A Short Review on Physico-Chemical Properties of Bacopa monnieri L

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Abstract

Material of our interest in the present study is the medicinally important Brahmi (Bacopa monnieri L.) herb. The herb has been so chosen because of its various pharmaceutical and medicinal properties. Since the important elemental constituents, phases and complexes of the medicinal plant possess different curative capability of human disease. So, it is important to know the details of the above herb, its chemicals composition, pharmaceutical and medicinal components, important elements and material phases present are defined in this mini-review.

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1. Introduction

Medicinal herb, viz. Bacopa monnieri L., like other plants is also affected by acid rain (AR). Bacopa monnieri (Family: Scrophulariaceae; Genus: Bacopa; Species: B. monnieri, English name Brahmi) is a herb which commonly grows in wet, damp and marshy areas found throughout India, Nepal, Sri Lanka, China, Taiwan, Viet Nam, Florida and other southern states of the USA (Daniel, 2005; Warrier et al., 1996; Khare, 2003). It has been used in traditional Indian system of medicine, the Ayurveda, for the treatment of anxiety, and in improving intellect and memory for several centuries. Bacopa is an important medicinal herb used in Ayurveda, where it is also known as "Brahmi," after Brahmi, the creator God (Hindu) of the universe. Bacopa monnieri (BM) has traditionally been employed as a neurological tonic and cognitive enhancer, and it is currently being studied for its possible neuroprotective properties (Pase et al., 2003). It was reported to possess anti-inflammatory, analgesic, antipyretic, sedative, free radical scavenging and anti-lipid peroxidative activities. It exhibits potent antioxidant and free radical scavenging properties. Besides, it also possesses anticancer, hepatoprotective, antiulcer, calcium antagonist, bronchovasodilatory, smooth muscle relaxant and mast cell stabilizing properties. Within this tiny herb are numerous brain boosting compounds, but the most active ones are bacoside A and bacoside B5. The pharmacological properties of BM have been studied extensively and the activities have been attributed mainly to the presence of characteristic saponins called "bacosides". This herb is also used in rebirthing therapy to accelerate trauma release and to make continuous breathing easier. BM is a well-known nootropic plant reported for its tranquilizing, sedative, cognitive-enhancing, hepatoprotective and antioxidant action. This plant grows in grasslands occurring aquatic sites, sand and wet soil occupying in the edges of freshwater or brackish pools, streams and lake beds.

735
1.1 Justification of Research
Bacopa is an important medicinal herb used in Ayurveda. BM has traditionally been employed for the treatment of a number of health problems. The pharmaceutically and medicinally important herb is easily available in and around our garden. By knowing the elements, phases, complexes present and discovering the new elements, new phases presence in this important herb, one can think for its potential application for other problems and treatment also. In our present review we aimed to report almost all significant elements, compounds, phases identified etc. present in BM. We expected that this work will be a good source knowledge for the future research in the above direction.

1.2 Brief Summary of Work
In the “Introduction” section, the importance of the Bacopa monnieri is described. Plant identification parameters are also described in the “Plant description”. Next to that, important characteristics properties and their analysis viz. Microscopic, Chemical, Elemental, Material phases, Pharmacological, Toxicology etc. have been derived in the “Characteristics properties” section. Finally, “Conclusions” present the concluding remark and outlines some important suggestions for future research.

2. Plant Description
Brahmi (B. monnieri L.) is a glabrous, succulent, small, prostrate or creeping annual herb, found throughout India in wetlands and damp places. Stem is thin, green or purplish green, about 1-2 mm thick, 10-30 cm long, soft; nodes and internodes are prominent, glabrous; and taste slightly bitter (Khare et al., 2003). Leaves are simple, opposite, decussate, green, sessile, 0.6-2.5 cm long, 3-8 mm broad, obvate-oblong; and taste slightly bitter. Flowers are small, axillary and solitary, pedicels 6-30 mm long, bracteoles shorter than pedicels as shown in Figure 1. Fruits are capsules upto 5 mm long, ovoid and glabrous. Root is thin, wiry, small, branched and creamish-yellow in color.

3. Characteristic properties
3.1 Microscopic analysis
The light microscopy (LM) and scanning electron microscopy (SEM) have always played an important role in the study of plant and cell. Microscopic (Serrano et al., 2010; Gabara et al., 2003; Bellani et al., 1997; Anna-Santos et al., 2006; Ali et al., 1999) observation of the B. monnieri stem shows single layer of epidermis followed by a wide cortex of thin-walled cells with very large intercellular spaces. The endodermis single layered; pericycle consisting of 1-2 layers; vascular ring continuous, composed of a narrow zone of phloem towards periphery and a wide ring of xylem towards centre. The centre occupied by a small pith with distinct intercellular spaces. The starch grains found simple, round to oval, present in a few cells of cortex and endodermis, measuring 4-14 μ in dia, and 8.0-14.0 x 2.5-9.0 μ id dia. respectively. Leaf of it shows a single layer of upper and lower endodermis covered with thin cuticle; glandular hairs sessile, subsidiary cells present on both surfaces. A few prismatic crystals of calcium oxalate occasionally found distributed in mesophyll cells. The mesophyll traversed by small veins surrounded by bundle sheath; no distinct midrib present. Root shows a single layer of epidermis, cortex having large air cavities; endodermis single layered; pericycle not distinct; stele consists of a thin layer of phloem with a few sieve elements and isolated material from xylem shows vessels with reticulate thickenings. Fine powder shows xylem vessels with reticulate thickening, glandular hairs, simple, round and oval starch grains, measuring 4-14 μ in diameter.

3.2 Chemical analysis
The chemicals (Mathew et al., 2010; Murthy et al., 2006; Bammidi et al., 2011; Soudararajan and Karrunakaran, 2011; Tiwari et al., 1998) present in brahmi, which are responsible for its brain and nerve regenerative effects, include hydocotylin, asiaticoside, valentine, pectic acid, sterol, fatty acids, tannin, volatile oils, ascorbic acid, thancunisidea, thancunic acid, glycosides, bhramoside, bhramic acid, isobramic acid, bhrominoside, betulic acid and stigmasterol. Moreover, vallerine, asiatic acid, jujube-cogenin and pseudojujubacogenin are also presented in B. Monnieri.

Traditionally, a number of chemical compounds have been isolated from Bacopa monnieri. Bacopa contains Alkaloids (Hydrocotyline, Brahmine and Herpestine), Glycoside (Asiaticoside and Thanakunicide), Flavonoids (Apigenin and Luteonin), Saponins (D-mannitol, Acid A, Monnierin [C51H82O213H2O] Bacoside A [C41H68O134H2O] and Bacoside B...
[C4H68O135H2O]), Phytochemicals (Betulinic acid, Wogonin, Oroxindin, Betulic acid, Stigmastranol, beta-sitosterol, Bacosides and Bacopasaponins), amino acids (alpha alanine, Aspartic acid, Glutamic acid and Serine) and esters, Heptacosane, Octacosane, Nonacosane, Triacontane, Henriciacontane, Dotriacontane, Nicotine, 3-formyl-4-hydroxy-2H-pyran [C6H6O3), and its 7- glucoside. Again, Saponins are considered to be the major active constituents of the plant. Saponins are glycosides, a sugar unit attached to an aglycone portion (the sapogenin). The sapogenin portion describes the type of saponin—either steroidal (4- ringed structure), or triterpenoid (5-ringed structure). However, the main active chemical constituents of Bacopa are the dammarane-type triterpenoid saponins (Saraswati et al., 1996) with the aglycones (jujubogenin and pseudojujubogenin) (Deepak and Amit, 2004). Again, the saponins consist of subclasses named as bacosides, bacopasides and bacopasapainons. Bacoside-A and Bacoside-B (an optical isomer of bacoside-A) were first identified by Chatterji et al. (Chatterji et al., 1963; Singh et al., 1998). Chemical structure of Bacoside-A, Bacoside-B and Bacoside-C are represented as 3–0–L–arabinopyranosyl–20–0–L–arabinopyranosyl–jujubogenin, 3–0–[α–L–arabinopyranosyl (1–2)α–L–arabinopyranosyl] pseudojujubogenin and 3-0-[β-D-glucopyranosyl (1-3) [α-L-arabinofuranosyl (1-2)] α-L-arabinopyranosyl] pseudojujubogenin, respectively (Saraswati et al., 1996).

3.3 Elemental analysis

Elemental concentrations of B. monnieri (Kumar et al., 2005; Garg et al., 2007; Singh et al., 1997; Behera et al., 2014a; Behera et al., 2014b) herb were determined by various multi-elemental analysis techniques. A number of active elemental constituents of the medicinal plants are the metabolic products of the plant cells. A number of minor and trace elements play an important role in the metabolism processes. These important elemental constituents of the medicinal plant possess different curative capability for human diseases. As reported in Kumar et al. (2005), there are 10 minor (mg/g) elements, viz. Al, Br, Ca, Cl, Fe, K, Mg, Na, P, and V present in Brahmi plant. Also, there are 12 trace (µg/g) elements viz. Ba, Co, Cr, Cs, Hg, La, Mn, Rh, Sc, Se, Th, and Zn detected in the Brahmi herb using neutron activation analysis (NAA) and Atomic Absorption Spectrometry (AAS) techniques. Again, in another report, elemental constituents of Brahmi herb have been analyzed using NAA and AAS techniques (Garg et al., 2007; Singh and Garg, 1997). There are 5 minor (w%) elements, viz. Al, Cl, Mg, Na, K, detected using NAA. The method involves thermal neutron irradiation in a reactor followed by counting at several intervals. Also, Cu, Co, Ni, Pb, Cr, Cd, Fe, Ca and Zn contents were determined by AAS. Concentration (w%) of 9 minor elements, viz. Na, Mg, Al, P, S, Cl, K, Ca, and Fe in B. monnieri herb were determined using the energy dispersive spectroscopy (EDS) technique by Behera et al. (2014a). Also, both minor (%) and trace (ppm) elemental concentrations of Brahmi herb were carried out using the proton-induced X-ray emission (PIXE) technique Behera et al. (2014b). The minor elements, viz. Fe, Ca, P, K, Cl are found in w%. However, the trace elements of Brahmi, viz. V, Cr, Mn, Co, Cu, Zn, As, Br, Se, Rb, Sr are observed in ppm level.

3.4 Material phase analysis

There are only a few reports on the crystallographic phase analysis of pharmaceuticals and medicinal plants (Scarlett et al., 2002; Gao et al., 2005; Mahitha et al., 2011; Behera et al., 2012). The X-ray powder diffraction study of plant materials shows various crystallographic phases, which are formed due to the presence of multiple elements in it. However, it is practically difficult to observe these crystallographic phases in the fibrous materials because of: (i) the contents of the multiple elements are low (mg/g), so they possess low-intense X-ray diffraction peak, and (ii) the fibrous materials usually possess high background intensity that creates problems to observe these low-intense peaks. X-ray powder diffraction study of Brahmi herb materials shows various crystallographic phases, which are formed due to the presence of multiple elements in BM. The main composition of the B. Monnieri herb material is cellulose (C6H10O5)n. The crystallographic phases observed from the B. monnieri herb grown in normal habitat are Paravauxite (FeAl2(PO4)2(OH)2;8H2O) (JCPDS-ICDD, 12-0427), Syngenite, syn (K2Ca(SO4)2H2O) (JCPDS-ICDD, 28-0739), Boehmite (Al2O3·H2O) (JCPDS-ICDD, 01-1283), Periclase, syn (MgO) (JCPDS-ICDD, 43-1022), etc. (Behera et al., 2012).

3.5 Pharmacological analysis

The pharmacological properties (Singh et al., 2006; Ali et al., 1998; Mathur et al., 2010; De et al., 2009; NANDAVE et al., 2007; JAGER et al., 2007; RASTOGI et al., 1964; ZHANG et al., 2011; DHANASEKHARAN et al., 2007; SIVARAMAKRISHNA et al., 2005; UDGIRE and PATHADE, 2012; PATIL et al., 2009) of B. monnieri have been studied extensively and the activities have been attributed mainly to the presence of characteristic saponins (bacosides). Again, Bacopa is a very good natural antioxidant which shows neuroprotective properties in the memory centers of the brain and cell-protective effects (RUSSO and BORRELLI, 2005). Again, epilepsy is a neuronal disorder characterized by learning, cognitive and memory impairments.
It also inhibits acetylcholinesterase, activates choline acetyltransferase, and increases cerebral blood flow (Aguirar and Borowski, 2013) and protects neurodegeneration in animal models (Calabrese et al., 2008; Jadiya et al., 2011; Saraf et al., 2008; Vollata et al., 2011; Ahirwar et al., 2012; Rastogi et al., 2012; Sairam et al., 2002). The preliminary clinical studies of the above herb have shown improvement of cognitive function in humans (Pase et al., 2012). However, the major chemicals responsible for various curative properties of Brahmi herb have already been described in the earlier section the ‘Chemical analysis’.

3.6 Toxicology analysis

Aqueous extracts of Bacopa monnieri may elevate serum thyroid and decrease spermatogenesis, sperm count, and fertility in male mice (Singh and Singh, 2009). The rat LD₅₀ was found to be 2400 mg/kg following a single oral administration (Allan et al., 2007). The most commonly reported adverse side effects of B. monnieri in humans are nausea, increased intestinal motility, and gastrointestinal upset (Singh and Dhawan, 1997; Pravina et al., 2007).

Toxic elements such as Cd, Cr, Hg, As, Rb, and Pb are present in the B. monnieri herb (Kumar et al., 2005; Narg et al., 2007; Singh and Garg, 1997; Behera et al., 2014a; Behera et al., 2014b; Shukla et al., 2007; Treleaven et al., 1993; Ernst, 2002). These environmental toxicants cause poisonous effects on both plants and animals. The toxic and heavy metals such as Pb, Hg, etc., have been a regular constituent in the Indian traditional Ayurvedic medicines. The efficacy and side effects of these elements are evaluated by various authors. It has been expected that these may cause serious harm to patients taking such remedies.

Conclusion

In pharmacologic studies, the whole plant of B. monnieri has been attributed with various medicinal properties including memory enhancing, anti-inflammatory, antioxidant, analgesia, reducing oxidation of fats in the bloodstream, antipyretic; sedative, hepatoprotective, cardiotonic and antiepileptic and these have been correlated to the presence of bacosides. B. monnieri has been used in traditional Ayurvedic treatment for epilepsy and asthma. It is also used in Ayurveda for ulcers, tumors, enlarged spleen, indigestion, inflammations, leprosy, anemia, and biliousness, ascites.

Bacopa monnieri has been used in traditional Indian medicine, the Ayurveda, for the treatment of anxiety, and in improving intellect and memory, for several centuries. In addition to memory boosting activity, it is also claimed to be useful in the treatment of cardiac, respiratory and neuropharmacological disorders like insomnia, insanity, depression, psychosis, epilepsy and stress. It has been reported to possess anti-inflammatory, analgesic, antipyretic, sedative, free radical scavenging and anti-lipid peroxidative activities. It is used also as a tranquilizer. The plant is anticancer, astringent, bitter, sweet, cooling, laxative, intellect promoting, anodyne, carminative, digestive, antioxidant, antimicrobial anti-inflammatooy, anticonvulsant, depurative, cardiotonic, bronchodilator, diuretic, emmenagogue, sudorific, febrifuge and a tonic.

Research Highlights

The review highlights the Physico-Chemical properties of Bacopa monnieri L. using a number of techniques are:

The microscopic analysis confirmed the starch grains found simple, round to oval, present in a few cells of cortex and endodermis, measuring 4-14 µ in dia, and 8.0-14.0 × 2.5-9.0 µ id dia. with its macro and microscopic characteristics.

Different spectroscopic techniques confirmed the Bacopa contains a number of chemical compounds such as: Alkaloids, Glycoside, Flavonoids, Saponins (D-mannitol, Acid A, Monnierin Bacoside A and Bacoside B), Phytochemicals, amino acids and esters, Heptacosane, Octacosane, Nonacosane, Triaccontane, Henriacontane, Dotriacontane, Nicotine, and its 7- glucoside.

There are about 10 minor (mg/g) elements, viz. Al, Br, Ca, Cl, Fe, K, Mg, Na, P, V and 12 trace (µg/g) elements viz. Ba, Co, Cr, Cs, Hg, La, Mn, Rb, Sc, Se, wTh, Zn present in the Brahmi plant identified using multi-elemental analysis techniques.

The crystallographic phases present in the B. monnieri herb are FeAl₂(PO₄)₂(OH)₂·8H₂O, K₂Ca(SO₄)₂·H₂O, Al₂O₃·H₂O, MgO, etc. were identified using X-ray diffraction technique.

It was suggested to future researchers to investigate the new trace elements present, new phases synthesized due to environmental effects, and the new complexes present in BM and that can be used as potential application for other problems and treatment.

Limitations

The review only states the qualitative estimation of the elements, phases, and complex present but not the quantitate presentation of the above parameters.
Since, concentration of the above parameters depends on a large number of parameters such as place of growth, environmental condition, water contents, acid rain fall etc. it is really difficult to gives the exact estimation of the contents.

**Recommendations**

Based on the above limitations, we recommended that the sample should be collect from different parts of the country with soil and water from the respective place to correlate the contents to get the exact concentration. The data should be taken care to minimize the sampling error, hence the standard errors and deviation.

**Author’s Contribution and Competing Interest**

I declare that all authors were actively involved in the study and have contributed significantly towards the writing of this Review. Author SB designed the study and wrote the first draft of the manuscript. Author BM prepared the X-ray analysis part with critical review/modification of the paper. Author PCM read and correct the manuscript with language polishing. Author PC read and approve the final version of the manuscript. I therefore, on behalf of all the authors declare that there is no conflict of interest among the authors in the present study.

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