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Bauhinia racemosa: A phytochemical treasure with diverse pharmacological activities

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ABSTRACT

Bauhinia racemosa, a plant of considerable importance in traditional medicine due to its diverse pharmacological properties. Originating from the Bauhinia genus, the botanical, ethnomedicinal, and phytochemical aspects of *Bauhinia racemosa* are explored. The botanical section covers taxonomy, distribution, and morphological features, offering insights into the plant's prevalence in South, Southeast, and East Asia. Ethnomedicinal uses are examined, revealing its historical significance in treating various ailments, including headache, fever, skin diseases, tumors, and gastrointestinal issues. The phytochemistry profile highlights the presence of bioactive compounds such as flavonoids, terpenoids, steroids, alkaloids, and tannins, emphasizing their potential therapeutic applications. Additionally, the nutritional value of *Bauhinia racemosa* seedsis underscored, emphasizing their richness in essential minerals and amino acids. The pharmacological section provides a detailed overview of the plant's diverse activities, including antitumor, antidiabetic, hepatoprotective, anti-inflammatory, antimicrobial, and anthelmintic properties. The review concludes by emphasizing the plant's significance in traditional medicine, its potential in drug development, and the need for further research to fully exploit its therapeutic benefits. This article contributes valuable insights into the multifaceted properties of *Bauhinia racemosa*, serving as a valuable resource for researchers, healthcare professionals, and enthusiasts interested in the intersection of traditional medicine and modern pharmacology.

Keywords: *Bauhinia racemosa*, Ethnomedicine, Phytochemistry, Pharmacological properties,Traditional medicine

Introduction

In ancient times, herbal medicines were the primary means of treating various diseases, representing a traditional system of medicine with roots dating back to antiquity (Sahu T, 2015). Today, these natural remedies continue to be widely utilized for healthcare purposes, as evidenced by their historical significance across ancient civilizations. The last decade has witnessed a resurgence of interest in natural therapies, leading to intensified studies on plant-based remedies. Especially in developing nations, traditional medicine remains prevalent, particularly in rural settings, for addressing a diverse array of health conditions. The therapeutic properties of plants, encompassing antioxidant, antimicrobial, and antipyretic effects, contribute to their enduring significance. However, the reliance on oral tradition for transmitting knowledge about therapeutic plants has resulted in a decline in awareness and recognition of these traditional remedies (Bhosale PS, 2021).

Plants synthesize a broad spectrum of chemical compounds, classified into primary and secondary metabolites based on their chemical structure, biosynthetic origin, and functional groups. While primary metabolites are essential for maintaining the physical integrity and fundamental metabolic processes of plant cells, secondary metabolites play a significant role in diverse physiological functions. Natural product chemistry has shed light on the capability of chemotaxonomy in elucidating relationships between various plant species (Sharanabasappa GK, 2007). Products derived from natural sources, such as plants, microorganisms, animals, or minerals, play a fundamental role in drug development for treating various diseases. These natural compounds serve as the foundation for synthesizing novel drugs in contemporary pharmaceutical research (Sahu T, 2015; Kessler RC, 2001).

The *Bauhinia racemosa* plant holds significance in traditional medicine, addressing diverse health issues. The genus, named after the Swiss French botanist Bauhinia brothers, includes numerous species cultivated in tropical regions, such as *B. purpurea, B. tomentosa, B. vestita, B. ovate, and Bauhinia acuminate*. Commonly known as Mountain Ebony and Kachnar in India and Pakistan, this genus holds historical significance and is frequently cultivated for its captivating white blossoms (Sahu T, 2015; Anonymous, 1995). Featuring approximately 300 species predominantly located in tropical regions, the Bauhinia genus has significantly contributed to human civilization since ancient times. These trees and shrubs, often reaching heights of 5-7 meters, are prevalent in deciduous forests (Fatima M, 2021; Panda P, 2015).

The aesthetic appeal of *Bauhinia racemosa*, particularly its white flowers, makes it a popular choice for planting in gardens and along roadsides (Fatima M, 2021; Panda P, 2015). In English, the plant is named Mountain Ebony, while in Hindi, it goes by various names such as Kachnal, Kanchanara, or Sonpatta. In Urdu, it is referred to as Gul-e-anehnal, and in Marathi, it is known as Sona, Sonpatta, or Apta. Widely distributed in South, Southeast, and East Asia, this tree thrives in harsh climatic conditions and holds nutritional significance by providing leaves as fodder for livestock. Additionally, its robust and weighty wood serves as a valuable source of fuel (Xiao Y, 2022).

This review aims to provide a holistic exploration of *Bauhinia racemosa*, encompassing its historical significance, botanical features, phytochemistry, ethnomedicinal uses, and diverse pharmacological activities.

Botanical profile of *Bauhinia racemosa*

Taxonomy of *Bauhinia racemosa*

Bauhinia, belonging to the Fabaceae family, is an extensive genus with approximately 300-350 species of trees, shrubs, and vines. This diverse genus has a predominantly tropical distribution and was historically categorized into four subgenera: Bauhinia (L.), Elayuna (Rafin.), Barklya (F.), and Phanera (Lour.) (Farag MA, 2015).

Bauhinia racemosa, Lam, falls under the Caesalpiniaceae family, contributing to the rich diversity of this plant family (Bhosale PS, 2021). As a genus, Bauhinia encompasses over 200 species of flowering plants, adding to the extensive and diverse Fabaceae family widely distributed across tropical regions (Sahu T, 2015; Anonymous, 1995).

Botanical Details (Sahu T, 2015):

- Botanical name: *Bauhinia racemosa* Lam.

- Local names:
  - English: Burmese Silk Orchid
  - Gujarati: Apto
  - Hindi: Kachnar
  - Kannada: Aapta, Aralukadumandara
  - Marathi: Sona Patti, Apta
  - Tamil: Sittacha

- Taxonomic hierarchy:
  - Kingdom: Plantae
  - Division: Angiosperms
  - Class: Eudicots
  - Order: Fabales
  - Family: Fabaceae
  - Subfamily: Caesalpinioideae (Sinou C, 2009)
  - Genus: Bauhinia
  - Species: *B. racemosa* (Anonymous, 2007)

Occurrence and distribution

Bauhinia racemosa is found abundantly in various regions, exhibiting versatile distribution (Kumar RS, 2005).

Global distribution

The plant is prevalent in India, Ceylon (Sri Lanka), China, and Timor (Kumar RS, 2005; Kirtikar KR, 1975). In the United States, it flourishes in regions such as Hawaii, coastal California, Texas, Louisiana, and Florida (Sahu T, 2015; Wunderlin R, 1987).

Indian distribution

It is particularly common in the foothills, flourishing up to an elevation of 1000 meters. The plant is widespread throughout Kerala, Tamil Nadu, and Maharashtra, among others except in specific regions like Jammu & Kashmir, Himachal Pradesh, Sikkim, Arunachal Pradesh, Assam, Nagaland, Meghalaya, Manipur, Tripura, and Mizoram (Sahu T, 2015).

Specific regional habitat

Bauhinia racemosa exhibits diverse geographical distribution across different regions in India. In the Semi-arid Region of Rajasthan, it prospers alongside various other fodder trees, such as *Prosopis cineraria, Acacia nilotica, Albizia lebbek, Ailanthus excelsa,* and *Azadirachta indica*. This adaptable plant is also found in the Western Himalayas, where its small, crooked, bushy form is widespread throughout India, reaching elevations of up to 1,650 meters in the western Himalayas (Bhosale PS, 2021). Additionally, *B. racemosa* contributes to the ecological tapestry of the Nilgiri Landscape in the Western Ghats, forming part of the tropical dry thorn ecosystem (Azizur RM, 2015).

Morphological characteristics

Bauhinia racemosa, characterized by its veining and evergreen growth pattern, is a robust plant that thrives with sturdy support. It typically assumes the growth form of a small deciduous tree or a sizable shrub, achieving a height of up to 5 meters. The leaves of this plant are compound, consisting of 2 connate leaflets covering about two-thirds of their length. Its flowers, which are white in color, are elegantly arranged in axillary racemes. The fruits of *B. racemosa* take the form of flat dehiscent pods, each containing 5-10 seeds, contributing to the reproductive cycle of this distinctive plant (Sahu T, 2015; Wunderlin R, 1987).

Caesalpiniaceae family habitat

Bauhinia (Caesalpiniaceae) primarily locates in low land and drier forest types of northwestern South America, stretching to Brazil and Argentina. It is also recorded in cerrado habitats (Azizur RM, 2015).

Description of plant parts

Stem

The stem is bluish-black and rough, with a pinkish-red interior that turns brown upon exposure. The surface is rough with vertical cracks, and young twigs are hairy. Additionally, the stem is longitudinally fissured (Fatima M, 2021; Sharma BD, 1996; Ali SI, 1973).

Leaves

The leaves are green, signifying vitality, and possess a compound structure broader than long. The leaflets are ovate, with a rounded apex, and exhibit a pubescent underside in their early stages of development. These leaves are divided halfway down into two lobes, creating a visually distinctive appearance. The upper surface is glabrous, while the underside is characterized by a hairy texture. The base typically assumes a cordate shape, and the leaves feature 7-9 prominent veins, emphasizing their structural intricacy. Furthermore, the leaves are characterized as orbicular, bifoliate, and arranged alternately in a distichous manner, displaying smooth margins. Their apices are mucronate, adding a pointed element, and the bases are chordate (Azizur RM, 2015).

Flowers

The flowers are white or pale yellow, arranged in terminal or leaf-opposed racemes. These small flowers are borne in loose racemes, measuring 5-10 centimeters in length. Each flower boasts a diameter of 7.5-12.5 centimeters, with five narrow lance-like petals and ten fertile stamens. The filaments of the stamens are hairy at the base, adding a unique texture to the floral composition. The ovary is hairy, and the stigma is sessile. The pedicel measures 5-10 millimeters in length, is covered in hair, and exhibits a joint near the middle, accompanied by brief, linear, and acute bracts. The hypanthium has a notably brief length, and the calyx, measuring approximately 6.0-8.0 millimeters, takes on a spathaceous form and is reflexed (Fatima M, 2021; Sharma BD, 1996; Ali SI, 1973). Flowering occurs from March to June, with the flowers predominantly white and appearing in axillary or terminal racemes (Azizur RM, 2015).

Fruits

The fruit takes the form of a pod that is oblong, compressed, frequently twisted, and displays a dark green coloration. Fruit-bearing takes place consistently throughout the entire season (Azizur RM, 2015).

Ethnomedicinal use of *Bauhinia racemosa*

Bauhinia racemosa holds significant ethnomedicinal value, with various parts of the plant being employed in traditional treatments.

Bark

The bark, known for its diverse therapeutic properties, is utilized in addressing conditions such as headache, malaria, dysentery, diarrhea, fever, skin diseases, tumors, and as a remedy for abscesses, warts, wounds, and various skin disorders (Kumar RS, 2005; Kirtikar KR, 1975).

Fiber

The fiber from *Bauhinia racemosa* serves a unique purpose, being employed to stitch wounds (Fatima M, 2021; Kirtikar KR, 1975).

Flower

The flowers are employed in addressing respiratory concerns, including cough and bronchitis (Fatima M, 2021; Kirtikar KR, 1975).

Fruit

The fruit, with its astringent properties, is utilized for its beneficial effects on the bowels (Fatima M, 2021; Kirtikar KR, 1975).

Leaves

Leaves play a role in managing conditions related to thirst, urinary discharges, quartan fever, headache, skin diseases, tumors, blood disorders, diarrhea, and dysentery (Fatima M, 2021; Anonymous, 1985; Nadkarni AK, 2007).

Stem Bark

The stem bark is recognized for its astringent properties and finds application in treating a spectrum of ailments, including headache, fever, skin diseases, tumors, blood diseases, dysentery, and diarrhea (Kumar RS, 2005; Kirtikar KR, 1975; Jain SK, 1964).

Traditional use of *Bauhinia racemosa*

Bauhinia racemosa has a rich history of traditional medicinal use, addressing a spectrum of ailments. The stem bark, known for its astringent properties, is utilized in treating conditions such as headache, fever, skin diseases, tumors, blood disorders, dysentery, and diarrhea (Sahu T, 2015; Kirtikar KR, 1975). Furthermore, it finds application in managing diverse health issues like diarrhea, dysentery, headache, and jaundice in traditional practices (Azizur RM, 2015).

Notably, ayurvedic doctors commonly employ *Bauhinia racemosa* in the prevention and treatment of cancer. In the tribal regions of southern Rajasthan, a traditional oral administration of a mixture containing its bark along with *Bridelia retusa* is a cultural practice. This mixture is traditionally believed to induce sterility in women, serving as a form of contraception (Azizur RM, 2015).

Phytochemistry profile of *Bauhinia racemosa*

The exploration and isolation of phytoconstituents are pivotal for uncovering potential treatment possibilities for various diseases. Similar phyto-compounds found in *B. racemosa*, such as mome inositol (*Cyamopsis tetragonoloba*), neophytadiene, resveratrol (*Arachis hypogaea, vitis vinifera*), lupeol (*Alstonia scholaris*), octacosane, β-sitosterol (*Clerodendrum infortunatum, Alstonia scholaris*), β-amyrin (*Alstonia boonei, Alstonia scholaris*), racemosol, galactolipid (*Phyllanthus emblica*), catechin (*Phyllanthus emblica*), betulin (*Alstonia scholaris*), quercetin (*Phyllanthus emblica, Allium sativum*), rutin (*Ginkgo biloba, Lycopersicon esculentum*), and kaempferol (*Mangifera indica, Allium sativum*), are common in various plants, each with a broad spectrum of pharmacological properties (Prabhu S, 2021; Prakash A, 1976; El Hossary GA; DeFeudis FV, 2003; Takeoka GR, 2003; Banskota AH, 2000).

Chemical constituents such as ß-sitosterol and ß-amyrin, potentially responsible for the plant's traditional use, have been isolated from the stem bark. Additionally, at least five flavonols (kaempferol and quercetin) and two coumarins (scopoletin and scopolin) were isolated from the leaves, while stilbene (resveratrol) was isolated from the heartwood of *B. racemosa* (Kumar RS, 2005; El Hossary GA).

Phytochemical analysis involves both quantitative and qualitative estimations of chemical constituents in the plant. The chemical composition varies in each part of the plant, contributing to the specific medicinal properties of each plant part. Preliminary phytochemical screening of the ethanolic extract of leaves and seeds of *B. racemosa* revealed the presence of flavonoids, glycosides, phenolic compounds, saponins, and tannins (Sinou C, 2009).

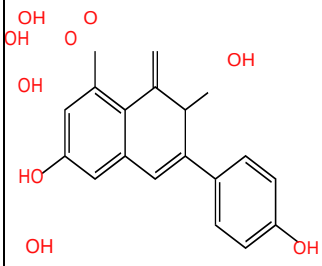
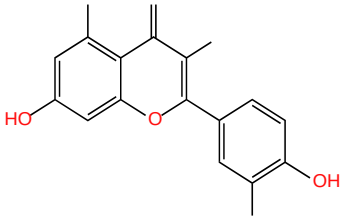
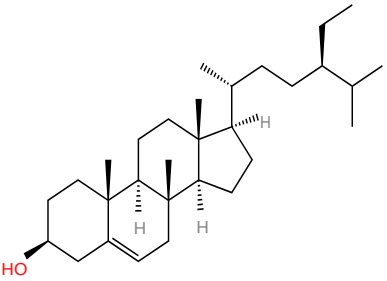
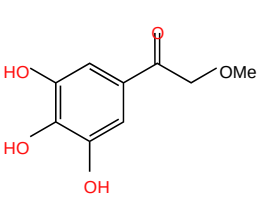
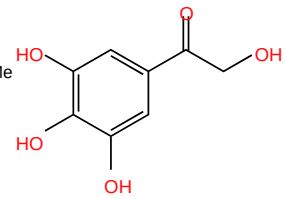
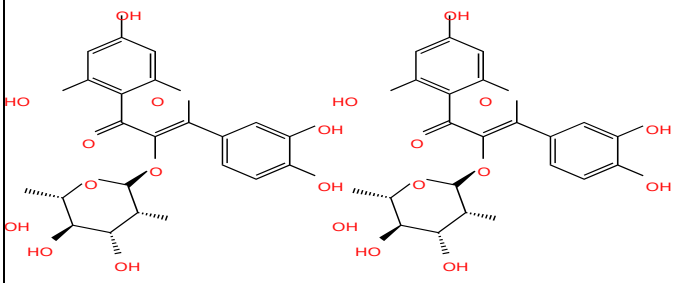
Several phytochemical constituents of *B. racemosa* have been isolated, primarily including flavonoids (kaempferol and quercetin), coumarins (scopoletin and scopolin), triterpenoids (β-amyrin), steroids (β-sitosterol), and stilbenes (resveratrol) (Sahu T, 2015; Prakash A, 1976; El Hossary GA; Anjaneyulu AS, 1984). Notably, major bioactive components include methyl gallate, gallic acid, kaempferol, quercetin, quercetin 3–O–α–rhamnoside, kaempferol 3–O–β–glucoside, myricetin 3–O–β–glucoside, and quercetin 3–O–rutinoside (Rashed K, 2014).

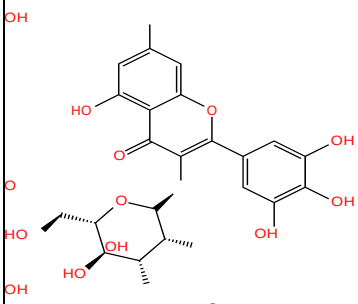
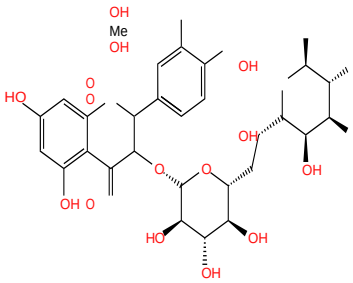
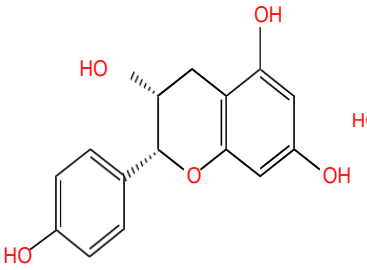
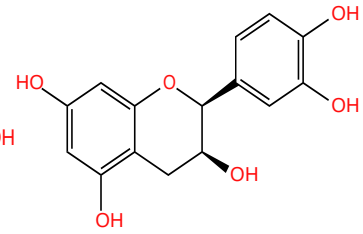
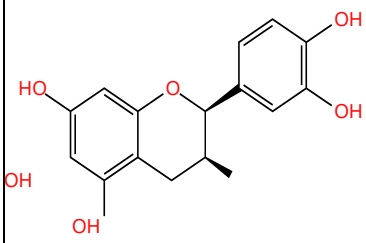
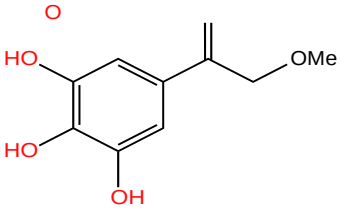
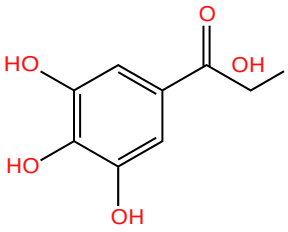
Additionally, three catechins–epiafzelechin, epicatechin, and catechin–were reported from *Bauhinia racemosa* Lam. Besides flavonoids, terpenes, steroids, alkaloids, aromatic acids, bibenzyls, and tannins were also scantly reported from *Bauhinia* species (Farag MA, 2015).

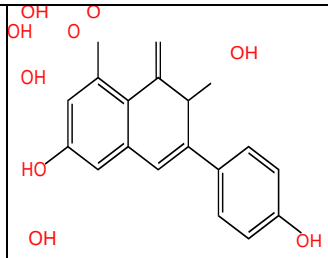
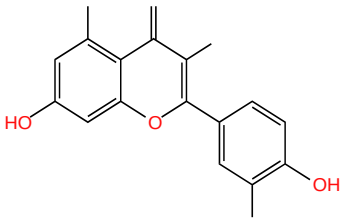
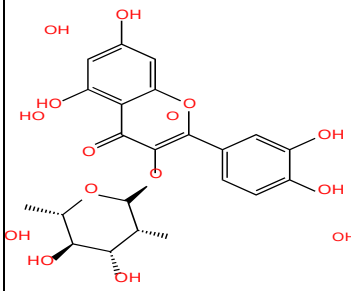
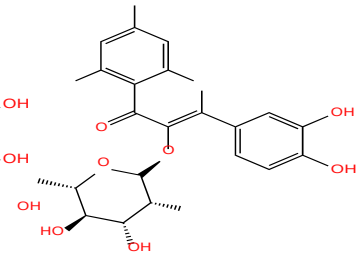
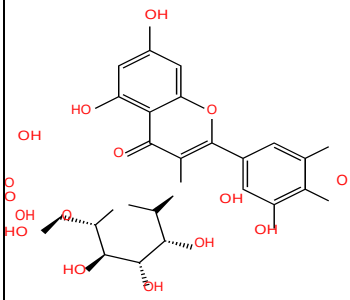
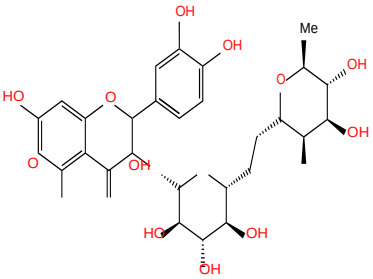
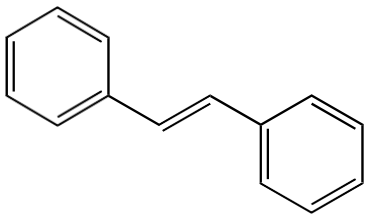
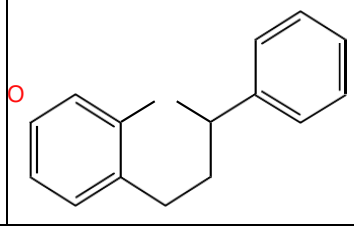
To summarize, the aerial parts contain methyl gallate, gallic acid, kaempferol, quercetin, quercetin 3–O–α–rhamnoside, kaempferol 3–O–β–glucoside, myricetin–3–O–β–glucoside, and quercetin–3–O–rutinoside (Rutin). The stem bark comprises quercetin, naringin, silymarin, anthocyanosides, sophoradin, saponins, and tannins. The leaves contain galactolipid, catechin class of compounds, phenol, 2,4-bis (1,1-dimethylethyl)-, mome inositol, neophytadiene, 6-

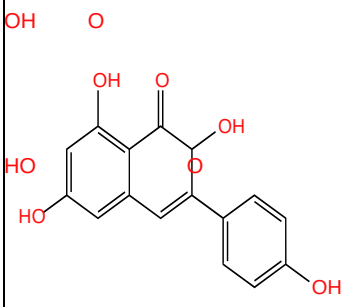
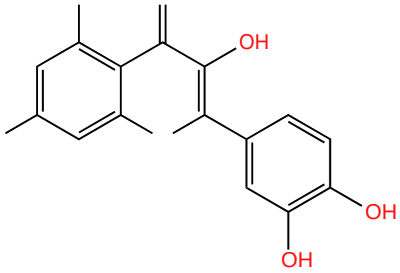
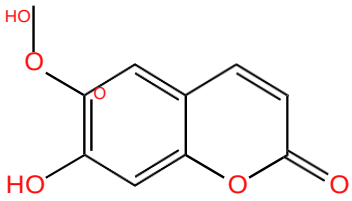
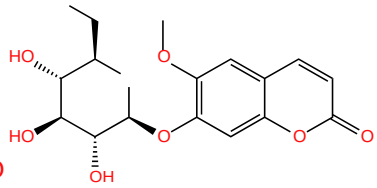
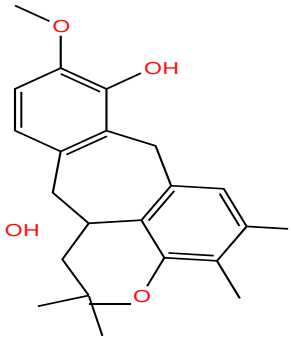
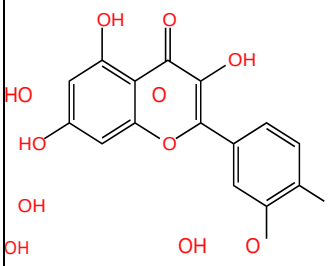
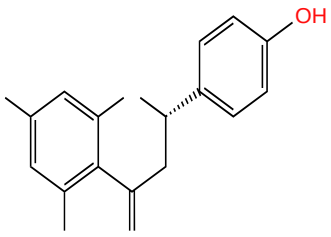
octen-1-ol,3,7-dimethyl-, propanoate, 16-heptadecenal, citronellyl butyrate. The roots yield racemosol, de-o-methyl racemosol, exhibiting antibacterial and antifungal properties (Fatima M, 2021).

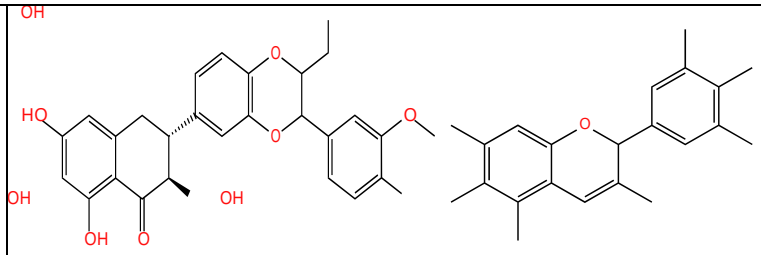
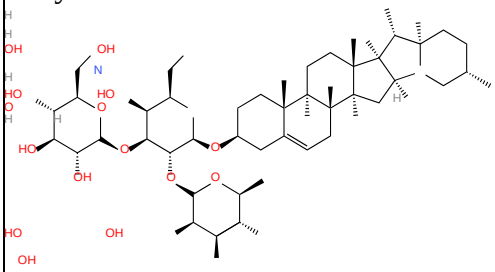
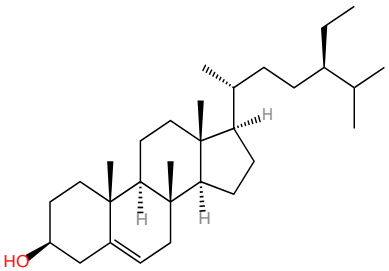
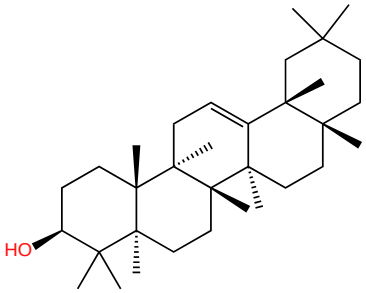
Table 1: Basic chemical structures of the phytochemicals

Parts of the plant	Chemical constituent	Structures
Common Phytoconstituents	Kaempferol; Quercetin; β-sitosterol	 Kaempferol  Quercetin  B-sitosterol
Major Bioactive Compounds	Methyl gallate; Gallic acid; Quercetin-3-o-α-rhamnoside; Kaempferol 3-o-β-glucoside; Myricetin 3-o-β-glucoside; Quercetin 3-o-rutinoside	 Methyl gallate  Gallic acid 

		Quercetin-3-o-α-rhamnoside  Kaempferol 3-o-β-glucoside  Myricetin 3-o-β-glucoside Quercetin 3-o-rutinoside
Catechins	Epiafzelechin; Epicatechin; Catechin	 Epiafzelechin  Epicatechin  Catechin
Aerial Parts	Methyl gallate; Gallic acid; Kaempferol; Quercetin; Quercetin 3-o-α-rhamnoside; Kaempferol 3- o-β-glucoside; Myricetin 3-o-β-glucoside; Quercetin 3-o-rutinoside	 Methyl gallate  Gallic acid

		  Kaempferol Quercetin   Quercetin 3-o-α-rhamnoside Kaempferol 3- o-β-glucoside   Myricetin 3-o-β- glucoside Quercetin 3-o-rutinoside
Heartwood	Stilbene (Resveratrol)	 Stilbene (Resveratrol)
Leaves	Flavanols	

	Coumarins	Flavanols  Kaempferol  Quercetin  Scopoletin  Scopolin
Roots	Racemosol	 Racemosol
Stem bark	Flavonoids	 Quercetin  Naringin

		 Silymarin Anthocyanosides  Saponins
Stem bark	Sterols	 β - Sitosterol  β- Amyrin

Nutritional values

The seeds of *Bauhinia racemosa* boast a rich nutritional profile, offering significant amounts of essential minerals. Notably, they are abundant in calcium, potassium, magnesium, zinc, manganese, and iron. The seed protein of *Bauhinia racemosa* is characterized by a predominance of glutelins, with lower levels of albumins and globulins. Essential amino acids such as isoleucine, lysine, phenylalanine, and tyrosine are present in high concentrations, while the content of sulfur amino acids is relatively limited in the seed proteins. In addition, the seed lipids contain higher levels of fatty acids, particularly linoleic, oleic, and palmitic acid (Fatima M, 2021; Davey MS, 2011; Gupta M, 2004; Nirmal SA, 2011).

Pharmacological profile of *Bauhinia racemosa*

Bauhinia racemosa displays a diverse range of pharmacological activities attributed to the presence of various active constituents across its plant parts. Noteworthy pharmacological studies have unveiled its chemoprotective antitumor activity, antidiabetic activity,

hepatoprotective effects, antiinflammatory properties, antimutagenic activity, antioxidant potential, antihyperlipidemic activity, and more.

Studies on the ethanol extract of *B. racemosa* leaves have indicated analgesic, antipyretic, antiinflammatory, antispasmodic, and antimicrobial activities. Additionally, the fresh flower buds exhibit antiulcer activity (Sahu T, 2015).

The plant showcases an extensive pharmacological spectrum, encompassing antifilarial activity, abortifacient properties, antianxiety effects, anthelmintic activity, antimicrobial attributes, antihistaminic effects, analgesic and antipyretic properties, antimalarial activity, antioxidant potential, anticarcinogenic properties, antitumor effects, antiulcerogenic efficacy, hepatoprotective benefits, and more (Azizur RM, 2015).

In traditional medicine, various parts of *B. racemosa* are utilized for their medicinal value. Flower buds demonstrate antiulcerogenic properties, seeds exhibit antibacterial benefits, roots contain compounds with profound antibacterial and antifungal activity, leaf extracts show antihyperglycemic and anthelmintic properties and stem bark is reported to be medicinally important for treating ailments such as headache, fever, skin diseases, and diarrhea (Xiao Y, 2022).

Specifically, the alcoholic extract of stem bark has shown anticancer and central nervous system depressant activities, inducing hypothermia in mice. Flower buds exhibit antiulcerogenic efficacy, while leaves demonstrate varying degrees of antiinflammatory, analgesic, antipyretic, and antispasmodic properties (Jain R, 2008; Akhtar AH, 1995; Dhar ML, 1968; Khatib, E. I. 1995). Pharmacological activities of *Bauhinia racemosa* are shown in Fig. 1.

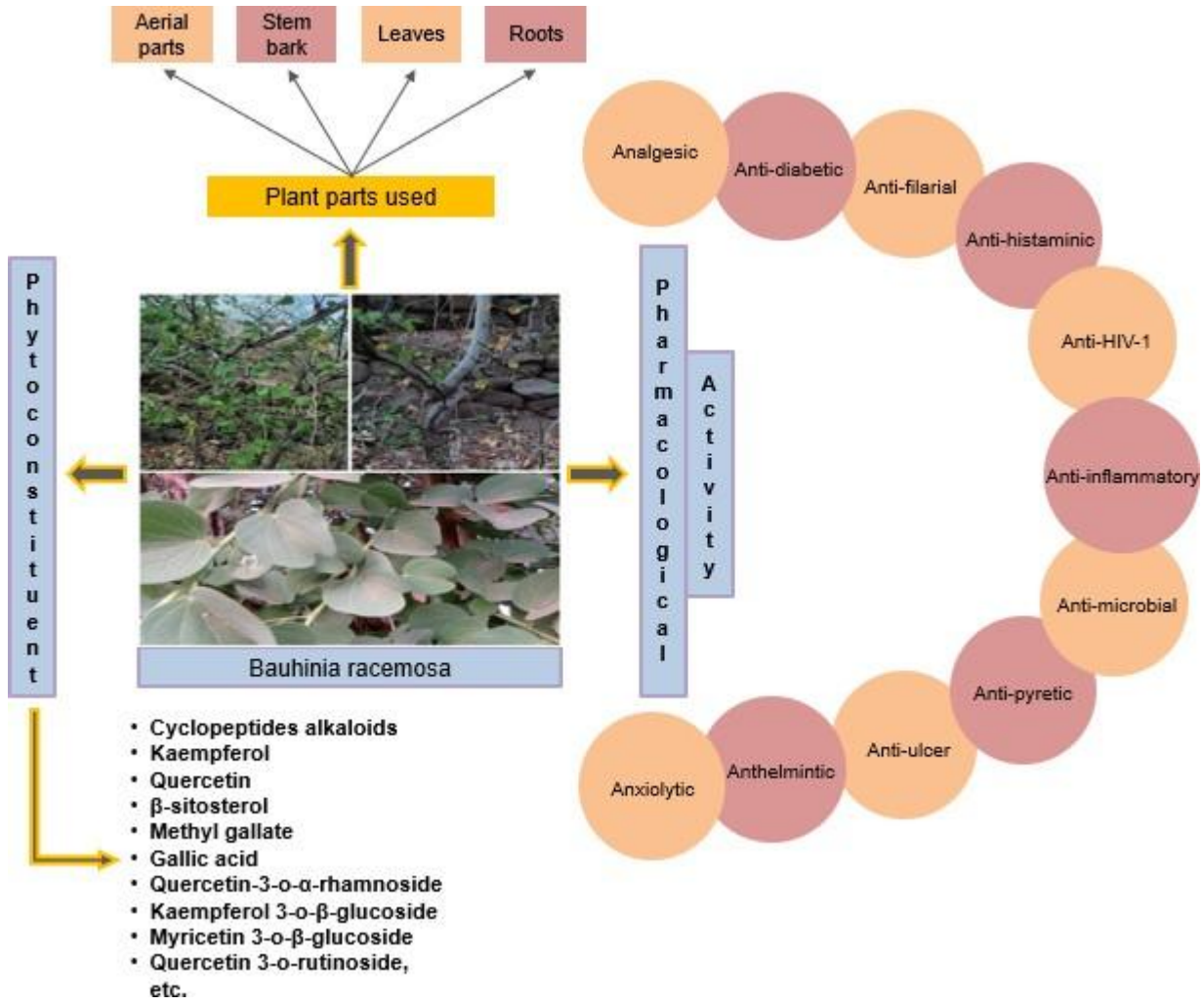


Fig. 1. Pharmacological activities of *Bauhinia racemosa*

Analgesic activity

The analgesic activity of the stem bark was assessed through a methanolic extract in two in vivo assay models: acetic acid-induced writhing in mice and hot plate reaction time. As a standard drug, aspirin was employed, and morphine served as the reference drug for the hot plate reaction time experiment.

In the acetic acid-induced writhing model, the methanolic extract exhibited significant inhibition of writhing, indicating its analgesic potential. Moreover, a synergistic effect with aspirin was observed, further enhancing the analgesic response. The hot plate reaction time experiment, using morphine as a reference, demonstrated comparable results in analgesic activity.

These findings suggest that the methanolic extract of the stem bark not only effectively inhibits acetic acid-induced writhing but also displays the potential for centrally-acting analgesia, as evidenced by the results of the hot plate reaction time experiment (Gupta M, 2004).

Antidiabetic activity

The antidiabetic activity of the petroleum ether extract from the leaves of *B. racemosa* was investigated using the streptozotocin (STZ)-induced diabetes model and the eighteen-hours fasted rat model, with doses of 250 mg/kg and 500 mg/kg. Glibenclamide served as the reference drug in the in vivo assay. The Oral Glucose Tolerance Test (OGTT) involved recording blood glucose levels at 0 minutes, 30 minutes, and 90 minutes, with additional analysis using the glucose oxidase/peroxide method. An insulin enzyme-linked immunosorbent assay test was conducted to assess the antidiabetic potential.

In the eighteen-hours fasted rat model, the extract demonstrated a decrease in blood glucose levels at a dose of 250 mg/kg, and at 500 mg/kg, it exhibited a comparable effect with glibenclamide. During the OGTT, although there was an initial increase in blood glucose levels at 30th minutes, a significant decrease was observed at the 90th minutes with the 500 mg/kg dose, comparable to the reference drug. In the STZ-induced diabetes model, fasting serum glucose levels and insulin levels were recorded at various intervals, revealing a substantial decrease in fasting serum glucose levels and an increase in insulin levels, affirming the antidiabetic potential of *B. racemosa* (Alex AM, 2020; Kumar V, 2017).

The α-amylase inhibitory activity exhibited by the ethanol extract of *B. racemosa* leaves underscores its role in diabetes management. The presence of bioactive phytochemicals in the extract makes the leaves a potential source of natural antidiabetic agents, contributing significantly to the prevention and management of Type-II diabetes (Gawade B, 2018).

Additionally, the estimation of phenolic content in the leaves identified hydroquinone, catechol, and 4-nitrophenol. Leaves were found to be richer in phenolic compounds compared to seeds, offering protection against UV rays and disease-causing microorganisms. The seed analysis revealed standard amino acids, including lysine, methionine, leucine, and phenylalanine. Thin Layer Chromatographic study of the seed oil identified phosphatidylinositol, lysophosphotidylethanolamine, and phosphatidylcholine (Alex AM, 2020; Sharanabasappa GK, 2007). The stembark was found to possess steroidal compounds such as β-amyrin and β-sitosterol (Alex AM, 2020; Jain R, 2002).

Antifilarial activity

The antifilarial potential of *B. racemosa* Lam. leaves was explored through a series of comprehensive studies. Initial steps involved ethanol extraction of the leaves, followed by fractionation using n-hexane, chloroform, and n-butanol. The n-butanol fraction emerged as the most promising, leading to the isolation of galactolipids and catechins. Both in vitro and in vivo investigations were undertaken to evaluate the antifilarial efficacy, focusing on the involvement of *Brugia malayi*, a human lymphatic filarial parasite.

In the in vitro studies, *B. malayi* specimens recovered from infected *Meriones unguiculatus* (jirds) were employed to assess adult worms and microfilaria forms. As benchmarks, Ivermectin and diethylcarbamazine were employed as reference drugs. Key parameters such as minimum inhibitory concentration (MIC), IC50 value, and CC50 value for the isolated galactolipids and catechins were meticulously determined. Notably, galactolipids exhibited significant anti-filarial activity in the in vitro assay, a trait attributed to the presence of long-chain fatty acids within galactolipids.

Moving into in vivo investigations on male jirds, galactolipids were administered subcutaneously and intraperitoneally at doses of 100 mg/kg and 50 mg/kg, respectively, over a 5-day period. The amalgamated findings from both in vitro and in vivo studies underscored the substantial anti-filarial activity of galactolipids derived from *B. racemosa*, surpassing the efficacy of the control, ivermectin (Azizur RM, 2015; Sashidhara KV, 2012).

Antihistaminic activity

The ethanol extract of *B. racemosa* leaves demonstrated a noteworthy anti-histaminic activity in male Swiss albino mice. Administration via intraperitoneal route at a dose of 50 mg/kg body weight resulted in the inhibition of clonidine-induced catalepsy. Intriguingly, there was no observable effect on haloperidol-induced catalepsy, highlighting the specificity of the inhibition to antihistaminic action without involvement of dopamine. The identified antihistaminic activity carries significant implications, suggesting a potential therapeutic role in the treatment of asthma (Gupta M, 2004).

Anti-human immunodeficiency-1 virus

The exploration of anti-HIV-1 activities in *B. racemosa* involved an in-depth investigation into its stem and fractions extracted using methanol, ethyl acetate, n-butanol, and aqueous solvents. Among these, the methanolic extracts emerged as particularly promising, displaying superior anti-HIV efficiency compared to other fractions with lower anti-HIV capacity.

Phytochemical analysis unveiled the presence of flavonoids, tannins, and terpenes not only in the methanol extract but also in extracts from other solvents of *B. racemosa*. Further isolation studies on the methanol extracts pinpointed triterpenic acids (oleanolic and ursolic), two hydrolysable tannins (gallic and ellagic acids), and three flavonoids (luteolin, quercetin 3-O-β-glucoside, and myricetin 3-O-β-glucoside) as the key constituents responsible for the observed anti-HIV-1 activity. This diverse phytochemical composition within the methanol extract positions *B. racemosa* as a potential anti-HIV-1 agent. The identified compounds contribute to its efficacy, showcasing the plant's potential utility in the development of novel therapeutic interventions against HIV-1 (Prabhu S, 2021).

Antiinflammatory activity

The antiinflammatory potential of the methanolic extract from the stem bark of *B. racemosa* was assessed using in-vivo techniques. A comprehensive evaluation included various models such as carrageenan-induced, dextran-induced, histamine & serotonin-induced, and cotton pellets-induced paw edema. The reference drug, indomethacin, a nonsteroidal antiinflammatory drug, was employed for comparative analysis. Mice were administered the extract at doses of 50, 100, and 200 mg/kg.

The results unveiled a remarkable antiinflammatory activity of *B. racemosa*, demonstrating efficacy comparable to the standard drug, indomethacin. This finding not only underscores the plant's potential as a rich source of antiinflammatory agents but also validates its traditional use in the treatment of inflammatory conditions. The observed effectiveness across diverse inflammatory models further strengthens the case for considering *B. racemosa* as a valuable candidate for the development of antiinflammatory therapies (Gupta M, 2004).

Antimicrobial activity

The antimicrobial efficacy of *B. racemosa* leaves was systematically investigated using aqueous and methanol extracts against standard bacterial and fungal cultures. In-vitro antimicrobial tests were meticulously conducted through the agar well diffusion method on Mueller Hinton agar and Sabouraud dextrose agar for bacterial and fungal cultures, respectively. Further, the MIC test was executed using a modified agar well diffusion method (Soni V, 2015; Dahikar SB, 2011; Kumar G, 2010).

The methanol extract demonstrated significantly higher inhibitory effects in comparison to the aqueous extract against the tested organisms. Its broad-spectrum activity encompassed inhibition of both Gram-negative bacteria (*Escherichia coli*, *Micrococcus luteus*, and *Pseudomonas aeruginosa*) and Gram-positive bacteria (*Bacillus subtilis*), along with fungi (*Candida albicans* and *Aspergillus niger*). Remarkably, both extracts exhibited maximum relative percentage inhibition against *A. niger*. MIC values for the methanol extract ranged from 1.5 to 25 mg/ml (Panda P, 2015; Kumar G, 2010; Ravikumar A, 2009).

In the pursuit of developing a new pharmaceutical drug from natural sources to combat enteric infections, antibacterial activity was specifically assessed against various enteric bacterial pathogens. The methanol extract of *B. racemosa* leaves displayed a broader range of antibacterial activity against these pathogens compared to the aqueous extract. Additionally, the ethyl acetate extract exhibited slightly higher antibacterial activity than the chloroform extract. This multi-faceted antimicrobial profile highlights the potential of *B. racemosa* as a valuable source for the development of pharmaceutical agents targeting a spectrum of microbial infections (Azizur RM, 2015; Anjaneyulu AS, 1984).

Antipyretic activity

The antipyretic potential of the methanolic extract from the stem bark of *B. racemosa* was investigated using yeast-induced hyperpyrexia in mice. Following 24 hours of oral administration of the extract and paracetamol (the standard drug), rectal temperatures were measured. A pre-drug control temperature was recorded one hour before administering the drug to fevered animals, and subsequent temperatures were documented after 1-4 hours of drug treatment.

The findings revealed that the extract exhibited significant antipyretic action, comparable to the standard drug paracetamol. This underscores the potential of *B. racemosa* as an effective antipyretic agent, demonstrating its capacity to alleviate fever induced by yeast in mice (Gupta M, 2004).

Antiulcer activity

The antiulcer activity of *B. racemosa* stem bark extracts (aqueous and alcoholic) was investigated using a paracetamol-induced gastric ulcer model in Wistar albino rats. The results demonstrated a reduction in the number of ulcers in animals treated with both alcoholic and aqueous extracts. Specifically, the alcoholic extract showed a decrease in the ulcer score, and this anti-ulcer activity was attributed to the presence of flavonoids in the plant. This suggests the potential of *B. racemosa* in mitigating paracetamol-induced gastric ulcers (Alex AM, 2020; Borikar VI, 2009).

Anthelmintic activity

The anthelmintic activity of *B. racemosa* was evaluated using various parts of the plant, including stem bark, leaves, seeds, and roots, against Indian adult earthworms (*Pheretima posthuma*). The leaves demonstrated a quicker onset of paralysis and death in earthworms compared to other plant parts. Further investigation into the anthelmintic activity of extracts from the leaves revealed that the petroleum ether extract at a concentration of 60 mg/ml exhibited the highest potency. The order of effectiveness was observed as petroleum ether > ethyl acetate > methanol > chloroform extract. The active principles present in the petroleum ether and ethyl acetate extracts contribute to the observed anthelmintic potential (Panda P, 2015; Girija B, 2009).

Anxiolytic activity

The anxiolytic-like effects of the methanolic extract of *B. racemosa* (MEBR) were studied in mice using behavioral models, including the elevated plus-maze, light-dark model, hole board test, and foot shock-induced freezing behavior. MEBR, administered at two different doses (150mg/kg and 300mg/kg), resulted in a significant increase in the time spent and the number of arm entries in the open arms of the elevated plus-maze. The extract also induced changes in behavior in other paradigms, such as the light-dark test, hole board test, and foot shock-induced freezing behavior test, comparable to the effects of the known anxiolytic drug, diazepam. These

findings suggest that MEBR exhibits effective anxiolytic properties (Panda P, 2015; Davey MS, 2011).

Hepatoprotective activity

The hepatoprotective effects of the methanol extract derived from the stem bark of *B. racemosa* Lam. (Caesalpiniaceae) in Wistar albino rats. The rats in various groups were exposed to paracetamol (500 mg/kg, p.o., once a day for 7 days) and carbon tetrachloride (CCl_4) (30% CCl_4, 1 ml/kg b.w. in liquid paraffin, administered three times i.p. at 72-hour intervals). Subsequently, the rats treated with paracetamol and CCl_4 received the methanol extract of *B. racemosa* at doses of 50, 100, and 200 mg/kg, as well as silymarin at 25 mg/kg.

The impact of the extract and silymarin on serum transaminase (SGOT, SGPT), alkaline phosphatase (ALP), bilirubin, and total protein was assessed in rats with induced hepatotoxicity. Furthermore, we examined the effects of the extract on lipid peroxidation (LPO), glutathione (GSH), superoxide dismutase (SOD), and catalase (CAT). The results indicated that both the plant extract and silymarin exhibited significant ($P < 0.05$) hepatoprotective effects by reducing the activity of serum enzymes, bilirubin, and lipid peroxidation. Moreover, they significantly ($P < 0.05$) increased the levels of GSH, SOD, CAT, and protein in a dose-dependent manner.

The alcoholic extract also demonstrated antioxidant effects on $FeCl_2$-ascorbate-induced lipid peroxidation in rat liver homogenate and superoxide scavenging activity. These findings suggest that the extract could protect liver cells from paracetamol-induced damage, possibly through its antioxidative effects on hepatocytes, thereby mitigating the adverse effects of toxic metabolites from paracetamol (Panda P, 2015; Gupta M, 2004; Kumar RS, 2005; Jangde CR, 2008; Kumar RS, 2007).

Conclusion

Bauhinia racemosa, a versatile plant with a rich historical and cultural significance, holds immense potential in the realm of natural medicine. Its diverse pharmacological activities, encompassing antidiabetic, anti-inflammatory, analgesic, antipyretic, and anti-microbial properties, highlight its therapeutic efficacy in addressing a wide range of ailments.

The presence of active phytoconstituents like flavonoids, terpenoids, and alkaloids across various plant parts contributes to its multifaceted medicinal properties. Further research exploring the precise mechanisms of action and potential synergistic effects within these bioactive compounds is crucial for unlocking the full therapeutic potential of this remarkable plant.

Bauhinia racemosa not only offers a promising avenue for the development of novel pharmacological agents but also presents a sustainable and readily available source of natural remedies. Integrating traditional knowledge with scientific advancements in phytochemistry and pharmacology can pave the way for the responsible utilization of this valuable plant resource in modern healthcare practices.

In conclusion, *Bauhinia racemosa* stands as a testament to the immense potential of nature's bounty in providing solutions for human health concerns. Continued research and development efforts, coupled with respect for traditional knowledge systems, can unlock the full spectrum of therapeutic possibilities offered by this fascinating plant.

Conflict of interest

The authors declare that there is no conflict of interest.

Authors contribution

Deepak Jha contributed to the conception and design of the review. The initial draft of the manuscript was authored by Deepak Jha and Pallavi Hangargekar. Ashish Singh Parihar, Chanchal Raj, and Ashish Jain performed reviews and provided comments on previous versions of the manuscript and guided in improving the quality of the manuscript. All authors have thoroughly reviewed and approved the final manuscript.

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References

- Alex, A. M., & Joghee, S. (2020). Phytochemistry and Therapeutic potential of Bauhinia racemosa Lam.-A Concise Review. *International Journal of Research in Pharmaceutical Sciences*, *11*(1), 1045-1050.Ali SI. (1973). Caesalpiniaceae. Flora of west Pakistan. *Fascicle*, 54.
- Akhtar, A. H., & Ahmad, K. U. (1995). Anti-ulcerogenic evaluation of the methanolic extracts of some indigenous medicinal plants of Pakistan in aspirin-ulcerated rats. *Journal of Ethnopharmacology*, *46*(1), 1-6.
- Anjaneyulu, A. S. R., Reddy, A. R., Reddy, D. S. K., Ward, R. S., Adhikesavalu, D., & Cameron, T. S. (1984). Pacharin: a new dibenzo (2, 3-6, 7) oxepin derivative from Bauhinia racemosa Lamk. *Tetrahedron*, *40*(21), 4245-4252.

- Azizur, R. M., Mehnaz, K., Hussain Arshad, A. M., & Mohd, K. (2015). Phytochemistry and pharmacology of traditionally Used tropical medicinal plant Bauhinia racemosa (Lam.). *The pharma research: An International Journal of Pharmacy Research*, *13*(1), 26-41.
- Banskota, A. H., Tezuka, Y., Adnyana, I. K., Xiong, Q., Hase, K., Tran, K. Q., ... & Kadota, S. (2000). Hepatoprotective effect of combretum quadrangulare and its constitutents. *Biological and Pharmaceutical Bulletin*, *23*(4), 456-460.
- Bhosale PS, Shete RV. (2021). A review on *Bauhinia racemosa*. *JETIR*, 8(5):894-901.
- Book Sunset Western Garden. (1995). 606–607. OED:Bauhinia.
- Borikar, V. I., Jangde, C. R., Philip, P., Rekhe, D. S., & Atole, S. K. (2009). Study of Antiulcer Activity of Bauhinia racemosa Lam in rats. *Veterinary World*, *2*(6), 217.
- Dahikar, S. B., Bhutada, S. A., Tambekar, D. H., Vibhute, S. K., & Kasture, S. B. (2011). In-vitro antibacterial efficacy of solvent extracts of leaves of Bauhinia racemosa Lam.(Caesalpiniaceae) against enteric bacterial pathogens. *International Journal of Pharmaceutical Sciences and Drug Research*, *3*(1), 32-34.
- Davey, M. S., Atlee, W. C., Bharathi, S. R. S. A., & Mohamed Farook, M. F. (2011). Antianxiety effect of methanolic extract of Bauhinia racemosa (Lamk) stem bark in mice.
- DeFeudis, F. V., Papadopoulos, V., & Drieu, K. (2003). Ginkgo biloba extracts and cancer: a research area in its infancy. *Fundamental & clinical pharmacology*, *17*(4), 405-417.
- Dhar, M. L., & Dhar, M. M. (1968). Screening of Indian plants for biological activity. Part I.
- El Hossary, G. A., Selim, M. A., Sayed, A. E., & Khaleel, A. E. (2000). Study of the flavonoid content of Bassia muricata and Bauhinia racemosa.
- Farag, M. A., Sakna, S. T., El-Fiky, N. M., Shabana, M. M., & Wessjohann, L. A. (2015). Phytochemical, antioxidant and antidiabetic evaluation of eight Bauhinia L. species from Egypt using UHPLC–PDA–qTOF-MS and chemometrics. *Phytochemistry*, *119*, 41-50.
- Fatima, M., Ahmed, S., Siddiqui, M. U. A., & ul Hasan, M. M. (2021). Medicinal uses, phytochemistry and pharmacology of Bauhinia racemosa lam. *Journal of Pharmacognosy and Phytochemistry*, *10*(2), 121-124.
- Gawade, B., & Farooqui, M. (2018). Screening of phytochemicals and in vitro antidiabetic activity of Bauhinia racemosa LAM. leaves. *Asian Journal of Pharmaceutical and Clinical Research*, 190-193.
- Genus: Bauhinia L. (2007). Germplasm Resources Information Network. United States Department of Agriculture. 2007-03-29. Archived from the original on 2012-05-03. Retrieved, 2010; 12: 06
- Girija, B., Bhalke, RD., Lodha, KR., Karmase, BC., Londhe, CG. (2009). Phytochemical investigation and in vitro anthelmintic activity of Bauhinia racemosa linn (leguminaceae), *Pharmacologyonline*, 1;300-303.
- Gupta, M., Mazumder, U. K., Kumar, R. S., & Kumar, T. S. (2004). Antitumor activity and antioxidant role of Bauhinia racemosa against Ehrlich ascites carcinoma in Swiss albino mice. *Acta Pharmacologica Sinica*, *25*, 1070-1076.

- Gupta, M., Mazumder, U. K., Siva, K. T., Gomathi, P., & SAMBATH, K. R. (2004). Antioxidant and hepatoprotective effects of bauhinia racemosa against paracetamol and carbon tetrachloride induced liver damagein rats.
- Jain, S. K. (1964). Wild plant-foods of the tribals of Bastar (Madhya Pradesh). *Proc. Nat. acad. Sci*, 56-80.
- Jain, R., Alam, S., & Saxena, U. (2002). A new tetracyclic phenol and other constituents from the roots of Bauhinia racemosa.
- Jain, R., Saxena, U., Rathore, K., & Jain, S. C. (2008). Bioactivities of polyphenolics from the roots of Bauhinia racemosa. *Archives of pharmacal research*, *31*, 1525-1529.
- Jangde, C. R., Bhandarkar, A. G., Philip, P., Ingle, K. S., Borikar, V., & Atole, S. K. (2008). Hepatoprotective effect of stem bark of Bauhinia racemosa Lam against paracetamol induced toxicity in rats. *Royal Veterinary Journal of India*, *4*(2), 57-61.
- Kessler, R. C., Davis, R. B., Foster, D. F., Van Rompay, M. I., Walters, E. E., Wilkey, S. A., ... & Eisenberg, D. M. (2001). Long-term trends in the use of complementary and alternative medical therapies in the United States. *Annals of internal medicine*, *135*(4), 262-268.
- EL KHATIBA, A. S., & Khaleel, A. E. (1995). Evaluation of some pharmacological properties of different extract of Bauhinia racemosa leaf and Bassia muricata whole plant.
- Kirtikar KR, Basu BD. (1975). Indian Medicinal Plants: Bishen Singh Mahendrapal Singh. Delhi, 3:1899-902.
- Kumar, R. S., Gupta, M., Mazumdar, U. K., Rajeshwar, Y., Kumar, T. S., Gomathi, P., & Roy, R. (2005). Effects of methanol extracts of Caesalpinia bonducella and Bauhinia racemosa on hematology and hepatorenal function in mice. *The Journal of toxicological sciences*, *30*(4), 265-274.
- Kumar, G., Karthik, L., & Rao, K. B. (2010). Phytochemical composition and in vitro antimicrobial activity of Bauhinia racemosa Lamk (Caesalpiniaceae). *International Journal of Pharmaceutical Sciences and Research*, *1*(11), 51.
- Kumar, V., Rathore, K., Jain, P., & Ahmed, Z. (2017). Biological activity of Bauhinia racemosa against Diabetes and Interlinked Disorders like Obesity and Hyperlipidemia. *Clinical Phytoscience*, *3*, 1-9.
- Kumar, R. S., Sivakumar, T., Sunderam, R. S., Gupta, M., Mazumdar, U. K., Gomathi, P., ... & Kumar, K. A. (2005). Antioxidant and antimicrobial activities of Bauhinia racemosa L. stem bark. *Brazilian journal of medical and biological research*, *38*, 1015-1024.
- Kumar, R. S., Sunderam, R. S., Sivakumar, T., Sivakumar, P., Sureshkumar, R., Kanagasabi, R., ... & Kumar, K. A. (2007). Effect of Bauhinia racemosa stem bark on N-nitrosodiethylamine-induced hepatocarcinogenesis in rats. *The American Journal of Chinese Medicine*, *35*(01), 103-114.
- Nadkarni, A. K. (2007). *Dr. KM Nadkarni's Indian materia medica: with Ayurvedic, Unani-tibbi, Siddha, allopathic, homeopathic, naturopathic & home remedies, appendices & indexes* (Vol. 1). Popular Prakashan.

- Nirmal, S. A., Dhasade, V. V., Laware, R. B., Rathi, R. A., & Kuchekar, B. S. (2011). Antihistaminic effect of Bauhinia racemosa leaves. *Journal of Young Pharmacists*, *3*(2), 129-131.
- Prabhu, S., Vijayakumar, S., Ramasubbu, R., Praseetha, P. K., Karthikeyan, K., Thiyagarajan, G., ... & Prakash, N. (2021). Traditional uses, phytochemistry and pharmacology of Bauhinia racemosa Lam.: a comprehensive review. *Future Journal of Pharmaceutical Sciences*, *7*(1), 101.
- Prakash, A., & Khosa, R. L. (1976). Chemical studies on Bauhini racemosa.
- Panda, P., Das, D., Dash, P., & Ghosh, G. (2015). Therapeutic potential of Bauhinia racemosa-a mini review. *Int J Pharm Sci Rev Res*, *32*(2), 169-179.
- Rashed, K., & Butnariu, M. (2014). Antimicrobial and antioxidant activities of Bauhinia racemosa Lam. and chemical content. *Iranian journal of pharmaceutical research: IJPR*, *13*(3), 1073.
- Ravikumar, A., & Rathinam, K. S. (2009). Antibacterial activity of hexane and acetone extracts of Peltophorum pterocarpum, Calvillea racemosa and Bauhinia purpurea. *Int. J. Chem. Sci*, *7*(3), 1751-1756.
- Sahu, T., & Sahu, J. (2015). Buahinia racemosa (Kachnar): A Review of its medicinal properties. *World J Pharm Res*, *4*(5), 686-696.
- Sashidhara, K. V., Singh, S. P., Misra, S., Gupta, J., & Misra-Bhattacharya, S. (2012). Galactolipids from Bauhinia racemosa as a new class of antifilarial agents against human lymphatic filarial parasite, Brugia malayi. *European journal of medicinal chemistry*, *50*, 230-235.
- Sharma BD, Lakshminarasimhan P. (1996). Flora of Maharashtra state. Kolkata: Botanical Survey of India.
- Sharanabasappa, G. K., Santosh, M. K., Shaila, D., Seetharam, Y. N., & Sanjeevarao, I. (2007). Phytochemical studies on Bauhinia racemosa lam. Bauhinia purpurea Linn. And hardwickia binata roxb. *Journal of Chemistry*, *4*, 21-31.
- Sinou, C., Forest, F., Lewis, G. P., & Bruneau, A. (2009). The genus Bauhinia sl (Leguminosae): a phylogeny based on the plastid trn L–trn F region. *Botany*, *87*(10), 947-960.
- Soni, V., Jha, A. K., Dwivedi, J., & Soni, P. (2015). Traditional uses, phytochemistry and pharmacology of Bauhinia racemosa Lam-a review. *CELLMED*, *5*(4), 24-1.
- Takeoka, G. R., & Dao, L. T. (2003). Antioxidant constituents of almond [Prunus dulcis (Mill.) DA Webb] hulls. *Journal of Agricultural and Food Chemistry*, *51*(2), 496-501.
- The Wealth of India. (1985). (New Delhi, India: National Institute of Science Communications and Information Resources, Council of Scientific and Industrial Research), 114.
- Wunderlin, R., Larsen, K., & Larsen, S. S. (1987). *Reorganization of the Cercideae (Fabaceae: caesalpinioideae)* (p. 28). Royal Danish Academy of Sciences and Letters.
- Xiao, Y., Qu, Y. Y., Hao, C. H., Tang, L., & Zhang, J. L. (2022). The complete chloroplast genome of Bauhinia racemosa Lam.(Fabaceae): a versatile tropical medicinal plant. *Mitochondrial DNA Part B*, *7*(8), 1528-1530.