International Journal of Pharmaceutical Research and Applications
Volume 10, Issue 01 Jan-Feb 2025, pp: 161-166 www.ijprajournal.com ISSN: 2456-4494

An Overview of Boerhaviadiffusa: Ethnobotany, Phytochemistry and Pharmacological Activities

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Date of Submission: 01-01-2025 Date of Acceptance: 10-01-2025

ABSTRACT
Boerhaviadiffusa (L.) also named as Punarnava is an important herbal medicine used in several traditional medical systems, such as Ayurveda, Unani, and Siddha. This plant has also been used for its therapeutic benefits especially against inflammatory diseases liver dysfunction and kidney diseases. In addition to its ethnobotanical heritage, due to its phytochemical profile, B. diffusa exhibits promising bioactive compounds such as alkaloids (e.g., punarnavine), flavonoids, glycosides, rotenoids, and phenolic compounds. These constituents are responsible for various pharmacological activities such as antioxidant, anti-inflammatory, hepatoprotective, nephroprotective, antimicrobial, and antidiabetic activities.
In spite of the historical use, and known activity of B. diffusa, additional studies are needed to detail the mechanisms of action of bioactive compounds, as well as the establishment of common B. diffusa preparations for therapeutic purposes. Combining traditional knowledge and modern scientific approach can be harnessed for exploring novel therapeutic agents from this precious medicinal plant. Up-and-coming research should investigate molecular mechanisms, novel drug delivery systems, and environmental elements playing a role in B. diffusa cultivation to warrant a continuous source of effective therapeutic compounds.
In summary, B. diffusa has considerable pharmacological potential that merits further investigation for medicinal applications. Due to its potential to adjust immune responses and its diverse biological functions, the plant has become significant in integrative medicine because of its application from traditional practice blended with modern scientific investigations.
Keywords: -Boerhaviadiffusa, phytochemistry, antioxidant, hepatoprotective,immunomodulatory

I. INTRODUCTION

Punarnava or Boerhavia diffusa L. (Family: Nyctaginaceae) is a perennial herbaceous flowering plant [1]. Punarnava literally means "one that restores or renews the body", signifying its high regard in traditional medicine systems, primary being Ayurveda. Its habitat extends throughout tropical and subtropical global latitudes, including areas of India, Africa, and the Americas, in nearly any variety of environment [2]. B. diffusa has been used for thousands of years in traditional medicine to treat various diseases. It is an herb known as a “Rasayana” in Ayurveda, meaning it is thought to reverse the aging process and help restore the body [3]. It is used as a remedy for jaundice, edema, dyspepsia, and abdominal disorders. It is one of the important ingredients in many herbal formulas due to its diuretic, hepatoprotective, and immunomodulatory activities [4]. And also, the leaves are eaten as a green vegetable in many parts of India, signifying its importance in nutrition and medicine.

One of the major alkaloids, punarnavine, has been isolated from the plant and has different pharmacological activities. Various substances like quercetin and kaempferol have been discovered, contributing to the plant's antioxidative forces. We show herein that nine new rotenoids were isolated together with one known compound from roots of M. boeravinone and named propagated according to the structural characteristics. Punarnavoside and other phenolics that the plant contains are responsible for its therapeutic effects [5,6].

The wide range of pharmacological activities is attributed to the diverse spectrum of phytochemicals present in the plant. Tons of studies have been performed to authenticate the conventional applications of B. diffusa, showing several pharmacological properties: Anti-inflammatory and Antioxidant: The herb has a considerable anti-inflammatory and antioxidant activities which gives assistance within the treatment of conditions associated with oxidative stress and inflammatory disorders [7].It has hepatoprotective properties as B. diffusa showed protection against several hepatotoxic agents,

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Volume 10, Issue 01 Jan-Feb 2025, pp: 161-166 www.ijprajournal.com ISSN: 2456-4494

validating its traditional use in liver diseases [8]. Nephroprotective: It has also been reported that the plant possesses diuretic properties and protects renal function, making it effective in the treatment of renal diseases [9].Antimicrobial: B. diffusahas been shown to have antimicrobial activity against different sorts of microbial pathogens, thus supporting its traditional use in the treatment of infectious diseases [7]. Evident Antidiabetic: The aforementioned plant has shown some activity as an antidiabetic agent that maybe reduces the level of blood glucose [10].Immunomodulatory: B. diffusa appeared to modulate the immune system, improving the body's defense mechanisms [11].

B. diffusais an exemplar of the rich encoded wisdom in traditional medicine practices. The massive pharmacological activities of B. diffusa are attributed to its rich ethnobotanical heritage, along with a diverse phytochemical profile [12]. Although the techniques of the traditional use of this plant have been corroborated with scientific studies, new research is needed to clarify the mechanisms of action of its bioactive compounds and to establish standardized preparations for use in therapeutic treatment. This unique synergy of traditional wisdom and scientific knowledge could lead to the identification of potential new therapeutic agents from this important medicinal plant.

II. ETHNOBOTANY

Punarnava (Boerhaviadiffusa), a biennial herbaceous herb of the Nyctaginaceae family, has played a vital role in holistic medicine because of its diversified ethnobotanical applications. Punarnava, which translates to “renewer” or “rejuvenator,” is a core part of traditional medicinal systems like Ayurveda, where it’s classified as a “Rasayana” herb due to its anti-aging and rejuvenating properties. It can be found in tropical and subtropical regions worldwide, including India, Africa, and the Americas, and grows in a wide range of habitats [7]. Due to its diuretic, hepatoprotective, and immunomodulatory ability, it has been used for hundreds of years in Eastern medicine as a treatment of jaundice, edema, abdominal disorders, and dyspepsia [7,13].As a rich source of numerous bioactive phytochemicals (including alkaloids, flavonoids, rotenoids, phenolic compounds), the plant contains an array of identified substances such as punarnavine, boeravinones, and quercetin, all of which are well-documented to hold the pharmacological activities observed [14].Several studies have demonstrated its antioxidant, anti-inflammatory, hepatoprotective, nephroprotective, antimicrobial, antidiabetic, and immunomodulatory properties, which confirmed its traditional uses: medicinal properties, health-promoting, and culinary use [7,15].In addition to this, the leaves of this plant are eaten as a vegetable in some areas, showing that it has some sort of nutritional value, not just medicinal. Although the mechanism of action of this plant still needs to be fully understood, the combination of the existing traditional knowledge of B.diffusa and modern pharmacology offers a good perspective to discover new therapeutic agents [16].

III. PHYTOCONSTITUENT AND THEIR PHARMACOLOGICAL EFFECT

B. diffusapossesses a diverse phytochemical profile, including numerous bioactive molecules, which give rise to its wide pharmacological activity. Alkaloids, flavonoids, rotenoids, glycosides, phenolic compounds, steroids, and lignans are some of the major classes of phytochemicals detected in B. diffusa, which together contribute to its therapeutic efficacy.

3.1. Flavonoids

B. diffusa contains flavonoids, including quercetin, kaempferol, and their glycoside forms. Such compounds have strong antioxidant, anti-inflammatory and hepatoprotective effects [17]. Pandey et al. (2005) investigated the hexane, chloroform, and ethanol extracts of B. diffusa, and isolated two compounds—Bd-I (eupalitin-3-O-β-D-galactopyranoside) and Bd-II (eupalitin) [18]. On a similar study Sharma et al. (2017) examined the leaf extract of B. diffusa and isolated the compounds quercetin 3-O-α-D-rhamnoside, eupalitin 3-O-β-Dgalactopyranoside, boeravinone B. [19].

3.2. Alkaloids

Boerhaviadiffusa is rich in a variety of alkaloids that contribute to its pharmacological effects. Some of the notable alkaloids found in B. diffusa include punarnavine is the most prominent alkaloid found in B. diffusa. It is a quinolizidine alkaloid and is primarily responsible for the plant's medicinal properties, including its antifibrinolytic, immunomodulatory, anticancer, and anti-inflammatory effects [6]. Hypoxanthine is another alkaloid present in B. diffusa, which has been shown to possess anti-inflammatory and antioxidant properties. Liriodendrin, another

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alkaloid present in B. diffusa, exhibits notable pharmacological activities, including anti-inflammatory effects. It is known for its role in reducing inflammation and is used in the treatment of inflammatory diseases [20].

3.3. Rotenoids

Rotenoids are one of the most distinctive classes of bioactive compounds found in B. diffusa. These compounds, particularly isolated from the roots, have been the subject of various studies due to their unique pharmacological properties, including antimicrobial, antioxidant, anti-inflammatory, and hepatoprotective effects. The most notable group of rotenoids isolated from B. diffusa are boeravinones, specifically Boeravinones A–J. These compounds are primarily found in the roots of the plant and have been shown to possess a wide range of biological activities. Boeravinones exhibit significant antioxidant, antibacterial, and cytotoxic effects [7,21]. Besides Boeravinone B, several other rotenoids isolated from B. diffusa have shown anti-inflammatory and antimicrobial properties. These compounds enhance the plant's therapeutic potential in managing conditions such as infections and chronic inflammatory diseases [20].

3.4. Glycosides

B. diffusacontains several glycosides, which are an important class of secondary metabolites responsible for many of the plant's therapeutic activities. Glycosides in B. diffusa contribute to its diuretic, anti-inflammatory, hepatoprotective, and antioxidant properties, making the plant a valuable medicinal resource. 3-O-β-D-glucopyranosyl sitosterol isolated by Sharma et al. (2017)[19].Punarnavoside is one of the major glycosides isolated from B. diffusa. It is known for its diuretic, anti-inflammatory, and hepatoprotective effects. Studies have shown that punarnavoside is responsible for much of the plant's therapeutic effects, particularly in treating kidney and liver disorders. The compound has been found to inhibit inflammation and protect against liver damage [17,22].Boerhaviamine, another glycoside found in B. diffusa, has shown significant hepatoprotective effects. This compound is thought to play a role in protecting liver cells from damage induced by toxic substances, which aligns with the plant's traditional use for liver ailments. Boerhaviamine is known for its antioxidant properties, which help in reducing oxidative stress within the liver [23,24].

3.5. Phenolic compounds

B. diffusais rich in various phenolic compounds that contribute to its diverse pharmacological activities, including antioxidant, anti-inflammatory, and hepatoprotective effects. These phenolic compounds are primarily responsible for the plant's ability to protect cells from oxidative stress and inflammation, which are central to many chronic diseases. Sharma et al. (2017) examined the leaf extract of B. diffusa and isolated the compounds uridine triacetateand β-sitosterol [19]. Punarnavoside is a prominent phenolic glycoside found in Boerhaviadiffusa. It is known for its anti-inflammatory, diuretic, and hepatoprotective properties. Punarnavoside has been shown to reduce oxidative stress and inflammation, which is particularly beneficial in treating conditions such as kidney and liver disorders [7,22]. Phenolic acids, including ferulic acid and caffeic acid, are also found in B. diffusa. These compounds are known for their antioxidant, anti-inflammatory, and hepatoprotective effects. Ferulic acid, in particular, has been shown to protect liver cells from oxidative damage and reduce the risk of liver diseases. Caffeic acid is similarly beneficial in preventing oxidative damage to cellular structures and supports anti-inflammatory activities, contributing to the plant's therapeutic uses in conditions such as liver cirrhosis and hepatitis [20,26].

3.6. Terpenes

B. diffusacontains various terpenoid compounds, which are known for their wide range of biological activities, including anti-inflammatory, antioxidant, antimicrobial, and anticancer properties. These compounds contribute significantly to the plant's pharmacological profile and are responsible for several of its therapeutic effects. Kaviya et al. (2022) examined the root ethanol extract of B. diffusaand identified and isolated the compounds like 2-(1,2-dihydroxyethyl)-5-[[2,5,7,8-tetramethyl -2-(4,8,12-trimethyltridecyl)-3,4-dihydrochromen-6-yl]oxy]oxolane-3,4-diol [27].β-amyrin and β-amyrin acetate two triterpenes isolated by Sharma et al. (2017) from the leave extract [19].

IV. FUTURE DIRECTION

Further studies on B. diffusa should also cover the molecular mechanisms of bioactive compounds (e.g., punarnavine and boeravinones), to signal high specific therapeutic paths because of their pharmacological activities. Which

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pharmacology collectively predicts: All its active principles are barrier-to-target kinetics because of their high rate of binding. Developed phytochemical separation techniques are expected to give maximum yield and consistency and efficacy. It is good to conduct preclinical and clinical trials to confirm its safety dosage and effectiveness compared to the compound possibility as hepatoprotective agent or nephroprotective.Nanoparticle drug delivery systems should be sufficient to boost the bioavailability and target specificity of the bioactive compounds. The antimicrobial character of the response to existing antibiotics and its positioning in the treatment of autoimmune diseases based on its immunomodulatory properties should be investigated. Environmental and growth studies will maintain the highest quality and output of therapeutic compounds. These areas of focus all reiterate the importance of positioning B. diffusa as modern pharmacology.

V. CONCLUSION

Punarnava (B. diffusa) is a powerful medicinal herb with an ancient history in traditional systems, including Ayurveda, Unani, and Siddha. The rich phytochemical composition of the entirety of the plant is responsible for the pencrafted pharmacological activities, including hepatoprotective, nephroprotective, antioxidant, anti-inflammatory, antimicrobial, and immunomodulatory properties. The therapeutic effects of these compounds in punarnava include punarnavine, flavonoids, glycosides, rotenoids, and phenolics, further substantiating its traditional uses like liver and kidney problems, inflammation, and oxidative stress. Despite being extensively studied and validated for a wide range of pharmacological benefits, there are still major unknowns surrounding its exact pathophysiological mechanisms, standardized preparations, and what would enable obtaining optimal doses. The insufficient clinical trial data has prevented its use from becoming established within modern pharmacotherapy. Future research should focus on molecular studies to explain its bioactive pathways and interactions and, thus, fully exploit its potential. Moreover, the advances in advanced drug delivery systems like nanoparticles can help in improving the bioavailability and target specificity of its bioactive constituents. From the other side, similar studies about environments and cultivation must be developed to provide a sustainable and quality supply of B. diffusa. Its ability to modulate the immune response also opens up avenues for potential application in autoimmune disease and immune health. Integrative medicine may hence utilize B. diffusaand its potential to connect traditional knowledge with modern science to address complex health challenges. Indeed, this plant represents an incredible wealth for the discovery of new drugs and treatment.

Consent for Publication
Not Applicable

Conflicts of Interest
The authors declare that there are no conflicts of interest, whether financial or otherwise.

Acknowledgements
The author greatly thankful to my respected guide, **Ms Chetna Tripathi**, Assistant Professor ofFaculty of Pharmaceutical Sciences,Mewar University, Chittorgarh and my Co-guide, **Md. Zulphakar Ali**, Assistant Professor ofFaculty of Pharmaceutical Sciences, Mewar University, Chittorgarh who supported and guided me for my project. Without their incisive feedback and steadfast encouragement, this work would not have been possible. I would like to pay my sincere gratitude to Mewar University, Chittorgarh for furnishing me with advice and as well as the necessary resources that is important to implement this project successfully.

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International Journal of Pharmaceutical Research and Applications
Volume 10, Issue 01 Jan-Feb 2025, pp: 161-166 www.ijprajournal.com ISSN: 2456-4494

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