

Review on phytochemical constituents, nutraceutical activities and health benefits of *Bryophyllum pinnatum* (Lam.)

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Abstract

Medicinal herbs have been used since ancient times and are in major demand due to the great efficiency, relatively lower side effect and easily available all around the world. *Bryophyllum pinnatum* (Lam.) Kurz., (Crassulaceae) commonly known as air plant or life plant or miracle leaves, etc. are extensively utilized in traditional medicine. It is widespread in tropical America, tropical Africa, India, Australia and, China. *Bryophyllum pinnatum* (Lam.) is characterized by being richest sources of variety of bioactive components such as alkaloids, tri-terpenes, glycosides, phenolic compounds, flavonoids, bufadienolides etc., and exerts numerous nutraceutical activities and various health benefits such as antidiabetic, anticancer, antibacterial, antihypertensive, anti-inflammatory, hepatoprotective, immune-modulatory, anti-lithogenic, anti-leishmanial etc. The beneficial effects of this plant may be attributed due to the presence of numerous secondary metabolites and other bioactive compounds in it and hence adding this herb into the food products may be considered to intensify the medicinal values. Not only that this magical plant is also important to be a traditional healers for treating a range of ailments including kidney stones, high blood pressure, asthma, colds, abscesses and bleeding disorders etc. This review will discuss the nutraceutical activities and health benefits of *Bryophyllum pinnatum* (Lam.) for treating various diseases.

Keywords: *Bryophyllum pinnatum* (Lam.); Nutraceutical; Air Plant; Bioactive mixtures; Traditional medicine; Health benefits

1. Introduction

According to the World Health Organization (WHO), medicinal plants are the great source to offer a diverse range of potential therapeutic drugs and these drugs can be relatively safe and economical as compared to the synthetic medicines [1] (WHO, 1998). *Bryophyllum pinnatum* (Lam.) is a perennial herb and native of Madagascar and southern Africa, which is naturalized throughout the tropics of the world and is widespread in tropical America, tropical Africa, India, Australia and, China [2] (Kamboj, A. and Saluja, A., 2009). This perennial plant thrives in India's wet and hot regions, like Bengal. It has 25 genera and about 450 species [3] (Selvakumar, P. et al., 2022). It has a straight, juicy, continuing shrub that develops about 1.5m tall featuring a hollow, four angled stem that is typically branched and reappearances through spores and also vegetatively from leaf bulbils [4] (Kamble, P. et al, 2024).

Bryophyllum pinnatum (Lam.) is belongs to the family of Crassulaceae, also known as *Kalanchoe pinnatum* is commonly used traditionally as a medicine in different regions of India and as well as in other parts of the world. In Ayurveda, the plant is popularly known as Pāṣāṇabheda, means “dissolver of stones” [5] (Khare, C. P., 2007). The Plant has been widely applied in traditional medicine for management of various diseases or as adjuvants to promote drug action. This plant has been identified as an important source of phyto-active compounds with verifiable medicinal properties [6] (Asiwe,

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E. S. et al., 2021). The leaves of *B. pinnatum* (Lam.) are widely used in traditional and ethnomedicinal practices for treatment of urinary insufficiency, urinary calculi, kidney and gall bladder stones [7, 8, 9, 10, 11, 12] (Prachi, Chauhan N. et al., 2009; Mondal, T. and Samanta, S., 2014; Mistry, J., 2015; Zahid, I.H. et al., 2013; Sikdar, M. and Dutta, U., 2008; Moromi, T., 2014). Leaves of *Bryophyllum pinnatum* (Lam.) are also known to possess numerous medicinal properties such as antimicrobial [13] (Okwu, D. E. and Nnamdi, F. U., 2011), antiulcer [14] (Pal, S. and Nag Chaudhuri, A.K., 1991), antihypertensive [15] (Ojewole, J.A., 2002), neurosedative and muscle relaxant [16] (Yemitan, O.K. and Salahdeen, H.M., 2005), anti-nociceptive, anti-inflammatory and anti-diabetic, [17] (Ojewole, J.A., 2005), uterine contractility [18] (Gwehenberger, B. et al., 2004) and nephroprotective [19] (Harlalka, G.V., et al., 2007) activities. Taxonomical Classification of *B. pinnatum* is given below;

- Kingdom: *Plantae* (Plants)
- Subkingdom: *Tracheobionta* (Vascular plants)
- Division/Phylum: *Spermatophyta* (Seed plants) / *Magnoliophyta* (Flowering plants)
- Class: *Magnoliopsida* (Dicotyledons)
- Subclass: *Rosidae*
- Order: *Saxifragales* (sometimes listed as *Rosales* in older literature)
- Family: *Crassulaceae* (Stonecrop family)
- Genus: *Bryophyllum* (or *Kalanchoe*)
- Species: *B. pinnatum* (Lam.) Oken

The traditional practitioners in around the world use this plant in numerous conditions like Raktasrava (bleeding disorders), Ashmari (renal calculi), Vrana (ulcers), Atisara (diarrhea) etc. As the plant is known for its ethno-botanical importance, many research works carried out around the world to validate the traditional medicinal and proved many pharmacological activities of different parts of this plant [20] (Taiwo O. Elufioye et al., 2022) (**Table 1**). The most popular application of this plant that have been reported like anti-diabetic activity, wound healing property, anti-lithogenic activity, hepatoprotective and anticancer property [21] (Nagaratna, A. et al., 2015).

Table 1 Ethno-botanical uses of *Bryophyllum pinnatum* (Lam.) [20] (Taiwo O. Elufioye et al., 2022)

Region/Country	Vernacular Name(s)	Uses	Parts Used
India (Bengal)	Patharkuchi	Urinary stones, bleeding disorder, ulcers, diarrhea	Leaf juice
India (Maharashtra)	Panfuti	Wound, ulcers, cough	Leaves
India (Odisha)	Amarapoi	Headache, general body pain, urinary disorders	Leaves and juice
India (Kerala)	Thukotali	Cancer, burn wound	Leaves
Southern India and Bengal	Parnabeeja	Renal disease, wound	Leaves
Caribbean (English-speaking)	Leaf of Life	Diabetes, burns, wounds, pains	Leaf juice
West Africa (incl. Nigeria)	Odaapue	Hypertension, diabetes, bruises, wounds, boils, abscesses, insect bites, arthritis, rheumatism, joint pains, headaches, body pains, childhood illnesses	Leaves, juice, roots
Taiwan	Luo Di Sheng Ken	Anti-cancer	Leaf extract
China	Da busi	Cancer, pains, wound	Leaf
Peru	Odaapue	Headache, fever, heartburn, urethritis, respiratory conditions	Leaf extract

In view of importance of traditional and ethno-medicinal values of *B. pinnatum* (Lam.) plant, the present review complements and extends the valuable information on phytochemical properties and nutraceutical activities and also discusses about numerous health benefits of this plant.

2. Result and Discussion

The importances of traditional system of medicine and of certain traditional medical practices are widely recognized all over the world. Recently, some authors have suggested that traditional medical system should be integrated into the mainstream of healthcare services due to their easy accessibility, availability, cultural acceptability, therapeutic potential and minimal cost [6] (Asiwe, E. S. et al., 2021). *B. pinnatum* (Lam.) is a well-known medicinal plant that has been used in many traditional systems of medicines since ancient times [3, 22, 23, 24] (Selvakumar, P. 2022; Latif, A. et al., 2019; Padhi, A. et al., 2024; Khooshbu, P. et al., 2019). It consist several beneficial components and exerts such numerous health benefits.

2.1 Phytochemical constituents:

A number of authors have been isolated and identified several phytochemical from leaves and other parts of *B. pinnatum* (Lam.) [23, 22] (Padhi, A. et al., 2024; Latif, A. et al., 2019). The major phytochemical constituents present in the plant are given in **Table.2** and **Figure. 1**. This plant content various organic acids such as isocitric acid, citric acid and bufadienolides like bryotoxin A, B, C [23] (Padhi, A. et al., 2024). The plant parts are an excellent sources of various compounds under the catagory of phenols, phenylpropanoids and flavanoids, such as Syringic acid, caffeic acid, 4-hydroxy-3 methoxy-cinnamic acid, 4-hydroxybenzoic acid, p-hydroxycinnamic acid, paracoumaric acid, ferulic acid, protocatechuic acid, phosphoenolpyruvate, protocatechuic acid., various triterpenoids and steroids such as α -amyrin, α - amyrinacetate, β -amyrin, β -amyrinacetate, bryophollenone, bryophollone, taraxerol, pseudo taraxasterol, 1,8- α -oleanane, friedelin, glutinol17 [23] (Padhi, A. et al., 2024).

The ethanolic leaf extract of the plant parts also contain several fatty acids such as stearic acid, palmitic acid and traces of the arachidic and behenic acid; various alkaloids such as saponins; glycosides; tannins and various flavonoids such as quercitrin, kapinnatoside, 8-methoxyquercetin-3, 7-di- Orhamnopyranoside, 3', 4'-dimethoxy quercetin, Afzelin and α -rhamnoisorobinare [22] (Latif, A. et al., 2019)

This herb is an excellent reserve of several vitamins such as ascorbic acid, niacin and thiamine and minerals i.e. Ca, Mg, Na, Fe, P, K and Zn [22] (Latif, A. et al., 2019). It also contains essential oils and about twenty-four various phytochemical compounds, out of which nonanal and (E)-geranyl acetone are the most abundant [22] (Latif, A. et al., 2019).

The GC-MS analysis of the ethanol extract of the leaves of *B. pinnatum* (Lam.) shows the presence of various compounds like, butyrolactone, 3,4-Epoxytetrahydrothiophene-1,1-dioxide, 1-Octen-3ol, Benzaldehyde, Oleic acid, Octadecanoic acid, n-Hexadecanoic acid [23] (Padhi, A. et al., 2024). The stem of *B. pinnatum* (Lam.) also shows the presence of various active constituents such as alkaloids, flavonoids, saponin, Tannin, phytate, phenol etc [23] (Padhi, A. et al., 2024).

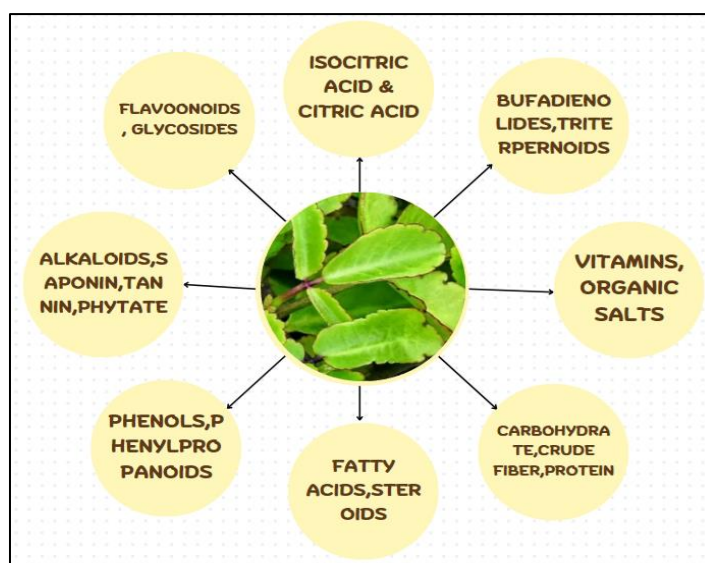


Figure 1 Category of Phytochemical present in *Bryophyllum pinnatum* (Lam.)

Table 2 List of Various Phytochemical components present in *Bryophyllum pinnatum* (Lam.) [22, 23](**Padhi, A. et al., 2024**; Latif, A. et al., 2019)

Compound Group	Specific Compounds
Organic Acids & Bufadienolides	Isocitric acid, Citric acid; Bryotoxins A, B, C
Phenols, Phenylpropanoids	Syringic acid, Caffeic acid, Ferulic acid, Paracoumaric acid etc.
Flavonoids	Quercitrin, Afzelin, α -Rhamnoisorobin etc.
Fatty Acids & Phytochemicals	Stearic, Palmitic, Arachidic, Behenic acids; Alkaloids, Saponins, Tannins
Triterpenoids & Steroids	α -/ β -Amyrin, Taraxerol, Bryophollenone etc.
Vitamins & Minerals	Ascorbic acid, Niacin, Thiamine; Ca, Mg, Na, Fe etc.
Essential Oils	Nonanal, (E)-Geranylacetone and others
GC-MS Identified Compounds	Butyrolactone, 1-Octen-3-ol, Oleic acid, Benzaldehyde, Oleic acid, Octadecanoic acid, n-Hexadecanoic acid.
Stem Constituents	Alkaloids, Flavonoids, Saponins, Tannins, Phenols, Calcium

2.2 Nutraceutical activity

The beneficial medicinal effects of plant materials typically result from the combinations of secondary metabolites such as alkaloids, tannins, phenolic compounds and flavonoids. Primarily, phenolic compounds are of great importance as cellular support material because they form an integral part of cell wall structure by polymeric phenolics. It has been observed that tannin reacts with proline-rich protein to produce irreversible complexes that result in the inhibition of the synthesis of cellular proteins. These are beneficial in curing abdominal ailments like diarrhoea. Various flavonoids have revealed a wide range of biological activities including antimicrobial, antioxidant, anti-inflammatory, anti-allergic and cytostatic. Tannins along with flavonoids are found to exhibit anti-diarrhoeal activity through inhibition of intestinal motility and anti-secretory effects. The saponins are beneficial in the management of inflammation. Alkaloids have recorded with their analgesic, antispasmodic and antibacterial actions. Many research findings have proved that leaves of *B. pinnatum* (Lam.) have an appreciable amount of such bioactive components like flavonoids, tannins, saponin, alkaloids, phenols and phenolic components etc. Ash, fat, protein, carbohydrate and fibre content of this plant are also appreciable. This indicates that these plants is a good source of nutrients and have potential nutraceutical value. [25] (Sharma, K. et al., 2019)

2.3 Health Benefits

The various biological activities and health benefits of *B. pinnatum* (Lam.) (**Figure. 2**) are associated with the presence of alkanes, alkanols, triterpenes and sterols [26] (Gaind, K.N., Gupta, R.L., 1972), triterpenoids and phenanthrenes [27] (Siddiqui, S. et al., 1989), flavonoids, bufadienolides, [28] (Yamagishi, T. et al., 1989) alkaloids, glycosides and lipids [29] (Devbhuti, D. et al., 2008) in various parts of this plant. The details of health benefits of this plant are discussed below.

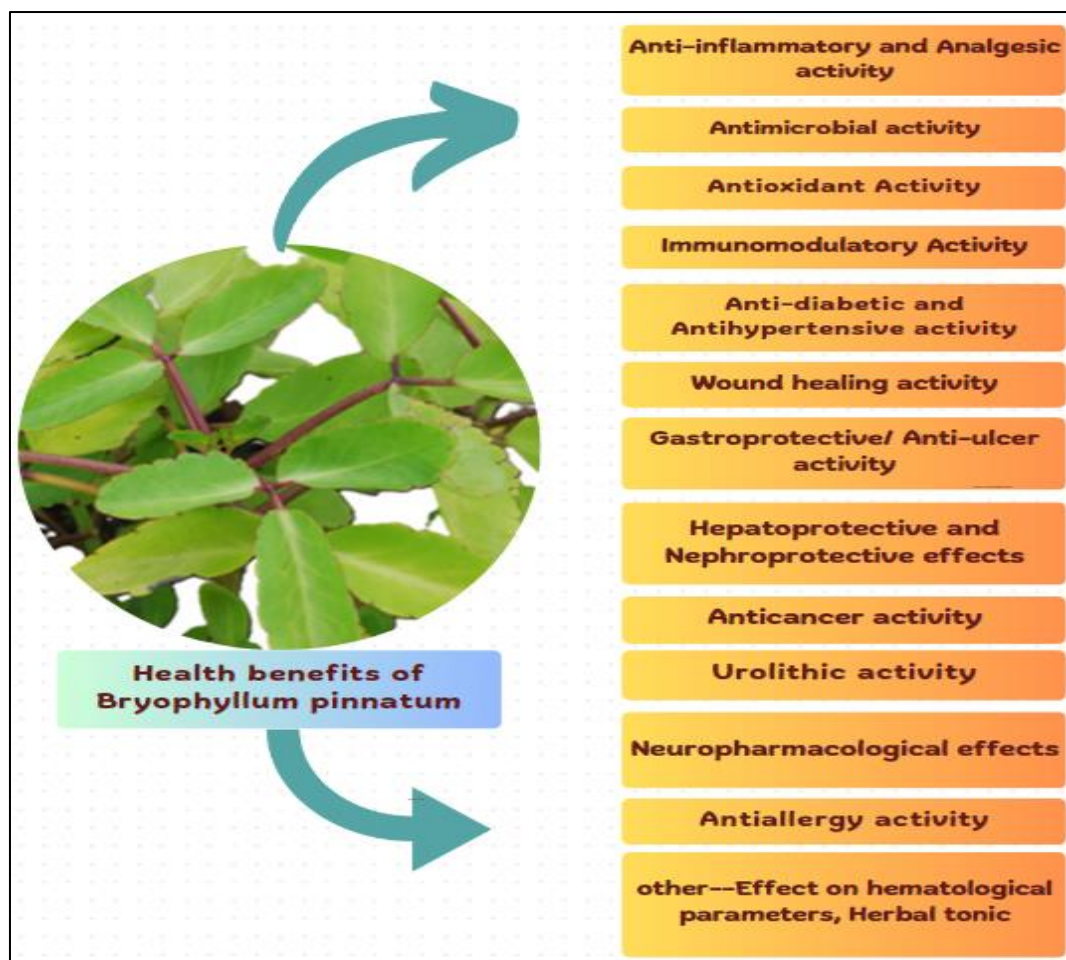


Figure 2 Health benefits of *Bryophyllum pinnatum* (Lam.)

2.4 Anti-inflammatory and Analgesic activity

The study has found that *B. pinnatum* (Lam.) is used for the anti-inflammatory and analgesic effects. It contains flavonoids which have ability to inhibit the cyclooxygenase enzyme and minimize the activity of α -tissue necrosis factor. In another study, from the leaves of *B. pinnatum*, a novel steroidal derivative has been separated and now its structure is also elucidated. In aqueous extract, this new steroidal compound was found to be active in reducing inflammation when tested by carrageenan induced rat paw edema and compared with diclofenac. Furthermore, it is also found that it has revealed 75.72% protection in analgesic activity when tested by mice, acetic acid induced writhing test, hence it has proven that aqueous extract of the plant has potent analgesic activity. Leaves ethanolic extract was proved to be effective against the topical acute and chronic inflammation which is due to cramming of the arachidonic acid pathway [22] (Latif, A. et al., 2019).

2.5 Antimicrobial activity

The *B. pinnatum* (Lam.) is also popular for its antimicrobial activity. The occurrence of phenolic component is responsible for its antimicrobial action. In a study, the plant's different crude extracts were analyzed for their antimicrobial effect and it was found that the extracts have broad spectrum anti-bacterial activity. Considerable antibacterial activity was confirmed against gram positive and gram-negative bacteria by the ethanolic extract of the plant. Methanolic extract of the roots was found to be effective against *S. aureus*, *P. aeruginosa* and *E. coli* but not effective against *C. albicans* [22] (Latif, A. et al., 2019)

2.6 Antioxidant Activity

In-vitro studies revealed that the *B. pinnatum* (Lam.) leaf extract possesses significant antioxidant as well as oxidative radical scavenging activities. In a study it was found that the aqueous leaf extract of *B. pinnatum* may have a nephroprotective effect in case of gentamicin-induced nephrotoxicity [24] (Khooshbu, P. et al., 2019). In another study, *B. pinnatum* (Lam.) was tested for its anti-oxidant activity by metal chelating assay, 1,1diphenyl-2-picrylhydrazyl

(DPPH) assay and 2,2'-azino-bis-(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) assay. Study outcomes have indicated that the ethanolic extract has marked anti-oxidant activity. Roots extracts have also exhibited the anti-oxidant effects when analyzed by DPPH assay [22] (Latif, A. et al., 2019)

2.7 Immuno-modulatory Activity

Studies have shown that the aqueous extract of *B. pinnatum* (Lam.) leaves have a significant inhibition of cell-mediated and humoral immune responses in mice in a model where spleen cells of animals were pre-treated with *B. pinnatum* leaf extract. A delayed-type hypersensitivity reaction to ovalbumin had been developed by intravenous and topical routes followed by intraperitoneal and oral routes. These indicated that the aqueous extract of *B. pinnatum* (Lam.) possesses an immunosuppressive activity. Recently, the protective effect of the leaves of *B. pinnatum* (Lam.) in fatal anaphylactic shock, likewise a Th 2 type T cell-driven immunopathology was reported. Oral protection in vivo was accompanied by a reduced production of IgE antibodies, reduced eosinophilia and impaired production of the IL-5, IL-10 and TNF- α cytokines. In-vitro, *B. pinnatum* prevented antigen induced mast cell degranulation and histamine release [23] (Padhi, A. et al., 2024)

2.8 Wound healing activity

The *B. pinnatum* (Lam.) is very also very popular for its wound healing properties. This plant is used topically for the healing of wounds in traditional therapeutics. It is proposed that the plant has saponins in huge amounts which promote wound healing by aggregating the erythrocytes. Moreover, tannins present in the plant also enhance the process of wound healing because of their astringent effect [22] (Latif, A. et al., 2019)

2.9 Gastroprotective and Anti-ulcer activity

B. pinnatum (Lam.) also possess gastroprotective effects and it has been verified by its striking dose dependent defensive effect on ethanol induced gastric injury. However, further studies should be carried out to validate its use in gastric ulcers [22] (Latif, A. et al., 2019). In a study it is found that it has a significant reduction in occurrence of ulceration and mean basal and histamine motivated gastrointestinal acid exudation in a dose reliant mode, therefore, modifying its apply as an antiulcer agent in tradition cure [24] (Khooshbu, P. et al., 2019)

2.10 Anti-diabetic activity

This plant is also well known for its antidiabetic effects. For many years, the plant has been utilized for its anti-hyperglycemic effects. The aqueous extract of leaves, after postprandial and streptozotocin induced diabetes in rats has exhibited striking hypoglycemic effects. Moreover, an advance investigation has confirmed its effectiveness in heart diseases and in diabetes [22] (Latif, A. et al., 2019)

2.11 Antihypertensive activity

Medicinal herb is been used for many year to treat various cardiovascular related disorders in folklore therapeutics. Studies have confirmed that aqueous extract of the leaves of this plant has an antihypertensive effect on rats and thus it justifies its use in folk medicines. It has been demonstrated that the extract has potent antioxidant effect on aorta thus plays a significant role in the lessening of blood pressure [22] (Latif, A. et al., 2019)

2.12 Urolithic activity

The medicinal herb is also been used for the treatment of renal stones in traditional medicines from ancient times. Studies have demonstrated that *B. pinnatum* (Lam.) leaves aqueous extract markedly decreases the level of urine oxalate and consequently it can be helpful in the cure of urolithiasis [7, 10, 30] (Prachi, Chauhan N et al., 2009; Zahid, I.H. et al., 2013; Yasir, F., Waqar, M.A., 2011). *B. pinnatum* (Lam.) has also been proven beneficial in the reduction of renal stones because it enhances the excretion of oxalate crystals by reducing the size of crystals and by converting them from dehydrate crystals to calcium oxalate monohydrate form [30] (Yasir F, Waqar MA, 2011). Further investigations have confirmed that the plant extracts protect the kidney cell from calcium oxalate crystals, oxidative stress and also lessened the formation of renal stones by increasing the solubility and excretion of these stones through the urine [22, 3] (Latif, A. et al., 2019, Selvakumar, P. 2022)

2.13 Hepatoprotective activity

The liquid extract of *B. pinnatum* (Lam.) has traditionally been utilized in Indian folk medicine for the treatment of jaundice [4] (Kamble, P. et al., 2024). The plant has been monitored for its hepatoprotective activity. In rats, carbon tetrachloride stimulated hepatic injury was induced and found that the ethanolic extract of the leaves reduces the levels

of liver enzymes, serum bilirubin, serum cholesterol and serum total protein [4, 22] (Kamble, P. et al., 2024; Latif, A. et al., 2019). Results have illustrated that the herb has an obvious hepatoprotective activity. Increased regeneration of hepatocytes and microsomal enzymes inhibition also defend the liver from damage [22] (Latif, A. et al., 2019)

2.14 Nephro-protective effects

B. pinnatum (Lam.) is widely used for its nephroprotective activity in folklore and the rationale behind its use has been proven by the studies. Results of an investigation have shown that this effect is dose dependent. In a study it is proved that due to the plant anti-oxidant and radical scavenging properties this plant has nephroprotective activity against the genatmicin induced nephro-toxicity in wistar rats [19] (Harlalka, G.V., 2007). In another study it is suggested that the juice of leaves is more effective in the cure of hyperactive bladder and has fewer side effects than anti-cholinergic drugs [22] (Latif, A. et al., 2019).

2.15 Neuropharmacological effects

B. pinnatum (Lam.) has been used since 1921 in predictable treatment as an antipsychotic mediator [24] (Khooshbu, P. et al., 2019). The presence of bufadienolides, a water-soluble component, is suggested as a potential cause for the central nervous system (CNS) depressing effect observed in the aqueous form of the leaf extract. Additionally, the plant has demonstrated sedative properties. Studies using the aqueous leaf extract revealed CNS depressive effects, with treated rats exhibiting reduced locomotor activity and decreased muscular tone when administered doses ranging from 50 to 200 mg/kg. Furthermore, the extract demonstrated a noticeable sedative effect, as demonstrated by a considerable decrease in impulsive behavior and the potentiation of pentobarbitone-induced sleep duration. These findings suggest that the aqueous leaf extract of *B. pinnatum* (Lam.) may have an impact on neurobehavioral activities, including sedation [4] (Kamble, P. et al., 2024).

2.16 Anti-allergy activity

B. pinnatum (Lam.) was found to reduce allergic responses in an in vitro research. Since mast cell degranulation is inhibited and histamine release is reduced, it has antiallergenic properties [3] (Selvakumar, P. 2022).

2.17 Anticancer activity

Leaf chloroform extract and its components reduced the growth of human testicular cancer cells. Apoptosis-associated protein electrolyte mobility shift assay were utilized to analyze human cervical carcinoma cells *in vitro*. Contaminants outperformed extracts in preventing cervical cancer [3] (Selvakumar, P. 2022).

2.18 Effect on hematological parameters

B. pinnatum (Lam.) ethanolic extract of the leaves has exhibited a marked effect on various hematological parameters i.e. it improves the hemoglobin level, packed cell volume and total white blood cell count [22] (Latif, A. et al., 2019).

2.19 Herbal tonic

Dietary fiber, niacin, and ascorbic acid are all found in the plant. This plant is used to cure prostate cancer as well as the common cold. *B. pinnatum* and other herb extracts in herbal compositions are said to operate as tonics, boosting health and respiration [3] (Selvakumar, P. 2022).

3. Side Effects of *Bryophyllum pinnatum* (Lam.)

Besides its various known benefits there may also be some side effects of this medicinal plant [23] (Padhi, A. et al., 2024), those are:

- **Gastrointestinal distress:** Some people may experience nausea; vomiting, or diarrhea after consuming *B. pinnatum* (Lam.).
- **Skin irritation:** Applying *B. pinnatum* (Lam.) topically can cause skin irritation or allergic reactions in some people.
- **Uterine contractions:** *B. pinnatum* (Lam.) has been traditionally used to induce labour and may cause uterine contractions in pregnant women. Therefore, pregnant women should avoid consuming this plant.
- **Lowers blood sugar:** *B. pinnatum* (Lam.) has been found to lower blood sugar levels, which can be dangerous for people with diabetes who are already taking medication to lower their blood sugar levels.

- **Interferes with blood clotting:** *B. pinnatum* (Lam.) contains compounds that can interfere with blood clotting, which may increase the risk of bleeding in people who are taking blood-thinning medications.

4. Conclusion

The various researches revealed that *Bryophyllum pinnatum* (Lam.) is a valuable medicinal plant used globally in traditional medicine. Different parts of this plant like leaves, stem and roots had been thoroughly used in traditional medicine in different areas around the world. It is a magical medicinal plant which is useful for treating several ailments, including kidney stones, hypertension, and abscesses and has been proven the properties like wound healing, anti-diabetic, antiulcer, hepato-protective, nephro-protective, antioxidant, immune-modulatory, anti-inflammatory, antimicrobial, anti-cancer activities. The plant parts contain several bioactive components such as flavonoids, phenolic components, sterols, alkaloids, saponin, triterpenoids, bufadenolides, organic acids, polysaccharides and vitamins which are thought to be responsible for most of the health benefits. These therapeutic benefits make this plant a promising, antioxidants and nutrient-enriched ingredient for effective uses as a nutraceutical and functional food.

Compliance with ethical standards

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Disclosure of conflict of interest

There is no conflict of interest.

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