Traditional uses, phytochemistry and pharmacology of Bauhinia racemosa Lam.: a comprehensive review

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Abstract

Background: Bauhinia racemosa is not familiarly known in Asian countries due to its limited existence and lack of medicinal information. It is commonly used as a medicine, ornamental plant, fence plant, and fodder for livestock since ancient times. It is also used as a landfill tree to avoid soil erosion of the forest.

Main body: In South India, people cultivate this plant in their premises in order to protect themselves from the effects of thunder. In this review, the various research prospects of this plant have been analyzed and are summarized. The aim of this review is to provide the traditional uses, phytochemicals and pharmacological activities of B. racemosa, and to highlight the current pharmacological developments of this medicinal plant.

Conclusions: The B. racemosa has immense therapeutic potential for treating diseases with both traditional and pharmacological applications. But many traditional uses of B. racemosa have not been validated by current investigations in the aspects of pharmaceutical. Until now, research on phyto-constituents from B. racemosa has not been done in an extensive way. Hence, the identified phytochemicals of B. racemosa should also be subjected to pharmacological studies to illuminate the biological mechanisms of these unreported secondary metabolites for the prevention of diseases or microbial infections and other health disorders of human and animal races.

Keywords: Bauhinia racemosa, Traditional uses, Phyto-chemistry, Pharmacognosy, Tablet binder, Masanumas 2

Background

Bauhinia racemosa Lam is a small, crooked, bushy, deciduous tree that can grow under very difficult climatic environments with drooping branches. This species is commonly found across India, which grows in the western Himalayas, in Ceylon, China, and Timor, to an altitude of 1650 m from sea level. It is widely used to fill blank areas of the forest land, since it prevents soil erosion. The matured leaves of B. racemosa are used for making Beedi (Indian cigarettes), whereas the young leaves are used as greens (side dish) by the Tamilians (Tamil Nadu, India). The bark and leaves of B. racemosa are sweetish and acrid, used as a refrigerant, astringent, in the treatment of headache, fever, skin diseases, blood diseases, dysentery, and diarrhea. A decoction of the bark is recommended as a useful wash for ulcers [1].

In ayurveda, the plant is commonly used for the treatment of initial stage of cancer [2, 3]. A large number of studies have confirmed that B. racemosa has a wide range of pharmacological effects, including antitumor activity, anti-inflammatory activity, analgesic effect, antipyretic, anti-hyper-glycemic activity, hepatoprotective activity, anti-microbial activities, antilucer activity, antihistaminic effect, anxiolytic activity, and anti-HIV activity [1]. The medical value of this plant attracts more attention of the people due to the complications of health issues. With the advent of chemical composition and pharmacological research, the clinical application of Bauhinia racemosa has been...
expanded. In addition, this plant product is cheap and widely available on earth, which has useful clinical applications and drug development prospects as well.

Hence, a growing number of researchers have dedicated their spare time to this wonderful plant in the last few decades, from botany to phytochemistry and pharmacology. The phytochemical studies have identified more than 37 chemicals from *B. racemosa*, including Phenolics, Flavonoids, Saponins, Glycosides, Terpenoids, Steroids, Propa-
noids, Coumarin, lipids, Alkaloids, and Tannins [4]. However, minimal numbers of articles have reviewed the comprehensive research of *B. racemosa*. The available record reveals that there is only a concise review of its phytochemistry and pharmacology, which may not be enough for researchers to completely understand this plant. Researchers have identified several new chemical components from *B. racemosa* and should perform more in-depth analyses of its pharmacological activities. This paper reviews the traditional uses, botany, phytochemistry, and pharmacological characteristics of *B. racemosa* in a precise form that helps to recognize readers to a stronger and deeper understanding of this medicinal plant and also provide thorough information for better research and development of *B. racemosa*. The extracts of leaves and bark have shown analgesic, anti-pyretic, antimicrobial, anti-inflammatory, anti-spasmodic, and anti-helmintic efficacy.

In South India, the plant is traditionally known as *idithangi*, *aaththi maram*, and *thathagi*. It is also called *Banraaj* in Bengali, *Kachmal* in Hindi, *Aapta* in Kannada, *Kosundra* in Punjabi, *Arampaali* in Malayalam, *Asundro* in Gujrati, *Sona* in Marathi, *Yugmapatra* in Sanskrit, *Arechettu* in Telugu, and *Kachnaar* in Unani around various parts of India.

Taxonomic treatment [5]

| Kingdom:                | Plantae                                      |
| Clade:                 | Tracheophytes                                |
| Clade:                 | Angiosperms                                  |
| Clade:                 | Eudicots                                    |
| Clade:                 | Rosids                                      |
| Order:                 | Fabales                                     |
| Family:                | Fabaceae                                    |
| Subfamily:             | Cercidoideae                                |
| Tribe:                 | Bauhinieae                                  |
| Genus:                 | Bauhinia                                    |
| Species:               | *racemosa* Lam.                             |

**Synonyms**

*Bauhinia parviflora* Vahl

*Piliostigma racemosa* (Lam.) Benth.

*Piliostigma racemosum*

**Main text**

Method and direction of data collection

Information on the traditional uses of *B. racemosa* has been collected from ethnomedical documentation and was gathered from few online web portals, including [www.flowersofindia.net](http://www.flowersofindia.net), [efloraofindia](http://www.efloraofindia.com), [http://senthuherbals.blogspot.com](http://senthuherbals.blogspot.com), and [http://www.bsienvisanic.in/](http://www.bsienvisanic.in/). To highlight the traditional uses of *B. racemosa* in Tamil Nadu, we searched using a variety of Tamil words, such as *thathagi*, *Aaththi Maram*, and *idithangi*. In this review, we have scrutinized the known ethnomedical uses, phytochemicals, pharmacological potentials, and fodder necessity of *B. racemosa*. We retrieved the research and review articles from Science Direct, PubMed, and other international publications using the keywords ethnomedical, phytochemistry, and pharmacology along with the name of *B. racemosa*. An online database [http://www.theplantlist.org](http://www.theplantlist.org) was used to confirm its botanical name. KEGG software was used for analyzing the pathway of human acid secretion and type-II diabetes mellitus.

**Ethnomedical uses and nutritional values**

*B. racemosa* has been used for medicinal purposes since ancient times; hence, it has a long history with therapeutic purposes in South India. Parts of this plant, such as whole, stem bark, leaves, and bark, are used for diabetes, stomach pain, piles, and intestinal ulcers by different ethnic groups in South India. In addition, parts of the plant are documented as traditional medicines for dysentery, diarrhea, malaria, influenza, epilepsy, vomiting, edema, constipation, gastritis, dyspepsia, and convalescents in various parts of India. These ethnomedical uses have been documented with the help of various ethnic people (Table 1). In addition, it has abundant protein values; hence, the leaves of *B. racemosa* are also given as fodder for animals to secrete more quantities of milk. We can give up to 4 to 5 kg of leaves for cow and 11/2 to 2 kg for a goat. Leaves and seeds consist of 8.9 ± 0.88 and 0.63 ± 0.98% of proteins respectively.

**Ayurvedic mixtures of *B. racemosa* (in market)**

Masanuma 2 is a blend of plant combinations (extracts of different plant parts). In the second month of pregnancy, it is advised the mother to prevent regular abortions, high-risk pregnancies, and improve high-value pregnancy. Each bottle consists of 120 tabs with a weight of 60 mg (each tablet). Each tablet contains *B. racemosa* stem bark, *Sesamum indicum* seed extracts, *Rubia cordifolia* stem extracts, and *Asparagus racemosus* root extracts respectively. This tablet was administered twice a day for lunch and dinner with two tablets each (anonymous).
Table 1 Traditional uses of *B. racemosa*

| Year of report | Recommended parts | Traditional uses                        | References |
|---------------|-------------------|-----------------------------------------|------------|
| 1935          | Bark fiber        | Wound stitching material                | [6]        |
| 1956          | Bark              | Ieprosy and leucoderma                  |            |
| 1982          | Leaves            | Urinary diseases                        | [7]        |
| 1996          | Stem bark         | Glandular inflammation                  | [8]        |
| 1998          | Root and bark     | Epilepsy                                 | [9]        |
| 1998          | Root and bark     | Epilepsy                                 | [10]       |
| 2007          | Gum               | Brain tumors                             |            |
| 2013          | Stem bark         | Abdominal Pain                           | [11]       |
| 2015          | Leaves            | Dysentery and diarrhea                   | [12]       |
| 2016          | Whole plant       | Anti-diabetes                            | [14]       |
| 2016          | Stem bark         | Intestinal Ulcer                         | [15]       |
| 2016          | Stem bark         | Dysentery and diarrhea                   | [16]       |
| 2016          | Leaves            | Piles                                    | [15]       |
| 2018          | Fruit             | Diarrhea and vomiting                    | [17]       |
| 2019          | Not specified     | Malaria, fever and Piles                 | [18]       |
| 2019          | Flower            | Cold and cough                           | [19]       |
| 2016          | Root              | Stomach ache                             |            |
| 2019          | Leaves            | Head ache and malaria                    | [20]       |

**Tablet binder**

Seed resins of *B. racemosa* are tested as tablet binder by Gangurde and Boraste [21]. In their tablet binder experiments, the seed mucilage has shown optimal results at 8% w/w concentration among the established formulations. They have also stated that seed resins are found to be as a better tablet binder and granulating agent in the wet granulation process [21].

**Phytochemistry**

The exploration and separation of phyto-constituents are very important in order to discover the possibilities for the treatment of diseases. Only a few studies have been undertaken relating to the phytoconstituents of *B. racemosa*. To date, over 37 compounds have been isolated from various parts of this plant and identified. In this review, phytoconstituents in *B. racemosa* are comprehensively reported, including alkaloids, steroids, triterpenoids, glycosides, tannins, saponins, phenolic compounds, flavonoids, galactolipid, catechin, and others [22, 23]. The identified phytochemicals of *B. racemosa* have been described in Table 2 and Fig. 1. Phytochemicals whose biological processes have not been recorded should not be ignored, and such phytoconstituents should be subject to different experiments until their biological activities have been detected. Phytoconstituents can vary from different parts of plants; hence, a thorough study should be needed to find a novel drug and to conserve the plant. Several scientific studies also have suggested that some flavonoids, triterpenoids, and steroids have a protective potential on the liver owing to their antioxidant effects [34–36]. Due to the presence of these compounds in methanolic extracts of *B. racemosa* (MEBR), it may play significant preventive measures in the liver damage caused by synthetic drugs.

Similar phyto-compounds of *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 embilica*), Catechin (*Phyllanthus embilica*), Betulin (*Alstonia scholaris*), Quercetin (*Phyllanthus embilica, Allium sativum*), Rutin (*Ginkgo biloba, Lycopersicon esculentum*), and Kaempferol (*Manigfera indica, Allium sativum*) are found in many plants which are having broad of pharmacological properties.

**Pharmacological descriptions of the metabolites and its market price**

The secondary metabolites of *B. racemosa* such as β-sitosterol, β-amyrin, kaempferol, rutin, quercetin, catechin, eicosanoic acid, -epiafzelechin, -epicatechin, protocatechuic acid, octacosanol, scopoletin, and scopolin are also found in other medicinal plants as well. Previous studies have indicated that such molecules have a wide
Table 2 Phytoconstituents of *B. racemosa* that have been extracted by different solvents

| S. No. | Phyto-constituents                                                                 | Compound category | Source         | Solvent            | References       |
|-------|-----------------------------------------------------------------------------------|-------------------|----------------|--------------------|------------------|
| 1     | (2S)-1,2-di-O-linolenoyl-3-O-α-Galactopyranosyl (1→6)-O-β-galactopyranosyl glycerol | Alkaloids         | Leaves         | Ethanol            | [24]             |
| 2     | (2S)-1-O-linolenoyl-2-O-palmitoyl-3-O-α-galactopyranosyl (1→6)-O-β-galactopyranosyl glycerol | Alkaloids         | Leaves         | Ethanol            | [24]             |
| 3     | (2S)-1-O-oleoyl-2-O-palmitoyl-3-O-α-Galactopyranosyl (1→6)-O-β-galactopyranosyl glycerol | Alkaloids         | Leaves         | Ethanol            | [24]             |
| 4     | 4-Nitrophenol                                                                     | Alkaloids         | Leaves         | Ethanol            | [4]              |
| 5     | Epiaflechin                                                                       | Flavonoids        | Heart wood     | Acetone            | [23, 26, 27]     |
| 6     | Pacharin                                                                          | Flavonoids        | Leaves         | Ethanol            | [25]             |
| 7     | (+)-Epicatechin                                                                    | Flavonoids        | Leaves         | Ethanol            | [25]             |
| 8     | Bauhinoxepin F                                                                    | Flavonoids        |                |                    |                  |
| 9     | 2-methoxy-6,6,8-trimethyl-5,6,11,12-tetrahydro-4bH-benzo[6,7]cyclohepta[1,2,3-de]chromene-1,9-diol | Flavonoids        |                |                    |                  |
| 10    | (4-flatoxin B1) 6,6,8-trimethyl-5,6,11,12-tetrahydro-4bH-benzo[6,7]cyclohepta[1,2,3-de]chromene-1,2,9-triol | Flavonoids        |                |                    |                  |
| 11    | 6-octen-1-ol,3,7-dimethyl-propanoate                                              | Flavonoids        | Leaves         | Ethanol            | [28]             |
| 12    | Citronellyl butyrate                                                               | Flavonoids        | Leaves         | Ethanol            | [28]             |
| 13    | De-O-methylracemosol                                                               | Flavonoids        | Heart wood     | Hexane             | [29]             |
| 14    | Kaempferol                                                                         | Flavonoids        | Aerial part    | Dichloromethane: ethyl acetate (95:5) | [30]             |
| 15    | Quercetin                                                                          | Flavonoids        | Aerial part    | Ethyl acetate: methanol (60:40) | [30]             |
| 16    | Kaempferol 3-O-β-glucoside                                                         | Flavonoids        | Aerial part    | Ethyl acetate      | [30]             |
| 17    | Myricetin 3-O-β-glucoside                                                          | Flavonoids        | Aerial part    | Ethyl acetate: methanol (60:40) | [30]             |
| 18    | Quercetin 3-O-rhamnoside                                                           | Flavonoids        | Aerial part    | Ethyl acetate      | [30]             |
| 19    | Methyl gallate                                                                    | Tannins           | Aerial part    | Dichloromethane: ethyl acetate (60:40) | [30]             |
| 20    | Gallic acid                                                                       | Tannins           | Aerial part    | Dichloromethane: ethyl acetate (90:10) | [30]             |
| 21    | Neophytadiene                                                                     | Terpenoids        | Leaves         | Ethanol            | [28]             |
| 22    | Racemosol                                                                         | Terpenoids        | Heart wood     | Hexane             | [29]             |
| 23    | Pacharin                                                                          | Terpenoids        | Heart wood     | Acetone            | [23, 26, 27]     |
| 24    | Lupeol                                                                            | Terpenoids        | Root           | Benzene            | [31]             |
| 25    | β-sitosterol                                                                       | Terpenoids        | Stem bark      | Petroleum ether    | [22]             |
| 26    | β-amyrin                                                                          | Terpenoids        | Flower bud     | Toluene : ethyl acetate (93:07) | [32]             |
| 27    | Protocatechuic acid                                                                | Phenols           | Leaves         | Ethanol            | [25]             |
| 28    | Resveratrol                                                                        | Phenols           | Heartwood      | Data not available | [33]             |
| 29    | Phenol,2,4-bis (1,1-dimethylethyl)                                                 | Phenols           | Leaves         | Ethanol            | [28]             |
| 30    | Epicatechin                                                                       | Phenols           | Leaves         | Ethanol            | [25]             |
| 31    | Octacosyl ferulate                                                                 | Propanoids        | Leaves         | Ethanol            | [28]             |
| 32    | Hexacosan-1-ol                                                                    | Lipids            |                |                    |                  |
| 33    | Octacosanol                                                                       | Lipids            | Stem bark      | Petroleum ether    | [22]             |
| 34    | 16-heptadecenal                                                                   | Lipids            | Leaves         | Ethanol            | [28]             |
range of pharmacological potential for human health complications (Table 3). Due to the pharmacological properties of these compounds, they are marketed at high prices in the market as seen in Table 4. These compounds are naturally present in medicinal plants like *B. racemosa*. We can take those comprising metabolites as food or decoction, even though we cannot consume them directly. If so, we can avoid the expenses and ignore the adverse effects as well.

**Pharmacology**

In recent years, pharmacological activities of crude extracts and metabolites of *B. racemosa* have been investigated as rich essential metabolites that make it a good microbicidal agent. Meanwhile, based on in vivo and in vitro experiments, the extracts of *B. racemosa* also promise stores of possible pharmacological effects such as anti-oxidant, antihistaminic, analgesic, antipyretic, anti-ulcer, anti-cancer, hepatoprotective, anti-diabetic, anti-HIV, and larvicidal activities.

Traditional uses in the treatment of asthma, gastrointestinal pain, piles, urinary diseases, glandular inflammation, dysentery, diarrhea, malaria, pneumonia, epilepsy, dehydration, edema, constipation, gastric dyspepsia, and convalescents have not yet been deeply studied. Also, the phytochemicals of *B. racemosa* are not yet studied. We, therefore, recommend that future studies should be based on verifying its traditional significance by advanced pharmacological research. In addition, the screening of the principal bioactive compounds and the mode of action has to be examined. Pharmacological actions of *B. racemosa* are defined in detail in the following sections.

**Anti-bacterial and anti-fungal activities**

Invasive fungal infections in the recent times have proven to be mortal, specifically in immune compromised patients [61, 62]. In addition, the number of animal or plant diseases caused by bacterial, fungal, and microbial infections is increasing. There is an urgent need to develop a new class of antimicrobial drugs and antibiotic substitutes to address this problem. In the foremost antimicrobial research of *B. racemosa*, Ali et al. [63] proved that the methanolic (MeOH) extracts of phenolic compounds reveals potent inhibitory activities against *Salmonella typhi* (96.64%), *Shigella boydii* (80.55%), and *Staphylococcus pyogenes* (81.12%), whereas the hexane extracts of that compounds exhibited possible inhibitory activity against *Staphylococcus aureus* (72.51). Similar to antibacterial test, they have analyzed the antifungal competency against 11 fungal strains by using methanol and hexane extracts of *B. racemosa*. Among the two extracts, the hexane extracts have shown excellent inhibitory activity against *Trichophyton longifusus* (71.04%) and *Pseudallescheria boydii* (83.80%), while the MeOH extracts have recorded better inhibitory ratio against *Microsporum canis*, *Trichophyton simii*, and *Trichophyton schoenleini* with the percentage of 98.44, 95.59, and 81.38. Furthermore, the various extracts of *B. racemosa* were tested on enteric pathogens such as *Proteus vulgaris*, *Staphylococcus epidermidis*, *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Klebsiella pneumonia*, *Salmonella typhi*, *Enterobacter aerogenes*, and *Salmonella typhimurium* [64]. Ultimately, the petroleum ether extracts reveals better inhibitory activity against *S. epidermidis*, *S. aureus*, and *S. typhi*. Following this, the chloroform extract has shown inhibitory action in opposition to *S. epidermidis* and *S. aureus*. Extracts of methanol has exposed maximum inhibitory proportion against *S. epidermidis*, *S. aureus*, *E. coli*, *P. aeruginosa*, *E. aerogenes*, and *S. typhimurium*. In addition, the extract of ethyl acetate has revealed maximum inhibitory activity against *S. aureus*, *P. vulgaris*, *S. epidermidis*, *P. aeruginosa*, *S. typhi*, and *S. typhimurium*. Dahikar et al. [64] reported that *B. racemosa* is having huge potential as antibacterial compounds against enteric pathogens and it can be used as alternative drugs for the diseases of enteric pathogens. Through this review, we suggest that further pharmacological studies are required to develop a new class of antibacterial drugs against enteric pathogens. Because, the enteric or diarrheal infections produce serious health complications of human being in developing nations, which leads to the death of 3.3 to 6.0 million children each year. Also, the infectious strains are harmful etiological agents in causing intermittent and continuous diarrhea in both children and adults [65]. Another antimicrobial approach

### Table 2 Phytoconstituents of *B. racemosa* that have been extracted by different solvents (Continued)

| No. | Phyto-constituents | No. | Phyto-constituents |
|-----|---------------------|-----|---------------------|
| 35. | Octacosan           | 36. | Myo-Inositol        |
| 37. | a-amyrrin           | 38. | Scopoletin          |
| 39. | Scopolin            |     |                     |

*References:*

[22], [28], [29], [30], [31], [32], [33], [34], [35], [36], [37], [38], [39], [40], [41], [42], [43], [44], [45], [46], [47], [48], [49], [50], [51], [52], [53], [54], [55], [56], [57], [58], [59], [60], [61], [62], [63], [64], [65].

*Source Solvent References*
Fig. 1 Phyto-constituents of Bauhinia racemosa (a–i). a Alkaloids: identified and isolated from B. racemosa. b Flavonoids: identified and isolated from B. racemosa. c Tannins: isolated and identified from B. racemosa. d Terpenoids: isolated and identified from B. racemosa. e Phenols: isolated and identified from B. racemosa. f Propanoids: isolated and identified from B. racemosa. g Lipids: isolated and identified from B. racemosa. h Steroids: isolated and identified from B. racemosa. i Coumarins: isolated and identified from B. racemosa.
exposed that the acetone and ethanol extracts demonstrated potent inhibitory action against all the tested strains than that of aqueous, chloroform, and petroleum ether [66], but this study lacked the comparative analysis with the commercial drugs (positive control) of enteric pathogens. In addition, no positive control drug was used during the experiments, making it difficult for other researchers to mimic the study and compare the results. Later, a study in 2005 revealed that the methanolic extract of B. racemosa stem bark had notable antimicrobial activities against Pseudomonas aeruginosa, Escherichia coli, Salmonella typhi, Shigella dysenteriae, Vibrio cholera, Staphylococcus aureus, Streptococcus pneumoniae, Micrococcus luteus, Staphylococcus epidermidis, Candida albicans, Aspergillus niger, Aspergillus flavus, and Alternaria solani at various concentrations. The various MEBR concentrations are 25, 50, 100, and 200 μg/disc. Besides this, according to Heinrich et al. [67], the quality of concentration should also be pharmacologically important. The concentration used by Chaimanee et al. [68] became much higher, having no benefit from a clinical perspective. To evaluate their effects on a wider variety of microbial strains, further formulations of the customized extracts are required. Though its reliability of earlier studies has been confirmed, more in-depth experiments are needed in the studies performed. The nature and quantity of the bioactive constituents in the extract are not apparent.

Table 3 Similar molecules and their prices in the market

| S. No. | Compound Name | CAS No. | Available dose | Cost (INR) |
|-------|---------------|---------|----------------|------------|
| 1.    | Resveratrol   | 501-36-0| 100 mg         | 11,532.82  |
|       |               |         | 500 mg         | 45,709.50  |
| 2.    | Lupeol        | 545-47-1| 25 mg          | 11,643.87  |
|       |               |         | 100 mg         | 32,646.11  |
| 3.    | β-Sitosterol  | 83-46-5 | 10 mg          | 15,840.05  |
|       |               |         | 25 mg          | 31,600.09  |
|       |               |         | 100 mg         | 87,130.26  |
| 4.    | β-amyrin      | 559-70-6| 10 mg          | 46,631.40  |
| 5.    | Kaempferol    | 520-18-3| 25 mg          | 10,977.87  |
|       |               |         | 100 mg         | 35,930.59  |
| 6.    | Scopolin      | 531-44-2| 10 mg          | 32,855.92  |

Table 4 Pharmacological applications of those identified molecules

| S. No. | Phyto-compounds | Biological activity                                                                 | References |
|-------|-----------------|--------------------------------------------------------------------------------------|------------|
| 1.    | Mome inositol   | Anti-proliferative, Antialopecic, anticirrhotic, antineuropathic, cholesterolytic and lipotropic activity | [37]       |
| 2.    | Neophytadiene   | Carminative, Gastrin inhibitor, Anticatarrhal, Antiprotozoal, antiparasitic          | [39]       |
| 3.    | Resveratrol     | Anti-inflammatory, neuroprotective, antiviral properties                              | [40]       |
| 4.    | Lupeol          | Anti-inflammatory, anti-microbial, anti-protozoal, anti-proliferative, anti-invasive, anti-angiogenic and cholesterol-lowering agent | [41]       |
| 5.    | Octacosane      | Anti-bacterial                                                                       | [42]       |
| 6.    | β-sitosterol    | Anti-diabetic activity, Anxietytic, sedative effects, Antalgic, anti-inflammatorv, immunomodulator, Antibacterial, Anti-cancer, Anti-inflammatory, Protect against NAFLD, Lipid lowering effect, Hepatoprotective, Protective effect on Pulmonary fibrosis, Wound healing effect, Antioxidant and Anti-diabetic | [43]       |
| 7.    | β-amyrin        | Anti-bacterial activity, anti-inflammatory, antioxidative, antioxidant, antipruritic, gastroprotective, liver injury, hepatoprotective, Antihyperglycemic and hypolipidemic | [44–51]   |
| 8.    | Racemosol       | Anti-bacterial activity, Acetylcholine sterase inhibitory                           | [52]       |
| 9.    | Galactolipid    | Anti-aggregators, decrease of vascular tone and blood pressure, and hence may prevent the development of cardiovascular diseases, reduce deaths and sudden cardiac arrest, preventing obesity and Type 2 diabetes, reduced risk of cancer, control stress such as mental and nutrient stress, | [53, 54]   |
| 10.   | Catechin        | Anti-inflammatory, antioxidant, anti-tumor, and hepato-protective bioflavonoid      | [55]       |
| 11.   | Betulin         | Anti-inflammatory, Anti-bacterial activity                                          | [56]       |
| 12.   | Quercetin       | Antioxidant, Allergy asthma, atopic diseases, Cardiovascular diseases, cancer, Diabetes, Alzheimer, Huntington, Parkinsonism, Sleep, Obesity, anticancer potential against prostate cancer | [57, 58]   |
| 13.   | Rutin           | Analgesic, Antioxidative, Anti-asthmatic, Anti-diabetic, Anti-hypercholesterolemic, Thyroid uptake promotion, Cardiovascular system, Hypertension , Blood coagulation , Anti-platelet aggregatory, Antiulcer, Anti-asthmatic, Anti-osteoarthritis, Anti-osteogenic, Anti-cataract, Ophthalmic, Diuretic, Improve quality of sperm and male reproductive organs, Chemotherapeutic, Antibacterial, Antifungal, Anti-mycobacterial, Larvicidal, Anti-malarial, Antiretroviral, Antiviral, Sunscreen effects, atopic dermatitis, Immune effects, Body strength, Anti fatigue, Organ protective effects, Neuro-protective activity, Retino-protective, Protective effect on lung tissue, Cardio-protective, Prevention of splenocyte apoptosis, Hepato-protective activity, Nephro-protective activity, Protective effect on blood vasculature | [59]       |
| 14.   | Kaempferol      | Apoptosis and growth inhibition, Energetic Impairment, angiogenesis, metastasis, inflammation, anticarcinogenic | [60]       |
Anti-inflammatory activity
Inflammation is a complicated, protective response of the host to any external stimuli. Experimental analysis on inflammatory pathways have demonstrated that inflammation can be tackled by controlling the signaling pathways including nuclear factor kappa light chain enhancer (NF-κB), inducible nitric oxide synthase (iNOS), tumor necrosis factor alpha (TNF-α), cyclooxygenase-2 (COX-2), and interleukin-6 (IL-6) [69]. Bauhinia racemosa is a natural source used to control inflammation due to its anti-inflammatory potential. The inflammatory activity of Wistar albino rats is studied by using the methanolic extracts of B. racemosa in 2005 by Gupta et al. [70]. For inducing acute paw edema, carrageenan, dextran, and mediators such as histamine and serotonin are administered to rats at different doses of 50, 100, and 200 mg/kg. For evaluating the anti-inflammatory potential of B. racemosa, the extracts are mixed with ethanol solvent and served inflammation agents subjected to animals at doses of 50, 100, and 200 mg. In their experiment, the indomethacin is used as a standard drug. The prepared extracts at a dose of 200 mg/kg shows significant anti-inflammatory effects in edema-induced animals, which is near to the prevention value of indomethacin. The inflammatory ranges are 44.8% in 200 mg of B. racemosa and 51.5% in 10 mg of indomethacin. The MEBR has therefore been reported by Gupta et al. [70] to have possible anti-inflammatory potential against acute and chronic inflammation effects.

Antioxidant effects
The formation of reactive oxygen species (ROS) in the organism would lead to an oxidative stress reaction. In various pathophysiological conditions, it can cause damage to cells or organ functions [69]. Previously, the research findings have shown that numerous natural resources consist of active metabolites with antioxidant properties that are now being exhibited their antioxidant potential by various chemical-based approaches, such as diphenylpicrylhydrazile (DPPH) radical scavenging potential assay and 2,2′-azino-bis (3-ethylbene zothiazoline-6-sulfonic acid) radical scavenging assay (ABTS) [71, 72]. In 2002, Heim et al. (2002) reported that the bio-flavonoids possess healthy antioxidant properties [73].

Kumar et al. [74] tested the antioxidant potential of stem bark of B. racemosa. The stem bark of B. racemosa is developed as crude extracts using methanol solvent to explore its potential in oxidative stress. The formulation is served at various concentrations such as 50, 100, 250, and 500 μg/ml. Antioxidant activity levels at different MEBR concentrations have found to be inhibited the lipid peroxidation of the linoleic acid system as 62.43% at 50 μg/ml, 67.21% at 100 μg/ml, 71.04% at 250 μg/ml, and 76.83% at 500 μg/ml as well. Especially, the dose of 500 μg/ml has shown significant inhibition in lipid peroxidation system as 76.83%, which is close to that of α-tocopherol maintained at 500 μg/ml. The inhibition value of the standard drug is 77.93% at 500 μg/ml. They also pointed out that the B. racemosa significantly inhibited the linoleic acid peroxidation as p < 0.05.

In 2007, Dasgupta and De [75] selected eleven medicinal plants and the plants were subjected to explore their antioxidant potential. Among the eleven plants, B. racemosa also displayed considerable enzymatic changes in different mechanisms, such as superoxide radical-scavenging activity, DPPH radical-scavenging response, and lipid peroxidation preventive effects.

In 1999, Wang and Wixon [76] reported B. racemosa can possess antioxidant properties due to the presence of phytochemicals such as flavonoids and biflavones. In 2002, Luo et al. [77] reported that the flavonoids and associated polyphenols of vegetables and fruits considerably contributed to be a better antioxidant potential.

Gupta et al. [78] demonstrated the antioxidant potential of B. racemosa toward Ehrlich ascites carcinoma (EAC). In their experiment, the lipid peroxidation levels rise to about 48.9% in EAC, which are substantially reduced by doses of 50, 100, and 200 mg/kg of ethanol solvent combined stem bark extracts of B. racemosa. The various concentrations of preparation reduced the lipid peroxidation levels to 11.4% at 50 mg/kg, 23.6% at 100 mg/kg, and 31.4% at 200 mg/kg. The various concentrations of preparation reduced the lipid peroxidation levels to 11.4% in 50 mg/kg, 23.6% in 100 mg/kg, and 31.4% in 200 mg/kg. In their experiment, the glutathione (GSH) levels significantly decreased in mice. The various doses of preparation have substantially raised the GSH level in cancerous mice as 7.4% at 50 mg/kg, 14.2% at 100 mg/kg, and 22.0% at 200 mg/kg. Superoxide dismutase (SOD) levels in the liver of cancer mice decreased by about 35.6%. SOD levels are significantly increased following doses of 50, 100, and 200 mg/kg. SOD levels substantially increases as 13.4% in 50 mg/kg, 23.9% in 100 mg/kg, and 27.2% in 200 mg/kg.

Anti-helminthic activity
Parasitic Helminthiasis has been recorded as a serious worm infestation and has been reported to be a major health issue worldwide. Hundreds of millions human infections by helminthes exist worldwide and has increased through world travel and immigration from the developing countries [79]. Hence, the previous research has been focused to find nature-based novel drugs for Helminthiasis. In this regard, Kumar et al. [80]
studied anthelmintic analysis on *Pheretima posthuma*, which was tested by using the solvents Petroleum ether, Ethanol, and aqueous mixed whole parts of plants. They are prepared at the concentrations of extract as 50, 75, and 100 mg. This research has accomplished with the standard drug Albendazole. Albendazole is used as a comparative agent for evaluating the anti-helmintic potential of plant extracts. After treatment, the paralysis and death of worms are also measured in all the tested concentrations. The tested extracts took time to paralyze the worms, which depend upon the dosage of extracts. The different concentrations of aqueous extracts have paralyzed the worms at 52 ± 0.2 min in 50 mg, 41 ± 0.6 min in 50 mg, and 36 ± 0.6 min in 100 mg. Whereas, various concentrations of ethanolic extracts have paralyzed the worms at 36 ± 0.6 min in 50 mg, 31 ± 0.8 min in 50 mg, and 24 ± 0.1 min in 100 mg. Furthermore, the various concentrations of petroleum ether extracts have paralyzed the worms at 58 ± 0.8 min in 50 mg, 45 ± 0.1 min in 50 mg, and 42 ± 0.2 min in 100 mg. Similarly, the mortality duration of worms are also noted at different concentrations of *B. racemosa* solvents. The tested aqueous extracts showed mortality time of worms as 59 ± 0.3 min in 50 mg, 50 ± 0.3 min in 75 mg, and 40 ± 0.4 min in 100 mg as well. Anti-helmintic activity is found on a dose-dependent basis, ethanol preparations showed a significant activity with that of the albendazole drug used as a testing drug to compare the effectiveness of *B. racemosa* stem bark dis- fraction. The isolations (2S)-1, 2-di-O-linolenoyl-3-O-α-galactopyranosyl-(1/6)-O-β-galactopyranosyl glycerol, (2S)-1-O-linolenoyl-2-O-palmitoyl-3-O-α-galactopyranosyl-(1/6)-O-β-galactopyranosyl glycerol, and (2S)-1-O-oleoyl-2-O-palmitoyl-3-O-α-galactopyranosyl-(1/6)-O-β- galactopyranosyl glycerolare characterized galactolipids, whereas the isolation (-)-epiafzelechin, (-)-epicatechin, and (-)-catechinare categorized as catechins together with protocatechuic acid.

Prior to n-butanol fractionation, the crude ethanolic extract of *B. racemosa* leaves was tested on *B. malayi* by in vitro assay, which showed (F1) 80% of migration reduction ratio in adult filarial parasites. In this crude extract analysis, the worms did not reveal 100% reduction in its migration, though it is paralyzed and only a tiny number of parasites have migrated slowly.

**Analgesic activity**

A research in 2005 has proved that Methanol mixed with *B. racemosa* stem bark possessed remarkable analgesic efficacy at the dose of 200 mg/kg. In writhing method, the inhibition activity is shown to be 53.41%. In hot plate method, the rate of reaction time significantly increased at the dose of 200 mg/kg, which improved from 9.36 ± 0.74 to 16.57 ± 1.34. Aspirin and morphine are used as control drugs to determine the ability of stem bark of *B. racemosa*. This is tested on acetic acid-induced writhing and the hot plate method pain-induced mice as well. Aspirin is used as a correspondent to analgesic action in acetic acid-induced writhing mice, whereas in the hot plate process, morphine is used as an analgesic agent in pain-induced mice. This experiment also examined analgesic efficacy using a mixture of MEBR and authorized drugs. There, the combinations exposed more potent analgesic activities than the individual doses of approved drugs and prepared extracts. Especially, the combinations of aspirin and MEBR exhibited remarkable writhes inhibition percentages such as 71.36% in 100 + 50 mg/kg, 77.04% in 100 + 100 mg/kg, and 84.02% in 100 + 200 mg/kg.

To determine the analgesic activity, the stem bark of *B. racemosa* was subjected to an analgesic experiment on tail lesion-induced albino Wister rats [84]. Analgin is used as a testing drug to compare the effectiveness of the *B. racemosa* stem bark with that of a commercial drug. The extracts are prepared using aqueous and ethanolic solvents and tested at different doses with each solvent at 100 mg/kg and 200 mg/kg respectively. Borikar et al. [84] reported that *B. racemosa* stem bark displayed substantial analgesic efficacy in Wister rat tail lesions when added with alcohol. They also reported that rats treated with aqueous extracts at a dose of 100 mg had no analgesic activity in tails. Eventually, 200 mg of *B. racemosa* alcoholic extract has a stronger analgesic

**Anti-filarial activity**

Parasitic Filarial disease is a commonly neglected mosquito borne disease in the tropics. Classified under the endemic diseases, has infected around 120 million people with 1.2 billion at a higher risk according to the reports of WHO [81]. The nematode causing filariasis, *Wuchereria bancrofti*, is responsible for the 91% of the infections while the remaining infections (9%) is produced by *Brugia malayi* and *Brugia timori*, especially in the Southeast Asian Countries. They inhabit the lymphatic system and further harm the tissue by producing hydrocele, lymphedema, and elephantiasis. Long-term permanent disability which accounts for the second largest kind of disability is caused by filariasis [82, 83].

In 2012, Sashidhara et al. [24] found that the Galactolipids as potential anti-filarial agents against the human lymphatic filarial parasites. The Galactolipids are isolated from the leaves of *B. racemosa*. They are fractionated as two classes of compounds such as galactolipid and catechin, which are isolated in n-butanol fraction. The isolations (2S)-1, 2-di-O-linolenoyl-3-O-α-galactopyranosyl-(1/6)-O-β-galactopyranosyl glycerol, (2S)-1-O-linolenoyl-2-O-palmitoyl-3-O-α-galactopyranosyl-(1/6)-O-β-galactopyranosyl glycerol, and (2S)-1-O-oleoyl-2-O-palmitoyl-3-O-α-galactopyranosyl-(1/6)-O-β-galactopyranosyl glycerolare characterized galactolipids, whereas the isolation (-)-epiafzelechin, (-)-epicatechin, and (-)-catechinare categorized as catechins together with protocatechuic acid.
function similar to 10 mg of analgin. In their experiment, the aqueous extract did not possess analgesic action due to a lack of adequate dose.

Chandrasekar and Prasanna [85] tested the analgesic potency of Bauhinia racemosa stem bark when mixed with petroleum ether. In order to evaluate the activity, the researchers used the animals in two techniques, such as acetic acid-induced writhing and thermal stimulus-induced pain test (hot plate methods). The animals were classified into three groups in both acetic acid induced writhing and hot plate method. In their trial, Aspirin was used as a control agent to the pain-induced rats by hot plate method. Eventually, Chandrashakar and Prasanna [85] reported that the petroleum ether mixed stem bark of B. racemosa had no substantial analgesic effects in animal model. From the conclusion of previous studies, we realized that it exposes efficient activities when the extract combined with the high polar solvents such methanol and alcoholic solvents.

**Hepatoprotective activities**

A research in 2004 has shown that the methanol solvent mixed stem bark of B. racemosa has potent hepatoprotective potentials against tetrachloride and paracetamol-induced liver damage in rats. The mixture of methanol solvent and stem bark is administered to rats at concentrations of 50, 100, and 200 mg/kg. They used various enzymatic activities, such as GSH, SOD, and catalase function, in rats following induction in liver injury. Following doses of MEBR, the enzyme activity was analyzed to assess the effectiveness of B. racemosa drugs. In paracetamol administered rats, the GSH levels decreased substantially compared to the normal group, while the overall homogenate of rats improved at doses of 50 mg as 2.43 μmol/g, 100 mg as 3.71 μmol/g, and 200 mg as 4.42 μmol/g. When seen in percentages, the different concentrations of MEBR effectively increased as 22.9% in 50 mg, 57.2% in 100 mg, and 76.2% in 200 mg, when compared to the paracetamol group. Similarly, GSH levels in the normal group were assessed as higher than those in the carbon tetrachloride (CCl₄) administered group. There, the GSH levels were higher than that of the administered CCl₄. Different doses of MEBR increased the GSH levels as 33.7% in 50 mg, 63.8% in 100 mg, and 97.2% in 200 mg.

The SOD levels were also decreased as 53.83 U/mg in paracetamol administered group when compared to normal group (91.76 U/mg). The SOD levels were also decreased as 53.83 U/mg in paracetamol administered group when compared to normal group (91.76 U/mg). Following treatment at doses of 50, 100, and 200 mg/kg of MEBR, the SOD levels improved dramatically as 17.6% in 50 mg/kg, 40.0% in 100 mg/kg, and 88.1% in 200 mg/kg. Similarly, the activity is decreased as 57.23 U/mg in CCl₄ administered group when compare to the normal group (91.76 U/mg). Following treatment at doses of 50, 100, and 200 mg/kg of MEBR, the SOD levels improved dramatically as 20.9% in 50 mg/kg, 37.7% in 100 mg/kg, and 87.7% in 200 mg/kg. The different concentrations of MEBR revealed efficient catalase enzyme activities in both paracetamol and tetrachloride induced hepatic damage. In paracetamol-induced hepatic damage, the different concentrations of MEBR increased the catalase enzyme activity as 25.9% in 50 mg, 54.8% in 100 mg, and 75.2 in 200 mg respectively, whereas in paracetamol-induced hepatic damage, the different concentrations of MEBR increased the catalase enzyme activity as 25.9% in 50 mg, 61.4% in 100 mg, and 82.9% in 200 mg respectively. Based on the experimental outcome, Gupta et al. [78] reported that the stem bark of Bauhinia racemosa had active hepatoprotective metabolites. They also indicated that the metabolites of MEBR could be used as alternate drugs to repair the liver cells from the hepatic injury of paracetamol and tetrachloride.

Subraya et al. [86], conducted an experiment on albino Wister rats to restore tetrachloride-induced hepatic damage to the liver cells, which was studied using ethyl acetate solvent blended with the stem bark extracts of Bauhinia racemosa. They induced hepatic injury in the rats group of II–V by using CCl₄. Then, the approved drug silymarin with a dose of 100 mg was administrated to the rats group-III, whereas the dose 200 mg ethyl acetate combined stem bark extracts of B. racemosa was administrated to the group IV. Based on their research findings, they stated that when compared to the approved drug silymarin, the mixtures of stem bark of B. racemosa revealed remarkable hepatoprotective potential. In 1979, Harborn [87] stated that the previous researchers reported the ethanol solvent mixed plant extracts were found to have much more amount flavonoids and glycosides. In phytochemical analysis of Subraya et al. [86], the ethyl acetate mixed stem bark of B. racemosa revealed the presence of flavonoids by qualitative analysis such as ferric chloride, alkaline reagent, and shinoda test.

In 2005, Kumaret et al [74], analyzed the hepatorenal and hematological potentiality of B. racemosa with various concentrations such as 100 mg/kg, 200 mg/kg, and 400 mg/kg. The stem bark extracts of B. racemosa was mixed with methanolic solvent and administered to the renal failure induced rats for analyze its potentials. In biochemical parameters, the mixtures of B. racemosa did not reveal any significant changes at doses of 100 mg/kg and 200 mg/kg. However, the bilirubin and serum enzymes such as glutamic pyruvic transaminase (GPT),...
glutamic oxaloacetic transaminase (GOT), and alkaline phosphatase (ALP) were enhanced at a dosage of 400 mg/kg. Furthermore, the levels of urea, uric acid, creatinine, cholesterol, and glucose were altered slightly in the rats treated at the dose of 400 mg/kg. Similarly, no substantial differences in hematological parameters such as white blood cells, neutrophils, lymphocytes, monocytes, red blood cells, hemoglobin, hematocrit (Hct), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), and platelets were revealed in rats treated at the doses of 100 mg/kg and 200 mg/kg. These parameters were altered in rats treated at the dose of 400 mg/kg. The renal failure-induced rats were subjected to experiments for hepatorenal potential of *B. racemosa*. In the rats treated at the doses of 100 and 200 mg, there were no substantial changes revealed in its liver, while the fatty liver was found in the rats treated at a dosage of 400 mg/kg.

**Anti-ulcerative effects**

At present, treatment of peptic ulcer is not satisfactory to humans due to the use of synthetic drugs, because all of the medicines used trigger several adverse reactions, such as arrhythmias, impotency, gynecomastia, and hematopoietic changes. We can escape from the adverse effects of synthetic drugs by using medicinal plants. In 1995, the flower buds of *B. racemosa* were prepared with methanol solvent and administered to ulcer-induced rats at a dosage of 2 g/kg [88]. Akhtar and Ahmed [88] have also reported that the flower buds of *B. racemosa* had a substantial decrease in acid production, pepsin production, and volume of gastric acid of ulcer-induced rat peptic activities. It may happen due to a decline of glanular secretion. In their study, the methanolic extracts of *B. racemosa* substantially improved the concentration of fucose and sialic acid in carbohydrate without a proteins reduction, and the mucin activity has also not changed. In ulcer-induced rats, methanol mixtures of *B. racemosa* flower buds inhibited ulcer formation at almost 64%. They reported that treatment not only inhibited acids and pepsin but also reinforced the mucosal barrier in ulcer rats. The ulcer genes and drug targets of the human gastric acid pathway are shown in Fig. 2.

**Anti-cancer activities of the herb**

All around the world, cancer is a leading cause of mortality. According to the reports of World Health Organization (WHO), the incidence of cancer cases is expected to rise by 75% in 2030 due to the population growth and the change in life style. Several chemotherapeutic drugs with different biochemical/molecular targets have been extensively used in this world to cure various types of cancers. At the same time, the drugs should not cause any adverse effects on humans. Researchers have been struggling to find effective therapeutic approaches to cancer and novel anti-cancer drugs over the last few decades. Hence, the search for alternative drugs from natural sources is important and it should also be less toxic [69]. Over the last few decades, a number of studies have revealed that *B. racemosa* extracts have anticancer properties such as antitumor effects in Ehrlich ascites carcinoma hepatocarcinogenesis and cervical cancer. In 2004, Gupta et al. [78] tested the capacity of *B. racemosa* stem bark in cancer mice (carcinoma-induced mice). Before being given to the mice, the stem bark extracts of *B. racemosa* were mixed with methanol solvents. Then, it was administered to the mice for examination of these kinds of biochemical parameters such as toxicity, antitumor resistance, lipid peroxidation, and antioxidant property. The normal body weights of tested mice were 20.70 ± 0.12 g. After administered the EAC, the body weights gradually increased to 26.70 ± 0.16 from the usual weight, whereas after given the stem bark of *B. racemosa* formulation in cancer mice, the body weights of the mice gradually reduced to 24.60 ± 0.19 in 50 mg, 22.50 ± 0.13 in 100 mg, and 21.20 ± 0.14. Also, 20 mg dose of 5-flourouracil has reduced the body weight to 20.70 ± 0.09 in cancer mice. Then, 200 mg of MEBR reduced the body weight similar to that of 5-flourouracil. They measured the life span of cancer mice after the treatment of MEBR, raising the life span to 34.12 in 50 mg, 68.75 in 100 mg, and 99.50 in 200 mg. The lifespan of 20 mg of prescribed drugs improved as 119.49, whereas they also revealed no life span for untreated EAC mice. The different concentrations of MEBR have reduced the volume of tumor cells in EAC mice as 3.37 ± 0.07 in 50 mg, 2.41 ± 0.03 in 100 mg, and 1.20 ± 0.01 in 200 mg. This value was compared with untreated EAC-bearing mice that possessed the volume of tumor cells as 4.51 ± 0.07. The viability of tumor cells considerably declined to 3.37 ± 0.07 in 50 mg, 2.41 ± 0.03 in 100 mg, and 1.20 ± 0.01 in 200 mg. Gupta et al. [78] reported that MEBR-treated animals at doses of 50, 100, and 200 mg/kg decreased body weight, tumor volume, packed cell volume, tumor cell count, and also reduced hematological parameters close to that of healthy mice. Their short-term toxicity studies reported that there were no adverse effects.

Azizur Rahman et al. [25] tested the apoptotic potential of *Bauhinia racemosa* stem bark against HeLa cell lines. Before being given to the mice, the stem bark extracts of *B. racemosa* were mixed with methanolic solvents. They treated HeLa cells with various concentrations of MEBR such as 25 μg/ml, 50 μg/ml, 100 μg/ml, and 200 μg/ml. HeLa cell viability significantly reduced in the treatment of MEBR.
concentrations \((p < 0.001, \text{IC}_{50} = 80 \mu g/ml)\), which decreases the cell viability of HeLa similar to that of tamoxifen \((p < 0.001, \text{IC}_{50} = 48 \mu g/ml)\) in a concentration-dependent manner. At the concentrations of 25 \(\mu g/ml\) and 50 mg/ml, the cell viability decreased to 90.90% and 78.20% respectively as compared to control; while at doses of 100 \(\mu g/ml\), 300 \(\mu g/ml\), and 500 \(\mu g/ml\), the cell viability decreased to 43.43%, 22.42%, and 8.25% respectively. Azizur Rahman et al. [25] reported that the concentrations 100 \(\mu g/ml\) and 300 \(\mu g/ml\) of MEBR have notable cytotoxic effects against the HeLa cancer cell line and their study was subjected to further tests. Results of the study demonstrated that total phenolic content in MEBR was 886.8252 mg GAE/g dried extract. Their findings revealed that the overall phenolic content was 886.8252 mg GAE/g of dried extract in MEBR. Eventually, they reported that it could be a new possible cytotoxic agent to HeLa cancer cells.

![Gastric acid secretion pathways](image)

**Fig. 2** Human gastric acid secretion pathways that serve the drug target site for curing ulcer activity (pink indicates diseased gene and blue indicates drug target site)

**Anti-histaminic activities of the medicinal plant**

The antihistamine potential of *B. racemosa* leaves was analyzed on Clonidine-induced catalepsy mice [89]. This was tested by using the ethanol combined leaves extract of *B. racemosa*. Then, the ethanolic extracts of *Bauhinia racemosa* (EEBR) was administered to catalepsy induced mice at dose of 50 mg/kg, whereas the Pheniramine maleate was used as the standard drug for catalepsy-induced mice. Catalepsy was inhibited by the EEBR at a dosage of 50 mg, while it was inactive against haloperidol-induced catalepsy. Finally, Nirmal et al. [89] reported that the ethanol extract of leaves of *B. racemosa* will be an effective alternative medicine for asthma.

**Anti-pyretic activities**

An antipyretic potential of *B. racemosa* stem bark was analyzed by yeast-induced pyrexia rats with MEBR at doses of 50, 100, and 200 mg/kg [70]. The antipyretic...
test started in the first hour on rats and the rats were monitored for 4 h after the administration of extracts. Compared to paracetamol (150 mg/kg), the oral administrations of MEBR at various concentrations have showed significant antipyretic potential in the yeast-induced rectal temperature.

A research in 2009 tested the antipyretic potential of stem bark of B. racemosa on pyrexia-induced male albino rats [90]. Before being given to the mice, the stem bark extracts of B. racemosa were mixed with alcohol and aqueous solvents. Then, the preparations were treated to the pyrexia induced rat at doses of 100 mg and 200 mg in each solvent to two independent groups. In rats with pyrexia, the 200 mg of aqueous extracts and 100 and 200 mg of alcoholic extracts possessed significant potential that were considerably reduced when the temperatures were maintained at 5% in rats within 3 h. Borikar et al. [90] reported that 200 mg of alcohol extracts reduced the rat's temperature to 99.5 ± 0.225 from 101.91 ± 0.267, which has also reduced the rat's temperature as close to that of paracetamol (99.56 ± 0.212) treatment.

Anti-diabetic effects

Diabetes mellitus is characterized by glucose hyperglycemia, hypoglycemia, hyperlipidemia, hyperlipidemia, and lipid and protein metabolisms defects. Obesity and lack of physical activity play an important role in diabetes. About 3.5 million deaths occur worldwide annually due to complications such as retinopathy, diabetic coma, nephropathy, neuropathy, diabetic ketoacidosis, and so on. There is an increase in illness-related mortality and morbidity, despite developments in the diagnosis and prevention of disease. Researchers are therefore keen to examine drugs from natural sources, especially plant metabolites. A research in 2012 tested the anti-diabetic potentials of B. racemosa leaves on alloxan-induced diabetic rats. Before being given to the rats, the leaf extracts of B. racemosa were mixed with methanol and aqueous solvents [91]. Then, the preparations were treated to the hyperglycemia-induced rats at doses of 200 mg and 400 mg in each solvent. In hyperglycemic rats, 200 and 400 mg of aqueous extracts of Bauhinia racemosa (AEBR) and MEBR have significantly increased body weight and also decreased body blood sugar levels when compared to the Pioglitazone. Prusty et al. [91] stated that extracts of AEBR and MEBR have increased pancreatic exocrine functions, such as insulin secretion, fatty liver changes, recovering the dead cells of β-islets, and also increased transport of blood glucose to the periphery.

Furthermore, in 2017, Kumar et al. [92] used B. racemosa leaves at doses of 250 mg and 500 mg to test their anti-diabetic efficacy in hyperglycemic animals. The anti-diabetic pathogenic activity on the 3T3-L1 cell line was also evaluated. A 500 mg dosage substantially reduced the blood glucose level (58.8 mg/dl) in a fasted rat within 4 h, which was equal to that of diabetic drug glibenclamide (51.4 mg/dl) in the in-vitro study. Oral glucose levels were also measured in three stages, such as 0 min, 30 min, and 90 min, for glucose primed rats. At 90 min, the glucose level was slightly lowered as 115.65 mg/dl from 152.92 mg/dl by 500 mg, which was closer (90.44 mg/dl) to that of the diabetic medication glibenclamide. At the conclusion of the trial, fasting serum glucose levels in diabetic rats decreased as much as 134.70 mg/dl in 250 mg and 143.88 mg/dl in 500 mg, while FSG levels also changed at weekly intervals as per dose-dependent treatment. Figure 3 shows the drug target site and the enzymes involved in type II diabetes mellitus of humans.

Larvicidal activity of the medicinal plant

Malik et al. [93] studied the larvicidal potential of B. racemosa and Lantana camera against the larvae of Anopheles stephensi mosquito, which were analyzed by using the solvents chloroform and ethyl acetate. Among the plant extracts, the ethyl acetate extracts of B. racemosa exposed efficient larvicidal effects. Based on their research outcomes, they reported that the plants can be used as an alternative way to control insects and also used to reduce the adverse effects of chemical pesticides in the environment.

Anti-HIV-1 activity of the B. racemosa

Human immunodeficiency virus (HIV) continues to be a serious public health issue worldwide. According to Palshetkar et al. [94], there are 37.9 million individuals are living with HIV worldwide, 36.2 million of them are adults and 1.7 million of them are below the ages of 15 years. Further, 1.7 million people are newly infected with viral infections. Globally, 770,000 people have globally died from acquired immunodeficiency syndrome (AIDS)-related diseases. Consequently, an effective drug is required to control the mortality and morbidity of HIV from natural sources. If it could be a plant, it will be better [94].

Khaled et al. [95] tested the anti-HIV activities of the stem of B. racemosa and its fractions by using the solvents methanol, ethyl acetate, n-butanol, and aqueous. Methanolic extracts of B. racemosa demonstrated greater anti-HIV efficiency, while other fractions displayed less anti-HIV capacity. Phytochemicals have also been studied in methanol and other solvents extracts of B. racemosa. Eventually, flavonoids, tannins, and terpenes have been found. Furthermore, the methanol extracts were subjected to further studies on isolation of phytochemicals. In this isolation study, the
phytochemicals such as triterpenic acids (oleanoic and ursolic), two hydrolysable tannins (gallic and ellagic acids) and three flavonoids (luteolin, quercetin 3-O-β-glucoside, and myricetin 3-O-β-glucoside) are identified. Khaled et al. [95] reported that methanol extract of *B. racemosa* has potential as an anti-HIV-1 agent. This is assumed that owing to the presence of different phytochemicals in the extracts of methanol, the antiviral activity can be revealed.

**Toxicity assessment**

In order to know the toxicity of *B. racemosa* leaves, at a dose of up to 2000 mg/kg were subjected to acute toxicity analyses prior to the diabetic clinical trial. Kumar et al. [92] report that the treatment did not cause any adverse effects and fatalities when administered to rats.

**Conclusions**

Plant metabolites have been sold in the market at high prices to satisfy the human health requirements. But we can procure these metabolites from native plants in rural and urban areas. Traditional applications, phytochemical, and pharmacological profiles of *B. racemosa* have been pointed out in detail in this review through the literature available since 1935. This review clearly reflects the importance of *B. racemosa* in the ayurvedic medicinal system, especially in the case of cancer. This plant extracts are preferred for treatment of cancer, especially during the early stages in Ayurveda. In southern India, this species is being nurtured in residential areas by traditional people to avoid the thundering impact because they believe that it is capable of neutralizing thunder. Thus, the plant is referred to as the lightning arrester (*Idithangi*) by the Tamilians.

As set out in Table 1, it has a wide range of traditional uses and is being treated by tribals and other traditional people worldwide. However, the plant has not yet been widely researched in the aspects of phytochemistry and pharmacology. To date, almost 37 phytoconstituents have been identified and extracted from different parts of the plant. *B. racemosa* has a larger quantity of flavonoids. Generally, flavonoid compounds have been more abundantly reported as having wide therapeutic potentials such as neuroprotective, anti-cancers, anti-hyperglycemia, anti-ulcer, steroid-genesis modulators, anti-inflammation, and so on [96]. These flavonoids (phytoconstituents) have been used for decades to minimize the health problems of the human race. Those
therapeutic potentials are expressed due to the existence of these secondary metabolites (Table 2). This plant formulation is also being marketed under the name Masa...Racemosol, Galactolipid, Catechin, Betulin, Quercetin, Rutin, and Kaempferol, only a limited number of pharmacological studies have been described on this plant. Further pharmacological studies are extensively needed in this extract as set out in Table 4. We hope that crude extracts will have significant effects on diseases due to the existence of such molecules. Traditionally, B. racemosa has been used for the treatment of dysentery, diarrhea, malaria, influenza, epilepsy, vomiting, edema, constipation, gastric, dyspepsia, and convalescents. Even though, no research has been conducted to date on the traditional uses of this herb. The extracts should therefore be subjected to pharmacological trials (in vitro and in vivo) to determine their biological ability. Toxicity studies in pharmacology and traditional uses are required to clarify their exact enzymatic pathways leading to toxic effects.

According to the pharmacological studies, we realized that the methanol and ethanol extracts of B. racemosa have shown high pharmacological activities. Consequently, in most pharmacology experiments, ethanol and methanol extraction were used. To date, no single drug (one product) of B. racemosa has been developed globally. In Ayurvedic medicine, it is used as a decoction at the early stage of cancer cases. This plant bark is also mixed with other plants parts and is recommended for the prevention of miscarriage during the second month of pregnancy.

Furthermore, a number of pharmacological studies have confirmed the potential antioxidant activity of B. racemosa. The antioxidant potential can be exposed by the presence of flavonoids at higher concentrations. Therefore, as an anti-oxidant agent, B. racemosa still has a broad testing part for researchers to analyze based on the existing research source, and it is important to further analyze its therapeuchic effectiveness. However, there are several more pharmacological studies in which B. racemosa have positive effects on cancer, pathogens, hyperlipidemia, antioxidants, and other diseases. In addition, existing pharmacological experiments and clinical data have not revealed any harmful effects of B. racemosa so far. As far as the phytochemicals are concerned, pharmacological and toxicological aspects are to be explored via thorough research on this plant.

This review also suggests that more pharmacological experiments are needed in this plant for knowing its therapeutic potential against certain mortal diseases. This review could help future researchers to understand the existing pharmacological capabilities of B. racemosa. We also hope that this review will support the phase of drug development in the pharmaceutical sector.

Abbreviations

B. racemosa: Bauhinia racemosa; APG: Angiosperm phylogeny group; β-sitosterol: Beta-sitosterol; β-amyrin: Beta-amyrin; HIV: Human immunodeficiency virus; MeOH: Methyl alcohol; NF-kβ: Nuclear factor kappa light chain enhancer; INOS: Inducible nitric oxide synthase; COX-2: Cyclooxygenase-2; TNF-α: Tumor necrosis factor alpha; IL-6: Interleukin-6; MEBR: Methanolic extract of Bauhinia racemosa; ROS: Reactive oxygen species; DPPH: 2,2-Di-phenyl-picyril-hydrazil; ABTS: 2,2-Azino-bis(3-ethylbenothiazoline-6-sulfonic acid); µg/ml: Microgram/milliliter; EAC: Ehrlich ascites carcinoma; SOD: Superoxide dismutase; LF: Lymphatic filariasis; GSH: Glutathione; CCl4: Carbon tetrachloride; GPT: Glutamic pyruvic transaminase; GOT: Glutamic oxaloacetic transaminase; ALP: Alkaline phosphatase; HCT: Hematocrit; MCV: Mean corpuscular volume; MCHC: Mean corpuscular hemoglobin; MCHC: Mean corpuscular hemoglobin concentration; EEBR: Ethanolic extracts of Bauhinia racemosa; AEBR: Aqueous extracts of Bauhinia racemosa; AIDS: Acquired immunodeficiency syndrome

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Authors’ contributions

SP and SV assisted in drawing the outline for the review and collected papers on the plant in a number of ways. In the writing, editing, and revising of the manuscript, RR and KK took part. PKP took part in language revision and polishing of the manuscript. GT and JS had the role to correct the field of taxonomy and pharmacology. NP played a key role in the developing structures of phyto-compounds and helped to correct the phytochemistry part as well. All authors have read and approved the manuscript.

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No conflict of interest between authors.

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89. Nirmal SA, Dhasade VV, Laware RB, Rathi RA, Kuchekar BS (2011) Antihistaminic effect of Bauhinia racemosa leaves. J Young Pharm 3(2):129–131. https://doi.org/10.4103/0975-1485.80301
90. Borikar VI, Jangde CR, Philip P, Rekhe DS, Atole SK (2009) Study of anti-pyretic activity of Bauhinia racemosa Lam in rats. Vet World 2:217–218
91. Prusty KB, Venkateshwar Rao J, Subudhi SK, Anitha Reddy P, Raj Kumar J (2012) Anti-hyperglycemic activity of extracts of leaves of Bauhinia racemosa Lamk (Family-Caesalpineaceae) on normal and aloxan-induced diabetic rats. Int J Pharm Res Allied Sci 1(4):94–99
92. Kumar V, Rathore K, Jain P, Ahmed Z (2017) Biological activity of Bauhinia racemosa against diabetes and interlinked disorders like obesity and hyperlipidemia. Clin Phytosci 3(1):7. https://doi.org/10.1186/s40816-017-0044-9
93. Malik B, Malik M, Balakrishnan N, Suresh B (2014) Evaluation of larvicidal activity of the different extracts against important species of mosquito: Anopheles stephensi. J Parasitol Vector Biol 6:11–15
94. Palshetkar A, Pathare N, Jadhav N, Pawar M, Wadhwani A, Kulkami S, Singh KK (2020) In vitro anti-HIV activity of some Indian medicinal plant extracts. BMC Complement Med Ther 20(1):69. https://doi.org/10.1186/s12906-020-2816-x
95. Khaled R, Meng-TL LTZ, Yong TZ (2013) Anti-HIV-1 potential of B. racemosa Lam. (Caesalpiniaceae) and Phytochemical profile. Topclass J Herbal Med 2:95–102
96. Panche AN, Diwan AD, Chandra SR (2016) Flavonoids: an overview. J Nutr Sci 5:47

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