https://doi.org/10.48047/AFJBS.6.12.2024.485-495

African Journal of Biological Sciences

Journal homepage: http://www.afjbs.com

Research Paper Open Access

LUDWIGIA ADSCENDENS: EXPLORING THE BOTANICAL AND PHARMACOLOGICAL ASPECTS

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Article History

Volume 6 Issue 12, 2024
Received: 25 May 2024
Accepted : 25 June 2024
doi:
10.48047/AFJBS.6.12.2024.485-495

ABSTRACT

Ludwigia adscendens, a prominent aquatic plant found in tropical and subtropical regions, is renowned for its diverse applications in traditional medicine and ecological significance. This review article aims to provide a comprehensive overview of the botanical and pharmacological aspects of *L. adscendens.* We explore the plant's taxonomy, morphology and distribution, emphasizing its unique characteristics within wetland ecosystems. Additionally, we delve into its phytochemical profile, highlighting bioactive compounds such as flavonoids, alkaloids, and tannins that contribute to its medicinal potential. The plant's traditional uses in treating ailments such as inflammation, infections, and diabetic disorders are also discussed, alongside recent scientific studies that validate these therapeutic properties. The review concludes with an evaluation of current challenges and future research directions for harnessing the full potential of *L. adscendens* in pharmacology and conservation.

Keywords: *Ludwigia adscendens*, pharmacology, phytochemistry, bioactive compounds, medicinal plants.

1. INTRODUCTION

Plants are thought to be the primary source of several significant secondary metabolites, including steroids and triterpenes, which are classified into distinct chemical classes based on their molecular structures. Phenolic compounds, saponins, and so forth **(Baky et al., 2022).** According to reports, herbal phytochemicals contain a variety of biological properties, including cytotoxicity, antidiabetic, antibacterial, anti-inflammatory, hepatoprotective, and lipid-lowering effects **(Shakya, 2016).** There are seven tribes, two subfamilies named Onagroideae and Ludwigioideae, and two major subdivisions that make up the Evening Primrose family **(Shawky et al., 2021).** The pantropic genus *Ludwigia*, which is a member of the Ludwigioideae subfamily, is home to roughly 82 species of water plants that are extensively found in both South and North America **(Baky et al., 2021).** The genus *Ludwigia* contains species that have been identified as having biological benefits, such as the antioxidant-rich *Ludwigia leptocarpa*, the antidiabetic *Ludwigia octovalvis*, the anti-inflammatory properties of *Ludwigia hyssopifolia* aerial parts, and the cytotoxic properties of *Ludwigia peploides* leaves, among others. In Egypt, two species of *Ludwigia L.* are commonly found: *L. stolonifera and L. erecta (L.) Hara* **(Amer et al., 2016).** Furthermore, *Ludwigia* is a well-known genus with traditional medicinal benefits for treating anthelmintic, antidiarrheal, carminative, and anti-inflammatory disorders. Furthermore, *L. stolonifera* is well-known for its economic significance due to its application in water bioremediation, which raises drinking water quality **(Baky et al., 2021).** Table 1 [6] provides a summary of the genus *Ludwigia*'s historical significance.

Table 1 Traditional uses previously reported for genus *Ludwigia* (Shawky et al., 2023)

Plants	**Traditional uses**	**References**
L. peploides	Treatment of acne vulgaris	(Nasri et al., 2015)
L. octovalvis	Remedy for nephritis, diarrhea, and headache	(Van and Bunyapraphatsara, 2002; Chang et al., 2004)
L. adscendens	Recovery of skin ulcers, astringent, anthelmintic, and anti-tussive	(Huang et al., 2007; Shilpi et al., 2010)
L. hyssopifolia	Used as carminative, purgative, astringent, anti-dysentery, anthelmintic, anti-diarrhea, and anti-flatulence	(Shaphiullah et al., 2003; Das et al., 2007; Zhang et al., 2019)
L. leptocarpa	For treatment of diarrhea and rheumatism	(Mabou et al., 2014)

The genus *Ludwigia Linnaeus*, which belongs to the family Onagraceae, is cosmopolitan and distributed. It contains approximately 90 species and 13 infraspecific taxa. The family is commonly known as the Willo-herb family and comprises approximately 832 species and 158 infraspecific taxa worldwide under 45 genera **(The Plant List 2013).** Eight species and one infraspecific taxon, including *Ludwigia adscendens (L.) H. Hara, L. decurrens Walt., L. linifolia (Vahl) R.S. Rao, L. octovalvis (Jacq.) P. H. Raven, L. octovalvis subsp. sessiliflora (Micheli) P. H. Raven, L. perennis L.,* and *L. peruviana (L.)* are among the eight species and one infraspecific taxon that are represented in India **(Barua, 2010; Shina, 1999; Rasingam, 2010).** *H. Hara, L. hyssopifolia (G. Don) Exell.,* and *L. prostrata Roxb.* This genus is represented in the Andaman and Nicobar Islands by five species **(Barua, 2010; Shina, 1999 and Rasingam, 2010),** including *L. hyssopifolia (G. Don) Exell, L. octovalvis (Jacq.) P. H. Raven, L. perennis L., L. peruviana (L.) H. Hara, and L. prostrata Roxb.* About 660 species of herbs, shrubs, and trees in 22 genera make up the flowering plant family Onagraceae Juss. It is widely distributed throughout subtropical and temperate zones, with a high population in both **(Wagner et al., 2007).** In the New World, the family is highly varied, with several species found in a variety of environments, particularly in western North America **(Rocha and De melo, 2020)**. The majority of the species in the genus *Ludwigia L.* are aquatic, and they are usually found growing on the margins of lakes and rivers in wet or flooded environments **(Oziegbe et al., 2011).** *Ludwigia* is distinguished from other genera of the Onagraceae by the lack of a floral tube, pollen grains arranged in tetrads or polyads, persistent sepals that remain after fertilization and until the fruit ripens, and a nectariferous disk at the stigma's base **(Eyde, 1978).** These traits bolster the genus's monophyly and suggest that *Ludwigia* is the sister group to the other members of the Onagraceae **(Wagner et al., 2007)**. Commonly known as water primrose, *Ludwigia adscendens* (L.) H. Hara is a species of herbaceous perennial in the family Onograceae. Although their broad tolerance to a variety of water conditions—from marshy to dry—is noted, it is more likely that the plants in the reserve had evolved certain adaptive features due to the unique hydrological conditions. *L. adscendens* is a 'wild' vegetable and used in folk medicine in several Southeast Asian and African nations, despite being regarded as a nuisance because of its capacity to infiltrate farms. Folks in Vietnam have reported using this herb to heal ailments like fever, cystitis, and painful urination. Additionally, the entire plant is crushed and applied externally to cure animal bites, eczema, zona, mammary gland abscesses, and irritation of the parotid glands

(Van chi, 2018; Ho, 2006; Van et al., 2021). The first contribution to the taxonomy of *Ludwigia* in Brazil was published in the *Flora Brasiliensis* **(Micheli, 1872),** with 37 species.

Despite several studies, the paleobiogeographic status and the journey of *Ludwigia*, in particular, synchronous to the continental drift is uncertain. The Indian plate occupied the connecting corridor for dissemination of several species during this journey. The morphology of *Ludwigia*-like pollen named as Corsinipollenites recorded from the Indian sub-continent during Late Cretaceous **(Prasad et al., 2018)** much before its collision with the Tibetan plate or its access to the NewWorld is discussed here in detailwith reference to the pollenmorphology of living species found in India. The descriptive and statistical account of pollen morphometry in seven extant species of *Ludwigia* using FESEM and LMis elucidated with an objective to outline the primitive and advance pollen characters with reference to Late Cretaceous and Pleistocene fossil pollen in order to trace the ancestry of the extant species in India **(Farooqui et al., 2019).**

The plant is used traditionally as a poultice to treat ulcers and skin disorders **(Yusuf et al., 1994),** as an astringent, emetic, antidysenteric and antihelmintic **(Kirtikar and Basu, 1918),** as a diuretic and for scalp, skin, eye and throat complaints **(Perry, 1980).** Stems and leaves are antiseptic; flowers have anti-inflammatory activity **(Ghani, 2003).**

2. DESCRIPTION AND OVERVIEW OF PLANT

The semi-aquatic *Ludwigia,* also known as Water Primrose, is an annual herb that grows at an altitude of approximately 1500 meters in moist soil along river banks, streams, lakes, and rice fields. The colors of the spade-shaped leaves vary from dark green to brownish-red. The lower surface of leaves is reddish-brown to deep crimson, while the upper surface is olive green. Its remarkable capacity to colonize quickly is attributed to its tolerance for a wide range of air temperature, hydrological, and climatic fluctuations, as well as its preference for high light intensity and neutral pH. Their growth can decrease floral and faunal variety **(Grillas et al., 1992; Dutartre et al., 1997)** and slow down water circulation, which can cause a significant siltation in aquatic habitats **(Dutartre, 1988).** The self-incompatibility during pollination is a trait associated with the family's origins, and it is known that only species of Onagraceae from North and South America exhibit this trait **(Baker, 1955).** There are roughly eight *Ludwigia* species that are exclusive to South America and several more that are present in North America. The Onagraceae family of plants is pollinated by bees, flies, butterflies, hummingbirds, and other animals **(Raven, 1979).** There have been reports from northern South America of honeybees found in Late Cretaceous ambers together with the viscin threads **(Pocknall and Jarzen, 2009).** Since conspicuous viscin threads bind tetrads together, the primitive bee pollination pattern for Onagraceae results in the discharge of miniature pollen. Known as plaeotropical species, *Ludwigia hyssopifolia, L. peruviana,* and *L. perennis* are native to the old world and have a genealogy back to Gondwanaland from the region's birth **(Cook, 1996).** Most species are considered to be New World, including *Ludwigia adscendens, L. decurrens, L. octovalvis, and L. octovalvis subsp. sessiliflora*. In India, one can typically find all of the researched *Ludwigia* species flourishing (Table 2).

Table 2 Distribution of *Ludwigia* in India.

PLANT TAXA	DISTRIBUTION	REFERENCES
Ludwigia adscendens (L.) H. Hara	Common in throughout India	Barua (2010)
Ludwigia perennis L.	Commonly grown in Central India, North- East India, Gangetic plains, South India and warmer part of North India	Barua (2010)
Ludwigia octavalvis subsp.	South India, Goa, Manipur	Barua

sessiflora (Micheli) P.H. Raven	and Uttar Pradesh	(2010)
Ludwigia octavalvis (Jacq.) P.H. Raven	Throughout Central India, Gangetic plains, Western ghats and South India	Barua (2010)
Ludwigia hyssopifolia (G. Don) Exell	North-East India, Central India and Andaman Islands	Barua (2010)
Ludwigia peruviana (L.) H. Hara	South India, Andaman and Assam	Barua (2010)
Ludwigia decurrens Walt.	Assam and West Bengal	Barua (2010)

3. TAXONOMICAL CLASSIFICATION

Kingdom: Plantae
Order: Myrtales
Family: Onagraceae
Genus: *Ludwigia*
Species: *L. adscendens*

4. BINOMIAL NAME

Ludwigia adscendens (L.) H.Hara

5. SYNONYMS [PLANT LIST]

Jussiaea adscendens L, Jussiaea diffusa Forssk, Jussiaea repens L, Jussiaea stolonifera Guill. & Perr, Ludwigia stolonifera (Guill. & Perr.) P.H.Raven

6. MORPHOLOGY OF PLANT

An aquatic perennial herbaceous creeper was called *Ludwigia adscendens*. They resemble growths that are either crawling through muddy, moist areas or floating on the water. The stem is round in cross-section, extensively branched, and branches sprouted from the leaf axils (Figure 1 A). "Breathing" roots held oxygen, which allowed the plant to be submerged in water while maintaining normal physiological functions (Figure 1 D), while "standard" roots grew from inter-node to assist the plant in adhering to moist soil (Figure 1 B). Foliage had leaves arranged alternately. With an entire edge and an acute or obtuse apex, every leaf is obovate or oblanceolate, ranging in length from 4 to 8 cm. The petiole is half as long as the leaf blade, the leaf blade is smooth, dark green on the upper side compared to the lower side. The midrib and veins, which are both white and very noticeable on the underside, are pinnate in venation (Figure 1 C) **(Van et al., 2021).**

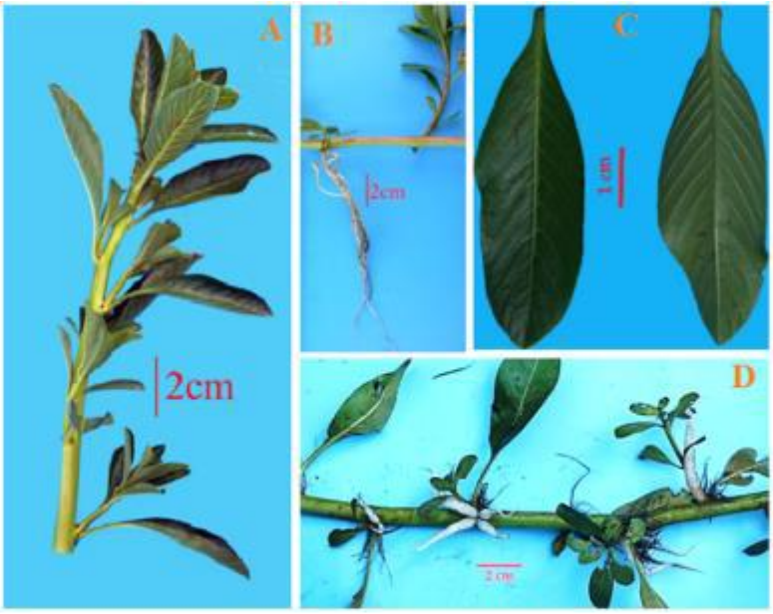

Figure 1 Vegetative organs of *Ludwigia adscendens* (Van et al., 2021)

The color of the flowers of *Ludwigia adscendens* is described as creamy white, to pale yellow, bright yellow, or dark yellow but there the petals are white with their base were bright yellow (Figure 2). The long, stalked (about 1 cm), bisexual, solitary blooms are borne in the axils of the top leaves. With five oblong, lanceolate lobes that are each 0.7–0.9 cm long and attached to the ovary, the calyx is tubular, glabrous, and measured 1.0–1.3 cm in length. Five ovoid, round, emarginate petals measuring 0.8–2 cm length and 0.8–1.2 cm broad made up the corolla. Stamens had 10 filaments, grouped in two rings that the outer shorter than the inner. The rectangular, 0.7–1.0 mm long anthers has a yellowish hue. The compound pistil is composed of a style with a globose stigma and an ovary with five carpels. When fruiting, the ripe fruit is a capsule, cylindrical, with fine hairs, 3 - 4 cm long, opening into 5 parts. The seeds are round, tiny, and in large numbers **(Das and Sivaperuman, 2020).**

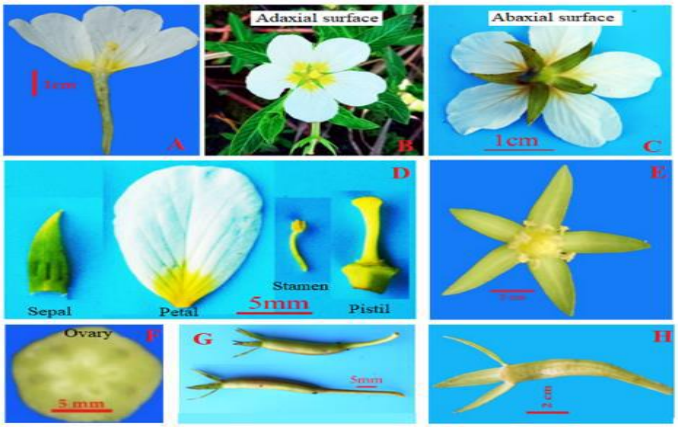

Figure 2 Reproductive organs of *Ludwigia adscendens (Van et al., 2021)*

While plants were described as having creamy white flowers in document **(Ho, 2006),** the descriptions in papers **(Van chi, 2018; Van et al., 2021; Barua, 2010)** indicated that the blooms of the plants were white. Additionally, document **(Ho, 2006)** mentioned that trichomes, or hairs, covered the underside of the leaves of plants in dry conditions. However, based on observations of plants in Lang Sen, only a few trichomes were visible on the underside of the petiole, possibly due to the plants' humid surroundings. *Ludwigia adscendens* plants in Lang Sen exhibited all of the morphological characteristics, and the descriptions in the aforementioned papers demonstrated the variety of morphology observed in this species.

7. PHYTOCHEMICAL COMPOSITION OF GENUS *LUDWIGIA*

According to **Baky et al., 2022** eleven compounds were isolated from the *L. adscendens* aerial parts ethyl acetate and n-butanol fractions after further investigation. Of them, six compounds (1-6) were found in the ethyl acetate fraction and five compounds (7-9) in the n-butanol fraction (Fig. 3). Together with ten known chemicals, compound 2 from the isolated compounds was found to be a novel natural compound.

Previously isolated compounds included are octyl gallate [1] **(Latha and Daisy, 2013),** 23-O-Coumaroylhederagenin- 28-O-β-D-glucopyranoside [3] (Chang et al., 2004), quercetin-3-O-glucoside [4] **(Marzouk et al., 2007),** *quercetin 3-O-α- L-rhamnoside-2''-(4'''-O-n-pentanoyl)-gallate* [5] **(Marzouk et al., 2007),** *myricetin-3-O-α-L-rhamnopyranoside* [6] **(Baky et al., 2022)**, *hederagenin* [7] **(Abaci et al., 2022)**, *α-D-tetraglucoside (α-Dglucopyranosyl-(2a → 1b)-O-α-D-glucopyranosyl-(2b → 1c)-O-α-D-glucopyranosyl-(2c → 1d)-O-α-D-glucopyranoside)* [8] **(Chung et al., 2014),** *α-D-pentaglucoside (α-D-glucopyranosyl-(2a → 1b)-O-D-glucopyranosyl- (2b → 1c)-O-α-D-glucopyranosyl-(2c → 1d)-O-α-Dglucopyranosyl-(2d → 1e)-O-α-Dglucopyranoside)* (9), *α-D-hexaglucoside (α-D-glucopyranosyl-(2a → 1b)- O-D-glucopyranosyl-(2b → 1c)-O-α-D-glucopyranosyl- (2c → 1d)-O-α-D-glucopyranosyl-(2d → 1e)-O-α- D-glucopyranosyl-(2e → 1f)-O-α-D-glucopyranoside)* [10], and *α-D-heptaglucoside (α-D-glucopyranosyl- (2a → 1b)-O-D-glucopyranosyl-(2b → 1c)-O-α-Dglucopyranosyl-(2c → 1d)-O-α-D-glucopyranosyl- (2d → 1e)-O-α-D-glucopyranosyl-(2e → 1f)-O-α-Dglucopyranosyl-(2f → 1 g)-O-α-D-glucopyranoside)* [11].

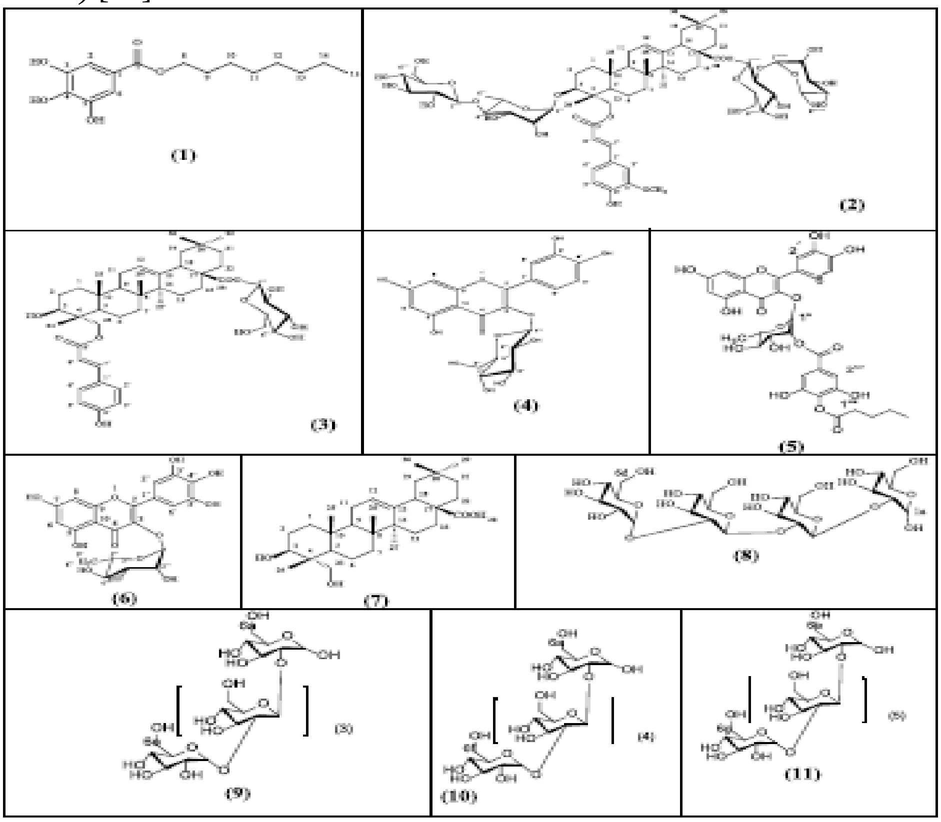

Fig. 3 Isolated compounds from *L. adscendens*

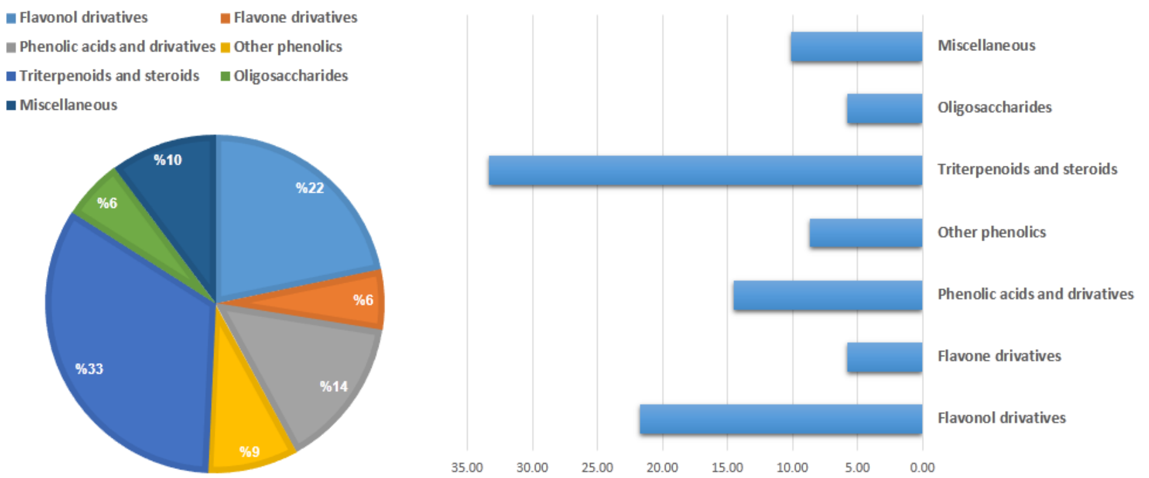

Figure 4. Relative percentage of each identified phytochemical class in genus *Ludwigia* (Shawky et al., 2023)

8. PHARMACOLOGICAL ACTIVITIES OF PLANT

1. Antioxidant and anti-inflammatory activities

Reactive oxygen species (ROS) and oxidative stress increase the harmful effects of free radicals in the human body, which makes them risk factors for a number of diseases and conditions, including cancer, diabetes, atherosclerosis, and degenerative diseases **(Huang et al., 2017)**. Rumor has it that the species *Ludwigia* contains large amounts of flavonoids and phenolic chemicals, two types of phytochemical antioxidants **(Baky et al., 2022).** When *Ludwigia octovalvis* leaves were examined for their antioxidant capacity using FRAP and DPPH, the results showed varying activity at 1256.88 µM TE/mg and 1080.84 µM TE/mg dry weight, respectively **(Yakob et al., 2012).** In a different investigation, the DPPH and NBT (nitroblue tetrazolium) assays were used to assess the antioxidant activity of *Ludwigia peploides* leaves methanolic extract, revealing IC50 values of 58 and 30 µg/ml, respectively, to assess the activity of scavenging free radicals **(Smida et al., 2018).** When *L. stolonifera's* aerial parts ethyl acetate extract was tested for anti-inflammatory properties, it showed inhibitory effect against leukotriene B4 (LTB4) in vitro **(Huang et al., 2017).**

2. Antitumor activity

The anti-cancer efficacy of the genus *Ludwigia* is one of its most notable characteristics. There have been reports of cytotoxic effects from *Ludwigia hyssopifolia* and *Ludwigia peploides* in their methanolic, aqueous, and ethyl acetate extracts. *Ludwigia peploides* leaf crude extract was tested for its cytotoxic potential in vitro **(Chang et al., 22004; Smida et al., 2018).** The results revealed that it had a low impact on human immortalized keratinocytes (HaCaT cells) (IC50 > 200 g/ml) and a strong effect on B16 cancer cell lines (IC50 = 5.5 g/ml) **(Smida et al., 2018).**

3. Antidiabetic activity

A metabolic condition known as diabetes is brought on by an excessively high blood glucose level. Enzyme inhibitors such as α-glucosidase and α-amylase can be used to treat type-2 diabetes patients by preventing the breakdown of complex carbs into glucose, with less negative effects and for financial reasons **(Sangilimuthu et al., 2021)**. The ethyl acetate extract of aerial parts of *L. stolonifera* (50 mg kg-1 body wt.) showed a strong hypoglycemic effect in mice with diabetes caused by alloxan **(Marzouk et al., 2007).** An aqueous ethanolic extract of *L. octovalvis* (0.1 g/kg) was administered to streptozotocin (STZ)- and high-fat diet (HFD)-induced diabetic mice. The outcomes demonstrated improvement in polyphagia, polydipsia, hyperglycemia, and glucose tolerance, which was comparable to that observed in STZ animals treated with metformin **(Lin et al., 2017).** It was observed that *L. octovalvis* extract and its active metabolite (β-sitosterol) dramatically increased the phosphorylation of AMP-activated protein kinase, accelerated the absorption of fluorescent glucose, and decreased glucose production in HepG2 hepatocellular cells. Moreover, *L. octovalvis* extract and β-sitosterol improved memory performance in HFD-fed mice and produced a hypoglycemic effect in streptozotocin (STZ)-induced diabetes, in comparison to metformin **(Lin et al., 2017).**

4. Anti-microbial effect

Antibiotic-resistant microorganisms are the result of both overuse and misuse of antibiotics. Therefore, it is believed to be essential to use antimicrobials produced from plants in order to give safe and effective alternatives to synthetic medication resistance. At MIC (minimum inhibitory concentration) and MBC (minimum bactericidal concentration) values of 62.5 and 125 g/ml, respectively, the methanolic extract from the roots of *L. octovalvis* inhibited *Pseudomonas aeruginosa*. The methanol extract of leaves of *L. octovalvis* exhibited notable inhibitory action against *E. coli*. The ethyl acetate extracts of *L. hyssopifolia* also showed a slight inhibitory effect on pathogenic bacteria, both gram-positive and gram-negative **(Das et al., 2007).** Aqueous methanolic, ethanolic, ethyl acetate, and butanol extracts of *L. leptocarpa* aerial, roots, or both portions of the plant have demonstrated a noteworthy antibacterial action **(Mabou et al., 2016).** When *L. peploides* leaves crude extract was tested for antibacterial activity using disc diffusion and broth micro-dilution against microorganisms that cause acne vulgaris, Propioni bacterium acnes was strongly suppressed at 1.9 g/ml **(Smida et al., 2018).**

5. Miscellaneous activities

Ludwigia plants exhibited additional biological activity of various plant extracts in addition to the biological activities already stated. Antimalarial activity was found in *L. erecta* methanol and aqueous extracts **(Mathaura et al., 2007).** As 1 mg of *L. stolonifera* aerial parts n-hexane extract equaled 36.36μM EDTA and the percentage of inhibition was 52.78%, *L. stolonifera* demonstrated metal chelation activity. Furthermore, 43.62% of the inhibitory capability was found for 1 mg of *Ludwigia stolonifera* roots n-hexane extract, which is equivalent to 29.67μM EDTA. Because *L. octovalvis* has a vasodilator effect with an EC50 of 1.18 mg/ml, its hydroalcoholic extract has recently shown antihypertensive efficacy **(Ratovonarindra et al., 2023).**

9. CONCLUSION

In conclusion, *Ludwigia adscendens* stands as a promising botanical species with a multifaceted potential that spans ecological, pharmacological, and botanical interests. This versatile plant, recognized for its adaptability and traditional medicinal use, presents a wealth of opportunities for further research and exploration. Current studies indicate that *Ludwigia adscendens* possesses several bioactive compounds that could contribute to innovative therapies and natural remedies. As research into its medicinal properties and potential applications expands, the plant may offer novel solutions for various health challenges. Moreover, its resilience and environmental adaptability present significant ecological benefits, making it an important species for conservation efforts and ecosystem management. In order to fully realize the benefits of *Ludwigia adscendens*, continued interdisciplinary research and sustainable utilization practices will be key.

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