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Leucas lavandulifolia Sm. (Lamiaceae): An updated review of traditional uses, phytochemistry, pharmacological activities and therapeutic potential

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Abstract
Leucas lavandulifolia Sm. (Family: Lamiaceae) is an aromatic annual medicinal herb widely distributed throughout tropical and subtropical Asia, particularly across the Indian subcontinent. The species has long been utilized in Ayurveda, Siddha, folk medicine, and ethnoveterinary practices for treating fever, respiratory ailments, headache, skin diseases, gastrointestinal disorders, snakebite, inflammation, and nervous disorders. Phytochemical investigations have revealed the presence of numerous bioactive constituents, including terpenoids, flavonoids, phenolic compounds, sterols, triterpenoids, glycosides, essential oils, fatty acids, and volatile constituents that contribute to its diverse pharmacological activities. Experimental studies have demonstrated antimicrobial, antifungal, anti-inflammatory, antioxidant, antiprotozoal, antispasmodic, antiviral, insecticidal, anthelmintic, and central nervous system depressant activities. Recent advances in chromatographic analysis, metabolomics, molecular pharmacology, and biotechnology have further improved understanding of its therapeutic potential. However, despite promising preclinical evidence, comprehensive phytochemical standardization, toxicity evaluation, pharmacokinetic investigations, and clinical validation remain limited. The present review critically compiles published literature from 2000–2025 together with classical reports to provide an updated overview of the taxonomy, botanical description, geographical distribution, ethnomedicinal importance, phytochemistry, pharmacological activities, safety aspects, and future research prospects of *L. lavandulifolia*. The review highlights the importance of this medicinal herb as a promising source of novel phytopharmaceuticals and identifies future research priorities for evidence-based therapeutic applications.

Keywords: *Leucas lavandulifolia*, Lamiaceae, ethnomedicine, phytochemistry, essential oil, bioactive compounds, herbal therapeutics

Introduction

Medicinal plants continue to play an indispensable role in global healthcare, with nearly 80% of the world's population relying partly on traditional herbal medicines for primary healthcare needs. Among these medicinal resources, members of the family Lamiaceae occupy a prominent position because of their rich diversity of essential oils, terpenoids, phenolic compounds, and flavonoids possessing considerable therapeutic value (WHO, 2023) [9].

The genus *Leucas* comprises approximately 80–116 species distributed mainly in tropical Africa, Asia, and Australia, with India representing one of the major centers of diversity. Numerous species of the genus have been extensively employed in traditional medicine for the treatment of fever, respiratory disorders, wounds, inflammatory diseases, gastrointestinal disturbances, skin infections, diabetes, rheumatism, and snakebite. Phytochemical investigations have identified more than 140 natural products from different *Leucas* species, including terpenoids, flavonoids, lignans, phenolic glycosides, sterols, fatty acids, and essential oils that contribute to their broad pharmacological activities.

Leucas lavandulifolia Sm. is one of the important medicinal species of this genus and has been traditionally used throughout India for managing fever, headache, common cold, loss of appetite, gastrointestinal disorders, dermatoses, nervous disorders, and snakebite. Classical medicinal literature reports that roasted leaves are administered as febrifuge, while crushed leaves and leaf decoctions are used as stomachic, vermifuge, sedative, and topical remedies for skin diseases.

Scientific investigations have validated several of these traditional applications by demonstrating antimicrobial, antifungal, anti-inflammatory, antioxidant, antispasmodic, antiprotozoal, antiviral, insecticidal, and central nervous system depressant activities. Nevertheless, comprehensive phytochemical characterization, molecular mechanism studies, clinical investigations, and pharmaceutical standardization remain relatively limited compared with other medicinal plants.

The present review critically summarizes available scientific evidence published between 2000 and 2025 together with classical literature to provide an updated account of the taxonomy, botanical description, geographical distribution, ethnomedicinal significance, phytochemistry, pharmacological activities, toxicity, and future pharmaceutical prospects of *Leucas lavandulifolia*.

Botanical Description and Taxonomy

Leucas lavandulifolia Sm. belongs to the family Lamiaceae, one of the largest families of aromatic medicinal plants, comprising approximately 236 genera and over 7,000 species worldwide (Harley *et al*., 2004) [7]. The genus *Leucas* consists of nearly 80 species distributed mainly in tropical Africa and Asia, with India representing one of its major centers of diversity (Kumar *et al*., 2023) [9].

Taxonomic Classification

Kingdom: Plantae
Division: Tracheophyta
Class: Magnoliopsida
Order: Lamiales

Family: Lamiaceae
Genus: *Leucas* R.Br.
Species: *Leucas lavandulifolia* Sm.

Synonym: *Leucas linifolia* (Roth) Spreng.
Leucas lavandulifolia is an erect, aromatic annual herb that usually grows between 20 and 60 cm in height. The stem is quadrangular, branched, and densely pubescent, which is characteristic of members of the family Lamiaceae (Harley *et al*., 2004) [7]. Leaves are opposite, sessile or subsessile, narrowly lanceolate to linear-lanceolate, measuring approximately 2–8 cm long, with entire or slightly serrated margins and acute apices. Numerous glandular trichomes distributed over the aerial parts produce volatile essential oils responsible for the characteristic aroma of the plant (Kumar *et al*., 2023) [9].

Flowers are white, bisexual, zygomorphic, and arranged in dense axillary verticillasters. The tubular calyx is persistent and ribbed, terminating in numerous narrow teeth, whereas the corolla is bilabiate with a densely hairy upper lip and a distinctly trilobed lower lip. The androecium consists of four didynamous stamens, while the superior ovary develops into four Smooth brown nutlets enclosed within the persistent calyx after fertilization (POWO, 2025).

Microscopically, the leaves exhibit a single-layered epidermis bearing abundant multicellular covering trichomes together with capitate and peltate glandular trichomes. Diacytic stomata, dorsiventral mesophyll, collateral vascular bundles, calcium oxalate crystals, and secretory oil glands represent important pharmacognostic characteristics useful for authentication and quality control of crude herbal drugs (Evans, 2009; Kumar *et al*., 2023) [4, 9].

Distribution and Habitat

Leucas lavandulifolia is indigenous to tropical and subtropical Asia and is widely distributed throughout India, Bangladesh, Nepal, Sri Lanka, Myanmar, Thailand, southern China, Malaysia, Indonesia, and the Philippines (POWO, 2025). Owing to its remarkable ecological adaptability, the species has also become naturalized in several African countries and northern Australia (Kumar *et al*., 2023) [9].

In India, the plant is widely distributed from the Himalayan foothills to peninsular India and occurs abundantly in Maharashtra, Gujarat, Rajasthan, Madhya Pradesh, Uttar Pradesh, Bihar, Odisha, West Bengal, Karnataka, Tamil Nadu, Kerala, Andhra Pradesh, Telangana, Assam, and other northeastern states (Nadkarni, 1954; Chopra *et al*., 1956) [3, 11]. The uploaded historical literature also describes the species as a common herb throughout the Indian plains and highlights its widespread medicinal use among rural communities.

The species commonly grows in open grasslands, cultivated fields, roadsides, wastelands, scrub forests, village commons, and disturbed habitats. It prefers well-drained sandy loam or loamy soils under full sunlight and grows successfully in regions receiving moderate rainfall with temperatures ranging from 20–35°C. The plant usually occurs from sea level up to approximately 1,500 m altitude and completes its life cycle during the rainy season (POWO, 2025; Kumar *et al*., 2023) [9].

Its rapid growth, prolific seed production, and tolerance to drought and nutrient-deficient soils enable *L. lavandulifolia* to establish stable populations in diverse ecological habitats. Despite its widespread occurrence, habitat degradation, indiscriminate harvesting, and changing land-use patterns may threaten local populations, emphasizing the need for sustainable harvesting and conservation strategies (WHO, 2023) [9].

Ethnomedicinal Uses

Leucas lavandulifolia occupies an important position in Ayurveda, Siddha, folk medicine, and ethnoveterinary healthcare systems owing to its broad spectrum of therapeutic applications. Traditional healers employ the leaves, flowers, stems, roots, and whole plant for treating fever, headache, respiratory disorders, gastrointestinal diseases, inflammatory conditions, skin infections, wounds, and snakebite (Chopra *et al*., 1956; Nadkarni, 1954) [3, 11].

In traditional Indian medicine, roasted leaves are administered as a febrifuge for the treatment of intermittent fever, whereas fresh leaf juice is used as a stomachic and vermifuge. Leaf decoctions are widely prescribed for cough, bronchitis, common cold, asthma, sore throat, diarrhea, dysentery, abdominal pain, and loss of appetite (Jain, 1991) [8]. The historical literature further reports that the plant has long been used as an antipyretic, stimulant, expectorant, and remedy for skin diseases and intestinal disorders.

External application of crushed leaves or leaf paste is a common traditional practice for managing wounds, boils, eczema, psoriasis, ringworm, insect bites, and inflammatory swellings because of the plant's antimicrobial and wound-healing properties (Kumar *et al*., 2023) [9]. Traditional formulations prepared by mixing *L. lavandulifolia* with *Curcuma longa*, *Rubia cordifolia*, and *Brassica campestris* have also been reported for the treatment of migraine, chronic headache, and snakebite in several indigenous communities (Sharma *et al*., 2012) [13].

Ethnoveterinary surveys have documented the use of leaf poultices for wound healing in livestock and decoctions as an anthelmintic and insect repellent. The aromatic foliage is also traditionally employed to repel mosquitoes and other household insects, reflecting the insecticidal potential of its volatile constituents (Kumar *et al*., 2023) [9].

Recent pharmacological investigations strongly support several traditional claims by demonstrating antimicrobial, antioxidant, anti-inflammatory, analgesic, antidiarrheal, antispasmodic, insecticidal, and wound-healing activities of different extracts and isolated phytochemicals. Nevertheless, well-designed clinical studies are still required to establish standardized dosage regimens, safety profiles, and therapeutic efficacy in humans (Kumar *et al*., 2023) [9].

Phytochemistry

Leucas lavandulifolia Sm. is recognized as a rich source of structurally diverse phytochemicals that contribute significantly to its ethnomedicinal importance and pharmacological activities. Phytochemical investigations carried out over the last several decades have demonstrated that different plant parts—including leaves, flowers, stems, roots, and the aerial parts—contain numerous classes of secondary metabolites such as terpenoids, flavonoids, phenolic compounds, alkaloids, sterols, triterpenoids, glycosides, tannins, saponins, essential oils, and fatty acids (Kumar *et al*., 2023; Sharma *et al*., 2012) [9, 13]. These bioactive constituents are largely responsible for the antioxidant, antimicrobial, anti-inflammatory, insecticidal, and hepatoprotective properties of the plant.

Preliminary phytochemical screening of methanolic, ethanolic, chloroform, petroleum ether, and aqueous extracts has consistently confirmed the presence of flavonoids, steroids, diterpenes, triterpenoids, tannins, carbohydrates, proteins, amino acids, glycosides, and volatile oils, while the concentration and composition vary depending on geographical origin, developmental stage, extraction solvent, and environmental conditions (Evans, 2009; Kumar *et al*., 2023) [4, 9]. The historical literature also reports the occurrence of sterols, triterpenoids, diterpenes, flavonoids, and long-chain aliphatic compounds in different parts of the plant.

Flavonoids constitute one of the most important classes of bioactive compounds identified in *L. lavandulifolia*. Chromatographic investigations have isolated apigenin, luteolin, quercetin, chrysoeriol, and their glycosidic derivatives, which exhibit remarkable antioxidant, anti-inflammatory, antimicrobial, and free radical scavenging activities (Kumar *et al*., 2023) [9]. These flavonoids contribute to membrane stabilization, inhibition of lipid peroxidation, and modulation of inflammatory signaling pathways, thereby supporting many of the traditional medicinal uses of the plant.

Terpenoids represent another major phytochemical group occurring in the species. Several diterpenes and triterpenes have been isolated from the aerial parts, while phytosterols such as β-sitosterol, stigmasterol, and campesterol have been reported from leaves and stems (Harborne, 1998) [6]. Pentacyclic triterpenoids including ursolic acid and oleanolic acid are particularly noteworthy because of their anti-inflammatory, antimicrobial, hepatoprotective, and anticancer activities. Earlier phytochemical investigations also identified compounds belonging to the diterpene and triterpene classes from the aerial parts of the plant.

The essential oil of *L. lavandulifolia* has attracted considerable scientific interest because of its medicinal and aromatic properties. Gas chromatography–mass spectrometry (GC–MS) analyses have identified numerous volatile constituents, including β-caryophyllene, germacrene D, α-pinene, β-pinene, limonene, linalool, α-humulene, caryophyllene oxide, and other oxygenated monoterpenes and sesquiterpenes (Kumar *et al*., 2023) [9]. These volatile constituents are primarily responsible for the characteristic aroma of the plant and contribute significantly to its antimicrobial, insecticidal, antifungal, and antioxidant activities.

Phenolic compounds constitute another important group of secondary metabolites. High-performance liquid chromatography (HPLC) and liquid chromatography–mass spectrometry (LC–MS) investigations have demonstrated the occurrence of phenolic acids such as gallic acid, caffeic acid, chlorogenic acid, ferulic acid, p-coumaric acid, and rosmarinic acid. These compounds exhibit strong antioxidant activity by scavenging reactive oxygen species, preventing oxidative damage, and protecting cellular biomolecules from free radical-mediated injury (Kumar *et al*., 2023) [9].

Phytochemical studies have also reported the presence of tannins, saponins, reducing sugars, amino acids, proteins, carbohydrates, and fixed oils in different plant organs. Although these constituents are generally regarded as primary metabolites, they may contribute synergistically to the overall therapeutic efficacy of the crude herbal preparations by enhancing antioxidant capacity, improving antimicrobial activity, and modulating immune responses (Evans, 2009) [4].

Recent advances in analytical chemistry have considerably improved the characterization of phytoconstituents in *L. lavandulifolia*. Sophisticated techniques including HPLC, UHPLC, GC–MS, LC–MS/MS, Fourier-transform infrared spectroscopy (FTIR), nuclear magnetic resonance (NMR), and metabolomic profiling have enabled the identification of numerous previously unreported compounds and facilitated chemotaxonomic comparisons among different *Leucas* species (Kumar *et al*., 2023) [9]. These analytical approaches have also contributed to quality control, authentication, and standardization of herbal materials intended for pharmaceutical use.

The phytochemical diversity of *L. lavandulifolia* provides a scientific basis for its broad spectrum of biological activities. Nevertheless, quantitative variation in metabolite composition due to geographical distribution, climatic conditions, harvesting season, and extraction methodology remains a significant challenge for the development of standardized herbal formulations. Therefore, future research should focus on metabolomic standardization, chemometric analysis, bioactivity-guided fractionation, and isolation of novel bioactive constituents to facilitate the development of evidence-based phytopharmaceuticals.

Pharmacognosy

Pharmacognostic evaluation is essential for the authentication, standardization, and quality control of herbal drugs derived from *Leucas lavandulifolia* Sm. Accurate identification of the crude drug is particularly important because several *Leucas* species exhibit similar morphological characteristics and are frequently substituted or adulterated in herbal markets. Therefore, detailed macroscopic, microscopic, physicochemical, and phytochemical characterization provides reliable criteria for ensuring the purity, identity, and quality of plant materials intended for medicinal use (Evans, 2009; WHO, 2011) [4, 15].

1. Macroscopic Characteristics

Leucas lavandulifolia is an erect, aromatic annual herb measuring approximately 20–60 cm in height. The stem is quadrangular, green to purplish-green, branched, and densely covered with multicellular hairs. Leaves are opposite, sessile or subsessile, linear-lanceolate to narrowly elliptic, measuring about 2–8 cm long and 0.3–1.5 cm wide, with acute apices, entire or slightly serrulate margins, and a pubescent surface. The leaves emit a characteristic aromatic odor owing to the presence of volatile essential oils (Harley *et al*., 2004; Kumar *et al*., 2023) [7, 9].

The flowers are white, bisexual, and arranged in dense axillary verticillasters. The calyx is tubular, persistent, pubescent, and distinctly ribbed with 8–10 narrow teeth. The corolla is bilabiate, with a hood-shaped upper lip and trilobed lower lip typical of members of the family Lamiaceae. The fruit consists of four smooth, oblong brown nutlets enclosed within the persistent calyx. Flowering and fruiting usually occur from July to November under Indian climatic conditions (POWO, 2025).

2. Microscopic Characteristics

Microscopic examination reveals several diagnostic anatomical features that facilitate the authentication of *L. lavandulifolia*. The leaf possesses a single-layered epidermis covered with a thick cuticle and bears numerous multicellular covering trichomes together with capitate and peltate glandular trichomes responsible for essential oil secretion. Diacytic stomata are confined predominantly to the lower epidermis, a characteristic feature of the family Lamiaceae (Metcalfe & Chalk, 1979).

The mesophyll is dorsiventral, differentiated into a single layer of elongated palisade cells beneath the upper epidermis and several layers of loosely arranged spongy parenchyma toward the lower surface. Numerous collateral vascular bundles are embedded within the mesophyll and surrounded by parenchymatous bundle sheaths. Calcium oxalate crystals, starch grains, and oil-containing secretory cells are occasionally observed in the cortical tissues (Evans, 2009) [4].

The stem transverse section exhibits a quadrangular outline with prominent collenchymatous patches beneath each ridge. The cortex is composed of chlorenchymatous and parenchymatous tissues followed by a distinct endodermis. The vascular bundles are collateral and arranged in a continuous ring enclosing a large parenchymatous pith. Abundant glandular trichomes and multicellular covering hairs are distributed over the epidermis and serve as important diagnostic features (Metcalfe & Chalk, 1979).

Root anatomy reveals a well-developed cork, broad cortical region, secondary phloem, xylem vessels, fibers, and medullary rays. The presence of lignified vessels and calcium oxalate crystals contributes to the pharmacognostic identification of the crude drug.

3. Powder Characteristics

Powder microscopy provides an important tool for detecting adulteration in powdered herbal materials. Powdered leaves and aerial parts of *L. lavandulifolia* are greenish-brown in color, aromatic in odor, and slightly bitter in taste. Microscopic examination of the powder reveals fragments of epidermis with diacytic stomata, multicellular covering trichomes, capitate and peltate glandular trichomes, spiral and reticulate xylem vessels, lignified fibers, pollen grains, calcium oxalate crystals, starch grains, and fragments of parenchymatous tissues. These features serve as characteristic diagnostic markers for routine quality control (WHO, 2011) [15].

4. Physicochemical Standards

Physicochemical evaluation is an essential component of herbal drug standardization. Parameters commonly determined include total ash, acid-insoluble ash, water-soluble ash, sulphated ash, loss on drying, moisture content, alcohol-soluble extractive value, water-soluble extractive value, pH, swelling index, and foreign organic matter. These quality control parameters provide valuable information regarding the purity, identity, and quality of crude herbal drugs while minimizing the risk of adulteration (WHO, 2011; Evans, 2009) [4, 15].

Fluorescence analysis of powdered plant material treated with different chemical reagents under visible and ultraviolet light has also been recommended as a rapid method for authentication of *Leucas* species.

5. Chromatographic Fingerprinting

Recent advances in chromatographic techniques have significantly improved pharmacognostic evaluation of *L. lavandulifolia*. High-performance thin-layer chromatography (HPTLC), high-performance liquid chromatography (HPLC), gas chromatography–mass spectrometry (GC–MS), liquid chromatography–mass spectrometry (LC–MS/MS), Fourier-transform infrared spectroscopy (FTIR), and nuclear magnetic resonance (NMR) spectroscopy are now routinely employed for qualitative and quantitative analysis of marker compounds (Kumar *et al*., 2023) [9].

Chromatographic fingerprinting enables identification of flavonoids, phenolic acids, terpenoids, sterols, and essential oil constituents while ensuring batch-to-batch consistency of herbal formulations. Such analytical approaches also facilitate detection of adulterants and substitution with closely related *Leucas* species.

6. Quality Control and Standardization

The increasing commercialization of herbal medicines necessitates stringent pharmacognostic quality control of *L. lavandulifolia*. Standardization should include botanical authentication, organoleptic evaluation, microscopic examination, physicochemical profiling, chromatographic fingerprinting, estimation of bioactive marker compounds, microbial load assessment, pesticide residue analysis, heavy metal determination, aflatoxin screening, and DNA barcoding for unequivocal species identification (WHO, 2011).

Modern quality assurance protocols integrating pharmacognosy, phytochemistry, molecular biology, and analytical chemistry provide reliable tools for developing standardized herbal formulations with consistent therapeutic efficacy and safety.

Pharmacological Activities

Leucas lavandulifolia Sm. has attracted considerable scientific attention because of its broad spectrum of biological activities, many of which substantiate its traditional medicinal uses. Pharmacological investigations conducted over the past three decades have demonstrated that extracts and isolated phytoconstituents from the leaves, aerial parts, stems, flowers, and whole plant possess antimicrobial, antioxidant, anti-inflammatory, analgesic, antipyretic, antidiarrheal, antispasmodic, antiprotozoal, insecticidal, hepatoprotective, neuropharmacological, and wound-healing properties. These biological activities are largely attributed to the presence of flavonoids, terpenoids, phenolic acids, sterols, triterpenoids, glycosides, and volatile essential oils (Kumar *et al*., 2023; Sharma *et al*., 2012) [9, 13].

1. Antimicrobial Activity

Antimicrobial activity is one of the most extensively investigated pharmacological properties of *L. lavandulifolia*. Methanolic, ethanolic, chloroform, petroleum ether, and aqueous extracts have demonstrated inhibitory activity against several Gram-positive and Gram-negative bacteria, including *Staphylococcus aureus*, *Bacillus subtilis*, *Escherichia coli*, *Salmonella typhi*, *Pseudomonas aeruginosa*, and *Klebsiella pneumoniae* (Kumar *et al*., 2023) [9]. The plant has also exhibited antifungal activity against *Candida albicans*, *Aspergillus niger*, and *Trichophyton* species. These antimicrobial effects are mainly attributed to flavonoids, phenolic compounds, and essential oil constituents such as β-caryophyllene, α-pinene, and limonene, which disrupt microbial cell membranes and interfere with metabolic processes.

2. Antioxidant Activity

Oxidative stress is implicated in numerous chronic diseases, including cardiovascular disorders, diabetes, neurodegenerative diseases, and cancer. Extracts of *L. lavandulifolia* possess remarkable antioxidant activity as demonstrated by DPPH, ABTS, FRAP, nitric oxide, hydroxyl radical, and superoxide radical scavenging assays (Kumar *et al*., 2023) [9]. The antioxidant potential is primarily associated with flavonoids, phenolic acids, tannins, and terpenoids, which neutralize reactive oxygen species, inhibit lipid peroxidation, and enhance endogenous antioxidant enzymes such as superoxide dismutase, catalase, and glutathione peroxidase.

3. Anti-inflammatory Activity

Inflammation represents one of the principal therapeutic targets of traditional *Leucas* preparations. Experimental studies have demonstrated that methanolic and ethanolic extracts significantly inhibit carrageenan-induced paw edema, cotton pellet granuloma formation, and other experimental models of inflammation (Kumar *et al*., 2023) [9]. The anti-inflammatory activity is mediated through inhibition of cyclooxygenase (COX), lipoxygenase (LOX), nitric oxide synthesis, and pro-inflammatory cytokines such as TNF-α, IL-1β, and IL-6. Flavonoids including apigenin and luteolin together with triterpenoids are considered the major anti-inflammatory constituents.

4. Analgesic and Antinociceptive Activity

The plant has traditionally been used to relieve headache, body pain, rheumatism, and inflammatory disorders. Experimental investigations have confirmed significant analgesic and antinociceptive activity using acetic acid-induced writhing, formalin-induced pain, and hot-plate models. Ahmed *et al*. (2001) [1] demonstrated that methanolic extracts of *L. lavandulifolia* significantly reduced nociceptive responses in experimental animals, supporting its traditional use as a pain-relieving herb. The uploaded historical literature also reports pronounced antinociceptive activity of the plant.

5. Antipyretic Activity

Traditional medical systems recommend roasted leaves and leaf decoctions for the treatment of fever. Pharmacological studies have confirmed significant antipyretic activity in experimentally induced pyrexia models, where plant extracts effectively reduced elevated body temperature. This activity is believed to result from inhibition of prostaglandin synthesis within the hypothalamic thermoregulatory center, thereby validating its traditional use as a febrifuge (Sharma *et al*., 2012) [13].

6. Antidiarrheal and Gastroprotective Activity

In Ayurveda and folk medicine, *L. lavandulifolia* is frequently prescribed for diarrhea, dysentery, abdominal pain, indigestion, and intestinal disorders. Experimental studies have demonstrated that aqueous and alcoholic extracts significantly reduce intestinal motility, intestinal secretion, and castor oil-induced diarrhea in laboratory animals (Kumar *et al*., 2023) [9]. Flavonoids and tannins likely contribute to these effects through modulation of intestinal smooth muscle activity and reduction of gastrointestinal inflammation.

7. Antiprotozoal and Antimalarial Activity

Several investigations have demonstrated antiprotozoal activity of *L. lavandulifolia* against pathogenic protozoa. Extracts have shown inhibitory effects against *Plasmodium* species and other protozoan parasites, suggesting potential application in tropical infectious diseases. The historical literature also documents antiprotozoal activity among the important biological properties of the plant. Further isolation of active compounds and mechanistic studies are necessary before clinical application.

8. Insecticidal and Mosquito Repellent Activity

The aromatic essential oils of *L. lavandulifolia* possess insecticidal and mosquito-repellent properties. Laboratory studies have demonstrated larvicidal and repellent activity against mosquitoes and agricultural insect pests. Volatile constituents including monoterpenes and sesquiterpenes interfere with insect nervous systems, making the plant a promising candidate for environmentally friendly botanical pesticides (Kumar *et al*., 2023) [9].

9. Hepatoprotective Activity

Recent investigations suggest that extracts of *L. lavandulifolia* protect hepatic tissues against experimentally induced oxidative damage by reducing lipid peroxidation and improving antioxidant defense systems. Flavonoids and phenolic compounds stabilize hepatocyte membranes and decrease serum biomarkers of liver injury, indicating potential use in managing hepatic disorders (Kumar *et al*., 2023) [9].

10. Neuropharmacological Activity

Traditional communities employ *L. lavandulifolia* for headache, nervous disorders, and insomnia. Experimental studies have reported mild central nervous system depressant, anxiolytic, and sedative effects, possibly mediated through modulation of γ-aminobutyric acid (GABA)-ergic neurotransmission. These observations support several ethnomedicinal applications but require further pharmacological and clinical validation (Sharma *et al*., 2012) [13].

11. Wound-Healing Activity

Leaf paste and fresh juice are widely applied to wounds, ulcers, burns, boils, eczema, and skin infections. Experimental wound models indicate that topical application of plant extracts accelerates wound contraction, collagen synthesis, angiogenesis, and epithelial regeneration while simultaneously reducing microbial contamination and oxidative stress (Kumar *et al*., 2023) [9]. These findings scientifically support the traditional external use of the plant.

12. Other Biological Activities

Various studies have reported additional biological activities including antifungal, antiviral, anthelmintic, immunomodulatory, antiulcer, and cytotoxic effects. Although many of these investigations remain preliminary, they indicate that *L. lavandulifolia* possesses considerable therapeutic potential. Modern approaches involving molecular docking, metabolomics, systems pharmacology, and bioactivity-guided isolation are expected to facilitate identification of novel lead molecules for future drug development (Kumar *et al*., 2023) [9].

Toxicology and Safety

Although *Leucas lavandulifolia* Sm. has been widely employed in traditional medicine for centuries, comprehensive toxicological investigations remain relatively limited compared with its pharmacological evaluation. Available experimental studies indicate that extracts of the plant exhibit a relatively wide margin of safety at therapeutic doses, supporting its long-standing use in Ayurveda, Siddha, and folk medicine (Kumar *et al*., 2023) [9]. Nevertheless, scientific validation of chronic toxicity, reproductive toxicity, genotoxicity, mutagenicity, and clinical safety remains inadequate.

1. Acute Toxicity

Acute toxicity studies conducted on aqueous, methanolic, and ethanolic extracts have demonstrated low toxicity in experimental animals. Oral administration of extracts at therapeutic doses did not produce mortality or significant behavioral abnormalities, suggesting that the plant possesses a relatively high safety margin. Most investigations have reported no significant alterations in locomotor activity, food consumption, body weight, or gross pathological findings following short-term administration (Sharma *et al*., 2012) [13].

The absence of severe acute toxicity may be attributed to the predominance of naturally occurring flavonoids, phenolic compounds, terpenoids, and phytosterols, which generally exhibit low toxicity compared with synthetic drugs (Evans, 2009) [4].

2. Subacute and Chronic Toxicity

Information regarding repeated-dose toxicity remains scarce. Limited experimental studies suggest that prolonged administration of plant extracts at moderate doses does not produce significant alterations in hepatic or renal biochemical markers. Histopathological examination of major organs has generally revealed no remarkable tissue abnormalities following experimental treatment; however, available evidence is insufficient for establishing long-term safety (Kumar *et al*., 2023) [9].

Consequently, systematic investigations involving 28-day, 90-day, and chronic toxicity protocols following OECD guidelines are required before pharmaceutical development.

3. Cytotoxicity and Genotoxicity

Several phytochemicals isolated from *L. lavandulifolia*, including flavonoids and terpenoids, have demonstrated selective cytotoxic effects against experimental cancer cell lines while exhibiting minimal toxicity toward normal mammalian cells (Kumar *et al*., 2023) [9]. Nevertheless, comprehensive genotoxicity, mutagenicity, carcinogenicity, and reproductive toxicity evaluations remain largely unavailable.

Future investigations employing micronucleus assays, Ames tests, chromosomal aberration studies, and reproductive toxicity models are essential for establishing a complete toxicological profile.

4. Herb–Drug Interactions

Since *L. lavandulifolia* contains multiple bioactive phytochemicals capable of influencing inflammatory pathways, oxidative stress, and hepatic metabolism, potential interactions with conventional drugs cannot be excluded. Particular caution should therefore be exercised when herbal preparations are administered concurrently with anticoagulants, antihypertensive agents, antidiabetic drugs, sedatives, or immunomodulatory medications until detailed pharmacokinetic interaction studies become available (WHO, 2013).

5. Safety During Pregnancy and Lactation

Traditional medicinal literature provides little scientific evidence regarding the use of *L. lavandulifolia* during pregnancy and breastfeeding. In the absence of adequate reproductive toxicity studies, medicinal use during pregnancy, lactation, and early childhood should be undertaken only under qualified medical supervision (WHO, 2013).

6. Quality Assurance and Safety Considerations

The safety of herbal preparations depends not only on intrinsic phytochemicals but also on the quality of raw materials. Contamination with heavy metals, pesticide residues, microbial pathogens, mycotoxins, and adulterants may significantly compromise safety. Therefore, cultivation, harvesting, processing, storage, and formulation of *L. lavandulifolia* should comply with Good Agricultural and Collection Practices (GACP), Good Manufacturing Practices (GMP), and WHO quality-control guidelines (WHO, 2011) [15].

Overall, currently available evidence indicates that *Leucas lavandulifolia* possesses a favorable safety profile when used at traditional therapeutic doses. However, rigorous toxicological investigations, pharmacokinetic studies, standardized extract development, and controlled clinical trials remain necessary to establish its long-term safety and evidence-based therapeutic application.

Biotechnological and Pharmaceutical Applications

Recent advances in biotechnology, pharmaceutical sciences, metabolomics, and molecular biology have substantially expanded the medicinal potential of *Leucas lavandulifolia* Sm. Modern approaches aim not only to conserve valuable germplasm but also to enhance the production of bioactive metabolites and facilitate the development of standardized phytopharmaceuticals (Kumar *et al*., 2023) [9].

1. Plant Tissue Culture and Micropropagation

Plant tissue culture offers an efficient strategy for the rapid multiplication and conservation of elite genotypes of *L. lavandulifolia*. *In vitro* propagation through shoot-tip, nodal, and axillary bud cultures enables the production of genetically uniform and disease-free planting material throughout the year. Micropropagation also reduces dependence on wild populations and contributes to sustainable utilization of medicinal resources.

Callus induction, cell suspension culture, and organogenesis have considerable potential for enhancing the production of pharmaceutically important secondary metabolites through elicitation, precursor feeding, and metabolic engineering techniques (George *et al*., 2008) [5].

2. Secondary Metabolite Enhancement

Biotechnological approaches such as hairy root culture, elicitor treatment, precursor supplementation, and metabolic engineering have emerged as promising strategies for increasing the synthesis of flavonoids, terpenoids, phenolic acids, and essential oils. These techniques permit controlled production of medicinal compounds independent of seasonal and environmental variations.

Integration of metabolomics with transcriptomics and proteomics can further facilitate the identification of genes involved in secondary metabolite biosynthesis, thereby improving phytochemical yield and quality (Kumar *et al*., 2023) [9].

3. Molecular Authentication

Accurate botanical identification is critical because several *Leucas* species possess similar morphological characteristics. DNA barcoding and molecular markers including RAPD, ISSR, SSR, AFLP, and chloroplast DNA sequencing provide reliable tools for species authentication, assessment of genetic diversity, detection of adulteration, and conservation planning (CBOL Plant Working Group, 2009) [2].

These molecular approaches are increasingly incorporated into quality-control protocols for herbal medicines.

4. Pharmaceutical Formulations

Extracts and purified phytochemicals obtained from *L. lavandulifolia* have promising applications in the development of herbal pharmaceuticals. Standardized formulations under investigation include:

a. Topical creams and ointments for wound healing, burns, eczema, and microbial skin infections.
b. Herbal gels and sprays possessing antimicrobial and anti-inflammatory activities.
c. Capsules and tablets prepared from standardized extracts for antioxidant and immunomodulatory applications.
d. Herbal teas and nutraceutical preparations rich in phenolic antioxidants.
e. Essential oil-based formulations for insect repellents, aromatherapy, and natural preservatives.

Such formulations may offer safer alternatives to synthetic drugs for selected conditions while preserving the therapeutic benefits of traditional medicine.

5. Nanotechnology-Based Drug Delivery

Green nanotechnology has emerged as an important area of medicinal plant research. Extracts of *Leucas* species have been investigated for the biosynthesis of silver, gold, and zinc oxide nanoparticles exhibiting enhanced antimicrobial, antioxidant, wound-healing, and anticancer activities.

Nanoformulations improve the bioavailability, stability, controlled release, and target specificity of phytochemicals while reducing toxicity and improving therapeutic efficacy. These advances create new opportunities for pharmaceutical development of *L. lavandulifolia* (Kumar *et al*., 2023) [9].

6. Computational Drug Discovery

Modern computational tools including molecular docking, molecular dynamics simulation, quantitative structure–activity relationship (QSAR) analysis, network pharmacology, and artificial intelligence-assisted drug discovery are increasingly being employed to identify potential therapeutic targets for phytochemicals isolated from *L. lavandulifolia*. These technologies facilitate prediction of biological activity, optimization of lead compounds, and rational design of novel phytopharmaceuticals.

Conclusion

Leucas lavandulifolia Sm. is an important medicinal herb belonging to the family Lamiaceae that has been extensively utilized in traditional healthcare systems throughout South and Southeast Asia. The present review comprehensively summarizes available scientific evidence and demonstrates that the species possesses remarkable ethnomedicinal significance supported by a diverse array of bioactive phytochemicals, including flavonoids, terpenoids, phenolic acids, sterols, triterpenoids, glycosides, tannins, saponins, and essential oils. These phytoconstituents provide a scientific basis for the plant's broad spectrum of biological activities and justify many of its traditional therapeutic applications. The uploaded historical literature, together with recent investigations, confirms the long-standing medicinal importance of the species.

Ethnopharmacological studies indicate that *L. lavandulifolia* has traditionally been employed for the treatment of fever, headache, respiratory disorders, gastrointestinal ailments, inflammatory diseases, wounds, skin infections, snakebite, and parasitic infestations. Contemporary pharmacological investigations have validated several of these traditional claims by demonstrating significant antimicrobial, antioxidant, anti-inflammatory, analgesic, antipyretic, antidiarrheal, antiprotozoal, insecticidal, hepatoprotective, wound-healing, and neuropharmacological activities (Kumar *et al*., 2023; Sharma *et al*., 2012) [9, 13]. These findings highlight the therapeutic promise of the species as a valuable source of novel phytopharmaceutical agents.

Phytochemical investigations have revealed the presence of numerous pharmacologically active compounds, while advances in chromatographic and spectroscopic techniques—including HPLC, GC–MS, LC–MS/MS, NMR, and metabolomic profiling—have considerably improved the characterization and standardization of its chemical constituents. Likewise, pharmacognostic studies have established reliable macroscopic, microscopic, physicochemical, and chromatographic parameters for authentication and quality control of crude herbal materials, thereby minimizing adulteration and ensuring consistency in herbal formulations (Evans, 2009 [4]; WHO, 2011).

Although available toxicological studies suggest that *L. lavandulifolia* possesses a relatively favorable safety profile at traditional therapeutic doses, comprehensive evaluations of chronic toxicity, reproductive toxicity, genotoxicity, carcinogenicity, pharmacokinetics, and herb–drug interactions remain insufficient. Consequently, rigorous preclinical investigations and well-designed randomized clinical trials are essential before standardized formulations can be widely recommended for evidence-based clinical practice.

Recent developments in biotechnology, tissue culture, molecular authentication, metabolomics, nanotechnology, and computational drug discovery have created new opportunities for sustainable utilization and pharmaceutical development of *L. lavandulifolia*. Integration of these modern technologies with traditional medicinal knowledge may facilitate large-scale production of standardized extracts, enhance secondary metabolite yield, improve quality assurance, and accelerate the discovery of novel therapeutic compounds.

Despite encouraging progress, several research gaps remain. Future investigations should focus on bioactivity-guided isolation of active principles, elucidation of molecular mechanisms of action, standardization of bioactive marker compounds, pharmacokinetic and pharmacodynamic studies, long-term safety evaluation, multicenter clinical trials, and development of pharmacopeial quality standards. In addition, conservation of natural populations, sustainable cultivation practices, and Good Agricultural and Collection Practices (GACP) should be promoted to ensure long-term availability of this valuable medicinal resource.

In conclusion, *Leucas lavandulifolia* Sm. represents a promising medicinal plant with substantial therapeutic, pharmaceutical, and economic potential. Continued multidisciplinary research integrating ethnobotany, phytochemistry, pharmacognosy, pharmacology, biotechnology, pharmaceutical sciences, and clinical medicine will be instrumental in translating this traditionally important herb into scientifically validated, safe, effective, and standardized phytopharmaceutical products for future healthcare applications.

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References

1. Ahmed M, Rahman MT, Alimuzzaman M, Shilpi JA. Antinociceptive activity of Leucas lavandulifolia. Fitoterapia,2001:72:704–706.
2. CBOL Plant Working Group. A DNA barcode for land plants. Proceedings of the National Academy of Sciences,2009:106(31):12794–12797.
3. Chopra RN, Nayar SL, Chopra IC. Glossary of Indian medicinal plants. Council of Scientific and Industrial Research, 1956.
4. Evans WC. Trease and Evans' Pharmacognosy (16th ed.). Saunders Elsevier, 2009.
5. George EF, Hall MA, De Klerk GJ. Plant propagation by tissue culture (3rd ed.). Springer, 2008.
6. Harborne JB. Phytochemical methods: A guide to modern techniques of plant analysis (3rd ed.). Chapman & Hall, 1998.
7. Harley RM, Atkins S, Budantsev AL, Cantino PD, Conn BJ, Grayer R, *et al*. Labiatae. In Kubitzki K, ed. The Families and Genera of Vascular Plants (Vol. 7, pp. 167–275). Springer, 2004.
8. Jain SK. Dictionary of Indian Folk Medicine and Ethnobotany. Deep Publications, 1991.
9. Kumar S, Singh N, Mittal A, Kharkwal H, Jain SK, Goel B. The genus Leucas: A review on phytochemistry and pharmacological activities. Fitoterapia,2023:167:105492.
10. Misra TN, Singh RS, Upadhyay J, Srivastava R. Chemical constituents of Leucas species. Phytochemistry, 1992.
11. Nadkarni KM. Indian Materia Medica (3rd ed.). Popular Prakashan, 1954.
12. Plants of the World Online. Leucas lavandulifolia Sm. Royal Botanic Gardens, Kew, 2025.
13. Sharma U, Singh A, Sahu R. Ethnobotanical and pharmacological review of the genus Leucas. Pharmacognosy Reviews,2012:6(12):181–189.
14. Viswanathan MB, Pillai GR. Chemical investigation of Leucas lavandulifolia. Indian Journal of Chemistry, 1981.
15. World Health Organization. Quality control methods for herbal materials. World Health Organization, 2011.
16. World Health Organization. WHO traditional medicine strategy: 2014–2023. World Health Organization, 2013.
17. World Health Organization. WHO global report on traditional and complementary medicine 2023. World Health Organization, 2023.