



A REVIEW ON PHYTOCHEMICAL AND PHARMACOLOGICAL ACTIVITIES OF BACCOPA MONNEIRI

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ABSTRACT

Bacopa monnieri is an important medicinal plant belongs to family Scrophulariaceae and has long been renowned for its medicinal properties. It is used in traditional medicine the treatment of a number of disorders, particularly those involving anxiety and mental disorders. It is currently being marketed in western countries as a memory-enhancing agent. The plant has been known to have different activities like anti-fungal, anti-cancer, hypoglycemic, anti-bacterial, anti-oxidant, anti-diarrheal, anti-inflammatory, anti-depressant, anti-epileptic, memory enhancer, anti-ulcer, hepatoprotective, analgesic, anti-hypertensive, anti-toxicity etc. This review describes the different active phytoconstituents, traditional uses and different pharmacological activities of Bacopa monnieri.

KEYWORDS: Bacopa monnieri, Phytochemistry, Chemical constituents, Ethanomedicinal uses Pharmacological activities.

INTRODUCTION

The interest in the use of herbal medicines are gaining importance all around the world. The World Health Organization (WHO) estimates that 80% of the world’s population presently uses herbal medicine for some aspects of primary health care.<sup>[1]</sup> Awareness of medicinal plants usage is a result of the many years of struggles against illnesses due to which man learned to pursue drugs in barks, seeds, fruit bodies, and other parts of the plants.<sup>[2]</sup> Bacopa monnieri Linn. Is also known as ‘Brahmi’ in Hindi and water hyssop in English is a small creeping herb with numerous branches, small fleshy, oblong leaves and purple flowers and belongs to Schrophulariaceae family. It grows in wet and sandy areas and near the streams in tropical regions. Flowers and fruits appear in summer. The stem and leaves of the plants are used for various medicinal purposes. It is used in traditional medicine to treat various nervous disorders, as a brain tonic to enhance memory development, learning, and concentration and to provide relief to patient with the anxiety. It is also used in digestive complains, for skin disorders, and as an antiepileptic, antipyretic, and analgesic. It was initially described in texts like Charaka Samhita, Atharva- ved and Susurtu Samhita around 6th century A.D. Today practitioners of Ayurveda recognize it as an adaptogen, a physiological agent that naturally increases the body’s resistance to physical and emotional stress. Most of the herbs contain lots of active constituents which combines to provide the plant its therapeutic value. The chemical substances that produce a distinct physiological action on the human

body are responsible for medicinal value of plants. Generally alkaloids, glycosides, flavonoids, tannin and phenolic compound are important bioactive compounds of plants.<sup>[3]</sup>

This review will illuminate the phytochemical profile of Bacopa monnieri along with traditional uses, its active chemical constituents and also focus on different pharmacological activities.

Taxonomic Classification<sup>[4]</sup>

Kingdom: Plantae  
Division: Tracheophyta  
Class: Magnoliopsida  
Order: Lamiales  
Family: Schrophulariaceae  
Genus: Bacopa  
Species: monnieri (L.)

Vernacular Names<sup>[5]</sup>

| Sr. No. | Language  | Vernacular Names            |
|---------|-----------|-----------------------------|
| 1       | English   | Indian pennywort, Moneywort |
| 2       | Hindi     | Baam                        |
| 3       | Kannada   | Brahmi, Kiru Brahmi         |
| 4       | Malayalam | Brahmi                      |
| 5       | Marathi   | Bramhi, Jalabrahmi          |
| 6       | Sanskrit  | Bramhi, Tikatalonika        |
| 7       | Tamil     | Neer bramhi, Pirami         |
| 8       | Telugu    | Sambrani aku                |
| 9       | Gujrathi  | Baam, Jalanevari            |

## DESCRIPTION OF HERB

*Bacopa monnieri* is a small, creeping, somewhat succulent herb. The leaf and flower bearing stems are 10-30 cm long and arise from creeping stems that form roots at the nodes. The growth habit of *Bacopa*, therefore, resembles that of peppermint. The leaves are simple, obovate-oblong, opposite, approximately 2 cm × 1 cm, with entire margins, flowers are blue or white with purple veins, solitarily on long pedicels in the leaf axils. The corolla is five lobed, white or pinkish with purple blotches. The fruit is an up to 5 mm capsule, which develops in the persistent calyx. *Bacopa* is a member of the family Scrophulariaceae.<sup>[6]</sup>



Figure 1: Fresh and dried herb of *Bacopa monnieri*.

## Chemical constituents

*Bacopa monnieri* mainly contains alkaloids such as brahmine, nicotine, and herpestine. Bacosides A [3-( $\alpha$ -L-arabinopyranosyl)-O- $\beta$ -D-glucopyranoside-10, 20-dihydroxy-16-keto-dammar-24-ene] was isolated from *Bacopa monnieri*. Triterpenoid saponins, saponins A, B and C and pseudojubilogenin glycoside were also isolated from *Bacopa monnieri*. They identified as 3-O- $\alpha$ -L-arabinopyranosyl-20-O- $\alpha$ -L-arabinopyranosyljubilogenin, 3-O-[ $\alpha$ -L-arabinofuranosyl-(1 $\rightarrow$ 2)- $\alpha$ -L-arabinopyranosyl]pseudojubilogenin, 3-O- $\beta$ -D-glucopyranosyl (1 $\rightarrow$ 3)-{ $\alpha$ -L-arabinofuranosyl-(1 $\rightarrow$ 2)}- $\alpha$ -L-arabinopyranosyl] pseudojubilogenin and 3-O-[ $\alpha$ -L-arabinofuranosyl-(1 $\rightarrow$ 2)- $\beta$ -D-glucopyranosyl] pseudojubilogenin. Bacosides I, II, III, IV and V were also isolated from *Bacopa monnieri* which identified as 3-O- $\alpha$ -L-arabinofuranosyl-(1 $\rightarrow$ 2)- $\beta$ -D-glucopyranosyljubilogenin, 3-O- $\beta$ -D-glucopyranosyl-(1 $\rightarrow$ 3)- $\alpha$ -L-arabinopyranosyl jubilogenin, 3-O- $\beta$ -D-glucopyranosyl-(1 $\rightarrow$ 3)- $\alpha$ -L-arabinofuranosyl pseudojubilogenin. *Bacopa monnieri* also contained betulinic acid, D-mannitol, stigmasterol,  $\beta$ -sitosterol and stigmasterol.<sup>[7, 8]</sup>

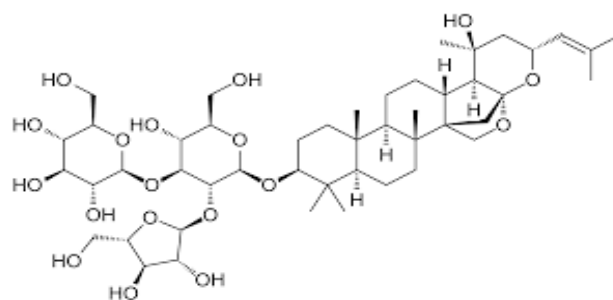


Figure 2: Chemical structure of Bacoside A.

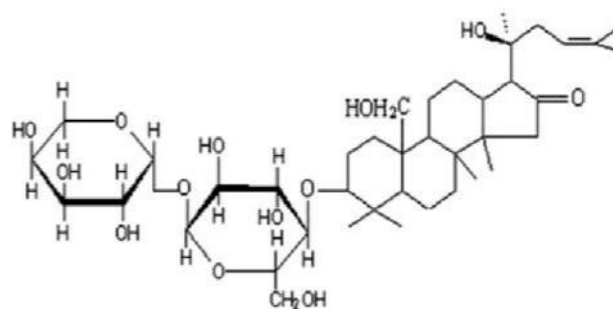


Figure 3: Chemical structure of Bacoside B.

## Macroscopic characteristics

The plant is succulent when fresh but becomes shriveled on drying; slightly bitter in taste, without any characteristic odor and composed of crumpled, matted broken pieces of roots, branching stems, leaves, flowers, and few tender fruits.<sup>[9, 10]</sup>

## Root

Fragments of dried main roots are cylindrical, about 5 mm in diameter, longitudinally wrinkled and off-white in color.

## Stem

Pieces of the stem are cylindrical, glabrous, nodes prominent, at places attached with vertically growing branches and ventrally to cluster of tortuous, brittle roots, internodes about 1-1.5 cm in length and 3-4 mm in diameter, pale yellowish green and with purplish tinge.

## Leaf

Simple, opposite and decussate, somewhat sessile, glabrous, obovate-oblong to spatulate in shape, 0.6-2.5 cm in length and 3-8 mm in width, entire, lower surface dotted with minute specks, obscurely 1-3 nerved, color faint green.<sup>[11]</sup>

## Flower

Pale blue or pinkish white, nearly regular, solitary, axillary. 0.6-3 cm in length, usually longer than the leaves with two linear bracteoles, pedicel slender, calyx glabrous, deeply 5 partite. Corolla gamopetalous, stamens 4, didynamous, anthers 2 celled, pistil carpel, syncarpous ovary two chambered with many ovules, style dilated toward the top, stigma bilobed.<sup>[12]</sup>

**Fruit**

Globose to ovoid, glabrous capsule, 5 mm in length, enclosed withinpersistent calyx, ped 1-3 cm long purplish when fresh.

**Microscopic characteristics****Root**

The root is irregularly circular to angular in shape and show an outermost piliferous layer, parenchymatous cortex with intervening air spaces and a centrally located solid core, of xylem encircled by narrow phloem. The piliferous layer is replaced by formation of cork cells, cortex is wide, parenchymatous, traversed with simple and compound starch grain intervened with air spaces, endodermis is distinct, a narrow band of phloem surrounding the located solid core of xylem composed of radially arranged isolated vessels, fibers, and medullary rays.<sup>[13]</sup>

**Stem**

The stem is almost circular in outline, shows outer epidermis, broad aerenchymatous cortex occupying the major area of the section, a distinct endodermis encircling the ring of stellar tissue and central parenchymatous pith with a layer of thick-walled celled epidermis covered with thin cuticle, cortex is very wide, consisting of chlorenchymatous aerenchyma embedded with starch grains, endodermis is distinct, encircling the narrow band of parenchymatous phloem and xylem, the central region being occupied by narrow parenchymatous pith embedded with simple and compound starch grains.

**Leaf**

The leaf passing through the midrib is almost cylindrical in outline with a very narrow elevation on the upper side of the midrib. Upper and lower epidermis, the cells of the upper being bigger in size and at places show striated cuticle, both the epidermis are embedded with stomata and bear sessile-glandular trichomes with multi cellular head. A narrow collenchymatous band is located underneath both the epidermis of the midrib and shows a centrally located conjoint collateral meristele encircled

by a parenchymatous sheath. The mesophyll tissue of the lamina is composed of spongy parenchyma, traversed with vascular strands; prismatic and few cluster crystals of calcium oxalate are embedded throughout the parenchymatous cells of the leaf.

**Powder**

Shows fragments of upper and lower epidermis of leaf in surface view embedded with sessile-glandular trichomes with 4-8 celled head and diacytic to anomocytic stomata, they being more on the lower side, with sinuous anticlinal walls and at places shows striated cuticle; prismatic, cluster crystals of calcium oxalate, starch grains and oil globules scattered as such throughout or embedded in the parenchymatous cells, fragments of longitudinally cut annular and spiral vessels, transversely cut fragments of stem showing aerenchymatous cortical.<sup>[14]</sup>

**Phytochemistry**

The pharmacological properties of *Bacopa monnieri* were studied extensively, and the activities were attributed mainly due to the presence of characteristic saponins called "bacosides". Bacosides are a complex mixture of structurally closely related compounds, glycosides of either jujubogenin or pseudojujubogenin. Bacosides comprise a family of 12 known analogs. Major bacopasaponins were bacosides A3, bacopaside II, bacopaside I, bacopaside X, bacopasaponin C, bacopaside N2 and the minor components are bacopasaponin F, bacopasaponin E, bacopaside N1 bacopaside III, bacopaside IV and bacopaside V 12. Four cucurbitacins, bacitracin A-D, a known cytotoxic, cucurbitacin E and three phenylethanoid glycosides, monnieraside I, III and plant inside B were isolated from the aerial part of *Bacopa monnieri*. Two common flavonoids, luteolin, and apigenin, have also been detected in *B. monnieri*.

**Ethano-medicinal uses**

The important ethano medicinal uses of *Bacopa monnieri* Linn are represented in Table 1.

**Table 1: Important ethno medicinal uses.**

| Medicinal Use                              | Traditional Formulation  |
|--|--|
| Memory enhancer, Cardiac tonic             | Plant juice is given orally as a diuretic, cardiac tonic and memory enhancer   |
| Memory enhancer                            | Mix <i>Bacopa monnieri</i> powder with <i>Saraca indica</i> bark powder in equal amounts. Administer 5g of this formulation to the patient every day                 |
| Epilepsy, bronchial and diarrheal ailments | Leave juice is used as a remedy of epilepsy, bronchial and diarrheal ailments  |
| Malaria                                    | Fresh plant material is crushed, and the extract is given orally   |
| Hair fall                                  | Plant juice is given as hair tonic especially in thinning and falling hairs Juice obtained from a mixture of crushed leaves, roots and white flowers is taken orally |
| Headache                                   | Juice obtained from a mixture of crushed leaves, roots and white flowers is taken orally   |
| Snakebite                                  | Plant Juice mixed with castor oil is applied externally to treat. Leaf powder decoction mixed with hot cow's milk taken orally                                       |

### Pharmacological activities

Taking a cue from the traditional ethnomedicinal use of this highly valuable plant, scientific studies have been designed and conducted to pharmacologically validate these claims. *Bacopa monnieri* Linn has been found to possess significant anti-depressant activity, anti-anxiety, anti-convulsant, anti-cancer, anti-inflammatory, antioxidant, anti-bacterial, anti-fungal, anti-ulcer, anti-diarrheal, anti-hypertensive, analgesic and anti-toxicity activity.

### Central nervous system effect

Brahmi Rasayan, an ayurvedic preparation, was studied in mice and rats for its effects on the central nervous system at oral doses ranging between 1 and 30 g/kg. Observational screening in mice was carried out following a multiparametric check list. The test material was studied for its effect on pentobarbitone hypnosis, motor coordination, tail-withdraws reaction time, electroshock, chemoconvulsions, haloperidol-induced catalepsy and conditioned avoidance response. The test material exhibited a sedative effect and significantly prolonged the hypnotic action of pentobarbitone. It produced a variable blockade of conditioned avoidance response. The presence of a significant antinociceptive effect, coupled with the ability of the test substance to offer protection against electroshock seizures and chemoconvulsions plus the ability to antagonize the haloperidol-induced catalepsy, suggests an involvement of the GABAergic system in the mediation of the central nervous system effects of Brahmi Rasayan.<sup>[16]</sup>

### Memory Enhancer

Behavioral studies in animals have shown that *Bacopa* improves motor learning, acquisition and retention, and delay extinction of newly acquired behavior. The methanol extract and different fractions of *B. monnieri* were evaluated for antidepressant activity in the forced swimming test (FST) and tail suspension test (TST) in mice. The results showed that the methanol extract, ethanol and butanol fraction significantly reduced the immobility times both in FST and TST in mice after being administered orally for 5 consecutive days. All tested samples, in the effective doses for FST and TST, showed no inhibitory effect against locomotor activity (LA) in mice.<sup>[17]</sup> On the other hand, it was found that bacosides facilitates anterograde memory and attenuate anterograde experimental amnesia induced by scopolamine and sodium nitrite possibly by improving the acetylcholine level and hypoxic conditions, respectively. A study on human memory in adults (aged between 40 and 65 years) show a significant effect of the *Bacopa monnieri* on a test for the retention of new information. Follow-up tests showed that the rate of learning was unaffected, suggesting that brahmi decreases the rate of forgetting of newly acquired information. Role of *Bacopa monnieri* as a cognitive enhancer and use of in polyherbal preparation for improving cognitive and behavioral outcome on child and adolescent have been suggested 28. Oral

administration of *Bacopa monnieri* extract to adult male Wistar rats for 60 days was found to be associated with enhanced learning dependent hippocampal long-term synaptic potentiation which plays a critical role in learning and memory.<sup>[18]</sup>

### Antidepressant activity

Bacosides A and B, bacosides I and II and bacosaponin C and the extract of *Bacopa monnieri* exhibited antidepressant activity, while bacoside VII did not have any antidepressant activity when tested on forced swimming and tail-suspension models in experimental animals, Studies carried out by researcher suggest the antidepressant property of *Bacopa monnieri*. Significantly reduced escape latency and plasma corticosterone level along with the significant restoration of body weight among the stressed rats has been observed on acute treatment with *Bacopa monnieri* extract. Such properties of *Bacopa* extract coincides with the effects of well-accepted antidepressant drug fluoxetine hydrochloride and prominently forecast the antidepressant property of *Bacopa monnieri* in stress-related neuropsychiatric disorders. Different doses of Brahmi exhibited antidepressant activity in mice in forced swimming test (FST), and shock-induced depression (SID) models.<sup>[19]</sup>

### Antianxiety Activity

Anti-anxiety property of *Bacopa monnieri* has been reported. *Bacopa* extract produced a dose-related anxiolytic activity in a rat model of clinical anxiety, qualitatively comparable to that of lorazepam, in all the test parameters. The advantage of *Bacopa monnieri* over the widely used benzodiazepine anxiolytics lies in the fact that it promotes cognition unlike the amnesic action of the latter. The traditional use of *Bacopa monnieri* as an anti-anxiety remedy in ayurvedic medicine is supported by both animal and clinical research. One of the study with 35 patients with diagnosed anxiety neurosis demonstrated that administration of brahmi syrup (30 ml daily in two divided doses, equivalent to 12 g dry crude extract of *bacopa*) resulted in a significant decrease in anxiety symptoms, level of anxiety, level of disability and mental fatigue and an increase in immediate memory span. In another study, effects of a standardized *Bacopa monnieri* (300 mg/day) on cognitive performance, anxiety and depression in the elderly was evaluated. The study provided further evidence that *Bacopa monnieri* has a good potential for safely enhancing cognitive performance in the ageing.<sup>[20]</sup>

### Anti-convulsant/anti-epileptic activity

Crude plant extract of *Bacopa monnieri* or bacosides has also shown anticonvulsive action. It possessed neuroprotective effects in glutamate-mediated excitotoxicity during seizures and cognitive damage occurring in association with pilocarpine-induced epilepsy. The ethanolic extract of *Bacopa monnieri* was tested for anticonvulsant activity using different convulsive models (pentylenetetrazole, maximal



electroshock, and strychnine-induced convulsion in rats, as well as hypoxic stress induced convulsions in mice and lithium-pilocarpine-induced status epilepticus). The ethanolic extract of *Bacopa monnieri* was administered as 50-55 mg/kg orally for rats and mice, respectively, 2 and 4 h before the respective convulsive stimuli. The ethanolic extract of leaves produced significant anticonvulsant activity for all the different models studied with a mechanism of action similar to that of benzodiazepines (GABA agonist). The anticonvulsant activity of alcoholic extract of *Bacopa monnieri* in albino rats, using pentylenetetrazole models have also been reported and suggested that the anticonvulsant activity of *Bacopa monnieri* may involve glutaminergic transmission or sodium channel blockage.<sup>[21]</sup>

### Neuroprotective role in Alzheimer and Parkinson's disease

Alzheimer's disease is an age-associated, irreversible, progressive neurodegenerative disease, characterized by severe memory loss, behavioural changes, and a notable decline in cognitive function. Management of the neurodegenerative disorder like Alzheimer's disease and increasing memory enhancement power is considered as one of the greatest challenges. Treating patients with Brahmi extract may be an alternative direction for ameliorating neurodegenerative disorders associated with the overwhelming oxidative stress as well as Alzheimer's disease. *Bacopa monnieri* extract shows a significant neuroprotective effect against Alzheimer's disease by stabilizing the structural and functional integrity of the membrane. The bacoside establish a healthy anti-oxidant environment in liver and brain. The neuroprotective activity is attributed to the regulation of mRNA translation and surface expression of neuroreceptors such as AMPAR, NMDAR, and GABAR in the various parts of the brain.<sup>[22]</sup> Neurodegenerative Parkinson's disease is associated with aggregation of protein alpha-synuclein and selective death of dopaminergic neurons, thereby leading to cognitive and motor impairment in patients. *B. monnieri* reduces alpha-synuclein aggregation, prevents dopaminergic neurodegeneration and restores the lipid content in two different strains of nematodes *C. elegans*; a transgenic model expressing "human" alpha-synuclein, and a pharmacological model expressing green fluorescent protein (GFP) specifically in the dopaminergic neurons treated with selective catecholaminergic neurotoxin 6-hydroxydopamine (6-OHDA), thereby proving its potential as a possible anti-parkinsonian agent. *Bacopa monnieri* showed a better response than levodopa in case of rotenone-induced rodent model of Parkinson disease. Thus, the *B. monnieri* may provide a platform for future drug discoveries and novel treatment strategies in Parkinson's disease and can act as anti-parkinsonian agent.<sup>[23]</sup>

### Anti-cancer activity

Cancer remains as one of the most common causes of mortality worldwide. Cancer chemoprevention by natural products is well accepted nowadays. Phytosterols are

natural products, showing anticancer activity, besides other activities. Stigmasterol, a phytosterol isolated from aerial parts of *Bacopa monnieri* show anticancer activity against Ehrlich ascites carcinoma (EAC) in Swiss albino mice. The antitumor activity of stigmasterol might be mediated through the activation of protein phosphatase 2A by ceramide causing apoptosis. Cytotoxic activity of ethanolic and dichloromethane extract of *Bacopa monnieri* against MCF-7, and MDA-MB 231 cell line have been observed. Cytotoxic activity in DCM fraction in both the cell lines may be due to the presence of cucurbitacins and betulinic acid in DCM fraction. The anti-cancer activity of the ethanolic extract of *Bacopa monnieri* against human breast cancer cell line (MDA-MB-468) is may be due to the synergistic effect of the secondary metabolites present in the extract. Study on the effect of *Bacopa monnieri* extract on gene expression in SH-SY5Y human neuroblastoma cells have revealed that several genes are regulated by *Bacopa monnieri* including genes for regulation of mRNA translation, and transmembrane transport, responses to oxidative stress and protein misfolding thus suggesting that *Bacopa monnieri* may protect against brain damage and improve brain development. Increased permeability by over-expression of AQP 1, a transmembrane protein responsible for water transport is a distinct feature of many human cancer cells including those of breast, colon, and prostate. Bacoside II inhibits the activity of aquaporins AQP1, thus reducing endothelial cell migration and induces apoptosis.<sup>[24]</sup>

### Antimicrobial activity

Methanol extracts were found to be the most potent antimicrobial agent in comparison to other extracts. Aqueous extracts showed no activity against any of the microorganisms. Hexane and petroleum ether extracts showed similar antimicrobial activity but less significant in comparison to methanol extracts. The minimum inhibitory concentration of the methanol extracts was found to be the lowest against *Escherichia coli*, *Salmonella typhimurium*, *Staphylococcus aureus*, and *Saccharomyces cerevisiae*. Methanolic extract (1 mg/ml) of callus of *B. monnieri* shows good activity against *Staphylococcus aureus*, *Salmonella typhi*, and *E. coli* and maximum activity was observed against *Staphylococcus aureus*. No activity was observed against *Klebsiella pneumoniae*. Ether extract of *B. monnieri* showed antimicrobial activity against four bacteria and one fungus, *Salmonella typhi*, *Pseudomonas*.<sup>[25]</sup>

### Anti-hyperglycemic activity

Methanolic extract of the plant possess significant anti-hyperglycemic potential. In OGTT (Oral glucose tolerance tests) conducted with glucose-challenged mice, the extract, administered at four doses of 50, 100, 200 and 400 mg per kg body weight, dose-dependently and significantly inhibited the increase in serum glucose concentrations, respectively, by 33.3, 34.2, 42.1 and 44.2%. The anti-diabetic potential of *Bacopa monnieri* in streptozotocin-induced diabetic rats was reported. The

elevated levels of blood glucose and glycated hemoglobin, whereas the reduced level of hemoglobin, total white blood cell count and platelet count in diabetic rats were normalized on treatment with Brahmi (500 mg/kg body weight) and were comparable with that of the glibenclamide (600 µg/kg body weight/day) treated rats. This study shows that *Bacopa monnieri* possesses significant antihyperglycaemic effects in streptozotocin-induced diabetic rats. An active compound (BM-1) isolated from leaves of *Bacopa monnieri* causes a significant fall in serum cholesterol, triglycerides, LDL and VLDL in normal rats. In diabetic rat, BM-1 also decreased the raised levels of serum cholesterol, triglycerides, LDL and VLDL but increased HDL cholesterol. It shows the possible use of *Bacopa monnieri* extract to treat hyperlipidemia in diabetics.<sup>[26]</sup>

#### Antifungal activity

Methanolic extract showed significant antifungal activity against *Candida albicans* and *Aspergillus niger*. The phytochemicals betulonic acid, wogonin and oroxindin isolated from the aerial parts of *Bacopa monnieri* possess significant antifungal activity against the two fungi *Alternaria alternata* and *Fusarium fusiformis*. *B. monnieri* whole plant extracts in methanol and ethanol: methanol solvent possesses better in-vitro anti-fungal activity against *A. niger*, *Candida albicans* and *Malassezia furfur* compared with the extract in other solvents. The GC-MS analysis confirms the presence of the various phytochemicals contributing for the antifungal activity. *Bacopa monnieri* also exhibits antifungal activity against dermatophytic fungi. Both aqueous and ethanolic extract of *B. monnieri* exhibited a very good anti-fungal activity against the dermatophyte fungi namely *Aspergillus niger*, *Aspergillus flavus*, *Trichophyton rubrum* and *Microsporum*.<sup>[27]</sup>

#### Anti-hypertensive activity

*Bacopa monnieri* provides traditional cognitive treatments possibly reflecting improved cerebral hemodynamics. However, little is known about the cardiovascular actions of Brahmi. Intravenous Brahmi extract (20-60 mg/kg) decreased systolic and diastolic pressures without affecting heart rate in anesthetized rats. Brahmi reduces blood pressure partly via releasing nitric oxide from the endothelium, with additional actions on vascular smooth muscle Ca<sup>2+</sup> homeostasis. A clear, prompt and constant anti-hypertensive action of *Bacopa* and at least as effective as the clinically used captopril has been observed. Recently, the cardioprotective activity of *Bacopa* extract was studied against ischemia/reperfusion injury using cardiac function and coronary flow as end-points. It was revealed that *Bacopa monnieri* improves myocardial function following ischemia/reperfusion injury through the recovery of coronary blood flow, contractile force and a decrease in infarct size. Thus, this extract or an active ingredient may lead to an efficacious and novel treatment for primary human hypertension.<sup>[28]</sup>

#### Gastro-intestinal effect

*Bacopa* has a protecting and curative result for stomach ulcers in rats. The *Bacopa* extract standardized for bacoside-A was evaluated for its prophylactic and healing effects in 5 models of stomach ulcers. At a dose of 20 mg/kg for 10 days, *Bacopa* extract considerably recovered penetrating ulcers iatrogenic by carboxylic acid, considerably reinforced the membrane barrier, and attenuate membrane exfoliation. The extract additionally eased stress-induced ulcers as determined by vital reduction in macromolecule peroxidation in rat stomach tissue layer.<sup>[29]</sup>

#### Endocrine effect

*Bacopa* extract (200 mg/kg orally) increased the thyroid hormone, T<sub>4</sub>, by 41 % in mice. T<sub>3</sub> was not stimulated, suggesting that the extract may directly stimulate synthesis and/or release of T<sub>4</sub> at the glandular level, while not affecting conversion of T<sub>4</sub> to T<sub>3</sub>. *Bacopa monnieri* extracts caused reversible suppression of spermatogenesis and fertility. The treatment caused reduction in motility and viability of the sperms and reduced the number of spermatozoa in caudaepididymidis and testis, and caused alterations in the somniferous tubules in mice.<sup>[30]</sup>

#### Sedative and tranquillizing properties

*Bacopa monnieri* as a sedative and tranquillizing properties was also studied. According to one study, sedative effect was due to glycosides named hersaponins.<sup>[31]</sup> The subsequent studies has found that the alcoholic extract, and to a lesser extent the aqueous extract of the whole plant exhibited tranquillizing effects on albino rats and dogs. It has also been found that the alcoholic extract of the plant and chlorpromazine improved the performance of rats in motor learning.<sup>[32]</sup> Another study has reported that a single dose of the glycoside hersaponin is better than pentobarbitone in facilitating acquisition.<sup>[33]</sup>

#### Cognition

Cognition is the mental processing that includes the attention of working memory, comprehending and producing language, calculating, reasoning, problem solving, and decision making. It is the process by which the sensory input is transformed, reduced, elaborated, stored, recovered, and used. In general cognition refers to an information processing view of an individual.<sup>[34]</sup> *B. monnieri* demonstrated enhanced attention and cognitive processing capability together with enhanced working memory. According to one study standardized bacoside-rich extract of *B. monnieri*, reversed the cognitive deficits induced by intracerebroventricularly administered colchicines and injection of ibotenic acid into the nucleus Basalis magnocellularis. Also *B. monnieri* was shown to reverse the depletion of acetylcholine, the reduction in choline acetylase activity and a decrease in muscarinic cholinergic receptor binding in the frontal cortex and hippocampus. The cognition facilitating activity of the *B. monnieri* extract

is attributed to the saponins, Bacoside A and Bacoside B, which are effective in much lower doses.<sup>[35]</sup> Numerous clinical studies have been carried out to date to establish the efficacy of *B. monnieri* in memory and attention disorders and to study its acute and chronic effects clinically on cognitive function. One of the study was done on seventy-six adult volunteers aged between 40 and 65 years. The results showed a significant effect of *B. monnieri* on the test for the retention of new information. In the follow-up tests, it was found that the BM decreases the rate of forgetting of newly acquired information. In adults, only chronic administration was shown to enhance cognitive effects. In another study on 38 healthy volunteers (ages 18-60), subjects were given a single dose of 300 mg *B. monnieri*. These results were attributed to BM's antioxidant properties and/or its effect on the cholinergic system.<sup>[36]</sup>

### CONCLUSION

It is concluded by the above literature that *Bacopa monnieri* is a highly potential medicinal plant that is being used in Ayurveda for a long time. The present review is a comprehensive literature analysis of the chemistry and various health beneficial functional properties of the plant *Bacopa monnieri*. It was observed that the plant possess various pharmacological properties. The pharmacological activity of this plant might be due to the presence of different biologically active compounds. The activity of *Bacopa monnieri* both as an anxiolytic and anti-depressant needs further evaluation, its potential as an anti-epileptic treatment and as a treatment to correct side effects of anti-epileptic drugs is another area to be studied in future. The antioxidant activity of brahmi may be useful in the treatment of human pathologies in which free radical production plays a key role which requires further study. Hence *Bacopa monnieri* has a promising future prospect.

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