies of Bomanowska et al., (2019) and Tokarska-Guzik et al., (2021) also reported the same observation of many Polish invasive plants belonging to the families: Asteraceae and Poaceae. These two plant families have been known to contribute most to the total number of alien species in local floras (Pyšek, 1998) and are also the most species-rich taxa (Gucwa-Przepióra et al., 2016). Majority of the IPS recorded in this review were herbs and this might be because herbaceous plants generally can coexist at high abundance, not only with each other but also with trees in the community (Deng et al., 2025). Other studies also report that herbs comprise the large majority of the alpha-diversity of the ecosystem (Spicer, 2020).

4.2 Pharmacological activities of Polish invasive plants

35 pharmacological activities possessed by Polish IPS were registered. These pharmacological activities may be due to the different therapeutic compounds (Fig. 7) such as rutin, kaempferol, quercetin, gallic acid, sitosterol, quercitrin, chlorogenic acid and apigenin recorded in Polish IPS. The presence of diverse pharmacological activities further offers a scientific basis for drug development and clinical applications, especially for invasive plants. Antibacterial activity had the highest frequency of mention, and this may provide a basis for combating antimicrobial resistance (AMR). AMR has skyrocketed due to the overuse of antibiotics and misuse against bacteria, thus creating serious hazards to global health (Amaral et al., 2022), which in the end threatens global health (Howard et al., 2026). There is an urgent need to develop new antibiotics that are effective against resistant bacteria (Al-dolaimy et al., 2024). Antioxidant and antiinflammatory activities were also registered in IPS, and these two can be utilised to develop diseases that arise due to reactive oxygen species and inflammation.

4.3 Therapeutic compounds in Polish invasive plants

Therapeutic compounds in IPS that contribute to antioxidant and antiinflammatory activities can be further investigated and utilised in natural product development. Chlorogenic acid (5-O-caffeoylquinic acid), a phenolic compound recorded in some Polish IPS such as *Amelanchier spicata* (Lam.) K.Koch, *Aronia x prunifolia* (Marshall) Rehder, *Clematis vitalba* L., *Lycium barbarum* L., *Quercus rubra* L., and *Reynoutria sachalinensis* (F. Schmidt) Nakai (Table 1), have demonstrated multiple biological properties, such as antioxidant, anti-inflammatory, antibacterial, antiviral, cardioprotective, hepatoprotective, neuroprotective, antihypertensive, anti-obesity, antidiabetic, antiapoptotic (Naveed et al., 2018).

Additionally, many in vivo studies and clinical trials have been done concerning the health benefits of chlorogenic acid as a nutraceutical agent for prevention and treatment of metabolic syndrome and associated diseases (Santana-Gálvez et al., 2017). Rutin, a flavonoid recorded in some Polish IPS such as *Acer negundo* L. and *Amaranthus retroflexus* L. has been known for its role in treating neurodegenerative diseases (Habtemariam, 2016), while hyperoside in IPS like *Amelanchier spicata* (Lam.) K.Koch has promising anticancer activity against different cancer types, such as lung, cervical, colon, and breast cancer, as well as anti-inflammatory, antibacterial, antiviral, antidepressant, and cardioprotective activity (Wang et al., 2022).

5. Limitations of the study

A myriad of biases may emerge while collecting ethnobotanical and ethnoveterinary data, and these always guide the reliability of research conclusions. For example, the reliance on limited studies, which are also localized, may fuel the collection of a narrow segment of traditional medicine knowledge (Tabuti et al., 2010). Another common bias is recall bias, where informants may talk about medicinal plants based on memory rather than thorough observation (Cunningham, 2001). This review did not include information on possible side or toxic effects that can arise from consuming invasive plants whether for human or animal use. The review did not also consider IPS in other protected areas of Poland, such as natural and planted forests, and wildlife reserves, yet they may also be under threat from IPS.

The 68 IPS documented are not the only invasive plants affecting Polish national parks, as there are many other invasive plants which though have not been documented and their information is thus inaccessible. Of the 68 IPS recorded, some of them lacked information on pharmacological activities and therapeutic compounds, thus affecting the reliability of the findings. For example, IPS like *Alopecurus myosuroides* Huds, *Anthoxanthum aristatum* Boiss.

Bromus carinatus Hook. & Arn., *Lemna turionifera* Landolt, and *Parthenocissus inserta* (A. Kern.) Fritsch had no information on their pharmacological activities and therapeutic compounds. Lastly, the review did not investigate the mechanism of action of the different pharmacological activities reported.

6. Conclusion and future direction

The present study documented the pharmacological activities and therapeutic compounds in invasive plants. The findings from this review study may guide the use of IPS in drug discovery and product development rather than destroying them. Although this review is geographically focused on Poland, its findings have significant relevance for the universal discourse on reconsidering the usage of IPS in complementary medicine or even in conventional medicine. For example, *Reynoutria japonica* Houtt, an invasive plant, has emerged as a promising invasive medicinal plant with diverse pharmacological activities, including potent antiinflammatory, antioxidant, antiviral, and neuroprotective effects, reportedly treating cerebral ischemia, inflammatory bowel disease, asthma, myocardial hypertrophy, and joint diseases (Ke et al., 2023). Therefore, utilising IPS rather than destroying them or developing expensive methods to control them will support sustainable development by converting biodiversity challenges into economically valuable resources, corresponding to the circular economy principles.

Abbreviations

AMR=antimicrobial resistance, IPS= Invasive plant species, NP= National park, PAs= Protected areas, PRISMA=Preferred Reporting Items for Systematic Reviews and Meta-Analyses, WHO= World Health Organisation

Declarations

Ethics and Consent to Participate: Not applicable

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CRedit authorship contribution statement: James Thomas Wanyama conceptualised the study, did the literature search, methodology, analysed the data, and drafted the manuscript. Barbara Tokarska-Guzik participated in conceptualising the study and editing the manuscript. All authors read and approved the final manuscript for submission.

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Figures

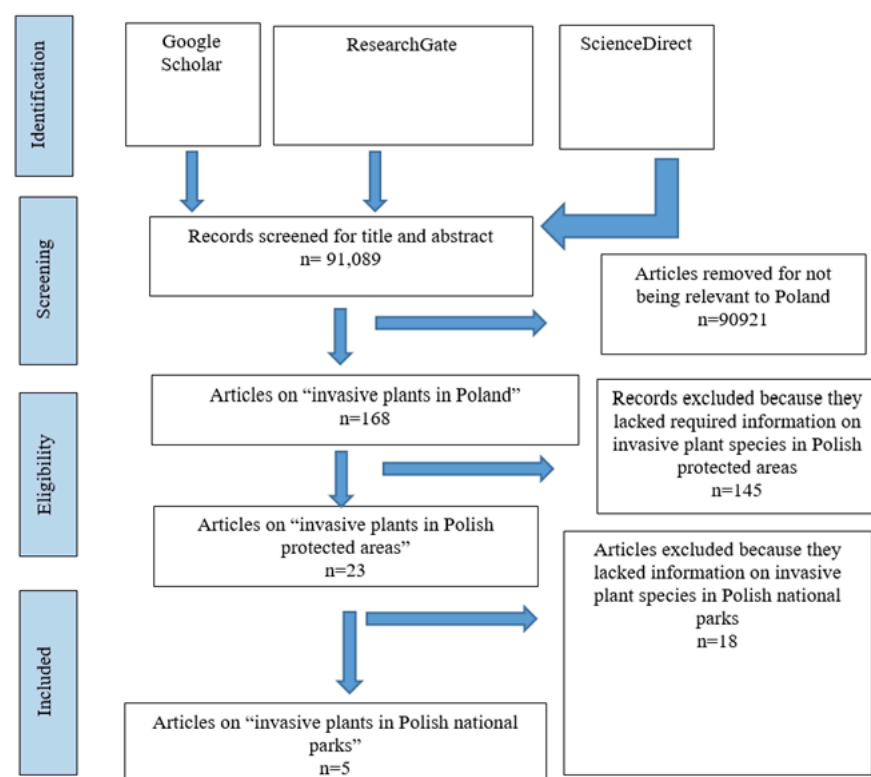


Figure 1

Flow diagram for selection of articles in the current study

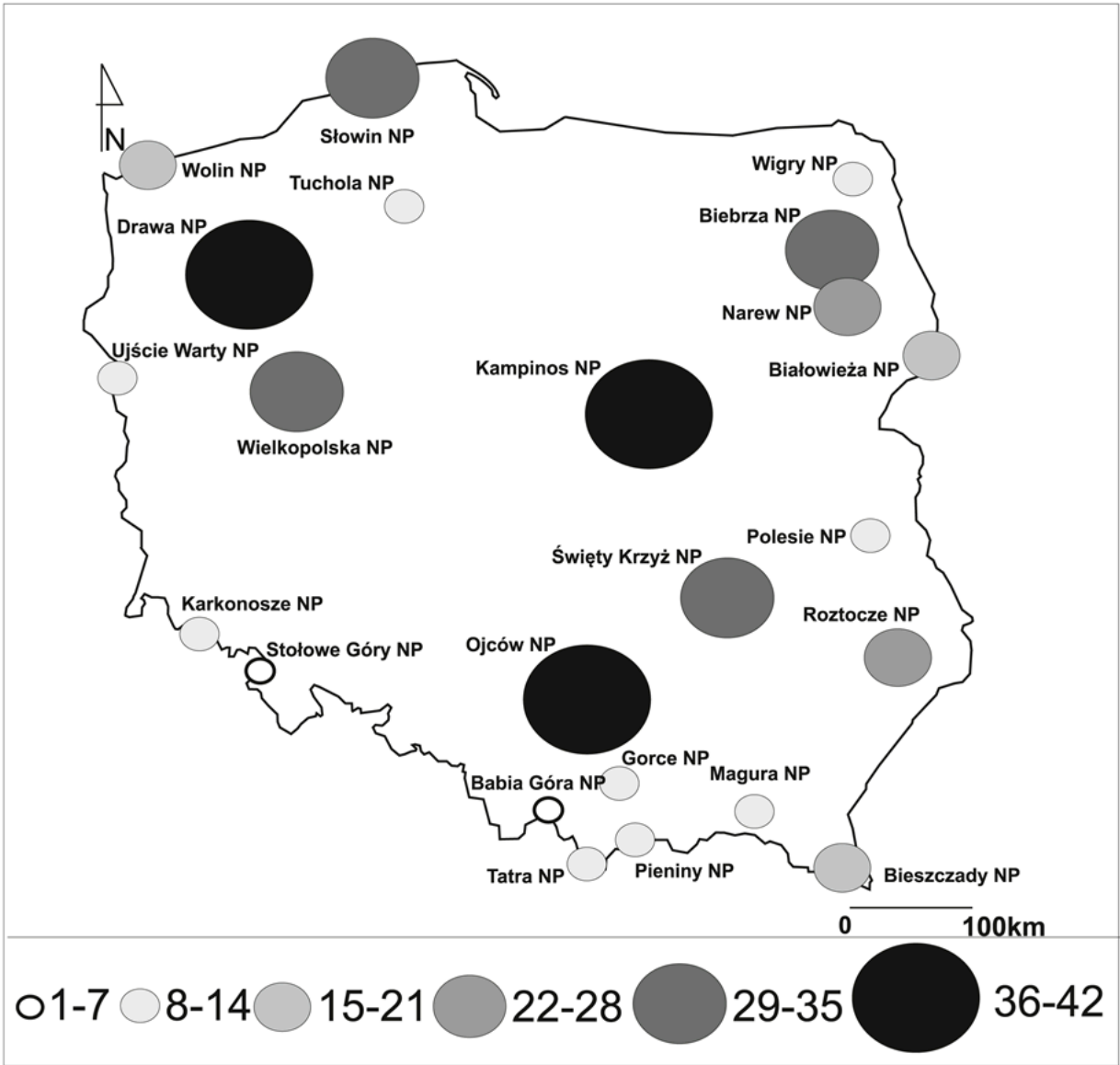


Figure 2

Map showing the location of the selected Polish national parks together with the number of invasive plants in NP (Image credits: <https://doi.org/10.7717/peerj.8034>)

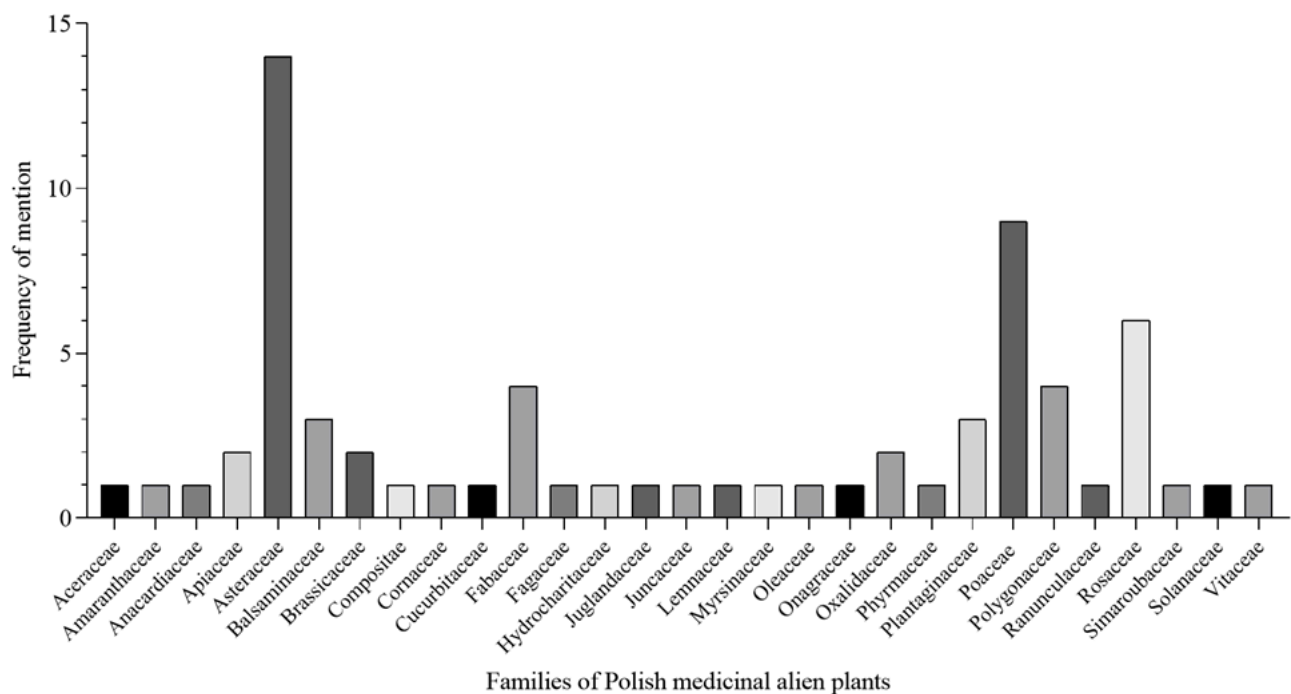


Figure 3

Families of invasive plant species against their frequency of mention

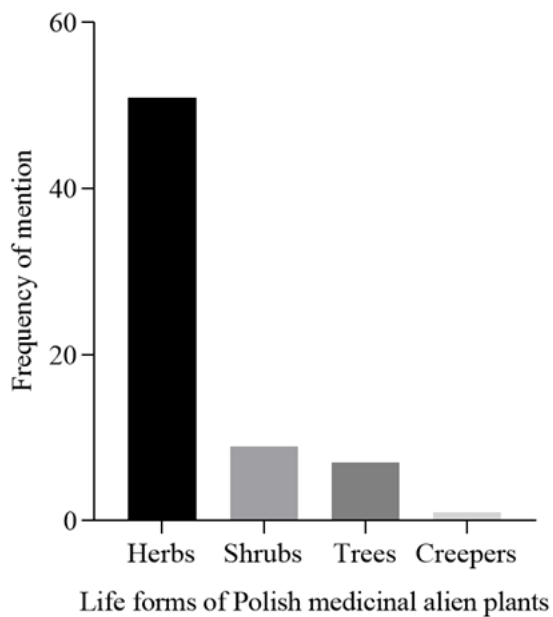


Figure 4

Life forms of Polish alien plants against their frequency of mention

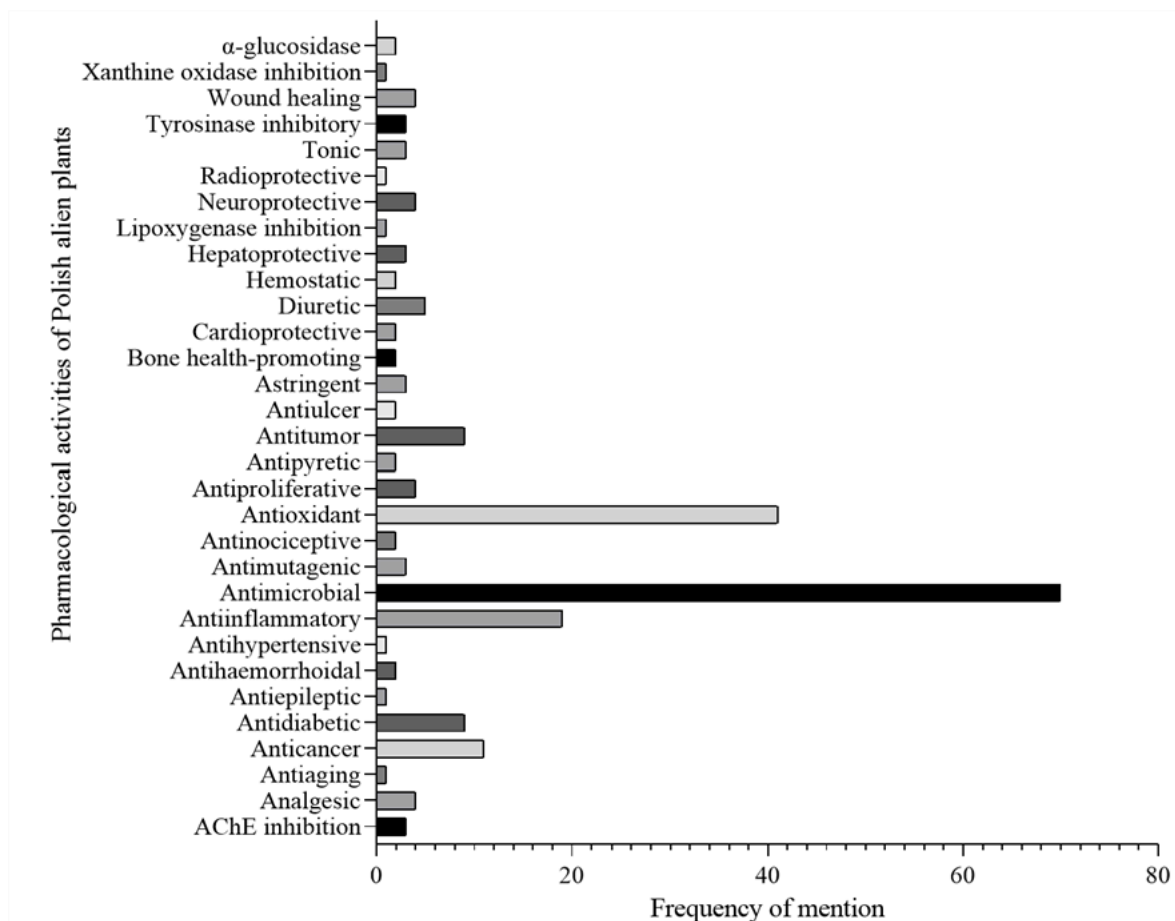


Figure 5

Pharmacological activities in Polish alien plants against their frequency of mention

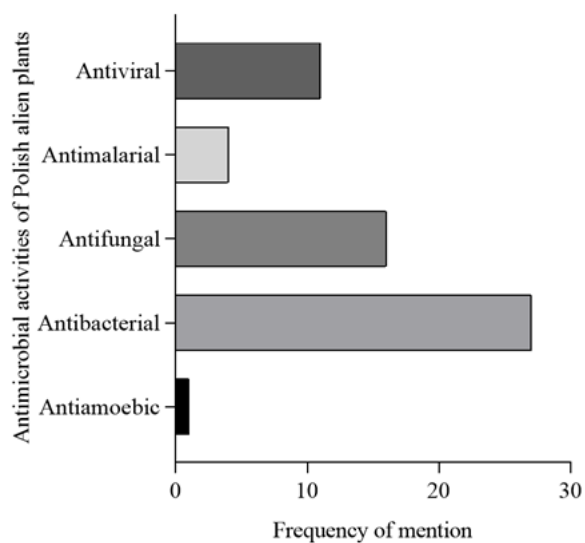


Figure 6

Antimicrobial activities in Polish alien plants against their frequency of mention

