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Review Article

Fallopia convolvulus (L.) Á. Löve: Review of traditional use, phytochemistry and pharmacology

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Abstract

Fallopia convolvulus (L.) Á. Löve, a widely distributed species of the Polygonaceae family, has long been valued in traditional medicine for its diverse therapeutic applications. This review investigates its phytochemical composition, traditional uses, and pharmacological potential, placing the plant in the broader context of natural product research. Bioactive compounds such as flavonoids, anthraquinones, steroids, and phenolic acids, which exhibit antioxidant, anti-inflammatory, antimicrobial, and anticancer activities, are compiled and analyzed. Modern techniques have identified novel compounds like falloconvolin A and B, as well as compounds with estrogenic and neuroprotective properties. To support this analysis, information was sourced from ethnobotanical, phytochemical, pharmacological, and clinical studies, utilizing databases like PubMed, Science Direct, and ResearchGate. This comprehensive analysis underscores the importance of further research to elucidate the mechanisms of action of its bioactive constituents and to explore its potential for pharmaceutical innovation. *Fallopia convolvulus* represents a promising, sustainable resource for developing novel therapeutic agents, bridging traditional medicine with modern science.

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Keywords

Fallopia convolvulus, Polygonaceae, phytochemicals, flavonoids, pharmacological activities, traditional medicine

Introduction

Plants are natural sources that efficiently produce a wide variety of phytoconstituents with high selectivity. Since the mid-19th century, numerous bioactive phytoconstituents have been isolated and identified. Many of these compounds are now used as active ingredients in modern medicines or serve as lead compounds for the development of new drugs (Uddin et al. 2011). These compounds are produced through the primary or secondary metabolism of living organisms. Secondary metabolites are chemically and taxonomically diverse compounds whose functions are not fully understood. They are extensively utilized in human medicine, veterinary care, agriculture, scientific research, and many other fields (Vasu et al. 2009). Plant products have been used in phytomedicines for centuries, sourced from barks, leaves, flowers, roots, fruits, and seeds. Understanding the chemical constituents of plants is important, as this knowledge can aid in the synthesis of complex chemical compounds (Wadankar et al. 2022). Given their importance in the context mentioned above, it is crucial to screen the chemical and pharmacological properties of plants to discover and develop new therapeutic agents with enhanced efficacy (Yadav et al. 2014).

Fallopia convolvulus (L.) Á. Löve, commonly referred to as black bindweed, is a species within the Polygonaceae family, which encompasses approximately twenty species. Most species of this genus are predominantly distributed in the northern temperate zone (Nimanthika 2014; Meng et al. 2021). *F. convolvulus* is a prevalent ruderal species in agroecosystems, including cultivated fields, gardens, and orchards. It can also be found in disturbed habitats such as wastelands, thickets, and along roadsides. Occasionally, it occurs along riverbanks and in pastures (Hume et al. 1983). *F. convolvulus* is indigenous to Eurasia and is widespread across Canada and the United States (Royer and Dickinson 1999). *F. convolvulus* has also been introduced to Africa, South America, Australia, New Zealand, and Oceania. It has been recorded in all three ecogeographic regions of Alaska (Klein 2011). *F. convolvulus* is an annual, climbing herb with slender, deep roots. The stems are delicate and can reach up to 91 cm in length, with long internodes. They exhibit free branching from the base and may sometimes display a reddish hue. The stems either trail along the ground or twine around neighboring plants. The leaves are alternate, ranging from 2.5 to 4 cm in length, and are elongate-ovate or sagittate in shape, with long petioles and basal lobes pointing backward. The leaves emerge from papery sheaths that encase the stems. The flowers are small, inconspicuous, measuring up to 6 mm in length, and are arranged in short axillary clusters of two to six. The fruits are triangular achenes, characterized by obtuse bases and pointed apices (Flora of North America Editorial Committee 1993; Royer and Dickinson 1999).

Species of *Fallopia* are native to Asia, but they are now widespread across various regions globally. In Europe, these taxa were introduced in the 19th century for ornamental purposes (Kallenberger et al. 2016). Species within the Polygonaceae family have been recognized as medicinal plants in Asia since ancient times. For instance, members of the genus *Calligonum* L. have been utilized for treating infections, invasions, and immune system disorders. The primary region of origin and distribution for many *Calligonum* species is the Iran-Turan area. Out of the 80 species in the genus, 30 are found in Kazakhstan. The roots of the species from *Acanthophyllum* Mey (Caryophyllaceae) have been traditionally used in Central Asian medicine for wound healing and as expectorants. The plant's constituents exhibit sedative, antisclerotic, and antimicrobial properties. This genus is native to southwestern Asia, particularly in areas bordering Iran and Afghanistan. Of the 50 species identified in Western Asia and the Iran-Turan region, 10 occur in Kazakhstan. *Rheum wittrockii* Lunstr was historically used by Kazakhs to treat gastroenteric and dermatological conditions, while *Rheum altaicum* Losinsk was employed as an anti-inflammatory and for treating skin diseases (Ryabushkina et al. 2008).

Chemotaxonomic studies of the *Fallopia* genus have shown that all species possess flavonoids with a largely uniform profile, with quercetin glycosides being the primary components (Kim et al. 2000a; Kim et al. 2000b). The flavonoid composition of *F. convolvulus* includes glycosides of quercetin, kaempferol, myricetin, apigenin, luteolin, rhamnetin, and isorhamnetin (Kim et al. 2000a; Smolarz 2002). Additionally, three distinctive flavonoid structures have been identified in this species: falloconvolin A and B, and quercetin-3-O-(2-E-esinapoxyl)-glucopyranoside (Zhang et al. 2011). Among the primary phytochemicals, tannins, phenolic acids, flavonoids, stilbenes (e.g., resveratrol), and anthraquinones (e.g., emodin) stand out for their diverse physiological and therapeutic effects. Numerous species within this genus are utilized as herbal remedies in traditional Chinese medicine, such as *Fallopia multiflora* (Thunb.) Harald. and *Fallopia denticulata* (Huang) A. J. Li, for treating conditions like inflammation, insomnia, infection, arthritis, and diarrhea (Meng et al. 2021). Knotweed has historically been employed in Asia for the treatment of skin burns, gallstones, hepatitis, inflammation, and osteomyelitis (Shen et al. 2011). In traditional Chinese and Japanese medicine, the rhizomes of certain species are used to treat hepatitis, hypertension, skin injuries, and bleeding. Recent studies have investigated the antibacterial, antifungal, antioxidant, anti-inflammatory, and neuroprotective properties of these plants.

Preliminary pharmacological data also suggest potential benefits in managing high cholesterol and certain types of cancer. Some species exhibit metal-binding properties and allelopathic effects, while others are being explored for agricultural applications, such as fodder production. The potential use of *Fallopia* species as energy plants is supported by their high calorific value. These findings underscore the need for further ecological, phytochemical, and pharmacological research to explore the broad potential applications of these plants (Kallenberger et al. 2016).

Materials and methods

Data from ethnobotanical, phytochemical, pharmacological, and clinical sources were gathered from various online journals, books, and magazines published between 1970 and 2024. Electronic databases such as Google Scholar, PubMed, Science Direct, ResearchGate, and other digital repositories were utilized for this research. Keywords such as *Fallopia convolvulus*, Polygonaceae, *Fallopia convolvulus* pharmacological activities, phytochemistry and related species were employed in these databases to explore their pharmacological and ethnomedicinal applications, which are discussed in this manuscript.

Taxonomic classification of *F. convolvulus* within the Polygonaceae family

The Polygonaceae is a family of angiosperms commonly known in the United States as the knotweed or smartweed-buckwheat family. The designation is derived from the genus *Polygonum* and was first introduced by Antoine Laurent de Jussieu in 1789 in his work *Genera Plantarum*. The name is attributed to the numerous swollen nodes found on the stems of certain species. It originates from Greek, where «poly» means «many» and «goni» refers to «knee» or «joint» (Jussieu 1789).

The Polygonaceae family comprises around 50 genera and approximately 1200 species (David 2008). These species can be annual herbs, perennial herbs, shrubs, trees, or lianas. The leaves, which arise from often swollen nodes, are typically alternate, though they can sometimes be opposite or whorled, simple, and petiolate or sessile, with generally entire margins. The stipules are almost always well-developed, fused within a tubular sheath that can be persistent or deciduous, hyaline to membranous, bilobed, or fringed at the apex, referred to as the ocrea. The ocrea is a unique feature of the Polygonaceae family, though it may be reduced or absent in the subfamily Eriogonoideae. Extrafloral nectary pits are located at the base of the petioles and in the nodal areas of genera such as *Fallopia* (including *Reynoutria*) and *Muehlenbeckia*. The inflorescences are axillary or terminal, consisting of simple or branched thyrsi, panicle-like, racemose, or spike-like structures that form dichasia or helicoid cymes. Each partial inflorescence is subtended by bracts, and each flower or cluster of flowers is accompanied by a persistent membranous ocreola, which corresponds to the fusion of the bracteoles. The flowers are small, trimerous, and hermaphroditic or unisexual (with dioecy being common). The tepals number 2–6, are often persistent, and may enlarge in fruit, fused at the base within a somewhat developed hypanthium, forming two whorls of three elements or one whorl of five elements. In the latter case, the tepal arises from the fusion of one segment of the outer whorl with one from the inner whorl, resulting in characteristic quincuncial aestivation. The stamens are typically equal in number to, or double or triple the number of tepals, ranging from 2 to 9, rarely more, and may be free or basally connate, alternating with the tepals. Pollen is typically tricolporate or pantoporate. Nectaries are often present, located between the bases of the filaments or fused into an annular disc at the base of the ovary. The ovary is superior, generally 2-4-carpellate (most often 3-carpellate), unilocular; styles are 1-3, free or proximally connate, with filiform, peltate, or capitate stigmas, which may be entire or fringed. The ovules are unique. The fruit is an achene, often trigonous or lenticular, typically subtended by an enlarging perianth, and more specifically classified as a diclesium (Spjut 1994). Some species such as *Fagopyrum* (buckwheat) and *Coccoloba* (sea grape) produce edible fruit; the petioles of *Rheum* (rhubarb) are edible, as are the leaves of certain *Rumex* species (sorrel). The rhizomes of *Rheum* are also valued for their medicinal properties. Additionally, some genera contain ornamental species and common weeds.

The Polygonaceae family is notably diverse in temperate regions of North America, Europe, and Southeast Asia, while having fewer representatives in South America, the Caribbean, Africa, and Australasia. Tropical species within the family are often woody shrubs, trees, or lianas. Several members of the Polygonaceae are recognized as problematic weeds, including Japanese knotweed (*Reynoutria japonica*), spiny three-corner jack (*Emex spinosa* L.), dock (*Rumex* L.), mile-a-minute (*Persicaria perfoliata* L.), and corallita (*Antigonon leptopus*). There are also crop species of minor economic significance, such as rhubarb (*Rheum rhabarbarum* L.) and buckwheat (*Fagopyrum esculentum*) (Ortiz 1994). The largest genera include *Eriogonum* (240 species), *Rumex* (200 species), *Coccoloba* (120 species), *Persicaria* (100 species), and *Calligonum* (80 species) (Freeman and Reveal 2005; Sanchez and Kron 2008).

The classification of the Polygonaceae has primarily relied on macromorphological features, such as the presence or absence of an ocrea, woodiness, and the arrangement of tepals. However, the classification system has been widely debated, leading to numerous proposed taxonomic schemes (Decraene and Akeroyd 1988). Numerous studies utilizing molecular data have confirmed that the Polygonaceae family is monophyletic. However, only recently have molecular studies begun to explore the large-scale phylogenetic relationships within the family (Lledó et al. 1998; Cuénoud et al. 2002; Chase et al. 2002). The Polygonaceae

is currently divided into three subfamilies: Eriogonoideae Arn., Polygonoideae Eaton, and Symmerioideae Meisn. (Haraldson 1978; Brandbyge 1993). The subfamilies Eriogonoideae and Polygonoideae do not align with many of the traditional classifications and were newly defined by Sanchez and Kron in 2008. Some surprising results emerged in the circumscription of these subfamilies when compared to traditional treatments based on morphological data. For example, genera within Coccolobeae, such as *Fallopia*, *Harpagocarpus*, *Muehlenbeckia*, and *Reynoutria*, were found to belong to Polygoneae (Sanchez and Kron 2008; Sanchez and Kron 2009).

The phylogenetic relationship between *Fallopia* and *Reynoutria* has been a subject of ongoing debate, with some researchers suggesting that these two genera are so closely related that they should be considered synonymous. Authors such as Ronse De Craene and Akeroyd (1988), Bailey and Stace (1992), and Yonekura and Ohashi (1997) included *Reynoutria* within *Fallopia*. In contrast, other scholars, including Nakai (1926), Holub (1970), Haraldson (1978), Tzvelev (1987, 1989), and Brandbyge (1993), argued that the genera should remain distinct (Schuster et al. 2011). *Muehlenbeckia* has long been considered closely related to *Fallopia* and *Reynoutria*, yet its status as a separate genus was never questioned. Molecular studies have revealed that *Fallopia* is more closely related to *Muehlenbeckia* than to *Reynoutria*, suggesting that the latter should be treated as a distinct genus (Sanchez and Kron 2009; Schuster et al. 2011; Sanchez et al. 2011).

Fallopia Adans. is a relatively small but highly variable genus with approximately 16 species (Kim et al. 2000a). The knotweed complex includes *Black bindweed* (*Fallopia convolvulus* (L.) Á. Löve), *Japanese knotweed* (*Fallopia japonica* (Houtt.)), a dwarf variant of *Japanese knotweed* (*Fallopia japonica* var. *compacta* (Hook.f.)), *giant knotweed* (*Fallopia sachalinensis* (F. Schmidt) Ronse Decr.), and their hybrid, *Bohemian knotweed* (*Fallopia* × *bohemica* (Chrtek and Chrtková)), among others (Drazan et al. 2021). In Fig. 1 provided a taxonomic classification of *Fallopia* species.

A taxonomic investigation aims to classify, identify, and determine the systematic placement of plant species. It involves the examination of morphological, molecular, and genetic traits to elucidate their phylogenetic relationships within the family. This analysis enhances the understanding of the specie's evolutionary lineage and its ecological adaptations.

The integration of various data sources, including macro- and micromorphological features, pollen morphology, and molecular markers, allows for the construction of a detailed phenotypic profile for multiple species within the Polygonaceae family. Evaluating these characteristics offers essential insights into the phylogenetic and phenetic connections among family members, elucidating the extent of their relatedness. Such comprehensive data are vital for precise species identification and resolving ambiguities due to phenotypic or ecotypic variation (Kosal 2023).

Traditional use

The genus *Fallopia* is renowned in traditional medicine, with extracts commonly used to treat conditions such as hepatitis, hepatic damage, inflammation, and post-menopausal disorders (Zhang et al. 2006a; Zhang et al. 2007; Chen et al. 2011; Liao et al. 2011) (Table 1). Bioactive compounds isolated from the rhizomes of *Fallopia* species have shown vasorelaxant, antioxidant, antibacterial, anti-inflammatory, and anti-tumor activities, contributing to the widespread use of *Fallopia* in traditional Chinese medicine. Several polyphenolic compounds with phytoestrogenic activity have been identified in the roots and rhizomes of various *Fallopia* species, including *F. multiflorum* and *F. japonica* (Frémont 2000; Matsuda et al. 2001; Zhang et al. 2005; Li-Shuang et al. 2006; Zhang et al. 2006b; Avula et al. 2007; Noda et al. 2009; Shen et al. 2011; Liao et al. 2011). Many of these phytoestrogens preferentially activate estrogen receptor beta (ERβ) over estrogen receptor alpha (ERα), and diets rich in phytoestrogens have been associated with a reduced incidence of hormone-related cancers, such as breast and prostate cancers (Adlercreutz 2002; Harris et al. 2005). ERβ activation has been shown to exert an antiproliferative effect in breast cells, providing a protective balance against ERα activation, which is linked to cellular proliferation (Sotoca Covaleda et al. 2008; Sotoca et al. 2008; Williams et al. 2008).

Recent research further supports *F. convolvulus*'s medicinal value, uncovering a broader range of pharmacological activities, including anti-fungal and neuroprotective effects.

Phytochemicals are isolated from *F. convolvulus*

Phytochemicals are bioactive compounds derived from plants that offer health and therapeutic benefits, including the prevention and treatment of various diseases. Naturally occurring in foods, these substances work synergistically, enhancing their potential to combat infections (Khaliq et al. 2023).

Scientists globally have investigated *F. convolvulus*, isolated numerous phytochemicals and conducted biological assays to evaluate their effects. A summary of the compounds isolated from *F. convolvulus* to date is presented in Table 2.

Although *F. convolvulus* has a long history of medicinal use, its chemical constituents began to be studied relatively recently. However, research into the isolation of bioactive molecules continues, with new compounds being discovered each year. For instance, in China, researchers isolated twenty compounds from an 85% ethanol extract of *F. convolvulus* roots. These included three sterols, three phenols, four anthraquinones, one chromone, two stilbenes, three amides, three flavonoids, and one organic acid. Modern phytochemical isolation techniques were employed, and the structures of these compounds were determined using

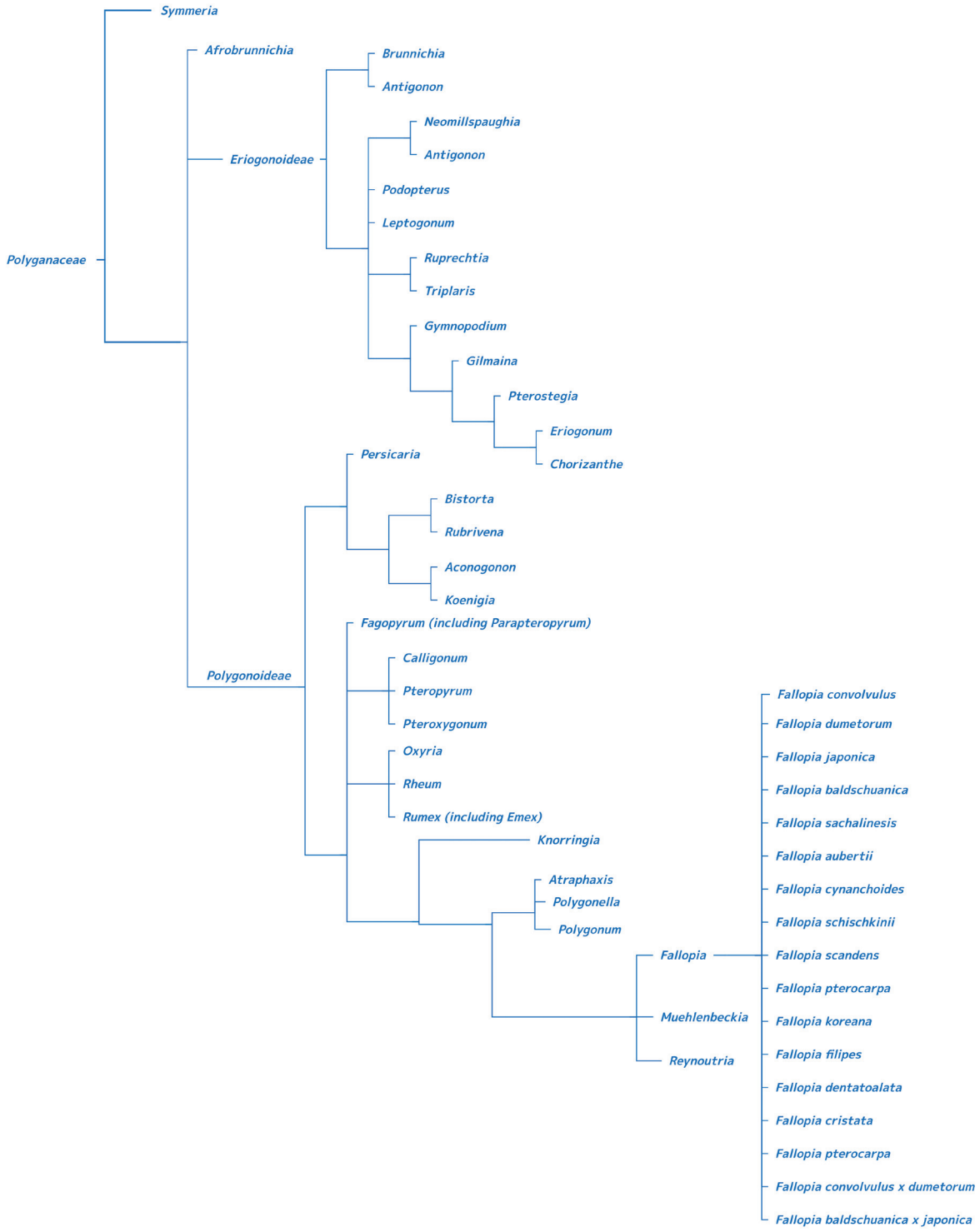


Figure 1. The phylogenetic tree of *Fallopia* species from the Polygonaceae family derived from a literature review.

spectroscopic methods and compared with existing data in the literature (Li et al. 2019). Additionally, a team of scientists isolated twenty-one flavonoid compounds from the leaves of *F. convolvulus*, identifying them as glycosylated derivatives of the flavonols kaempferol, quercetin, and myricetin, and the flavones apigenin and luteolin. Among these, quercetin 3-O-galactoside and quercetin 3-O-glucoside were found to be the major flavonoid constituents (Kim et al. 2000a). Flavonoids are known for their anti-inflammatory, antiviral, antitumor, and antibacterial activities (Agrawal 2011). Furthermore, twelve compounds were isolated from the herbs of *F. convolvulus* using Sephadex LH-20 column chromatography. These compounds, identified through physicochemical properties and spectroscopic evidence, included quercetin, luteolin, chrysoeriol, apigenin, kaempferol-3-O-beta-D-glucoside, quercetin-3-O-rhamnoside, N-trans-coumaroyl tyramine, loliolide, ethylparaben, beta-sitosterol, daucosterol, and n-hexadecanoic acid.

Table 1. Medicinal properties of *F. convolvulus*.

Plant	Medicinal properties	Activity mechanism	References
F. convolvulus	anti-tumor	Inhibition of cell growth, inhibition of protein kinase activities, induction of apoptosis, inhibition of metalloproteinases secretion, inhibition of tumor cell invasion, inhibition of adhesion/spreading of cells	Kanadaswami et al. 2005
	anti-inflammatory	suppression of proinflammatory gene expression, inhibition of proinflammatory cytokine production and chemotactic agents	Alshalmani 2011
	antibacterial	disruption of cell membranes, inhibition of nucleic acid synthesis, suppression of key bacterial enzymes, efflux pump inhibition, prevention of biofilm formation	Rodríguez et al. 2023
	antioxidant	neutralization of free radicals via redox reactions, direct scavenging of free radicals, metal ion chelation, inhibition of oxidases, activation of antioxidant enzymes	Sanjay and Shukla 2021
	vasorelaxant	stimulation of O_2^- production in endothelial cells and scavenging of O_2^- in interstitial fluid, reduction of cytosolic Ca^{2+} in smooth muscle cells	Alshalmani 2011

Table 2. Biologically active compounds are found in *F. convolvulus*.

Chemical class	Chemical compounds	Part of the plant	Country	References
Flavonoids (flavonol aglycones)	kaempferol	leaf	South Korea	Kim et al. 2000a
	quercetin			
	myricetin			
Flavonoids (flavone aglycones)	apigenin	leaf	South Korea	Kim et al. 2000a
	luteolin			
	chrysoeriol	herbs	China	Chen et al. 2010
Flavonoids (flavonol glycosides)	quercetin 3-O-galactoside	leaf	South Korea	Kim et al. 2000a
	quercetin 3-O-glucoside			
	quercetin 3-O-rhamnoside	herbs	China	Chen et al. 2010
	kaempferol 3-O-beta-D-glucoside	herbs	China	Chen et al. 2010
Flavonoids (flavan-3-ol)	2,3-*cis*-(2R, 3R)-(−)-epiafzelechin-3-*O*-p-coumarate (rhodoeosein)	seed	USA	Brennan et al. 2013
Alkaloid (amide)	N-trans-coumaroyl tyramine	herbs	China	Chen et al. 2010
Lactones (monoterpene lactones)	loliolide	herbs	China	Chen et al. 2010
Parabens	ethylparaben	herbs	China	Chen et al. 2010
Steroids	beta-sitosterol	herbs	China	Chen et al. 2010
	daucosterol			
Fatty acids	n-hexadecanoic acid	herbs	China	Chen et al. 2010
Polyphenols (anthraquinones)	emodin	seed	USA	Brennan et al. 2013

Notably, quercetin-3-O-rhamnoside, N-trans-coumaroyl tyramine, loliolide, and ethylparaben were isolated from the *Fallopia* genus for the first time (Chen et al. 2010). The structures of biologically active compounds isolated from *F. convolvulus* are presented in Fig. 2.

The researchers identified three novel flavonoids: falloconvolin A, falloconvolin B, and quercetin-3-O-(2-E-sinapoxyl)-glucopyranoside, together with 17 known phenolic compounds, which were isolated from the active ethyl acetate (EtOAC) extract. Their structures were determined using spectroscopic methods and based on literature data (Zhang et al. 2011). There is limited information available in databases regarding their structures and pharmacological properties. Phenolic compounds are a diverse group of chemicals characterized by the presence of a phenol ring. These compounds exhibit a range of biological activities, although the precise mechanisms underlying their disease-preventive effects remain unclear. Their primary pharmacological property is antioxidant activity, although numerous studies have also reported their anti-inflammatory, anti-aging, antiproliferative, and antioxidant effects. Antioxidant enzymes play a key role in mitigating oxidative damage (Rahman et al. 2021). In addition, the research team isolated emodin and a novel flavan-3-ol, (-)-epiafzelechin-3-O-p-coumarate (rhodoeosein), from the roots of *F. convolvulus*. The absolute stereochemistry of rhodoeosein was determined using 1D and 2D Nuclear Magnetic Resonance (NMR), optical rotation, and circular dichroism. Emodin was identified through High-performance liquid chromatography with diode array detection (HPLC/DAD), Liquid chromatography with tandem mass spectrometry (LC/MS/MS), and Fourier transform ion cyclotron resonance mass spectrometry (FT/ICR-MS) (Brennan et al. 2013).

Phytochemical analysis of *F. convolvulus* identified the presence of steroids, anthraquinones, flavonoids, chromones, and amides. As a result, the plant's composition showcases a wide range of pharmacological properties, emphasizing its considerable potential in natural medicine. These compounds, commonly linked to antioxidant,

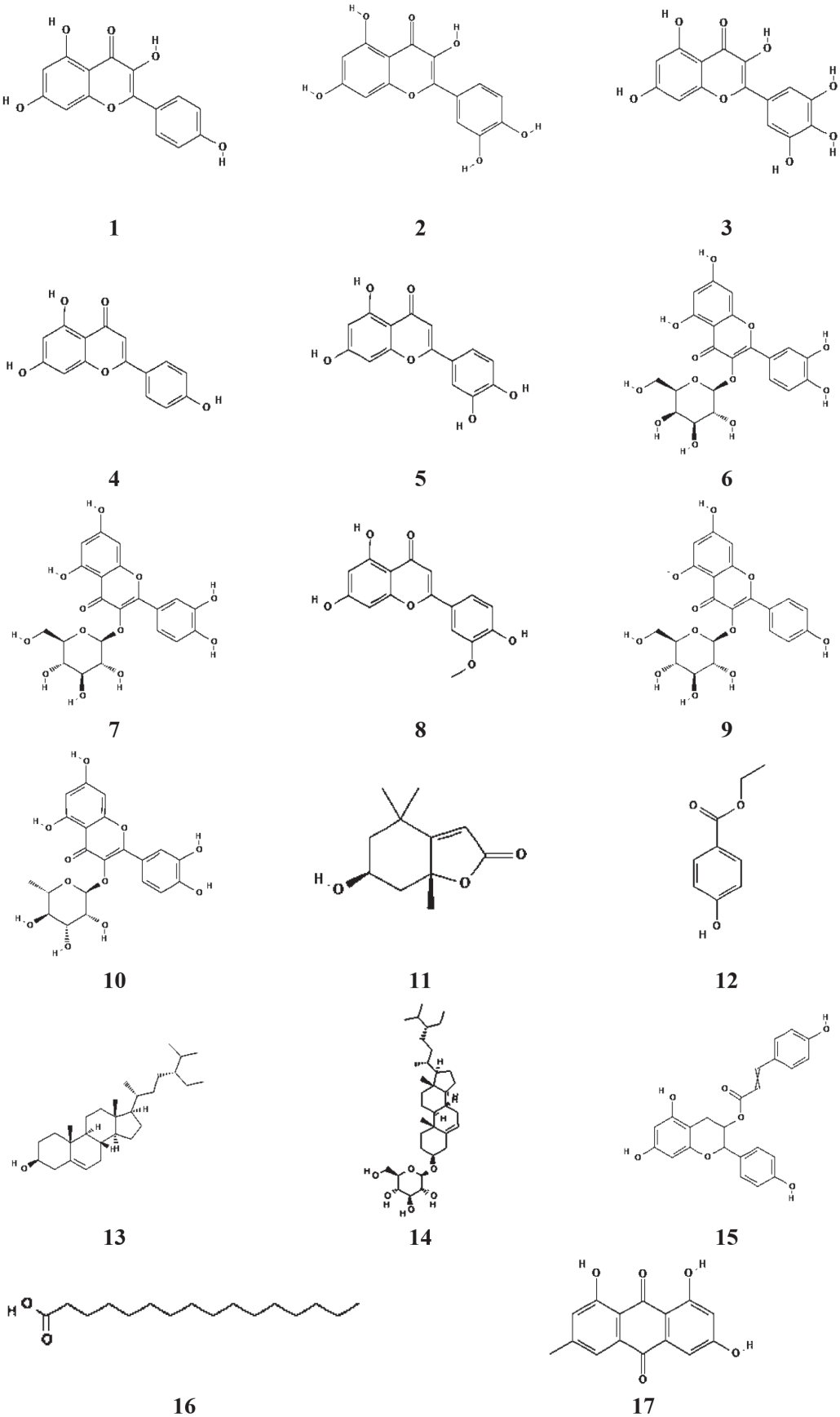


Figure 2. The structures of biologically active compounds isolated from *F. convolvulus*: **1.** Kaempferol; **2.** Quercetin; **3.** Myricetin; **4.** Apigenin; **5.** Luteolin; **6.** Quercetin 3-O-galactoside; **7.** Quercetin 3-O-glucoside; **8.** Chrysoeriol; **9.** Kaempferol-3-O-beta-D-glucoside; **10.** Quercetin-3-O-rhamnoside; **11.** Loliolide; **12.** Ethylparaben; **13.** Beta-sitosterol; **14.** Daucosterol; **15.** 2,3-*cis*-(2R,3R)-(−)-epiafzelechin-3-*O*-p-coumarate (rhodoeosein); **16.** n-hexadecanoic acid; **17.** Emodin.

anti-inflammatory, and anticancer effects, offer promising opportunities for pharmaceutical research and the creation of new therapeutic agents. The ongoing discovery of novel compounds further broadens the therapeutic applications of *Fallopia*, underscoring its potential integration into contemporary pharmaceutical practices.

Pharmacology activities of *F. convolvulus*

The exploration of numerous plant species for their phytochemical content and pharmacological properties remains limited, presenting a crucial gap in current research. Future studies on the bioactive compounds in *F. convolvulus* are necessary to gain a deeper understanding of their molecular actions both *in vivo* and *in vitro* and to ensure their safety for human consumption.

Consequently, the accumulation of data regarding the pharmacological properties of *F. convolvulus* is expanding continuously. For instance, recent studies have elucidated two novel pharmacological activities of *F. convolvulus*. Table 3 summarizes several pharmacological properties associated with the bioactive compounds identified in this plant.

Anticancer activity

Cancer is a term used to describe a diverse group of diseases characterized by the uncontrolled and abnormal proliferation of cells, which can invade and damage normal body tissues. These cells often possess the ability to metastasize, spreading throughout the body. Cancer is the second leading cause of death globally, highlighting the urgent need for effective therapeutic interventions. *F. convolvulus* and *F. dumetorum* comprised stems, leaves, flowers, and fruits, whereas *F. aubertii* included flowers (AF), as well as stems and leaves (AH). These plant components were subjected to extraction using three solvents: ethanol (EtOH), 50% ethanol (EtOH 50%), and water (H_2O) under reflux conditions. The resulting extracts were concentrated using a rotary evaporator (RVO 004; Ingos, Prague, Czech Republic) and lyophilized at -55 °C (CoolSafe ScanVac 55; LaboGene, Lynge, Denmark). For cell culture experiments, the extracts (AF_{ha}, AF_e, AF_w, and AH_{ha}) were reconstituted in dimethyl sulfoxide (DMSO) at a final concentration of 100 mg/ml and stored at -20 °C. Serial dilutions were made to achieve concentrations of 3, 30, 100, and 300 μg/ml. The highest cytotoxicity to cancer cells was observed in extracts derived from *F. convolvulus*, indicating its potential for further therapeutic investigation (Olaru et al. 2015).

Antifungal activity

The fungus *Xylaria* sp. Z184, isolated for the first time from the leaves of *F. convolvulus*, led to the discovery of several novel compounds. These include three new pyranone derivatives, named fallopiaxylaresters A–C, a new bisabolane-type sesquiterpenoid called fallopiaxylarol A, and the

Table 3. Pharmacological activities of bioactive compounds identified in *F. convolvulus*.

№	Chemical compounds	Pharmacological activities	References
1	kaempferol	anti-carcinogenic, antibacterial, antifungal, antiprotozoal	Periferakis et al. 2022
2	quercetin	antioxidant, anti-inflammatory, anti-tumor	Haghi et al. 2017
3	myricetin	hepatoprotective, antitumour, anti- inflammatory, analgesic, and antidiabetic	Imran et al. 2021
4	apigenin	anti-inflammatory, anti-tumor, anti-oxidation, neuroprotection, antibacterial	Li et al. 2023
5	luteolin	antioxidant, antidiabetic	Kozlovskaya et al. 2022
6	quercetin 3-O-galactoside	antioxidant, hepatoproective, antimicrobial, anti-ostoporotic	Karadeniz et al. 2023
7	quercetin 3-O-glucoside	antihistamine, anti-inflammatory, anticarcinogenic	Razavi et al. 2009
8	chrysoeriol	anticancer, anti-hyperlipidemic, antioxidant	Aboulaghras et al. 2022
9	kaempferol-3-O-beta-D-glucoside	antioxidant, anticancer, anticoagulant	Demydiak et al. 2023
10	quercetin-3-O-rhamnoside	antioxidant, anti-inflammatory	Cui et al. 2022
11	N-trans-coumaroyl tyramine	anti-diabetic	Qais et al. 2018
12	loliolide	anti-viral, anti-inflammatory	Park et al. 2018
13	ethylparaben	estrogenic, antiandrogenic	Gao et al. 2020
14	beta-sitosterol	antimicrobial, anticancer, antioxidant	Ambavade et al. 2014
15	daucosterol	anticancer, anti-hyperlipidemic, antioxidant	El Omari et al. 2022
16	n-hexadecanoic acid	antioxidant, antibacterial	Purushothaman et al. 2024
17	falloconvolin A	–	–
18	falloconvolin B	–	–
19	quercetin-3-*O*-(2-*E*-sinapoxyl)-glucopyranoside	–	–
20	2,3-*cis*-(2R,3R)-(−)-epiafzelechin-3-*O*-p-coumarate (rhodoeosein)	estrogen activity	Brennan et al. 2013
21	emodin	antiviral, anti-ulcerogenic, anticancer	Hsu and Chung 2012

first complete set of spectroscopic data for the previously identified pestalotiopyrone M. Additionally, a range of known compounds were isolated, consisting of six pyranone derivatives, three sesquiterpenoids, three isocoumarin derivatives, and one aromatic allenic ether. The biological activities of these compounds were investigated, with a focus on their anti-inflammatory, antimicrobial, and α-glucosidase-inhibitory effects. *In vitro* bioassays revealed that compounds 5, 7, and 8 exhibited weak growth inhibition against *Staphylococcus aureus* ssp. *aureus*, while the crude fungal extract demonstrated a potent ability to inhibit nitric oxide (NO) production in LPS-stimulated RAW 264.7 mouse macrophages, with an inhibition rate of 77.28 ± 0.82% at 50 μg/mL. However, none of the isolated compounds displayed similar inhibitory effects on no production, suggesting that other structural types of compounds in the extract may be responsible for the observed anti-inflammatory activity. This study not only identifies four novel compounds but also expands the understanding of the structural diversity within the Xylaria metabolomes (Zhang et al. 2024).

Estrogenic activity

The estrogenic properties of seeds from *Fallopia* species have not been previously investigated, precluding direct comparisons with seeds of other *Fallopia* species. However, extracts of seeds from *F. convolvulus* and *F. dumetorum* were analyzed for estrogenic activity using the human ovarian carcinoma cell line BG1Luc4E2. Following the initial screening, the *F. convolvulus* seed extract was subjected to crude fractionation by normal-phase chromatography, and the resulting fractions (equivalent to 8 mg of seeds per mL) were evaluated for estrogenic activity in the BG1Luc4E2 cell line. The estrogenic compounds within the seeds were hypothesized to exhibit both polar and nonpolar characteristics, as active fractions were eluted with solvents ranging from 20% ethyl acetate in *n*-hexane to 5% ethanol in ethyl acetate. Estrogenic potency of the crude fractions was quantified relative to an E2-dependent luciferase induction standard curve (data not shown), following the protocol described by Natarajan et al. (Natarajan et al. 2002). Crude fractions 3, 4, and 6 of *F. convolvulus* exhibited estrogenic potencies of 0.21, 2.4, and 0.76 nM E2 equivalents per gram of seed, corresponding to 4 ± 0.6%, 39 ± 1%, and 16 ± 1% of maximal E2 activity, respectively.

The estrogenic activity of rhodoeosein was assessed in two human cell lines, where its cell-type-specific effects were demonstrated. To the best of our knowledge, rhodoeosein is the first reported flavan-3-ol to exhibit estrogenic properties *in vitro*. In addition to rhodoeosein, *F. convolvulus* seeds were found to contain emodin, a well-known and potent estrogenic compound. Both rhodoeosein and emodin were also detected in the closely related species *F. dumetorum*. Analysis of the relative estrogenic potencies (REP) of emodin and rhodoeosein in SKBR3 cells transfected with either ERα or ERβ revealed that both phytoestrogens exhibit greater potency in ERβ-transfected cells compared to ERα-transfected cells. Furthermore, emodin displayed higher potency than rhodoeosein across both estrogen receptor subtypes.

The *in vivo* effects of these compounds have not yet been investigated; however, the complex polyphenolic composition of *F. convolvulus* seeds suggests potential therapeutic applications (Brennan et al. 2013).

Conclusions

Fallopia convolvulus (L.) Á. Löve, from the Polygonaceae family, shows strong pharmacological potential due to its rich content of flavonoids, anthraquinones, steroids, and phenolic compounds. Modern studies confirm its traditional use for treating inflammation, infections, and liver disorders, and reveal additional antioxidant, anti-inflammatory, anticancer, estrogenic, antimicrobial, and neuroprotective effects. Notable compounds like falloconvolin A and B, along with quercetin and kaempferol, enhance its value, particularly for cardiovascular and metabolic diseases. Its ecological adaptability makes it a sustainable resource for drug development. However, further research is needed to fully understand its bioactive mechanisms and integrate it into modern medicine.

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statements

The authors declared that no clinical trials were used in the present study.

The authors declared that no experiments on humans or human tissues were performed for the present study.

The authors declared that no informed consent was obtained from the humans, donors or donors' representatives participating in the study.

The authors declared that no experiments on animals were performed for the present study.

The authors declared that no commercially available immortalised human and animal cell lines were used in the present study.

Use of AI

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Author contributions

Conceptualization, Z.A. (Zhanbota Akmuratkyzy), A.A. and M.K.; writing-original draft preparation, Z.A. (Zhanbota Akmuratkyzy); writing-review and editing, Z.A. (Zhanbota Akmuratkyzy); visualization, A.A., Z.N., R.S., G.K. and K.J.; supervision, A.T.; project administration, B.K., Z.A. (Zhanar Aubakirova) and B.D.; funding acquisition, M.Z., R.Z. and Z.B. All authors have read and agreed to the published version of the manuscript.

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Data availability

All of the data that support the findings of this study are available in the main text.

References

Aboulaghras S, Sahib N, Bakrim S, Benali T, Charfi S, Guaouguaou FE, Omari NE, Gallo M, Montesano D, Zengin G, Taghzouti K, Bouyahya A (2022) Health benefits and pharmacological aspects of chrysoeriol. Pharmaceuticals 15(8): 973. https://doi.org/10.3390/ph15080973

Adlercreutz H (2002) Phyto-oestrogens and cancer. The lancet oncology 3(6): 364–373. https://doi.org/10.1016/S1470-2045(02)00777-5

Agrawal AD (2011) Pharmacological activities of flavonoids: a review. International Journal of Pharmaceutical Sciences and Nanotechnology 4(2): 1394–1398. https://doi.org/10.37285/ijpsn.2011.4.2.3

Alshalmani SK (2011) Comparison of the effects of dietary flavonoids and statins on lipopolysaccharide-induced vascular inflammation, 18–22.

Ambavade SD, Misar AV, Ambavade PD (2014) Pharmacological, nutritional, and analytical aspects of β-sitosterol: a review. Oriental Pharmacy and Experimental Medicine 14: 193–211. https://doi.org/10.1007/s13596-014-0151-9

Avula B, Joshi VC, Wang YH, Khan IA (2007) Simultaneous identification and quantification of anthraquinones, polydatin, and resveratrol in *Polygonum multiflorum*, various *Polygonum* species, and dietary supplements by liquid chromatography and microscopic study of *Polygonum* species. Journal of AOAC International 90(6): 1532–1538. https://doi.org/10.1093/jaoac/90.6.1532

Brandbyge J (1993) Polygonaceae. Flowering Plants Dicotyledons: Magnoliid, Hamamelid and Caryophyllid Families. Berlin, Heidelberg: Springer Berlin Heidelberg, 531–544. https://doi.org/10.1007/978-3-662-02899-5_63

Brennan JC, Denison MS, Holstege DM, Magiatis P, Dallas JL, Gutierrez EG, Soshilov AA, Millam JR (2013) 2, 3-cis-2R, 3R-(−)-epiafzelechin-3-O-p-coumarate, a novel flavan-3-ol isolated from *Fallopia convolvulus* seed, is an estrogen receptor agonist in human cell lines. BMC complementary and alternative medicine 13: 1–14. https://doi.org/10.1186/1472-6882-13-133

Chase MW, Zmarzty S, Lledo MD, Wurdack KJ, Swensen SM, Fay MF (2002) When in doubt, put it in Flacourtiaceae: a molecular phylogenetic analysis based on plastid rbcL DNA sequences. KEW bulletin 57: 141–181. https://doi.org/10.2307/4110825

Chen HS, Liu Y, Lin LQ, Zhao JL, Zhang CP, Jin JC, Wang L, Bai MH, Wang YC, Liu M, Shen BZ (2011) Anti-proliferative effect of an extract of the root of *Polygonum multiflorum* Thunb. on MCF-7 human breast cancer cells and the possible mechanisms. Molecular medicine reports 4(6): 1313–1319. https://doi.org/10.3892/mmr.2011.574

Chen J, Zhang C, Zhang M (2010) Chemical constituents from aerial parts of *Fallopia convolvulus*. [Zhongguo Zhong yao za zhi= Zhongguo Zhongyao Zazhi=] China Journal of Chinese Materia Medica 35(23): 3165–3167.

Cuénoud P, Savolainen V, Chatrou LW, Powell M, Grayer RJ, Chase MW (2002) Molecular phylogenetics of Caryophyllales based on nuclear 18S rDNA and plastid rbcL, atpB, and matK DNA sequences. American Journal of Botany 89(1): 132–144. https://doi.org/10.3732/ajb.89.1.132

Cui J, Zong W, Zhao N, Yuan R (2022) Burdock (*Arctium lappa* L.) leaf flavonoids rich in morin and quercetin 3-O-rhamnoside ameliorate lipopolysaccharide-induced inflammation and oxidative stress in RAW264.7 cells. Food Science & Nutrition 10(8): 2718–2726. https://doi.org/10.1002/fsn3.2875

David JM (2008) Mabberley's Plant Book. Third edition. Cambridge University Press, UK.

Decraene LPR, Akeroyd JR (1988) Generic limits in *Polygonum* and related genera (Polygonaceae) on the basis of floral characters. Botanical Journal of the Linnean Society 98(4): 321–371. https://doi.org/10.1111/j.1095-8339.1988.tb01706.x

Demydiak D, Slobodianiuk L, Gerush O, Budniak L, Sydor V, Skrynchuk O, Demydiak O, Panasenko N, Ratynskyi V (2023) HPLC-DAD analysis of flavonoids and hydroxycinnamic acids in Aster novi-belgii L. Pharmacia 70: 745–750. https://doi.org/10.3897/pharmacia.70.e94344

Drazan D, Smith AG, Anderson NO, Becker R, Clark M (2021) History of knotweed (*Fallopia* spp.) invasiveness. Weed Science 69(6): 617–623. https://doi.org/10.1017/wsc.2021.62

El Omari N, Jaouadi I, Lahyaoui M, Benali T, Taha D, Bakrim S, Menyiy NE, Kamari FE, Zengin G, Bangar SP, Lorenzo JM, Gallo M, Montesano D, Bouyahya A (2022) Natural sources, pharmacological properties, and health benefits of daucosterol: versatility of actions. Applied Sciences 12(12): 5779. https://doi.org/10.3390/app12125779

Flora of North America Editorial Committee [Ed.] (1993) Flora of North America (2): Pteridophytes and Gymnosperms (2). Oxford University Press.

Frémont L (2000) Biological effects of resveratrol. Life Sciences 66(8): 663–673. https://doi.org/10.1016/S0024-3205(99)00410-5

Freeman CC, Reveal JL (2005) Polygonaceae. Flora of North America, Oxford University Press, Oxford (5): 216–221.

Gao L, Li Y, Xie H, Wang Y, Zhao H, Zhang M, Gu W (2020) Effect of ethylparaben on the growth and development of *Drosophila melanogaster* on preadult. Environmental Toxicology and Pharmacology 80: 103495. https://doi.org/10.1016/j.etap.2020.103495

Haghi A, Azimi H, Rahimi R (2017) A comprehensive review on pharmacotherapeutics of three phytochemicals, curcumin, quercetin, and allicin, in the treatment of gastric cancer. Journal of Gastrointestinal Cancer 48: 314–320. https://doi.org/10.1007/s12029-017-9997-7

Harris DM, Besselink E, Henning SM, Go VLW, Heber D (2005) Phytoestrogens induce differential estrogen receptor alpha-or beta-mediated responses in transfected breast cancer cells. Experimental Biology and Medicine 230(8): 558–568. https://doi.org/10.1177/153537020523000807

Haraldson K (1978) Anatomy and taxonomy in Polygonaceae subfam. Polygonoideae Meissn. emend. Jaretzky. Symbolae Botamicae Upsalienses 22: 1–95.

Hsu SC, Chung JG (2012) Anticancer potential of emodin. BioMedicine 2(3): 108–116. https://doi.org/10.1016/j.biomed.2012.03.003

Hume L, Martinez J, Best K (1983) The Biology of Canadian Weeds: 60. *Polygonum convolvulus* L. Canadian journal of plant science 63(4): 959–971. https://doi.org/10.4141/cjps83-121

Imran M, Saeed F, Hussain G, Imran A, Mehmood Z, Gondal TA, El-Ghorab A, Ahmad I, Pezzani R, Arshad MU, Bacha U, Shariarti MA, Rauf A, Muhammad N, Shah ZA, Zengin G, Islam S (2021) Myricetin: A comprehensive review on its biological potentials. Food Science & Nutrition 9(10): 5854–5868. https://doi.org/10.1002/fsn3.2513

Jussieu AL (1789) Genera Plantarum, secundum ordines naturales disposita juxta methodum in Horto Regio Parisiensi exaratam, anno 1774. Herrisant and Barrois, Paris, France, 82 pp. https://doi.org/10.5962/bhl.title.284

Kallenberger HB, Horváth G, Balogh L, Balázs VL, Papp N (2016) Adventív *Fallopia* taxonok botanikai, fitokémiai és gyógyászati jellemzése. Botanikai Közlemények 103(1): 119–134. https://doi.org/10.17716/BotKozlem.2016.103.1.119

Kanadaswami C, Lee LT, Lee PPH, Hwang JJ, Ke FC, Huang YT, Lee MT (2005) The antitumor activities of flavonoids. In vivo 19(5): 895–909.

Karadeniz F, Oh JH, Seo Y, Yang J, Lee H, Kong CS (2023) Quercetin 3-O-galactoside isolated from Limonium tetragonum inhibits melanogenesis by regulating PKA/MITF signaling and ERK activation. International Journal of Molecular Sciences 24(4): 3064. https://doi.org/10.3390/ijms24043064

Khaliq T, Akhter S, Sultan P, Hassan QP (2023) Critical review on *Rumex dentatus* L. a strong pharmacophore and the future medicine: Pharmacology, phytochemical analysis and traditional uses. Heliyon 9(3). https://doi.org/10.1016/j.heliyon.2023.e14159

Kim MH, Park JH, Park CW (2000a) Flavonoid chemistry of *Fallopia* section *Fallopia* (Polygonaceae). Biochemical Systematics and Ecology 28(5): 433–441. https://doi.org/10.1016/S0305-1978(99)00084-8

Kim MH, Park JH, Won H, Park CW (2000b) Flavonoid chemistry and chromosome numbers of *Fallopia* section *Pleuropterus* (Polygonaceae). Canadian Journal of Botany 78(9): 1136–1143. https://doi.org/10.1139/b00-079

Klein H (2011) Black bindweed *Fallopia convolvulus* (Linnaeus) A. Love or *Polygonum convolvulus*. University of Alaska, Anchorage, 1–3.

Kosal E (2023) Phylogeny & The Importance of DNA. Introductory Biology: Ecology, Evolution, and Biodiversity.

Kozlovskaya EP, Popov AM, Styshova ON, Vakhrushev AI, Rutckova TA, Podvolotskaya AB, Tekutyeva LA (2022) Comparative study of the pharmacological properties of luteolin and its 7, 3′-disulfate. Marine Drugs 20(7): 426. https://doi.org/10.3390/md20070426

Li K, Zhang Z, Zhao G, Sun P, Cui B, Chi S (2019) Chemical constituents from the roots of *Fallopia convolvulus* (L.) A. Löve. Biochemical Systematics and Ecology 84: 26–28. https://doi.org/10.1016/j.bse.2019.03.003

Li Z, Zhou J, Ji L, Liang Y, Xie S (2023) Recent advances in the pharmacological actions of apigenin, its complexes, and its derivatives. Food Reviews International 39(9): 6568–6601. https://doi.org/10.1080/87559129.2022.2122989

Liao SG, Zhang LJ, Sun F, Zhang JJ, Chen AY, Lan YY, Li YJ, Wang AM, He X, Xiong Y, Dong L, Chen XJ, Li YT, Zuo L, Wang YL (2011) Antibacterial and anti-inflammatory effects of extracts and fractions from Polygonum capitatum. Journal of Ethnopharmacology 134(3): 1006–1009. https://doi.org/10.1016/j.jep.2011.01.050

Li-Shuang LV, Gu X, Chi-Tang HO, Tang J (2006) Stilbene glycosides from the roots of *Polygonum multiflorum* Thunb and their in vitro antioxidant activities. Journal of Food Lipids 13(2): 131–144. https://doi.org/10.1111/j.1745-4522.2006.00039.x

Lledó MD, Crespo MB, Cameron KM, Fay MF, Chase MW (1998) Systematics of Plumbaginaceae based upon cladistic analysis of rbcL sequence data. Systematic Botany 23: 21–29. https://doi.org/10.2307/2419571

Matsuda H, Shimoda H, Morikawa T, Yoshikawa M (2001) Phytoestrogens from the roots of *Polygonum cuspidatum* (Polygonaceae): structure-requirement of hydroxyanthraquinones for estrogenic activity. Bioorganic & Medicinal Chemistry Letters 11(14): 1839–1842. https://doi.org/10.1016/S0960-894X(01)00318-3

Meng L, Qi W, Zhang X, Zhang D, Huang Y, Shi M, Li H (2021) Phytochemical and chemotaxonomic study on *Fallopia dentatoalata* (Fr. Schm.) Holub. Biochemical Systematics and Ecology 98: 104331. https://doi.org/10.1016/j.bse.2021.104331

Natarajan K, Overstreet JW, Rogers JM, Denison MS, Chen J, Lohstroh PN, McConnell DS, Lasley BL (2002) Detection of xenoestrogens in serum after immunoprecipitation of endogenous steroidal estrogens. Environmental Health Perspectives 110(8): 791–795. https://doi.org/10.1289/ehp.02110791

Nimanthika WJ (2014) *Fallopia convolvulus* (L.) Á. Löve (Polygonaceae): predicting potential environmental and economic impact to Sri Lanka. Annals of Sri Lanka Department of Agriculture 16: 247–262.

Noda T, Yamada T, Ohkubo T, Omura T, Ono T, Adachi T, Awaya T, Tasaki Y, Shimizu K, Matsubara K (2009) Hot-water-extracts of *Polygonum multiflorum* do not induce any toxicity but elicit limited beneficial effects on the liver in mice. Journal of Health Science 55(5): 720–725. https://doi.org/10.1248/jhs.55.720

Olaru OT, Venables L, Van De Venter M, Nitulescu GM, Margina D, Spandidos DA, Tsatsakis AM (2015) Anticancer potential of selected Fallopia Adans species. Oncology Letters 10(3): 1323–1332. https://doi.org/10.3892/ol.2015.3453

Ortiz JJ (1994) Etnoflora yucatanense fasc. 10, Polygonaceae. Mérida, México: Facultad de Medicina Veterinaria y Zootecnia, Universidad Autónoma de Yucatán.

Park SH, Choi E, Kim S, Kim DS, Kim JH, Chang S, Choi JS, Park KJ, Roh KB, Lee J, Yoo BC, Cho JY (2018) Oxidative stress-protective and anti-melanogenic effects of loliolide and ethanol extract from fresh water green algae, *Prasiola japonica*. International journal of molecular sciences 19(9): 2825. https://doi.org/10.3390/ijms19092825

Periferakis A, Periferakis K, Badarau IA, Petran EM, Popa DC, Caruntu A, Costache RS, Scheau C, Caruntu C, Costache DO (2022) Kaempferol: antimicrobial properties, sources, clinical, and traditional applications. International Journal of Molecular Sciences 23(23): 15054. https://doi.org/10.3390/ijms232315054

Purushothaman R, Vishnuram MG, Ramanathan DT (2024) Isolation and Identification of N-Hexadecanoic Acid from *Excoecaria agallocha* L. and its Antibacterial and Antioxidant Activity. Journal of Emerging Technologies and Innovative Research 11(1): 332–342. https://doi.org/10.2139/ssrn.4886224

Qais N, Jahan S, Shajib MS (2018) A review on anti-diabetic plants. Dhaka University Journal of Pharmaceutical Sciences 17(1): 139–152. https://doi.org/10.3329/dujps.v17i1.37130

Rahman MM, Rahaman MS, Islam MR, Rahman F, Mithi FM, Alqahtani T, Almikhlafi MA, Alghamdi SQ, Alruwaili AS, Hossain MS, Ahmed M, Das R, Emran TB, Uddin MS (2021) Role of phenolic compounds in human disease: Current knowledge and future prospects. Molecules 27(1): 233. https://doi.org/10.3390/molecules27010233

Razavi SM, Zahri S, Zarrini G, Nazemiyeh H, Mohammadi S (2009) Biological activity of quercetin-3-O-glucoside, a known plant flavonoid. Russian Journal of Bioorganic Chemistry 35: 376–378. https://doi.org/10.1134/S1068162009030133

Rodríguez B, Pacheco L, Bernal I, Piña M (2023) Mechanisms of action of flavonoids: antioxidant, antibacterial and antifungal properties. Ciencia, Ambiente y Clima 6(2): 33–66. https://doi.org/10.22206/cac.2023.v6i2.3021

Royer F, Dickinson R (1999) Weeds of Canada and the Northern United States: A guide for identification. University of Alberta, 434 pp.

Ryabushkina N, Gemedjieva N, Kobaisy M, Cantrell Charles L (2008) Brief review of Kazakhstan flora and use of its wild species. Asian and Australasian Journal of Plant Science and Biotechnology 2(2): 64–71.

Sanchez A, Kron KA (2008) Phylogenetics of Polygonaceae with an emphasis on the evolution of Eriogonoideae. Systematic Botany 33(1): 87–96. https://doi.org/10.1600/036364408783887456

Sanchez A, Kron KA (2009) Phylogenetic relationships of Afrobrunnichia Hutch. & Dalziel (Polygonaceae) based on three chloroplast genes and ITS. Taxon 58(3): 781–792. https://doi.org/10.1002/tax.583008

Sanchez A, Schuster TM, Burke JM, Kron KA (2011) Taxonomy of Polygonoideae (Polygonaceae): a new tribal classification. Taxon 60(1): 151–160. https://doi.org/10.1002/tax.601013

Sanjay SS, Shukla AK (2021) Mechanism of antioxidant activity. Potential Therapeutic Applications of Nano-antioxidants, 83–99. https://doi.org/10.1007/978-981-16-1143-8_4

Schuster TM, Reveal JL, Kron KA (2011) Phylogeny of Polygoneae (Polygonaceae: Polygonoideae). Taxon 60(6): 1653–1666. https://doi.org/10.1002/tax.606010

Shen MY, Liu YJ, Don MJ, Liu HY, Chen ZW, Mettling C, Corbeau P, Chiang CK, Jang YS, Li TH, Young P, Chang CLT, Lin YL, Yang WC (2011) Combined phytochemistry and chemotaxis assays for identification and mechanistic analysis of anti-inflammatory phytochemicals in *Fallopia japonica*. PLoS One 6(11): e27480. https://doi.org/10.1371/journal.pone.0027480

Smolarz HD (2002) Comparative study on the free flavonoid aglycones in herbs of different species of *Polygonum* L. Acta Poloniae Pharmaceutica 59(2): 145–148.

Sotoca Covaleda AM, Van den Berg H, Vervoort J, Van der Saag P, Ström A, Gustafsson JA, Rietjens I, Murk AJ (2008) Influence of cellular ERα/ERβ ratio on the ERα-agonist induced proliferation of human T47D breast cancer cells. Toxicological sciences 105(2): 303–311. https://doi.org/10.1093/toxsci/kfn141

Sotoca AM, Ratman D, Van Der Saag P, Ström A, Gustafsson JA, Vervoort J, Rietjens I, Murk AJ (2008) Phytoestrogen-mediated inhibition of proliferation of the human T47D breast cancer cells depends on the ERα/ERβ ratio. The Journal of Steroid Biochemistry and Molecular Biology 112(4–5): 171–178. https://doi.org/10.1016/j.jsbmb.2008.10.002

Spjut RW (1994) A systematic treatment of fruit types. New York Botanical Garden, New York, 182 pp.

Uddin G, Rauf A, Siddiqui BS, Shah SQ (2011) Preliminary comparative phytochemical screening of Diospyros lotus Stewart. Middle-East Journal of Scientific Research 10(1): 78–81.

Vasu K, Vinayasagar Goud J, Suryam A, Charya MAS (2009) Biomolecular and phytochemical analyses of three aquatic angiosperms. African Journal of Microbiology Research 3(8): 418–421.

Wadankar GD, Kute MV, Wankhede PJ (2022) Phytochemical analysis of Tinospora cordifolia and Adathoda vasica. International Journal of Advanced Research in Biological Sciences 9(5): 120–128.

Williams C, Edvardsson K, Lewandowski SA, Ström A, Gustafsson JA (2008) A genome-wide study of the repressive effects of estrogen receptor beta on estrogen receptor alpha signaling in breast cancer cells. Oncogene 27(7): 1019–1032. https://doi.org/10.1038/sj.onc.1210712

Yadav M, Chatterji S, Kumar Gupta S, Watal G (2014) Preliminary phytochemical screening of six medicinal plants used in traditional medicine. International Journal of Pharmacy and Pharmaceutical Sciences 6(5): 539–42.

Zhang CF, Chen J, Zhao LQ, Zhang D, Zhang M, Wang ZT (2011) Three new flavonoids from the active extract of *Fallopia convolvulus*. Journal of Asian natural products research 13(02): 136–142. https://doi.org/10.1080/10286020.2010.546357

Zhang Q, Yang J, Wang D, Wu C (2006a) Genotoxic studies on Panax Ginseng, Polygonum Multiflorum and their compatibility in mouse peripheral lymphocyte cells. Acta Pharmacologica Sinica 27: 288–288.

Zhang C, Zhang X, Zhang Y, Xu Q, Xiao H, Liang X (2006b) Analysis of estrogenic compounds in *Polygonum cuspidatum* by bioassay and high performance liquid chromatography. Journal of ethnopharmacology 105(1–2): 223–228. https://doi.org/10.1016/j.jep.2005.10.029

Zhang YZ, Shen JF, Xu JY, Xiao JH, Wang JL (2007) Inhibitory effects of 2, 3, 5, 4′-tetrahydroxystilbene-2-O-β-D-glucoside on experimental inflammation and cyclooxygenase 2 activity. Journal of Asian Natural Products Research 9(4): 355–363. https://doi.org/10.1080/10286020600727772

Zhang CZ, Wang SX, Zhang Y, Chen JP, Liang XM (2005) In vitro estrogenic activities of Chinese medicinal plants traditionally used for the management of menopausal symptoms. Journal of Ethnopharmacology 98(3): 295–300. https://doi.org/10.1016/j.jep.2005.01.033

Zhang Y, Jin Y, Yan W, Gu P, Zeng Z, Li Z, Zhang G, Wei M, Xue Y (2024) New Pyranone Derivatives and Sesquiterpenoid Isolated from the Endophytic Fungus *Xylaria* sp. Z184. Molecules 29(8): 1728. https://doi.org/10.3390/molecules29081728