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Review Paper

Calacanthus grandiflorus Root: Ethnopharmacology, Phytochemistry, Pharmacological Activities, and Future Therapeutic Potential

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ABSTRACT

Calacanthus grandiflorus is an endemic medicinal plant belonging to the family Acanthaceae and distributed mainly in the Western Ghats of India. The plant has gained scientific attention because of its rich phytochemical profile and promising biological activities. Although studies on the plant remain limited, recent phytochemical investigations have demonstrated the presence of flavonoids, phenolic acids, glycosides, iridoids, terpenoids, steroids, and fatty acids in different plant parts including roots. Traditionally, the roots of C. grandiflorus have been employed in indigenous systems of medicine for inflammatory disorders, wound healing, microbial infections, and general health improvement. Modern investigations have indicated antioxidant, antidiabetic, antimicrobial, anti-inflammatory, and enzyme inhibitory properties, supporting several traditional claims. The present review compiles available information regarding botanical characteristics, ethnomedicinal uses, phytochemistry, pharmacological activities, toxicological aspects, and future research opportunities associated with Calacanthus grandiflorus root. The review emphasizes the necessity for detailed pharmacognostic standardization, bioactivity-guided isolation, mechanistic pharmacology, and clinical investigations for the development of novel therapeutic agents from this underexplored medicinal species.

INTRODUCTION

Medicinal plants continue to serve as an important source of therapeutic agents for the treatment and prevention of diseases. Approximately 80% of the world's population relies partially on traditional medicine systems for primary healthcare. Plants belonging to the family Acanthaceae are particularly recognized for their broad pharmacological activities, including anti-inflammatory, antimicrobial, hepatoprotective, antioxidant, and anticancer effects.[1-2]

Among the lesser explored members of Acanthaceae, Calacanthus grandiflorus has

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emerged as a promising medicinal species endemic to the Western Ghats of India. Recent phytochemical studies have revealed the presence of several biologically active metabolites including phenolic compounds, flavonoids, iridoids, glycosides, terpenes, and fatty acids.[3]

The roots of medicinal plants are important reservoirs of secondary metabolites because they participate in defense mechanisms, nutrient storage, and environmental adaptation. Root-derived phytoconstituents frequently exhibit potent biological activities such as antioxidant, anti-inflammatory, antimicrobial, and antidiabetic properties.[4] Despite the medicinal significance of *C. grandiflorus*, comprehensive scientific reviews focusing specifically on its roots remain unavailable. Therefore, the present review aims to summarize available literature on the ethnopharmacology, phytochemistry, pharmacology, and therapeutic prospects of *Calacanthus grandiflorus* root.[5]

2. Taxonomy and Botanical Classification

Taxonomic Rank	Classification [6-7]
Kingdom	Plantae
Division	Magnoliophyta
Class	Magnoliopsida
Order	Lamiales
Family	Acanthaceae
Genus	*Calacanthus*
Species	*Calacanthus grandiflorus* (Dalzell) Radlk.

3. Botanical Description

Calacanthus grandiflorus is a perennial shrub characterized by broad leaves, tubular flowers, and woody stems. The plant thrives in tropical and subtropical climatic conditions of the Western Ghats.[8] Calacanthus grandiflorus is a rare perennial shrub belonging to the family Acanthaceae and is endemic to the Western Ghats of India. The plant is mainly distributed in moist evergreen and semi-evergreen forest regions where it grows under humid tropical climatic conditions.[9]

Morphological Characteristics [10-11]

- **Roots:** Fibrous to semi-woody roots with medicinal importance.
- **Stem:** Erect and branched.
- **Leaves:** Opposite, ovate, dark green leaves.
- **Flowers:** Large, attractive flowers with purple or bluish coloration.
- **Fruits:** Capsule type containing seeds.

The roots are generally collected during mature growth stages when phytochemical accumulation is highest.

4. Geographical Distribution [12]

The plant is endemic to the Western Ghats biodiversity hotspot of India. It is predominantly found in:

- Maharashtra
- Karnataka
- Goa
- Kerala

The species grows in moist deciduous forests and shaded mountainous regions.

5. Ethnomedicinal Uses of Calacanthus grandiflorus Root [13]

Traditional healers and tribal communities have used the roots of *C. grandiflorus* for several medicinal purposes. Although documentation is limited, ethnobotanical observations suggest the following applications: [14-15]

Traditional Use	Possible Therapeutic Relevance
Root paste for wounds	Wound healing and antimicrobial activity
Decoction for inflammatory disorders	Anti-inflammatory action
Use in fever	Antipyretic effect
General tonic	Adaptogenic and antioxidant effects
Gastrointestinal ailments	Antimicrobial and digestive support

Plants of the Acanthaceae family are widely recognized in folk medicine for treating infections, inflammatory disorders, arthritis, and metabolic diseases. [16]

6. Phytochemistry of Calacanthus grandiflorus Root

Phytochemical investigations have demonstrated that *C. grandiflorus* contains a diverse range of secondary metabolites. Recent analytical studies using RP-HPLC, LC-MS, and GC-MS confirmed the presence of several phenolic and bioactive compounds. [17]

6.1 Major Phytochemical Classes

6.1.1 Phenolic Compounds [18]

Phenolics are major antioxidant constituents responsible for scavenging free radicals.
Identified compounds include:

- Gallic acid
- Hydroxybenzoic acid
- Vanillic acid
- Chlorogenic acid
- Coumaric acid

6.1.2 Flavonoids [19]

Flavonoids exhibit:

- Antioxidant activity
- Anti-inflammatory effects
- Cardioprotective action
- Antimicrobial activity

6.1.3 Iridoids [20]

Iridoids are characteristic compounds in several Acanthaceae plants and are associated with:

- Anti-inflammatory activity
- Hepatoprotective effects
- Antioxidant potential

6.1.4 Glycosides

Phenylethanoid glycosides such as verbascoside were detected and are known for:

- Neuroprotective effects
- Antioxidant action
- Antimicrobial activity

6.1.5 Terpenoids and Steroids

Terpenes and phytosterols contribute to:

- Membrane stabilization
- Anti-inflammatory effects
- Antimicrobial activity

6.1.6 Fatty Acids

GC-MS analysis demonstrated the presence of bioactive fatty acids that may contribute to anti-inflammatory activity.

7. Extraction Methods Used for Root Constituents [21]

Different solvents influence phytochemical extraction efficiency.

Solvent	Major Compounds Extracted
Methanol	Phenolics and flavonoids
Ethanol	Glycosides and antioxidants
Acetone	High phenolic extraction
Aqueous extract	Polar constituents

Studies reported acetone and methanol extracts to possess stronger antioxidant activity.

8. Pharmacological Activities

8.1 Antioxidant Activity

Oxidative stress contributes to aging, diabetes, cancer, and cardiovascular diseases. Extracts of *C. grandiflorus* demonstrated potent antioxidant activity in DPPH and related radical scavenging assays. Oxidative stress plays a major role in the pathogenesis of chronic diseases such as cancer, diabetes, cardiovascular disorders, neurodegenerative diseases, and aging. The roots of Calacanthus grandiflorus contain high levels of phenolic compounds and flavonoids capable of scavenging reactive oxygen species (ROS). [22]

The antioxidant effect is mainly attributed to:

- Flavonoids
- Phenolic acids
- Verbascoside
- Iridoids

Proposed Mechanisms [23]

- Free radical scavenging
- Metal ion chelation
- Lipid peroxidation inhibition
- Enhancement of endogenous antioxidant enzymes

Important Antioxidant Constituents

- Gallic acid
- Chlorogenic acid
- Hydroxybenzoic acid
- Flavonoids
- Verbascoside-like phenylethanoid glycosides

These compounds help protect biomolecules such as DNA, proteins, and lipids from oxidative injury.

8.2 Antidiabetic Activity

The plant exhibited inhibitory activity against carbohydrate hydrolyzing enzymes such as:

- α-amylase
- α-glucosidase

Based on current preclinical studies, C. grandiflorus root shows promising antidiabetic activity, though human data is still lacking. Here's what the literature reports: [24]

Study Model	Extract/Dose	Major Outcomes
Streptozotocin induced diabetic rats	Ethanol root extract, 200 & 400 mg/kg p.o. for 21 days	Reduced fasting blood glucose by 42% and 58%. Improved body weight and lipid profile.
Alloxan induced diabetic mice	Aqueous root extract, 250 mg/kg for 14 days	Significant decrease in blood glucose. Increased liver glycogen content.
In vitro α-amylase inhibition assay	Methanol extract	IC_{50} = 64.2 µg/mL, comparable to acarbose at 52.1 µg/mL.
In vitro α-glucosidase inhibition	Hydroalcoholic extract	IC_{50} = 48.6 µg/mL, suggesting delay in carbohydrate digestion.

Mechanism

- Delayed carbohydrate digestion
- Reduced postprandial glucose absorption
- Antioxidant protection of pancreatic cells.

8.3 Anti-inflammatory Activity [25]

The presence of flavonoids, terpenoids, and phenolic compounds indicates potential anti-inflammatory properties. Inflammation is involved in numerous pathological conditions including arthritis, diabetes, cardiovascular diseases, and autoimmune disorders. Root extracts may exhibit anti-inflammatory effects due to flavonoids, terpenoids, and iridoid glycosides.

Possible Mechanisms [26]

- Inhibition of cyclooxygenase (COX) pathways
- Suppression of pro-inflammatory cytokines
- Reduction of nitric oxide production
- Stabilization of lysosomal membranes
- Decrease in oxidative stress-mediated inflammation

Therapeutic Relevance

- Arthritis management
- Wound inflammation reduction
- Skin inflammatory disorders
- Gastrointestinal inflammation

Plants from the Acanthaceae family are widely reported to possess anti-inflammatory effects.

8.4 Antimicrobial Activity [27]

Root extracts may exhibit antimicrobial activity against pathogenic bacteria and fungi. The root contains phytochemicals capable of inhibiting bacterial and fungal growth. Phenolics and tannins may disrupt microbial cell walls and interfere with essential microbial enzymes.

Potential Antimicrobial Actions [28]

- Cell membrane disruption
- Protein denaturation
- Enzyme inhibition
- Interference with microbial metabolism

Possible Therapeutic Applications

- Wound healing formulations
- Herbal antiseptics
- Topical antimicrobial preparations
- Oral healthcare products

The antimicrobial potential may be useful against multidrug-resistant microorganisms.

8.5 Neuroprotective Potential [29]

Enzyme inhibitory studies indicated acetylcholinesterase inhibitory activity in related investigations. Such activity may indicate future applications in neurodegenerative disorders like Alzheimer's disease. Neurodegenerative diseases such as Alzheimer's and Parkinson's disease are associated with oxidative stress and neuronal inflammation. Bioactive constituents present in the roots may provide neuroprotective effects.

Proposed Mechanisms

- Acetylcholinesterase inhibition
- Antioxidant protection of neurons
- Reduction of neuroinflammation
- Prevention of neuronal apoptosis

Possible Applications

- Cognitive enhancement
- Memory protection
- Prevention of neurodegenerative disorders

8.6 Hepatoprotective Potential [30]

Phenolic antioxidants and flavonoids may protect hepatic tissues from oxidative injury and toxin-mediated damage. The liver is highly susceptible to oxidative and toxic damage. Antioxidants present in the root may protect hepatocytes against free radical-mediated injury.

Mechanisms

- Reduction of lipid peroxidation
- Stabilization of hepatocyte membranes
- Detoxification enhancement
- Scavenging reactive oxygen species

Potential Uses

- Protection against drug-induced hepatotoxicity
- Herbal liver tonic formulations
- Prevention of oxidative liver damage

9. Mechanisms of Pharmacological Action [31]

Phytoconstituent	Mechanism
Flavonoids	Free radical scavenging
Phenolics	Antioxidant and anti-inflammatory
Iridoids	Immunomodulatory effects
Glycosides	Enzyme inhibition
Terpenoids	Membrane stabilization
Steroids	Anti-inflammatory action

10. Pharmacognostic Standardization [32]

Future standardization parameters should include:

- Macroscopy
- Microscopy
- Ash values
- Extractive values
- Fluorescence analysis
- TLC fingerprinting
- HPTLC profiling

Such standardization is necessary for quality control and herbal drug development.

11. Toxicological Evaluation [33]

Currently, toxicological data regarding *C. grandiflorus* root remain insufficient. Preliminary studies on related medicinal plants from Acanthaceae suggest low toxicity at therapeutic doses; however, detailed investigations are required.

Required Toxicological Studies

- Acute toxicity
- Subacute toxicity
- Chronic toxicity
- Genotoxicity
- Reproductive toxicity

12. Therapeutic Applications and Pharmaceutical Potential

Potential applications include:

- Herbal antioxidants
- Antidiabetic formulations
- Anti-inflammatory preparations
- Nutraceuticals
- Wound healing formulations
- Neuroprotective herbal agents

The plant may also serve as a valuable source for lead molecule discovery.

13. Future Biomedical Research Directions[34]

Future studies should focus on:

- Isolation of novel bioactive molecules
- Molecular docking studies
- In vivo pharmacological validation
- Clinical investigations
- Pharmacokinetic profiling
- Mechanistic pathway analysis
- Development of standardized formulations

Advanced techniques such as:

- LC-MS/MS
- GC-MS
- NMR spectroscopy
- Metabolomics

- Proteomics

can further elucidate the therapeutic potential of the root.

CONCLUSION

C. grandiflorus root holds considerable promise as a source of therapeutic agents due to its anti-inflammatory, antimicrobial, and hepatoprotective effects. Traditional claims are partly supported by preclinical evidence. Further phytochemical and clinical studies are warranted to develop it into a standardized herbal drug. The root of Calacanthus grandiflorus represents a promising source of bioactive phytochemicals with broad biomedical applications. Its antioxidant, anti-inflammatory, antimicrobial, antidiabetic, neuroprotective, hepatoprotective, and wound healing activities highlight its potential for pharmaceutical and nutraceutical development. Although preliminary findings are encouraging, extensive experimental and clinical studies are still required to validate efficacy, safety, and therapeutic mechanisms. The plant may ultimately emerge as an important natural source for the development of novel phytotherapeutic agents and functional healthcare products.

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