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Lawsonia inermis L. (Henna): A Comprehensive Review of Its Phytochemistry, Pharmacological Potential, Traditional Uses, and Commercial Applications

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Abstract

Lawsonia inermis L., commonly known as henna, is a multipurpose plant with centuries-old applications in traditional medicine, cosmetics, and rituals across Asia, Africa, and the Middle East. This review provides a comprehensive synthesis of its taxonomy, phytochemistry, pharmacological activities, ethnomedicinal applications, and commercial significance. The plant's bioactive constituents – including lawsone, flavonoids, phenolics, and terpenoids – underpin its broad therapeutic effects, such as antioxidant, antimicrobial, anti-inflammatory, wound healing, antidiabetic, anticancer, and immunomodulatory activities. Despite extensive traditional use and emerging pharmacological validation, challenges remain regarding extract standardisation, clinical evaluation, and mechanistic understanding. This paper highlights the need for advanced studies, including clinical trials and bioavailability optimisation, to fully harness L. inermis as a scientifically validated phytopharmaceutical. Integrating traditional knowledge with modern research could elevate henna's role in global healthcare while ensuring its sustainable utilisation.

Keywords: *Lawsonia inermis, henna, lawsone, phytochemistry, ethnomedicine, pharmacological activity, antioxidant, antimicrobial, traditional medicine, herbal therapeutics, bioactive compounds, wound healing, natural dye, antidiabetic, anticancer.*

1. Introduction

Lawsonia inermis L., commonly referred to as henna, is a perennial shrub belonging to the family Lythraceae, which has a long history of use in traditional medicine and cultural rituals. The plant is particularly famous for yielding a reddish-orange colour from the compound lawsone (2-hydroxy-1,4-naphthoquinone), which is found primarily in its leaves. Lawsone, as reported by Oda et al. (2018), is the major active compound that gives henna its colouring properties, which have contributed to its being a standard ingredient in cosmetic and ceremonial applications for centuries. [49] highlighted the broad geographical and cultural significance of *L. inermis* in Asia, Africa, and the Middle East, where it finds application in rituals, healing, and as a plant dye. Apart from its colouring role, the plant contains a wide variety of phytochemicals—e.g., triterpenoids, flavonoids, and phenolic acids—which serve to promote a wide variety of biological activities. [9] has named these compounds as being responsible for their drug efficacy. Traditionally, *L. inermis*' therapeutic uses have been recognised by traditional medical systems worldwide. It was reported used by [35] in Ayurvedic medicine, and [20] used it in wound care, infection management, and metabolism disorder treatment via generation-to-generation transmission of ethnomedicinal information. These conventional claims have been provided with scientific justification by recent experimental research. Its antioxidant, antidiabetic, antimicrobial, and anti-inflammatory activities were documented by [42], [50], and [2] further investigated its immunomodulatory and wound-healing activities, further establishing its significance in current phytotherapeutic research.

Notwithstanding the growing amount of evidence, hurdles like extract standardisation, toxicity testing, and strict clinical trials are still present. The review herein covers an overall discussion on *L. inermis*, including its taxonomy, phytochemistry, ethnopharmacological history, therapeutic attributes, and prospects in commercialisation. This is aimed at bridging traditional knowledge with contemporary science to aid future innovation and sustainable use of this multipurpose plant.

2. Taxonomy and Botanical Description

L. inermis L. is the single known species in the genus Lawsonia and is found in the family Lythraceae, which is placed in the order Myrtales. Its taxonomic status as a dicotyledonous angiosperm has been repeatedly upheld in every classification scheme that has been put forth by Bentham and Hooker, Engler and Prantl, Cronquist, and the Angiosperm Phylogeny Group (APG). [49] had characterised *L. inermis* as a much-branched, smooth shrub or small tree, usually 2 to 6 metres tall. The plant is readily identified by its opposite, simple leaves that range from elliptic to lance-shaped shapes, usually 1.5 to 5 centimetres long [4,6]. These leaves have entire margins and acute tips and are either sessile or attached by very short petioles. The plant bears fragrant flowers arranged in terminal panicles. Each flower consists of four petals, from white to pale pink, and has prominent stamens. [9] reports that the fruits are tiny, spherical capsules measuring 4–8 millimetres in diameter, containing numerous angular seeds. The bark is typically thin and greyish-brown, and it peels in fine layers as the plant grows [7,10]. One of the major botanical features of *L. inermis* is that it produces the orange-red pigment lawsone, which is deposited

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in the leaves [49]. observed that the pigment is significant from a historical point of view for its applications in traditional body adornment, natural hair dyeing, and colouring of fabrics. Table 1. Comparative taxonomic classification of *L. inermis* L. according to different botanical systems (Bentham & Hooker, Engler & Prantl, Cronquist, and the Angiosperm Phylogeny Group).

Table 1: Comparative Taxonomic Classification of L. inermis According to Different Systems

Taxonomic Rank	Bentham & Hooker	Engler & Prantl	Cronquist	APG (Angiosperm Phylogeny Group)
Kingdom	Plantae	Plantae	Plantae	Plantae
Division / Clade	Angiosperms	Angiosperms	Angiosperms	Angiosperms
Class / Clade	Dicotyledons	Dicotyledons	Dicotyledons	Eudicots
Subclass / Clade	Polypetalae	Sympetalae	—	—
Order	Myrtales	Myrtales	Myrtales	Myrtales
Family	Lythraceae	Lythraceae	Lythraceae	Lythraceae
Genus	Lawsonia	Lawsonia	Lawsonia	Lawsonia
Species	*L. inermis*	*L. inermis*	*L. inermis*	*L. inermis*

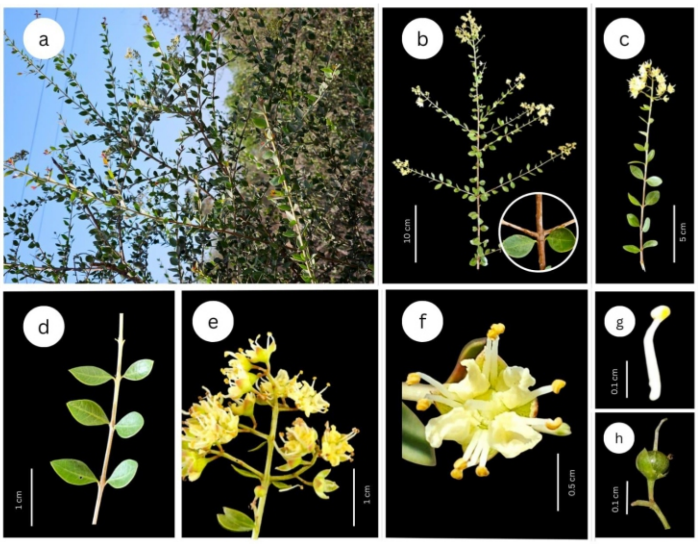

Figure I. This figure details the morphological features of *L. inermis* (henna). (a) presents the mature plant naturally occurring in its environment, with its bushy appearance- (b) provides a flowered branch, which emphasises the opposite phyllotaxy also seen here clearly in the inset. (c) offers a single flowered twig with minute, opposite leaves. (d) gives a close-up of the leaves, which are elliptic, entire, and oppositely arranged on the stem. (e) gives the inflorescence with many minute flowers aggregated in terminal cymes. (t) gives a close-up of one flower, displaying whitish-yellowish petals and bold stamens. (g) gives a single stamen with a bilobed anther, and (h) gives a mature green fruit, which is a tiny capsule.

3. Synonyms and Vernacular Names

The botanical name Lawsonia was given in commemoration of Dr. Isaac Lawson, an 18th-century Scottish doctor. The species name inermis refers to the usually spineless twigs of the plant, which separate it from other thorny shrubs. Because of its wide geographic range and morphological variability, *L. inermis* has been placed under different synonyms in the past. These synonyms, documented in ancient botanical works, are listed in Table 2.

Table 2: Synonyms and Protologues of L. inermis and Related Taxa

Name	Protologue
*Lawsonia coccinea*Sm.	Cycl. 20: n.° 3 (1812)
*Lawsonia alba*Lam.	Encycl. 3: 106 (1789)
*Lawsonia purpurea*Lam.	Encycl. 3: 107 (1789)
*Lawsonia spinosa*L.	Sp. Pl. : 349 (1753)
*Lawsonia falcifolia*Stokes	Bot. Mat. Med. 2: 364 (1812)
*Rotantha combretoides*Baker	J. Linn. Soc., Bot. 25: 317 (1890)
Alcanna spinosa (L.) Gaertn.	Fruct. Sem. Pl. 2: 133 (1790)
*Casearia multiflora*Spreng.	Pl. Min. Cogn. Pug. 2: 61 (1815)
*Lawsonia speciosa*L.	Sp. Pl. 1: 349 1753
L. inermis var. spinosa(L.) Pers.	Syn. Pl. 1: 405 (1805)
*Lawsonia alba var. flavescens*Hassk.	Flora 25(2, Beibl. 1): 34 (1842)
*Lawsonia alba var. miniate*Hassk.	Flora 25(2, Beibl. 1): 34 (1842)
Alkanna spinosa(L.) Gaertn.	Fruct. Sem. Pl. 2: 133 (1790)

L. inermis has a large number of vernacular names, which highlight its extensive cultural and medicinal use. It is "henna" or "Egyptian privet" in the English language [1]. It is named as "mehndi" in Urdu and Hindi, "mendi" in Gujarati and Marathi, and "maruthani" in Tamil. In the Arabic-speaking world, it is also known as "hina" or "henné." There are similar names given to it in Persian and Swahili cultures. As identified by [1], an array of vernacular names is employed throughout Asia and Africa, each signifying the plant's function in religious, cosmetic, and medicinal practices. Some examples include "inai" in Indonesian and Malay, "dan" in Burmese, "kaaw" in Lao, and "thian daeng" in Thai. Table 3 presents a list of these names to show the local vocabulary and cultural extent of L. inermis.

Table 3: Vernacular Names of L. inermisin Various Indian and Regional Languages

Language	Vernacular Name
Arabic	Hina
Persian	Hina
Bengali	Mehedi
English	HennaPlant,EgyptianPrivet
Gujarati	Mendi,Medi, Mendi
Hindi	Mehendi,Hena
Kannada	Gorante,Mayilanchi
Malayalam	Marutonni, Pontalasi
Kashmir	Mohuz
Marathi	Mendi,Mehndi, Mendhi
Oriya	Manjuati, Benjati
Punjabi	Hinna,Mehndi
Sanskrit	Kukravaka, Shahashara, Kokadanta, Mendika, Raktgarbha, Ragangi
Tamil	Marutonni, Aivanam, Marithondi, Maruthoni, Aivani, Korandam, Kurandagam, Kurinji, Pida
Telugu	Goranta, Gorata, Krommi, Kuravakammu, Maida, Pachapeddagoranta, Goranti
Urdu	Mehndi

4. Cultivation and Distribution

L. inermis, or henna, is a hardy plant species that withstands dryness and semi-desert conditions. The plant tends to grow up to a size of about six metres but can be kept in check at a shorter height by way of pruning, thereby maximising production of leaves as a harvest commodity, as has been observed by [50]. Ideal growth is achieved in sandy, drained soils under full sun and is particularly well-suited for tropical and subtropical environments. It is restricted in the colder areas by its frost sensitivity [50]. In the conventional farm environments, *L. inermis* is commonly planted on field borders or around residences and serves as both a protective hedge and a source of dye-producing leaves that are easily accessible. Its deep root system plays a key role in soil stabilisation in erosion-welded landscapes, also enhancing its ecological importance [36,50] observed that the plant is commonly cultivated by small-scale farmers without the need for sophisticated tools or mechanised agriculture, highlighting its contribution to sustainable, low-input agriculture. Geographically, *L. inermis* ranges over a large area, from North Africa to South and Southeast Asia, the Middle East, and segments of the Americas and Australia. It is widely cultivated in nations like India, Iran, Egypt, and Sudan, both for local consumption and international export, especially of its dried form, powdered leaves, for cosmetics and natural dye industries, making it economically significant.

5. Ethnobotanical Applications

L. inermis L., widely revered in traditional medicine, has been integrated for centuries into diverse healing systems, including Ayurveda, Unani, Persian medicine, African indigenous practices, and tribal healthcare across South Asia. Its therapeutic relevance spans nearly every plant part—leaves, flowers, bark, seeds, and roots—each offering distinct medicinal applications [35,40]. The leaves are the most frequently utilised, prepared as poultices or pastes to manage a variety of dermatological conditions such as wounds, ulcers, and infections. They are also formulated into decoctions or infusions for treating systemic ailments like fever, bronchitis, leukoderma, and migraines. Furthermore, *L. inermis* leaves are used traditionally as emmenagogues and diuretics and in the treatment of syphilitic ulcers, scabies, and amenorrhoea [35,40]. Their use in hair dyeing and body art further highlights the plant's cultural and cosmetic roles. The fragrant flowers of *L. inermis* are employed for their soothing properties, with flower infusions used to alleviate bruises and headaches and to stimulate menstruation. Their essential oils, known for their aromatic qualities, are often used in the formulation of traditional perfumes [30,35]. Bark extracts are prepared as pastes or decoctions to treat liver and spleen enlargement, jaundice, urinary complications, chronic dermal diseases, and leprosy, reflecting their internal and topical applications in folk medicine [30,41]. Henna seeds also possess medicinal value. According to [20], powdered seeds mixed with ghee are prescribed in traditional treatments for dysentery and liver disorders, likely owing to their deodorising and antimicrobial activity. The roots of *L. inermis* are traditionally administered to address sexually transmitted infections such as gonorrhoea and herpes and are also used for managing nervous system complaints and inflammatory eye conditions. [40] noted the use of root pulp for treating scalp boils in children, while root decoctions are consumed as diuretics in parts of Southeast Asia. Some ethnomedical records even mention their use as abortifacients when combined with indigo. Across cultural landscapes, *L. inermis* is prepared in various forms—pastes, oils, decoctions, or infusions—to address a spectrum of health conditions, from skin and metabolic disorders to gynaecological and neurological complaints. These time-honoured practices emphasise the plant's deep-rooted significance in ethnomedicine and its continuing value in integrative healthcare systems. Table 4. Ethnomedicinal applications of *L. inermis* across diverse geographic regions, highlighting plant parts used, traditional preparation methods, therapeutic uses, and associated healing systems.

Table 4: Ethnomedicinal Uses of L. inermis Across Different Cultures and Traditional Systems

Region / Culture	Plant Part Used	Mode of Use / Preparation	Application / Use	Ethnomedical System	Reference
India (Ayurveda)	Leaves, Bark	Paste, decoction	Skin diseases, burns, jaundice, leprosy	Ayurvedic	[9]
Gujarat & Rajasthan (Tribal)	Leaves, Root	Leaf poultice, oral powder	Joint pain, stomachache	Tribal Folk Medicine	[1]
Middle East	Leaves	Paste of powdered leaves	Body art, antifungal treatment	Cultural / Folk	[9]
Africa (North & East)	Leaves, Bark	Juice, decoction for skin application	Eczema, wounds, boils	African Traditional	[1]
Iran (Persian Medicine)	Seeds, Flowers, Leaves	Powder, infusion, paste	Fever, ulcers, headaches	Iranian Traditional	[9]
Pakistan (Rural)	Leaves	Paste, oil-based preparation	Hair care, cooling, sunstroke remedy	Ethnomedicine	[1]
Unani System	Bark, Seeds	Ointment, seed decoction	Wound healing, inflammation	Unani Medicine	[9]
Tamil Nadu & Kerala (India)	Leaves, Flowers	Leaf paste, flower tea	Hair dye, cooling effect, stress relief	Dravidian Cultural Practice	[1]
Bangladesh	Leaves	Paste, oil mixture	Dandruff, fungal infections	Folk / Cultural	[1]
Egypt	Leaves, Bark	Leaf paste, bark poultice	Mummification, inflammation, skin applications	Historical / Cultural	[9]
Southeast Asia (Indonesia, Malaysia)	Leaves, Roots	Leaf powder, root decoction	Skin allergy treatment, natural dyeing	Traditional / Cosmetic	[24]

6. Phytochemistry

L. inermis is a phytochemically dense species, distinguished by its diverse range of bioactive compounds which form the basis of its medicinal, cosmetic, and dyeing uses. The major active compound is lawsone (2-hydroxy-1,4-naphthoquinone), a naphthoquinone which occurs naturally and is responsible for the plant's distinctive red-orange colour and most of its pharmacological activities. Lawsone is found mainly in the leaves but has also been identified in flowers and stems. Another major compound is lawsonoside, a lawsonoside glycoside derivative. These compounds collectively constitute the biochemical foundation for the plant's historical application in skin, hair, and wound therapy. In addition to lawsone, *L. inermis* encompasses a broad range of secondary metabolites, such as flavonoids (apigenin, luteolin, kaempferol, and quercetin)—frequently present as glycosides. These secondary metabolites have potent antioxidant and anti-inflammatory activities. Phenolic compounds like gallic acid and coumarins are involved in free radical scavenging activity. Naphthoquinones like 1,4-naphthoquinone and structural analogues exhibit antimicrobial and cytotoxic activity. Terpenoids such as ursolic acid, betulinic acid, and arjunolic acid are known to possess anti-inflammatory and anticancer activity. Alkaloids and benzenoids add further variability to the plant's pharmacodynamic profile. *L. inermis*'s essential oil composition is very much geographically variable. Such oils are often comprised of apocarotenoids, oxygenated sesquiterpenes, and other volatiles that impart the aroma and bioactivity of the plant. Additionally, mineral analysis has found *L. inermis* leaves to be a source of iron, calcium, potassium, and phosphorus, further enhancing its nutritional and medicinal value. Interestingly, the phytochemical composition is different based on geographical location, conditions, and fresh or dried plant material [50]. Instead of trying to list all compounds found in *L. inermis*, this study highlights the primary constituents that are most directly connected with its pharmacological activity. Table 5 and Figure 2 consolidate the principal phytochemical classes and typical compounds isolated from various parts of the plant, highlighting the plant's chemical diversity and pharmacological promise.

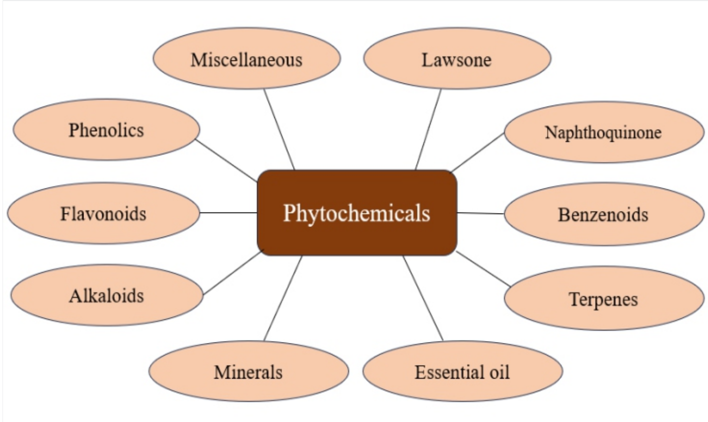

Figure 2: Various phytochemical groups present in the plant of L. inermis.

Table5: Phytochemicals and classes of various bioactive compounds present in L. inermis

Phytochemicals	Description	Reference
Miscellaneous	Leucocyanidin, epicatechin, catechin, and quercetin detected in the processed samples were consistent with those detected in the initial extracts. 2-hydroxy-1,4-naphthoquinone was the major pigment found in henna. Ultraviolet (UV) spectroscopy was applied to analyze the henna leaf extract. Spray drying of an aqueous henna extract by a co-current spray dryer yielded a fine brown powder with a yield of 33–35%. There were approximately 70 phenolic compounds identified in different parts of *L. inermis*. Lawsone, which is a naphthoquinone-based coloring agent, has been linked to various therapeutic advantages.	[49]
Lawsone	*L. inermis* contains 2-hydroxy-1,4-naphthoquinone (lawsone). HPLC analysis revealed that the extracts from its flowers, leaves, and branches contained 116.9, 486.2, and 5.4 μg/g (due to lower lawsone concentration in stems) of lawsone, respectively.	[9]
Naphthoquinone	Other derivatives of naphthoquinone, such as 1,3-dihydroxy naphthalene, 1,4-naphthoquinone, 1,2-dihydroxy-4-glucosyl naphthalene, and 1,2,4-trihydroxynaphthalene-2-O-β-D-glucopyranoside, were also extracted from the leaves of *L. inermis*.	[5,16]
Benzenoids	Most of the benzenoid derivatives, lawsoinermone, inermidioic acid, inermic acid, (E)-methyl 3-(4-hydroxyphenyl) acrylate, (E)-ethyl 3 (4-hydroxyphenyl) acrylate, caffeoyl alcohol, ethyl 2-methyl benzoate, benzene-1,2-dicarboxylic acid, monomethyl ortho phthalate, methyl 2-ethylbenzoate, methyl 2-methyl benzoate, and ethyl 2-methyl benzoate were extracted from the aerial part of *L. inermis*	[51]
Terpenes and non-terpene derivatives	Five triterpenes were isolated from the methanol extract of *L. inermis* leaves, which were rosamutin, euscaphic acid, 1b,2b,3b,19a-tetrahydroxyurs-12-en-28-oic acid, ursolic acid, and arjunic acid. The first four compounds were ursane-type triterpenes, whereas the fifth was found to be an oleane-type triterpene. Non-terpene derivatives were the major class of compounds in *L. inermis* essential oil, and their percentages were 78% in Malaysian samples, 53% in Nigerian samples, 40% in Ethiopian samples, and 19.8% in Tunisian samples.	[34] [24]
Phenols	The ethyl acetate fraction of *L. inermis* ethanolic leaf extracts had a total phenol content of 30.80±1.90 GAE/gm, while the total flavonoids were 79.16±2.72 GAE/gm of dried extracts. The petroleum ether fraction of *L. inermis* ethanolic leaf extracts had a total phenol content of 39.39±2.46 GAE/gm, with total flavonoids being 51.39±1.37 GAE/gm of dried extracts. On the other hand, the total phenols and flavonoids from chloroform fraction of the ethanolic extracts of *L. inermis* leaves were found to be 58.40±1.96 GAE/gm and 35±1.74 GAE/gm dry extract, respectively. Total phenolics of the hexane, chloroform, and methanolic henna seed extracts were found as 3.5±1.4, 55.7±2.44, and 457.5±3.4 g of gallic acid equivalent per Kg of dry weight, respectively. The overall flavonoids in hexane, chloroform, and methanolic extracts of henna seeds were 21.6±2.4, 120.7±3.9, and 199.9±2.1 mg of quercetin equivalent per kg of dry weight, respectively. Moreover, the overall tannins in hexane, chloroform, and methanolic extracts of henna seeds were 50.0±4.5, 93.7±3.9, and 28.0±3.5 mg of quercetin equivalent per kg of dry weight, respectively.	[31,41]

Flavonoids	Flavonoids extracted from *L. inermis* were: apigenin, apigenin-7 glucoside, apigenin-4-glycoside, apigenin-4'-O-β-D-glucopyranoside, luteolin, luteolin-7-glucoside, luteolin-3-glucoside, kampferol, quercetin, isoscutellarin, tricin, kaempferin, isoquercitrin and (-) catechin, 7-hydroxy-3,5-dimethoxy-6,8-dimethyl flavone, 3, 7, 4', 5' Tetrahydroxy-6-methoxyflavone and 4'-hydroxyflavanone.	[22,47]
Mineral analysis	A mineral profile of 25 *L. inermis* samples harvested from the coastal oases of Gabès in southeastern Tunisia indicated significant difference in mineral composition between stems and leaves. Sodium varied between 0.08% and 0.69% in the leaves and 0.08% and 0.46% in the stems. Potassium ranged between 0.16% and 0.47% in the leaves and between 0.15% and 0.81% in the stems. Calcium varied between 0.2% and 0.41% in leaves and 0.11% to 0.47% in stems, whereas magnesium levels varied between 0.09% and 0.23% in leaves and 0.03% to 0.11% in stems. Phosphorus varied significantly between 2.57% and 6.29% in leaves and 2.73% to 9.84% in stems. Copper levels varied between 0.06% and 1.87% in leaves and trace amounts up to 11.27% in stems. The zinc content varied from 0.47% to 2.92% in leaves and from 0.2% to 7.39% in stems. Iron varied from 4.03% to 28.77% in leaves and 1.17% to 15.85% in stems, and manganese varied from 0.27% to 1.28% in leaves and 0.14% to 0.95% in stems. Nitrogen varied dramatically from 0.14% to 4.72% in leaves and from 0.17% to 0.56% in stems.	[53]
Essential oil	Composition analysis of the essential oil obtained from *L. inermis* plants in Tunisia indicated that the most abundant class of compounds was apocarotenoids (33.6%). This was succeeded by non-terpenederivatives (19.8%), oxygenated sesquiterpenes (12.4%), monoterpene hydrocarbons (9.8%), sesquiterpene hydrocarbons (8.2%), oxygenated monoterpenes (5.6%), oxygenated diterpenes (3.0%), and diterpene hydrocarbons (1.6%). A detailed composition of the chemical constituents found in the essential oil and their corresponding percentages is: (E)-2-Hexanal (0.2%), Tricyclene (3.0%), Sabinene (1.0%), β-Pinene (0.1%), 6-Methyl-5-hepten-2-one (0.1%), Myrcene (0.5%), α-Terpinene (0.4%), p-Cymene (0.4%), Limonene (1.0%), (E)-β-Ocimene (0.2%), γ-Terpinene (1.0%), p-Cymenene (0.3%), Terpinolene (0.6%), Linalool (1.2%), N-Nonanal (0.6%), 1,3,8-p-Menthatriene (0.1%), cis-p-Mentha-2,8-dien-1-ol (0.3%), Camphor (0.2%), Trans-Verbenol (0.2%), Neroloxide (0.1%), (E)-2-Nonen-1-al (0.2%), Terpinen-4-ol (0.3%), Safranal (0.3%), N-Decanal (0.3%), Trans-Pulegol (1.0%), Trans-Carveol (0.3%), Cis-Pulegol (0.1%), Ascaridole (0.2%), Isobornyl Acetate (0.6%), Carvacrol (0.7%), Neryl Acetate (1.6%), α-Copaene (0.1%), Longifolene (0.1%), Dodecanal (0.2%), β-Caryophyllene (0.9%), Cis-Dictamol (0.2%), α-Guaiene (0.3%), Geranylacetone (13.4%), γ-Muurolene (0.2%), Germacrene (0.6%), (E)-β-Ionene (2.9%), Cis-β-Guaiene (0.5%), α-Muurolene (1.5%), (E,E)-α-Farnesene (0.9%), Trans-γ-Cadinene (1.2%), δ-Cadinene (1.5%), β-Thujaplicinol (3.3%), α-Cadinene (0.3%), (E)-Nerolidol (1.4%), Globulol (0.3%), Thujopsan-2-α-ol (1.1%), Cartol (0.4%), Guaiol (0.7%), 5-Epi-7-α-Eudesmol (2.2%), α-Acorenol (0.7%), β-Acorenol (0.3%), Epi-α-Cadinol (1.2%), α-Muurolol (0.2%), α-Cadinol (0.7%), Intermediol (0.2%), N-Tetradecanol (0.5%), β-Bisabolol (0.2%), Elemol Acetate (0.5%), α-Bisabolol (0.2%), Heptadecane (0.4%), (Z,E)-Farnesol (0.1%), (E,E)-Farnesol (0.5%), Tetranoic Acid (3.1%), (Z,E)-Farnesyl Acetate (0.2%), Khusinol Acetate (0.4%), Cyclopentadecanolide (0.2%), (E,E)-Farnesyl Acetate (1.5%), Hexahydrofarnesylacetone (11.5%), Farnesylacetone (5.5%), Methylhexadecanoate (1.3%), Phytol (2.0%), Hexadecanoic Acid (8.3%), Manoyloxide (1.0%), Abietatriene (0.5%), and Abietadiene (1.0%). This intricate profile illustrates the chemical variability and probable bioactivity of *L. inermis* essential oil.	[41]

7. Pharmacology

The pharmacological utility of *L. inermis* (henna) has been extensively illustrated via both in vivo and in vitro experiments. A body of literature spanning several decades has verified that various parts of the plant—including the leaves, but also flowers, seeds, bark, and roots—share a broad spectrum of biological activity. Such drug-like properties are primarily due to the availability of a broad spectrum of phytochemicals like lawsone, flavonoids, phenolics, and triterpenoids. The pharmacological activities seen in model systems are antioxidant, antimicrobial, anti-inflammatory, antidiabetic, wound-healing, and anticancer. All of these pharmacological effects are associated with certain classes of bioactive molecules, several of which are depicted and described in Figure 3. These figures give a pictorial account of the major therapeutic actions and the key molecules involved. This part will critically review the pharmacodynamic effects of *L. inermis*, highlighting the relationship between its chemical constituents and reported biological activities.

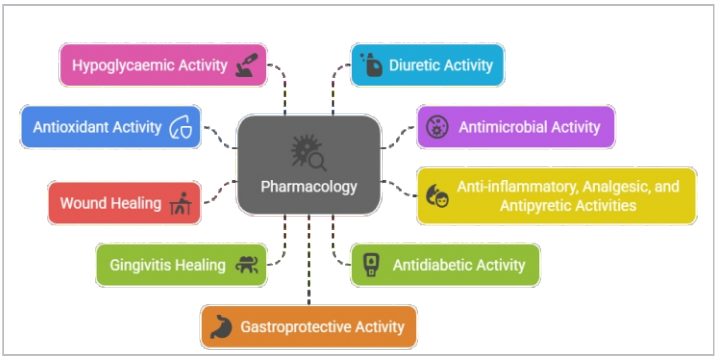

Figure 3: Pharmacological activities of L. inermis

7.1 Antioxidant Activity

The antioxidant activity of *L. inermis* has been widely demonstrated using various in vitro assays, particularly the DPPH and ABTS radical scavenging methods. [14] reported that among several extracts tested, the ethanolic and decoction preparations exhibited the most potent free radical scavenging effects, with IC_{50} values of 14.1 ± 0.5 mg/L and 13.0 ± 0.6 mg/L, respectively, in the DPPH assay. The ethyl acetate fraction also demonstrated notable activity (IC_{50} = 29.5 ± 0.8 mg/L), whereas the petroleum ether fraction showed comparatively lower efficacy. Similar trends were observed in ABTS radical scavenging assays. In another study, [36] evaluated the antioxidant and DNA-protective effects of aqueous leaf extracts of *L. inermis*. Their findings indicated DPPH and ABTS IC_{50} values of 352.77 μg/mL and 380.87 μg/mL, respectively. The extract also scavenged 59.75% of hydroxyl radicals in the deoxyribose degradation assay and conferred protection to plasmid DNA against oxidative damage. Further phytochemical exploration by [23] led to the isolation of a novel compound, 1,2,4-trihydroxynaphthalene-2-O-β-D-glucopyranoside (THNG), from the leaves. This compound exhibited significant antioxidant capacity and inhibited amyloid-β42 aggregation, suggesting potential neuroprotective properties. [19] assessed the antioxidant capacity of seed extracts using various solvents. The methanolic extract was the most effective, with IC_{50} values of 4.6 mg/L (DPPH) and 3.0 mg/L (ABTS), whereas the hexane and chloroform fractions were relatively inactive (IC_{50} > 100 mg/L). Interestingly, the petroleum ether fraction of ethanolic leaf extract showed antioxidant activity comparable to ascorbic acid (79.16 ± 0.98% vs. 78.07 ± 1.2%), followed by the ethyl acetate and chloroform fractions. Antioxidant efficacy was found to be concentration-dependent.

7.2 Antimicrobial Activity

The antimicrobial potential of *L. inermis* has been extensively documented across various geographic regions and microbial strains. In a study by [29], henna samples collected from different regions of Oman were tested against *Pseudomonas aeruginosa*, including the reference strain NCTC 10662 and eleven freshly isolated clinical strains. Among the tested samples, extracts from the Al Sharqiya region exhibited the most consistent and potent antibacterial activity across all isolates. Similarly, [27] evaluated the antibacterial efficacy of *L. inermis* leaf extracts against seven clinical bacterial isolates, including several gram-negative pathogens. Their results confirmed the antimicrobial promise of henna as a natural alternative to conventional antibiotics. [46] investigated the phytochemical constituents and antimicrobial activity of *L. inermis* to validate its traditional use in Ayurvedic medicine. Their findings demonstrated a clear dose-dependent inhibition of microbial growth, substantiating its classification as a "Rasayana" (rejuvenative agent) in classical Indian therapeutic systems. The underlying mechanisms of antimicrobial activity were further explored by [13], who attributed this property predominantly to the plant's rich flavonoid content. These bioactive compounds were proposed to exert their effects through mechanisms such as interference with bacterial cell cycles and induction of programmed cell death. Agar well diffusion assays confirmed the significant antibacterial activity of the flavonoid-rich methanolic extracts. [45] expanded on this by comparing extracts from in vitro- and in vivo-grown *L. inermis* plants. While both types showed antimicrobial activity, extracts from undifferentiated callus tissues lacked bioactive compounds, indicating that secondary metabolite production is closely linked to the developmental stage and tissue differentiation of the plant.

7.3 Anti-inflammatory, Analgesic, and Antipyretic Activities

The anti-inflammatory and analgesic activity of *L. inermis* has been explored with the use of animal models.

In one of the first pharmacological studies, [8] showed that ethanolic leaf extracts given orally, in doses of 0.25-2.0 g/kg, resulted in a dose-dependent decrease in inflammation, pain, and fever in rats. Sub-fractionation of the crude extract into butanol, chloroform, and aqueous fractions identified that the butanol and chloroform fractions were much more potent than the crude extract, with little activity detected in the aqueous fraction. The butanolic fraction administered at a 500 mg/kg dose exhibited a significant analgesic effect in experimental models. From the chloroform fraction, Alia and colleagues were able to purify a compound identified using chromatographic and spectroscopic methods as 2-hydroxy-1,4-naphthoquinone, otherwise known as lawsone. This compound showed marked anti-inflammatory, analgesic, and antipyretic activity, lending scientific credence to the use of the plant in traditional systems of healing. [28] went on to further detail the pharmacologically active constituents of L. inermis by isolating various crystalline compounds from its alcoholic extract. Of these, luteolin was isolated in a yield of 0.95% and recognised by its distinctive melting point of 237°C. Further purification of the extract provided traces of lawsone and two other significant compounds: laxanthone II (melting point of 180°C) and a 3-O-glucoside derivative of β-sitosterol, isolated in a yield of 1.87%. These results collectively exhibit the intricate phytochemical content of *L. inermis* and its application in the management of conditions related to inflammation.

7.4 Wound Healing

L. inermis ethanol extract (200 mg/kg/day) was assessed for wound healing potential in rats through the use of excision, incision, and dead space wound models. In the excision model, the animals were grouped into three groups of six and treated topically with the extract, while in the incision and dead space models, two groups of six rats were treated orally. The animals treated with extract exhibited a 71% reduction in wound area compared to a 58% reduction in the control group. Enhanced wound contraction, enhanced breaking strength of skin, enhanced hydroxyproline content, and favourable histological results all indicate the effectiveness of *L. inermis* in wound healing [42]. The research also confirmed that henna leaf extracts possess antimicrobial activity against microorganisms responsible for burn wound infection. Both chloroform and water extracts of *L. inermis* were screened against primary pathogens of burns, justifying their application in traditional medicine in treating and controlling burn infection [38]. The ethanol extract of *L. inermis* (administered at 200 mg/kg/day) was evaluated for wound healing in rats using excision, incision, and dead space wound models. The treated group of animals displayed a much larger percentage of contraction of the wound ($p<0.001$), decreased epithelialisation time ($p<0.001$), enhanced skin tensile strength ($p<0.001$), and improved weight of granulation tissue ($p<0.001$) and hydroxyproline ($p<0.05$) compared to control. Treated animals exhibited 71% wound area reduction relative to controls. Histological analysis on day 10 revealed more organised collagen fibres, increased fibroblast activity, and reduced inflammation in the treated group [42]. Plant material like Adiantum capillus-veneris, Commiphora molmol, Aloe vera, and henna was investigated in another study for its wound healing activity. Powdered dried resins and leaves were mixed with an equal volume of Vaseline to form an ointment, which was applied to wounds on 60 diabetic and non-diabetic rats. The findings showed a significant reduction in Mmp9 gene expression ($p<0.05$) in diabetic rats after 14 days, indicating quicker healing than in untreated groups [25]. Topical application of henna extract was found to possess excellent antibacterial, antifungal, and healing effects in a wound. In healing the diabetic foot, fissure and crack healing were enhanced by henna. A 1-gram dose of ground henna leaves mixed with 10 ml of distilled water was topically applied, covered, and left for 4–6 hours. The therapy created an extended moisture barrier, minimising repeated application [39]. Additionally, gelatin and oxidised starch-based bioactive nanofibres loaded with L. *inermis* were developed for second-degree burn wound treatment. In vivo results indicated that henna-loaded nanofibres significantly enhanced wound closure without inducing any adverse suppurative reactions. Immunohistochemical analysis of treated tissue demonstrated reduced inflammation and reduced macrophages in the wound site, confirming henna's healing and anti-inflammatory activities.

7.5 Gingivitis Healing

The anti-inflammatory effect of *L. inermis* on gingivitis has been shown in animal and human experiments. [52] examined the effects of methanolic leaf extracts of *L. inermis* in the management of chemically induced gingivitis in Sprague Dawley rats. Hydrogen peroxide 10% was used to induce gingival damage to the mandibular labial area. Comparison among three extract concentrations—62.500, 31.250, and 15.625 µg/ml—was made in the study. Although no significant statistical difference between L. inermis and povidone-iodine treatments was seen overall, the highest dose of extract significantly alleviated inflammatory cell infiltration and supported improved recovery of epithelial as well as connective tissues. The same research group also performed a clinical trial to evaluate the healing potential of *L. inermis* leaf infusion in patients with gingivitis. 63 subjects were all told to rinse with infusions at 50,000, 10,000, and 5,000 µg/ml concentrations, in addition to comparisons to a placebo and a 0.1% hexetidine solution. The henna infusion at the 10,000 µg/ml concentration resulted in an 80% decrease in the gingival bleeding index, marginally outdoing hexetidine, which had a 76% decrease. These results indicate that *L. inermis* leaf preparations can be used as a potential herbal adjunct in oral hygiene.

7.6 Antidiabetic Activity

The antidiabetic activity of *L. inermis* has been established by several in vivo studies using diabetic animal models. [50] studied the action of a hydroalcoholic extract of *L. inermis* given at doses of 100, 200, and 400 mg/kg in alloxan-induced diabetic rats and dyslipidemic rats. The maximum dose (400 mg/kg) resulted in a 39.08% decrease in blood glucose levels by day 21, demonstrating efficacy comparable to conventional antidiabetic drugs like glibenclamide and metformin. Apart from glycaemic control, the extract positively affected lipid metabolism, serum albumin, total plasma protein, and creatinine levels. Ankita et al. (2017) went on further to prove the plant's antidiabetic potential by evaluating the capacity of methanolic extract to inhibit amylase, a carbohydrate digesting enzyme. With a concentration level of 10 µg/mL, the extract inhibited amylase by 60.97%, suggesting an activity for minimizing postprandial hyperglycemia. There in vivo studies also established that administration with an ethanolic extract of 400 mg/kg body weight decreased blood glucose significantly in diabetic mice compared to control groups receiving no treatment. [3] assessed the effect of *L. inermis* leaf 70% ethanol extract in diabetic mice induced by alloxan. Administration of 0.8 g/kg body weight resulted in a remarkable decrease in blood glucose from 194 mg/dL to normal values within 14 days. Interestingly, total cholesterol reduced from 148.9 mg/dL to 55.3 mg/dL, and triglycerides reduced from 225.7 mg/dL to 76.9 mg/dL, highlighting the dual hypoglycaemic and hypolipidaemic activity of the extract.

7.7 Hypoglycaemic Activity

[11] conducted an experiment to test the influence of L. inermis (henna) leaves treated with ethanol on blood glucose levels and superoxide dismutase (SOD) enzyme activity in Wistar mice, employing a posttest-only control group design. The findings showed that blood glucose levels decreased significantly with respect to the control group. A slight increase in SOD activity was observed, but it was not statistically significant. The 400 mg/kg of the ethanolic extract significantly reduced blood glucose levels, while its activity toward SOD wasn't significantly different. [21] compared the hypoglycemic and antihyperglycemic activities of ethanolic L. inermis leaf extract in normal and streptozotocin-induced diabetic rats. Orally, they treated the animals with the extract for 28 days at concentrations of 150, 300, and 500 mg/kg body weight. A remarkable decrease in blood glucose was noted in diabetic rats that received the extract, especially at the 500 mg/kg dose, which proved to be stronger than glibenclamide (10 mg/kg), indicating strong anti-diabetic activity of the extract. In the same manner, [12] also reported that L. inermis significantly lowered hyperglycaemic and hypercholesterolaemic blood values in alloxan-induced diabetic mice. The extract also normalised the levels of glucose, triglycerides, and cholesterol in the blood. The study by [3] studied the effects of a 70% ethanol leaf extract of L. inermis on alloxan-induced diabetic mice' blood glucose, total cholesterol, and triglyceride levels. Following 14 days of therapy with a dose of 0.8 g/kg body weight, blood glucose levels decreased significantly, with decreases in total cholesterol and triglyceride levels.

7.8 Diuretic Activity

L. inermis leaf extracts' diuretic activities were tested by [18] using rodent models. Aqueous and ethanolic extracts were orally given at dosages of 250 mg/kg and 500 mg/kg. Both dosage levels yielded a significant dose-dependent increase in urine output, with the ethanolic extract performing better than the aqueous one at both dosages. Particularly, rats treated with the aqueous extract generated 4.6 ml and 6.1 ml of urine at 250 mg/kg and 500 mg/kg, respectively. Those treated with the ethanolic extract excreted 7.3 ml at 250 mg/kg and 9.0 ml at 500 mg/kg and showed a more potent diuretic effect. Electrolyte analysis also confirmed these results: in the aqueous extract group, sodium, potassium, and chloride levels rose from 113.8, 66.6, and 127.3 mEq/L (low dose) to 127.8, 73.6, and 155.6 mEq/L (high dose). Values in the ethanolic extract group increased even higher, from 120.5, 71.2, and 147.5 mEq/L to 136.2, 89.13, and 170.5 mEq/L, respectively. These results indicate that *L. inermis*—especially in ethanolic extract form—is a good diuretic with the additional advantage of stimulating electrolyte excretion and thus a candidate for herbal diuretic preparations.

7.9 Gastroprotective Activity

The gastric tissue protective activity of *L. inermis* has been confirmed in various experimental and clinical trials. [26] carried out an in vivo evaluation involving albino rats to evaluate the plant's gastroprotective activity against gastric damage. The results showed that *L. inermis* had a significant inhibitory effect on gastric juice volume, acidity, and ulceration. Of the various solvent extracts tried, the chloroform extract showed the greatest gastroprotective activity, superior to alcoholic and aqueous formulations. [37] highlighted that peptic ulcer disease (PUD), which involves lesions in the duodenal or stomach lining, is still a prevalent health condition worldwide. While traditional drugs such as proton pump inhibitors and H2 blockers are commonly applied, their side effects, particularly in combination with the use of NSAIDs, have generated interest in seeking plant-based substitutes. To substantiate its conventional application, [15] conducted a study of the effects of methanolic leaf extracts of *L. inermis* on gastric injury prevention. Their findings supported robust anti-ulcer potential, affirming its use in Indian folk and ethnomedicinal applications as a gastroprotective agent. Clinical evidence came from Davood [32], who tested topical henna usage in a randomised controlled trial involving 80 patients in the intensive care unit. Subjects were grouped into intervention and control groups. Intervention group subjects underwent henna treatments over the sacral region as part of standard ulcer prevention procedures. At the completion of the study, decubitus ulcers were found in six subjects of the control group, but no such occurrence was seen in the intervention group, demonstrating statistically significant protection and displaying henna's healing and ulcer-preventive effects.

7.10 Anticancer Activity

L. inermis has been studied for its anticancer activity in both in vitro and in vivo models. [2] assessed the plant's total methanolic extract's chemopreventive activity in a nitrosamine-induced mouse model of hepatocellular carcinoma. Both *L. inermis* and the control octreotide lowered tumour development by modulating oxidative stress and disturbing somatostatin receptor action. In a different study, [33] investigated various quinone compounds from *L. inermis*, including lawsone, juglone, arbutin, emodin, alizarin, and anthraquinones, for their antiproliferative activities againstHCT-15 human colon cancer cells. Naphthoquinones and anthraquinones were more active than monocyclic quinones, with half-maximal inhibitory concentrations (IC_{50}) < 12.5 µg/ml. Cell cycle analysis showed that lawsone and juglone arrested cells mainly in the S phase, while emodin arrested cell progression from G1 to S phase. Further screening by other researchers revealed the cytotoxic potential of fifteen flower-derived compounds from *L. inermis* against human cancer cell lines such as MCF-7, HeLa, HCT-116, and HT-29. Two particular compounds exceeded 5-fluorouracil—the positive control—in cytotoxicity, with IC_{50} values of 1.42 µM in HeLa cells and 2.24 µM in MCF-7 cells. Additionally, aqueous extracts of *L. inermis* leaves showed anticancer activity, particularly against COLO-205 colon cancer cells, with a GI_{50} value of 121.03 µg/ml. Seed extracts from hexane, chloroform, and methanol were assayed against HCT-116 cells, with the highest cytotoxic activity (IC_{50} = 45 mg/L) found in chloroform extracts, while hexane and methanolic extracts exhibited low activity (IC_{50} > 100 µg/ml). In vivo studies also confirmed the plant's antitumor activity. [44] administered *L. inermis* extract (10 mg/kg per day) to mice implanted with Ehrlich Ascites Carcinoma (EAC) for two weeks. The extract significantly increased survival and decreased viable tumour cell counts. Treated animals exhibited reduced gluteal tumour masses and higher levels of reduced glutathione (GSH), indicating antioxidant protection. The investigation suggested that henna's oxidative characteristics, including the formation of reactive oxygen species and modulation of intracellular pH, are likely responsible for its pro-apoptotic effects in cancer cells. [53] conducted a study with 70 Swiss albino female mice, allocating them to four treatment groups: tap water alone, *L. inermis* alone, EAC cells with tap water, and EAC cells with *L. inermis*. At the end of the study, *L. inermis* significantly decreased tumour burden and enhanced various biomarkers such as subcutaneous fat thickness, tumour diameter, pH, GSH level, and malondialdehyde (MDA) content in liver tissue. These findings support the candidacy of *L. inermis* as a natural adjuvant in cancer treatment through oxidative and apoptotic pathways.

7.11 Immunomodulatory Activity

This passage details the immunomodulatory effects of *L. inermis*, based on research conducted. The study used bioassay-guided fractionation of the leaf methanolic extract to isolate seven phytochemicals. Among these were three new compounds identified within the *Lawsonia* genus: p-coumaric acid, 2-methoxy-3-methyl-1,4-naphthoquinone, and apiin. The other compounds, such as lawsone, apigenin, luteolin, and cosmosiin, had previously been identified. The immunomodulatory potential of these isolated compounds was evaluated using an in vitro lymphocyte transformation assay, which measures immune cell proliferation. The results demonstrated that the compounds found in *L. inermis* leaves could modulate immune function, suggesting the plant's potential use in immunotherapeutic applications.

7.12 Contraceptive Potential

Experiments have proved that ethanolic extract from powdered henna seeds has antifertility activity. Subsequent studies showed that the application of henna leaves, either in suspension form or blended into the rat diet, also produces antifertility. Interestingly, the antifertility effect caused by the extract was irreversible and eventually resulted in sterility. Additional studies by [48] examined the antifertility activity of *L. inermis* root extract, which is among the most widely used plant parts in traditional contraception. Healthy male and female rats were employed in their research to assess different reproductive parameters such as body weight, mating ratio, pre-implantation rate, and number of corpora lutea. The findings included a decrease in body weight and a significant loss of implantation sites in the treated group versus the control. A dose-response relationship, which was significant, was found between the henna extract (and ethinyl oestradiol) and the number of implantation sites. Moreover, significant variation was found between the number of corpora lutea and the percentage of pre-implantation loss between both treated and control groups. The results confirm the conclusion that *L. inermis* shows strong antifertility activity, with a scientific basis to support its use as a natural contraceptive.

7.13 Pharmacokinetics

The pharmacokinetic profiling of *L. inermis* (henna) in biological systems remains underexplored, but its adsorptive and interactive properties have been studied in environmental and analytical contexts.

A number of studies suggest that the plant could have practical applications in fields like environmental remediation and pharmaceutical analysis. [43] explored the adsorption capacity of *L. inermis* wood-based activated carbon (LWAC) for the herbicide bentazon in a batch process. Their findings indicated that the adsorption process follows a pseudo-second-order kinetic model, suggesting a strong interaction between the adsorbent and the herbicide. Thermodynamic data supported the idea that the adsorption process is spontaneous and exothermic, with the negative values for Gibbs free energy (ΔG) and accompanying changes in enthalpy (ΔH) and entropy (ΔS). [17] investigated the potential of *L. inermis* biomass for the removal of zinc ions (Zn^{2+}) from aqueous solutions. Their research found that the plant's biomass could efficiently adsorb zinc, with the optimal removal achieved at a concentration of 0.2 g/L of biomass and at a specific pH. The adsorption process reached equilibrium within 60 minutes, proving *L. inermis*'s ability to act as a natural biosorbent for heavy metals, which can be applied in environmental cleanup efforts. developed a kinetic spectrophotometric method for detecting cefadroxil in pharmaceutical formulations using *L. inermis* leaf extract. In this assay, the leaf extract reacts with cefadroxil in an alkaline medium with potassium permanganate, yielding a yellow chromogen with absorbance at 410 nm. This method proved effective in measuring cefadroxil concentrations in commercial drug samples, highlighting the potential of *L. inermis* extract in analytical chemistry.

8. Work Conducted on *L. Inermis*

The bibliometric analysis of *L. inermis* (henna) research published between 2014 and 2025 reveals a dynamic and thriving academic landscape that spans multiple scientific disciplines. The analysis draws attention to several key aspects of the research ecosystem surrounding this plant, highlighting its growing significance in various fields. Key Findings: 1. Scope of Research: - Corpus Size: Out of an initial set of 16,827 journal articles, 1,067 were selected based on stringent criteria of scientific quality and relevance. - Published in 662 journals: These articles were spread across 662 peer-reviewed journals, signifying the interdisciplinary nature of *L. inermis* research. This diversity in publication outlets reflects the plant's broad relevance across multiple research fields. 2. Research Trends Over Time: - Time Frame: The 11-year period (2014–2025) provides a comprehensive view of the research trajectory, which is ideal for identifying trends and developments in scholarly attention and thematic focus. - Mean Publication Age: At 3.91 years, this suggests that most of the selected articles are recent, further indicating that *L. inermis* continues to be an active and relevant topic in ongoing scientific investigations. 3. Impact and Citations: - Citation Performance: On average, each article received 21.33 citations, with an annual citation rate of an average of 13.42 citations per year per publication. This indicates a strong academic impact and relevance in the scientific community. - High Citation Rates: The continued high citation rate suggests that *L. inermis* research is not only widely disseminated but also contributes significantly to subsequent scholarly work. 4. Thematic Diversity: - Keyword Analysis: The analysis yielded 11,120 unique keywords, illustrating the thematic variety and interdisciplinary nature of *L. inermis* studies. Key research areas include: - Pharmacology: Exploring the plant's therapeutic properties, especially in ethnomedicine. - Ethnobotany: The cultural and traditional uses of the plant in various regions. - Dermatology: Its applications in skincare, cosmetics, and treatment of dermatological conditions. - Cosmetic Science: Investigating the use of henna in beauty products. 5. Collaboration and Authorship: - Author Contributions: The study involved 9,966 unique researchers, with an average of 4.21 authors per paper. This signifies a collaborative research environment, with strong inter-institutional and interdisciplinary engagement. - Research Productivity: On average, each author published 15.95 articles, suggesting a sustained, high-output research trend. This may result from recurring collaborations and contributions from established scholars.

Table 6: Summary of Research Publications and Bibliometric Data on L. inermis (2014–2025)

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	2014-2025
Sources (Journals)	662
Articles selected	1067
Average years from publication	3.91
Average citations per article	21.33
Average citations per year	13.42
ARTICLE TYPES	
Journal papers	16827
ARTICLE CONTENTS	
Keywords	11120
AUTHORS	
Authors	9966
Authors per article	4.21
Articles per author	15.95

9. Conclusion and Future Perspectives

This in-depth review highlights the increasing significance of *L. inermis* L. (henna) as a bridge between traditional medicine and contemporary pharmacotherapy. Its long-documented history of use in ethnomedicine is increasingly substantiated by scientific data, especially in the areas of pharmacology, phytochemistry, and dermatology. Through thorough investigation of its bioactive profile, this publication confirms the validity of henna's traditional uses while pointing to its promise in the creation of affordable, plant-derived therapeutics for global health issues. The phytochemical diversity of *L. inermis*—ranging from lawsone, flavonoids, and terpenoids to phenolic acids—constitutes the biochemical foundation for its multifaceted therapeutic potentials. The antioxidant, antimicrobial, anti-inflammatory, wound-healing, antidiabetic, and anticancer activities of the plant have been supported by scientific evidence. Lawsone, in fact, has emerged as a potential lead compound for new drug research. In addition, the long history of use of the plant for cosmetic purposes, including natural hair colouring and protective skin products, adds to its applied interest. Its hardness of cultivation and adaptability to different climates make *L. inermis* an eco-friendly source of both medicinal and industrial applications. Even with these hopeful results, a number of limitations need to be overcome. A significant proportion of available evidence comes from in vitro experiments and animal studies, with sparse human clinical trials. Phytochemical content variability—due to environmental, geographic, and processing factors—provides challenges for reproducibility. In addition, the mechanism of action of many of the plant's components is not yet well understood, and extensive toxicological information regarding long-term consumption is not available. Standardisation of extraction methods and formulation procedures is also required to facilitate consistent results among studies. To advance the therapeutic application of *L. inermis*, future research should prioritise the isolation and characterisation of novel bioactive molecules.

Well-designed clinical trials are essential to confirm their efficacy and safety, particularly for chronic conditions such as cancer, diabetes, and inflammatory diseases. Investigating synergistic effects with other botanicals and employing nanotechnology-based delivery systems may enhance bioavailability and therapeutic outcomes, especially in antimicrobial and wound-healing contexts. Of equal significance is the creation of standardised cultivation regimens and formulation protocols to guarantee uniformity in quality and strength. Additional research into henna's contraceptive and immunomodulatory actions may uncover new pharmacological uses. Synthesising traditional ethnobotanical knowledge with stringent scientific protocols will be essential to solidifying *L. inermis* as a dependable, culturally relevant phytopharmaceutical agent in contemporary healthcare systems. Other promising directions involve the establishment of sustainable cultivation practices and standardisation procedures to provide consistent quality and potency. Investigations into henna's immunomodulatory and contraceptive activities can lead to new therapeutic agents. Lastly, the blending of traditional knowledge with contemporary scientific methods will be essential to maximise henna's role in global healthcare systems, possibly leading to the establishment of standardised phytopharmaceuticals while maintaining its cultural heritage.

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Conflict of Interest

The authors declare no conflict of interest.

Data Availability Statement

All data generated and analysed during this study are fully included in the manuscript. No additional datasets were created or used.

Author Contributions

CJ Conceptualization, Literature collection, Writing – Original Draft, Review and Editing, Figure and Table preparation. KS: Phytochemical data analysis, Literature validation, Writing – Pharmacology Section, References formatting.KNO: Ethnobotanical data compilation, Review of traditional medicine content, Critical Revision of the manuscript.BAJ: Supervision, Final Manuscript Review, Scientific Guidance, and Overall Project Administration. All authors have read and approved the final manuscript.

AI Assistance Statement

AI assistance was used solely for language enhancement, grammar refinement, and improving the readability of the manuscript. No AI-generated content was included in the research design, data analysis, or interpretation of results.

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