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# Pharmaceutical potential of aquatic plant *Pistia stratiotes* (L.) and *Eichhornia crassipes*

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**Abstract:** *Pistia stratiotes* L. commonly known as water lettuce belongs to Araceae. It has been used in various medicines for the treatment of eczema, leprosy, ulcers, piles, stomach disorder, throat and mouth inflammation, a few to mention. *Eichhornia crassipes* (Mart.) Solms (Waterhyacinth), an aquatic perennial herb present throughout the world, has a myriad of metabolites. Extracts, as well as pure compounds isolated from this plant, have been demonstrated to possess pharmacological activities. This review article is a compilation of the updated information regarding phytochemical, pharmacological, medicinal, bioremediation potential, allelopathy, utilization and management of water lettuce and waterhyacinth.

**Keywords:** Bioremediation, Allelopathy, Inflammation, Phytochemical

## 1. Introduction

Mankind through observation and experience developed knowledge of the properties of plants as a source of food and medicines. Phytochemicals are as important as synthetic medicines since in some regions it is the only source of medicine. In the history of ancient civilizations, the use of medicinal herbs for curing diseases has been documented. Drugs were used in crude forms as decoctions, infusions, tinctures and poultices. Phytochemicals play an important role in the pharmaceutical industry as raw materials or as a particular drug. Secondary metabolites obtained from the plants are found to be an important source of various phytochemicals that could be used for the production of pharmaceuticals. In the developing countries, approximately 80% of the populations still rely on the traditional medicine derived from the plants for health care needs. Thus the demand for herbal medicines is continuously increasing day by day in comparison to the synthetic drugs. India is called the botanical garden of the world for its rich natural resources.

### *2.1. Pistia stratiotes*

*Pistia stratiotes*, also known as 'Jal kumbhi', water cabbage, water lettuce, Nile cabbage, or shellflower is a free floating aquatic plant of streams, lakes and ponds. Due to its stoloniferous nature it is always found anchored to the hydrosoil when the water level recedes and in marshland conditions and loves alkaline/lime-rich water. *P. stratiotes* belongs to arum/ Araceae family [1].

***Figure 1.*** *Pistia stratiotes*

*Pistia stratiotes* L., is a free floating, aquatic plant with sessile leaves forming a rosette. The leaves are pale-green, 10-20 cm long and 10 cm wide, spathulate to obovate with a rounded to truncate apex. Around 7-15 veins run parallel from the base. The lower surface is covered with whitish hairs [2-5]. Inflorescence is axillary, solitary, spathulated with a single pistillate flower at base, and 2-8 staminate flowers above. Flowers are unisexual, staminate with two stamens, pistillate with unilocular ovary having numerous ovules, a slender style and penicillate stigma, the fruit with many thin seeds [6]. Its seeds germinate on the hydro-soil and float to the surface within 5 days. Germination can also occur in the dark. *P. stratiotes* does not survive freezing temperatures. Germination does not occur below 20°C. It flowers in summer and give fruits at the end of hot season [7]. The seeds float on the surface for few days, transported by currents and water fowl, before they sink to the bottom [4].

A large number of medicinal and other uses are attributed to *P. stratiotes* which makes it a very special plant to be exploited [8]. The recent upsurge in herbal medicines has made it possible to transform traditional medicine into a modern industry to deliver healthcare to the common man[9]. *P. stratiotes* from medicinal point is used as antiseptic, antitubercular and antidysentric. Its extract is used as an anodyne for eyewash and for relieving ear complaints. Its ash is applied to scalp for curing ringworm. Leaf extract is used in eczema, leprosy, ulcers, piles, and syphilis. Leaf extract boiled in coconut oil is applied to the skin in chronic dermatitis [8]. Its concoction is useful for relieving nervous disorders, fever and intestinal bacterial infections. *P. stratiotes* is useful in the treatment of stomach disorder, throat and mouth inflammation [10]. It was reported that ethanol and hot water fractions of the plant exerts antimicrobial action on a few pathogenic bacteria while chloroform fraction of the same plant possess both antifungal and antibacterial activities on some pathogens [11]

#### *2.1.1. Phytochemical Content of Pistia Stratiotes*

*P. stratiotes* plant extracts consist of various alkaloids, glycosides, flavonoids and phytosterols. Leaf and stem extract consist of 92.9% H2O, 1.4% protein, 0.3% fats, 2.6% carbohydrates, 0.9% crude fiber and 1.9% minerals (mostly potassium and phosphorous). Leaves are rich in vitamins A & C, stigma-sterol, stigma-steryl, stigma-sterate and palmitic acids are found in abundance. 2-di-cgl-cosy-flavones of vicenin and lucenin type, anthocyanin cyaniding-3-glucoside, luteolin-7-glucoside and mono-C-glcosyl flavones–vitexin and orientin have also been isolated from the plant[12]. Stratioside II (a new C13 norterpene glucoside) is the major component of this plant. Leaves are rich in proteins, essential amino acids, stigmatane, sito-sterol acyl glycosides and minerals[13]. Vicenin an anticancer agent[14] and cyanidin-3-glucoside (an anthocyanin) is present[15]. The plant contains large amounts of di-c-glycosyl-flavones similar to vicenin and lucenin and their derivatives, traces of anthocyanin; cyanidin-3- glucoside and a luteolin-7-glycoside, mono-cglycosylflavones, vitexin and orientin [16]. Using column chromatography resulted in isolation of stigmastanes as well as eight new compounds as Ergosta-7, 22-diene-3,5,6-triol, 7-hydroxyl-sitosterol, sitoindoside, soya-cerebroside, luteolin, chrysoeriol 4-*O*-Dglucopyranoside, sitosterol and daucoterol[17,18]. The flavonoid chemistry of *P. stratiotes* shows an evolutionary link between the aroids and the lemnaceae due to similar biochemical pathways to most flavonoids, which strengthens the concept that lemnaceae may have arisen from a *Pistia*-like ancestor [16]. *P. stratiotes* can be used as a model plant in biochemical study of oxalic acid formation and calcium regulation as related to calcium oxalate production in pure cultures [19].

### *2.2. Pharmacological Uses of of Pistia Stratiotes*

#### *2.2.1. Biogas Production*

*Pistia stratiotes* can be utilized as a substrate for biogas production in batch digestion. With inoculation, a high rate of biogas with an average 58-68% methane production and significant concentrations of propionic, butyric, isobutyric, valeric, and isovaleric acids. The addition of inoculum improves the performance significantly [20]. It can be exploited for bio-fuels through GM bacteria, this will help in managing the weed, mitigating water pollution, relieving energy problems and protecting the aquatic ecosystem [21].

#### *2.2.2. Role in Water Purification*

*Pistia stratiotes* L. is a ‘hyperaccumulator’ by removing heavy metals, organic compounds and radio-nuclides from water [22]. It purifies the polluted aquatic system from deterimental metals. Lower size of the plant for removal of heavy metals is a credit for this plant as compared to water hyacinth [23-26]. It can be used for Zn extraction from industrial wastes as it has strong affinity to Zn absorption in an ecofriendly manner [27]. The same is true about mercury too [28]. The accumulation of heavy metals like Fe, Zn, Cu, Cr, and Cd does not cause any toxic effect on the plant which qualifies the plant to be used for the phyto-remediation of waste water for heavy metals on large-scale [29]. *P. stratiotes* is best candidate for in situ bioremediation of drug contaminated water body as it is more sensitive than the other aquatic plants tested. Thus it is recommended for quinolone bioremediation but less effective for sulphonamide [30].

#### *2.2.3. Biological and Pharmacological Activities*

*Pistia stratiotes* leaves extract is capable to reduce superoxides and nitric oxide radicals and to lower free radical induced cell injury. The ethanolic extract of this plant leaves inhibits the enzyme xanthine oxidase and hence uric acid formation, the xanthine oxidase inhibitor is used in the treatment of gout [31]. The antipyretic nature of the extract can be utilized for treating fever [32]. The leaves are used as disinfectant and for the treatment of tuberculosis, dysentery, eczema, leprosy, ulcer, piles, syphilis and parasitic worms [33,34]. The ash of water lettuce is used for curing tinea. Egami *et al.*, reported the antibacterial activity in the plant [35]. *P. stratiotes* works as antioxidant [36], bronchodilator [37], antitumor [38], antifungal [39], diuretic[40], antiprotease [41], emollient [42], antidiabetic[43] and antimicrobial [44].

#### *2.2.4. Anti-Inflammatory Activity*

Water lettuce is traditionally used for curing opthalmia and iritis in Ghana, due to its analgesic anti-inflammatory effect[32],[42],[45,46]. Its water and ethanolic extracts given in acute inflammation relieve hyperalgesia by inhibiting the chemicals (histamine, serotonin, prostaglandin, and bradykinin) that stimulates and sensitizes the nociceptor[47]. The phytochemical screening revealed presence of some flavonoids and sterols, which might be the source of the anti-inflammatory activity of this plant [48,49].

#### *2.2.5. Diuretic Activity*

Pallavi *et al*., reported antidiabetic and diuretic activities in the leaf extracts of water lettuce [40]. They found that oral administration of the extracts produced significant diuretic action which might be its ability to block sugar absorption. The ethanolic leaf extract of this plant has significant diuretic activity, and supports the traditional practice of using water lettuce as diuretic [50].

#### *2.2.6. Antifungal Activity*

Natarajan *et al*., found that *P. stratiotes* methanolic extract was most effective against dermatophytes. The antifungal activity of water lettuce justify its use for curing different diseases with fungal or fungal-like symptoms, like ringworm infection of the scalp, syphilitic eruptions, skin infections, boils, and wounds, and highlight the worth of indigenous knowledge of ethno-botany in choosing water lettuce to discover new medicines[51].

#### *2.2.7. Anti Microbial Activity*

The extract of *Pistia stratiotes* showed antibacterial [44],[52,53] antifungal[54,55], antiviral[56-58] and antialgal activities[59,60]. Flavonoids and phenolic derivatives of water lettuce affected the function of bacterial cell membrane as a result inhibited their growth[61,62].

#### *2.2.8. Wound Healing Potential*

*Pistia stratiotes* contains large amount of compounds that have antioxidant activity[63]. Sterols from this plant are reported to be responsible for wound healing property of the plant [64]. The healing potential is due to its ability to trigger angiogenesis and mitogenesis at the site[65]. The wound healing property of water lettuce is attributed to certain compounds present in the plant which work alone or in combination with other compounds in the healing process.

#### *2.2.9. Allelopathic Effects on Terrestrial Plants*

The allelopathic potential of water lettuce is a best source for weed management. Screening provides important basic information on inhibitory effects and their potential for weed control [66]. Some alellochemicals caused root cell death indirectly by production of reactive oxygen species that worked as signaling molecules that changed hormonal balance during seed germination[67]. Germination of lettuce in aqueous extracts of corn residues, caused necrotic root tips and shorter roots due to damage of meristematic tissue[68]. Eucalyptol also inhibits the roots growth of lettuce seedlings[69].

## 3. *Eichhornia Crassipes* (Mart.) Solms

*Eichhornia crassipes* (Mart.) Solms is an aquatic perennial herb that belongs to the family Pontederiaceae, an erect free-floating herbaceous plant, spread throughout the world. Eight other genera occur in this family of predominantly neotropical, freshwater aquatics, and eight species in the genus *Eichhornia*. The English common names of *Eichhornia crassipes* are waterhyacinth, water hyacinth and water-hyacinth. Waterhyacinth is the standardized spelling adopted by the Weed Science Society of America to denote that it is not an aquatic relative of true “hyacinth” (*Hyacinthus* spp.), as the two-word spelling suggests[70]. Waterhyacinth contains many phytochemicals[71-74]. Many phenalene compounds have been isolated from waterhyacinth[75-78]. The plant has been reported to show antimicrobial activity[79-83], antioxidant activity[84,85][74], wound healing activity[86,87], antitumour activity [88] and larvicidal activity[89].

*Eichhornia crassipes* is a free-floating aquatic macrophyte that displays two different morphologies with intermediates, dependent on the conditions in which it grows. In dense stands, the petioles are elongated (up to 1 m in length in nutrient-rich waters devoid of herbivores) with circular leaves; but are short (<30 cm) and bulbous, with kidney-shaped leaves where the plants are not in dense mats, or along the edge of infestations[90]. The 6–10 glabrous leaves are arranged in basal rosettes, each leaf lasting up to 6–8 weeks before senescence. Both the rhizome and the fibrous, feathery roots remain submerged. The root morphology is highly plastic and the plasticity is related to nutrient, particularly phosphorus(P), availability in the water. Lateral roots are generally longer and denser at low P levels than at high P levels[91]. The root–shoot ratio varies inversely with nutrient, particularly nitrogen, availability.

***Figure 2.*** *Eichhornia crassipes*

Reproduction is both sexual and vegetative. The showy flowers are pale blue or violet, displaying a yellow central patch in the standard perianth lobe, and are borne in spikes. The Pontederiaceae is one of only two monocotyledonous families that display genetic polymorphism of tristyly, in which all flowers of an individual plant possess one of three distinct corresponding style and stamen length phenotypes[92]. Flowers produce large numbers of longlived seeds that can remain viable for up to 20 years in sediments[93,94]. Sexual reproduction is limited by a scarcity of suitable pollinators and lack of appropriate sites for germination and seedling establishment[95]. The main mode of population increase is vegetative, via ramets (daughter plants) formed from axillary buds on stolons produced through elongation of internodes[90]. Once the ramets have developed roots, the stolons either decay or break, separating from the parent plant. Thus *E. crassipes* populations increase rapidly, doubling under suitable conditions every 11–18 days[96]. Neutral pH favors *E. crassipes* proliferation, although the plant can tolerate pH levels from 4 to 10; high light intensities and nutrient-rich water also encourage population build-up. Growth is directly correlated with nutrient concentrations[94] – as nitrogen and phosphorus increase in concentration, so too does *E. crassipes* biomass accumulation[97,98].

### *3.1. Phytochemical Content of Eichhornia Crassipes*

Waterhyacinth possesses nutritionally important compounds like phenolics, flavonoids, glutathione [99] and many other metabolites.

#### *3.1.1. Phenolic Compounds*

Phenolic compounds are a large and diverse group of molecules, which include many different families of aromatic secondary metabolites in plants. Phenolic compounds are detected in the leaves [100,101], methanol extract [102,103], aqueous extract [73] and ethyl acetate extract [74] of waterhyacinth. 4-Methylresorcinol, 2-methylresorcinol, catechol, pyrogallol, and genetisic, *p*-hydroxybenzoic, syringic, vanillic and salicylic acids have been detected by TLC in the ethanolic shoot extract, whereas 4-methylresorcinol, 2-methylresorcinol, resorcinol, catechol, and genetisic and salicylic acids were present in rhizomes [104]. 1(2,4-Dihydroxyphenyl)2(4-methoxy-3-nitrophenyl) ethanone was identified in the ethanol extract by GC-MS [105].

#### *3.1.2. Alkaloids*

Phytochemical investigation of the plant showed the presence of alkaloids in waterhyacinth [103,73,74,72]. Qualitative separation of alkaloids by TLC revealed that cytisine and tomatine are present both in the shoot and rhizome, whereas codeine, thebaine and quinine are present in the shoot, and the rhizome contains nicotine [73]. GC-MS analysis of the methanol extract of waterhyacinth showed the presence of 18,19-secoyohimban-19-oic acid, and 16,17,20,21-tetradehydro-16-(hydroxymethyl)-methyl ester [102], whereas pipradrol, and 1H-pyrrole,1-phenyl were detected in the ethanol extract [105].

#### *3.1.3. Terpenoids*

Terpenoids were detected in various extracts of waterhyacinth [102,103,73,74]. 3,7,11,15-Tetramethyl-2-hexadecen-1- ol and phytol were identified in the ethanol extract by GC-MS [105]. Growth regulating substances, indole compounds and gibberellins were separated from the roots of the plant [106,107]. Carotene was extracted from waterhyacinth by different methods.

#### *3.1.4. Sterols*

Sterols are present in various extracts of waterhyacinth [103,73,74]. Campesterol**,** stigmasterol and sitosterol were detected in the sterol mixture isolated from the acetone extract [108]. Hydroxystigmata-4, 22- dien-3-one (**35**), a novel steroid, has also been isolated [109].

#### *3.1.5. Glycosides*

Glycosides [72], in particular cardiac glycosides [73], were reported in the chloroform and aqueous extracts of the shoot, respectively. Monogalactosyldiglycerides and digalactosyldiglycerides are the major glycolipids. Phospholipids found in the roots, leaf stalks and flowers are respectively phosphatidylcholine, phosphatidylglycerol and phosphatidylethanolamine. The major fatty acids in the roots, leaf stalks, leaves and flowers are palmitic and linoleic, linoleic, palmitic, linolenic and linoleic, respectively [110]. Stigmatic exudates of waterhyacinth contain the soluble sugars, fructose, sucrose, and free fatty acids [111]. Analysis of the polysaccharide revealed that the heteropolysaccharide of waterhyacinth is composed of D-xylose, L-galactose and Larabinose [112].

#### *3.1.6. Other Metabolites*

Resins [113] are present in waterhyacinth. Saponin in chloroform and methanol extracts [72,103], and anthroquinone in the chloroform extract [110] of waterhyacinth were observed. The aqueous extract of waterhyacinth shoot contains phlobatannin, quinone, anthraquinone and cardiac glycosides, whereas phlobatannin and cardiac glycosides are absent in the rhizome [73].

### *3.2. Pharmacological Content of Eichhornia Crassipes*

#### *3.2.1. Antimicrobial Activity*

Many researchers have evaluated the antimicrobial activity of various extracts of the plant. The methanol extract and its fractions showed antimicrobial (bacterial and fungal) and anti-algal activities (green microalgae and cyanobacteria) using the paper disc diffusion bioassay. Waterhyacinth extract showed activity against *Staphylococcus aureus, Escherichia coli, Penicillium* and *Aspergillus niger*, but the activity depended on pH, concentration and action time [114]. The methanolic extract of waterhyacinth showed activity against *Alternaria alternata, Aspergillus flavus, Fusarium oxysporum, Rhizoctonia solani*, and *Xanthomonas compestries* [115].

#### *3.2.2. Antioxidant Activity*

*Eichhornia crassipes* exposed to various concentrations of Ag, Cd, Cr, Cu, Hg, Ni, Pb and Zn hydroponically for 21 days showed increases in the activity of catalase, peroxidase and superoxide dismutase, and there was differential inducement among the metals. Overall, Zn had the least inducement of the antioxidant enzymes in *Eichhornia crassipes* and *Pistia stratiotes*, while Hg had the highest inducement [116]. The reducing power of the aqueous extract and fractions – ethanol, aqueous, methanol and aqueous- of waterhyacinth evaluated for their reducing power capability at five different concentrations showed increasing absorbance and this was related to their high antioxidant capacity [117]. The DPPH scavenging assay of the light petroleum, acetone, ethyl acetate, aqueous, and hydrolyzed extracts, and fractions showed that the hydrolyzed extract has good DPPH scavenging activity [87].

#### *3.2.3. Wound Healing Activity*

The methanolic extract of waterhyacinth leaves in the form of an ointment, at two different concentrations (10% and 15%, w/w of leaf extract in a simple ointment base) were investigated for their wound healing potential in an excision experimental model of wounds in rats. The treatments showed better wound contraction ability that was significantly greater than that of the control [86].

#### *3.2.4. Antitumor Activity*

A methanolic leaf extract of waterhyacinth (50%) at different doses (200 mg/kg body weight to 500 mg/kg body weight) showed good response against B16F10 *in vivo* melanoma tumor bearing hybrid mice models (from Swiss albino female and C57BL male) [88]. Some fractions exhibited selective anticancer activity against a liver cancer cell line, while other fractions exhibited high anticancer activity against hormone dependent tumor types (cervix and breast cancers). The potency of the crude extract compared to its fractions has been attributed to the auto-synergistic effect of these fractions within the same extract [118].

#### *3.2.5. Larvicidal Activity*

*Chironomus ramosus* Chaudhuri eggs and larvae subjected to varying concentrations of crude root extracts of *E. crassipes* (final concentrations 0.25–2.5%) showed 100% efficiency [119] Larvicidal, pupicidal and repellent activity carried out on the light petroleum, ethyl acetate, and aqueous extracts, and methanol and ethanol fractions against *Culex quinquefasciatus* in our laboratory showed good activity.

#### *3.2.6. Eichhornia Crassipes as Adsorbate*

Waterhyacinth efficiently removes a vast range of pollutants, from suspended materials, nutrients and organic matter to heavy metals [120,121] and pathogens.

#### *3.2.7. Other Potential Uses of Eichhornia Crassipes*

Waterhyacinth can be effectively used to improve the livelihood of many people either for harvesting the plant or in other ways where it can be effectively utilized. Waterhyacinth can be used in agriculture as a fertilizer, feed [122], biomanure [123], a protein source for animal and possibly human nutrition, and as fiber for ruminants, and for energy production. It is also used for the preparation of high caloric fuel (HCF) [124], cogeneration of H2 and CH4 [125], and liquid fuels [126]. Water hyacinth fiber is also used as a filler in the manufacture of natural rubber (STR20), where it increases the hardness and modulus of the products [127].

***Table 1.*** *Photochemical estimation of Pistia stratiotes and Eichhornia crassipes*

| S.No. | Phytochemical | *Pistia stratiotes* | *Eichhornia crassipes* |
|---|---|---|---|
| 1 | Alkaloids | + | + |
| 2 | Flavonoids | + | + |
| 3 | Tannins | - | + |
| 4 | Saponins | - | - |
| 5 | Terpenoids | - | + |
| 6 | Sterols | + | - |
| 7 | Antraquinones | - | + |
| 8 | Phenols | - | + |
| 9 | Quinones | - | + |
| 10 | Carbohydrates | - | - |
| 11 | Proteins | - | - |
| 12 | Glycosides | + | + |
| 13 | Reducing sugar | + | + |
| 14 | Steroids | + | + |

## 4. Conclusion

The elaboration of a wide variety of phytochemicals from Water lettuce and waterhyacinth, their significant pharmacological activity, and their large scale harvesting for other utilities render the plants of potential importance. Being a hyper-accumulator it is the cheapest tool for the phyto-remediation of polluted water bodies in removing heavy metals and to denature the antibiotics released into water. Phytochemicals present in the plants indicates relevance to large scale harvesting, chemical modification, and utilization. If some useful compounds could be isolated, which is considered a threat to the environment and economy, it could be harvested and constructively used. Though there are many works citing the use of this plant in bioremediation and energy production, the plant has been exploited only to a certain extent in terms of its phytochemicals. Based on this review, the economic impact of water lettuce and waterhyacinth is huge as it involves both the control of growth and the problem caused by the plant on the ecosystem.

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