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Review

A Comprehensive Review on Bauhinia Variegata

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Abstract:
Bauhinia Variegata Linn. (Fabaceae), also known as Kachnar or Mountain Ebony, is a medicinal tree found in tropical and subtropical climates. This thorough analysis combines the pharmacological, phytochemical, and traditional use of numerous plant parts, such as leaves, flowers, seeds, bark, buds, and roots. Phytochemical analysis has identified various beneficial chemicals, including flavonoids (quercetin, rutin, kaempferol, apigenin), phenolic acids, tannins, steroids (β-sitosterol, lupeol), alkaloids, and glycosides. These constituents have a wide range of pharmacological activities, including antioxidant, antimicrobial, anti-inflammatory, antidiabetic, anticancer, anti-ulcer, hepatoprotective, hypolipidemic, immunomodulatory, anti-arthritic, wound healing, nephroprotective, antihelmintic, and anti-tubercular properties. Traditional medicine uses B. variegata to treat diarrhea, dysentery, skin illnesses, ulcers, leprosy, bronchitis, tumors, jaundice, and snake poisoning. Additionally, the plant provides food (flowers, buds, seeds), feed, lumber, gum, and fiber. Experimental research with in vitro and in vivo models have proven its efficiency, particularly in free radical scavenging, glucose regulation, and microbial growth inhibition. The insulin-like protein discovered in leaves has potential for diabetic management. This study focuses on Bauhinia variegata's medicinal potential as a natural source of medication candidates for oxidative stress-related disorders, metabolic syndromes, and infectious diseases, highlighting the need for additional clinical research.

Keyword: Bauhinia variegate, Kachnar, Phytochemicals, Antioxidant activity, Antidiabetic, Flavonoids

Introduction:

Bauhinia variegata, a small to medium-sized tree in the Leguminosae family, is commonly referred to as cow's paw, cow hoof, orchid tree, or kachnar. This species of Bauhinia is widely found in tropical and subtropical regions, particularly in China, the Indian subcontinent, Southeast Asia, Africa, and South America.(fig.1&2) *Bauhinia Variegata* Linn. Is an important medicinal plant belonging to family Caesalpiniaceae. It is also known as like kachnar (Hindi), Raktakanchan (Marathi), Mountain ebony or orchid tree (English)[1–3].Various components of the *B. variegata* plant, including the leaves, flowers, floral buds, seeds, roots, & stem bark are employed for their antioxidant, antimutagenic, and antibacterial characteristics, as illustrated in Fig.3 Additionally, these components are utilised to treat diseases like cancer and diarrhoea[4-9]. *B. Variegata's* flowers, seeds, fruits, and vegetables are frequently eaten because they are full of nutrients and contain a variety of chemicals that are helpful in the treatment of many diseases[10]. β-sitosterol, kaempferol-3-glucoside, tannins, carbohydrates, amides, reducing sugars, vitamin C, crude protein, fibres, calcium, phosphorus, quercetin, rutin, quercitrin, apigenin, apigenin-7-O-glucoside,

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heptatriacontan-12, 13-diol, and dotetracontan-15-en-9-ol are the chemical constituents that have been extracted from the plant[11]. Experiments in vivo and in vitro have shown that the medicinal benefits of Bauhinia species are mostly related to their presence of flavonoid compounds[12].Plant phenolics, including phenolic acids, tannins, and flavonoids, are powerful antioxidants found in various foods such as vegetables, fruits, nuts, seeds, roots, and bark. The ability of phenolic compounds for use as antioxidants is determined by the redox potential of their hydroxyl groups which can act as reducing agents, hydrogen donors, and oxygen quenchers[13-14].*Bauhinia variegata's* leaves, bark, and flowers may find free radicals using the hydroxyl radical technique. *Bauhinia variegata* is a potential herbal medication for treating free radical-induced disorders such as cancer, diabetes, and atherosclerosis. Folk medicine uses various components of this plant to treat conditions such as jaundice, infections, leprosy, bronchitis, tumors, discomfort and inflammation[15-16].

Fig.1 Bauhinia Variegata Leaf

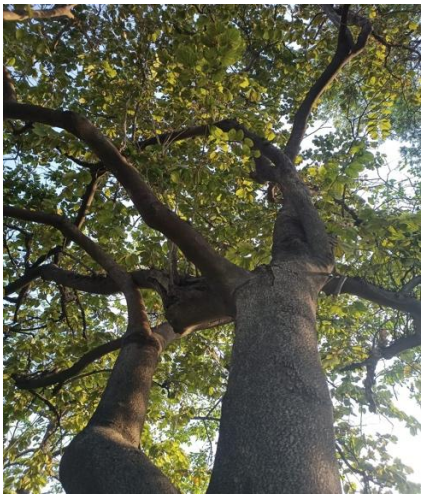

Fig.2 Bauhinia Variegata Tree

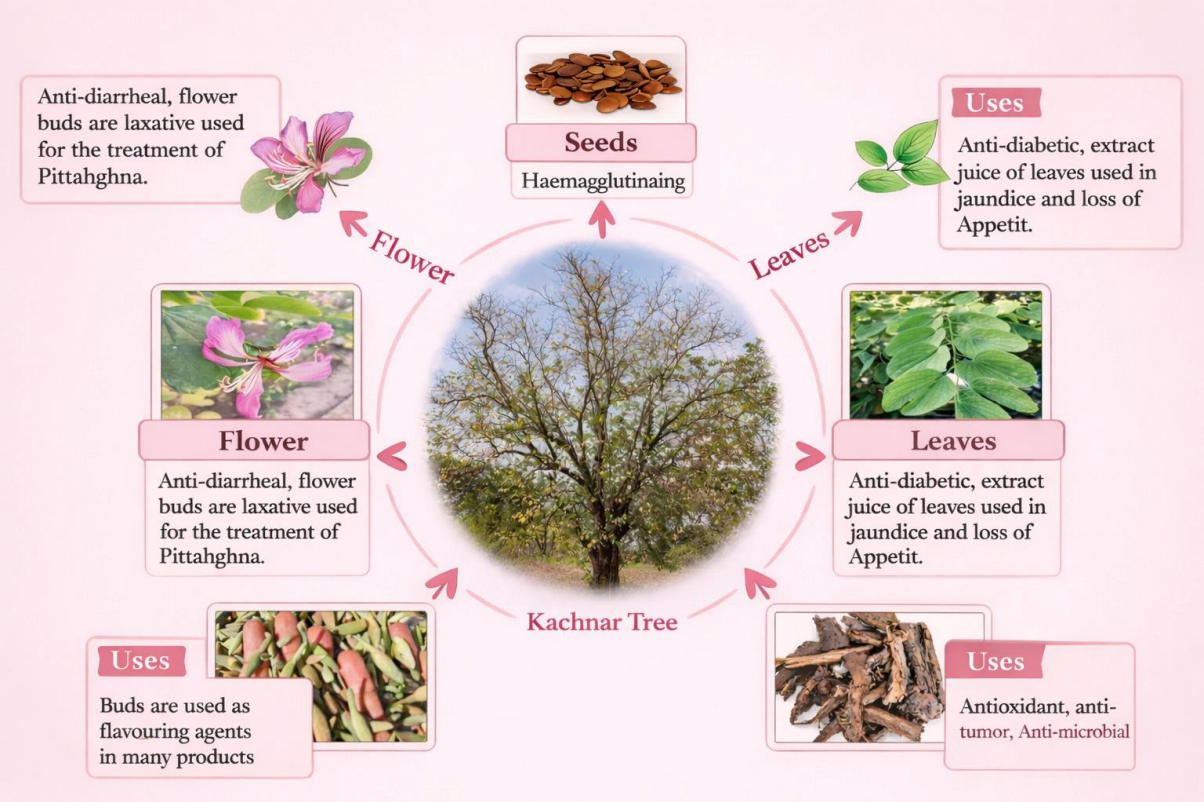

Fig .3 Utility of different plant parts of *Bauhinia variegata*

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❖ **TAXONOMICAL PROPERTIES:-**

Kingdome	Plantae
Class	Dicotyledons
Sub-class	Polypetalae
Series	Calyciflorae
Order	Rosales
Family	Fabaceae (cesalpinaceae)
Genus	Bauhinia
Species	Variegate

❖ **VENTRICULAR NAMES:-** [17]

English	Mountain Ebony , Orchid Tree
Hindi	Kachnar , Kaniar
Kannada	Kempu Mandara
Marathi	Kanchan
Telugu	Devakanchanamu ,
Malayalam	Kovidaram , Malayakathi
Gujarati	Chapmakati
Bengali	Raktakanchan

PHYTOCHEMICAL CONSTITUENTS OF KACHNAR:

1. LEAVES:

The juice extorted from leaves and roots of *B. variegata* is used by people of tribe named Gond of the Indian state named Madhya Pradesh to treat chest pain. The leaves of the tree have molluscicidal activity which is due to the quercetin and saponin present in them[18]. Lupeol, alkaloids, fat, glycoside, phenolics.lignin, saponins, terpenoids, B-sitosterol, tannins. kaempferol-3-glucoside, rutin, quercetin, apigenin, apigenin-70-glucoside amides. Carbohydrates, protein, vitaminc, calcium, and phosphorus[19].The leaves were also found to contain crude protein, calcium and phosphorous.Leaves of this plant were also reported to contain volatile oil. The analysis of oil by GC/MS showed presence of germacrene D, spathulenol, δ- and γcadinene[20].Leaves have flavonoids like quercetin, rutin, kaempferol. It is scientifically proved that flavonoids have significant effects on blood glucose level.One study showed that, aqueous extract of leaves of *Bauhinia variegata* can effectively decrease the elevated plasma glucose level and can be evolved as a phytomedicine in treatment of type I diabetes [21]. Immunolocalization of the insulin-like protein in the leaves of *Bauhinia variegata* was performed by transmission electron microscopy using a polyclonal anti-insulin human antibody. Localization in the leaf blades revealed that the insulin-like protein is present mainly in chloroplasts where it is also found associated with crystals which may be calcium oxalate. The presence of an insulin-like protein in chloroplasts may indicate its involvement in carbohydrate metabolism [22].

2. FLOWERS:

Flower are variously coloured, in few-flowered, lateral, sessile or short peduncled corymbus, the uppermost petal darker and variegated usually appearing before the leaves in short axillary or terminal racemes, stamens 5, staminodes absent[23].The list

of phytoconstituents isolated from flowers of this plant *Bauhinia variegata* are as follows: Quercitroside. Isoquercitroside, rutoside, taxifoline rhamnoside, kaempferol-3-glucoside, myricetol glycoside [24], apigenin, ascorbic, aspartic, glutamic, octadecanoic acid, keto acids, amino acid, tannins [25], cyaniding-3-glucoside, malvidin-3-glucoside, malvidin-3-diglucoside, peonidin-3- glucoside, peonidin-3-diglucoside, 3-galactoside and 3-rhamnoglucoside of kaempferol [26].

3. SEEDS:-

The seeds contains carbohydrates, proteins, amino acids, ascorbic acid, flavonoids, alkaloids, leucoanthocyanines , aspartic acid, glutamic acid, arginine, glycine, alanine, histidine, isoleucine, lysine, methionine, phenylalanine, proline, serine, threonine, tyrosine, valine [27].and 5-hydroxy7,3',4',5'-tetra-methoxyflavone5-O-beta-D-xylopyranosyl-alpha-L-rhamnopyranoside [28].

4. BARK:-

The bark is alterative, astringent and tonic and it is useful in the treatment of skin diseases, scrofula and ulcers. The bark decoction is used for diarrhea control, as an astringent alternative and for treating scrofula, skin diseases and ulcers. The extracts of *Glycosmis pentaphylla* and *B. variegata* show a free radical scavenging activity comparable to that of ascorbic acid. The overall antioxidant activity can be attributed to flavonoids, phenolic and other phytochemical constituents which can be a source of natural antioxidant that may have greater importance as therapeutic agent in preventing or showing oxidative stress related degenerative diseases [29]. Bark is grey with longitudinal cracks and pale pink inside[23]. 5,7- Dihydroxy and 5,7-dimethoxy- flavones- 4-0- alpha-L-rhamnopyranosyle- beta- D-glucopyranosides, kaempferol-3- glucoside lupeol and β-sitosterol have been isolated from the stem. Quercitroside, isoquercitroside, rutoside, taxifoline, rhamnoside, myricetol glycoside, apigenin-7-0- glucoside quercetin, rutin, apigenin; ascorbic acid, aspartic, glutamic, octadeconoic acids, keto and amino acids and tannins have also been reported. 3-glucosides of peonidin and cyaniding, malvidin and peonidin, 3-diglucosides malvidin obtained from the pale violet flowers while the white flowers contain 3-galactoside and 3-rhamnoglucoside of kaempferol[30].

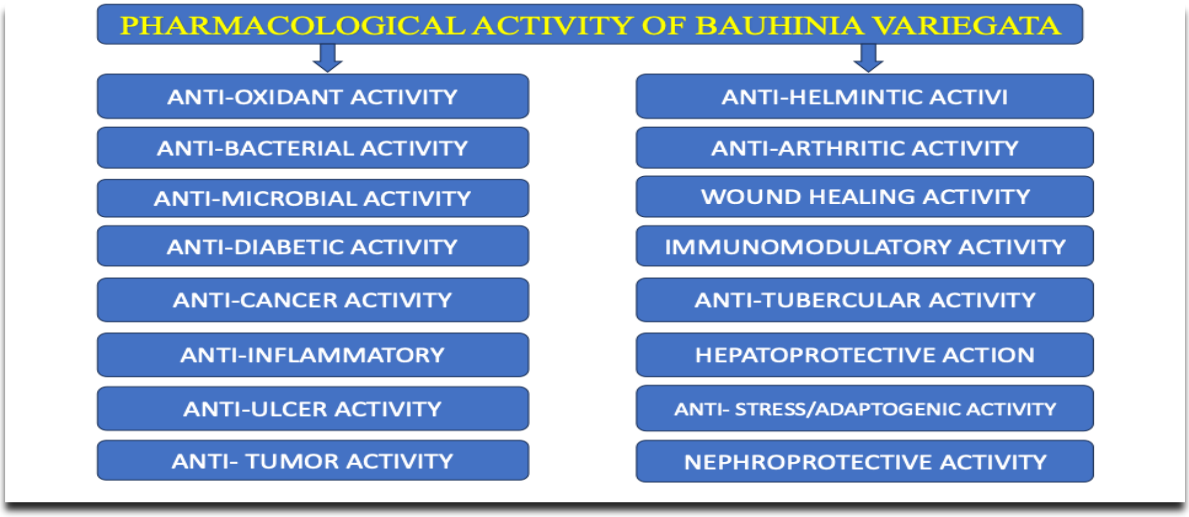
5. BUDS:

The dried buds are used in the treatment of piles, dysentery, diarrhea and worms [31].These buds were extracted using both maceration and hot percolation procedures, with maceration with 100% alcohol producing the maximum recovery of semi-solid gummy mass (33.3%). In contrast, heated percolation with 100% alcohol resulted in a reduced recovery of semi-solid gummy extract, which was only 28.3% [32]. The methanolic and aqueous extracts

of *Bauhinia variegata* flowering buds contained secondary metabolites such as flavonoids (1.26±0.06 and 4.26±0.26 mg/QE/g), phenols (3.96±0.09 and 4.74±0.97 mg/GAE/g), total amino acids (7.71±9.8 and 9.47±23.74 mg/Gly/g), and cytotoxic studies (brine shrimp lethality assay) with LD50 of 241.778 and 489.7061 µg/mL, respectively [33]. The amounts of vanillic acid (0.35%), caffeic acid (0.04%), kaempferol (1.53%), and syringic acid (0.01%) in the methanolic fractions of B. variegata flower buds were determined quantitatively using the HPTLC method [34]. B. variegata flowering bud acetone extracts showed 85.34% DPPH scavenging efficacy. The phosphomolybdenum complex assay found 173.5 µM AAE/100g, FW (micromolar ascorbic acid equivalents per 100 grams, fresh weight), but the FRAP value was 41.17 mM GAE/100g. These values are important for identifying the extract's total antioxidant capacity as well as for identifying ascorbic acid, phenolics, tocopherols, and carotenoids [35].

6. ROOT:

The root is used as an antidote to snake poison. A decoction of the root is used to treat dyspepsia.To verify its medicinal potential a lot of study and scientific research has been carried out [31]. A new flavanone, (2S)−5, 7-dimethoxy-30, 40 – methylenedioxyflavanone, dihydrodibenzoxepin, and 5, 6-dihydro-1, 7-dihydroxy-3, 4-dimethoxy-2-methyldibenz [b, f]doxepin, together with three recognized flavonoids, were discovered through phytochemical investigation of the root of B. variegate Linn[36].Glycosides, carbohydrates, tannins, phenolic substances, proteins, flavonoids, and free amino acids were detected by phytochemical analysis of alcoholic extracts from the root of *B. variegata*. The extract's high level of 86.38% phenolic compounds was revealed by polyphenol analysis. Antioxidant activity analyses showed significant antioxidant capabilities with IC50 values of 55.27 ± 2.57 µg/mL against ascorbic acid and 125.52 ± 8.15 µg/mL against curcumin.The notable antimutagenic properties of the alcoholic extract significantly decreased the percentage of Micronucleated Normal Cells Erythrocytes (MNNCE), Micronucleated Polychromatic Erythrocytes (MNPCE), and the P/N ratio at 24, 48, and 72 hours after cyclophosphamide-induced mutagenicity. A strong antioxidant, *B. Variegata* root alcoholic extract effectively inhibits cyclophosphamide-induced mutagenesis[6].



PHARMACOLOGICAL ACTIVITY:-

1. **Anti-oxidant activity:** *B.Variegata Linn.* shows strong antioxidant activity in both its ethanolic and aqueous extracts. Increasing the concentration of *B. variegata* extracts causes a progressive increase in activity to remove free radicals in the DPPH test, according to [37]. The phosphomolybdate experiment revealed a pattern of dose-dependent antioxidant activity. It was demonstrated that the extracts' total phenolic content and antioxidant activity were directly correlated. The highest FRAP levels were found in *B. variegata* using L-dopa extract [38]. At different concentrations, the extracts' ability to remove superoxide radical [39], nitric oxide [39,40], hydrogen peroxide [41], DPPH (1,2-diphenyl-2-picrylhydrazyl) radical [42], and its reducing power was assessed. Butylated hydroxy anisole (BHA) and ascorbic acid are employed as standards for several in vitro antioxidant studies[39].
2. **Anti-microbial activity:** The alcohol extract of *B.Variegata Linn.* has been demonstrated to have considerable antibiotic effects against gram-positive and gram-negative bacteria, including Escherichia coli, Enterobacter aerogenes, Klebsiella, Streptococcus pneumoniae, Bacillus subtilis, and Staphylococcus aureus [43]. The *B. variegata* Linn. increased clear suppresses microbe growth at concentrations ranging from 50 to 300 ug/ml in agar diffusion method [44]. B. subtilis was found to be the target of the largest zone of inhibition. In disc diffusion experiments, a variety of *B. variegata* solvent extracts inhibited the growth of Staphylococcus aureus [45].
3. **Anti-inflammatory activity:** The chemical constituents of non woody parts have anti-inflammatory activity against inhibiting the lipopolysaccharides and interferon γ induced nitric oxide (NO) and cytokines. A novel flavonol glyycoside obtained from ethanolic extract of root 5, 7, 3’ 4’ tetrahydroxy-3-methoxy- 7-o-α-Lrhamnopyranosyl (1→3) –o-β-dgalactopyranoside, has anti-inflammatory property [46]. Adult albino wistar rats were used to test the hydroalcoholic extract (stem bark) of B. purpurea for anti-inflammatory and anti-arthritic properties utilizing models of carrageenan-induced paw edema and adjuvant-induced arthritis, respectively. rats and contrasted with the common medication atorvastatin, which lowers cholesterol. A high-fat diet containing cholesterol, sodium cholate, and coconut oil combined with animal feed caused hyperlipidemia. The scientists found that when the extract was taken orally for 30 days at a dose of 300 mg/kg/day, there was a slight gain in body weight along with a notable rise in blood HDL-C and a drop in total cholesterol, LDL, and triglycerides[47].
4. **Anti-bacterial activity:** The fruit of *Bauhinia variegata* was tested for antibacterial activity using the disc

diffusion method. Add approximately 28 g of dissolved NA to 1000 mL of water and thoroughly shake. The media is sterilized for 15 minutes using an autoclave at 121°C and 15 psi. First, prepared media was placed into the petri dish and allowed to harden. To inoculate the agar plate, streak it with bacterial strain using a spreader. Place three soaked 6mm discs of desired extract concentration, Ciprofloxacin (positive control), and DMSO (negative control) at equal distances. After that, incubate for one day at 37 °C. The minimum inhibitory concentration that stops bacterial growth was then found.The zone of inhibition surrounding the sample and control discs was then measured in millimeters using a ruler, and the dilution of different concentrations at 200 mg, 400 mg, and 600 mg was examined using the same approach. Three runs of this assay were conducted [48].

5. **Anti-diabetic activity:** Plant species also have insulin-like sequences, including domain structures. This may provide a biological foundation for the efficacy of plant decoctions and extracts in the treatment of hyperglycemia [49]. In streptozotocin (STZ) and alloxan-induced diabetic rats, oral administration of ethanolic, aqueous, and hydroalcoholic extract of *Bauhinia Variegata* leaves and stem bark at several doses, such as 200 and 400 mg/kg, decreased the high blood glucose level by boosting glucose metabolism [50]. The inhibition of α-amylase and α-glucosidase study models was used to assess the antidiabetic activity of the plant materials (BVP, BVC, BVN, and BVM). Enzymes called α-amylase and α-glucosidase improve the absorption of glucose by breaking down polysaccharide binding. By blocking these enzymes, blood sugar levels are regulated and glucose uptake is delayed [51].
6. **Anti-cancer activity:** A test in a laboratory container revealed that *Bauhinia variegata* extract stopped the growth of certain cell lines, which was harmful to tumor growth47. Another evaluation discovered that methanolic concentrate of *Bauhinia variegata* leaves at measurements of 300, 600, and 900 mg/kg in cyclophosphamide-initiated mutagenesis in bone marrow cells of mice displayed anti-mutagenic activity by preserving the arrangement of micronucleus and chromosomal abnormalities[52].Ethanolic extract demonstrated anticancer efficacy against Dalton's ascetic *Bauhinia variegata* lymphoma (DAL) in Swiss albino mice and liver cancers in rats [53]. Research demonstrates that leaf extracts from *Bauhinia Variegata* Klebsiella pneumoniae E. coli have antibacterial, antioxidant, and anticancer properties against Proteus Pseudomonas spp. and spp. It demonstrated considerable antioxidant action in the beta carotene bleaching assay. Ethyl acetate fraction shown cytotoxicity against MCF-7 and THP-1 cell lines [54].
7. **Anti-tumor activity:** Melanoma cell lines were procured from National Cell Science Centre in Pune and kept in our laboratory. Our institute's animal colony provided the C57 Bl hybrid mice, which were 6-7 weeks old, of both sexes, and weighed an average of 25 grams. They received a conventional mouse pellet meal and unlimited access to water while being kept in excellent laboratory conditions. Every mouse was housed in a temperature and light control environment. A cell suspension containing 0.5 million cells per animal was administered. The animals were monitored when the melanoma cell line was implanted, and the experiment began when the tumors appeared ten days later. Each animal's tumor volume and survival time were noted during the 30-day oral Kachanar extract treatment[55].
8. **Nephroprotective activity:** Rats treated with gentamicin showed significantly higher levels of urine creatinine, serum creatinine, serum urea, and blood urea nitrogen compared to those given with aqueous and ethanolic extracts of *Bauhinia Variegata* Linn. Reversed the effects of gentamicin, demonstrating nephroprotective action. When the antioxidant defense system is strong, the

nephrotoxicity caused by gentamicin is simultaneously significantly reduced. Gentamicin-induced nephrotoxicity may cause an increase in ROS due to inactivation of antioxidant enzymes including SOD and GSHPx. Numerous studies have linked nephrotoxicity to oxidative stress. Kidney function impairment is associated with elevated serum creatinine and urea levels, as well as MDA levels in kidney tissue, indicating lipid peroxidation. This molecule plays a crucial role in cell integrity and metabolism [56,57].

9. **Hypolipidemic activity:** Lipid metabolism is controlled in a variety of ways. Lipid metabolism is mostly regulated by enzymes. One of the enzymes involved in the manufacture of cholesterol is 3-hydroxy-3-methylglutaryl coenzyme A (HMG-CoA) reductase[58].In addition to being secondary metabolic dysregulations linked to diabetes,hyperlipidemia and hypercholesterolemia are also elevated risk factors for the onset of diabetes[59].Hyperlipidemia is a highly predictive risk factor for atherosclerosis, coronary artery disease, and cerebral vascular disease[60]. The importance of developing natural lipid-lowering drugs and formulations has grown in recent years [61]. Numerous medicinal plants have been studied and proven to have active principles that can treat hyperlipidemia . This report examines the potential benefits of indigenous plants in treating hyperlipidemia[62].
10. **Immunomodulatory activity:** The ethanolic extract from *B.variegata* stem bark affected both the primary and secondary antibody responses. Additionally, It also raised the percentage of neutrophil adhesion and the phagocytic index [63].
11. **Anti-helmintic activity:** Watery and chloroform concentrates of *B. variegata* bark were tested for anti-helmintic activity against Pheretima posthuma and Ascardia galli. All extricates showed a subordinate (25, 50, and 100 mg/ml) inhibition of unrestricted motility (loss of motion) and delay of death of the worm. Remove extracted from bark not only killed the Pheretima posthuma but also killed the Ascardia galli. The perceptions were comparable to the conventional drug piperazine citrate at a concentration of 20 mg/mL and purified water as a control. Both concentrates showed the most severe vermicide effect at a centralization of 100 mg/ml. According to the results of the test, *B.Variegata* bark's watery and chloroform concentrate may have anthelmintic properties [64].
12. **Anti-arthritic activity:** The anti-arthritic effect of an ethanolic extract of *B.variegata* was investigated by administering the ethanolic extract orally at the tested dose level of 250 mg/kg to rats with complete Freund's adjuvant (CFA) induced arthritis for 15 days. After 15 days, the rats were slaughtered, their blood collected, and the serum separated. Following that, several parameters such as alanine amino transferase (ALT), alkaline phosphatase (ALP), total cholesterol, and triglycerides were measured. The levels of several antioxidant enzymes, including catalase, glutathione peroxidase (GPx), superoxide dismutase (SOD), and lipid peroxidase (LPO), were also assessed in the liver and kidney of normal, arthritic control, and extract-treated rats. The results of these research demonstrate that administering this dramatically increased Paw Edema volume in rats and altered the biochemical parameters as well as the levels of numerous antioxidant enzymes that were impacted in arthritic animals. The study indicated that ethanolic extracts of this plant had a substantial antiarthritic effect in rats[65].
13. **Wound healing activity:** *B. variegata* plays an important role in wound healing and has been utilized as a healing agent since antiquity. A poly-herbal liniment can be created by combining mountain ebony, Rhododendron arboretum and Myrica esculenta in various ratios depending on the requirement [66]. In pale-skinned Wistar rats, the injury-recovery movement of

ethanolic and fluid concentrates of the foundation of BV at concentrations of 200 and 400 mg/kg bw was tested using extraction and entry point twisted models [67]. Extraction and cut damage models with fluid and ethanolic BV foundation concentrations at both assessments resulted in considerable injury healing. This was comparable to the extraction wound model treated with framycetin, the standard treatment [68,69].

14. **Anti-tubercular activity:** Clinical research has shown that preparing Bauhinia stem bark improves the effectiveness of anti-tubercular medications used to treat tubercular cervical lymphadenitis [70].
15. **Anti-ulcer activity:** The alcohol-based extraction of the stembark and stem of *B. variegata* Linn produced a positive effect as an anti-ulcer action against stomach ulcers induced by "pyloric ligation and NSAIDs (aspirin) induced model". The crude liquid of the plant (oral administration) decreased the bulk of acid secretion, total, free acidity, and acid index when compared to the control group. This study concluded that an alcohol-based extract of B. variegate Linn. produced significant ($P<0.001$) stomach acid protection[71]. Additionally, the stems, roots, and leaves can be used to treat leprosy, diabetes, ulcers, infections, discomfort, and jaundice [72]. There is anti-ulcer action in *Bauhinia variegata*. Rats with stomach ulcers caused by aspirin and pylorus ligation were used to test the anti-ulcer properties of an alcoholic extract of *Bauhinia variegata* stem (250 mg/kg). *Bauhinia variegata* stem extract was found to considerably reduce stomach secretions, which in turn reduced the ulcer index [73].
16. **Hepatoprotective activity:** The leaf extract is used to treat piles and as a laxative. Dried buds are used to cure worms, tumors, diarrhea, dysentery, and piles [74]. The ethanolic extract of *Bauhinia variegata* is hepatoprotective against carbon tetrachloride-induced liver damage in rats. In this study, carbon tetrachloride 1 ml/kg mixed in olive oil (1:1) was administered orally to produce liver injury. Silymarin (100mg/kg) orally was employed as the reference medication. Several biochemical indicators, including aspartate aminotransferase (AST), alanine aminotransferase (ALT), alkaline phosphatase (ALP), total bilirubin, malondialdehyde (MDA), glutathione (GSH), and catalase (CAT), were also measured, followed by histology. BVEE (400mg and 600mg/kg) was found to be more powerful than BVEE (200mg and 100mg/kg) [75].
17. **Anti-stress & Adaptogenic activity:** *Bauhinia variegata* is also used to make ayurvedic medications for diarrhea, dysentery, goiter, lymphadenitis, worm infestation, rectal prolapse, and as a depurative (blood purifier). It also helps the liver detoxify better [76]. The impact of ethanolic bark extract of *Bauhinia variegata* on oxidative stress caused by cold restraint stress (CRS) and iron overload (IO) oxidative stress was studied. They observed alterations in antioxidant enzymes such as GSH, CAT, SOD, and LPO. The extract effectively controlled stress-induced fluctuations in biochemical levels and antioxidant enzymes in stress models [77].
18. **Haemagglutinating Activity:** *B. Variegata* seeds are high in protein and exhibit hemagglutinating properties [78]. Aside from playing an important role in traditional medicine, *B. variegata* is directly and indirectly related with various goods, including:
    - **Food:** Flowers and flower buds are eaten as vegetables in several countries, including Pakistan, India, and Nepal.
    - **Fiber:** Fiber is derived from weak stems and used to make rope.
    - **Timber:** Because its wood is brown and moderately hard, it is used to make agricultural equipment.
    - **Fodder:** Sheep and goats can also benefit from *B. Variegata* as feed. Each tree typically

produces 15–20 kg of dry materials annually.

- **Gum or resin:** The tree generates gum, which is used as both an adhesive and an industrial product.
- **Lipids:** The *B. variegata* seeds consist of 20% endocarp and 80% kernel. They extract 16.5% of pale yellow, fatty oil using petroleum ether but only 6.1% with a hydraulic press.
- **Medicine:** Cough, diarrhoea, bleeding hemorrhoids, dysentery, heartburn, skin conditions, sore throat, TB, dyspepsia, bronchitis, leprosy, hematuria, indigestion, malaria, menorrhagia ulcer, obesity, and worms are all treated with it.[79]

FUTURE PERSPECTIVES:

Despite the extensive pharmacological data supporting Bauhinia variegata's value as a medicinal plant, various research gaps must be addressed before it can be completely utilized for therapeutic purposes.

1. Clinical Trials: The majority of research is restricted to animal and in vitro models. To confirm efficacy, safety, dose, and any drug interactions, well-designed, randomized controlled human trials are desperately needed.
2. Mechanistic Studies: While bioactive substances like flavonoids and insulin-like proteins have been found, their precise molecular processes, receptor interactions, and signaling cascades require deeper elucidation using modern omics technologies (proteomics, metabolomics, genomes).
3. Standardization: To ensure repeatable quality, batch-to-batch consistency, and regulatory approval as phytomedicine, standardized extracts including measurable marker chemicals (such as quercetin, rutin, and kaempferol) must be developed.
4. Formulation Development: Innovative drug delivery technologies, including nanoparticles, nanoemulsions, liposomes, and phytosomes, may improve the bioavailability, stability, and targeted delivery of B. variegata bioactives.
5. Toxicological Evaluation: To figure out safe therapeutic periods, long-term toxicity studies, including chronic, sub-chronic, and reproductive toxicity assessments, are required.
6. Isolation of New Compounds: Innovative spectroscopic and chromatographic methods may reveal new bioactive compounds with special therapeutic uses, especially in metabolic diseases and cancer.

CONCLUSION:

Bauhinia variegata is a multifaceted medicinal plant with significant therapeutic potential. Its many phytoconstituents—flavonoids, phenolics, tannins, and sterols—support a wide variety of pharmacological actions, including antioxidant, antibacterial, antidiabetic, anti-inflammatory, anticancer, hepatoprotective, and wound healing qualities. Modern scientific investigations have supported traditional treatment methods for diarrhea, ulcers, skin problems, and diabetes. The presence of insulin-like proteins in leaves holds hope for diabetes control. While preclinical evidence is strong, more clinical studies, standardized extracts, and safety assessments are required to transform B. variegata into useful, evidence-based phytomedicines for human health.

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