

Phytochemical Profile and Therapeutic Perspectives of *Bauhinia variegata* Linn (Kachnar)

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Abstract

Review Article

Bauhinia variegata Linn (Kachnar) a medicinal plant in the family of Fabaceae, has been well utilized in traditional medicinal systems for the management of different disorders. This review provides a summary of the phytochemical composition and medicines of various parts of the plant such as its bark, leaves, flowers, buds, seed and roots. Its dried leaves contain flavonoids, alkaloids, tannins, phenolic compounds, terpenoids, saponins, glycosides and steroids; all of these have been identified as responsible for its wide range of pharmacological actions. Different extract of *Bauhinia variegata* has been reported with strong antioxidant, antimicrobial, antihyperlipidemic, anticancer, antidiabetic, anticataract, antiviral, anti-inflammatory, hepatoprotective, nephroprotective and wound healing activity. Its phenolic and flavonoid nature is primarily responsible for its antioxidant, cytoprotective activities. Phytotherapeutic potential use, backed up by scientific evidence from in vitro and in vivo studies, has been revealed.

Keywords: *Bauhinia variegata*; flavonoids; antioxidant activity; antimicrobial; activity anticancer activity; antiviral activity.

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1. INTRODUCTION

Medicinal plants represent an important source of bioactive secondary metabolites that play a significant role in the prevention and management of various diseases. The therapeutic potential of these plants is largely attributed to the presence of diverse phytochemicals capable of exerting specific physiological effects in the human body.[1] In addition to their medicinal value, several plants are also recognized for their ornamental and cultural importance in traditional Indian healthcare practices.[2] *Bauhinia variegata* Linn., belonging to the family Fabaceae and subfamily Caesalpinioideae, is commonly known as Mountain Ebony in English, Kachnar in Hindi, and Raktakanchanara in Marathi.[3] It is an important medicinal plant widely used in traditional systems of medicine, including Ayurveda, Unani, and Homeopathy. The genus *Bauhinia* comprises approximately 250 species distributed throughout tropical regions of the world. *Bauhinia variegata* is native to South and Southeast Asia and is widely distributed across India and China, where it is valued for both its medicinal importance and its attractive flowers and ornamental foliage.[4] Different parts of *Bauhinia variegata*, including the bark, roots, leaves, seeds, and flowers, are

extensively used in traditional medicine for the management of dyspepsia, bronchitis, leprosy, ulcers, and obesity, and are regarded as astringent, tonic, and anthelmintic remedies.[5] Phytochemical investigations of the stem bark have revealed the presence of flavonoids, alkaloids, tannins, and saponins, which are associated with immunomodulatory, antibacterial, and hepatoprotective activities.[6] Leaves of *Bauhinia variegata* contain several bioactive constituents belonging to the classes of terpenoids, alkaloids, glycosides, steroids, and flavonoids, including neophytadiene, palmidrol, phytol, and γ -sitosterol, which have been reported to possess diverse pharmacological properties.[7] The pink-purple or white fragrant flowers contain terpenoid constituents exhibiting notable antioxidant and antibacterial activities.[8] The flowering buds are traditionally employed in the treatment of dysentery, diarrhea, and hemorrhoids.[9] In addition, alcoholic root extracts have demonstrated potent antioxidant and chemopreventive effects against cyclophosphamide-induced mutagenesis.[10] Root infusions are also traditionally used for cardiovascular ailments and flatulence and have been reported to possess antihyperlipidemic activity, suggesting a potential role in obesity management.[11]

The present review aims to critically compile and discuss the phytochemical constituents and experimentally validated therapeutic activities of *Bauhinia variegata*, with special emphasis on its antioxidant, antimicrobial, antihyperlipidemic,

anticancer, antidiabetic, anticataract, anti-inflammatory, nephroprotective, and wound healing properties.

2. TAXONOMY AND BOTANICAL PROFILE:

2.1. Taxonomical classification [11]:

Table 1: Taxonomical classification *Bauhinia variegata*

Taxonomical Rank	Classification
Kingdom	Plantae
Subkingdom	Tracheophyta
Super division	Spermatophyta
Division	Magnoliophyta
Class	Magnoliopsida (Dicotyledonae)
Order	Fabales
Family	Fabaceae (Leguminosae)
Sub-family	Caesalpinioideae

2.3. Vernacular names [12]:

Table 2: Vernacular names of *Bauhinia variegata*

Language	Vernacular Name
English	Mountain Ebony, Orchid Tree, Camel's Foot Tree
Hindi	Kachnar, Rakta Kachnar
Sanskrit	Kanchanara, Rakta Kanchanara
Marathi	Raktakanchanara, Kanchan
Bengali	Kanchan
Tamil	Mandarai
Gujarati	Kanchanar

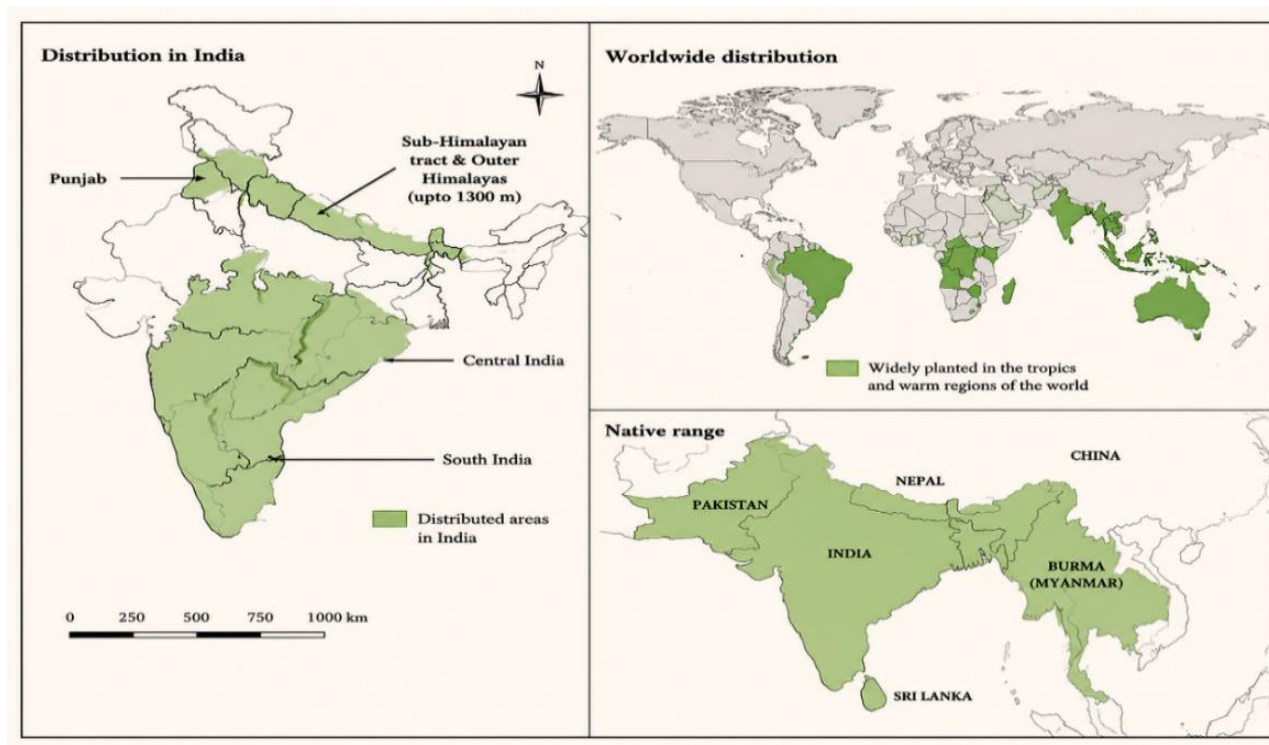


Figure 1: Geographical distribution of *Bauhinia variegata* Linn

2.4. Geographical distribution:

It is distributed throughout India which include Punjab, central and south India, sub-Himalayan tract,

outer Himalayas 'upon an altitude of 1300m. It is widely planted in the tropics and warm region of the world. It is native to South Asia and Southeast Asia, from southern

China, Burma, India, Nepal, Pakistan, and Sri Lanka. [13]

2.5. Botanical description:

Bauhinia variegata Linn. is a medium-sized, deciduous, fast-growing, and sun-loving tree that typically attains a height of 10-15 m. It possesses a short,

dark grey to brown trunk with a broad, spreading crown and slender, pubescent young branches. The species grows well in tropical and subtropical climates and is commonly found on rocky hill slopes as well as sandy loam and loamy soils. It prefers well-drained, slightly acidic soils and exhibits poor tolerance to saline conditions. [14]



Fig. 2: *Bauhinia variegata* plant with its parts

2.5.1. Bark:

The bark is greyish-brown, rough, and fissured externally, with transverse cracks and exfoliations, while the inner surface is creamish-white, becoming reddish-brown upon drying. [15]

2.5.2. Leaves:

The leaves are simple, alternate, broadly ovate to orbicular, and characteristically bilobed at the apex, resembling a camel's hoof. They measure approximately 8-15 cm in length, possess palmate venation, and have entire margins with smooth, glabrous surfaces. The leaves are green when fresh and turn brown on drying. Leaflets exhibit nyctinasty ("sleep") movements, folding during the night. [16]

2.5.3. Flowers:

The flowers are large, bisexual, fragrant, and showy, arranged in terminal or axillary racemes. They are usually pink, rosy-purple, or white, with five unequal petals measuring approximately 4-6 cm in length. Flowering generally occurs before the emergence of new leaves, enhancing the ornamental value of the tree. [17]

2.5.4. Seeds:

The seeds are flattened, smooth, dark brown, and oval to ellipsoidal, measuring approximately 15-16 mm in length and 11-13 mm in width. [18]

2.5.5. Root:

The root of *Bauhinia variegata* Linn. consists of a well-developed taproot with numerous lateral roots, providing firm anchorage and efficient absorption of water and nutrients. The roots are woody, cylindrical, and brownish externally, with a cream to pale-yellow inner surface. They possess a characteristic odour and a slightly astringent taste. [19]

3. PHYTOCHEMICAL PROFILE:

The phytochemicals composition of *Bauhinia variegata* is diverse and includes a wide array of secondary metabolites such as flavonoids, alkaloids, terpenoids, phenolic compounds, saponins, and tannins. These phytoconstituents contribute to the plant's medicinal properties and biological activities. The major phytoconstituents found in different part of *Bauhinia variegata* Linn shown on the table.2,

Table 3: Phytochemicals of *Bauhinia variegata* Linn

Plant part	Major constituents	References
Leaves	Alkaloids, Cardiac glycosides, Tannins, Quercetin, Rut.in, Apigenin, Apig.enin-7-O-glucoside, Germacrene D, Spathulenol δ -Cadinene, heptagrid. acontan-12,13-diol, Dotetr.acont-15-en-9-ol	[20].
Bark	Lupeol, β -Sitosterol, Quercitroside, Isoquercitroside, Rutoside (Rutin), Taxifolin, Rhamnoside, Myricetin, glycoside, Apig.enin-7-O-glucoside, Quercetin, Apigenin, Ascorbic acid, Aspartic acid, Glutamic acid, Octadecanoic acid, Keto aci.ds, Ami.no aci.ds, Tannins, 5,7-Dihydrox.yflavone-4-O- α -L-rhamnopyranosyl- β -D-glucopyranoside, 5,7-Dimethox.yflavone-4-O- α -L-rhamnopyranosyl- β -D-glucopyranoside, Kaempferol-3-glucoside	[21]. [22].
Flowers	Quercitroside, isoquercitroside, rutoside, taxifolin rhamnoside, kaempferol-3-glucoside, myricetin glycoside, apigenin, ascorbic acid, aspartic acid, glutamic acid, octadecanoic acid, keto aci.ds, ami.no aci.ds, tannins, cyanidin-3-glucoside, malvidin-3-glucoside, malvidin-3-diglucoside, peonidin-3-glucoside, peonidin-3-diglucoside, kaempferol-3-galactoside, and kaempferol-3-rhamnoglucoside.	[23]. [24]. [25].
Buds	Flavo.noids, phenols, amino aci.ds, vanillic acid, caffeic acid, kaempferol, syringic acid, ascorbic acid, phenolic compounds, tocopherols, and carotenoids.	[26].
Seeds	Carbohydrates, proteins, ami.no aci.ds, ascorbic acid, flavonoids, alkaloids, leucoanthocyanins, aspartic acid, glutamic acid, arginine, glycine, alanine, histidine, isoleucine, lysine, methionine, phenylalanine, proline, serine, threonine, tyrosine, valine, and 5-hydr.oxy-7,3',4',5'-tetramethoxyflavone-5-O- β -D-xylopyr.anosyl- α -L-rhamnopy.ranoside.	[27]. [28].
Root	(2S)-5,7-dimethoxy-3',4' methylenedioxyflavanone, dihydrodibenzoxepin, 5,6-dihydro-1,7-dihydroxy-3,4-dimethoxy-2-methyldibenz [b,f] doxepin, flavonoids, glycosides, carbohydrates, tannins, phenolic compounds, proteins, and free ami.no aci.ds.	[29].

4. THERAPEUTIC PERSPECTIVE:

Bauhinia variegata Linn. has been studied for medicinal effects and is known to contain a variety of bioactive phytochemicals including flavonoids, phenolic compounds, tannins, terpenoids, saponins, alkaloids and glycosides. These constituents have been linked to a wide range of pharmacological activities, which justify the traditional use of the plant in the management of several diseases.

4.1. Antioxidant Activity:

The aqueous and ethanolic extracts of *B. variegata* L. have demonstrated significant antioxidant activity in various in vitro assays. The % free radical scavenging activity gradually increases with increasing concentrations of *B. variegata* extracts in DPPH radical scavenging assay. Dose dependent antioxidant activity pattern was also observed in phosphomolybdate assay. Antioxidant activity was directly correlated with the amount of total phenolic contents in the extracts. *Bauhinia variegata* in L-dopa extract has shown the highest FRAP (Ferric reducing antioxidant power) values. [30]

4.2. Anti- microbial Activity:

Various studies have suggested that *Bauhinia variegata* may serve as a promising natural source of antimicrobial agents. Extracts prepared using methanol, chloroform, and water have shown inhibitory effects against a range of Gram-positive and Gram-negative bacteria, including *Bacillus cereus*, *Staphylococcus aureus*, *Klebsiella pneumonia*, *Escherichia coli*, and *Pseudomonas pseudo alcaligenes*. Comparative evaluations indicate that methanolic extracts generally possess stronger antibacterial activity than aqueous extracts. Leaf extracts obtained with alcoholic solvents have also demonstrated superior antimicrobial efficacy

relative to other solvent systems. Moreover, methanolic extracts derived from both conventionally grown and tissue-cultured plants exhibited broad-spectrum antimicrobial activity, although *E. coli* and *Pseudomonas aeruginosa* showed resistance at a concentration of 50 μ g/mL. Ethanolic stem bark extract has additionally been reported to inhibit the growth of *Bacillus subtilis*, *Salmonella typhi*, *Shigella dysenteriae*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Vibrio cholerae*, supporting the traditional use of the plant in infectious conditions. [31]

4.3. Anti hyperlipidemic Activity:

The methanolic stem bark extract of *Bauhinia variegata* has demonstrated notable hypolipidemic and antioxidant effects in experimental models of diet-induced hypercholesterolemia. Administration of the extract to high-cholesterol-fed albino rats significantly reduced serum total cholesterol, low-density lipoprotein, very low-density lipoprotein, triglycerides, and phospholipid levels. The treatment also improved endogenous antioxidant defense by elevating superoxide dismutase and reduced glutathione levels, while decreasing lipid peroxidation, indicating protection against oxidative stress-mediated tissue damage. In addition, aqueous root extracts administered to high-fat diet-fed rats at doses of 200 and 400 mg/kg produced significant anti-obesity effects, which were associated with hypoglycemic and hypolipidemic actions. These findings suggest that *Bauhinia variegata* possesses promising metabolic protective properties and may be useful in the management of obesity, hyperlipidemia, and related oxidative stress disorders. [32]

4.4. Anticancer Activity:

The ethanolic extract of *Bauhinia variegata* has demonstrated significant antitumor potential in

experimental cancer models, including Dalton's ascitic lymphoma. The extracts also exhibited hepatoprotective effects by protecting hepatic tissue against diethyl nitrosamine-induced cytotoxicity. In addition, ethanolic extract showed cytotoxic activity against Ehrlich ascites carcinoma (EAC) mouse cell lines. Methanolic stem bark extract administered at doses of 500 and 1000 mg/kg body weight produced marked chemo preventive effects in a 7,12-dimethylbenz [a] anthracene and croton oil-induced skin papilloma model in mice. Treatment with the extract significantly reduced tumor incidence, papilloma formation, tumor yield, and tumor burden. Restoration of depleted glutathione levels in treated animals further suggested that the anticancer activity may be associated with enhancement of antioxidant defense mechanisms. These results suggest that *Bauhinia variegata* possesses significant anticancer and cytoprotective properties and need for further mechanistic and clinical investigations. [33]

4.5. Anti-diabetic Activity:

Bauhinia variegata Linn has long been used in traditional medicine as an antidiabetic plant, and its leaves and stem bark are incorporated into various herbal preparations for the management of blood glucose levels. The antidiabetic activity of the plant has been associated with the presence of insulin-like proteins in these plant parts. Experimental studies in mammalian models have demonstrated that *B. variegata* extracts possess significant hypoglycemic and antidiabetic effects, particularly the ethanolic leaf extract. In addition, roseoside, a major metabolite identified in the ethanolic leaf extract, has been reported to exhibit insulinotropic activity toward pancreatic β -cells of the INS-1 cell line. This compound may act synergistically with chloroplast-associated proteins present in the extract, thereby enhancing insulin secretion and contributing to the overall antidiabetic potential of the plant. These findings support the traditional use of *Bauhinia variegata* in diabetes management and suggest its potential as a source of novel antidiabetic agents, although further mechanistic and clinical studies are required to establish its therapeutic efficacy and safety. [34,35]

4.6. Anticataract activity

The ethanolic stem bark extract of *Bauhinia variegata* Linn has shown promising anticataract activity, which appears to be largely associated with its antioxidant constituents. Among the reported bioactive compounds, rhamnocitrin exhibited notable protective effects against cataract formation. Other phytoconstituents, including 5,3'-dihydroxy-6,7,4'-trimethoxyflavanone and 2,4,8,9,10-pentahydroxy-3,7-dimethoxy-anthracene-6-O- α -L-rhamnopyranoside, also demonstrated significant anticataract potential in ovine lens and chick embryo models. These compounds effectively inhibited hydrogen peroxide- and hydrocortisone-induced lens opacification in a dose-dependent manner, suggesting that their protective effects are mediated through antioxidant mechanisms.

The findings indicate that *Bauhinia variegata* may possess therapeutic potential in the prevention or management of oxidative stress-related cataract genesis. [36]

4.7. Anti-inflammatory Effects

Bauhinia variegata Linn exhibits significant anti-inflammatory activity and has been traditionally used for the management of inflammatory conditions. Experimental studies have shown that extracts of the plant can effectively reduce inflammatory responses and related symptoms. The anti-inflammatory effect is believed to be mediated through the suppression of pro-inflammatory cytokines and the inhibition of important inflammatory enzymes and mediators involved in the progression of inflammations. These findings suggest that the bioactive constituents of *Bauhinia variegata* Linn may contribute to its therapeutic potential in inflammatory disorders. [37]

4.8. Hepatoprotective Activity:

Bauhinia variegata has demonstrated hepatoprotective activity in experimental models of hepatic injury. Stem bark and other extracts have been reported to protect liver tissue against chemically induced hepatotoxicity, including diethyl nitrosamine-induced damage. The hepatoprotective effect is believed to be associated with its antioxidant constituents, which reduce oxidative stress and lipid peroxidation in hepatic tissues. These results indicate that *Bauhinia variegata* exerts protective effects on hepatic tissue and may represent a promising natural agent for maintaining liver function and reducing chemically induced hepatic injury. [38]

4.9. Nephroprotective Activity

The ethanolic and aqueous root extracts of *Bauhinia variegata* Linn have demonstrated significant antioxidant and nephroprotective activities in a gentamicin-induced nephrotoxicity model in rats. Oral administration of the extracts at doses of 200 and 400 mg/kg body weight produced marked free radical scavenging effects. Treatment with both extracts significantly reduced elevated serum creatinine, serum urea, blood urea nitrogen, and urinary creatinine levels, indicating protection against gentamicin-induced renal dysfunction. Histopathological examination further confirmed the nephroprotective effect by showing improvement in renal tissue architecture. These findings suggest that the root extracts of *Bauhinia variegata* may protect renal tissue against oxidative stress-mediated nephrotoxicity. [39]

4.10. Wound healing effect

The wound healing potential of ethanolic and aqueous root extracts of *Bauhinia variegata* Linn was evaluated in albino Wistar rats using excision and incision wound models. Oral administration of the extracts at doses of 200 and 400 mg/kg body weight significantly enhanced wound healing in both

experimental models. The treated groups showed improved wound contraction and tissue repair compared with the control group, and the effect observed in the excision wound model was comparable to that produced by the standard drug framycetin. These researches indicate that *Bauhinia variegata* root extracts possess significant wound healing activity and may facilitate tissue regeneration and repair. [40]

4.11. Antiviral activity

Bauhinia variegata has demonstrated significant antiviral activity against Coxsackievirus B3 (CVB3) in both in vitro and in vivo studies. Among the methanol, chloroform, ethyl acetate, butanol, and aqueous leaf extracts, the methanolic extract exhibited the strongest anti-CVB3 effect, showing a high therapeutic index and marked reduction in viral titer. In CVB3-infected mice, oral administration of the methanolic extract reduced morbidity, mortality, viral load, myocardial pathological changes, and serum AST, LDH, and CK levels, indicating antiviral and cardioprotective effects. The activity may be related to inhibition of viral attachment or entry into host cells, suggesting that *Bauhinia variegata* is a promising natural source for antiviral drug development.

CONCLUSION

Bauhinia variegata Linn. seems to be an important medicinal plant and may have great medicinal potential and can be used for a long time in traditional medicine. The plant contains high concentration of flavonoids, phenolics, terpenoids, alkaloids, tannins and glycosides in different parts of the plant such as bark, leaves, flowers, seeds, and roots. The aforementioned constituents demonstrated a plethora of biological activities in experimental studies including anti-oxidant, anti-inflammatory, antimicrobial, antidiabetic, hepatoprotective, nephroprotective, wound healing, anticancer and antihyperlipidemic properties. The scientific data in support of the traditional uses of *Bauhinia variegata* and its potential to natural therapeutic agents is highlighted. Most of the studies, however, have been conducted in experimental models; there is not enough information available from well-designed clinical studies. Further studies on the identification of most active compounds, uncovering their mechanism of action, the establishment of safety profiles and creating standardized formulations are required. In general, the *Bauhinia variegata* Linn. seems promising medicinal plant with therapeutic potential. Further pharmacognostic, phytochemical, pharmacological and clinical research could contribute to the development of quality and acclaimed herbal products from this plant.

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