

# A Comprehensive Review of Pharmacognostic and Phytochemical Profile of *Bauhinia Variegata*

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## ABSTRACT

*Bauhinia variegata* (Kanchanar) is an important medicinal plant used in traditional systems of medicine such as Ayurveda, Siddha, and Unani systems. The present review deals with the pharmacognostic and phytochemical characteristics of *Bauhinia variegata*, particularly focusing on the macroscopic and microscopic characteristics of the leaves and flowers. The pharmacognostic analysis is very important for the identification and authentication of crude drugs and its quality control in the preparation of herbal formulations. The macroscopic analysis includes the characteristic bilobed leaves resembling the shape and size of the camel's hoof, orchid-shaped flowers, and other important features that distinguish the drug from other closely related species such as *Bauhinia purpurea* and *Bauhinia racemosa*. The microscopic analysis includes the diagnostic anatomical features such as the presence of a single layer of epidermis, presence of paracytic stomata, palisade and spongy parenchyma tissue, calcium oxalate crystals, and the well-developed vascular tissue. The powder microscopic analysis includes the presence of important diagnostic features such as the presence of epidermal elements, trichomes, spiral and reticulate vessel elements, and prismatic crystals. The preliminary phytochemical screening of leaf and flower extracts of *B. variegata* reveals the presence of different bioactive compounds like flavonoids, phenolic compounds, tannins, glycosides, saponins, terpenoids, sterols, and anthocyanins. These phytochemicals are responsible for different pharmacological properties of medicinal plants, which include antioxidant, anti-inflammatory, antimicrobial, and anticancer properties. Various extraction techniques like maceration, percolation, Soxhlet extraction, decoction, and modern techniques are used to obtain these bioactive compounds from medicinal plants. The pharmacognostic and phytochemical studies of *B. variegata* provide a scientific basis for the identification, standardization, and therapeutic use of *B. variegata* in herbal medicine and pharmaceutical research.

**Keywords:** *Bauhinia variegata*; Kanchanar; Pharmacognosy; Powder microscopy; Phytochemical screening; Medicinal plants; Leaf and flower morphology; Herbal drug standardization; Flavonoids; Traditional medicine

## INTRODUCTION

Plants have always been essential to the advancement of human civilization because they provide clothes, food, shelter, and above all medicine. Due to its numerous therapeutic uses in Ayurveda, Siddha, Unani, and ethno medical traditions throughout Asia, *Bauhinia variegata* (Kanchanar) stands out among thousands of medicinal plants used historically. The plant's powerful ability to treat ailments like glandular swellings (granthi), thyroid enlargement (galganda), obesity (medoroga), skin disorders (kustha), tumors (arbuda), wounds, and respiratory issues has been

mentioned in traditional Ayurvedic writings. The plant's inclusion in the well-known polyherbal composition Kanchanar Guggulu highlights its significance in traditional medicine even further. Due to the shortcomings of synthetic medications, rising antibiotic resistance, the frequency of chronic illnesses, and a worldwide desire for natural treatments with few adverse effects, there has been a notable trend in recent years toward plant-based therapeutic agents. In order to confirm their traditional usage and investigate their potential in contemporary medication development, medicinal plants such as *B. variegata* are being reevaluated

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scientifically. *B. variegata* is a medium-sized deciduous tree in the Fabaceae family that is distinguished by its camel-foot-shaped leaves and lovely orchid-like flowers.<sup>[1]</sup> *Bauhinia purpurea*, sometimes called Kovidara or the Purple Orchid Tree, is a significant decorative and medicinal species in the Fabaceae family. The plant is grown for its aesthetic value and is widely utilised in traditional medicine in India, Sri Lanka, Nepal, China, Malaysia, and other tropical Asian countries. Ayurveda uses a variety of plant parts, including the bark, leaves, flowers, and

pod, to treat glandular swellings, ulcers, fever, skin conditions, tumours, and digestive issues.<sup>[2]</sup> *Bauhinia racemosa* Lam., a small deciduous tree in the Fabaceae family, is often referred to as the Bidi Leaf Tree or "Bhojpatra/Ashta-varna." It is extensively found in tropical Southeast Asian countries, including India, Sri Lanka, and Myanmar. Diarrhoea, dysentery, inflammation, ulcers, tumours, skin conditions, and respiratory issues have all historically been treated with the herb in Ayurveda.<sup>[3]</sup>



Fig: Leaf of *Bauhinia Variegata*<sup>[6]</sup>

## Pharmacognostic Profile of Kanchanar

Table: Taxonomical Classification

| Rank          | Classification                |
|---------------|-------------------------------|
| Kingdom       | Plantae                       |
| Subkingdom    | Tracheophyta                  |
| Superdivision | Spermatophyta                 |
| Division      | Magnoliophyta                 |
| Class         | Magnoliopsida (Dicotyledonae) |
| Order         | Fabales                       |
| Family        | Fabaceae (Leguminosae)        |
| Subfamily     | Caesalpinioideae              |

## Macroscopic study

### 1. Morphology in General:

Has simple, alternating, clearly bilobed leaves that resemble camel feet or cow hoofs. A crucial diagnostic feature is this bifid look.<sup>[4]</sup> The leaves have a distinctive symmetry along the vertical axis and grow on thin branches.<sup>[5]</sup>

### Size and Dimensions

*Bauhinia variegata* typically has leaves that are 10–20 cm long and petioles that are 2–5 cm in length. Their

overall size can vary significantly depending on several ecological and physiological factors including tree age, soil composition, water availability, and geographical location. Variations in leaf thickness, distribution, and general morphology are caused by these environmental factors.<sup>[7]</sup>

### Shape and Apex

***Bauhinia variegata*:** Leaves are large, rounded to broadly ovate, with a deep median cleft, forming two nearly symmetrical lobes. The apex of each lobe can

be flat, rounded, or slightly pointed, depending upon its age.

***Bauhinia purpurea*:** Leaves are not as bilobed as in *B. variegata* the middle cleft is shallow, and the lobes are rounded. The tip of a leaf lobe usually appears rounded. Leaves are longer and narrower.

***Bauhinia racemosa*:** Leaves are simple, small, oval to oblong, and not bilobed. The apex is entire, rounded, and rarely very slightly mucronate. This is an important distinguishing characteristic, separating it well from *B. variegata* and *B. purpurea*.

**Table: Macroscopical Characters**

| Feature       | <i>B. variegata</i> | <i>B. purpurea</i> | <i>B. racemosa</i> |
|---------------|---------------------|--------------------|--------------------|
| Leaf Size     | Large (10–20 cm)    | Medium (8–16 cm)   | Small (3–7 cm)     |
| Lobation      | Deeply bilobed      | Moderately bilobed | Shallowly bilobed  |
| Flower Size   | Large, orchid-like  | Large, purple      | Small, white       |
| Flower Colour | pink/purple         | Deep purple        | White              |
| Inflorescence | Panicles            | Racemes            | Long racemes       |
| Fruit         | 15–30 cm pods       | 15–20 cm pods      | 10–15 cm pods      |



**Fig: Flower of *bauhinia variegata*** <sup>[8]</sup>



**Fig: Flower of *bauhinia racemosa*** <sup>[9]</sup>

## 2. Microscopic Study

### Leaf Microscopy (T.S.): Upper Epidermis

***Bauhinia variegata*:** *Bauhinia variegata* Single layered, polygonal cells, closely packed, Thick, smooth, well developed cuticle, No trichomes, Anticlinal walls straight and

***Bauhinia. Purpurea*:** Similar single-layered epidermis but cuticle thinner, Occasional unicellular trichomes present (help in distinguishing it from *B. variegata*). Epidermal cell size slightly smaller and less.

***Bauhinia Racemosa*:** Epidermal cells above are small, thin-walled, with a very thin cuticle. Epidermal hairs are present, usually in form of unicells. Epidermal surface appears opaque as a result of a sparse cutin layer <sup>[10]</sup>

- **Palisade Parenchyma**

***Bauhinia variegata*:** 1-2 layers of long columnar palisade cells, Chlorenchymatous, rich in chloroplasts Deep green in color, Compact closely together to

***Bauhinia Purpurea*:** Typically, a single layer of palisade cells (Thin leaf), Cells are shorter and less compact, Chloroplasts are moderately numerous.

***Bauhinia Racemosa*:** There is only a single layer of palisade cells, which is very thin, Small, loosely packed, suggesting a reduced amount of photosynthetic parenchyma, Mesophyll <sup>[11]</sup>

- **Spongy Parenchyma**

***Bauhinia variegata*:** Well-developed, loosely arranged spongy cells, Numerous air spaces efficient gaseous exchange. Large portion of mesophyll occupied by spongy zone, Traversed by veinlets and small vascular bundles.

**Bauhinia purpurea:** Moderately developed spongy layer, Fewer air cavities than *B. variegata*, Veins are smaller and less frequent.

**Bauhinia racemosa:** Very tender spongy tissue, relatively few intercellular spaces, the leaf is thin due to the lack of mesophyll differentiation.<sup>[12]</sup>

**Table: Microscopical Characters**

| Feature        | <i>B. variegata</i> | <i>B. purpurea</i> | <i>B. racemosa</i> |
|----------------|---------------------|--------------------|--------------------|
| Trichomes      | Absent              | Present            | Present            |
| Palisade layer | 1–2 layers, compact | 1 layer            | Thin, weak         |
| Spongy tissue  | Well developed      | Moderate           | Poorly developed   |
| Cuticle        | Thick               | Moderate           | Thin               |
| Midrib         | Strong, arched      | Moderate           | Slender            |
| Crystals       | Abundant            | Moderate           | Few                |
| Stomata        | Paracytic           | Paracytic          | Paracytic          |

## Powder Microscopy Study

Powder microscopy forms a very integral part of pharmacognostical evaluation and is employed for identification and authentication of crude plant drugs in their powdered state. Microscopic examination provides a sound scientific approach toward verification of authenticity, detection of adulteration, and establishment of diagnostic profiles, since most herbal crude drugs, like *Bauhinia* (Kanchanar) leaf and flower, are traded, transported, or used in powdered conditions. Powdered microscopy assumes greater significance when morphological characters are lost during processing or grinding.

### 1. Purpose of Powder microscopy:

The following are the primary goals of powdered microscopy. Authentication One of the most important applications of powder microscopy is authentication, ensuring that the powdered crude drug being evaluated truly represents its botanical identity as proclaimed. Conventional macroscopic identification is made impossible by the fact that many therapeutic plant parts, such as leaves, flowers, barks, and roots, are available commercially in fragmented or powdered forms. According to its microscopic diagnostic features, powder microscopy provides a scientific means of identifying the crude drug. While authentication is being carried out, unique microscopic features like the epidermal cells, stomatal type, trichomes, crystals, fibers, xylem elements, starch grains, and secretory structures are some of the salient microscopic anatomical features that are closely observed under a microscope. These micro-characters are highly specific biological

markers for every species of plant even in the ground, dried, or processed states. For example, reticulate arteries, unicellular trichomes, calcium oxalate crystals, and paracytic stomata may distinguish *Bauhinia* from other Fabaceae species.<sup>[13]</sup> Evaluation of Diagnostic Constants Evaluation of diagnostic constants is among the most critical uses of powdered microscopy, as these quantifiable anatomical characters aid to establish the authenticity of crude drugs and distinguish them from closely allied species, adulterants, or substitutes. Quantitative microscopic parameters with constancy for a specific species irrespective of environmental or geographic variation include stomatal index, palisade ratio, vein-islet number, stomatal number, and vein termination number. In the absence of morphological characters when the drug is treated, powdered, or processed, these constants become dependable on taxonomic markers, providing scientific evidence for identification purposes. All these constants are determined by powdered microscopy, which employs coloring chemicals, cleaning agents, and calibrated ocular micrometers in order to view epidermal and tissue fragments at both low and high magnification. These values serve as established reference points in quality management since they cannot be altered by maturity, climate, soil conditions, or time of harvest. Determination of diagnostic constants is particularly important for discriminating between plant species that are morphologically similar but cannot be differentiated by macroscopic examination alone. Detection of Adulterants and Substituents of Adulterants and replacements detection is one of the most important uses of powdered microscopy, especially in the quality monitoring of herbal raw

materials. Crude pharmaceuticals are often delivered as powders, which makes their identification based on macroscopic features very difficult. Adulteration may occur accidentally because of a misidentification during collection, or it may be intentional using less expensive plant parts to increase profit. Such adulteration not only diminishes the therapeutic effectiveness of herbal medicine but may pose serious health risks because of the poisonous or biologically inactive plant fragments.<sup>[14]</sup>

## 2. Methodology Preparation of powder

Phytoconstituents are preserved by shade-drying flowers and leaves, Mechanical grinders are used for coarse grinding, for a consistent particle size, powder is sieved using 60–80 mesh, kept in sealed containers to prevent absorption of moisture. Slide Preparation: A small sprinkle of powder is mounted on a clean slide using the following reagents: Water+glycerin for general viewing, Lactophenol for enhancement and clarification, Phenolglucinol + HCl for staining lignified tissues, Iodine solution for detecting starch, Sudan III for lipids-containing elements, Chloral hydrate to clear epidermal fragments. If need be, before placing the coverslip, the slide should be gently warmed to clarify the internal structures.<sup>[15]</sup>

## 3. Microscopic Inspection:

Low power (10×) for general tissue fragment identification, High power (40×) for detailed anatomical features, Examining calcium oxalate crystals under polarized light, if possible.<sup>[16]</sup>

## 4. Kanchnar Leaf Powder Diagnostic Features of Epidermal Cells Upper epidermis:

thick cuticle, polygonal, with straight walls, the lower epidermis is wavy and thin-walled with many stomata

The stomata The family Fabaceae is characterized by its paracytic stomata, Bean-shaped guard cells have transparent nuclei. Trichomal elongated, eglandular, unicellular trichomes, often broken off at the base, leaving behind characteristic fragments. Calcium Oxalate Crystals Prismatic, and widely distributed in the mesophyll, dissolved in HCl dilution. vessels that are reticulate, annular, and spiral, Long, tapering, thick-walled xylem fibres. Palisade cells are tightly packed rows, spherical, spongy cells with gaps between them, Tannin cells and chlorophyll.<sup>[17]</sup>

## 5. Bauhinia Flower Powder Pollen Grains Diagnostic Features Tricolpate, elliptical spherical:

Under a microscope, bright yellow. Petal Fragments Anthocyanin-bearing fragments with a purple-pink coloured, Epidermal papillose cells Tissues Anther Remaining pollen sacs, filamentary tissues with thin walls. Vascular Aspects Reticulate and spiral vessel. fibers connected with the tissues of flower stalks. Crystals of prismatic calcium oxalate from floral stem tissue. Trichomal Short, non-glandular, and single-celled. Xylem Elements spiral, annular, and reticulate vessels. xylem fibers long thick-walled tapered Mesophyll fragments Palisade cells in closely packed rows. Spongy cells are rounded with intercellular spaces. Presence of chlorophyll and tannin cells.<sup>[18]</sup>

## 6. Significance of powder microscopy:

in quality assurance helps in authenticating the genuinity of powdered materials used in Ayurvedic preparations like Kanchnar Guggulu. prevents adulteration with misleading appearance, ensures pharmaceutical products are reproducible and uniform, facilitates the statutory recording of standards for botanical drugs.<sup>[19]</sup>

**Table no. 6.1: Diagnostic Reactions Based on Reagents.**

| Reagent              | Observation       | Interpretation                     |
|----------------------|-------------------|------------------------------------|
| Phloroglucinol + HCl | Red staining      | Presence of lignin (xylem, fibers) |
| Iodine               | Blue coloration   | Starch granules present (few)      |
| Sudan III            | Orange red        | Lipid-containing tissues           |
| Dilute HCl           | Crystals dissolve | Confirms calcium oxalate           |

## Phytochemical profile leaf and flower of *Bauhinia variegata*, *Bauhinia purpurea*, and *Bauhinia racemosa* (Kanchanar)

Phytochemicals kanchanar diverse and wide-ranging phytochemical profile underpins both modern phytotherapy and its traditional Ayurvedic medicinal use. Various primary and secondary metabolites are represented in Kanchanar leaves, including flavonoids, phenolic acids, tannins, triterpenoids, glycosides, sterols, saponins, and sugars.<sup>[20]</sup> The most common phytochemicals identified from leaf extracts include quercetin, kaempferol, rutin, apigenin, and luteolin. Said flavonoids serve as the strong basis for antioxidant, anti-inflammation, and anti-cancer potential via scavenging activities.<sup>[21]</sup> The presence of condensed and hydrolyzable tannins further contributes to the astringent and antibacterial properties of the plant. Leaf extracts also contain saponins and triterpenoids, including lupeol and  $\beta$ -sitosterol, possessing hepatoprotective, immunomodulatory, and anti-inflammatory properties. The phytochemical profile of the *Bauhinia variegata* flower is equally complicated, dominated by flavonoids and anthocyanins, which impart a distinctive pink to purple color. Flavonoids present in flowers, such as kaempferol, quercetin, isoquercetin, and other glycosylated derivatives, possess potent cytoprotective and antioxidant activities. Anthocyanins with strong free radical-scavenging properties have been identified to include derivatives of cyanidin and delphinidin.<sup>[22]</sup> Besides, the floral tissues contain tannins, phenolic acids, and traces of volatile chemicals and essential oils, which possess antibacterial and anti-inflammatory properties. Traditionally utilized for respiratory and throat ailments, the flower's demulcent and soothing properties are enriched with the presence of polysaccharides and mucilage. Biochemical analysis revealed that the flower extracts contain amino acids, organic acids, and traces of alkaloids, which further justifies their broad spectrum of traditional uses. The leaves and flowers of *Bauhinia variegata* act in synergy, accumulating a phytochemical reservoir composed of bioactive compounds responsible for anti-inflammatory, anti-tumor, anti-diabetic, antioxidant, and antibacterial actions attributed to this plant. The diversified chemical constituents of Kanchanar confirm its widespread use in traditional

Ayurvedic medicine, particularly in the treatment of swollen glands, thyroid disorders, lymphatic congestion, and metabolic imbalances, and make it an important botanical resource for herbal formulations.<sup>[23]</sup>

### 1. Different Extraction Techniques for Leaves and Flowers of Kanchanar

Extraction is an important step in separating bioactive components from plant materials in pharmacognostic and phytochemical studies. The process of extraction and choice of solvent have a great impact on the yield, chemical profile, and type of chemical extracted.<sup>[24]</sup> Most of the phytochemicals present in the leaves and flowers of kanchanar, such as flavonoids, tannins, phenolics, sterols, glycosides, anthocyanins, and triterpenoids, require proper extraction methods. Some of the major extraction methods employed in herbal research are mentioned below:<sup>[25]</sup>

- **Maceration**

One of the oldest and simplest extraction techniques for thermolabile plant constituents is maceration. The powdered leaves or flowers are soaked for 48 to 72 hours at room temperature in an appropriate solvent; water, ethanol, or hydroalcoholic mixture. The shaking from time to time enhances the process of extraction by increasing solvent penetration. Flavonoids, glycosides, mucilage, and phenolic compounds, whose active properties do not require heat, are particularly well-suited for extraction by maceration. In general, flower extracts are prepared using this process as many floral constituents, especially anthocyanins, are liable to decompose on heating.<sup>[26]</sup>

- **Percolation**

Percolation is a continuous extraction technique and an improvement over maceration. The powdered medication, after being packed in a percolator and moistened with solvent, is left standing for a full day. The solvent is then slowly percolated to effectively dissolve the phytochemicals. Tannins, phenolics, triterpenoids, and alkaloids are extracted from leaves and flowers through this technique. The herbal medicine industry commonly uses percolation to generate more concentrated extracts.<sup>[27]</sup>

- **Soxhlet Extraction (Hot Continuous Extraction):**

One of the most popular techniques for thorough plant material extraction is soxhlet extraction. The powder of the dried leaf or flower is placed within a thimble; the sample is repeatedly passed into a boiling solvent. This method, by employing fairly high temperatures, ensures full extraction in less time.<sup>[28]</sup>

- **Decoction**

Involves boiling plant material in water for a fixed period. In Ayurveda, Kanchanar is classically extracted by decoction (kashaya). In prescriptions like Kanchanar guggulu, it is particularly used for the bark, leaves, and flowers. Decoction is effective for water-soluble ingredients like tannins, mucilage, glycosides, and polyphenols. High temperatures can destroy some of the delicate flower components.<sup>[29]</sup> Microwaves enhance the extraction efficiency through the rapid heating of the plant-solvent mixture. MAE works very well with the flavonoids, tannins, and phenolics of the leaf. For flowers, MAE should be controlled since it can degrade the pigments that are sensitive to heat. Shorter periods of extraction are coupled with excellent yields.<sup>[30]</sup>

- **Supercritical Fluid Extraction (SFE)**

This advanced technique uses scCO<sub>2</sub> as its solvent. It is very effective in yielding non-polar compounds like terpenoids, sterols, lipids, and volatile oils. SFE yields extracts with higher purities that are completely free of solvents, but it is applied less frequently in the case of *B. variegata*. Slightly polar compounds are extracted by adding co-solvents such as ethanol.<sup>[31]</sup>

- **Hydrodistillation**

Components that are volatile the flowers are subjected to hydrodistillation to extract essential oils and aromatic chemicals. Although there are not many volatiles in *B. variegata* flowers, aromatic chemicals with antibacterial qualities can be extracted by moderate hydrodistillation.<sup>[32]</sup>

- **Infusion**

Similar to herbal tea, infusion is another mild extraction process. The leaf or flower powder is

immersed for a short period in hot or cold water. It can be used to extract the anthocyanins, Glycosides of flavonoids, Mucilage, Phenolics that dissolve in water, Flowers are often infused in order to preserve their color and antioxidant properties.<sup>[33]</sup>

## 2. Preliminary Phytochemical Screening of *Bauhinia variegata* *B. purpurea*, and *B. racemosa* Leaf and Flowers

Preliminary phytochemical screening is an important stage in the pharmacognostic evaluation of medicinal plants, which involves a series of basic qualitative chemical tests to identify the presence of major classes of phytoconstituents.<sup>[34]</sup> Various bioactive metabolites present in the leaves and flowers of kanchanar are responsible for possessing medicinal properties. To evaluate the phytochemical profile of each plant part, the following screening is commonly carried out using various solvent extracts such as petroleum ether, chloroform, ethanol, methanol, and aqueous extracts.<sup>[35]</sup>

## 3. Preliminary Phytochemical Screening of kanchanar Leaves

The preliminary phytochemical screening of leaves and flowers of *Bauhinia* indicates various secondary metabolites that are pharmacologically and taxonomically important. Standard qualitative testing yielded a phytochemical profile, which is in conformity with the earlier publications on the *Bauhinia* genus that frequently reported strong amounts of terpenoids, anthocyanins, phenolics, tannins, glycosides, and flavonoids in different plant parts.<sup>[36]</sup> Various pharmacological studies have established that these compounds are responsible for the plant's antioxidant, anti-inflammatory, anticancer, antibacterial, and hepatoprotective properties.<sup>[37]</sup>

- **Alkaloids Test:**

Dragendorff's, Mayer's, Wagner's, and Hager's reagents, Observation: Light precipitation and the presence of trace amounts of alkaloids Although *Bauhinia variegata* is not typically considered an alkaloid-rich genus, the presence of alkaloids in methanolic extracts may be due to trace amounts of nitrogenous metabolites. The new findings agree with earlier research that also identifies *Bauhinia* species

as having low contents of alkaloids. Trace amounts generally indicate the presence of low-molecular-weight alkaloids, which are associated with stress physiology rather than any noteworthy pharmacological action. [38]

- **Flavonoids Test:**

Shinoda test, pink or red, Yellow precipitate in the lead acetate test, Bright yellow colorless with acid in the alkaline reagent test High flavonoid concentration, including rutin, kaempferol, and quercetin, kanchanar leaves are abundant in flavonols, especially: The quercetin, kaempferol, Quercetin-3-rutinoside, or rutin [39]. In Bauhinia species, flavonoids are frequently shown to be important antioxidant chemicals. They are directly related to bioactivities such free radical scavenging, anti-inflammatory, anti-diabetic, and anticancer properties, and they shield the plant from UV exposure and oxidative damage. Flower extracts have significantly larger concentrations of anthocyanins and flavonoids, which is why numerous pharmacological studies have shown that they have stronger coloring and more potent radical-scavenging activity. [40]

- **Phenolics and Tannin Tests:**

Ferric chloride: green or blue-black, Bulky white precipitate leads to acetate. Conclusion: A lot of tannins and phenolics, High amounts of tannins and phenolic chemicals were discovered, supporting previous findings that leaves and flowers had potent phenolic profiles, including: Gallic Acid, Ellagic Acid, Tannins of pyrogallol type, derivatives of catechins. Phenolics play a major role in wound healing, astringent properties, antibacterial activity, and antioxidant capacity. The leaf is particularly rich in tannins, which is consistent with the traditional Ayurvedic uses of Kanchar, which include styptic, wound-binding, and anti-diarrheal properties. [41]

- **Saponins Test:**

Foam test, stable, persistent foam, Conclusion: moderate presence Although they are not predominant in *B. variegata*, the surfactant, expectorant, and antibacterial quality of saponins supports biological activities related to immunomodulation and membrane permeability

enhancement. Their amphiphilic nature also allows them to enhance extract absorbability and to act in synergy with other substances. [42]

- **Glycosides Test:**

Keller-Killiani, cardiac glycosides brown rings, Pink, red anthraquinone glycosides in Borntrager's test and glycosides are present, Anthraquinone type glycosides and cardiac glycosides were recommended [43] Bauhinia species have been found to contain glycosides, mainly flavonoid glycosidic derivatives (kaempferol-3-glucoside, quercetin-3-glucoside). Their presence justifies many pharmacological activities: cardio-protective action, mild laxative, oxidative, anti-inflammatory. Anthocyanin glycosides are among the types of glycosides found in flowers which impart purple or pink colour to them. [44]

- **Terpenoids and Sterols Tests:**

Salkowski, interface reddish-brown, Liebermann-Burchard: blue-green color. Conclusion: The triterpenoids and phytosterols like lupeol and  $\beta$ -sitosterol were present [45] Lupeol, an anti-inflammatory agent, promotes wound healing;  $\beta$ -sitosterol is anti-hyperlipidemic and anti-inflammatory. Other triterpenoids and sterols have been frequently recorded in Kanchar. Their presence supports the hepatoprotective, anti-inflammatory, and anti-arthritis properties shown in earlier studies. [46,47]

- **Proteins and Amino Acids Tests:**

Biuret & Ninhydrin. slightly positive, Conclusion: Low concentration. Plant proteins are not important bioactive components in Bauhinia, but they may have limited functions in defense, storage, and enzyme activity. [48]

### **Future Prospects of *Bauhinia variegata*, *B. purpurea*, and *B. racemosa***

- Preparation of a pharmacognostic monograph for leaves and flowers of *Bauhinia variegata*.
- Development of standards for differentiating pink and white varieties of flowers.

- Employment of diagnostic macroscopic, microscopic, and powder microscopic traits in common authentication.
- Use of developed standards in identifying adulteration and ensuring quality of raw materials.
- Extension of Preliminary Phytochemical Screening to Advanced Analytical Techniques for Marker Identification
- Correlation of phytochemical constituents with reported pharmacological activities.
- Optimization and standardization of extraction procedures.
- Application of physicochemical parameters in quality control of herbal formulations.
- Promotion of Development of Herbal/Phytopharmaceutical Preparations with a View
- Basis for future studies in toxicology, preclinical studies, and clinical studies.
- Promotion of evidence-based usage of *Bauhinia variegata* in traditional and conventional medicine.
- Contribution to conservation, cultivation, and selection of superior chemotypes.

## CONCLUSION

The outstanding pharmacognostic, morphological, microscopic, and phytochemical properties of *Bauhinia variegata* (Kanchanar) are highlighted in this thorough review, which supports the plant's long-standing traditional use in Ayurveda and other indigenous medical systems. A number of diagnostic characteristics, including bilobed leaves, palmate venation, paracytic stomata, unicellular trichomes, calcium oxalate crystals, and distinctive vascular elements, are confirmed by thorough macroscopic and microscopic analyses. These characteristics together support accurate identification and authentication of the crude drug. By offering reliable diagnostic indicators useful for identifying adulteration and guaranteeing purity, powder microscopy significantly enhances quality evaluation. Flavonoids, phenolics, tannins, terpenoids, sterols, glycosides, saponins, and anthocyanins are among the many bioactive components found in leaves and flowers, according to preliminary phytochemical analysis.

With unique macroscopic, microscopic, and powder microscopy features that enable accurate identification and authenticity, *Bauhinia purpurea* is a pharmacologically and botanically valuable species. It is distinguished from closely related species like *B. variegata* and *B. racemosa* by its bilobed leaves, purple zygomorphic flowers, and distinctive three fertile stamens. While powder microscopy shows diagnostic features like unicellular trichomes, spiral vessels, papillary petal fragments, and tricolpate pollen grains, microscopic analysis reveals typical dorsiventral leaf anatomy with paracytic stomata, well-developed palisade tissues, and prismatic calcium oxalate crystals. *Bauhinia racemosa* pharmacognostic analysis reveals unique powder, microscopic, and macroscopic traits that set it apart from *B. variegata* and *B. purpurea*. Its smaller leaves with shallow lobation, dorsiventral leaf morphology, paracytic stomata, prismatic crystals, spiral vessels, and characteristic powder microscopy markers are important distinguishing characteristics. For the plant material used in herbal formulations to be standardised, authenticated, and quality controlled, these characteristics are crucial.

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