Review Article

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BOERHAVIA DIFFUSA (PUNARNAVA): A REVIEW BASED ON ITS AYURVEDIC AND MODERN THERAPEUTIC USES

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ABSTRACT

Boerhavia diffusa (Punarnava), is a perennial herb which is a member of Nyctaginaceae family, mainly found in tropical and sub-tropical areas. It is one of the most important medicinal herbs which has been used in traditional medicine systems since from the ancient times. The extract of each part of *Boerhavia diffusa* is associated with wide range of therapeutic properties which are used in the treatment of various ailments. It is utilized in various ways in different cultures. Number of phytochemical constituents are present in this medicinal herb for example punarnavine, hypoxanthine 9-L-arabinofuranoside, hentriacontane, β-sitosterol, hexacosanoic, stearic, palmitic, arachidic acids, boerhavin and boerhavic acid, arginine, aspartic acid, glutamic acid etc. Some of the therapeutic properties of *Boerhavia diffusa* include hepatoprotective, anti-inflammatory, anti-fibrinolytic, anti-cancer, anti-diabetic, immuno-modulatory, anti-diabetic, anti-viral, anti-depressant, anti-obesity. The present review paper is focused on the Ayurvedic overview of *Boerhavia diffusa* (Punarnava), its phytochemical constituents, associated therapeutic properties and its utilization in traditional medicinal system like Ayurveda and Folk system.

Keywords: Punarnava, Rasapanchaka, Punarnavine, Boeravinone A, Anti-diabetic

INTRODUCTION

There is a close interaction of humans with the environment for fulfilling their day-to-day needs. Humans depend upon plants for food, shelter, medicines and other basic needs. Plants are the ultimate source of therapeutics in nature. Traditional systems of medicine like Ayurveda, Siddha, Yunani, Folk, rely upon medicinal plants which are claimed to be the backbone of these systems. Around 3.3 billion out of 7.5 billion of the total world population, uses herbal products in their day-to-day routine[1]. These medicinal plants play a major role of a general ecological health marker[2,3]. Most of the ethnic group in various nations of the world uses medicinal herbs in their own way for maintaining health[4,5]. Alkaloids, phenols, tannins and flavonoids are commonly known as the principal phytochemicals of medicinal plants which possess different biological properties which are used for curing various disorders and maintaining the health[6]. *Boerhavia diffusa* (Figure 1) is one of the most important medicinal herbs of four o'clock family (Nyctaginaceae) that holds a significant position in all systems of medicines like Ayurveda, Siddha. Yunani and Folk system. *Boerhavia diffusa* is described in Atharvaveda as ‘’ because of its regenerating nature. It is also called as ‘spiderlings’ due to its spider like spreading nature[7]. The genus *Boerhavia* got its name after 18th century Dutch botanist Hermann Boerhaave whereas the species was named so because of its diffuse branching pattern[8,9]. Its therapeutic activities are well recognized across the globe. Each part of this plant especially the leaves and roots are being used for curing several ailments, for example asthma, skin problems, kidney related issues, pain etc.[10,11]. *Boerhavia diffusa* has lipids, lignins, flavonoids, alkaloids, triterpenoids, phlobaphenes and ursolic acid present in it[12]. The major phytochemicals present in *Boerhavia diffusa* are Boerhavia acid, Boeravinone, palmitic acid, sitosterol, esters of sitosterol, Punarnavine, Boerhavia acid etc[13]. *Boerhavia diffusa* is a rich source of vitamins, carbohydrate, protein, tannin, saponin, flavonoid and terpenoid[14]. *Boerhavia diffusa* is mainly used as a treatment therapy for depression and diabetes. This plant is associated with properties like immunomodulatory, anti-oxidant, anti-viral, hepatoprotective, anti-tumor, anti-bacterial etc. It is also consumed as a vegetable in many regions. Taxonomy and vernacular names of *Boerhavia diffusa* (Punarnava) is shown in Table 1 and 2 respectively.

Figure 1: *Boerhavia diffusa* (Punarnava)

Table 1: Taxonomy of *Boerhavia diffusa* (Punarnava)

Taxonomic Rank	Taxon
Kingdom	Plantae
Subkingdom	Tracheobionta
Division	Magnoliophyta
Class	Magnoliopsida
Subclass	Caryophyllidae
Order	Caryophyllales
Family	Nyctaginaceae
Genus	*Boerhavia*
Species	*diffusa*
Common name	Punarnava

Table 2: Vernacular Names of *Boerhavia diffusa* (Punarnava)

English	Red Hogweed, Spreading Hogweed, Fowl's Lice, Hog Weed, Pig Weed Spreading Hogweed, Red Hogweed, Horse Purslane, Red Spiderling, Tarvine
Sanskrit	
Hindi	Lal, Beshakapore, Santh, Shothagni, Rakta, biskhafra
Malayalam	Thazhuthama
Bengali	Punarnnava
Kanarese	Kommegida
Gujarati	Vakhakhaparo, Dholia-saturdo, satodi
Marathi	Tambadivasu, Ghetuli
Tamil	Chattarani, mukaratte
Telugu	Galijeru
Oriya	Lalapuiruni Nalipuruni
Punjabi	Khattan
Kannada	Komma
Kashmiri	Vanjula
Assamese	Ranga Punarnabha[15]

Botanical description of *Boerhavia diffusa* (Punarnava)

Boerhavia diffusa (Punarnava) is an erect perennial herbaceous branched herb which reaches the height up to 50 cm. Its stem is greenish purple in color and is tube shaped in structure. Stem is swollen at the nodal region, is glabrous in nature. Roots are tuberous and rod-shaped in structure which are yellow to brownish gray in color. Roots are unpleasant in taste. Leaves are opposite and often present in unequal pairs. They are ovate-oblong/sub cordate at the base. Flat margins are present on the leaves. Green color is more predominantly present on the upper surface of the leaves. Upper surface of the leaves is smooth while the lower surface is hairy and white/pinkish in color. Flowers are small sessile, paniculate and have subcapitate clusters on axillary racemes or terminal panicles. They are 10-30 cm long and are pink, purple/ white in color. The base of calyx is 0.5-1.5 mm, the limbs are funnel like in shape and are red or violet in color. The number of stamen present is 2-3. Fruits are glandular, and are narrowly oblong ovoid, which are enclosed in a perianth tube (cylindrical shape). They are 5-ribbed/5-angled like in shape[16].

Geographical distribution of *Boerhavia diffusa* (Punarnava)

Genus *Boerhavia*, has 40 species which are cultivated in tropical and subtropical countries like India, Sri Lanka Egypt, Sudan, Ghana, South Africa, Nigeria, China, Sudan, Australia, Philippines, Iran etc. 6 species out of 40 species of genus *Boerhavia* are found in India which are *B. diffusa, B. erecta, B. rependa, B. chinensis, B. hirsute and B. rubicunda.* In India it is mainly found in warmer regions of the country. It grows widely during rains in marshy places[17,18].

Phytochemical constituents of *Boerhavia diffusa*

Boerhavia diffusa contains phytochemicals like alkaloids (Punarnavine)[19], glycosides like Hypoxanthine 9-L-arabinofuranoside, Hentriacontane, β-sitosterol and ursolic acid, Glycoside Punarnavoside, C-methylflavone 5,7-dihydroxy-3',4'-dimethoxy- 6,8- dimethylflavone β-ecdysone, triacontane, β-sitosterol- β-D-glucoside among which β-sitosterol is present in the leaves. Acids like Acids tetracosanoic, hexacosanoic, stearic, palmitic, arachidic acids Boerhavin and boerhavic acid have been isolated from this plant. Boerhavic acid is present in the upper parts of the plants[20,21]. Lignans like Liriodendrin, syringaresinol mono- β- D-glucoside Glycoprotein[22,23], phenolic compounds for example 3,4-dihydroxy-5-methoxycinnamoylrhamnoside, Quercetin 3-O-rhamnosyl (1→6) galactoside (quercetin 3-O-robinobioside), Quercetin 3-O-(2″- rhamnosyl)-robinobioside Kaempferol 3-O-(2″-rhamnosyl)-robinobioside, Quercetin Kaempferol etc. are present in *Boerhavia diffusa*[24]. Amino acids like alanine, arginine, aspartic acid, glutamic acid, leucine, methionine, ornithine, phenylalanine, proline, serine, threonine, tryptophan, tyrosine, asparagine, glycine and valine, which are mainly present in the leaves and roots of the plant[25]. Other chemical constituent of *Boerhavia diffusa* are sterols, steroids and sugars[26,27]. Volatile compounds like camphor and safranal are present in the leaves. The leaves contain proteins, fats, carbohydrates and minerals like potassium nitrate and other potassium salts. Androst-5-ene analogue (a steroid) and flavones, 6', 5'-dimethoxy-5, 7, 3- trihydroxyflavone are present in the aerial parts of the plant[28]. Flavonoid's derivatives (quercetin-3-O-robinobioside, eupalitin-3-O-galactosyl (1-2)-glucoside, kaempferol-3-Orobinobioside and eupalitin-3-O-galactoside), one aglycone, quercetin is also present in the leaves. The ether extracts i.e., rotenoids mainly Boeravinone A, Boeravinone B, Boeravinone C, Boeravinone D, Boeravinone E, Boeravinone F, Boeravinone G, Boeravinone H have been found in the roots[29-33]. Ecdysterone, a phytoecdysone has been isolated from the root extract of *Boerhavia diffusa*[34]. Novel c-methyl flavone and dihydrofuranoxanthone and borhavine respectively are reported to be present in the roots of *Boerhavia diffusa*[35,36]. Flavonoid derivatives like quercetin-3-O-robinobioside and eupalitin-3-O-galactosyl (1-2)-glucoside are also present in the roots. Punarnavine I and Punarnavine II are two quinolizidine alkaloids extracted from roots, stem as well as from the leaves[37]. Structures of some important phytochemical constituents are shown in Figure 2.

Folk view on *Boerhavia diffusa* (Punarnava)

The ultimate source of medicine around the world is plants and they have been used by different cultures and communities for the fulfilment of basic needs like food, shelter, clothes and maintaining the health since the ancient times. According to WHO report, approximately 80% of world population relies on classical systems of medicines for their health[38,39]. Around 35,000 medicinal plant species are used in traditional and ethno medicinal practices around the globe[40]. Folk medicines and remedies are popular among rural and tribal communities of the world. The people of such communities have knowledge regarding the traditional use of plants and such information has been passed on them by their ancestors. Punarnava (*Boerhavia diffusa)* is commonly used medicinal herb in folk practices. It is used to treat variety of ailments. For instance, In Tamil Nadu folk people of Villupuram area use the decoction of root of *Boerhavia diffusa* against dyspepsia, jaundice, enlargement of spleen, abdominal pain. They also use it as an antistress agent[41,42]. In Mirpur area of Pakistan, people utilize leaves of this plant as emoluments and as a carminative agent in powder form. They use juice of this plant against hypertension. Flowers are being used for treating jaundice. Leave extract is used against renal stone and bladder stone. They also use this plant for rheumatism, poxes[43]. People of Cholistan Desert area of Pakistan use root decoction of this plant in conditions like Kidney failure, hematuria and painful urination[44]. Some tribes of Malda-West Dinajpur Districts West Bengal use this plant in curing asthma. They used to make a paste of *Boerhavia diffusa* root, ginger and 2 peppers, which is used for 7 days in continuity to get relief from asthma[45]. As per the report, *Boerhavia diffusa* plant juice is taken orally as a treatment for snake bite in tribes of Chinnar wildlife sanctuary[46]. *Boerhavia diffusa* leaves are used in cooked form to get relief form hypotension in Jaintia tribe of Meghalaya. they also used it for asthma and jaundice treatment[47]. In some areas of Haryana people use decoction of whole plant with ginger and black pepper in jaundice[48].

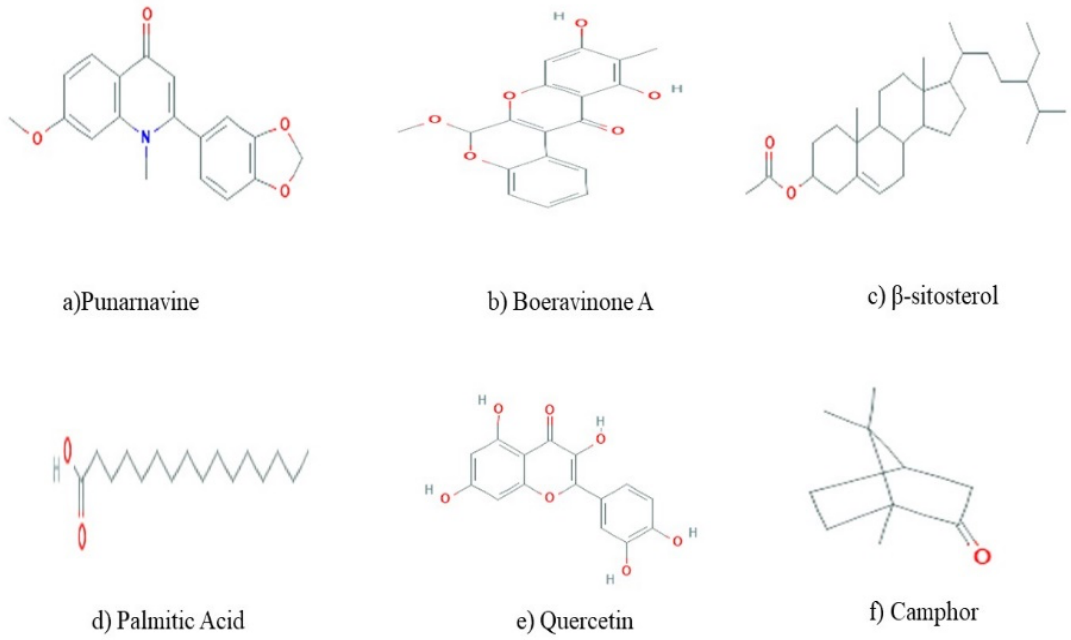

Figure 2: Chemical structures of some important phytochemicals of *Boerhavia diffusa*

In Assam, people use the paste of leaves in skin disease as a remedy[49]. It is used as a cure for abscesses, leprosy, wounds, edematous swellings in paste form[50]. Folk people of Papikondalu Forest, Andhra Pradesh use the plant in powdered form mixed with coconut oil and apply on the affected skin as a remedy[51]. Tribal people of Madhya Pradesh use *Boerhavia diffusa* plant roots in gonorrhea, dropsy and also in heart and kidney issues. Each part of the plant like seed, leaves, seeds as well as juice and decoction are utilized in conditions like urinary infection, jaundice and other problems related to urination[52,53]. In Some remote villages of Bihar, it is used against menstrual issues like prolonged abnormal menstrual period. It is used in paste form which is made by the aerial parts of the plant and administered with honey[54]. It is used in juice form for treating asthma in some areas of Andhra Pradesh whereas in Adilabad District, it is used in treating anemia[55,56]. The leaves of this plant are also used as a folk remedy for erectile dysfunction in Democratic Republic of the Congo[57]. The roots of *Boerhavia diffusa* are used by Kallanai Thanjavur district people in Dyspepsia, jaundice[58]. In Rampur, Uttar Pradesh its root decoction is used in Asthma and arthritis[59]. This plant is used in treating dysuria in Dhenkana, Odisha[60]. Nepalese people use cooked leaves against tumor, spleen enlargement, abdominal pains and joint pain whereas in bronchial asthma they used dried leaves for the treatment. They cure scabies with *Boerhavia diffusa* seed extract. People of Baglung District treat backache with the juice of this plant[61,62]. In Palakkad area, plant decoction to wash out the kidney stone[63]. In Gorakhpur this plant as a whole or its parts are used to treat variety of diseases like asthma, anemia, jaundice, snake venom, epilepsy, heart disease and cough bronchitis[64]. In Tapkeshwari Hill, Bhuj, Kachchh people use root paste and root juice in dropsy, fistula, and wounds[65]. People of Bankura District, West Bengal, use the young shoot of *Boerhavia diffusa* as vegetable[66]. In Pondicherry this plant is used as an anti-diabetic[67]. It is orally administered as blood purifier and to get relief from muscle pain.

Ayurvedic view on *Boerhavia diffusa* (Punarnava)

Punarnava is a significant herb which has been used in Ayurveda since the ancient times. In Ayurveda it is classified among "rasayana" herbs. This herb is associated with several healing properties and has been used to treat variety of ailments. This herb significantly works on three components (commonly called as *"Doshas"* in Ayurveda) of the body i.e., Vata (Space and Air component), Pitta (Fire and water component) and Kapha (Water and earth component). It maintains Vata, Pitta, Kapha Doshas[68]. Properties of *Boerhavia diffusa* as per Ayurveda are shown in Table 3.

Table 3. Rasa Panchaka/ Properties of *Boerhavia diffusa* (Punarnava) as per Ayurveda

Sanskrit/English	Sanskrit/English
Virya/Potency	Ushna/Warm
Vipaka/Metabolic property	Madhur/Sweet
Guna/Physical property	Laghu/Small, Ruksha/Dry
Rasa/Taste	Madhura/Sweet, Tikta/Bitter, Kashaya/Pungent[69]

It is used externally in lepa (paste) form or tail (oil) for curing swelling and orally administered for digestion related issues. In Ayurveda *Boerhavia diffusa (*Punarnava) is used in many important herbal formulations[70]. Some of important Ayurvedic herbal formulations are:

- Dyarishta: It mainly acts on excretory system. It is used against edema, kidney failure[71].
- Guggulu: This formulation is mainly used to get relief from rheumatoid arthritis, hernia, gout, sciatica, frozen shoulder, backache, urinary bladder pain, spondylitis[72].
- Sava: It is used against inflammation[73].
- Staka Kwatha Churna: It is used as a diuretic, rejuvenator. It is used against oedema[74].

- Di Mandura: This Ayurvedic herbal formulation is used in case of iron deficiency and in kidney and liver related issues[75].
- Sukumara Ghrita: this formulation is effective against Vibandha (constipation), Udara Roga (abdomen related issues), Gulma (abdominal lump), Pleeha Roga (splenic disease), Vidradhi (abscess), Shopha (oedema), Yoni shula (genital pain), Arsha (Haemorrhoids), Vriddhi (hydrocele), Vata vyadhi (Vata Dosha diseases), Vatarakta (gout) and used as a drug for Snehapana (oleation therapy) in Poorvakarma (preceding procedure) for Shodhana Karma[76].
- Varuni: It is used in Rhinitis and pain[77].

Modern view on *Boerhavia diffusa* (Punarnava)

Altered herbal drugs present in market give the proof of what and how much changes have been done on the already available natural form of the herbal drugs. These modifications are done either by altering the actual chain formation/chemical compositions, by changing their passage of line or by using different preparation methods[78]. In today's scenario adulteration is one of the most common practice of degrading the herbal drugs. Adulteration changes the chemical composition of the herbal drugs. Therefore, people are losing their faith from herbal medicines due to the variety of adulterants present in them. Rate of toxicity associated with these drugs increases with the increasing extent of modifications[79-84]. Traditional Ayurvedic herbal formulations of *Boerhavia diffusa* (Punarnava) are associated with wide range of biological properties which cure various ailments without causing any adverse impacts on the body. So instead of taking health risk by using altered forms of herbal drugs we need to promote traditional Ayurvedic system of medicine. There is no toxicity and any adverse effects are associated with the Ayurvedic drugs while there are variety of risk factors associated with the modern drugs.

Therapeutic uses of *Boerhavia diffusa*

Boerhavia diffusa is known to have such phytochemical constituents which are associated with significant therapeutic properties. There are various *in-vitro* and *in-vivo* studies which have been carried out to check out each of its therapeutic property. The findings of the studies suggest that *Boerhavia diffusa* can be used further for new medical discoveries. Table 3 showing some of the clinical studies in support of therapeutic properties of *Boerhavia diffusa.*

Table 4: Reported therapeutic uses of *Boerhavia diffusa*

Immunomodulatory	A study was conducted on BALB/c mice model to check the immunomodulatory activity of *Boerhavia diffusa.* The result showed that Punarnavine enhanced the stem cell proliferation, differentiation of stem cells and antibody formation process. It also suppressed the pro inflammatory cytokines in Balb/c mice[85]. Another *in-vitro* study demonstrated that ethanolic extract of the plant has immunosuppressive potential[86].
Antidiabetic activity	As per the results of an experimental study conducted on streptozotocin-induced NIDDM rats to investigate the anti-diabetic property of *Boerhavia diffusa*, leaf extract has properties to lower down the blood glucose level[87]. One more study was conducted on alloxan induced diabetic rats to investigate the anti-diabetic potential of *Boerhavia diffusa* showed that the aqueous extract of the leaf caused a significant decline in high level of blood glucose and also increased the plasma insulin level[88].
Anti-oxidant	The results of reported *in-vitro* study to evaluate the anti-oxidant activity by using Fe-EDTA method showed that *Boerhavia diffusa* carries anti-oxidant properties[89]. As per the results of another *in-vitro* study, anti-oxidant properties of ethanolic extract are better than the anti-oxidant properties of chloroform and aqueous extract of *Boerhavia diffusa*[90]. Ethanolic extract was found to have significant anti-oxidant property in another *in-vitro* study carried out by using thiocyanate method[91].
Anti-inflammatory	Ether, dichloromethane, ethanol and water extracts of *Boerhavia diffusa* were examined to check out the anti-inflammatory activity of this plant and it was found that ethanol extract was most effective against formalin induced inflammation in rat models[92]. An *in vivo* study on carrageenan induced rat paw edema model and cotton pellet induced granuloma model was performed to check the acute anti-inflammatory and sub-acute anti-inflammatory potential of *Boerhavia diffusa.* Results demonstrated that aqueous leaves extract has acute and sub-acute anti-inflammatory action in dose dependent method[93].
Anti-obesity	*In-vivo* study on male Wistar rats were performed to check out the anti-obesity property of the *Boerhavia diffusa*[94].
Anti-viral	The ethanolic root extract of *Boerhavia diffusa,* has anti-viral activity against many viruses. A study was conducted to check this property in which ethanolic extract was found to have significant inhibitory impact on the surface antigen of Hepatitis B Virus (HBsAg). It also inhibited the HBV DNA polymerase enzyme[95].
Anti-analgesic	The *in-vivo* study on acetic acid induced writhing's test in mice showed the analgesic activity by inhibiting the pain that was induced by acetic acid. Root powder of *Boerhavia diffusa* at dose 150 mg/kg significantly reduced the number of writhing responses[96].
Hepatoprotective	The results of reported study on experimentally induced carbon tetrachloride hepatotoxicity in rats and mice showed that alcoholic extract of *Boerhavia diffusa* when administered orally produced hepatoprotective activity[97].
Anti-convulsant	A reported study on *Boerhavia diffusa* for the evaluation of anti-convulsant activity, came up with results that methanolic extract and its various fractions like liriodendrin had anti-convulsant action against pentylenetetrazol (PTZ)-induced seizures. This suggests that *Boerhavia diffusa* can be a good anti-convulsant agent[98].
Anti-metastatic	The *in-vivo* study on B16F-10 melanoma cells in C57BL/6 mice for investigating anti-metastatic activity showed that Punarnavine is associated with the anti-metastatic property of *Boerhavia diffusa*[99].
Anti-bacterial	An experimental study was performed on gram positive bacterial species viz., *Staphylococcus aureus, Bacillus subtilis, Streptococcus faecalis and Micrococcus luteus,* and gram-negative bacterial species *Escherichia coli, Pseudomonas aeruginosa, Salmonella typhii, Klebsiella pneumoniae, Proteus vulgaris, Serratia marcescens, Shigella flexneri and Vibrio cholera* to check the anti-bacterial potential of *Boerhavia diffusa.* It was found that ethanol, methanol, chloroform, ethyl acetate and aqueous extracts exhibited inhibitory activity against these bacterial species. Among all the extracts, ethanol extract was more significant inhibitor against all the bacterial species except *Vibrio cholera*[100].
Antiproliferative	According to a study ethanolic extract of *Boerhavia diffusa* was found to have inhibitory action against T cell mitogen phytohemagglutinin and concanavalin A-stimulated proliferation of human peripheral blood mononuclear cells (PBMC). It also inhibited the proliferation of purified protein derivative antigen-stimulated PBMC[101].

Anti-depressant	The ethanolic extract and Punarnavine of *Boerhavia diffusa* both are associated the anti-depressant nature of this plant. A reported study on Swiss albino mice models has proved antidepressant nature of ethanolic extract and Punarnavine by interacting with a1-adrenoceptors, dopamine D2 receptors, serotonergic, and GABA receptors, and by inhibitory action on brain monoamine oxidase activity[102].
Anti-tumor	An *in-vivo* study on Swiss albino mice having Dalton's ascetic lymphoma (DAL), showed the antitumor nature of ethanolic extract of *Boerhavia diffusa* L.[103]. Thus, it can be concluded that *Boerhavia diffusa* has anti-tumor properties associated with it.
Anti-fertility	Methanolic extract of *Boerhavia diffusa* root is associated with anti-fertility property. A study carried out on female rats demonstrated the antiestrogen, anti-implantation activities of methanolic extract[104].

CONCLUSION

Conclusively *Boerhavia diffusa* (Punarnava), is one of the most frequently used medicinal herbs in various systems of medicines like Ayurveda, Siddha, Yunani and Folk system. This herb is associated with some significant therapeutic actions. It is utilized in the treatment of several diseases. Various research studies have been done on each of its phytochemical constituents to investigate the associated pharmacological and therapeutic properties of them. As per the reported clinical studies the leaf and root extract of the plant has wide range of biological properties like anti-bacterial, antiviral, anti-diabetic, anti-estrogenic etc. The alkaloid extracted from the leaves of *Boerhavia diffusa* named Punarnavine is one of the major Phytochemical extracted from this plant which has immunomodulatory properties. Whereas it is used as a vegetable in many tribes around the world. Folk people use this herb mainly against jaundice, asthma, wounds and for skin related problems. While in Ayurveda it is used in many formulations for treating variety of diseases.

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