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BOERHAVIA DIFFUSA L: REVIEW

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ABSTRACT

Boerhavia diffusa Linn.(F: Nyctaginaceae) a medicinal plant as a whole was commonly known to the world as "Spreading hogweed" and in Sanskrit as "Punarnava", is widely distributed over the tropical, subtropical and temperate regions of the world. It is reported to possess antiaging, disease prevention, and life strengthening activities which hold enormous influence in disease burden and affordability/availability of healthcare in the world. It is traditionally used mostly in treating different ailments like asthma, urinary disorders, leucorrhea, rheumatism, and encephalitis. In addition different solvent extract of this plant proved to have different pharmacological activities viz. immunosuppressant, anti-diabetic, anti-oxidant, anti-cancer, analgesic, hepatoprotective, anti-viral, antifungal and anti-fibrinolytic activity. Phytochemical screening of the root of the plant revealed that it is rich in alkaloid content of nearly 2%, moreover other constituents namely flavonoids, steroids, triterpenoids, lipids, lignin, carbohydrates, proteins.

INTRODUCTION

Boerhavia diffusa L. (Nyctaginaceae), commonly known as 'Punarnava' in the Indian system of medicine, is a perennial creeping herb found throughout the waste land of India. Its name is derived from two words, Punar (= once again /regaining/restoring) and Nava (=new, renew or young), so the literal meaning of the name is, one which becomes new or young again.This name signifies the rejuvenating property of Punarnava. It is a Rasayan herb of Ayurveda which renews the body or restores youth.given for the treatment of anasarca, ascites and jaundice.The roots are reputed to be diuretic and laxative and are given for the treatment of anasarca, ascites and jaundice. The roots are reputed to be diuretic and laxative and are given for the treatment of anasarca, ascites and jaundice[1].

Geographical Distribution and Habitat:
Genus *Boerhavia*, consisting of 40 species is distributed in tropical and sub-tropical regions and warm climate. It is found in Ceylon, Australia, Sudan and Malay Peninsula, extending to China,Africa, America and Islands of the Pacific. Among 40 species of*Boerhavia*, 6 species are found in India, namely *B. diffusa, B. erecta, B. rependa, B. chinensis, B. hirsute and B. rubicunda. Boerhavia diffusa* in India is found in warmer parts of the country and throughout up to 2,000 m altitude in the Himalayan region. It is a perennial, spreading hogweed, commonly occurring abundantly in waste places, ditches and marshy placesduring rains. The plant is also cultivated to some extent in West Bengal[2].
Taxonomical Classification[3]: -

Kingdom: Plantae
Subkingdom: Tracheobionta
Superdivision: Spermatophyta
Division: Magnoliophyta
Class: Magnoliopsida
Subclass: Caryophyllidae
Order: Caryophyllales
Family: Nyctaginaceae
Genus*: Boerhaavia* L.
Species: *Boerhaavia diffusa* L.
Scientific Name*: Boerhaavia diffusa* Linn.
Family Name: Hog weed, Horse Purslane.

Common Names (Vernacular names):

Gujarati: Dholia-saturdo, Moto-satoda.
Hindi: Gadahpurna, Lalpunarnava, Snathikari, Biskhafra, Beshakapori
Kannada: Kommegida, Sanadika, Kommeberu, Komma
Marathi: Tambadivasu
Sanskrit: Kahtilla, Sophaghni, Varshabhu, Punarnava, Raktakanda, Shothaghni,
Bengali: Punurnava, Raktapunarnava
Tamil: Mukaratee-Kirei
Telugu: Punernava,
English: Horse Purslene, spreeding Hog - Weed
Assamese: RangaPunarnabha

Morphology :

Boerhavia Diffusa - a perennial locomotion weed, prostrate or ascending herb, up to one m long or additional having spreading branches. The plant grows extravagantly within the season, and mature seeds area unit fashioned in October-November[4]. Leaves - ovate, shape. Flowers - minute, typically fascicled or sub umbellate on the last word branch lets, pink, white and concerning one.5 mm long. Tap root - stalk, cylindrical to narrowly cigar-shaped to conelike or tapering, light-weight yellow, brown or chromatic grey.

Figure1: *Boerhavia Diffusa* plant

Figure 2: *Boerhavia Diffusa* root.

Phyto-chemical constituents:

Phytochemistry: The *Boerhaviadiffusa* plant contains a large number of such compounds as flavonoids, alkaloids, steroids, triterpenoids, lipids, lignins, carbohydrates, proteins, and Glycoproteins[5-10]. Phytochemical screening of the roots from garden-grown in vivo plants of *B. diffusa* of different ages revealed that the maximum alkaloid content (2%) accumulated in the roots of 3-yearold mature plants. The herb and roots are rich in proteins and fats. The herb contains 15 amino acids, including 6 essential amino acids, while the root contains 14 amino acids, including 7 essential amino acids. Plant contained large quantities of potassium nitrate, besides punarnavine[11]. Many rotenoids have been isolated from the roots of the *Boerhavia diffusa*[12]. Plant also includes a series Pharmacological Potential of Boerhavia diffusa boeravinones viz., boeravinone A, boeravinone B, boeravinone C, boeravinone D, boeravinone E and boeravinone F. Punarnavoside, a phenolic glycoside, is reportedly present in roots [13,14]. C-methyl flavone also has been isolated from *Boerhavia diffusa* roots [15]. Two known lignans viz., liriodendrin and syringaresinol mono-β-D-glycoside have been Isolated[16].Presence of a purine nucleoside hypoxanthine 9-L-arabinose[17] , dihydroisofuroxanthone-borhavine[18] , phytosterols[19,20] have been isolated from the plant. It contains about 0.04 % of alkaloids known as punarnavine and

punernavoside, an antifibrinolytic agent. It also contains about 6 % of potassium nitrate, an oily substance, and ursolic acid[21],The seeds of this plant contain fatty acids and allantoin and the roots containalkaloids[22].The green stalk of the plant has also been reported to contain boerhavin and boerhaavic acid[23].

Pharmacological activities:

The plant has gained lot of importance in the field of phytochemistry because of its various pharmacological and biological activities such as immunomodulatory effects, immunosuppressive activity, antimetastatic activity, antioxidant activity, antidiabetic activity antiproliferative and antiestrogenic activity, analgesic and anti-inflammatory activity, antibacterial activity, antistress and adaptogenic activity, ant lymphoproliferative activity, nitric oxide scavenging activity, hepatoprotective activity, anti-viral activity, bronchial asthma, anti fibrinolytic activity, chemo preventive action, genetic diversity analysis, anticonvulsant activity.

Immunostimulatory Activity

In vivo studies: Mungantiwar and coworkers analyzed the immunomodulation by BD (aqueous extract, 50–200 mg/Kg/day orally) and showed significant leucocytosis and reduced mortality (50%) in pretreated mice using *E. coli*-induced abdominal sepsis stress model. The extract also reversed the elevation in the levels of glucose, cholesterol, SGPT, and BUN and reduction in triglycerides induced by cold and forced swimming stress in rats [24]. The alkaloidal fraction has shown a remarkable effect in leveling the increase in plasma cortisol and averting the decrease in immune system performance in rats [25]. In another study, Sumanth and coworker compared the effect of BD with ashwagandha and found comparable increase in total swimming time in mice when fed with alcoholic extract. The extract showed more potent effect on the count of total WBC, glucose level, and plasma cortisol level. The extract produced macrophage phagocytic activity comparable to the drug levamisole [26]. Mungantiwar and coworkers continued the studies on immunomodulation and found that the alkaloidal fraction (25–100 mg/Kg p.o.) considerably decreased and delayed hypersensitivity reactions in animals. The author recommended that the immunostimulation is due to metabolic alteration of the alkaloid to its active form [27].

Immunosuppressive Activity

In vitro studies: Mehrotra and coworkers studied the immunomodulation produced by an ethanolic extract of BD roots (100 and 500μg/mL) in inhibition of NK cells cytotoxicity, LPS-induced NO production, and quantification of mRNA. The extract prevented *in vitro* cytotoxicity in human NK cells and also inhibited NO generation in mouse macrophage cells along with production of IL-2 and TNF-α (MIC ~ 10μg/mL) in human PBMCs. The author suggested good immunosuppressive properties possibly because of alkaloid/lignan [28]. However Pandey and coworkers worked on hexane, chloroform, and ethanol extracts of BD leaves and found inhibition of PHA stimulated proliferation of PBMCs, two-way MLR, NK cell cytotoxicity, and LPS-induced NO production by RAW 264.7 when treated with chloroform and ethanol extracts (5–500μg/mL). Eupalitin-3-*O*-β-*D*-galactopyranoside isolated from the ethanolic extract showed more effectiveness. It decreased the production of IL-2 and TNF-α in human PBMCs and repressed NF-κB and AP-1, thereby depressing activation and proliferation of T cells. The author suggested specific potential of eupalitin-3-*O*-β-*D*-galactopyranoside for immunosuppression[29]. Furthermore, Pandey and coworkers[29] isolated eupalitin-3-*O*-β-*D*-galactopyranoside and ascribed the immunosuppressive property to it. This compound has also been reported to possess antiosteoporotic activity [30]. Osteoporosis is a disorder with an inflammation-aging component and it has been emerged that it has an immune component also. Cytokines which are secreted for immune response are also important for development

and activation of osteoclasts besides being critical for the immunity [31]**.**

Anticancer Activity:

In vitro studies: Srivastava and coworker showed a dose-dependent *in vitro* cytotoxic effect of the extract of the BD root and the leaf in HeLa and U-87 tumor cell lines. Crude ethanolic extract of the root (200μg/mL) and the leaf (300μg/mL) showed 30 and 40% cell death while alkaloidal fraction (300μg/mL) and methotrexate (200 nM) showed 40% cell death [32].

Mehrotra and coworkers analyzed the effect of 95% ethanolic root extract on T cell mitogen PHA, Con-A, and PPD antigen-stimulated proliferation of human PBMC. It inhibited PBMC proliferation induced by all above stimulators and human mixed lymphocyte culture. The extract showed the inhibition of various cell lines (mouse and human) with special mention of lymphoma and leukemic cells [33]. Ahmed-Belkacem and coworkers isolated two rotenoids (boeravinones G and H) from BD roots and found them potential efflux inhibitors for breast cancer resistance protein (ABCG2). The authors also proposed a correlation between structure and activity of compounds having BCRP inhibitory activity [34]. Chopra and coworkers performed bioassay guided fractionation of 95% ethanolic extract of BD root and have observed 30% cell death in HeLa cell line (300μg/mL). Further purification with column chromatography yielded a more potent fraction which has shown 85% and 55% cell death in 72 and 24 h, respectively, at a dose of 300μg/mL [35].

S. Sreeja and coworkers analyzed antiproliferative and antiestrogenic potential of methanolic extract of whole plant of BD in MCF-7 cell line and showed reduction in cell viability (46.8%) in 48 h at 320μg/mL [36]. The extract also showed reduction in estradiol-induced cell proliferation. MCF-7 cells treated with varying concentrations of the extract (20–320μg/mL) showed G_0-G_1 arrest by increasing the population of G_0-G_1 phase from 69.1% to 75.8%. *In vivo* studies: Leyon and coworkers studied the effect of aqueous methanolic (3 : 7) extract of BD whole plant on metastasis in a model of B16F10 melanoma in C57BL/6 mice. The extract showed 87% and 95% inhibition of metastasis at 0.5 mg/dose simultaneously and prophylactically. The survival rate of mice was also increased up to 157%. The extract given prophylactically produced 85% reduction in serum parameters indicative of metastasis [37]. Further the author isolated punarnavine from the extract which has shown antibody-dependent cellular and complement mediated cytotoxicity along with enhancement of NK cells activity. Punarnavine increased the production of IL-2 and IFN-γ [38]. Levels of GM-CSF and proinflammatory cytokines such as IL-1α, IL-6, and TNF-α were significantly lowered by punarnavine administration. Further, the author found that prophylactic and simultaneous treatment with punarnavine (40 mg/kg) can restrain the lung melanoma metastasis up to 95.25%–93.9%, respectively, for 10 days after tumor inoculation. Punarnavine administration probably suppresses or downregulates the expression of MMP-2, MMP-9, VEGF, ERK-1, and ERK-2 in the lung tissue of metastasis-induced animals [39]. Manu and coworkers estimated the protection provided by 70% aq. methanolic extract of the whole plant (20 mg/kg, i.p.) in bone marrow and intestine of mice (dosed sub lethally by 600 rads in single dose). Total WBC count was reduced by 46.66% in the extract treated group in comparison to 80% in the control group on day 9 after radiation exposure. In the presence of BD extract the effect of radiation on bone marrow cellularity can be seen by only 46% reduction in cellularity compared with 68% reduction in radiation alone. An interesting fact is that, on the 11th day, the count of bone marrow cellularity surpassed the initial value by 9.2%. The elevated level of serum and liver LAP, GPT, and lipid peroxidation after radiation exposure was normalized in the extract treated group [40]. An important indication of BD in traditional medicine is abdominal tumor. Various studies (*in vitro* and *in vivo*) suggest the presence of potential anticancer compounds in various extracts prepared from various plant parts. Manu and coworker

isolated the alkaloid punarnavine from the rootsband reported it to have an antimetastatic potential [40]. In another study, boeravinones G and H have shown potential inhibition of drug efflux by breast cancer resistance protein (ABCG2) [34]. Radiotherapy holds an important stake in cancer treatment in spite of the major adverse effect of myelosuppression or immunosuppression which may result in increased susceptibility to infection during the course of cancer treatment. There are several approaches to maintain the immunity level of the cancer patient to improve the overall condition. Herbal formulations containing plant derived immunomodulators might be a considerable approach in this regard. BD offers a multiple target regimen in cancer therapy. It has anticancer, immunomodulatory, and radioprotective activity. So it could be proven to be a beneficial supplement in the cancer therapy. Glucuronic acid and hexosamines form a vital part in many structural polysaccharides and glycosaminoglycans (GAG) found in the ground substance of extra cellular matrix (ECM). Tumor cells can induce the host stromal cells to supplement the matrix components necessary for the growing tumor[41]. Hyaluronic acid (HA) is a GAG made of repeated disaccharide units of D-glucuronic acid and N-acetyl D-glucosamine [42, 43]. It is a well-known promoter of metastasis and elevated level is seen in several types of tumor regardless of tumor grade [44] and promotes metastasis by opening up spaces for tumor cells to migrate through ECM, by interacting with cell surface receptors for HA [45]. The degradation of HA by HAase (Hyaluronidase) liberates disaccharide units that are good promoters of angiogenesis as well by modulating the proliferation, adhesion and migration of endothelial cells [46]. An elevated level of the structural monosaccharides of HA is seen in the metastasis induced control animals, positively contributing tothe elevation of HA in the tumor microenvironment. This in turn will enhance the possibility of metastasis and tumor directed angiogenesis. But the treatment of Boerhavia diffusa extract reduced the levels of these structural monosaccharides significantly thereby indicating a decrease in the metastatic potential of B16F10 melanoma. The reduction of these sugars along with the inhibition of gelatinase activity will also negatively contribute to tumor angiogenesis, which is essential for the tumor to grow beyond a maximum size.

Antidiabetic and Hypoglycemic Activity

In vivo studies: Chude and coworkers showed non-dose-dependent reduction in sugar levels in alloxan induced diabetic rats upon administration of aqueous extract of leaf of BD. They showed 51.95% reduction in sugar level at the 6th hour after administration of 200 mg/Kg extract [47]. In another work, Satheesh and coworkers compared the aqueous extract of the leaves (200 mg/Kg) with glibenclamide (600μg/Kg) in alloxan induced diabetic rats. The extract increases the plasma insulin level from 4.92μU/mL to 10.4μU/mL while glibenclamide attains the peak insulin level of 9.74μU/mL. The extract completely restores initial glucose concentration in 120 min while glibenclamide leaves the level of glucose elevated by almost 10% [48, 49].

BD leaves chloroform extract has shown dose-dependent hypoglycemia in experimentally diabetic rats. Glibenclamide (25μg/Kg) and BD leaf extract (200 mg/Kg) gave the percent glucose reduction of 59.01% and 38.63%, respectively, in the fourth week. The author hypothesized that β-cells renewal or some extra pancreatic action is responsible for such activity [50]. *Ex vivo*, Gulati and coworkers have accounted the α-glucosidase inhibitory activity for the ethanolic extract (1.72μg/mL) [51]. The author found no traditional or ethnobotanical reports of the antidiabetic activity in BD plant and the formulations containing BD as an ingredient; however the above studies clearly indicate the antihyperglycemic potential of BD. Only one proprietary formulation from Unani-Tibb system (Glucostop) has been indicated in the management of diabetes.

Antifibrinolytic Activity: *In vivo* studies: Srivastava and coworkers studied the effect of

BD extract on IUD-induced bleeding in rhesus monkeys and established antifibrinolytic activity of BD extract [52]. Further they evaluated the mechanism of this activity and discovered NAD-dependent-15-hydroxy-prostagtandin dehydrogenase activity in the endometrium [53]. Further exploration showed the role of vascular and t-PA in IUD-fitted menstruating monkeys [54]. Barthwal and Srivastava compared antifibrinolytic agents (ε-aminocaproic acid, 100 mg/Kg/day orally, and tranexamic acid, 5.5 mg/Kg/day, i.v.), anti-inflammatory drugs (indomethacin, 1.5 mg/Kg/day, ibuprofen, 3.3 mg/Kg/day, and naproxen, 3 mg/Kg/Day; orally), and root extract of the BD (50 mg/Kg/Day, orally) on various parameters of menstrual cycle in IUD-fitted monkeys. They observed a high increase in duration and loss of iron after IUD insertion. Antifibrinolytic and anti-inflammatory agents reduced the duration and iron loss in menstruation and the activity of t-PA independently whereas root extract of BD (50 mg/Kg, orally) showed greater reduction in the duration of menstrual flow, iron loss, and t-PA activity. The author suggested reduction in t-PA activity leading to decrease in MBL causing reduced MIL in IUD-fitted monkeys [55,56].

Anti-Inflammatory Activity: *In vivo* studies: Mudgal studied the anti-inflammatory effect of aqueous insoluble alcoholic extract of BD in rats. The leaves and flower extracts have shown anti-inflammatory activity by only 55.78% decrease in rat paw edema [57]. Hiruma-Lima and coworkers evaluated BD leaf extracts (juice and lyophilized decoction) for its toxicity and analgesic-anti-inflammatory activities. Juice and lyophilized decoction of the leaves (both 1000 mg/kg; p.o.) produced 50 and 47% inhibition of abdominal writhing in mice in comparison to dipyrone sodium (200 mg/kg). The juice also increased the latency in hot plate test in mice in comparison to morphine. Another important observation was reversal of action of juice by pretreatment with naloxone (5 mg/kg, i.p.), except for the decoction. So the author proposed the opioid related mechanism of antinociception [58]. Asadullah isolated β-sitosterol from BD roots and reported 61.29% edema in rats [59].Inflammation is an important use of BD. This plant is also called sothaghni which means that who alleviate inflammation.

Diuretic and Renal Activity

In vitro studies: Chauhan and coworkers studied the effect of aqueous extract on growth inhibition of struvite crystals, made up of ammonium magnesium phosphate hexahydrate (AMPH), commonly found in urinary stone (calculi) in women. 0.5 and 1.0% extract administration produced 50 and 71.42% decrease in crystal size. The administration of 1.0% BD extract caused dissolution of crystal by day 4. When studied *in vitro*, 0.5 and 1% extracts have, respectively, shown 88.89 and 138.89% enhanced rate of dissolution in gel at the gel-liquid interface [60].

In vivo studies: Mudal compared the effect of *Convolvulus pluricaulis* and BD against hypotension, potentiation of barbiturate hypnosis, and diuretic and anti-inflammatory activities. The authors found significant diuretic activity in BD root extract (water insoluble portion of alcoholic extract) collected in a rainy season. The authors found 90.3% increase in the volume of urine in rats treated with the extract (300 mg/Kg) whereas extract of leaves and flower showed 67.22% increase in the volume of urine [57]. Singh and coworkers studied the effect of aqueous ethanolic extract on *E. coli*-induced acute pyelonephritis in rats. The extract (50 mg/Kg p.o.) administered twice orally showed 42.85% decrease in number of animals showing signs of renal changes. The administration of the extract (50 mg/Kg p.o.) twice orally showed 99.09% decrease in bacterial count per mL of urine [61]. Wahi and coworkers isolated alkaloid punarnavine and water soluble base choline from BD roots and evaluated them for effects on frogs' heart, frogs' skeletal muscle (rectus abdominis), and diuresis. The authors found significant diuresis after administration of the alkaloid (5 mg/100 g) in rats [62].

Sathyapriya and coworkers evaluated the effect of the aqueous extract of the whole plant of BD on osmotic fragility in erythrocyte from

polycystic ESRD patients. It significantly decreased the osmotic fragility in erythrocyte from polycystic ESRD patients. The authors suggested it for a property of altering the erythrocyte membrane composition or a direct/indirect effect on the intracellular sodium and alleviation of oxidative stress [63]. Pareta et al. [64] studied the antioxidant potential of BD extract in urinary stones by means of inhibition of oxidative trauma and kidney cell damage and observed decrease in calcium oxalate deposition. Yasir et al. [65] reported the ability of ethanolic extract of BD in shrinking crystal size and promoting calcium oxalate dihydrate (COD) crystals formation more than monohydrate (COM) crystals. Singh and coworkers reported the potent renoprotective potentials of BD on alloxan induced diabetic rats indicated by effective glucoregulation, maintenance of serum ionic status and renal Na^+-K^+ ATPase activity, and antioxidant status [61].

Anti oxidant activity

M. Amarnath Satheesh and L. Pari were reported that Administration of *Boerhaavia diffusa* leaf extract (BLEt; 200 mg/kg) for 4 weeks resulted in a significant reduction in thiobarbutric acid reactive substances and hydroperoxides, with a significant increase in reduced glutathione, superoxidedismutase(SOD), catalase, glutathione peroxidase and glutathione-S-transferase in liver and kidney of alloxan induced diabetic rats. The results suggest that BLEt has remarkable antidiabetic activity and can improve antioxidant status in alloxan induced diabetic rats[66].

Hepatoprotective Activity

In vivo studies: Gulati and coworkers prepared 50% aqueous ethanolic extract of BD roots and evaluated hepatoprotection at a dose of 100 mg/100 g in hepatotoxicity induced by country made liquor. BD extract reduced the increment in serum parameters indicative of damage to the liver. The increase in SGPT, SAP, triglycerides, and total lipid levels was decreased by almost 50% by administration of BD extract while the level of cholesterol was completely restored. SGOT level was not much affected by BD extract. Histopathological study of the liver showed minimal fatty cysts in BD treated group. The author suggested an additional antilipidemic activity along with hepatoprotective activity [51]. Chandan and coworkers evaluated the 50% aqueous ethanolic extract of BD whole plant given orally for its hepatoprotective activity in carbon tetrachloride induced hepatotoxicity in rats. The extract significantly decreased CCl_4 induced increase in hexobarbitone sleeping time from 225 min to 200 min. It also lowers the SGPT level from 260μmol/min to 200μmol/min. It showed reduction of the serum levels of SGPT, SGOT, and bilirubin from 270 to 205, 140 to 120, and 1.95 to 1.2μmol, respectively. It also significantly decreased the increase in prothrombin time induced by CCl_4 from 30.43 to 19.01 sec. In this test, bromosulphalein clearance was reduced to 3 times from 16 times by administration of BD extract. It also almost doubles the flow of bile [67]. Rawat and coworkers studied the effect of various factors for the hepatoprotection by BD extract and found that aqueous extract (2 mL/Kg) of 1–3 cm diameter roots from May displayed significant protection for serum parameters, that is, GOT (82.55%), GPT (74.16%), and ALP (51.47%), but not GLDH and bilirubin in thioacetamide-induced hepatotoxicity. It has been noted in this study that the roots, which were thin, showed maximum protection of serum parameters [68].

Devaki and coworkers studied the effect of ethanolic extract of BD on tissue defense system against ethanol-induced hepatic injury in rats. The administration of BD extract (150 mg/kg/day for 30 days, orally) reversed the increase in the levels of lipid peroxides and increased the activities of superoxide dismutase, catalase, glutathione peroxidase, and glutathione-S-transferase and reduced glutathione levels [69]. Olaleye and coworkers evaluated the aqueous and ethanolic extracts of fresh leaves for antioxidant components and activity by *in vitro* and *in vivo* assays. Antioxidative evaluation of the ethanolic extract has shown appreciable quantities of

phenolic and flavonoid content along with vitamins C and E. It also contained selenium and zinc. Pretreatment with BD aqueous and ethanolic extracts reduced enzymatic activities and serum bilirubin caused by acetaminophen. The increase in alkaline phosphatase was reduced by almost 50% by aqueous and ethanolic extracts (both 400 mg/Kg, orally for 7 days) whereas the increase in ALT and AST was decreased by more than 70% and serum LDH level was restored. The increase in TBARS was also neutralized by aqueous and ethanolic extracts [70]. Venkatalakshmi et al. accounted for protection against paracetamol induced hepatotoxicity for BD extracts (Venkatalakshmi, 2011) [71].

Antibacterial Activity

In vitro studies: the aqueous and ethanolic extracts of BD (whole plant) were found active against *Streptococcus* group (10–19 mm), *Neisseria gonorrhoeae* (ethanolic and water ex.; 5–9 mm), *Salmonella typhimurium* (ethanolic and water ex.; more than 20 mm), *Shigella dysenteriae* (ethanolic and water ex.; more than 20 mm), *Corynebacterium diphtheriae* (water ex.; more than 20 mm), and *Clostridium tetani* (ethanolic ex.; 10–19 mm) [72]. It was observed that ethanolic and aqueous extracts possess antibacterial activity against *Bacillus subtilis* and *Escherichia coli*. The minimum inhibitory concentration of ethanolic extract was found to be 125 and 250μg/mL for *B. subtilis* and *E. coli*, while the aqueous extract showed 250μg/mL for *B. subtilis* and *E. coli*, respectively [73]. Umamaheswari and coworkers studied the effect of various extracts prepared from BD roots against Gram-positive (*Staphylococcus, Bacillus, Streptococcus*, and *Micrococcus*) and Gram-negative (*E. coli, Pseudomonas, Salmonella, Klebsiella, Proteus, Serratia*, and *Shigella*) bacterial strains by observing the zone of inhibition. The ethanol extract of BD leaves demonstrated highest activity [74].

Kant and coworkers established the effectiveness of BD as an adjuvant to chemotherapy in clinical trials conducted on 50 patients newly diagnosed with pulmonary tuberculosis. The clinical recovery rate was faster in BD treated group than in the control. At the end of the 4-week follow-up, 80% of the patients were relieved of cough compared to only 52% in the control group. Similarly, 88% of the patients in the treated group were afebrile in 4 weeks compared to 60% of control. Fever relief was observed in 6 weeks in comparison to 8 weeks in the control groups, respectively. The mean weight gain in the treated group was higher than that in the control group. The rate of sputum conversion was significantly faster in the treated group than in the control group [75].

Antifungal Activity:

In vitro studies: Agrawal and coworkers evaluated the antifungal activity of ethyl acetate extract of the roots of BD and have shown mycelial growth inhibition for *Microsporum gypseum* (78.83%), *M. fulvum* (62.33%), and *M. canis* (42.30%) in that order at 1 mg/mL. The increase in concentration of extract also inhibited sporulation [76].

Microsporum gypseum have been documented as a cause of dermatophytosis which can be characterized by redness of the skin, small papular vesicles, fissures, and scaling. Formulations containing BD (punarnavadyarishta, punarnavadi mandura) have been used for such indications.

Anticonvulsant Activity

In vivo activity: Goel and coworkers have shown anticonvulsant activity in pentylenetetrazol (PTZ) induced seizures in mice and concluded that the calcium antagonist activity is responsible for this since the activity was maintained only by liodendrin-rich fraction, additionally established by anticonvulsant activity in BAY k-8644-induced seizures [77].

CONCLUSION:

Boerhavia diffusa (BD) is a plant of repute in traditional as well as ethnobotanical systems of medicine in various parts of world. Throughout the millennia *Boerhavia diffusa* plant has developed into a phenomenon medicinal plant

having an excess of chemical constituents helpful against a many number of disorders. This plant finds extensive importance in the traditional herb based preparations in the worldwide. It contains diverse chemical compounds which have shown therapeutic activities, for example, diuresis, anticancer, anti-inflammation, hepatoprotection, and immunomodulation. However, it still has not been able to claim its position in herbal market. In the current scenario of plant based medicinal products, BD can prove to be an effective and affordable commodity for hepatoprotection, diuresis, and immunomodulation. It is also a source of structurally novel rotenoid compounds which can show possibilities to design novel semisynthetic compounds for newer indications.Although there are gaps in the studies carried out so far, which need to be associated in order to develop the full medicinal potential of *Boerhavia diffusa*, it is still very comprehensible that this is a plant with incredible extensive use nowadays and also with extraordinary potential for the future research.

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