



Review

Ethnomedicinal uses, phytochemistry and pharmacological properties of the genus *Boerhavia*

Kapil S. Patil, Sanjivani R. Bhalsing*

Department of Biotechnology, School of Life Sciences, North Maharashtra University, Jalgaon 425001, Maharashtra, India

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ABSTRACT

Ethnopharmacological relevance: The genus *Boerhavia* is widely distributed in tropical, subtropical and temperate regions of the world including Mexico, America, Africa, Asia, Indian Ocean Islands, Pacific Islands and Australia. The genus *Boerhavia* is extensively used by local peoples and medicinal practitioners for treatments of hepatitis, urinary disorders, gastro intestinal diseases, inflammations, skin problems, infectious diseases and asthma. Present review focused on traditional uses, phytochemistry, pharmacology and toxicology of *Boerhavia* genus to support potential scope for advance ethnopharmacological study.

Materials and methods: Information on the *Boerhavia* species was collected from classical books on medicinal plants, pharmacopoeias and scientific databases like PubMed, Scopus, Google Scholar, Web of Science and others. Also scientific literatures based on ethnomedicinal surveys, Ph.D. and M.Sc. dissertations, published papers from Elsevier, Taylor and Francis, Springer, ACS as well as Wiley publishers and reports by government bodies and documentations were assessed.

Results: A total of 180 compounds from *Boerhavia* genus were isolated of which *B. diffusa* alone shared around 131 compounds and for most of which it is currently an exclusive source. In the genus, phenolic glycosides and flavonoids contribute approximately 97 compounds. These includes eupalitin, rotenoids like boeravinones, coccineons, alkaloid i.e. betanin and punarnavine etc., showing vital pharmaceutical activities such as anticancer, anti-inflammatory, antioxidant and immunomodulatory.

Conclusion: *Boerhavia* is an important genus with wide range of medicinal uses. However, most of the available scientific literatures have lacked relevant doses, duration and positive controls for examining bioefficacy of extracts and its active compounds. In some studies, taxonomic errors were encountered. Moreover, there is need for accurate methods in testing the safety and ethnomedicinal validity of *Boerhavia* species.

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Abbreviations: IL-2, Interleukin-2; NK, Natural Killer; TNF, Tumour Necrosis Factor; PBMCs, Peripheral Blood Mononuclear Cells; ROS, Reactive Oxygen Species; MAP, Mitogen-Activated Protein; ESR, Electron Spin Resonance; HBV, Hepatitis-B Virus; Th1, T helper 1; IFN, Interferon; WSSV, White Spot Syndrome Virus; VEGF, Vascular Endothelial Growth Factor; RT-PCR, Reverse Transcription Polymerase Chain Reaction; ELISA, Enzyme-Linked Immunosorbent Assay; HUVECs, Human Umbilical Vein Endothelial Cells; ATO, Arsenic Trioxide; NO, Nitric Oxide; IC₅₀, 50% Inhibition Concentration; EC₅₀, Half Maximal Effective Concentration; ED₅₀, Median Effective Dose; LC₅₀, Half Maximal Lethal Concentration; HPLC-PAD, High-performance Liquid Chromatography with Pulsed Amperometric Detector; ESI-MS, Electrospray Ionisation Mass Spectrometry; MMP, Matrix Metallo Peptidase; MOA, Monoamino Oxidase. EtOH, Ethanol; MeOH, Methanol; RSC₅₀, Radical Scavenging Capacity of 50%; TDI, Toluene Diisocyanate; CMC, Carboxymethylcellulose

* Corresponding author.

E-mail address: bhalsingsr@gmail.com (S.R. Bhalsing).<http://dx.doi.org/10.1016/j.jep.2016.01.042>

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1. Introduction

1.1. *Boerhavia* genus

Boerhavia (frequently spelled '*Boerhaavia*') is highly polymorphic genus of Nyctaginaceae also known as four-o'clock family because most of the species open their flowers four hours after noon i.e. in early evening or morning (Fosberg, 1978; Levin et al., 2001). Nyctaginaceae encompasses 391 species in 32 genera. Due to taxonomic conflict and concepts, the genus *Boerhavia* includes variable number (20–40) of species (synonyms and homonyms) of subtropical or panatropical herbs (Fosberg, 1978; Douglas and Manos, 2007). This has impacted scientific exploitations of some species of *Boerhavia* as only one species i.e. *B. diffusa* is predominantly studied. Most *Boerhavia* species possess worldwide medicinal uses and hence occupied positions in different systems of medicine including Indian Ayurveda, Siddha and Unani, Martinican medicine, African medicine, traditional Chinese medicines as well as Indian and Brazilian pharmacopoeia. Six important species viz., *B. diffusa*, *B. repens*, *B. chinensis*, *B. erecta*, *B. elegans* (synonym: *B. rubicund*) and *B. reniformis* (synonym: *B. rependa*) are found in India (Chopra, 1969; Dev, 2006). Out of 180 isolated compounds from *Boerhavia* genus, *B. diffusa* shared about 131 compounds and for most of these compounds, it is currently an exclusive source. Following this 46 compounds have been isolated from *B. erecta*. The compounds from *Boerhavia* genus include characteristic chromoalkaloids, quinonolizidine alkaloids i.e. punarnavine, flavonoids, phenolic glycosides, phenolic acids, sterols and organic acids. Also many pharmacological activities in *B. diffusa* have been reported and there are some reviews which included information on *B. diffusa*. However, the present review also covers studies in other species of *Boerhavia* genus and recent pharmacological data of *B. diffusa* published in last 5–6 years.

2. Geographical distribution and botanical description

Boerhavia species are widespread and the dispersal is mostly due to birds and human activity. The genus name *Boerhavia* was given in honour of Hermann Boerhaave, a famous Dutch physician of the 18th century. The distribution of *Boerhavia* species is in the

warmer parts up to an altitude of 2000 m. Besides this, they are found in disturbed areas, waste places, roadsides, dry pinelands, among scrub on tropical reefs (Spellenberg, 2004). Although native to India and Brazil, *B. diffusa* is found in the tropical, subtropical and temperate regions of the world. This may imply that worldwide distribution of *B. diffusa* have helped for establishment of its broader ethnomedicinal spectrum and hence a material of interest for most industries and researchers. In India *rakt punarnava* (*B. diffusa*) is known to possess more medicinal importance than *shweta punarnava* (*B. erecta*). Alone in Kerala state of India, the demand of *B. diffusa* roots was 1, 150 metric tonnes in year 2000 and it is among the 46 medicinal plants sourced largely from wastelands (Tewari, 2000; Ved and Goraya, 2007; Pathak et al., 2012; Patil and Bhalsing, 2015). However, considerable information on phytochemistry and pharmacology of *B. diffusa* is available under the taxonomically inappropriate names such as *Boerhavia diffusa* Linn., *Boerhavia Diffusa* etc. All the names of *Boerhavia* species discussed in this review have been checked against www.theplantlist.org. Nevertheless, most scientific literatures provided different synonyms for *Boerhavia* species because of taxonomic errors or incorrectly identified from local peoples. For example, in the literature there are many synonyms have been provided for *B. diffusa* such as *Boerhavia glabrata*, *B. repens*, *B. erecta*, *B. rependa*, *B. procumbens* etc. which are actually different species (Douglas and Manos, 2007; Selvaraj et al., 2012). Also, species name *Boerhavia rependa* Willd is used in literatures for which the accepted name is *Boerhavia reniformis* Chiov. In addition, studies are also conducted under the name *Boerhavia chinensis* (L.) Asch. & Schweinf. but the accepted species name is *Boerhavia chinensis* (L.) Rottb. The species name *Boerhavia paniculata* has been recently used in literature for accepted name *Boerhavia paludosa* (Domin) Meikle. Beside the above taxonomic errors, the sources of error also seem to be those which are described by Rivera et al. (2014) and this can lead to an erroneous future research. Though *Boerhavia* is well polymorphic genus, a comprehensive and reliable taxonomic approach is still needed for identification of *Boerhavia* species. Few noteworthy studies using molecular tools such as ITS genes are recently carried out in this respect (Douglas and Manos, 2007; Selvaraj et al., 2012). The detailed geographical distributions of some traditionally used *Boerhavia* species are enlisted in Table 1.

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