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Pharmacological Insights into *Boerhavia Diffusa L.*: Traditional Therapeutic Uses, Phytochemistry, And Contemporary Pharmacological Evidence

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Abstract

Boerhavia diffusa L. (Family: *Nyctaginaceae*), commonly known as Punarnava, is an important medicinal herb widely used in traditional Ayurvedic medicine for the management of hepatic, renal, inflammatory, metabolic and immune-related disorders (Kaur, 2019). This species has regained renewed scientific interest, owing to the growing interest in plant-derived therapeutics, owing to the wide range of bioactive phytochemicals and varied pharmacological activities. The plant contains a variety of secondary metabolites such as alkaloids, flavonoids, rotenoids, lignans, steroids, glycosides, phenolic compounds and phytosterols which collectively contribute to its therapeutic potential. The experimental studies have shown significant anti-inflammatory, analgesic, hepatoprotective, nephroprotective, diuretic, antioxidant, antidiabetic, antimicrobial, immunomodulatory, anticancer, radioprotective, antihistaminic, anticonvulsant, antiulcer and adaptogenic properties. Several in vitro, in vivo and limited clinical studies have validated the pharmacological activities of B. diffusa. Boerhavia diffusa.can be a valuable source of novel therapeutic agents. Despite a large body of experimental evidence, there are still several challenges for standardization of plant extracts, identification of active phytoconstituents, elucidation of molecular mechanisms, pharmacokinetic characterization, toxicity evaluation and large-scale clinical validation. The existing literature is dispersed across various disciplines, making it difficult to achieve a complete understanding of the plant's pharmacological potential. This review critically summarizes the published evidence on ethnomedicinal importance,

phytochemical composition and pharmacological properties of Boerhavia diffusa. It also identifies the current research gaps and future perspectives for the translation of traditional knowledge into evidence-based therapeutic applications. The review highlights the importance of integrating phytochemical investigations, molecular pharmacology and clinical research to establish Boerhavia diffusa.as a scientifically validated medicinal plant for future pharmaceutical development.

Keywords: *Boerhavia diffusa*; Punarnava; Nyctaginaceae; Medicinal plants; Phytochemistry; Ethnomedicine; Antioxidant; Hepatoprotective; Immunomodulatory

1. Introduction

Medicinal plants have served as the foundation of traditional healthcare systems for thousands of years and continue to play a significant role in modern drug discovery(B, 2025; Oliveira et al., 2023, p. 221) Traditional systems like Ayurveda, Siddha and Unani are of the opinion that many plant species have therapeutic properties which can prevent and cure a wide spectrum of human ailments. In the last decades, the emergence of chronic diseases, antimicrobial resistance, adverse effects of synthetic drugs and the increasing public preference for natural products have increased the research on medicinal plants as safer and more effective therapeutic alternatives. Among these medicinal plants, Boerhavia diffusa L. species has been extensively studied due to its great ethnopharmacological importance and wide spectrum of pharmacology.

Punarnava (Boerhavia diffusa L.) is a member of the family Nyctaginaceae. It is a perennial creeping herb with thick taproot, diffusely branched stems, ovate leaves, small pinkish flowers and sticky one-seeded fruits (Das et al., 2023, p. 1297301; Kumar & Singh, 2025). The genus Boerhavia was named after the Dutch physician and botanist Hermann Boerhaave (1668–1738). The species epithet diffusa refers to its widely spreading habit. The plant is widely distributed throughout tropical and subtropical regions, including India, Sri Lanka, Africa, Southeast Asia, and South America, where it grows abundantly in cultivated fields, wastelands, roadsides, and grasslands.

Punarnava is considered a Rasayana (rejuvenating) herb in Ayurvedic medicine due to its capability of restoring physiological balance and enhancing vitality (Mondal et al., 2024; Pandey, 2025, p. 2) The Sanskrit word “Punarnava” literally means “becoming new again.” Traditionally, it’s believed that the plant helps to rejuvenate the body’s tissues and promote longevity. Classical Ayurvedic texts recommended Punarnava for treatment of edema, liver disorders, urinary diseases, inflammation, arthritis, ascites, anemia, respiratory disorders and various metabolic abnormalities. Due to its wide therapeutic applications, the plant has been an essential ingredient in many classical Ayurvedic formulations for centuries. Phytochemical studies revealed the presence of a variety of biologically active secondary metabolites in the roots, stems, leaves, flowers and seeds of B. diffusa.(Y. Kumar et al., 2025; S. Kumar & Singh, 2025) Major constituents are alkaloids (especially punarnavine), rotenoids (boeravinones), flavonoids, lignans, steroids, glycosides, xanthones, phenolic compounds, amino acids, carbohydrates, fatty acids and phytosterols. These phytochemicals have multiple

biological activities via antioxidant, anti-inflammatory, immunomodulatory, enzyme-regulatory and cytoprotective mechanisms. The synergistic interaction between these compounds is thought to be the foundation of the plant's extensive pharmacological potential (Mubeen et al., 2025; Rarison et al., 2023)

During the last 50 years, several traditional claims of Boerhavia diffusa.have been scientifically proved and studied. Experimental studies have shown significant analgesic, anti-inflammatory, hepatoprotective, nephroprotective, diuretic, antioxidant, antimicrobial, antiviral, immunomodulatory, antidiabetic, anticancer, antiulcer, antihistaminic, anticonvulsant, adaptogenic, radioprotective, hypolipidemic, antiosteoporotic and antimetastatic activities(Alhazmi et al., 2021, p. 637567; Mehta et al., 2021) These pharmacological effects are mainly due to the presence of various phytochemicals in the plant and its ability to modulate oxidative stress, inflammatory mediators, immune responses, apoptosis and several cellular signaling pathways. Although many studies on individual pharmacological properties of Boerhavia diffusa.have been published, literature is still scattered in various disciplines. Variations in extraction methods, plant parts used, phytochemical composition, experimental models, dosage regimens, and outcome measures have led to inconsistencies in efficacy and mechanisms of action. Moreover, most of the published studies are laboratory based and well-designed clinical trials, standardized formulations, pharmacokinetic analyses and long term safety assessments are lacking comparatively. Thus, a full synthesis of the current scientific evidence is needed to consolidate the current knowledge and to identify the future research priorities. The current review aims at a critical appraisal of the traditional therapeutic uses, phytochemistry and experimentally established pharmacological actions of Boerhavia diffusa. It further highlights significant knowledge gaps that need to be bridged to enable the development of standardised evidence-based phytopharmaceuticals from this medicinal plant.

2. Research Gap and Problem Statement

Pharmacological studies have well established the therapeutic potential of Boerhavia diffusa, however, major gaps in the research still exist that limit its clinical translation. First, most of the published work is based on in vitro experiments or animal models, and high-quality randomized clinical trials that evaluate efficacy and safety in human populations are still limited. Thus, definitive clinical recommendations for the therapeutic application of Boerhavia diffusa.cannot be determined yet. Second, the methods of extraction, solvent systems, geographical origin of plant material, harvesting season and plant parts used vary greatly. The phytochemical composition and biological activity of these factors are significantly affected, leading to inconsistent results in different investigations. Third, although many bioactive compounds such as punarnavine, boeravinones, flavonoids and phenolic constituents are isolated, the exact molecular mechanisms behind many pharmacological activities are not well known. Further research including genomics, metabolomics, proteomics, molecular docking and system pharmacology is required to identify target specific mechanisms. Fourth, there are insufficient comprehensive pharmacokinetics studies on absorption, distribution, metabolism, excretion, herb–drug interactions, and long-term toxicity. Such investigations are necessary prior to the development of standardised pharmaceutical formulations for clinical use. Finally, most review articles have been focused

on single pharmacological activities, instead of integrating traditional medicinal knowledge, phytochemistry, pharmacological evidence, mechanistic insights and future clinical applications into one comprehensive framework. This fragmentation does not allow a holistic understanding of the therapeutic potential of Boerhavia diffusa.

Problem Statement

Despite centuries of traditional use and increasing scientific evidence for the pharmacological potential of Boerhavia diffusa, the available literature is scattered, heterogeneous and non-standardized. Inconsistencies introduced by differences in experimental methodologies, phytochemical characterization, extract preparation and biological evaluation hamper comparison between studies and evidence-based clinical application.
The poor integration of traditional ethnomedicinal knowledge with modern pharmacological and phytochemical studies has limited the translation of laboratory findings to therapeutic practice. Therefore, a comprehensive review is needed to systematically organize the existing evidence, critically evaluate the current scientific knowledge, identify the deficiencies in research and provide future directions for the development of standardized phytopharmaceuticals and conduct rigorous clinical investigations on Boerhavia diffusa.

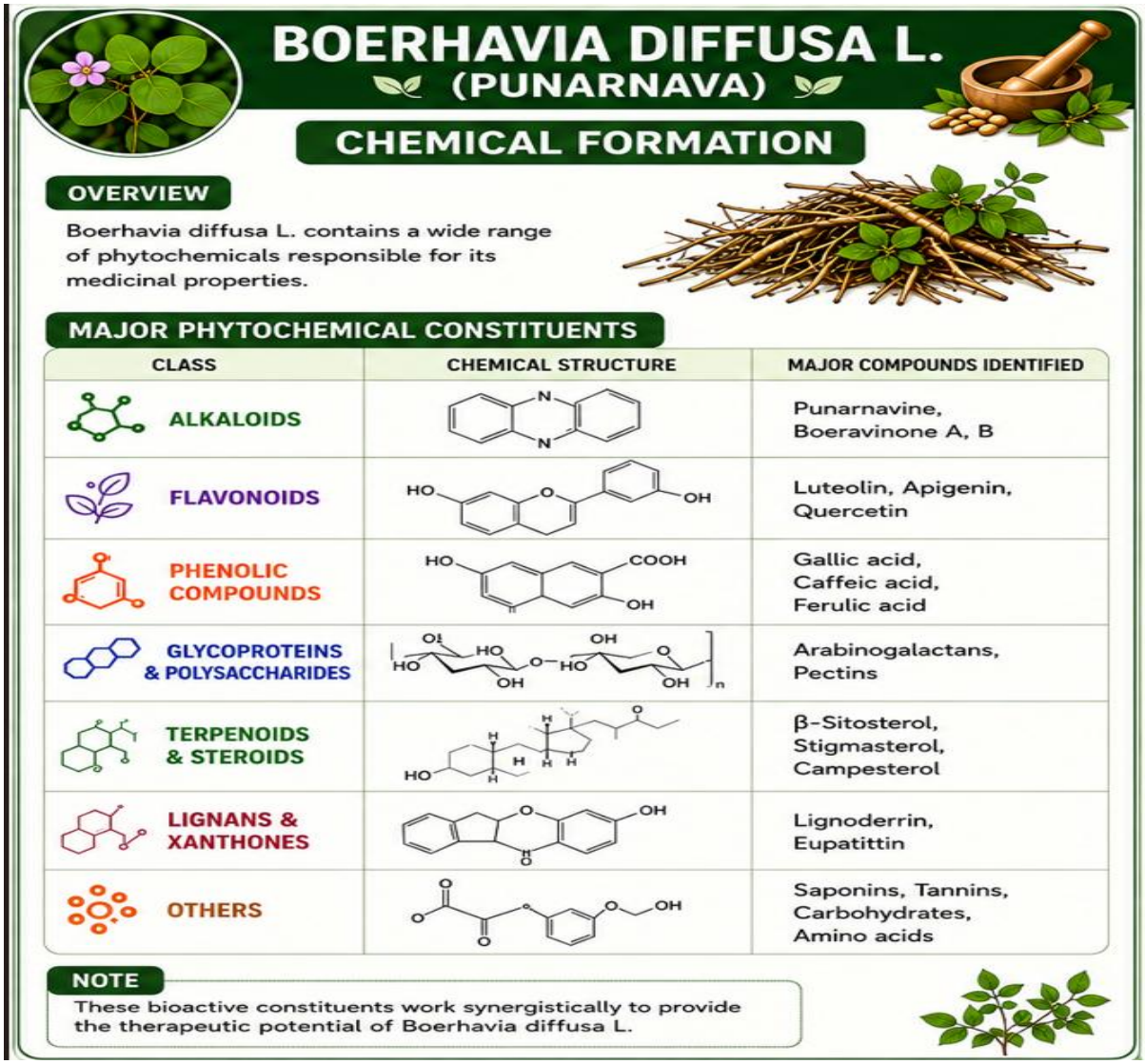
3. Review of Literature

The following review is based on the studies cited in your uploaded manuscript and reorganized into a chronological and thematic sequence. The chronology follows the publication years of the cited studies within each topic while retaining the evidence presented in your source document.

S. No.	Country/Region	Local/Common Name	Plant Part Used	Traditional Medicinal Use	Ethnomedicinal System	Key Reference(s)
1	Bangladesh	Punarnava	Leaves, root	Dysentery, jaundice, digestive disorders	Traditional medicine	Regional ethnobotanical reports
2	Brazil	Erva-tostão	Leaves	Pain, inflammation, liver disorders	Folk medicine	(Hiruma-Lima et al., 2000)
3	Brazil	Erva-tostão	Whole plant	Rheumatism and arthritis	Traditional medicine	Brazilian ethnopharmacological studies
4	Caribbean Islands (Martinique)	Local herb	Leaves	Analgesic and anti-inflammatory agent	Folk medicine	(Hiruma-Lima et al., 2000)
5	China	Imported medicinal herb	Whole plant	Anti-inflammatory and nephroprotective herbal formulations	Traditional Chinese herbal practice	Modern pharmacognosy reports

6	Côte d'Ivoire	Local medicinal herb	Root	Asthma and respiratory disorders	Traditional medicine	Irie-N Guessan et al. (2011)
7	Ethiopia	Local herb	Whole plant	Gastrointestinal infections	Indigenous medicine	Ethiopian ethnobotanical surveys
8	Ghana	Local herb	Leaves	Wounds, boils, skin diseases	Traditional medicine	West African ethnobotanical reports
9	India	Punarnava	Root, whole plant	Edema, liver disorders, kidney diseases, ascites, jaundice, anemia, diabetes, arthritis	Ayurveda	Chopra et al. (1956); Singh & Udupa (1972); (Agrawal et al., 2011)
10	India	Punarnava	Leaves	Wound healing, inflammation, skin infections	Folk medicine	(Agrawal et al., 2011)
11	India	Punarnava	Root	Urinary tract disorders and nephritis	Ayurveda	(Rawat et al., 1997)
12	Indonesia	Local name	Leaves	Skin infections and wounds	Jamu medicine	Indonesian medicinal plant surveys
13	Jamaica	Hogweed	Whole plant	Hypertension, kidney disorders	Traditional medicine	Caribbean medicinal plant literature
14	Kenya	Hogweed	Whole plant	Fever, urinary disorders	Traditional medicine	African ethnobotanical surveys
15	Malaysia	Local herb	Whole plant	Liver diseases and inflammation	Malay traditional medicine	Regional ethnobotanical reports
16	Mexico	Yerba rastrera	Whole plant	Diuretic and stomach ailments	Folk medicine	Mexican ethnobotanical reports
17	Nepal	Punarnava	Whole plant	Diuretic, fever, stomach disorders	Traditional medicine	Ethnobotanical surveys
18	Nigeria	Hogweed	Root	Epilepsy and convulsive disorders	Traditional African medicine	(Adesina, 1979)
19	Nigeria	Hogweed	Whole plant	Malaria, fever, gastrointestinal disorders	Folk medicine	(Adefokun et al., 2015)

20	Pakistan	Itsit	Root	Kidney stones, edema, urinary infections	Unani medicine	Regional medicinal plant surveys
21	Peru	Local herb	Whole plant	Renal disorders, edema	Amazonian traditional medicine	Ethnobotanical surveys
22	Philippines	Local herb	Root	Diuretic and urinary tract disorders	Folk medicine	Philippine medicinal plant literature
23	South Africa	Spiderling	Whole plant	Gastrointestinal disorders and infections	Indigenous medicine	African herbal medicine reports
24	Sri Lanka	Sarana	Whole plant	Liver disorders, urinary diseases, inflammatory conditions	Ayurveda	Sri Lankan Ayurvedic literature
25	Tanzania	Local name	Root	Diuretic and kidney disorders	Traditional medicine	East African medicinal plant literature
26	Thailand	Local medicinal herb	Whole plant	Fever, urinary diseases	Traditional Thai medicine	Southeast Asian ethnobotanical reports
27	Trinidad and Tobago	Local herb	Whole plant	Diabetes and inflammatory diseases	Folk medicine	Caribbean ethnomedicine
28	Uganda	Local medicinal herb	Leaves	Wounds and skin diseases	Traditional medicine	East African medicinal plant surveys
29	Worldwide (Herbal medicine)	Punarnava	Root and whole plant	Hepatoprotective, nephroprotective, antioxidant, immunomodulatory, antidiabetic, anti-inflammatory herbal formulations	Complementary and Integrative Medicine	Nayak & Thirunavoukkarasu (2016); Salman Khan et al. (2013)
30	Zimbabwe	Local herb	Whole plant	Fever and urinary disorders	Traditional medicine	African ethnobotanical reports



3.1 Traditional Uses of *Boerhavia diffusa*

Boerhavia diffusa L. commonly known as Punarnava is a herb of great importance in traditional Indian medicine since centuries. Mentioned in classical Ayurvedic literature as a rejuvenating ('Rasayana') herb used in management of edema, liver disorders, urinary tract diseases, inflammation, arthritis, anemia, respiratory ailments, ascites and gastrointestinal disorders. The different parts of the plant such as root, leaf, stem and whole plant are used in different Ayurvedic formulations due to their diuretic, hepatoprotective, anti-inflammatory and restorative properties. Chopra et al. (1956) in their early scientific documentation, reported the extensive ethnomedicinal uses of Punarnava and identified it as an important medicinal species in Indian traditional medicine. Later, Singh and Udupa (1972) demonstrated its successful use in nephrotic syndrome and helminthic infections, confirming many of its traditional claims. In the following decades, many pharmacological studies confirmed several of the ethnomedicinal uses, in particular for renal, hepatic, inflammatory and metabolic disorders. Recently, (Agrawal et al., 2011; Salman Khan et al., 2013; Nayak and Thirunavouk karasu, 2016) reviewed the traditional knowledge with experimental evidence and validated the fact that many classical therapeutic claims are substantiated by the modern pharmacological studies.

3.2 Phytochemical Constituents

The rich phytochemical composition of Boerhavia diffusa.is considered to be the main source of its pharmacological potential. During the decades of investigation many secondary metabolites have been identified from different plant tissues.
Initial phytochemical investigations were mainly concerned with the alkaloids and steroidal constituents responsible for the medicinal activity of the plant. Later studies identified several biologically active rotenoids called boeravinones, flavonoids, lignans, glycosides, xanthones, phenolic compounds, amino acids, carbohydrates, fatty acids, phytosterols and essential minerals. Among these constituents, punarnavine, boeravinones A-H, eupalitin-3-O-β-D-galactopyranoside, liriodendrin and various flavonoids have attracted much attention of scientists due to their diverse pharmacological properties.

In the 1990s, additional rotenoids and flavonoids with immunomodulatory and anticancer activities were identified by researchers. The identification of boeravinones G and H as inhibitors of breast cancer resistance protein has further stimulated interest in the plant's chemotherapeutic potential. Recent metabolomic studies have shown a broader spectrum of antioxidant phenolics and flavonoids, indicating a collective effect of multiple phytochemicals instead of a single bioactive compound. These results suggest the therapeutic efficacy of Boerhavia diffusa.is due to combined action of several groups of phytochemicals acting through several molecular pathways.

3.3 Pharmacological Activities

3.3.1 Analgesic and Anti-inflammatory Activity

Anti-inflammatory activity was one of the earliest pharmacological properties studied in B. diffusa. The aqueous and acetone root extracts of the plant significantly reduced the carrageenan-induced oedema and formaldehyde-induced arthritis in experimental animals (Bhalla et al., 1971). Mudgal (1974) later reported that maximum anti-inflammatory activity was obtained from the extracts of roots, stem, leaves and flowers during rainy season indicating seasonal variation in therapeutic efficacy. In the decades that followed, research grew. The fresh leaf juice has been shown to exhibit significant antinociceptive activity through central analgesic mechanisms (Hiruma-Lima et al., 2000). Later studies showed inhibition of cyclooxygenase (COX-1), suppression of inflammatory mediators, reduction of bacterial induced renal inflammation, and improvement of inflammatory lesions in experimental pyelonephritis. More recent reviews have concluded that the anti-inflammatory properties of Boerhavia diffusa.and its traditional use for inflammatory disorders are due to the presence of flavonoids, rotenoids and phenolic compounds in general (Agrawal et al., 2011).

3.3.2 Hepatoprotective Activity

The scientific evaluation of hepatoprotective activity was started in early 1970. The protective effect of Boerhavia diffusa.root extracts against chemically induced liver injury was first reported by Surange and Pendse (1972). Further studies of (Chakraborti & Handa, 1989) observed significant reductions in serum SGOT, SGPT and alkaline phosphatase levels in carbon tetrachloride induced hepatotoxicity.

In the 1990s, Chandan et al. (1991) and Rajkumari et al. (1991) reported that alcoholic extracts of roots and whole plant restored the normal liver function by reducing the elevated serum

enzymes and improving the bile secretion. Rawat et al. (1997) also showed that hepatoprotective activity depended on root size, season of harvest and dosage form, and that aqueous preparations were more effective than the powdered materials. Protection against ethanol and paracetamol-induced hepatic injury was demonstrated in further studies by restoration of antioxidant enzymes and reduction of histopathological liver damage (Devaki et al., 2005; Venkatalakshmi et al., 2011). The main hepatoprotective phytochemicals responsible for antioxidant and membrane-stabilizing effects were recently found to be rotenoids, flavonoids and steroidal constituents.

3.3.3 Diuretic and Nephroprotective Activity

One of the oldest scientifically validated therapeutic activities of Boerhavia diffusa.is its diuretic property. Chowdhury and Sen (1955) reported that after administration of plant extracts, urine output increased and renal enzyme activity was modulated. Mudgal (1974) reported that the diuretic activity was seasonal, and the highest activity was found in the roots collected in the rainy season. Further studies have confirmed the plant's ability to promote sodium excretion while maintaining potassium balance, thus justifying its traditional use in oedema, nephritis, ascites and renal insufficiency. Experimental studies have also demonstrated therapeutic efficacy against E. coli-induced pyelonephritis, urolithiasis, nephrotic syndrome and chronic renal inflammation. Recent studies have demonstrated nephroprotective mechanisms by antioxidant defense, attenuation of oxidative stress, stabilization of renal cellular architecture and enhancement of renal biochemical markers which may be useful in chronic kidney diseases.

3.3.4 Adaptogenic and Antistress Activity

Interest in B' diffusa adaptogenic effects emerged in the late twentieth century. Alkaloidal fractions normalized plasma cortisol, improved antibody production and normalized glucose and lipid metabolism in stress conditions (Mungantiwar et al. 1997).

Sumanth and Mustafa (2007) subsequently reported enhanced carbon clearance, leukocytosis and stimulation of the reticuloendothelial system which are indicative of increased nonspecific immunity. Later studies have concluded that flavonoids, alkaloids, sterols and glycosides contribute synergistically to the plant's adaptogenic activity, supporting its traditional use as a rejuvenating herb.

3.3.5 Immunomodulatory Activity

The finding of the alkaloid punarnavine has enhanced immunomodulatory research. (Mungantiwar et al., 1999) first demonstrated that alkaloidal fractions had a significant effect on antibody production and delayed hypersensitivity responses in experimental animals. Ethanolic root extracts were found to inhibit NK-cell cytotoxicity, nitric oxide production and cytokine secretion (Mehrotra et al., 2002). Subsequently, eupalitin-3-O-β-D-galactopyranoside was isolated by (Pandey et al., 2005) that showed significant immunosuppressive activity by inhibiting the proliferation of peripheral blood mononuclear cells and production of inflammatory cytokines. Later studies by Manu and Kuttan (2009) indicated that purified punarnavine increased bone marrow cellularity, splenocyte proliferation and immune-cell activation, and decreased pro-inflammatory cytokine production, suggesting possible therapeutic uses in autoimmune and inflammatory diseases.

3.3.6 Antidiabetic Activity

Diabetes mellitus is one of the most common metabolic diseases worldwide. Antihyperglycemic property of medicinal plants has been extensively studied. Boerhavia diffusa has attracted significant interest for its anti-diabetic activity that involves modulation of glucose metabolism, improvement in pancreatic function and reduction in oxidative stress associated with diabetes. One of the earliest studies was conducted by (Elayasuriyan, 2017) who demonstrated that root extracts significantly reduced blood glucose levels and serum cortisol concentrations in dexamethasone-induced diabetic rats. During the same period, (Pari & Satheesh, 2004) reported that aqueous leaf extracts (200 mg/kg body weight) significantly reduced the blood glucose, but increased the hepatic hexokinase activity and decreased the glucose-6-phosphatase and fructose-1,6bisphosphatase activities in alloxan induced diabetic rats. The results suggested an increased glucose utilization and a decreased hepatic gluconeogenesis. Later on, (Nalamolu et al., 2004) showed dose dependent antihyperglycemic activity of chloroform leaf extracts in streptozotocin induced diabetic rats. The authors proposed that extrapancreatic mechanisms and regeneration of pancreatic β-cells could be possible explanations for the observed effects. Later Bhatia et al. (2011) showed that methanolic and ethanolic extracts significantly decreased hyperglycemia, restored body weight and normalized food and water intake in diabetic experimental animals.
The antidiabetic activity of B.diffusa has been attributed to multiple mechanisms such as enhancement of insulin secretion, improvement of insulin sensitivity, inhibition of oxidative stress, regeneration of pancreatic β-cells, modulation of carbohydrate-metabolizing enzymes and suppression of inflammatory mediators associated with diabetes (Agrawal et al., 2011).

3.3.7 Antioxidant Activity

Oxidative stress is an important factor in the pathogenesis of several chronic diseases such as diabetes, cardiovascular diseases, neurodegenerative diseases, cancer and aging. Consequently, a lot of research has been conducted on the antioxidant potential of Boerhavia diffusa. Initial evidence was provided by studies showing inhibition of lipid peroxidation and free radical scavenging activities (Gordon, 1990; Harman, 1992). Later studies of Devaki et al. (2005) indicated restoration of endogenous antioxidant enzymes during experimentally induced hepatotoxicity.

Rachh et al. (2009) found that the ethanolic extracts had higher antioxidant activity than the methanolic extracts. The same period Premkumar et al. (2010) showed that aqueous leaf extracts significantly enhanced cellular antioxidant defense systems . Administration of leaf extracts to diabetic rats resulted in a decrease in the level of thiobarbituric acid reactive substances and hydroperoxides and an increase in the activities of glutathione, catalase, superoxide dismutase, glutathione peroxidase and glutathione-S-transferase (Satheesh & Pari, 2004). The most detailed evaluation was reported by Juna Beegum et al., 2016 who confirmed significant scavenging activity against DPPH, nitric oxide and reactive oxygen species. Their study also found that leaf extracts had higher antioxidant potential than root extracts. Taken together these results show that phenolic compounds, flavonoids and rotenoids are important contributors to the antioxidant potential of Boerhavia diffusa.and thereby protect cellular macromolecules from oxidative damage.

3.3.8 Antimicrobial Activity

The antimicrobial properties of *Boerhavia diffusa* have been investigated against numerous bacterial and fungal pathogens.

Olukoya et al. (1993) first reported broad-spectrum antibacterial activity against *Neisseria gonorrhoeae*, *Salmonella typhimurium*, *Shigella dysenteriae*, *Clostridium tetani*, and *Corynebacterium diphtheriae*. Subsequent investigations by (Agrawal et al., 2005) demonstrated antifungal activity against dermatophytic fungi.

Later studies by **Girish and Satish (2008)** showed inhibitory activity against several clinically important bacteria, including *Escherichia coli*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Proteus mirabilis*, *Salmonella typhi*, and *Klebsiella* species. **Desai et al. (2011)** further demonstrated that ethanolic and aqueous extracts exhibited antibacterial activity against both Gram-positive and Gram-negative organisms.

Recent investigations attribute the antimicrobial activity primarily to flavonoids, alkaloids, phenolic compounds, and glycosides that interfere with microbial cell wall integrity, enzyme systems, and oxidative metabolism. These findings support the traditional use of *Boerhavia diffusa.*for treating infectious diseases.

3.3.9 Antiviral Activity

Scientific data on the antiviral activity are still relatively limited. But, Lohani et al. (2007) demonstrated antiviral activity against phytopathogenic viruses (Singh et al., 2021, p. 55930) but significant biological activity of Boerhavia diffusa.was described. They identified a glycoprotein (16-20 KD) which can induce systemic resistance in tobacco plants. Later reviews have determined that the antiviral activity against plant viruses has been well documented, however studies with human viral pathogens are still limited. Therefore, more molecular and clinical studies are needed to evaluate the antiviral potential of Boerhavia diffusa.against important medically viruses.

3.3.10 Anticancer, Antiproliferative, and Antimetastatic Activity

The bioactive rotenoids isolated from Boerhavia diffusa attracted considerable interest for its anticancer potential. Hydroalcoholic extracts strongly suppressed lung metastasis of B16F10 melanoma cells in mice (Leyon et al., 2005), and improved survival and reduced biochemical indicators of neoplastic growth. (Ahmed-Belkacem et al., 2007) later found boeravinones G and H as powerful inhibitors of breast cancer resistance protein (ABCG2), hinting to prospective uses in combating multidrug resistance. (Mehrotra et al., 2002) and (Sreeja & Sreeja, 2009) showed antiproliferative effects on many human cancer cell lines including breast and cervical cancer cells. Ethanolic root extracts were cytotoxic to tumor cells (Srivastava et al. 2005) by around 30–40% and validated reduction of HeLa cell growth (Srivastava et al. 2010). Recent reviews suggest that anticancer activity of Boerhavia diffusa.is mediated through induction of apoptosis, angiogenesis inhibition, suppression of matrix metalloproteinases, immunomodulation, antioxidant activity and interference with cancer cell proliferation pathways and the plant has good promise for future chemotherapeutic research.

3.3.11 Radioprotective Activity

Radioprotective investigation was first carried out by Thali et al., (1998) and they showed protection against radiation induced hematopoietic injury in experimental animals by restoring hemoglobin concentration and erythrocyte count.

Manu et al. (2007) later reported that hydroalcoholic extracts reduced tissue damage induced by gamma radiation and increased survival. These findings indicate that the radioprotection involves antioxidant activity, immunomodulation and stimulation of endogenous defense mechanisms. However, further studies are needed before clinical application can be considered, although promising.

3.3.12 Antiulcer Activity

The gastroprotective action of *Boerhavia diffusa*.has been studied in experimental ulcer models. (Gharate & Kasture, 2012) exhibited a substantial reduction in ulcer index and enhanced gastrointestinal protection after the administration of plant extracts. The antiulcer action was ascribed to antioxidant effects, decrease of stomach acidity, improvement of mucosal defense and inhibition of inflammatory mediators. These results justify the traditional usage of Punarnava in gastrointestinal diseases.

3.3.13 Antihistaminic Activity

Another major conventional indication of *Boerhavia diffusa*.is respiratory problems. Ethanolic root extracts of Suralkar et al. (2012) reduced histamine-induced contraction of isolated goat tracheal preparations and greatly delayed pre-convulsive dyspnea time in guinea pigs. These results imply bronchodilatory and antihistaminic qualities which may be beneficial in allergic asthma and other hypersensitivity conditions.

3.3.14 Anticonvulsant Activity

Boerhavia diffusa has been used traditionally in Nigeria for treatment of epilepsy. Anticonvulsant action of root extracts was initially reported by (Adesina 1979). Lami et al. (1991) identified a calcium channel antagonist, liriodendrin, which was held responsible for the anticonvulsant activity of the plant.

More recently, anticonvulsant effect in experimental seizure models was validated by Goel and Kaur (2011) and calcium channel blockage was indicated as the key mechanism. These studies validate the ethnomedicinal use of *Boerhavia diffusa*.in neurological diseases.

3.3.15 Hypolipidemic Activity

Hyperlipidemia is a major risk factor for cardiovascular disease. Khan et al. (2011) proved that Boerhavia diffusa.treatment dramatically lowered the levels of total cholesterol, triglycerides, low-density lipoprotein cholesterol, verylow-density lipoprotein cholesterol, and malondialdehyde, while elevating the high-density lipoprotein cholesterol. Later, Iqbal et al. (2012) validated protection from oxidative alteration of low-density lipoproteins and erythrocytes. The data found indicate that the antioxidant activity of the plant and its modulation of lipid metabolism mediate the cardioprotective benefits.

3.3.16 Antiosteoporotic Activity

Research on immune modulation and osteoporosis led to studies on Boerhavia diffusa. Li et al. (1996) found immunoregulatory systems involved in the metabolism of bone. Following this idea, (Pandey et al., 2005) discovered eupalitin-3-O-β-D-galactopyranoside showing immunosuppressive and antiosteoporotic effects. Recent reviews reveal that regulation of inflammatory cytokines, suppression of osteoclast development and antioxidant activity may jointly contribute to the antiosteoporotic potential of B. diffusa. Nevertheless, clinical validation is limited.

3.3.18 Other Biological Activities

In addition to the pharmacological properties described above, *Boerhavia diffusa* exhibits several other biologically significant activities. **Singh et al. (1991)** demonstrated the absence of teratogenic effects following administration during pregnancy in experimental animals, suggesting a favorable safety profile under the investigated conditions.

Deshmukh et al. (1982) reported insecticidal activity associated with ecdysone isolated from the roots. Earlier investigations by **Singh and Udupa (1972)** demonstrated antihelminthic activity against intestinal parasites. Furthermore, (Borrelli et al., 2006) identified boeravinone E as a potent spasmolytic compound capable of reducing intestinal smooth muscle contraction through calcium-dependent mechanisms. Collectively, these findings further broaden the therapeutic spectrum of *Boerhavia diffusa* and reinforce its importance as a multipurpose medicinal plant in traditional and modern pharmacology.

4. Discussion

Boerhavia diffusa L. is one of the most studied medicinal plants because of its vast range of pharmacological properties and long history of usage in traditional Ayurvedic medicine . The whole data examined in this study indicates that the plant has substantial therapeutic potential against inflammatory, hepatic, renal, metabolic, infectious, immune-mediated and neoplastic illnesses. Experimental investigations in the last few decades have consistently shown that the biological activities of Boerhavia diffusa.are associated with its diverse phytochemical composition including alkaloids, flavonoids, rotenoids, lignans, phenolic compounds, glycosides, steroids and phytosterols. A chronological review of the published research indicates a progressive increase in scientific understanding. The early work in the 1950s and 1970s concentrated on proving the traditional assertions of diuretic, anti-inflammatory and hepatoprotective effects. These investigations provided the pharmacological basis for later studies that demonstrated considerable therapeutic results in experimental animal models. During the 1980s and 1990s, research widened to encompass nephroprotective, anticonvulsant, immunomodulatory and antioxidant effects, and the isolation of various bioactive compounds clarified the phytochemical foundation of these actions. Since the early 2000s, advances in molecular biology, immunology and analytical chemistry have enabled scientists to study more complex pharmacological mechanisms, such as cytokine regulation, induction of apoptosis, antioxidant signalling pathways, inhibition of matrix metalloproteinase and modulation of multidrug-resistance.

Among the documented pharmacological actions, the majority of experimental studies suggest hepatoprotective and nephroprotective effects. Several investigations have showed that the treatment of *Boerhavia diffusa*.extracts consistently resulted in a decrease of serum hepatic enzymes, restoration of antioxidant enzyme activities, improvement in histopathological architecture, and normalization of renal biochemical parameters. These results justify the traditional use of Punarnava in liver and renal problems and show that antioxidant and anti-inflammatory pathways are major processes involved in tissue protection. Several studies have revealed the potent diuretic effect thus confirming its traditional use in edema, nephritis, ascites and urinary problems. *Boerhavia diffusa*.has also attracted a lot of scientific research for its antidiabetic potential. Experiments have shown repeatedly that blood glucose levels are reduced, pancreatic β-cell activity is improved, insulin production is enhanced and hepatic carbohydrate-metabolizing enzymes are altered. Furthermore, antioxidant activity appears to

be protective of pancreatic tissues against oxidative stress, therefore improving glucose control. These findings are intriguing, but, almost of the data available are from animal models, therefore pointing to the necessity of well-designed clinical studies before any treatment suggestions can be made. Investigations on cancer have increased enormously in the last two decades. Some investigations indicated antiproliferative, cytotoxic, antimetastatic and immunomodulatory properties against various cancer cell lines and experimental tumor models.

The discovery of boeravinones as inhibitors of breast cancer resistance protein and observed apoptosis induction indicate significant prospects for future anticancer medication development. However, the existing data is mostly preclinical and full toxicological review and controlled clinical studies would be required before clinical translation can be considered. The present literature has numerous limitations, despite the strong pharmacological findings. With relation to extraction processes, solvents, dose regimens, plant sections studied, experimental models and result measurements there is variation. Such diversity makes it difficult to produce standardized herbal formulations and to compare research directly.

Further, few research are available to investigate pharmacokinetic features, herb–drug interactions, chronic toxicity or long-term clinical safety. Moreover, molecular targets responsible for many of the described pharmacological actions have not been completely identified yet . Such constraints underline the need of multi-disciplinary research such as phytochemistry, metabolomics, molecular pharmacology, systems biology and clinical sciences.

Future work should involve standardization of extract production, identification of marker chemicals of pharmacological activity, elucidation of molecular signaling pathways, pharmacokinetic profiles and toxicity studies, and multicenter randomized clinical trials. These techniques will assist the conversion of traditional knowledge into evidence-based medicinal treatments and the production of standardized phytopharmaceutical compounds derived from the *Boerhavia diffusa*.

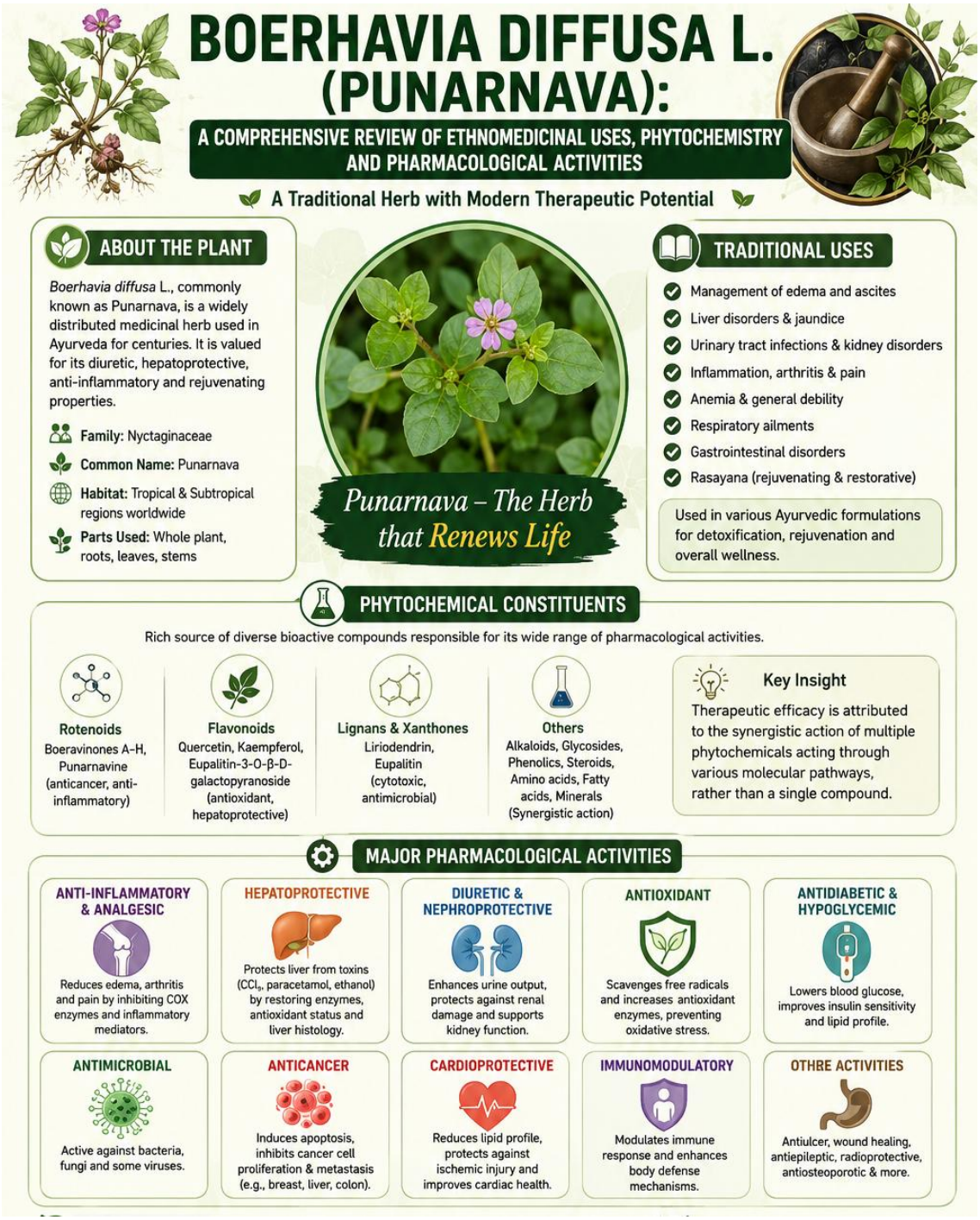


Fig:1 Major Phytochemical constituents

5. Conclusion

The present review suggests that Boerhavia diffusa L. is a significant medicinal plant with outstanding ethnopharmacological importance and wide pharmacological potential. The traditional Ayurvedic knowledge on its usage in hepatic illnesses, renal diseases, inflammation, edema, diabetes and immunological dysfunction has been substantiated by multiple experimental studies in the last several decades. The therapeutic effectiveness of the plant is due to the presence of a plethora of bioactive phytochemicals like alkaloids, flavonoids, rotenoids, lignans, phenolic compounds, steroids, glycosides, and phytosterols that possess

antioxidant, anti-inflammatory, immunomodulatory, cytoprotective and metabolic regulatory properties.

The existing evidence supports that Boerhavia diffusa.has significant hepatoprotective, nephroprotective, diuretic, antioxidant, antidiabetic, antimicrobial, anticancer, immunomodulatory, radioprotective, antiulcer, antihistaminic, anticonvulsant, hypolipidemic, antiosteoporotic, and antiplasmodial action. Most of the published work has, however, been confined to in vitro research and animal models. Therefore, further investigations are needed to standardize the manufacture of extracts, to do pharmacokinetic profiling, to investigate the molecular mechanisms of action, to assess toxicity and to carry out randomized controlled clinical trials to confirm its therapeutic effectiveness and safety in people. Boerhavia diffusa, as a whole, is a very potential source of new bioactive chemicals for future pharmaceutical research. The combination of traditional medicinal knowledge with current pharmacological and clinical research will continue to go a long way in the creation of safe, standardized and evidence-based phytotherapeutic solutions that can treat many chronic and developing human illnesses.

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