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Exploring the Phytochemistry and Pharmacological Significance of *Clerodendrum wallichii*

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Abstract:

Clerodendrum wallichii Merr. (*Lamiaceae*), commonly known as the nodding *Clerodendrum*, is a medicinal shrub native to the Himalayan region and parts of South and Southeast Asia. It has long been utilised in traditional and ethnomedicinal systems for the management of various ailments, including gastrointestinal disorders, inflammatory conditions, and febrile illnesses. This review systematically synthesises the available information on the botanical, pharmacognostic, phytochemical, pharmacological, and toxicological aspects of *C. wallichii*. Pharmacognostic investigations have identified several diagnostic features, including anisocytic stomata, multicellular trichomes, and calcium oxalate crystals, which are valuable for species authentication and quality control. Phytochemical studies have revealed the presence of diverse secondary metabolites, including clerodane-type diterpenoids, phenolic compounds, and flavonoid glycosides, such as quercetin and kaempferol derivatives, predominantly in the leaves. Preclinical studies have demonstrated antioxidant, analgesic, antidiarrheal, and cytotoxic activities, thereby providing scientific support for some of the plant's traditional medicinal applications. Despite these promising findings, comprehensive information regarding the molecular mechanisms of action, long-term toxicological safety, and clinical efficacy of *C. wallichii* remains limited. Future research should focus on advanced phytochemical characterisation, chromatographic fingerprinting, mechanistic investigations, toxicological evaluation, and well-designed clinical studies to facilitate the development of standardised, safe, and evidence-based botanical therapeutics derived from *C. wallichii*.

Major Findings: *Clerodendrum wallichii* possesses considerable pharmacological potential owing to its rich phytochemical composition, which includes flavonoids, phenolic compounds, and other bioactive constituents. Preclinical studies have demonstrated that the plant exhibits antioxidant, analgesic, antidiarrheal, and cytotoxic activities, providing scientific support for some of its traditional medicinal uses. Nevertheless, further investigations, particularly detailed phytochemical studies, mechanistic evaluations, toxicological assessments, and clinical trials, are required to validate its therapeutic efficacy and establish its potential for clinical application.

Keywords: Bioactive Compounds, *Clerodendrum wallichii*, *Lamiaceae*, Pharmacology, Phytochemistry, Traditional Medicine

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1. Introduction

Natural products continue to play a significant role in modern drug discovery and pharmaceutical development. Many plant-derived medicines are widely used worldwide for their therapeutic benefits and effectiveness in preventing and treating various diseases. In many developing countries, traditional herbal medicines remain an important component of primary healthcare systems[1]. In addition, approximately 80% of the population in developing countries relies on traditional herbal medicines as a primary source of healthcare. Consequently, there is a pressing need for the systematic scientific validation of these botanical resources with respect to their safety, efficacy, quality, and standardisation[2].

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The genus *Clerodendrum* (family: *Lamiaceae*), comprising more than 500 species distributed throughout tropical and subtropical regions, has attracted considerable scientific interest because of its rich diversity of secondary metabolites and associated pharmacological potential[2]. Several species within the genus *Clerodendrum* have been reported to exhibit antioxidant, anti-inflammatory, hepatoprotective, and anticancer activities, which are attributed to the presence of diverse bioactive constituents, including flavonoids, phenolic compounds, and clerodane-type diterpenoids. As a member of the family *Lamiaceae*, the genus *Clerodendrum* is particularly noted for its rich diversity of secondary metabolites, including clerodane diterpenoids and iridoid glycosides.

Clerodendrum wallichii Merr. can be distinguished from related species by its characteristic pendulous inflorescences and distinctive morphological features. Although numerous *Clerodendrum* species have been extensively investigated for their phytochemical composition and pharmacological activities, comparatively little scientific research has focused on *C. wallichii*. Despite its traditional medicinal use in the Himalayan regions of India, Nepal, and Bhutan, the phytochemistry, pharmacological properties, and therapeutic potential of *C. wallichii* remain insufficiently explored[3,4].

In the Himalayan regions of Uttarakhand and Sikkim, *C. wallichii* is utilised in traditional human healthcare practices and ethnoveterinary medicine. Local practitioners have traditionally employed leaf decoctions for the management of fever and microbial infections, reflecting their reported antipyretic and antimicrobial properties. However, comprehensive pharmacognostic and phytochemical standardisation studies of regional ecotypes of *C. wallichii* remain limited. Traditional *Ayurvedic* and folk medicinal systems in Northeast India and Uttarakhand have long used this species to treat diarrhoea, fever, and inflammatory skin disorders. Nevertheless, the available literature documenting these ethnomedicinal applications remains fragmented and relatively sparse. Recent preclinical investigations have provided preliminary scientific support for some of these traditional uses by demonstrating analgesic, antioxidant, cytotoxic, and other biological activities in various *in vitro* and *in vivo* experimental models[5,6].

At present, there is no comprehensive review that integrates the traditional uses of *C. wallichii* with its phytochemical composition, pharmacological properties, and pharmacognostic standardisation. Growing concerns regarding antimicrobial resistance and the adverse effects associated with long-term use of conventional non-steroidal anti-inflammatory drugs (NSAIDs)[7] have renewed interest in medicinal plants, including species of the genus *Clerodendrum*. Among these, *C. wallichii* has a long history of traditional use for managing inflammatory conditions and dysentery[8].

Preliminary studies indicate that *C. wallichii* possesses a favourable safety profile and promising biological activities. However, comprehensive toxicological investigations, particularly chronic toxicity studies, are still lacking. Therefore, further pharmacological, toxicological, and clinical evaluations are required to establish its safety and efficacy and to assess its potential as a source of novel phytopharmaceutical agents. This review integrates botanical, phytochemical, pharmacological, pharmacognostic, and toxicological evidence to provide a comprehensive overview of the therapeutic potential of *C. wallichii* and to identify key gaps and future research priorities[9]. The overall framework of the review is illustrated in Figure 1.

2. Materials and Methods

To prepare this review, a comprehensive literature search was conducted to collect relevant information on the phytochemistry, pharmacology, ethnomedicinal uses, pharmacognosy, toxicity, and biological activities of *Clerodendrum wallichii* Merr. The literature search was performed using the electronic databases PubMed, Scopus, Google Scholar, Web of Science, and ScienceDirect. Articles published between January 2000 and March 2026 were considered for inclusion. The search strategy employed combinations of the keywords "*Clerodendrum wallichii*", "phytochemistry", "pharmacology", "traditional medicine", "ethnomedicine", "pharmacognosy", "toxicity", and "bioactive compounds". Original research articles, review articles, ethnobotanical reports, and experimental studies related to the botanical description, traditional and ethnomedicinal uses, phytochemical composition, pharmacological activities, pharmacognostic characteristics, and

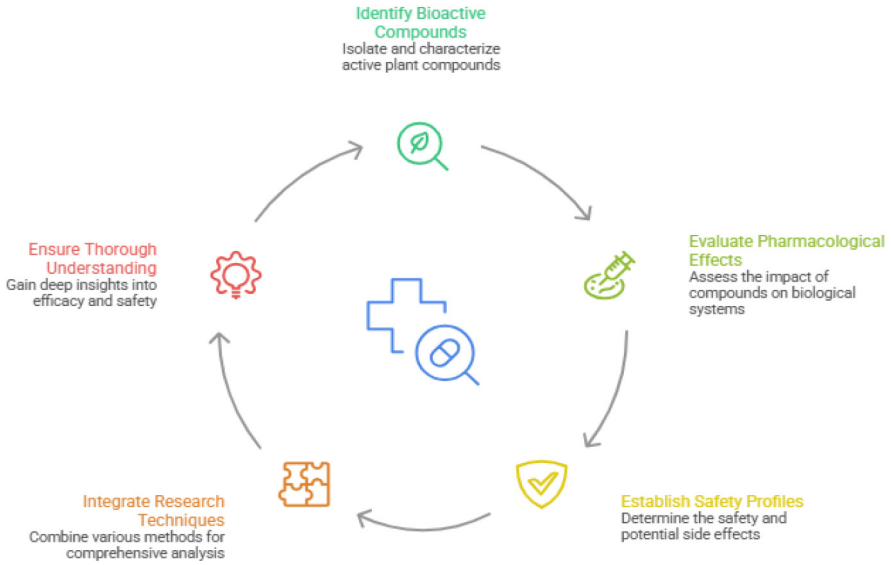


Figure 1. Schematic representation of the integrated approach for the pharmacological validation of *C. wallichii*.

toxicological profile of *C. wallichii* were included. Studies lacking sufficient scientific evidence, duplicate publications, conference abstracts or proceedings without full text, and articles not specifically related to *C. wallichii* were excluded. The collected literature was critically evaluated and organised into thematic sections to provide an updated overview of the current knowledge on *C. wallichii* and to identify key research gaps and future directions for investigation.

3. Botanical Description

Figure 2 illustrates some of the prominent botanical features of *Clerodendrum wallichii* Merr., a medicinal shrub belonging to the tropical genus *Clerodendrum*. The species is widely distributed throughout India, including the states of Sikkim, Assam, Meghalaya, Mizoram, Maharashtra, and Uttarakhand. It commonly occurs along forest margins and on mountainous slopes in tropical and subtropical regions, where warm and humid climatic conditions prevail. The plant is well-adapted to well-drained soils and is typically found at moderate to high elevations.

Morphologically, *C. wallichii* is a robust, erect shrub with opposite leaves that are generally oblong to lanceolate in shape. The leaves are characterised by prominent venation, moderately long petioles, and smooth to slightly pubescent surfaces. These morphological features provide useful diagnostic characteristics for distinguishing *C. wallichii* from related species within the genus and family[6].

Clerodendrum wallichii bears attractive clusters of flowers, typically arranged in terminal inflorescences and occasionally in axillary positions. The flowers are tubular, fragrant, and white to pale pink in colour. A characteristic feature of the species is the presence of long, exserted stamens that extend beyond the corolla tube, a trait commonly observed in many members of the *Clerodendrum* genus[6]. The plant produces small drupaceous fruits containing seeds that serve as the primary means of reproduction. Pharmacognostic and anatomical studies have identified several diagnostic microscopic characteristics that can be used for the identification and authentication of *C. wallichii*. These include multicellular trichomes, well-developed xylem vessels, anisocytic stomata, and calcium oxalate crystals in the leaf tissues, as summarised in Table 1. In addition, the leaves exhibit well-defined epidermal layers, differentiated palisade and spongy mesophyll tissues, and distinct vascular bundles, all of which are valuable taxonomic and pharmacognostic markers. Collectively, these morphological and anatomical features provide important criteria for the authentication, standardisation, and quality control of herbal materials and formulations derived from *C. wallichii*[11].

Table 1. Diagnostic pharmacognostic and microscopic markers of *C. wallichii*[6]

Feature	Description and Diagnostic Value
Stomatal Type	Anisocytic (Cruciferous); predominantly on the abaxial (lower) surface.
Trichomes	Presence of both non-glandular multicellular trichomes and capitate glandular trichomes.
Crystals	Numerous calcium oxalate crystals (prismatic and cubic shapes) are localised in the mesophyll and cortical parenchyma.
Vascular Bundle	Arc-shaped collateral vascular bundles with well-developed xylem vessels and phloem fibres.
Epidermis	Single layer of rectangular cells with a thick, striated cuticle.
Mesophyll	Differentiated into a single layer of palisade parenchyma and 3–4 layers of spongy mesophyll.

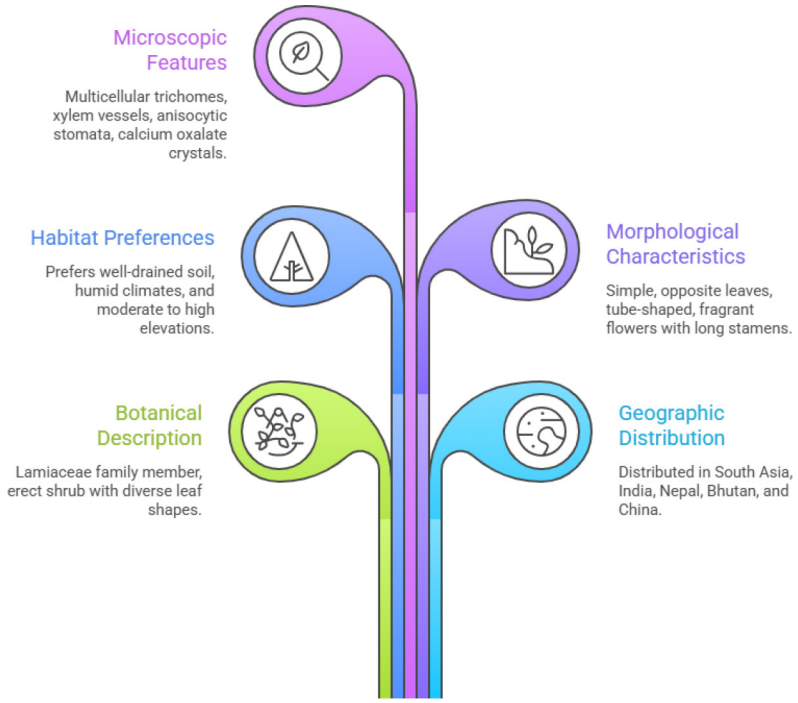


Figure 2. Botanical description.

4. Ethnobotanical and Traditional Medicinal Uses

Clerodendrum wallichii is widely known for its use in folk medicine and ethnic medicine systems across the various regions in which it grows. Communities residing in the Himalayas and parts of South and Southeast Asia have utilised the leaves of *C. wallichii* to treat various diseases for centuries, as summarised in Table 2. There is also an established body of traditional knowledge indicating that it may offer therapeutic benefits for gastrointestinal disease, inflammation, and fevers, as well as for skin diseases. Regarding folk medicine, leaf extracts from *C. wallichii* have been used to treat diarrhoea and dysentery, providing and confirming the possibility of *C. wallichii* being antidiarrhoeal. Preparations, such as decoctions and infusions of leaves, are also used to treat both fever and pain, thus indicating the possibility of being analgesic and antipyretic. Furthermore, extracts or crushed leaf preparations have been applied externally to the skin to treat skin infections, wounds, and inflammation. The similarities of these uses of *C. wallichii*. The uses of other members of the *Clerodendrum* genus have been well documented by the Ayurvedic, Unani, and folk medicinal systems, which have recognised the antimicrobial, anti-inflammatory, hepatoprotective, and antioxidant effects of many other *Clerodendrum* species. The continuing use of *C. wallichii* in traditional medicine demonstrates its practical value and

Table 2. Ethnobotanical uses of *C. wallichii* by region

Region / Community	Plant Part Used	Preparation	Traditional Indication
Northeast India	Leaves	Decoction	Diarrhoea, Dysentery, Malaria
Sikkim (Tribal)	Roots	Paste	Skin diseases, Boils
Uttarakhand	Leaves	Infusion	Fever (Antipyretic)
Bangladesh	Whole Plant	Juice	Anthelmintic (Intestinal worms)

warrants further investigation into its constituents[9]. Furthermore, knowledge about how people use and regard the plants in their environment has been collected for many years by local people. This traditional use has been recorded and is important to document to help preserve indigenous knowledge, as well as provide direction for future research into the possible benefits of using *C. wallichii* products as medicinal agents and for finding new compounds that may possess medicinal properties[12,13].

5. Phytochemical Constituent

Phytochemical investigations of the *Clerodendrum* genus have revealed a diverse array of secondary metabolites that contribute to its wide range of pharmacological activities. Species within this genus are known to contain monoterpenes, sesquiterpenes, diterpenoids, triterpenoids, flavonoids, phenolic compounds, steroids, glycosides, alkaloids, and anthraquinones. These phytochemical constituents are believed to play important roles in the biological activities reported for various *Clerodendrum* species. Many of these compounds have been associated with therapeutic effects and have attracted considerable interest because of their potential applications in both traditional and modern medicine[6,14].

Terpenoids constitute one of the major classes of phytochemicals reported in *Clerodendrum* species. Monoterpenes and sesquiterpenes have been associated with anti-inflammatory and antimicrobial activities, whereas diterpenoids and triterpenoids have been reported to exhibit anticancer, hepatoprotective, and immunomodulatory effects. Steroidal compounds identified in *Clerodendrum* species have also been linked to anti-inflammatory activity and may influence hormonal regulation. Glycosides, including iridoid and phenylethanoid glycosides, have been widely reported to possess antioxidant, neuroprotective, and cardioprotective properties. Flavonoids and phenolic compounds represent another important group of bioactive constituents in *Clerodendrum* species. Owing to their ability to scavenge free radicals and reduce oxidative stress, these compounds contribute significantly to the antioxidant potential of the genus. Furthermore, flavonoids, phenolic acids, and related phenolic constituents have been associated with a range of biological activities, including anti-inflammatory, antimicrobial, antidiabetic, and anticancer effects[15].

Phytochemical investigations reported for *Clerodendrum wallichii* Merr. (Table 3) remain limited compared with those conducted on other species of the *Clerodendrum* genus. Nevertheless, preliminary studies have revealed the presence of substantial amounts of phenolic compounds and flavonoids in *C. wallichii* extracts. These phytochemical classes are likely to contribute to the antioxidant and other biological activities reported for the plant. Qualitative phytochemical screening has also identified the presence of alkaloids, terpenoids, steroids, and glycosides, which may collectively contribute to its pharmacological properties. The phytochemical composition of *C. wallichii* is likely influenced by several factors, including geographical origin, climatic conditions, soil characteristics, plant developmental stage, and extraction methodology[6]. Therefore, comprehensive phytochemical investigations employing advanced analytical techniques, such as High-Performance Liquid Chromatography (HPLC), Gas Chromatography–Mass Spectrometry (GC–MS), Liquid Chromatography–Mass Spectrometry (LC–MS), and Nuclear Magnetic Resonance (NMR) spectroscopy, are required to fully characterise its chemical constituents. Such studies would enhance our understanding of the bioactive compounds present in *C. wallichii*, facilitate the development of standardised herbal formulations, and support the discovery of novel therapeutic agents derived from this species[16,17].

Table 3. Phytoconstituents of *C. wallichii*

Compound Class	Chemical Constituents
Flavonoids	Quercetin, Apigenin, Kaempferol
Phenolic Acids	Ferulic acid, Caffeic acid
Diterpenoids	Clerodane-type diterpenes
Steroids	beta-sitosterol, Clerosterol
Glycosides	Iridoids, Phenylethanoids

6. Pharmacological Studies

Numerous studies have investigated the pharmacological activities of *Clerodendrum wallichii* Merr., as shown in Figure 3. Experimental evidence suggests that *C. wallichii* possesses a wide range of biological and therapeutic activities, which are attributed to the presence of diverse bioactive constituents, including flavonoids, phenolic compounds, terpenoids, and glycosides. These findings provide scientific support for the traditional medicinal use of the plant and highlight its potential as a valuable source of natural therapeutic agents for future drug discovery and development.

6.1 Antidiarrheal Effects

Preclinical studies have demonstrated that hydroalcoholic leaf extracts of *Clerodendrum wallichii* possess significant antidiarrheal activity. In animal models, the hydroalcoholic extract produced statistically significant reductions ($p < 0.05$) in diarrhoea induced by castor oil and magnesium sulfate and exhibited greater efficacy than the chloroform fraction. These findings provide pharmacological support for the traditional use of *C. wallichii* in the management of diarrhoea and dysentery. However, further studies are required to identify the bioactive constituents responsible for these effects, elucidate the underlying mechanisms of action, establish standardised dosage regimens, and evaluate the long-term safety and efficacy of *C. wallichii* through well-designed clinical investigations[17].

6.2 Analgesic and Antioxidant Activity

The Methanolic Extract of *Clerodendrum wallichii* (MECW) has been reported to exhibit both central and peripheral analgesic activities. In Swiss albino mice, administration of MECW at doses of 200 and 400 mg/kg significantly increased pain reaction time in the tail-flick test and reduced the number of abdominal constrictions in the acetic acid-induced writhing assay. In the tail-flick model, MECW at a dose of 400 mg/kg increased pain reaction latency by 362.19% at 60 min post-treatment, compared with 452.08% for morphine (2 mg/kg). Similarly, in the acetic acid-induced writhing test, MECW produced a dose-dependent inhibition of abdominal constrictions, with reductions of 60.38% and 69.81% at doses of 200 and 400 mg/kg, respectively, whereas diclofenac sodium (50 mg/kg) produced 73.58% inhibition. These findings suggest that *C. wallichii* possesses significant analgesic potential, exhibiting both centrally and peripherally mediated antinociceptive effects. However, the precise molecular mechanisms underlying these activities remain to be elucidated through further pharmacological and mechanistic studies. *C. wallichii* has been reported to possess both analgesic and antioxidant activities. Among the tested extracts, the methanolic extract contained the highest total phenolic content (75.44 ± 0.68 mg Gallic Acid Equivalents [GAE]/g extract). Furthermore, the water-soluble fraction exhibited the strongest DPPH free radical scavenging activity, with an IC_{50} value of 7.23 ± 0.05, compared with the standard antioxidant butylated hydroxytoluene (BHT), which showed an IC_{50} value of 25.18 ± 1.89. These findings suggest that the potent antioxidant activity of *C. wallichii* may be attributed to its high content of phenolic and flavonoid compounds, which are capable of scavenging reactive oxygen species and mitigating oxidative stress[18].

6.3 Cytotoxicity

The cytotoxic potential of *C. wallichii* has been evaluated using the Brine Shrimp Lethality Assay (BSLA), a widely employed preliminary screening method for the detection of biologically active compounds with potential cytotoxic properties. Among the tested fractions, the petroleum ether-soluble fraction exhibited the highest cytotoxic activity ($LC_{50} = 0.78 \pm 0.03$ µg/mL), followed by the carbon tetrachloride-soluble fraction ($LC_{50} = 1.30 \pm 0.05$ µg/mL). In contrast, the methanolic extract demonstrated comparatively lower toxicity. These findings suggest that the cytotoxic activity of *C. wallichii* is primarily associated with its non-polar constituents, such as terpenoids and other secondary metabolites. Although the brine shrimp lethality assay provides a useful preliminary indication of cytotoxic

potential, its predictive value for anticancer activity in humans remains limited. Consequently, the observed cytotoxic effects cannot be directly extrapolated to human cancer cells or specific mechanisms of action. Further investigations involving standardised *in vitro* and *in vivo* cytotoxicity assays, mechanistic studies, and the isolation and characterisation of active compounds from the non-polar fractions are required to evaluate the anticancer potential of *C. wallichii* more comprehensively[18].

6.4 Other Biological Activity

Numerous biological activities have been reported across different species of the *Clerodendrum* genus. Several species have been extensively investigated for their pharmacological potential, including antimicrobial, anti-inflammatory, hepatoprotective, antidiabetic, hypoglycemic, neuroprotective, cardioprotective, and anticancer activities. Extracts and isolated phytoconstituents from various *Clerodendrum* species have been reported to exhibit a wide range of biological activities. These include antimicrobial effects through the inhibition of microbial growth, modulation of inflammatory pathways, protection of hepatic tissue against oxidative damage, regulation of blood glucose levels, and neuroprotective effects. The diverse pharmacological activities associated with *Clerodendrum* species highlight the therapeutic significance of this genus and its potential as a source of novel drug candidates and pharmaceutical formulations. Furthermore, the combined action of multiple phytochemicals present in these plants may contribute to synergistic therapeutic effects, thereby enhancing their overall biological activity. Despite

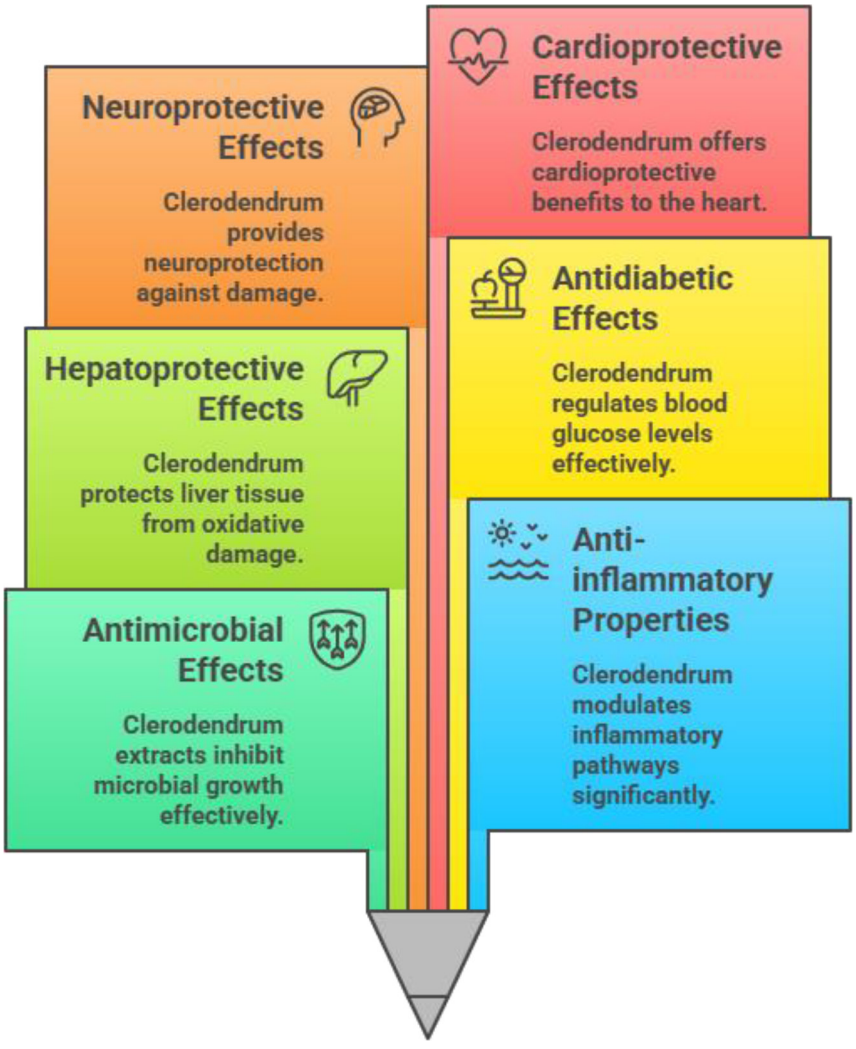


Figure 3. Pharmacological Potential of *C. wallichii*.

the growing body of scientific evidence supporting the medicinal potential of *Clerodendrum* species, comprehensive pharmacological investigations, detailed toxicological assessments, and well-designed clinical trials remain necessary to establish the safety, efficacy, and therapeutic applicability of *C. wallichii* and other related species[3,17,18].

7. Pharmacognostic and Physicochemical Studies

This study is essential for the authentication, standardisation, and quality assessment of medicinal plants. In *Clerodendrum wallichii* Merr., both macroscopic and microscopic features provide reliable diagnostic markers for distinguishing the species from closely related taxa and detecting potential adulteration. Microscopic examination of the powdered leaves revealed several characteristic features, including multicellular hairs, reticulate xylem vessels, anisocytic stomata, stellate trichomes, adaxial and abaxial epidermal cells, and square and cubic calcium oxalate crystals. These diagnostic characters can serve as valuable tools for the botanical identification and quality control of *C. wallichii*[6]. The physicochemical parameters of *C. wallichii* leaves were evaluated according to World Health Organisation (WHO) guidelines. The total ash, acid-insoluble ash, and water-soluble ash contents were found to be 10.48 ± 0.027%, 1.08 ± 0.063%, and 8.17 ± 0.011% (w/w), respectively. The loss on drying (moisture content) was 9.3% (w/w), indicating an acceptable moisture level for storage stability and reduced risk of microbial deterioration. The extractive values of *C. wallichii* leaves were determined using both cold and hot extraction methods. The cold extraction method yielded extractive values of 1.31% (w/w) and 2.19% (w/w) for ethanol and water, respectively, whereas the corresponding hot extraction method yielded 2.15% (w/w) and 3.17% (w/w). Extractive values were also determined using various organic solvents, including petroleum ether, chloroform, acetone, ethyl acetate, and hexane. The yields varied according to the polarity of the solvent and the extraction conditions employed. These physicochemical parameters provide valuable reference standards for the authentication, quality control, and standardisation of *C. wallichii* and may facilitate the development of stable, reproducible herbal formulations with consistent therapeutic efficacy[16,19].

8. Toxicological Profile and Safety Assessment

The clinical applicability of phytotherapeutic agents depends on both their therapeutic efficacy and safety profile. The safety of *C. wallichii* has been preliminarily assessed through acute oral toxicity studies and in vitro cellular safety evaluations, the results of which are summarised in Table 4. These investigations provide important initial evidence regarding the safety margin of *C. wallichii* and support its potential for further pharmacological and clinical development[20,17].

8.1 Acute Toxicity Studies (Oral)

Acute oral toxicity studies conducted in accordance with OECD Test Guideline (TG) 423 indicate that the methanolic and aqueous leaf extracts of *C. wallichii* possess low acute toxicity. In Swiss albino mice, a single oral dose of 2000 mg/kg body weight produced no observable signs of toxicity, including behavioural changes, tremors, or mortality, during the 14-day observation period. Based on these findings, the extracts may be considered to have a wide safety margin and are consistent with GHS Category 5 (low acute toxicity) classification[6,20].

8.2 Sub-acute and Chronic Toxicity

The promising findings from acute toxicity studies should be interpreted with caution, as long-term (90-day) sub-chronic toxicity data for *C. wallichii* are currently lacking. Consequently, the safety of prolonged exposure to the plant and its extracts has not yet been fully established. Nevertheless, preliminary studies suggest that administration of therapeutic doses (200–400 mg/kg) does not result in significant alterations in hematological parameters, including Red Blood Cell (RBC) count, White Blood Cell (WBC) count, and haemoglobin levels, nor in biochemical markers of hepatic and renal function, such as Alanine Aminotransferase (ALT), Aspartate Aminotransferase (AST), urea, and creatinine. Further sub-chronic and chronic toxicity studies are required to confirm the long-term safety profile of *C. wallichii*[20].

8.3 Cytotoxicity and Nano-bio Interactions

Although preliminary studies suggest that *Clerodendrum wallichii* possesses a favourable safety profile with low acute toxicity, caution should be exercised regarding its long-term use and administration at higher doses, particularly due to the presence of clerodane-type diterpenoids, which may exhibit cytotoxic effects under certain conditions. In recent years, *C. wallichii* extracts have been increasingly explored for the green synthesis of metallic nanoparticles. However, the safety profile of the plant extract cannot be directly extrapolated to the nanoparticles synthesised from it, as nanoparticle formation may alter physicochemical properties, biological interactions, and toxicity profiles. Therefore, comprehensive investigations are required to assess the safety and biomedical potential of *C. wallichii*-derived nanoparticles. Future studies should focus on nanotoxicity, immunogenicity, pharmacokinetics, bioavailability, and biodistribution, including their ability to cross biological barriers such as the blood–brain barrier, to establish their suitability for biomedical applications[21,22].

9. Future Prospects and Research Gaps

Although the ethnomedicinal and pharmacological potential of *Clerodendrum wallichii* appears to be significant, research on this species remains limited compared with that on other members of the *Clerodendrum* genus. Several research gaps must be addressed to fully realise its therapeutic potential. To gain a comprehensive understanding of the pharmacological effects of *C. wallichii*, further investigations are required, particularly detailed phytochemical studies aimed at the identification, isolation, and characterisation of the bioactive constituents responsible for its reported biological activities. The application of advanced analytical techniques, such as gas chromatography–mass spectrometry, liquid chromatography–mass spectrometry, and nuclear magnetic resonance spectroscopy, would facilitate the discovery and characterisation of novel compounds with potential therapeutic value. Furthermore, comprehensive toxicological evaluations should be conducted before clinical application, including acute, subacute, and chronic toxicity studies, as well as genotoxicity and reproductive toxicity assessments. In addition, well-designed and adequately powered clinical trials are required to validate traditional ethnomedical claims and translate preclinical findings into evidence-based therapeutic applications. The current body of literature predominantly focuses on the crude extracts of *C. wallichii*, while limited attention has been given to elucidating the molecular mechanisms underlying its reported biological activities. Further mechanistic investigations employing advanced approaches in molecular biology, genomics, proteomics, and metabolomics are necessary to clarify the modulation of signalling pathways and molecular targets associated with the bioactive constituents of *C. wallichii*. Moreover, the development of standardised herbal formulations derived from *C. wallichii* offers significant potential for the pharmaceutical and nutraceutical industries. However, the establishment of rigorous quality-control standards, optimised dosage forms, stability profiles, and appropriate regulatory frameworks will be essential for the successful commercialisation and clinical acceptance of *C. wallichii*-based products. Additionally, increasing demand for medicinal plants threatens biodiversity; therefore, to promote the conservation and sustainable use of *C. wallichii*, biological farming techniques, biotechnology, and sustainable harvesting practices that promote long-term access to this important medicinal plant should be emphasized[23-25].

Table 4. Summary of toxicological parameters for *C. wallichii*

Parameter	Experimental Model	Observation / Result	References
Acute Oral Toxicity	Mice (OECD 423)	LD^{50}> 2000 mg/kg	20,17
Analgesic, antioxidant	Mice	No significant tremors or lethargy	14
Hepatotoxicity	Rat (Serum ALT/AST)	No significant elevation at 400 mg/kg	3
Nephrotoxicity	Rat (Creatinine/Urea)	Within normal physiological limits	14
Brine Shrimp Lethality	*Artemia salina*	LC_{50} < 100 \mu g/mL (Potent)	13

10. Conclusion

Clerodendrum wallichii is an important medicinal plant with a long history of use in traditional medicine and a wide range of reported pharmacological activities. Available evidence suggests that the plant possesses antidiarrheal, analgesic, antioxidant, cytotoxic, and other biological activities, which are largely attributed to its rich phytochemical composition, including flavonoids, phenolic compounds, and clerodane diterpenoids. However, most of the existing studies are limited to preclinical investigations, and there remains a lack of comprehensive information regarding its mechanisms of action, chronic toxicity, standardised dosage regimens, and clinical efficacy. Furthermore, dedicated studies are required to evaluate the toxicity and safety aspects associated with the nanotechnology-based synthesis and application of *C. wallichii*-derived nanoparticles. Future research should adopt a multidisciplinary approach encompassing pharmacognostic standardisation, phytochemical characterisation, toxicological evaluation, mechanistic studies, and well-designed clinical trials to facilitate the development of safe, effective, and evidence-based therapeutics derived from this plant.

11. Acknowledgement

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Author Contribution

Mahamedha Deorari conducted the literature search, compiled and curated the data, interpreted the findings, prepared the tables and figures, and drafted the original manuscript. Nidhi Gairola critically reviewed the manuscript and approved the final version for submission. Bhuwan Chandra Joshi supervised the study, provided intellectual input, critically revised the manuscript for important scientific content, and approved the final version of the manuscript. All authors have read and agreed to the published version of the manuscript.