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INDIAN AQUATIC PLANTS AS PROSPECTIVE THERAPEUTIC OPTIONS

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Abstract

Aquatic plants are noteworthy forms of plant-life and they are commonly found to have specialized footing in pond ecosystem. However, they can be even found in other water bodies like lakes, channels, swamps, and rivers. These plants have been considered unproductive and impractical for long and have been measured more as of weeds. Although the aquatic conditions of India are ironic sources of various of such plant species, studies pertaining to reckon their medicinal uses are scanty. Yet, some recent studies reported various pharmacological properties such as antiulcer, antiemetic, astringent, anthelmintic, ant dysentery, diuretic, anti-inflammatory, antioxidant, hypercholesterolemia, antipyretic, hepatoprotective, hypoglycaemic, antifungal, of many of these aquatic plant species. Hence, it was thought worthy to provide an overall therapeutic potential of these aquatic plants. In this regard, this review highlights different prospective therapeutic potential of commonly available aquatic plants of different regions of India, that will help readers and researchers interested to peruse research in evaluating the therapeutic effectives of extracts or isolated components of these plant species to establish their applicability in field of medicine.

Keywords: Aquatic plants; Therapeutic options; Ecosystem; India

Introduction

Since ages, dependance of human being for the fulfilling their simple needs like medicines, food stuffs, flavors, clothing, shelters, and transportation count on “nature”. Medicinal plants have displayed an impactful protagonist in the health care system especially in most of the developing nations of the world (Dar et.al.,2017). Facts have revealed that natural products are better options for their therapeutic effectiveness even comparable to synthetic molecules (Imtiaz et.al.,2020)(Subramaniyan et.al.,2019).Hence, they have been used in healing various disorders from minor fevers to severe infections and are extensively known for their excellent pharmacological effects on human being. About 2000 natural products are comprised in “Materia Medica” having therapeutic value, out of which 400 are of mineral and animal origin while the rest being of vegetable origin. Besides, the traditional medicine practice in India, Ayurveda suggests approximately 1250 Indian medicinal plant used as additive, supportive, or preemptive therapeutic preparations

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by serving as raw materials for healing and treatments. The use of herbal drugs is vastly increasing over the modern synthetic drug preparation, as they are easily available and have greater therapeutic value with less expenditure. (Pathak et.al.,2019)(Sarma et.al.,2014)

Previously plants from aquatic eco-system were measured impractical, fruitless, and even as harmful but with the emerging epoch they are representing numerous ecological characteristic-functions and values. For the supportable life expectancy provision, the importance of aquatic ecosystem has been accepted in many parts of the world since long. These aquatic angiosperms help to upsurge efficiency of aquatic ecosystem and preserves equilibrium in ecosystem. However, these plants are still underneath fewer considerations in scientific research work and consequently their possible therapeutic applications remain unexploited. Further, these ecosystems have very supple morphology and misperceive development behaviors. These plants own distinct structural amendment with adaptive consequence. India comprises a main landmass of aquatic ecosystem in the world. This could be due to its climatic condition, perennial rivers, fertile soil, dense forest, rich and tranquil expanses of meadows. (Niroula et.al.,1990) Despite of such wide availability of such aquatic vegetation in India the literature pertaining to the therapeutic utility of these plants is scanty. To measure the usefulness of such aquatic flora for their possible therapeutic applications, this review will be a valuable mean. Further this review complies worth of some aquatic plants found or cultivated in India with high therapeutic importance

1) *Aeschynomene aspera*

Aeschynomene aspera is a species of flowering plant in the family of Fabaceae. Its common names include Sola, Sola Pith Plant, Pith Plant, Laugauni or Netti (Tamil). The low-density pith from this plant is used to make Hats which is also known as pith helmets. (Karimulla et.al.,2014) In India, several products use pith as insulation, useful as green manure, or cover crop. The roots and leaves are used to heal jaundice, joint pain and swelling. (Imtiaz et.al.,2020) Roots and aerial part of plant are also used for treatment of mumps, cold, cough and fever. Its crude extract is proven to increase semen consistency (Panda et.al.,2011) and recommended for painful micturition and to break down uric acid calculi. The plant extract contains secondary metabolites like tannins, glycosides, carbohydrates, gums, reducing sugars, flavonoids, alkaloids, and steroids. Some of them are shown to possess free radical scavenging activity. Hepatoprotective activity of *A. aspera* was also reported. (Imtiaz et.al.,2020)

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Figure 1: Aeschynomene aspera

Source : https://www.herbal-organic.com/en/herb/15708

2) *Aponogeton crispus*

In the tropical and subtropical regions of Africa, Asia, and Australia this obligate aquatic (fresh water) genus *Aponogetons* are found. This genus comprises of several species, all over the world and it is represented approximately by 57 species belonging to the family Aponogetonaceae. These species are existing in free floating groups. Among them few species are very well known namely *Aponogeton undulates*, *Aponogeton ulvaceus*, *Aponogeton natans*, *Aponogeton crispus*, *Aponogeton appendiculatus*, *Aponogeton dystachois.*(Chowdhury et.al.,2019) *A.crispus* is among the four species of this genus found in Sri Lanka namely *Aponogeton rigidifolius* Bruggen , *A. jacobsenii* Bruggen, *A. crispus* and *A. natans* .These species are popular aquarium plant known by the vernacular name “Kekatiya”. (Manawaduge, C. G.et.al.2016). In India, *A. crispus* is found in states of Andhra Pradesh, Kerala, Karnataka, Tamil Nadu, West Bengal and Maharastra. (Sujana et.al.,2016)Whole plant and tubers of A*ponogeton crispus* are used in various treatment like burning sensation of the body, heart diseases, nausea, diabetes, wounds, and excessive thirst. It is used as an “Ayurvedic medicine” and has medicinal value which consists of reduction of pithadosa and increase vatha and kaphadosha and improves vision .*A. crispu s*has also been reported for its oral hypoglycemic activity. (Chowdhury et.al.,2019)

Figure 2: Aponogeton crispus

Source:https://www.floridaaquatic.com/aponogeton-crispus

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3) *Ceratophyllum demersum*

Ceratophyllum demersum is a perennial, obligate, cosmopolitan sea plant. Due to its compact whirls resembling a racoon's tail or as Hornwort it is universally known as Coontail.(Syed, et.al.,2018) *Ceratophyllum demersum* belongs to the family Ceratophyllaceae. It is a submerged macrophyte known for its rapid invasion in new areas which leads to reduction in water flow and causes imbalance in water environment oxygenation. It is also responsible for reduction in species richness and fish mortality. Development of this plant takes place in depth from 0.5 to 8.5m and reproduce by stem and seed fragmentation. It is native plant of tropical America and tends to spread very quickly, forms dense settlements in aquatic flora. (Garlich et.al.,2016) Even under low concentration of nutritional condition this plant has high capacity for vegetative propagation and biomass production, thus helpful in removal of excess nutrients and cadmium from stagnant water. This plant has potential source of heavy metal accumulation from water. (Abu, 2017)

Figure 3: Ceratophyllum demersum

Source : https://en.wikipedia.org/wiki/Ceratophyllum_demersum

4) *Enhydra fluctuans*

Enhydra fluctuans is commonly known as water cress or marsh herb. It is a hydrophytic plant and mostly found in between the month of November to January on wet roadside canals and marshy waste places. It is a trailing marsh herb that grows annually. The leaves of this plant are sessile of length 2.5-7.5 cm linear to oblong and margins are variously dented,30-60cm long, are slightly bitter, cure inflammation, skin diseases and smallpox.(Kuri et.al.,2014)The flowers color varies from white to greenish white. Stem measures 30cm or more in length, are branched, fleshy and hairy. It is mainly found in Bangladesh, China, Malaysia, South East Asia, and Tropical Africa. North east region and Assam are predominant places for this plant in India. It is richly found in Jaintia hills areas in Meghalaya and Agartala in Tripura. (Sarma et.al.,2014) Itis nutritious in nature and used for treating various diseases like dropsy, anasarca, snakebite, and ascites. This plant is reported with many pharmacological activities like antioxidative, analgesic (Ruhul et.al.,2012)

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cytotoxic, antimicrobial, hepatoprotective, hypotensive, CNS depressant, antidiarrheal activity(Kuri, S.et.al.2014) anti-cancer activity, anti-inflammatory activity, antidiabetic.(Sarma et.al.,2014)It is semiaquatic, vegetative, herbaceous plant, edible in nature and possess strong pungent odor. It is commonly used as traditional medicine in India for edema, cough, leprosy, cooling, carminative, tonic, skin diseases, neurological disorder etc.(Deb, S.et.al.2016)This plant is rich in β-carotenes, proteins, sesquiterpenes, lactones, gibberellins, flavonoids, stigmasterol, saponins, myricil alcohol, a number of diterpenoid acids and their isovalerate and angelate derivative.(Deb et.al.,2016)It also contains myricyl alcohol, kaurol, sesquiterpene lactones including germacranolide, enhydrin, fluctuanin and fluctuandin.(Ali et.al.,2013)

Figure 4: Enhydra fluctuans

Source :https://commons.wikimedia.org/wiki/File:Hingcha.jpg

5) *Hygroryza aristata*

Hygroryza aristata is an aquatic floating grass, commonly known as Asian water grass. In sunny place this floating grass rapidly grows in tidally flooded low lying wetlands, canals, and bells. During production of vegetables and spice crop seedling, on floating beds this grass is poorly used for preparation of compost fertilizer by accumulating water hyacinth. This grass has spongy stem with feathery whorled roots at nodes which gives insects, mollusks, zooplanktons, and crustaceans place for hiding. It also contains crude proteins for efficient growth of grass carp. (Hossain et.al.,2020) It is a perennial plant mainly found in Tropical Asia. This plant grows at 400-800m above sea level in paddy fields and ponds. (Chung et.al.,2011) It is used as traditional medicine as emollient, galactagogue, in diarrhea, fatigue and general weakness. This plant is also used in aquariums at 20-30^{o} C water temperature. Seeds of the plants are used as cooling and astringent to urinary tract and soothing of biliousness. (Rashid et.al.,2019)

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Figure 5: Hygroryza aristata

Source :https://commons.wikimedia.org/wiki/File:Hygroryza_aristata_kz01.jpg

6) *Ipomea aquatica*

Ipomea aquatica (synonym: *Ipomoea reptans* Linn.) is a perennial herb originated in china and found throughout India, Ceylon, Tropical Asia, Africa, and Australia and belongs to family Convolvulaceae. In India and USA, it is grown wildly as weed, and commercially grown in South East Asia such as China, Singapore, Indonesia, Malaysia, Hong Kong. (Manvar et.al.,2013) Flowers and leaves of *Ipomoea aquatica* possess antioxidant activity and showed oral hypoglycemic activity in streptozotocin induced diabetic Wistar rats and Type II diabetic patients. Methanolic extract of the leaves of *Ipomoea aquatica* showed hypolipidemic activity. This plant is also used in Unani system of medicine in fever, jaundice, bronchitis, liver complaints, carminative, biliousness. In Assam it is used traditionally in nervous and general debility of female. (Manvar et.al.,2011)Its leaves are very rich source of proteins, carotenes, amino acids like aspartic acid, threonine, serine, glutamic acid, proline, glycine, alanine, leucine, tyrosine, lysine, histidine; arginine and minerals like sodium, potassium, calcium, iron, magnesium and zinc, sugars like glucose, fructose, sucrose, fiber, lipids and fats, organic acids like malic acid, citric acid, oxalic acid, vitamins, starch, polyphenols like myricetin, quercetin, luteolin, apigenin, kaempferol, dihydroquercetin glycoside and ash. It is also used as edible source as green leafy vegetable in salads and as fodder, mainly terminal shoot and leaves are taken. Extract of *Ipomoea aquatica* leaves are orally given to increase antioxidant related disorders in the ancient science of Indian medicine and homeopathy. To treat high blood pressure and nose bleeding, this plant extract is being used. As an anthelminthic its floral buds are used, and it is also effective against *Escherichia coli, Pseudomonas aeruginosa* and *Bacillus subtilis* infections. (Singh et.al.,2016)

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Figure 6: Ipomea aquatica

Source :https://commons.wikimedia.org/wiki/File:Ipomoea_aquatica_(Marsh_Glory)_flower_W_IMG_0405.jpg

7) *Ludwigia adscendens*

Ludwigia adscendens (L.) is commonly known as water primrose. It is an invasive perennial herb and forms dense mats in stagnant water. It is a perennial herb with spindle shaped pneumatophores in clusters at nodes of floating stems. It is much branched, glabrous with ascending tip plant contain light brown capsule with dark brown ribs. (Oyedeji et.al.,2011) Traditionally this plant is used to treat ulcers and skin disorders as a poultice, as emetic, as an astringent, anthelmintic and antidysentery, as diuretic and for scalp, skin, eye, and throat infections. As an antiseptic, the stem and leaves are used, and flowers are used as anti-inflammatory. (Shilpi et.al.,2010) In Europe *Ludwigia* species is used as an ornamental plant because of its showy yellow flowers. They are also used for toxicity study and in labs used as attachment host in the rearing of insects. In Nigeria leaves of *Ludwigia* are fed to livestock in Mali. This plant is used for various skin disorders and possess anti-inflammatory activity especially flower part. Medicinally this plant is also used for its febrifugal and ant swelling properties. (Oyedeji et.al.,2011)

Figure 7: Ludwigia adscendens

Source: https://www.flickr.com/photos/eyeweed/3538935828

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8*) Nelumbo nucifera*

Nelumbo nucifera also known as Indian or sacred lotus of family Nymphaeaceae, has various common names e.g. Indian lotus, Chinese water lily and synonym *Nelumbium nelumbo, N. speciosa, N. speciosum and Nymphaea nelumbo*. It is one of the important aquatic plant not only has its importance for its ornamental properties but also has numerous medicinal uses. It possesses strong cooling, astringent, and demulcent properties. (Suvetha et.al.,2014)Traditionally leaf, rhizome, seed and flower are used for the treatment of pharyngopathy, pectoralgia, spermatorrhoea, leukoderma, smallpox, dysentery, cough, haematemesis, epistaxis, haemoptysis, haematuria, metrorrhagia, hyperlipidemia, fever, cholera, hepatopathy and hyperdipsia. According to Ayurvedic system of medicine this plant is used for diuretic, anthelmintic, treatment of vomiting, skin disease, leprosy, and nervous disorder. It is also used commonly for the purpose of tissue inflammation, cancer and poison antidote. From various parts of *N. nucifera* different phytoconstituents has been isolated such as alkaloids, steroids, triterpenoids, flavonoids, glycosides and polyphenols. (Mukherjee .et.al.,2009) *N. nucifera* shows some unique property like it possess long viability period seeds, lotus effect is shown by the leaves, it can regulate temperature of its flower and has self-cleaning property.

(Sheikh et.al., 2014)

Figure 8: Nelumbo nucifera

Source :https://commons.wikimedia.org/wiki/File:Sacred Lotus_(Nelumbo_nucifera)_flower_bud_..._(32643713998).jpg

9) *Neptunia oleracea*

Neptuniaoleracea Lour. belongs to family Fabaceae, commonly known as Garden puff or water mimosa. It is also called water sensitive plant or garden mimosa. The species is native to tropical and subtropical regions of India and southeast Asia, mostly grows in moist and swampy environment. The genus *Neptunia*, means “of the seas”, for Neptune’s, the Greek god of the seas and “*oleracea”* means of cultivation, aromatic, esculent, vegetable. There are 11 species comes under the genus Neptunia. (Bhunia et.al.,2012) In India this plant is used as edible food plant, but

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health risk associated issues are still under consideration. Growth of this plant takes place rapidly over the surface of water once it is fully established along with white spongy aerenchymal tissue under stem. It can remove metals from contaminated water. (Bhunia et.al.,2012)It is reported to possess astringent, antimicrobial, and anticancer properties. The roots of the plant are used in late stages of syphilis. (Wahab et.al.,2014)

Figure 9: Neptunia oleracea

Source:https://commons.wikimedia.org/wiki/File:Neptunia_oleracea_2zz.jpg

10) *Nymphoides hydrophylla*

Nymphoides hydrophylla is an aquatic herb commonly known as white water snowflake, because of structure of flower resembling like snowflake it is named so. (Kumar et.al., 2021) This plant grows in lakes, ponds and ditches and found in Cambodia, Bhutan, Bangladesh and India. Morphological features include long stem bearing tuft of roots, broad 5-10cm leaves orbicular in nature. Flowers with white corolla yellow towards base. It is a perennial aquatic herb deeply rooted in slowly flowing water. (Moghal et.al.,2013) In many tropical waterbodies this plant is grown for the amenity purposes. (Kumar et.al.,2021) In the treatment of fever and jaundice this plant is commonly used as a substitute of Chiretta. For the cure of ulcers and insect bites leaves and stalks of plant is used with pounded oil and for parasitic infection decoction of plant leaves is being used. Seeds are useful for anthelmintic treatment. Leaves of the plant is rich in 11 amino acids including 6 essential amino acid. (Moghal et.al.,2013) *N. Hydrophylla* also contains crude fat, carbohydrate, fibres and proteins. (Kumar et.al.,2021)

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Figure 10: Nymphoides hydrophylla

Source :https://commons.wikimedia.org/wiki/File:Nymphoides_hydrophylla_7917.jpg

11*) Rotala rotundifolia*

Rotala rotundifolia is a perennial amphibious herb, water loving submersed plant, mainly found in paddy fields and marsh lands. The plant grows in optimal temperature at a range of 20-28^0 C and pH of 5-8. It is a native of Bangladesh, India, Bhutan, Myanmar, Nepal, Thailand, Vietnam, Laos, China, and Japan. It is one of the aquarium plants widely grown. Its stem can grow up to 70cm long, are floating and creeping. The submerged and emerged leaves are lance shaped up to 2cm in length and green to red in color while other is 1-2cm in size and green in color. (Navya et.al.,2018). These leaves vary from decussate to elliptical form which turn winein color in high intensity of light.(Zhang et al.,2011)In Queensland of Australia and new South Wales and in thermal water bodies of Hungary this plant is naturalized.(Navya et.al.,2018) The plants form a good bunch in the aquarium with lots of side shoots and often featured in the Dutch and nature – style aquascapes. Bright rose petalled flowers bloom on the emergent spike like inflorescences. This fast-growing plant is, however, sensitive to unfavorable conditions, when it will react by producing smaller leaves. (Zhang et al., 2011)(Navya et.al.,2018) The plant still needs to be evaluated for its therapeutic efficacy.

Figure 11: Rotala rotundifolia

Source :https://www.flickr.com/photos/dinesh_valke/26978562447

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12) *Sagittaria trifolia*

Sagittariatrifolia is a native herb of China having wetland habitat and mainly found in the rice grown areas of the world. It is also known as Chinese arrowhead, three leaf plant species and arrowroot. It is widely distributed in Macao, HongKong and Taiwan and also found in India, Cambodia, Indonesia, Malaysia, Turkmenistan, Russia, Nepal, Iran, Vietnam, Thailand, Afghanistan, Kazakhstan and Myanmar. In china this plant has been used as traditional Chinese herbal medicine and vegetable.(Zou et.al.,2010)It is reported that this plant has important role in water purification as it possesses the quality of absorbing phosphorus and nitrogen from water. Every part of the plant is considered beneficial as it contain 364 calories/100g, i.e., carbohydrate 76.2 g, protein 17 g, fiber 3.1 g, ash 5.8 g, fat 1 g, phosphorus 561 mg, calcium 44 mg, potassium 2480 mg, iron 8.8 mg, thiamine 0.54 mg, riboflavin 0.14 mg, niacin 4.76 mg and ascorbic acid 17 mg, with no carotene in its tubers and dried root part. (Ahmed et.al.,2019)It is a great source of mineral composition as P 165 mg, Ca 13 mg, K 729 mg, Fe 2.6 mg, riboflavin 0.04 mg, thiamine 0.16 mg, niacin 1.4 mg, moisture 70.6% and ascorbic acid 5 mg. Various skin disorders are cured by the extraction of leaves. Corms of the plant is rich in inducing premature birth in human being. (Zou et.al.,2010)

Figure 12: Sagittaria trifolia

Source: http://tropical.theferns.info/viewtropical.php?id=Sagittaria+trifolia

13) *Spirodela polyrhiza*

Spirodela polyrhiza is a member of Lemnaceae family of group monocotyledons. It is a species of duckweed, commonly known as greater duckweed. It is a widely distributed rapidly growing aquatic plant with shorter life span found in the region of Korea, Japan, China, and India. It is used for treating inflammation, urticaria and skin disease in these countries.(Das et.al.,2012) On the surface of water bodies (ponds ,lakes , ditches) with sufficient nutrients this plant makes mat like covering under natural conditions especially if the water is warm. Structurally it is a smooth, round, flat disc 1to ½ cm wide. It prevents the growth of harmful weeds and mainly grows in rice field. It is a good option for phytoremediation as it accumulates good amount of arsenic when exposed to arsenate. (Rahman et.al.,2007) This plant shows the

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process if asexual budding and vegetative growth, is used as source of food by waterfowl. It is a rich source of proteins, as a food source for ducks and geese. The greater duckweed is harvested for pig feed and cattle in Asia and Africa. The ethanolic and methanolic extract of plant consist of Flavonoids which possess potent antioxidant activities. Effect on preadipocyte and proliferation is shown in crude ethanolic extract of *S. polyrrhiza* species. It also has potentiality as phyto-filtration in paddy soils or contaminated water bodies. (Das et.al.,2012))

Figure 13: Spirodela polyrhiza

Source :https://commons.wikimedia.org/wiki/File:SpirodelaPolyrhiza2.jpg

14) *Trapa natans*

Trapa natans L. is known by the common name Sringhataka in Sanskrit and Singhara in Kannada. It is widely distributed aquatic herb found in greater parts of India. It is edible seed mainly cultivated for the purpose of food source in lakes and ponds. *Trapa natans* is a rich source of carbohydrates, minerals, calcium, phosphate, iron, copper, manganese, magnesium, sodium and potassium. The plant kernels possess some vitamins like thiamine, riboflavin, nicotinic acid, vitamin C, vitamin A, D-amylase, and considerable number of phosphorylases. (Kutschera et.al.,2015) The plant is being used for many medicinal purposes as it contains non nutritional antioxidants such as flavonoids, flavones, and total phenolic contents. Carbohydrates, saponins, phytosterols, fixed oils and fat are present in seeds of plant and pericarp of it consists of tannins, flavonoids, and glycosides, while dried seeds are used as cooling and stomachic. The nuts of the *Trapa natans* are given with milk in leucorrhea and seminal weakness. The fruit part of plant is very essential, being used for antidiarrheal, refrigerant, nutritive and tonic and used in bilious affections. For diarrhea and dysentery acrid juice of plant is used.(Chowdhury et.al.,2016)The whole plant of *Trapa Natans* has reported for many pharmacological activities like hepato-protective activity, antibacterial activity, antifungal activity anti-diabetic activity, analgesic activity, anti-inflammatory activity, antioxidant activity and free radical scavenging activity. According to Unani system of medicine this plant is being used for sexual weakness, spermatorrhea, general debility, dysentery, dry cough, bleeding disorders, anal fissure, lumbago, dental caries, sore throat, bilious affections, bronchitis, tuberculosis, renal calculi and fatigue.(Das et.al.,2011)(Bharthi et.al.,2015)

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Figure 14 : Trapa natans

Source : https://www.flickr.com/photos/chesbayprogram/5057595026

15) *Nymphaea stellata*

Nymphaea a worldwide known genus, consists of 45-50 species in it belongs to family *Nympheaceae*. The genus *Nymphaea* in Greek symbolizes “Water nymph” and the species *stellata* in Latin symbolizes “star shaped”. *Nymphaea* consists of so many synonyms as follows *Nymphaeacyanea*Roxb., *Nymphaeamalabarica*Poir. *Nymphaea minima* F. M. Bailey, *Nymphaeapunctata* Edgew, and *Nymphaea versicolor* Sims. *N. caerula* is given by some botanist. Ayurvedic formulations of India uses *N. stellata* as an ingredient and traditional healers usesits morphological part for treating many diseases. *N. stellata* consists of various constituents in its solvent extract such as sterols, alkaloids, saponins, tannins, and flavonoids. Its flower choloroform extract consist of new sterol named Nymphayol (25,26-dinorcholest-5-en-3b-ol) and also contain various constituents are astragalin, corilagin, gallic acid, gallic acid methyl ester, isokaempferide, kaempferol, quercetin-3-methyl ether, quercetin, 2,3,4,6-tetra-o-galloyl dextroglucose and 3-o-methylquercetin-3'-o-beta dextroxylopyranoside. Seeds of the plant is reported to have protein, pentosan, mucilage, and tannins. (Raja et.al.,2010) The plant extract showed antihyperglycemic and antihepatotoxic effect and used to treat blennorrhagia, diarrhea, diuretic, dyspepsia, fever, piles, and tumor as a folk medicine. As a vegetable part the tender leaves, peduncles, flowering stalks of *N. stellata* are used. For both internal and external use pistils with black pepper are used. Seeds in form of flour is used with wheat and barley. In India roots and seeds are consumed by the ethnic community as a diet called “Dhaparkoki”. In Philippinesislands it is used in boiled form. Rhizomes are used for tanning purpose. (Chowdhury et.al.,2013) The whole plant is reported to possess pharmacological activity, flower showed hepatoprotective activity against CCl4–induced hepatic damage. It has an acrid, bitter-sweet taste, removes impurities from blood, cools, and cough, is used for biliousness, for vomiting, giddiness, worm infestation, and burning of the skin. For heart palpitation and as a narcotic flower decoction is used. Dyspepsia, diarrhea, and piles is treated by the powder of rootstock. Stem and rhizome infusion are used for the treatment of blennorrhagia and urinary tract

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infection. Leaves are used topically in erysipelas. In ayurvedic system of medicine seeds are used in diabetes mellitus. (Chowdhury et.al.,2013) (Das et.al.,2012)

Figure 15: Nymphaea stellata

Source :https://en.wikipedia.org/wiki/Nymphaea_nouchali

16) *Hydrilla verticillata*

Hydrilla verticillata (L.F.) Royle commonly called as water thyme in English and in Tamil as cikavalakam, cimpaka and amiranappaciandjhangi or kureli in Hindi. It belongs to family Hydrocharitaceae. This plant is found in temperate and tropical regions in the world is native to central Africa and Australia and widely distributed in India, Sri Lanka, China, Europe, United states, and Malaysia. It is a submerged perennial aquatic herb and slender that grows on surface of water and multiplied by vegetative propagation. (Araki et.al.,2003) It consists of little white flowers with long stalk and potato like tubers attached with roots. stem is 7.6 cm in length, branched rooting at nodes. (AB et.al., 2017) Chemical analysis reveals constituent as alkaloids, flavonoids, terpenoids, saponins and phenols. In tribal medicines all parts of this plant are used for neurological problems, malnutrition, cardiovascular diseases, gastrointestinal disturbances, improves blood circulation, diabetes, detoxification, immunity booster and slow ageing process.(Annie et.al.,2016) Pharmacological activity like antibacterial, antimicrobial, and wound healing properties. Hydrilla is very valuable for vegetarians. It consists of very essentials nutrients needed for the body like vitamins B_{12},calcium,iron,polysaccharides, micro and macro nutrients, and amino acids. Since, it contains rich minerals and vitamins, it is called “green food”. It is considered as “green food” because it contains all essential nutrients in it. It also contains beta carotene, free radical scavenging, antiaging, antioxidant and antipollution properties. It also contains chlorophyll 4,9 and essential nutrients maintains mental health, tissues, and bones of body. Scientist revealed that it contains highest amount of calcium than any other food source on earth. (Annie et.al.,2016) Plant aqueous extract shown central nervous system depressant activity, also possess antitumor and antibacterial activity. (Pal et.al.,2006)

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Figure 16: Hydrilla verticillata

Source :https://commons.wikimedia.org/wiki/File:Hydrilla_verticillata-1-bsi-yercaud-salem-India.jpg

17) *Pistia stratiotes*

Pistia stratiotes is a stoloniferous aquatic c plant that floats on the surface of lakes, streams, and stagnant water ponds. It is widely distributed throughout in India, Africa, America, and tropical and subtropical region of Asia. (Tripathi et.al.,2010) It forms serious clogging on water surface s it forms dense mat over it which hinders waterflow and effects water ecosystem, fishing, swimming, boating and water sports and also a region behind harboring mosquito larvae that carries filarial parasites. In hot summer season the flowers blooms and fruits develop after rain. If it enters paddy field, it damages rice crop as it forms roots in the soil causes lower available oxygen and pH of water. Plant is also used to feed buffalos and swine. (Khan et.al.,2014) Medicinally this plant is used as antiseptic, antidysentery and antitubercular. For relieve of eye and ear complication extract of *Pistia stratiotes* is being used. Plant ash is used to cure ringworm. For the relieve of chronic dermatitis leaf extract boiled in coconut oil is used and leaf extract used for eczema, leprosy, ulcers, piles, and syphilis. Its decoction is used to sure fever, nervous disorders and intestinal bacterial infection, stomach, throat, and mouth inflammation. Chloroform fraction of plant show antifungal and antibacterial activity. (Khan et.al.,2014) (Franceschi et.al.,1993)

Figure 17: Pistia stratiotes

Source:https://en.wikipedia.org/wiki/Pistia

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Table 1: Aquatic plant species and their distribution in India.

Sl. no.	Plant Species	Distribution in India	Secondary metabolites and isolated compounds	*References*
1	Aeschynomene aspera	Assam, Bihar, Delhi, Jammu-Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Sikkim, Tamil Nadu, Uttar Pradesh, West Bengal	Tannins, glycosides, carbohydrates, gums, reducing sugars, flavonoids, alkaloids, and steroids.	*(Imtiaz, H. et.al.2020)*
2	Aponogeton crispus	State - Kerala, District: Wayanad	Protocatechuic acid, Chlorogenic acid caffeic acid, Trans-p-coumaric acid Hydroxy benzoic acid, Hydroxy Cinnamic acid, and Flavonoids like Quercetin, Catchin, Rutin	*(Aruna et al., 2012)*
3	Ceratophyllum demersum	Assam, Bihar, Madhya Pradesh, Maharashtra, Punjab, Rajasthan;	alkaloids, phenols and flavonoids	*(Mohamedomar et al., 2017)*
4	Enhydra fluctuans	North east region mostly in Assam, East Himalaya	β-carotenes, proteins, lactones sesquiterpenes, gibberellins, flavonoids, stigmasterol, saponins, myricil alcohol, a number of diterpenoid acids and their isovalerate and angelate derivative	*(Deb,S.et.al.2016) (Ijaz, A. S.,et.al.2014)*
5	Hygroryza aristata	Assam, Punjab, Uttar Pradesh	Cycloeucalenol, β-sitosterol & stigmasterol mixture, eicosanoic acid 2,3-dihydroxypropyl ester and butcosanoic acid 2,3-dihydroxypropyl ester , coumaric acid and methyl	*(Chung et al., 2011)*

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			coumarate	
6	Hydrilla verticillata	Andhra Pradesh, Arunachal Pradesh, Assam, Uttar Pradesh, Delhi, Mizoram, Bihar, Goa, Gujrat,Haryana, Himachal, Jammu and Kashmir, Karnataka, Karela,Madhya Pradesh, Maharashtra,Manipur, Tamil Nadu, Tripura, West Bengal	Bicyclo(3.1.1) heptane,2,6,6-trimethyl-, (1.alpha.,2.beta., 5.alpha) 2-penatdecanone,6,10,14-trimethyl , Hexadecanoic acid, ethyl ester , Phytol , Linoleic acid ethyl ester and 9,12,15-Octadecatrienoic acid ethyl ester,(z,z,z)	*(Pandi Prabha and Rajkumar, 2015)*
7	Ipomea aquatica	Assam, Bihar, Madhya Pradesh, Odisha, Rajasthan, Uttar Pradesh	Proteins, carotenes, amino acids like aspartic acid, threonine, serine, glutamic acid, proline, glycine, alanine, leucine, tyrosine, lysine, histidine; arginine polyphenols like myricetin, quercetin, luteolin, apigenin, kaempferol, dihydroquercetin glycoside	*(Singh, P. K. et.al.2016)*
8	Ludwigia adscendens	Kerala, Thiruvananthapuram, Kannur Maharashtra:Thane, Karnataka: Belgaum, Coorg, Hassan, Mysore, N. Kanara, Shimoga, Kerala: Alapuzha, Idukki, Kasaragod, Kollam, Kottayam, Kozhikode, Malapuram, Pathanamthitta Tamil Nadu	Squalene , betulonic acid , betulin , betulinic acid , a mixture of (24R)-6b-hydroxy-stigmast-4-en-3-one and (22E,24R)-6b-hydroxy-stigmast4,22-dien-3-one , pteleoellagic acid ,3,30 ,40 -tri-Omethyl ellagic acid , dihydroquercetin or (þ)-trans taxifolin , quercetin , protocatechuic acid , afzelin , quercitrin ,	*(Shilpi ,J.A.et.al.2010)*

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			methyl gallate , gallic acid and myricitrin	
9	Nelumbo nucifera	Assam, Kashmir, Madhya Pradesh, Manipur, Odisha, Rajasthan, Tamil Nadu, Uttar Pradesh;	Alkaloids, steroids, triterpenoids, flavonoids, glycosides and polyphenols.	*(Mukherjee, P. K.et.al.2009)*
10	Neptunia oleracea	North East India, Maharashtra: Konkan	Catechin and derivatives of quercetin, kaempferol, myricetin, and apigenin, phenolic acids (caffeic, gallic and 3,4-O-dimethylgallic acids), flavonoids and phenolic acids	*(Lee. Et.al.2019)*
11	Nymphoides hydrophylla	Assam, Maharashtra, Madhya Pradesh, Odisha, Kerala	fat, carbohydrate, fibres and proteins	*(Kumar, S.et.al.2021)*
12	Pistia stratiotes	Andhra Pradesh,Telangana, Karnataka, Kerala, Maharashtra, Orissa, Tamil Nadu	alkaloids, flavonoids, tannins, phenolic compounds, steroids, saponins and glycosides	*(Tyagi.2017)*
13	Rotala rotundifolia	Assam, Madhya Pradesh, Meghalaya	flavonols and its glycosides, kaempferol, quercetin, quercetin 3-O-β- D-glucuronide methyl ester, and quercetin 3-O-β-D-glucuronide	*(Zhang et.al.2011)*
14	Sagittaria trifolia	Kerala, Maharashtra, Orissa	flavonoids, phenols, saponins, tannins, glycosides and steroids except for alkaloids and terpenoids	*(Ahmed, M. et.al.2019)*
15	Spirodela polyrhiza	Moist temperate and Tropical regions Kerala	alkaloids, steroids, flavonoids and saponins, manool, biformen and phytol	*(Kurashov et.al.2016)*
16	Trapa natans	Assam, Odisha, Manipur, Rajasthan Uttar Pradesh	Thiamine, riboflavin, nicotinic acid, vitamin C, vitamin A, D-amylase,	*(Chowdhury DU, S.et.al.2016)*

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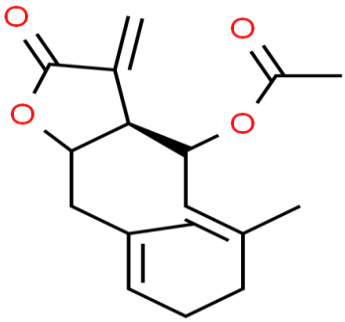
17	Nymphaea stellata	Andaman & Nicobar Islands, Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Chhattisgarh, Goa, Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Nagaland, Odisha, Rajasthan, Tamil Nadu, Tripura, Uttar Pradesh, Uttarakhand, West Bengal.	sterols, alkaloids, saponins, tannins, and flavonoids, astragalin, corilagin, gallic acid, gallic acid methyl ester, isokaempferide, kaempferol, quercetin-3-methyl ether, quercetin, 2,3,4,6-tetra-o-galloyl dextroglucose and 3-o-methylquercetin-3'-o-beta dextroxylopyranoside	*(Bharthi, V.et.al.2015)*

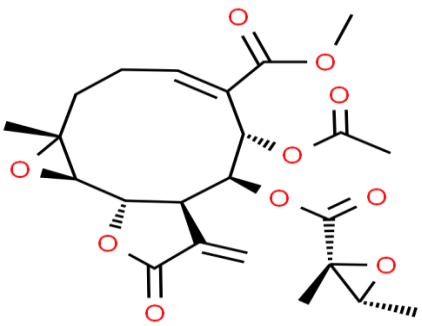
Some important ssecondary metabolites obtained from Indian Aquatic plants

1. Myricyl alcohol

2. Germacranolide



3. Enhydrin



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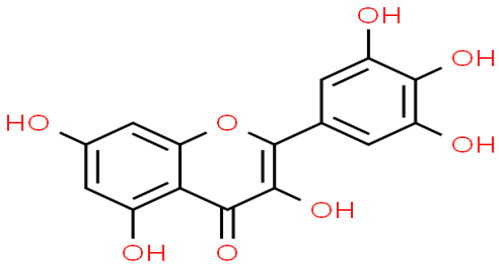
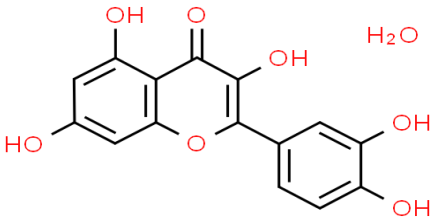
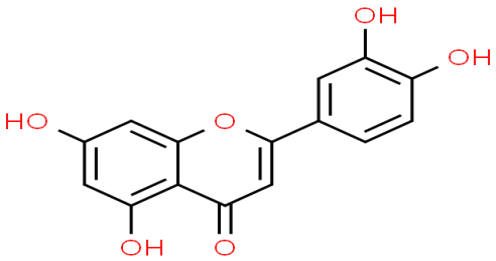
4.Myricetin



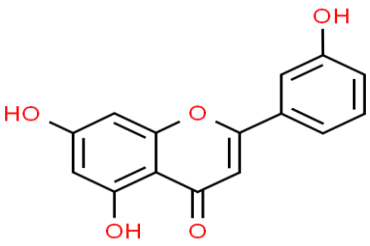
5.Quercetin



6.Luteolin



7. Apigenin



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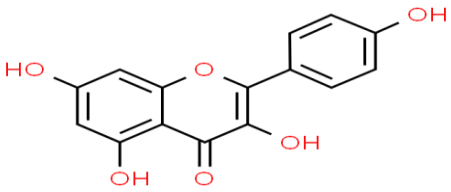
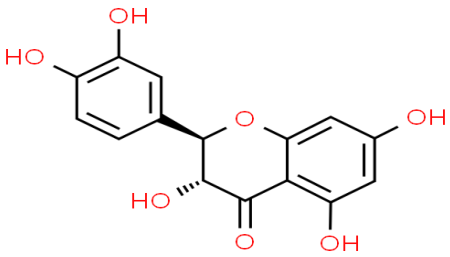
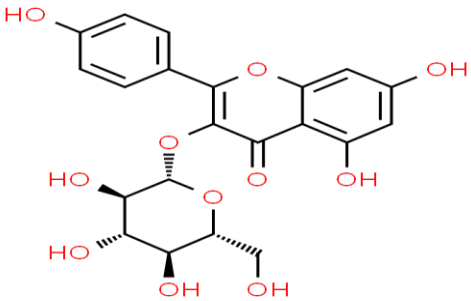
8. Kaempferol



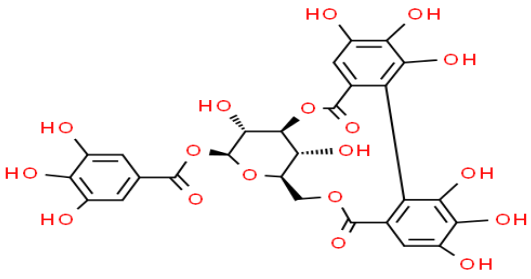
9. Dihydroquercetin glycoside



10. Astragalin



11. Corilagin



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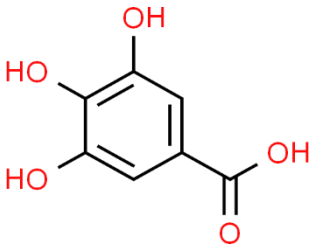
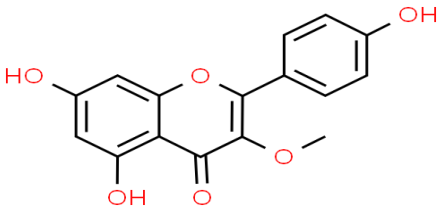
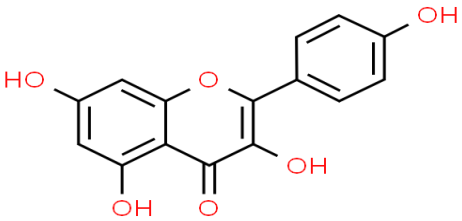
12. Gallic acid



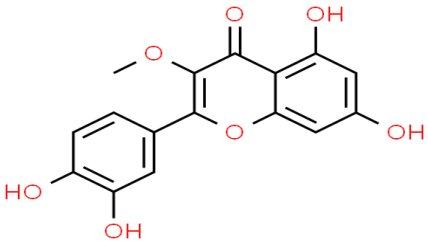
13. Isokaempferide



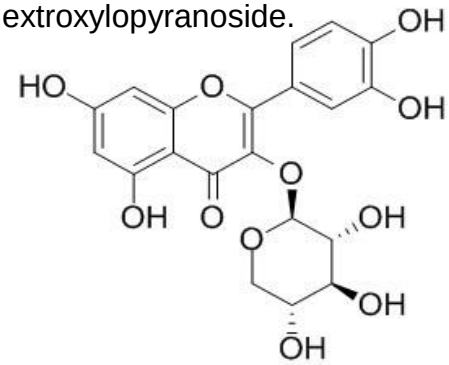
14.Kaempferol



15. Quercetin-3-methyl ether



16. 3-o-methylquercetin-3'-o-beta dextroxylopyranoside.



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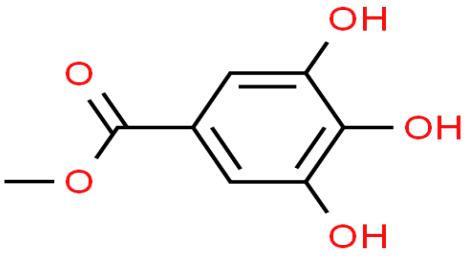
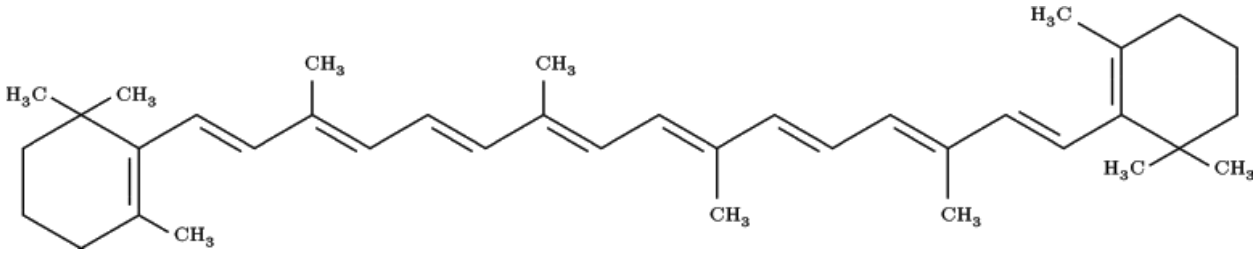
17.Gallic acid methyl ester



18. Beta carotene



Conclusion

Till date the utilization of land-based plants is common in India and across the globe for their therapeutic possibilities are because they are more in figures and secondly can be obtained easily. Aquatic-plant based formulations, have rarely been detected in literatures. Several ethnomedicinal surveys aiming to explore the therapeutic utility of such plants among various tribes and communal near water bodies of different regions of India will be an efficient approach to establish ground level proof about the therapeutic importance of these plants. Moreover, the phytochemical screening and the stated pharmacological activities of different aquatic plant species discussed in this article, proposed the occurrence of valued bioactive compounds. Consequently, widespread investigations are essential in isolating and characterizing the compounds from several aquatic plant species of India, to prove their promising role in new drug developments.

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