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RESEARCH ARTICLE

WATER HYACINTH: AN OVERVIEW

Iswariya, V.T., Yerram Shravya, Sriram Gayathri, Pardesh Nikhitha, Ch. Sailaja, Ravali, M, Siri, U.

Cmr Collage of Pharmacy, Kandlakoya, Medchal, Hyderabad, Telangana, India

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ABSTRACT

Water hyacinth, also known as *Eichhornia crassipes*, is native to South America but has spread throughout the world to tropical and subtropical regions. These invasive plants are notorious for their rapid growth and ability to form thick mats on water surfaces, causing ecological, economic and social problems. Rapid expansion can reduce biodiversity, clog waterways and limit access to water resources for activities such as agriculture, fishing and transport. In addition, water hyacinth can be a breeding ground for disease-carrying organisms, causing health problems for nearby populations. Actions to control water hyacinth include physical removal, biological agents such as pesticides, and chemical treatments. However, these methods can be problematic due to their vigorous growth and rapid regeneration under favorable conditions. To effectively address these issues, integrated management strategies that focus on environmental sustainability and community participation are essential. Protecting aquatic ecosystems and ensuring the management of water resources requires coordinated action at local, regional and global levels. The aim of this review is to examine the ecological impact of water hyacinth on the aquatic environment and propose practical solutions to reduce its negative effects. Despite its unhealthy nature, water hyacinth has benefits such as house building, soil erosion control, water purification and economic value in some areas.

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INTRODUCTION

Water hyacinth derives its origin from the Amazonia basin in South America and dates to 1816. Subsequently, it was introduced as an ornamental plant to North America at the end of the 1800s. It first appeared in Africa in the early 1900s and in Europe in the 1930s (Derese *et al.,* 2022). *Eichhornia crassipes* (water hyacinth) remains the most widely distributed and vicious aquatic weed. It has spread from the Amazon Back to Top basin to many tropical and subtropical regions of the world. It has been reported in Brazil, Argentina, Paraguay, Venezuela, and Chile, El Salvador, Panama, Costa Rica, Mexico, Portugal, Spain, Israel, Italy, Japan, India, and Indonesia; the United States of America and Virgin Islands ; and several parts of Africa including Nigeria, Ethiopia, Kenya, South Africa, Zambia, and Zimbabwe (Opeyemi *et al.,*2020). Water hyacinth (WH) is considered a harmful weed worldwide as it breeds rapidly and reduces nutrients and oxygen from water bodies, severely disturbing the growth of flora and fauna. Growing oil prices and exhaustion of current fossil fuel assets, together with the incessant increase in greenhouse gas release, have raised the necessity to discover and develop novel renewable bioenergy resources that do not need cultivable land and freshwater (Abdullah Adil Ansari, 2024).

Invasive Species: A species from another country or ecosystem that causes economic or environmental harm or harms human health.

Native Species: A species that evolved and is naturally distributed in the region (Durlov Lahon, 2023).

Weed: General term for any plant growing where it is not wanted. Ever since humans first attempted the cultivation of plants, they have had to fight the invasion by weeds into areas chosen for crops.

Biological Source: Water hyacinth, an indigenous monocot aquatic plant of Brazil and Ecuador region of South America, is associated with the group of plants called lilies. It belongs to the genus *Eichhornia*, which comprises seven species: *E. natans*, *E. eterosperma*, *E. crassipes*, *E. azurea*, *E. diversifolia*, *E. paniculata*, and *E. paradoxa*. Among the seven species, only two species are prolific in Africa, namely, *E. natans* and *E. crassipes*, the latter being abundant in Nigeria

FAMILY: Pontederiaceae

Water-hyacinth is a floating plant that has clusters of leaves which are circular to oval-shaped leaves with malleable covered petioles with spongy stalks arising from a base of dark purple feathery roots. The leaf clusters are often linked by smooth horizontal stems (called stolon's). Linked plants form dense rafts in the water and mud (Water Hyacinth, 2010) and carry aesthetic lilac to blue flowers. The fully grown plant comprises long, pendant roots, rhizomes, stolon's, leaves, inflorescences, and fruit.

Leaves: Rosettes of leaves with spongy, inflated, or bulbous petioles up to 30 cm (12 in.) or more, especially toward the base; leaf blades that are round or broadly elliptic, glossy green, and up to 15 cm (6 in.) wide (Water Hyacinth, 2020). The leaves and stems are able to float on the water's surface because they have air-filled sacs. The plant's enormous, dense, glossy, ovoid leaves can reach heights of up to 1 meter above the surface of the water, with an average height of 40–60 cm.

***Flowers*:** Single spike of several (8 to 15) showy flowers above rosette, to 30 cm (12 in.) long. Flowers lavender-blue with a yellow blotch, to 5 cm (2 in.) wide, (Water Hyacinth, 2010). The plant's inflorescence can support 6–10 flowers similar to the lily, with each flower being 4–7 cm in diameter (Opeyemi I. Ayanda, 2020) somewhat 2-lipped; 6 petals, 6 stamens.

Fruit: 3-celled capsule with many minute, ribbed seeds; seeds form in submerged, withered flowers (Water Hyacinth, 2020).

Reproduction: Reproduction in the plant may be by vegetative means, occurring through the generation of stolons and Sexual reproduction can also be initiated through seeds from its flowers by the agents of insects. The seed spread can be through a number of mechanisms including humans and the legs of birds (Derese, 2022). The seeds are capable of existing in water for six years, Thus making water hyacinth tough to eradicate and of 4 daughter plants (from each mother plant) which possess the ability to reproduce after two weeks, and the absence of any known natural adversary of its seeds and its ability to develop into mats of up to 2 m thick (Opeyemi, 2020).

Fig. 1. Water hyacinth

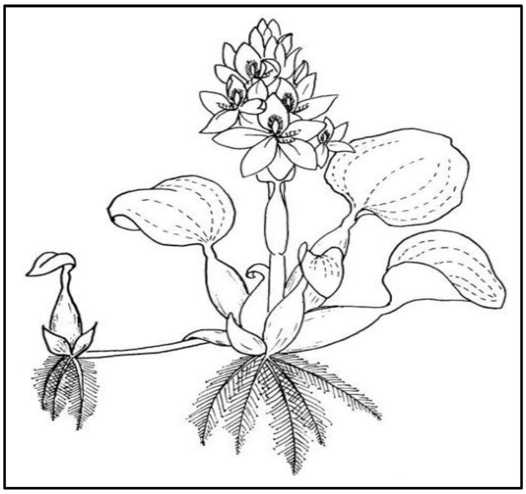

Fig. 2. Asexual reproduction of water hyacinth

Taxonomy

Domain: Eukaryota
Kingdom: Plantae
Phylum: Spermatophyta
Subphylum: Angiospermae
Class: Monocotyledon
Order: Pontederiales
Family: Pontederiaceae
Genus: Eichhornia
Species: Eichhornia crassipes (Opeyemi, 2020).

Chemical Constituents: The phytochemical composition of *E. crassipes* has been extensively explored, revealing diverse secondary metabolites, among them polyphenols (9.73%), flavonoids (10.49%), fatty acids (10.1%), alkaloids (7.4%), sterols (6.17%), and other compounds (19.13%). Several primary metabolites were-galactose, L-arabinose, and D-xylose, as well as hemicellulose, cellulose, glycolipids, and triacylglycerols Phosphatidyl ethanolamine, phosphatidyl choline, and phosphatidyl glycerol are the main phospholipids identified in the flowers, leaves, stalks, and roots. The leaves contain several amino acids and are mainly rich in leucine, asparagine, and glutamine. Two fractions of peptides have also been identified from the leaves as Leu Phe and Phe-Phe-Glu [7] Water hyacinth plant has 95% moisture content, 0.04% nitrogen, 1.0% ash, 0.20% K O, 0.06% P O, and 3.5% organic matter. On a dry-weight basis, it has 75.8% organic matter, 1.5% nitrogen, and 24.2% ash. The ash also contains 28.7% K O, 1.8% Na O, 12.8% Cao, 21.0% Cl, and 7.0% P O. Through the analysis of the Kjeldahl technique, the WH plant yields: 0.72 g methionine, 4.72 g phenylalanine, 4.32 g threonine, 5.34 g lysine, 4.32 g isoleucine, 0.27 g valine, and 7.2 g leucine per 100 g crude protein (Derese, 2022).

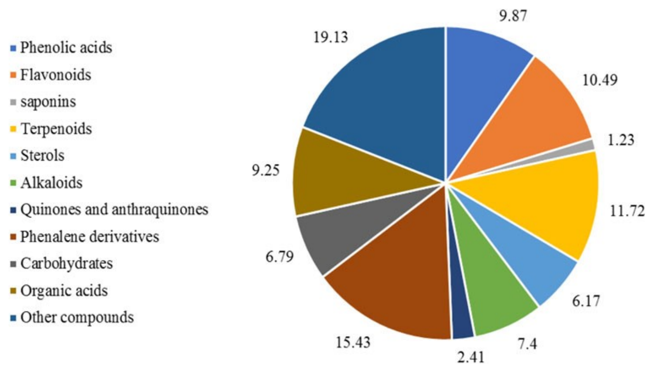

Fig. 3. Chemical constituents pie chart

Advantages

- biogas and biofuel production
- medicinal functions
- Vermicomposting
- compost production
- Bioremediation (Opeyemi, 2020)
- Water hyacinth can remove toxic contents. These characteristics of removing pollutants in heavy metals were very important phenomena of these water hyacinth plants.
- From the water hyacinth residue some of the useful and commercial different types of products were derived like ethanol, biogas, bio hydrogen, bio polymer, composites, fish and pig feeds, biofuel with more calorific value and mushroom cultivations.
- Aesthetic items
- Decoration Flowers
- Disposal food plates
- Biodegradable paper
- Gift papers
- Non-conventional protein sources for animal feed (Derese, 2022).
- Traditionally, the plant is used to treat gastrointestinal disorders, such as diarrhea, intestinal worms, digestive disorders, and flatulence (Mamdouh).
- Handicraft and furniture making (Derese *et al.,* 2022).

Disadvantages

- Interference with irrigation and drainage system, Increase in disease outbreaks (malaria, cholera, etc.)
- Less access to water points (domestic and livestock use) and Lack of clean water and Disappearance of the esthetic value of water bodies.
- Increase in incidence of snake and crocodile bites and Reduced fish catches
- Difficulties in electricity generation
- Difficulties in water transportation, Difficulties in water extraction and purification Increased siltation
- suppressing the growth of native plants and birds and negatively affecting microbes

- Water hyacinth prevents the growth and abundance of phytoplankton under large mats, ultimately affecting
- Large water hyacinth mats prevent the transfer of oxygen from the air to the water surface or decrease oxygen production by other plants and algae due to low dissolved oxygen situations initiate the release of phosphorus from the silt, which then quickens eutrophication and can prompt a resulting increment in algae
- Water-hyacinth mats lower dissolved oxygen concentrations, damaging fish populations.
- One acre of water-hyacinth can yearly deposit as much as 500 tons of rotting plant material on the bottom of a waterway.

Utilization of Water Hyacinth

Animal feed formulation, Immunostimulant effect, Insecticidal activity, Antioxidant activities, Antitumor / cytotoxic activities, Hepatoprotective activities, Phytoremediation

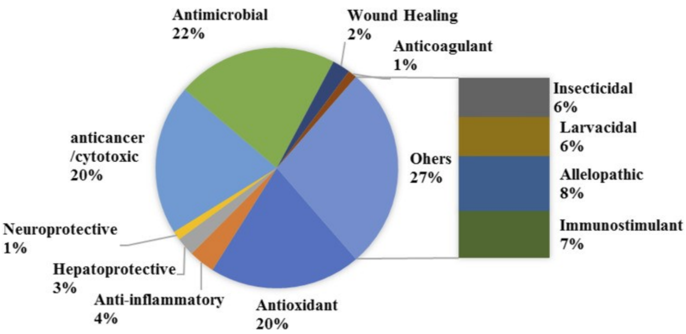

Fig. 4. Medicinal functions of water hyacinth

Value-added products from e. crassipes (mart.) solms

The biorefinery of *E. crassipes* biomass revealed several enzymes and valuable products. Furfural and hydroxy methyl furfural, for instance, were produced using the nonhazardous oxidant ($FeCl_3$) method with the highest yield of 7.9 *wt*% of the dry mass of the plant Moreover, due to *E. crassipes* availability, low price, and its high percentage of cellulose, the plant is considered a favorable source to produce fibers, superconductors, and supercapacitors. The liquid tar obtained from the plant (rich in phenolic compounds) yielded 29% of carbon fiber, which makes the plant suitable for fiber production. In addition, different biopolymers with diverse applications along with several enzymes such as cellulase, β-glucosidase, and xylanase were obtained from the plant biomass [Table 1]. The enzymes are produced from the plant residue, as carbon source, by submerged fermentation or under solid state fermentation using different microorganisms. The production of these enzymes is harnessed on large for cost-effective industrial applications [Table 2] presents the different enzymes produced from *E. crassipes* residue.

Management of Water Hyacinth

Water hyacinth management is of utmost importance. If the weed is not properly managed, aquatic life could suffer. Getting rid of the weed completely may be difficult to achieve due to its ability to grow fast and spread within a short period of time; however, the sole objective of any control measure should be to eliminate the plant faster than it grows. The best control strategy is to prevent its growth in water bodies. The long-term effects of individual control techniques, with continued utilization, should help mitigate the negative impacts of this plant. To achieve more efficiency, a combination of control strategies may be employed. There are three major ways by which water hyacinth is being controlled: mechanical/manual, chemical, and biological control.

Mechanical/Manual Removal

This method involves the use of machines and other designated pieces of equipment for removal of the weed from water. Mechanical mowers, destroyer boats, mechanized dredgers, weed harvester tractors, and crusher Boats are some of the machines used. The removed weed is moved onto the bed of the equipment. However, it is important to ensure that non target species are not impacted by the process of removing the weeds. Mechanical removal can be a prelude to chemical control whereby the water is then sprayed with herbicides after the weeds have been removed. This control method may be expensive considering the nature of the equipment in use. Manual removal does not require any technical expertise, especially when plants are removed from the water body with the use of hands, but it is only effective for a small body of water and, hence, inefficient in massive lakes or water bodies. It also has the drawback of being time-consuming. This control method can bring about changes in dissolved oxygen content of water. Aquatic vegetation cutters or "Swamp devils" have been used widely throughout the world, and booms are often used in conjunction to reduce weed expansion. These techniques have often worked in that weed can be contained and removed. However, often as a result of the sheer scale of the problem, bennet's are typically short lived as a cleared site can be inundated with new weed in a matter of days, either through growth of any remaining weed or immigration of plants from outside of the site. Furthermore, booms can become overburdened from the weight of the weed and machinery can breakdown.

Chemical Control Technique

This technique involves the application of herbicides to get rid of the weed. Paraquat and Glyphosate are two chemicals widely used. This method of control is quick, efficient, and not costly but it requires a select skill to be efficient. Even though stakeholders in issues concerning the environment advise that caution be taken when chemical control is being considered because of the effects it may have on nontarget organisms, these fears are not always actualized.

Table 1. Value-chemicals produced from *e. crassipes* and their applications

Products	Process	Yield	Applications
Furfurals and hydroxyl methylfurfural	Chemical and thermal pretreatment on lignocellulosic biomass Nonhazardous oxidant (FeCl3)	7.9%/DM	Biorefinery product fossil oil derivatives
Cellulose xanthogenate	Extraction with NaOH and CS2 yielded alkali-treatment	DN	Increase the heavy metal adsorption
Hydrogel	Chemical treatments	DN	Potential for future applications in nanocomposites
Polyhydroxyalkanoate	Acid pretreatment + fermentation by *Pseudomonas aeruginosa*	65.51%/DM	Biopolymer: bioplastic
Hydrogel	Polyvinyl alcohol + glutaraldehyde	DN	Biopolymer (control release technology)
Polyhydroxybutyrate	Alkaline, peracetic acid pretreatment and enzymatic saccharification (by *Ralstoniaeutropha* ATCC 17699)	73%/DM	Biopolymer: the most important biodegradable plastics
Nanofibers	Chemical and mechanical treatments	DN	Composites, biodegradable thin films, adsorbents
Carbon fiber	Water hyacinth liquid tar	29%/DM	Precursor for the preparation of composite materials
Carbon microsphere	Subcritical water process	0.1019 g/g DM	-
Composite	Solution impregnation and hot curving methods	DN	Natural fibers are reinforced with polymer composites to produce low-cost materials of engineering
Nanocrystalline cellulose	Chemical and mechanical treatments	DN	Potential application in various fields, especially as a reinforcing agent in bio nanocomposites
Laccase	Solid state fermentation by *Pycnoporus sanguineus* SYBC-L1 Synthesis by *Phanerochaete chrysosporium* NCIM 1197	32.02 U/DM 16.74 U/DM	Application in harsh industry
Biopolymer composites	Extraction of water hyacinth fibers + tapioca powder	10%/DM	Mechanical and thermal properties. Thermal resistance and the lowest moisture absorption
Water hyacinth composite/ NiO composite	Carbonization of water hyacinth + hydrothermal route	DN	Electrode materials for supercapacitors
Bio nanocomposite	Ultrasonic vibration during gelation	DN	Bioplastic

DN, data not available; DM, dry mass.

Table 2. Enzymes produced from *e. crassipes* residue

Enzymes	Applications	Microorganisms	Process
Cellulase	Food, textiles, and paper industry	*Trichoderma Reesie*	Fermentation
		Aspergillus Niger	Submerged fermentation
		Trichoderma viride	
		Aspergillus Niger	Physical and biophysical pretreatment + fermentation
β-glucosidase	Key enzyme in the final step in hydrolysis of cellulose by converting cellobiose to glucose	*Rhizopus oryzae*	Solid state fermentation
Xylanase	Paper industries, additive in animal feedstock, food additives, ingredient in detergents, fabric care compositions, and biofuel production	*Trichoderma*	

Table 3. Bactericidal and antifungal potential of various extracts of *e.* crassipes

Plant part used	Nature of extract	Bacteria studied	Fungal strains	Method adapted	Findings
The whole plant	n-hexane	*Salmonella typhi*, *Klebsiella pneumoniae*, *Agrobacterium tumefaciens*, *B. subtilis*, *B. atrophaeus*, *E. coli*, *S. aureus*, ,*P. aeruginosa*	*C. albicans*	Disk diffusion method	The n-hexane extract was active against all tested pathogenic bacteria except *S. typhi*, the extract was also active against *C. albicans*. The antibacterial activity was comparable to the used standards
Flowers	Methanol extract	*S. aureus* MTCC 23313, *Vibrio cholerae* MTCC 1957	-	Disk diffusion method	The methanolic floral extract possess significant antibacterial activity at 20 μg/ml against the tested bacteria
					S. aureus was found to be more sensitive compared to *V. cholera*
Leaves	Methanolic extract	Coagulase-negative *Staphylococcus epidermidis* (CoNS1, CoNS2, and CoNS3), methicillin-resistant *S. aureus* (MRSA1 and MRSA2)	-	Disk diffusion method	A maximum zone of inhibition = 14.63 ± 0.16 mm at 1,000 μg/ml
		S. aureus ATCC 25923, *S. aureus* ATCC 29213, *S. aureus* ATCC 43300, oxacillin-sensitive *S. aureus* (SOSA1 and SOSA2)			A minimum zone of inhibition of 10.17 ± 0.35 mm was observed against *S. aureus* TCC 43300
Water hyacinth biomass	Acetone, n-butyl alcohol, distilled water ethanol, and methanol	*B. subtilis*, *B. cereus*, *E. coli*, *L. casei*, *P. aeruginosa*	*A. flavus*, *A. Niger*, *A. alternata*, *C. albicans*	Serial tube dilution technique	MIC = (8–64 μg/ml) against all tested bacteria and fungi
			Colletotrichum gloeosporioides, *Fusarium solani*		However, n-butanol and methanol have the most effective activities against *Gloeosporioides*, *F. solani*, and *B. Subtilis*
Water hyacinth leaves	Hydro-methanolic extract	Human and aquatic pathogens	-	Disk diffusion test	The antimicrobial activity significantly increased against *E. coli* in hydro-methanolic extract and against *S. iniae* in the aqueous extract. The MIC and MBC were 64–256 mg/ml and 128–512 mg/ml, respectively
Leaves	Ethanol extract	*Aggregatibacter actinomycetemcomitans*	-	Serial tube dilution technique	No growth of *A. actinomycetemcomitans* at concentrations of 100%–6.25% leaf extract
Leaves	Ethanol	*S. aureus*, *Escherichia coli*	-	Disk diffusion method	The ethanolic extract exhibited good antibacterial activity against *S. aureus*, better than the activity against *E. coli* with ZOI more than 15 mm at 500 μg/ml
Root, stem, and leaf	Petroleum ether, chloroform, methanoland aqueous	*Xanthomonas axonopodis*, *Bordetella pertussis*	-	Disk diffusion method	ZOI = 17 mm recorded in leaf methanol extract against *B. pertussis*; ZOI = (29 mm) recorded in chloroform extract against *B. cinerea*
Leaves	Ethanol extract	Subgingival plaque bacteria colony	*Penicillium italicum*, *Botrytis cinerea*	Serial tube dilution technique	No growth of subgingival plaque bacteria in groups of 100%, 50%, 25%, 12.5%, and 6.25%. The growth was only seen at 3.125% and the number of bacteria colonies increased at 1.56%

Other nonherbicidal chemicals are now being used for the control of water hyacinth. The main problem associated with herbicide use, and indeed the reason they are not used as widely as they might be, is the potential effect, real or perceived, of chemicals on humans either directly through ingestion or indirectly through reduced income. Man affected rivers and lakes are major sources of drinking water, and Therefore, the problem of ingestion is clear. Also, the sites most affected by water hyacinth, and therefore most in need of herbicide application, are typically adjacent to lakeshore communities and farmlands, which increases the risk of destroying nontargeted plants and crops (Widad Ben Bakrim, 2022).

Biological Control Technique

Biological control alternatives include the exploitation of a host as a distinct natural adversary of water hyacinth to decrease the population size of the weed. To date, some of the natural enemies that have been reported include moths (*Bellura* spp., *Xubida* spp., *Niphograpta* spp.), flies (*Thrypticus* spp., *Megamelus scutellaris*), mites (*Orthogalumna terebrantis*), weevils (*Neochetina* spp.), and grasshoppers (*Cornops aquaticum*). Furthermore, fungal species, *Trichothecium* spp., *Aspergillus* spp., *Trichoderma* spp., *Fusarium* spp., and *Rhizoctonia* spp. were introduced into water hyacinth-infested waters in Lake Tana, and they were reported to be very promising as biocontrol agents of the weed. *Megamelus scutellaris* (Hemiptera) has also been tried with some degree of success. It is suggested that an integrated approach of this insect with mycoherbicide will enhance the biological control of the weed. Biological control is an ecologically safe technique, although it is a difficult process and slow to initiate (Opeyemi, 2020).

CONCLUSION

Rapid expansion can reduce biodiversity, clog waterways and limit access to water resources for activities such as agriculture, fishing and transport. In addition, water hyacinth can be a breeding ground for disease-carrying organisms, causing health problems for nearby populations. Actions to control water hyacinth include physical removal, biological agents such as pesticides, and chemical treatments. However, these methods can be problematic due to their vigorous growth and rapid regeneration under favorable conditions. To effectively address these issues, integrated management strategies that focus on environmental sustainability and community participation are essential. Protecting aquatic ecosystems and ensuring the management of water resources requires coordinated action at local, regional and global levels.

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