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Review Article
Therapeutic Potential of Some Aquatic Macrophytes: An Overview

Krupa Unadkat and Punita Parikh

Department of Botany, Faculty of Science, The Maharaja Sayajirao University of Baroda, Vadodara, Gujarat, India

Abstract
In ancient times herbal plants have been using as traditional medicine as they are incredible sources of biologically active compounds with therapeutic properties. Though herbal plants play a vital role in prevention and treatment, diverse groups of people were using herbal plants for the treatment of various human diseases. Globally, several plants of various ethnicities have been associated with the development of human civilization. However, phytochemical ingredients within plants increase the medicinal value of it. Recently, the conceivable source for the development of new herbal drugs is known to be medicinal plants as they possess immense healing properties. In the 21st century, the management of healthcare against various emerging diseases is a real big challenge. Therapeutic effects of medicinal plants act as convivial for optimistic future medicine. In recent years, there has been a renaissance of interest to rediscover the potential of medicinal plants as a source of medicament. Moreover, aquatic plants are considered a menace as they are often resulting in eutrophication but this is also an illusion. Many aquatic plants are precious for mankind as they possess alleviating properties that are worth mentioning for several years. Therefore, the present review aims to understand the therapeutical properties of selected aquatic plants (*Lemna minor* L., *Hydrilla verticillata* L., *Ceretophyllum demesrum* L. *Ipomea aquatica*, *Salviia minima* L.) as a future source of herbal drugs.

Key words: Medicinal plants, antimicrobial activity, antioxidant activity, therapeutical properties, herbal drugs, aquatic plants, immunity

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Corresponding Author: Krupa Unadkat, Department of Botany, The Maharaja Sayajirao University of Baroda, Vadodara-390002, Gujarat, India
Tel: 9925765908

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INTRODUCTION

Nature is a key reservoir of salvation for human beings as it conserves various remedies in plants, animals and other sources to heal the infirmity of mankind[1]. Medicinal plants are one of the most significant contributors amongst all of them. Medicinal plants as raw material, refined crude extracts and mixture have been used in the preparations of herbal medicine.

In prehistoric times, all the major systems of medicine such as Ayurveda, Western medicine, Unani and those of orient medicines had used plants to treat various diseases. Hence, the plant kingdom has got extensive alertness as a speculative source of new drugs which results in the development of new protocol and technologies for the extraction of plant components based on biological activities rather than chemical compounds. In the present day, the allopathic system of medicine also believes that many important life-saving medicines are of plant origin only.

From the last 50 years, the majority of significant drugs using in modern medicinal practice have been isolated/ derivated from plants. These chemical components illustrate the therapeutic properties of either plants or animal drugs. Augmentation of herbal drugs accomplished in various national health care programs as per the recommendation and encouragement of WHO because they are simply cost-effective, within the reach of ordinary people and are time tested so, much safer[2]. Therefore, by the screening of natural resources such as plant and animal extracts/oil detection of precious drugs obtained which facilitate the treatment of numerous human diseses[3].

In modern researches on bioactive molecules, plants are usually analyzed by comparing sophisticated bioassay with a bioassay of the fraction of medicinal plants used by traditional healers. As a result, several new therapeutically essential compounds isolated from plants. Several new pharmacologically active components and a huge number of effective drugs with curative properties have been developed by the efforts and dedication of researchers[4].

Aquatic plants are the most important component of the aquatic ecosystem[5]. Human survival depends on aquatic biodiversities and their ecological niche. For instance, an aquatic microorganism helps to break down detrimental toxins as well as nutrients from human waste products. These microorganisms are also helpful in the secondary and tertiary process of removing contaminants from municipal wastewater containing mainly household sewage and some industrial wastewater[6].

Freshwater plant biodiversity includes phytoplankton as well as aquatic macrophytes. Aquatic macrophytes consist of some macroalgae, several bryophytes like mosses and liverworts, ferns and angiosperms that occur in seasonally or permanently wet environments. In an aquatic environment, these aquatic macrophytes have an important structural role and are highly productive[7]. Apart from this the people of Europe and Asia widely used aquatic plants as medicine. In Russia, China and some European countries family Lemnaceae are commonly used in the preparation of folk medicine. Chinese and Russian folk medicine, a tincture of *Lemna minor* is used in hives, vitiligo, asthma, influenza and as a general tonic[8].

This review aims to enhance awareness regarding the medicinal value of some aquatic macrophytes with the help of authentic publications and by the incorporation of traditional knowledge of local communities in this aspect.

Therapeutic properties of aquatic plants: The healthy life of people is one of the best services provide by medicinal plants. Therapeutic properties of medicinal plants are unique characteristics as it helps in the healing of various human diseases[9]. Antibacterial, antifungal and antiviral activities are crucial therapeutical properties of medicinal plants which noticeable by many researchers for hundreds of years[10-12].

***Lemna minor*:** They are perennial or exceptionally annual. Generally found in a very wide range of aquatic habitats. Fronds solitary or usually remaining in groups of 2-10 or more[13].

Antioxidant activity: A protocol of different *in vitro* models was followed to analyzed the antioxidant activities of duckweed by many investigators. Lyophilized water extract and ethanol extract of duckweed used on lipid peroxidation of linoleic acid emulsion, inhibition of 100 and 94.2% obtained at 45 μg mL^{-1} concentrations by the lyophilized water extract and ethanol extract, respectively while Butylated hydroxyanisole (BHA), Butylated Hydroxytoluene (BHT), α-tocopherol and Trolox confirmed inhibition of 92.2, 99.6, 84.6 and 95.6%, respectively. H_2O_2 scavenging activity, Ferrous ion chelating activity and Superoxide scavenging activity of lyophilized water extract and ethanol extract were 92.3±2.8 and 85.7±1.1, 63.0±6.9 and 61.0±6.0 and 38.8±3.1 and 23.0±2.4%, respectively[14]. Parikh and Unadkat reported an enhanced level of antioxidant enzymes like catalase and guaiacol peroxide in *L. polyrhiza* on exposure to various Zinc metal ion concentrations indicating oxidative stress in the test plants[15].

Antimicrobial activity: Two extracts of duckweed namely lyophilized water extract and ethanolic extracts were experimented with for checking antimicrobial activities against different species of *Staphylococcus* (*S. epidermidis*, *S. saprophyticus* and *S. warneri*), *Citrobacter* (*C. freundii* and *C. koseri*) *Neisseria* (*N. lactamica*, *N. sicca*), *Bacillus* (*B. cereus* and *B. subtilis*) as well as *Micrococcus luteus* and *Streptococcus pneumoniae.* These were also studied for anticandidal effects against *Candida parapsilosis* and *C. glabrata*. The results envisaged that mostly all the gram-positive and gram-negative bacteria and *Candida* species showed inhibition by both extracts. In a similar experiment, the aqueous extract of *Lemna minor* was studied against isolates of four bacterial strains, i.e., *Pseudomonas fluorescens, Salmonella typhi*, *E. coli* and *Bacillus subtilis*) and one fungal strain for its antimicrobial activity. All the tested strains including fungal strain show maximum inhibition at higher concentrations of the plant extract as compared to control[16].

***Hydrilla verticillata* L.:** They are mostly perennial but sometimes annual. Totally submerged and growing in still or slowly flowing water.

Antioxidant activity: The percent inhibition of 2,2-diphenylpicrylhydrazyl (DPPH) free radicals was measured at various concentrations. If the free radical scavenging activity of *Hydrilla verticillata L.* were compared with standard ascorbic acid, the dose-response curve was obtained in which the highest activity marked at 100 μg mL^{-1}. Inhibition of DPPH radicals found a maximum of 29.60% in the ethanolic extract of *Hydrilla verticillata* L. Vitamin E and Vitamin C showed about 47.30 and 80.38% inhibitory effects within the concentration range (100 μg mL^{-1}), respectively[17]. Just as antioxidant enzyme activity gets enhanced in response to various stresses on the plants, Proline, an amino acid also accumulates in plants to the imposition of a wide range of biotic and abiotic stresses. This is reported by Krupa and Punita[18].

Antimicrobial activity: A positive inhibitory effect against bacteria and a negative effect against fungi were obtained by using an ethanolic extract of *Hydrilla verticillata*. The antimicrobial activity is less effective against gram-negative bacteria than gram-positive bacteria. But it has no antifungal activity. A zone of inhibition, increasing in all bacterial strains with increasing concentration of ethanolic extract of the plant. A concentration of 250 and 500 μg mL^{-1} of plant extract had no inhibitory effect on E. Coli while a concentration of 750 and 1000 μg mL^{-1} showed a zone of clearance 9 and 11 mm, respectively. In *E. coli* zone of clearance was 11 mm at a concentration of 1000 μg mL^{-1} while 9 mm at a concentration of 750 and 250 μg mL^{-1}. Similarly, in *B. subtilis* zone of clearance was 15 mm at a concentration of 1000 μg mL^{-1} while 9 mm at a concentration of 750 and 250 μg mL^{-1} [17].

Antitumor activity: *Hydrilla* medicinally used for digestion and gastrointestinal function improves blood circulation, helps in detoxification, good for neurological health[19] and cardiovascular function. It increases endurance, helps in blood sugar control strengthens immunity to protect the body from invaders and slows ageing[20]. Hydrilla contains otteliones A and B which are biologically important, structurally novel natural products and exhibit potent antitumor activity[21].

***Ceratophyllum desmersum* L.:** They are perennial or sometimes annual, totally submerged, rootless, free-swimming plants. Shoot tips often with the shorten internodes giving it a 'bottle brush' appearance.

Antioxidant activities: Antioxidant contents (β-carotene, flavonoid, lycopene and total phenols) of methanol and water extracts obtained from *C. demersum* determined. Among these extracts, the highest component levels were detected in the water. Considering total phenolic contents, the water extract of *C. demersum* was reported to possess the highest quantity (76.55 μg mg^{-1})[22].

Antimicrobial activities: The process of extraction of *Ceratophyllum demersum* L. with other plants was carried out with aqueous and some organic solvents such as chloroform, ethanol and methanol. This plant extract was examined against seventeen different microorganisms, including Gram-positive and Gram-negative bacteria and fungi. From different sources, nine of these known organisms were imported such as *Bacillus subtilis* 1020, *Bacillus cereus* 1080, *Staphylococcus aureus, Erwinia carotovora* NCPPB 312, *Candida albicans, Candida tropicalis, Aspergillus niger, Fusarium oxysporum and Penicillium italicum*. API 20E strip system (BioMereux) was used for the isolation and identification of eight microbial genera. Species-level identification of One hundred pathogenic bacteria isolates belonging to eight genera was performed. These organisms are *Escherichia coli* (20%), *Pseudomonas aeruginosa* (16%), *Klebsiella pneumoniae* (14%), *Salmonella colerasuis* (13%),

Shigella sp. (11%), *Serratialique faciens* (10%), *Proteus vulgaris* (9%) and *Brennerianigri fluens* (7%).

In pilot experiments, the various solvent used for the extraction of test microorganisms and the efficiency of the extracts may vary with the solvent used in the extraction. This extract is used for antimicrobial activity against test microorganisms. The reported zone of inhibition for *Fusarium oxysporum* was 48±0.01 mm, for *Pseudomonas aeruginosa* 59±0.02 mm and for *Salmonella cholerasuis* it was 55±0.01 mm, Aqueous extract being the highly effective one while using *C. demersum.* Except for *Aspergillus niger*. ethanolic extract of *C. demersum* recoded antimicrobial activities against all tested organisms On using chloroform extracts *Escherichia coli*, *Aspergillus niger* and *Penicillium italicum* showed resistance[23].

Anti-inflammatory properties: The carrageen induced rat paw edema model at the doses of 250 and 500 mg kg^{-1} with 1% CMC (10 mg kg^{-1} p.o.) as control and Nimesulide (50 mg kg^{-1} p.o.) was used to analyze the anti-inflammatory activity of methanol extract of the whole plant of *C. demersum*. The methanol extract of *C. demersum* at the dose of 250 and 500 mg kg^{-1} b.wt., showed significantly ($p<0.01$) reduction paw volume[24].

Antipyretic properties: Brewer's yeast (*Saccharomyces cerevisiae*) induced pyrexia method in Wistar rats was used to check antipyretic activity. The rats were nurtured in separate cages with food and water for 7 days before the experiment. For experimental study animals with constant rectal temperature (37.5-38.40) were selected. Male Wistar albino rats weighing, 150-200 gm were divided into four groups of 6 animals each. The first group of the animals received 1% CMC (10 mL kg^{-1} of b.wt., p.o.) served as a control, the second group served as the reference standard received Paracetamol (50 mg kg^{-1} of b.wt., p.o) while the third and fourth group received a methanol extract (250 and 500 of mg kg^{-1} b.wt., p.o.), respectively. Fever was induced by injecting 2 mL kg^{-1} of 20% aqueous suspension of Brewer's yeast in distilled water and 18 hrs after yeast injection the vehicle, extract and standard drug was administered. Rectal temperature was recorded by clinical thermometer at 0, 1, 2 and 3 hrs after drug administration. The methanol extract of *C. demersum* (MECD) at the dose of 250 and500 mg kg^{-1} b.wt., showed significantly ($p<0.01$) reduction in the number of writhes and paw volume and at the dose 500 mg kg^{-1} b.wt., showed significantly ($p<0.05$) reduction in pyrexia[25].

***Ipomea aquatica forsk*:** They are perennial usually floating on stagnant water but sometimes found on the banks of pools, canals and rivers. It is often cultivated for its edible shoots and as medicine.

Antioxidant properties: It was reported that a high level of polyphenolic compounds is a key component of plants[26]. The presence of vitamin C and phenolic compounds in the plants provides an excellent antioxidant activity of the plant[27]. It was reported that a 1-diphenyl-2 picrylhydrazyl (DPPH) study of ethanolic extract of *I. aquatica* leaves shows an IC_{50} value of 0.387 mg mL^{-1}, whereas 2,2'-azino-bis 3-ethylbenzothiazoline-6-sulfonic acid (ABTS) method displays IC_{50} values of 0.394 mg mL^{-1} [28]. However, the highest radical-scavenging activity was recorded in the ethanol extract of the stem as compared to water extract of leaf and stem but methanol extract IA showed outstanding DPPH free radical scavenging activity (85%), which is very close to the synthetic antioxidant butyl hydroxyanisole (95%)[29].

Antimicrobial activity: The preliminary phytochemical screening of methanol extracts of leaves of *I. aquatica* showed the presence of flavonoids while that of the flowers showed the presence of flavonoids and anthocyanins. Thus the flavanoids present in methanol extracts of leaves and flowers of *I. aquatica* may responsible for antibacterial activity[30]. The therapeutic potential of plants could serve the purpose with lesser side effects and confirmed with the help of antimicrobial activities as they are often associated with synthetic antimicrobial agents. Primary screening illustrated that phytochemicals are components of plants as they are less toxic and more effective medicines in controlling the growth of microorganism[31].

Pharmacological properties: From the traditional point of view such as Ayurveda and homeopathy, leaves extracts of *I. aquatica* are directed orally to cure antioxidant-related ailments[32].

***Salvinia minima*:** They are free-floating aquatic fern and contain a horizontal rhizome lying just below the surface of the water with floating leaves.

Antimicrobial properties: The antimicrobial activity was fairly well distributed among pteridophytes. The selected fern species (Salvinia minima) examined exhibited antimicrobial properties against various test pathogens used[33].

Antinociceptive activity: Plant extract reveals a dose-dependent increase in the latency time with control. In the hot plate method, the high potent antinociceptive activity was observed by aqueous extract of *Salvinia minima* (100, 200 and 300 mg kg^{-1} orally). However, the extract (200 and 300 mg kg^{-1}) administered for 60-90 min reaches significant analgesic effect[34].

CONCLUSION

The importance of phytochemicals, strategies, guidelines and standards for botanical medicine was recognized by the World Health Organization (WHO). Medicinal plants have been a source of a variety of phytochemicals since ancient times. In various diseases treatment, pure compounds and extensively as crude material of plants were used. Plant-based natural products have been recognized for many years as a source of therapeutic agents. They are often responsible for the discovery of new drugs. The value and demand for traditional remedies for curing various diseases have been increased universally in different communities. But detailed screening of novel biologically active compounds of aquatic plants is required for the discovery and development of modern medicine. These would help in reducing human suffering against the fatal disease.

SIGNIFICANCE STATEMENT

The study discovers the anatectic potential of Aquatic plants that can be beneficial to a layman of society for their health improvement because recent researches on nutrition and food science have focused on plant products/extracts with potential antioxidant and antimicrobial activities. The results serve as a scientific basis for further development of drugs from Aquatic plants. Additionally, the Aquatic plants of this study could serve as a source for antimicrobial agents against food spoilage and pathogens. Thus a new theory on bioactive compounds/phytochemicals of Aquatic plants, the development of safer antioxidants from natural origins and the antimicrobial potential of aquatic macrophytes that enhances the shelf-life and food safety may have arrived.

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