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Therapeutic Potential of *Bauhinia Racemosa* In The Management of Chronic Diseases: A Comprehensive Review

Priyanka Farakute[1], Shubhangi Sutar[*2], Sayali Kulkarni[3], Pallavi Mane[3], Shweta Patil[3], Komal Pisal[3], Smita Mali[1], Savita More[4]

[1]Department of Pharmacognosy, Ashokrao Mane College of Pharmacy, Peth- Vadgaon, Maharashtra, India 416112

[2]Department of Quality Assurance, Ashokrao Mane College of Pharmacy, Peth- Vadgaon, Maharashtra, India 416112

[3]Shree Santkrupa College of Pharmacy, Ghogaon, Karad, India 415111

[4]GES College of Pharmacy Limb, Satara, Maharashtra, India 415015

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ABSTRACT:

Bauhinia racemosa Lam., a member of the family Fabaceae, is a traditionally valued medicinal plant extensively distributed across the Indian subcontinent and Southeast Asia. The present review comprehensively summarizes the phytochemical composition, pharmacological activities, and therapeutic relevance of B. racemosa in the management of chronic non-communicable diseases (NCDs). Chronic disorders such as type 2 diabetes mellitus, cardiovascular diseases, cancer, inflammatory conditions, and chronic liver diseases are primarily driven by oxidative stress, persistent inflammation, and metabolic dysregulation. A wide range of bioactivities, including antidiabetic, antioxidant, anti-inflammatory, hepatoprotective, anticancer, antiulcer, antimicrobial, antihistaminic, anxiolytic, and anti-HIV qualities, have been found in B. racemosa. These effects are largely attributed to its rich phytochemical profile comprising flavonoids (kaempferol, quercetin), triterpenoids (lupeol, betulin), phenolic acids, tannins, and other polyphenolic constituents. Preclinical investigations demonstrate modulation of key molecular pathways associated with redox balance, inflammatory mediators, apoptosis, and lipid metabolism. Furthermore, by increasing bioavailability and target specificity, developments in nanotechnology and innovative drug delivery methods have improved the therapeutic potential of B. racemosa extracts. Despite promising experimental findings, clinical validation remains limited. This review highlights the mechanistic insights, therapeutic potential, and formulation strategies of B. racemosa, while identifying critical gaps that must be addressed to facilitate its translation into evidence-based phytopharmaceutical interventions for chronic disease management.

INTRODUCTION:

Chronic non-communicable diseases (NCDs), including type 2 diabetes mellitus (T2DM), cardiovascular disorders, chronic liver diseases, cancer, and persistent inflammatory conditions, account for more than 70% of global mortality and impose a substantial socioeconomic burden on healthcare systems worldwide [1]. Although conventional pharmacotherapy remains the primary approach for disease management, its prolonged use is often associated with adverse drug reactions, reduced patient compliance, therapeutic resistance, and high treatment costs [2]. These limitations have stimulated growing scientific interest in plant-derived therapeutic agents with multitargeted mechanisms, disease-modifying properties, and improved safety profiles [3].

In this context, *B. racemosa*, a member of the family Fabaceae (subfamily Caesalpiniaceae), has attracted considerable attention [4]. It is a moderately small deciduous tree characterized by a crooked, bushy habit with pendulous branches, and is easily identifiable by its distinctive bilobed leaves resembling a camel's hoof and racemose inflorescences of yellowish-white flowers [5]. The species is widely distributed across the Indian subcontinent, including the Western Himalayan region, and extends to Sri Lanka (Ceylon), China, and Timor, occurring from plains to elevations of approximately 1650 m. Owing to its ecological resilience, it is frequently utilized in afforestation and land reclamation programs for soil stabilization and erosion control. The plant is known by various vernacular names such as Apta and Kanchanara (Hindi), Sona-patri and Arimeda (Sanskrit), Avala (Tamil), Apta (Marathi), and Tella-mandaram (Telugu), reflecting its widespread traditional relevance [6].

Ethnomedicinally, *B. racemosa* has long been employed for the management of diverse ailments, including diarrhea, dysentery, pyrexia, cephalgia, dermatological disorders, diabetes mellitus, inflammatory conditions, and neoplastic diseases. Bark decoctions are traditionally applied for ulcer healing, while the mature leaves are used in the manufacture of traditional in some areas, tender leaves and Indian beedis are eaten as green vegetables. The bark and leaves exhibit sweetish and mildly acrid properties, contributing to their refrigerant and astringent effects described in traditional systems of medicine [7].

Phytochemical investigations have revealed that *B. racemosa* is rich in bioactive secondary metabolites, including flavonoids (e.g., kaempferol, quercetin), triterpenoids (e.g., lupeol, betulin), phenolic acids, tannins, and saponins. These constituents underpin its broad pharmacological profile. Experimental studies have demonstrated significant antioxidant, antidiabetic, anti-inflammatory, hepatoprotective, antimicrobial, antifilarial, anthelmintic, antimalarial, cardioprotective, and anticancer activities. The flowers exhibit mild laxative properties, whereas the seeds have shown antibacterial potential. Such findings substantiate many of the traditional claims and position the species as a promising candidate for further drug development [8].

From a molecular standpoint, oxidative stress and persistent inflammation play a major role in the development and course of the majority of NCDs. The polyphenolic antioxidants and multifunctional phytoconstituents of *B. racemosa* appear to modulate key molecular pathways involved in redox imbalance, inflammatory mediator release, and metabolic dysregulation [9]. By targeting multiple signaling cascades, the plant exhibits a pleiotropic pharmacological profile that may be particularly advantageous in complex chronic disorders [10]. Given its diverse bioactivities, *B. racemosa* holds significant potential for incorporation into advanced pharmaceutical and nutraceutical formulations. Nanoparticles, phytosomes, liposomes, solid lipid nanoparticles, nanoemulsions, transdermal systems, and herbal gels are examples of novel drug delivery systems that may improve the medication's targeted delivery, physicochemical stability, and bioavailability. Such approaches could improve therapeutic efficacy, reduce dosing frequency, and minimize systemic adverse effects [11].

Despite encouraging preclinical data, there is still little clinical practice translation. Reproducibility and therapeutic dependability must be established through carefully planned clinical studies, extract standardisation, pharmacokinetic profiling, and long-term safety assessments. This review therefore aims to comprehensively consolidate the existing literature on the phytochemistry, pharmacological activities, molecular mechanisms, and emerging formulation strategies of *B. racemosa*, with particular emphasis on its potential role in the prevention and management of chronic non-communicable diseases.

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Morphological Illustration of *Bauhinia Racemosa*

Table 1: Morphological Characteristics of *B. racemosa* Lam. [12]

Characteristic	Description
Habit	Small, broad-leaved deciduous tree reaching up to ~12 m in height
Bark	Grey to black; rough, thinly scaly with prominent vertical fissures/cracks
Leaf	Simple, bilobed, alternate; stipules small and caduceus (shed early)
Inflorescence	Terminal and leaf-opposed racemes, few-flowered
Flowers	Bisexual; ~10–12 mm diameter; yellowish-white; complete and regular
Fruits	Oblong, turgid pods measuring 15–22 × 1.5–2 cm; blackish-brown; horned apex; indehiscent
Seeds	10–20 seeds per pod; ovoid in shape

Table 2: *B. racemosa* common names in different languages

Bengali	Banarji
English	Mountain ebony
Gujrati	Asundro
Hindi	Ashta, Jhineri, Katmauli, Kachnal
Panjabi	Kosundro
Sanskit	Yugmapatra, Ashmantaka
Marathi	Apata
Tamil	Atti, Tataki
Telagu	Tella arechetu
Urdu	Kachnaar

Table 3: Taxonomical Classification of *B. racemosa*

Kingdome	Plantae
Division	Magnoliophyta
Class	Magnoliopsida
Order	Fabales
Family	Fabiaceae
Sub-Family	Caesalpiniaceae
Genus	Bauhinia
Species	Racemosa

Figure 1: Plant of *B. racemosa*

Pharmacological activities of *b. Racemosa:*

Pharmacological versatility of *B. racemosa* has been substantiated through diverse experimental investigations, highlighting its potential against infectious, metabolic, inflammatory, neoplastic, and neurobehavioral disorders. The following sections summarize key bioactivities relevant to chronic and infectious disease management.

Anti-HIV activity:

Anti-HIV potential of *B. racemosa* extracts has been evaluated using the syncytia formation assay to assess inhibition of acute HIV-1 infectivity. In this model, C8166 cells (4×10^2 cells/well) were infected with HIV-1 at a multiplicity of infection (MOI) of 0.015. The cells were then incubated for three days at 37°C in a humidified 5% CO2 atmosphere, either with or without graded doses of the test substances. Zidovudine (AZT) served as the positive control. Post-infection, cytopathic effects were quantified by counting multinucleated giant cells (syncytia) under an inverted microscope (100× magnification). The percentage inhibition of syncytia formation was calculated relative to the infected control, and the 50% effective concentration (EC_{50}) and 50% cytotoxic concentration (CC_{50}) were determined [13]. These findings indicate that *B. racemosa* possesses inhibitory activity against HIV-1 replication, warranting further mechanistic and molecular investigations to identify active antiviral constituents.

Antidiabetic activity:
Preclinical studies have demonstrated significant antidiabetic effects of *B. racemosa* extracts in experimentally induced diabetic rat models. Treatment resulted in a marked reduction in fasting blood glucose levels and significant improvement in lipid parameters, including decreased serum triglycerides, total cholesterol, and low-density lipoprotein (LDL) levels, alongside increased high-density lipoprotein (HDL) concentrations [14]. These results support its potential use in the management of metabolic syndrome and type 2 diabetes mellitus by suggesting antihyperglycemic, hypolipidemic, and antiadipogenic qualities.

Antihistaminic activity:
In mouse models, the ethanolic leaf extract of *B. racemosa* has demonstrated notable antihistaminic action. Administration (50 mg/kg, i.p.) effectively inhibited clonidine-induced catalepsy, while showing no significant effect on haloperidol-induced catalepsy, indicating selective antihistaminic action without dopaminergic interference [15]. These results validate its traditional use in asthma and allergic conditions and suggest that polar phytoconstituents may mediate histamine receptor antagonism.

Antioxidant activity:
B. racemosa methanolic extract has shown robust antioxidant potential across multiple in vitro assays. Using the ammonium thiocyanate method to evaluate lipid peroxidation, MEBR exhibited concentration-dependent inhibition (62.43–76.83% at 50–500 µg/mL), comparable to α-tocopherol at equivalent concentrations. The IC_{50} value (38.46 µg/mL) indicated significant suppression of linoleic acid peroxidation ($P < 0.05$). Its great ability to scavenge free radicals is further supported by its high Trolox equivalent antioxidant capacity (TEAC) values and significant total polyphenol content. These antioxidant effects are largely attributed to flavonoids, biflavones, tannins, and coumarins, which may neutralize free radicals, reduce hydroperoxides, and chelate transition metal ions [5,16].

Antiulcer activity:
Stem bark extracts (aqueous and alcoholic) of *B. racemosa* have demonstrated significant gastroprotective effects in paracetamol- and aspirin-induced ulcer models in rats. Treatment markedly reduced ulcer number, ulcer index, and lesion incidence while enhancing the healing index. The alcoholic extract exhibited stronger dose-dependent protection. The antiulcer activity is primarily attributed to flavonoid-mediated mechanisms, including reduced gastric acid secretion, inhibition of peptic activity, and reinforcement of mucosal defenses [17].

Anticancer activity:
Both *in vitro* and *in vivo* experiments have confirmed B. racemosa's antitumor potential. In mice with Ehrlich ascites carcinoma, methanolic stem bark extracts considerably decreased tumour volume, extended mean survival time, and restored haematological parameters. These effects were associated with decreased lipid peroxidation and enhanced endogenous antioxidant enzyme activity (GSH, SOD, CAT). In vitro studies further indicate dose-dependent cytotoxicity and induction of apoptosis, potentially mediated through oxidative stress modulation, caspase activation, and cell-cycle arrest [18]. Collectively, these findings highlight the plant's multi-targeted antineoplastic potential and support bioassay-guided isolation of active principles.

Hepatoprotective activity:
Ethanolic stem bark extract has demonstrated significant hepatoprotective activity in paracetamol-induced hepatotoxicity models. Administration of the extract (75–225 mg/kg, b.w.) restored elevated serum AST, ALT, LDH, and ALP levels toward normal values and improved total protein content in a dose-dependent manner. Histopathological evaluation revealed reduced centrilobular necrosis and hepatocellular degeneration in treated groups, confirming membrane stabilization and regenerative effects [19,20].

Anti-inflammatory, analgesic, and antipyretic activity:
In models of paw oedema generated by carrageenan, dextran, histamine, and serotonin, methanolic stem bark extract significantly reduced acute inflammation, with the greatest oedema reduction (~43–46%) occurring at 200 mg/kg. In chronic inflammation (cotton pellet granuloma model), the extract reduced granuloma formation by approximately 50%, comparable to indomethacin. It also suppressed leukocyte migration, demonstrated central and peripheral analgesic effects in hot plate and acetic acid-induced writhing tests, and produced dose-dependent antipyretic activity in yeast-induced pyrexia models [21].

Anxiolytic activity:
Swiss albino mice given methanolic extract (150–300 mg/kg) orally showed a significant increase in both the amount of time spent in the lit compartment in the light–dark test and open-arm exploration in the elevated plus maze. Enhanced exploratory behavior and reduced freezing responses further indicated anxiolytic potential, possibly mediated via modulation of central neurotransmitter pathways [22].

Antimicrobial and antifungal activity:
Utilising disc and agar well diffusion experiments, methanolic stem bark extract has shown broad-spectrum antibacterial efficacy against a variety of bacterial and fungal diseases. Significant inhibitory zones were observed at concentrations ranging from 25–200 µg/disc, with ofloxacin and miconazole nitrate as reference standards. Additionally, biosynthesized silver nanoparticles derived from *B. racemosa* extracts exhibited potent antibacterial activity against Gram-positive and Gram-negative strains, as well as antifungal efficacy against *Aspergillus niger*, suggesting synergistic enhancement through nanotechnological approaches [23]. Although antifungal studies specific to *B. racemosa* remain limited, related species within the genus have shown dose-dependent inhibition of fungal spore germination [24]. Given its comparable phytochemical composition, similar antifungal potential is plausible and merits focused investigation.

Endophyte-mediated antibacterial activity:
Additionally, endophytic fungi isolated from *B. racemosa* tissues have shown antibacterial activity against Escherichia coli and Bacillus subtilis. These findings suggest that the plant's associated microbial community may contribute to its overall antimicrobial profile through the production of bioactive secondary metabolites [25].

Future Prospective:
Although substantial preclinical evidence supports the therapeutic potential of *Bauhinia racemosa*, several challenges must be addressed to enable its clinical translation. Future research should prioritize bioassay-guided fractionation to isolate and structurally characterize active phytoconstituents responsible for specific pharmacological effects. Detailed mechanistic studies at molecular and genomic levels are necessary to elucidate signaling pathways, receptor interactions, and gene expression modulation. Standardization of extracts, establishment of quality control parameters, and development of validated biomarkers are essential to ensure reproducibility and batch-to-batch consistency. Comprehensive pharmacokinetic, toxicological, and long-term safety evaluations, including chronic toxicity and herb–drug interaction studies, are critically required. Well-designed randomized controlled clinical trials must be conducted to substantiate efficacy in human populations. Additionally, integration of advanced drug delivery platforms such as nanoparticles, phytosomes, and nanoemulsions may enhance bioavailability and targeted delivery, thereby improving therapeutic outcomes. Exploration of synergistic combinations with conventional drugs may further expand its applicability in integrative medicine.

CONCLUSION:
In conclusion, *B. racemosa* represents a pharmacologically versatile medicinal plant with significant therapeutic promise against chronic non-communicable diseases and infectious conditions. Multitargeted biological actions, including as antioxidant, anti-inflammatory, antidiabetic, hepatoprotective, anticancer, and antibacterial properties, are supported by its varied phytochemical composition. Preclinical results demonstrate its potential as a source of novel bioactive chemicals and firmly support its traditional use. However, the absence of robust clinical evidence and standardized formulations remains a critical limitation. Future interdisciplinary research integrating phytochemistry, molecular pharmacology, toxicology, and clinical sciences is essential to fully harness the therapeutic potential of *B. racemosa* and facilitate its development into safe, effective, and standardized phytopharmaceutical products suitable for modern healthcare systems.

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