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Eichhornia Crassipes (Mart.) Solms: A Comprehensive Review of its Pharmacological Activities

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A B S T R A C T

Eichhornia crassipes, commonly known as water hyacinth, is an invasive aquatic plant with significant ecological and economic impacts globally. Despite its notoriety, this plant is rich in bioactive compounds like flavonoids, phenolics, and tannins, exhibiting diverse pharmacological activities. These include antioxidant, cytotoxic, antimicrobial, and mosquito larvicidal properties. Eichhornia crassipes also shows promise in environmental applications such as wastewater treatment and biofertilizer production. Its therapeutic potential has captured scientific interest, showcasing its dual role as a problematic invasive species and a source of valuable bioactive compounds.

Eichhornia crassipes notoriously manifests as an invasive aquatic plant having rather significant ecological impacts and yielding massive economic burdens worldwide suddenly. Bioactive compounds present therein have garnered considerable scientific interest due largely to their ostensibly vast therapeutic potential. Eichhornia crassipes exhibits diverse pharmacological properties including antioxidant and cytotoxic activities while also showcasing environmental benefits remarkably

Keywords: *Eichhornia crassipes* (mart.) Solms, phytochemistry pharmacology, biological activities

Introduction

Eichhornia crassipes (Mart.) Solms , known as water hyacinth, is a native of South America but has gone global. Its proliferation on water surfaces leads to leads to other environmental problems, such as biodiversity reduction and waterway obstruction (*Aboul-Enein et al.*, 2011). Although an invasive aquatic plant, water hyacinth contains many bioactive compounds including flavonoids, phenolics, and polysaccharides, with evidence of pharmacological significance (*Adelodun et al.*, 2020; *Arifkhodzhaev & Shoyakubov, et al.*, 1995). societal problems including a significant loss of water resources, it has a wide range of uses because it is well-known for numerous industrial uses like animal feed, wastewater treatment (absorption of heavy metals), bioenergy, and biofertilizer manufacturing. Sterols, alkaloids, phenolics, flavonoids, tannins, and saponins are among the many bioactive secondary metabolites that are abundant in *E. crassipes* Numerous therapeutic benefits of these secondary metabolites are widely recognized. The results of this review indicate that several isolated chemicals and extracts from *E. crassipes.*

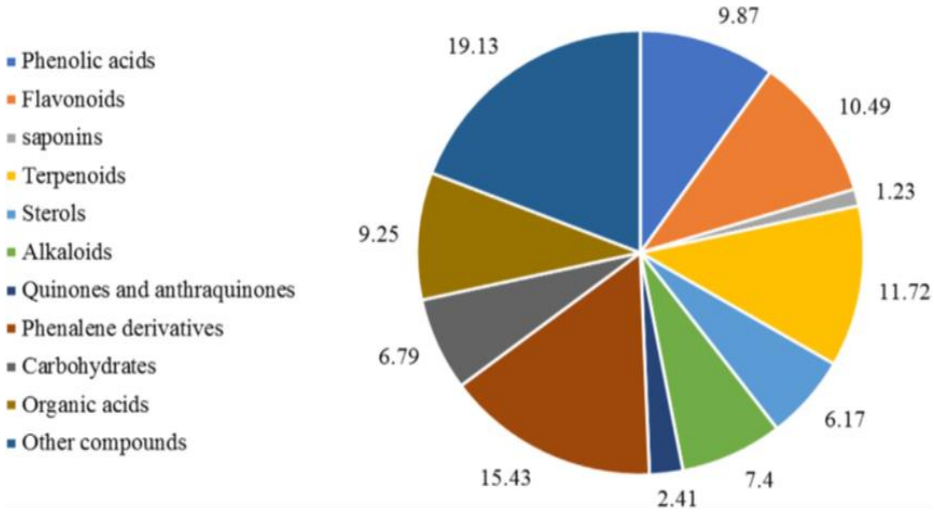
FIGURE:1 (A) Eichhornia Crassipes (Mart.) from Lake Tana, Ethiopia.

BOTANICAL DESCRIPTION

The Pontederiaceae family possesses nine genera, including Eichhornia. The latter is composed of eight species of aquatic plants, among them is *Eichhornia crassipes* (Mart.) Solms: synonym of *Pontederia crassipes* (Mart.). The mature plant as roots, leaves, stolon, inflorescences, and fruit clusters (*Parsons and Cuthbertson, et al.,* 2001). The root morphology is highly plastic and fibrous, having one single main root with many laterals, forming a huge root system. Because each lateral root has a root tip, *E. crassipes* may exploit nutrients in a low-nutrient water body, which makes the lateral roots longer and denser at low phosphorus concentrations. *E. crassipes* petioles are both erect and horizontal as stolon. There are two types of leaves, thin and round. The thin ones stand erect while the round ones possess a slightly undulating edge. In addition, the two types of leaves are soft, glossy, and glabrous . The leaves possess semi-parallel veins following their curvature (Parsons and Cuthbertson, 2001). The plant possesses beautiful violet flowers with six petals that may be found throughout the year under favour able conditions. However, the intensity of flowering may differ over the four seasons. The fruit contains 300 seeds in a slim three celled capsule which measures 1–1.5 mm long with many longitudinal ribs. In regions with temperatures around25°C, the seeds can remain inactive for up to 20 years and then germinate with water. Generally, temperatures between20 and 35°C enhance germination while temperatures around35°C enhance rapid growth (*Parsons and Cuthbertson, et al.,* 2001; *Malik et al.,* 2007).

Table 2-Taxonomical classification:

Taxonomical classification
Kingdom: Plantae (Plants)
Phylum: Tracheophyta (Vascular plants)
Class: Liliopsida (Monocots)
Order: Commelinales (Spiderworts and Allies)
Family: Pontederiaceae (Pickerel Weed Family)
Genus: Eichhornia
Species: *Eichhornia crassipes* (Mart.) Solms.



Pharmacological Activities

1.Antioxidant Properties

The antioxidant potential of *Eichhornia crassipes* is due to high phenolic compounds and flavonoids contents. These indeed compound neutralizes free radicals hence oxidative stress which is the key determinant in chronic diseases like cancer and neurodegenerative disorders (*AboulEnein et al.,* 2014). Extracts of this plant have been reported to show great in vitro free radical scavenging activity which can be used as a basis for its therapeutic applications (*Aboul-Enein et al.,* 2011).

The potent antioxidant activity of *Eichhornia crassipes* reflects a wealth of phytochemicals with high levels of phenolic compounds and flavonoids. These naturally existing bioactive substances aid in combating free radicals, unstable molecules produced during metabolic processes and as a result of environmental exposures. Free radicals—when not reigned in—cause oxidative stress a pathophysiological derailment which plays a crucial role in the

onset and progression of a wide range of chronic and degenerative disorders such as cardiovascular, neoplastic, diabetic, neurodegenerative, including Alzheimer's and Parkinson's diseases.

Water hyacinth's phenolic compounds are highly regarded for their strong electron-donating capability. Phenolic molecules stabilize the free radicals by donating electrons, stopping the chain reactions that cause cellular damage. This free radical scavenging property ameliorates oxidative injury to lipids, proteins, and DNA, which lowers the risks for healthy cells to undergo mutagenesis and apoptosis (*Aboul-Enein et al.,* 2014). Flavonoids constitute another essential antioxidant class also found in *Eichhornia crassipes* which shares its protective effects due to metal ion chelation, inhibition of ROS formation, and modulation of signalling pathways involved in inflammation and oxidative stress.

In vitro studies show significant antioxidant activity of water hyacinth extracts, which supports the therapeutic uses of these plants. The free radical scavenging potentials for the plant have been demonstrated by diverse assays e.g., DPPH- (2,2-diphenyl-1-picrylhydrazyl) radical scavenging assay, and ABTS-potentials (2,2′-azino-bis [3-ethylbenzothiazoline-6-sulfonate]) assay .

Besides its numerous biochemical properties, the ecological abundance of *Eichhornia crassipes* represents a great source for potential large-scale extraction and use in the generation of antioxidant formulations. With its high productivity in varied aquatic ecosystems, it provides a bio-resource base that brings harmony with environmental sustainability and circular bioeconomy. Harnessing its antioxidant potential, scientists can utilize this invasive species to aid in human health, rather than treat it as merely as ecological pest.

Using it as a source of bioactive secondary metabolite, the cytotoxic and anticancer potential of *Eichhornia crassipes* is a topic of great attention. Compounds isolated from water hyacinth have been shown to have cytotoxic activity on different cancer cell lines, including breast, liver and colon cancer cell lines (*Aboul-Enein et al.,* 2014). The therapeutic efficacy of these compounds is mostly attributed to the presence of secondary metabolites like flavonoids, tannins, saponins, and phenolics exerting multifaceted biological activities. Of these bioactive components, flavonoids have an especially important role in countering cancer cells. They have direct and indirect anticancer mechanisms. Flavonoids can directly interact with various cancer cell receptors, inducing apoptosis, a programmed cell death mechanism necessary for removing defective or aberrant cells. Flavonoids cytotoxicity on malignant cells is highly efficient due to their ability to impair mitochondrial function and activate caspase-dependent pathways. These compounds indirectly modulate fundamental molecular signaling pathways including the PI3K/Akt and MAPK pathways, is one of the key events in carcinogenesis. The dual nature of phenolics—antioxidant vs pro-apoptotic—highlights their candidate therapeutic role in cancer therapy Furthermore, the phenolic compounds offered by water hyacinth appear to have antioxidant activities along with anticancer effects. Phenolics exert a protective effect by scavenging free radical species and decreasing oxidative stress while protecting against DNA damage, which

that are involved in cancer cell growth and therapy resistance. Tannins, another important class of secondary metabolites in *Eichhornia crassipes*, are involved in cytotoxicity by affecting the structural integrity of cancer cell membranes, resulting in lysis and cell death. What is unique with water hyacinth is its efficiency as a source of anticancer agents. Varying cytotoxic activity has been shown by extracts from different plant parts, such as leaves, roots, and flowers, also suggesting that the whole plant is used for medicinal purposes. These results form the basis for the isolation and characterization of novel anticancer agents obtained from Eichhornia crassipes

In addition, its cytotoxicity also includes multidrug-resistant (MDR) cell lines not only established cancer cell lineages. This property may prove to be exceedingly beneficial in treating what is one of the biggest dilemmas in modern oncology, i.e., drug resistance. Interestingly, several compounds isolated from *Eichhornia crassipes* have been found to potentiate the activity of standard chemotherapeutic agents in MDR cancer cells. Although promising metabolite cytotoxicity and anticancer activity were demonstrated, the elucidation of the mechanisms of action of such bioactive compounds is required. They must undergo preclinical studies to demonstrate their potential efficacy and safety, and then clinical trials to properly vet them for human use. Improvements in extraction and purification, for example with chromatographic methods and bioassay-guided fractionation, have also become increasingly important.

2. Cytotoxic and Anticancer Effects

Research indicates that bioactive compounds isolated from water hyacinth exhibit cytotoxic effects against various cancer cell lines, including breast, liver, and colon cancers (*Aboul-Enein et al.,* 2014). This is primarily due to the presence of secondary metabolites like flavonoids and tannins, which induce apoptosis and inhibit cancer cell proliferation

3.Antimicrobial Activity

The antimicrobial properties of *Eichhornia crassipes* have been known to neem much about its effectiveness towards a large spectrum of pathogens. For instance, extracts from its leaves inhibited the growth of Aggregatibacter actinomycetemcomitans Periodontal disease-associated bacterium (*Afidati et al.*, 2019). This finding gives support to its potential use in natural antimicrobial agents development.

Eichhornia crassipes has gained much scientific attention for its in vitro antimicrobial potential as it has been shown to be effective against various microbial pathogens. It is thought that its bioactive compounds, such as alkaloids, flavonoids, tannins, and saponins contribute to its antimicrobial pieces of information. These phytochemicals lyse microbial cell walls, impair enzyme functions, and limit the replication of pathogenic microorganisms.extracts from the leaves of *Eichhornia crassipes* have shown considerable inhibitory activity against Aggregatibacter actinomycetemcomitans. a bacterium closely related to periodontal disease (*Afidati et al.,* 2019). 'Periodontal disease' is a common dental disease that results in inflammation of the gums and, if untreated, also results in loss of teeth. Furthermore, the fact that the plant was able to suppress A. actinomycetemcomitans implies that it may lead to the production of natural therapeutics for oral health. Apart from its antibacterial potential, *Eichhornia*

crassipes has several advantages over synthetic antimicrobial agents. The growing rates of antimicrobial resistance in pathogenic microorganisms have triggered the finding of alternative solutions. Natural plant-based antimicrobials, such as those from Eichhornia crassipes, represent a promising prospect to tackle this global health fight. Unlike synthetic drugs, plant-based compounds are less likely to lead to resistance owing to their complex chemical structures and multitarget mechanism of action. Moreover, the abundance of the plant in ecology makes it an irresistible source for the development of antimicrobial drugs. *Eichhornia crassipes* is an invasive species that rapidly grows, creating notable challenges to the environment. Keeping its ecological impact in check by using its biomass for pharmaceutical applications will create a second life for it when the plant gets infected, and it will be able to produce high-value antimicrobial products.

4.Mosquito Larvicidal Activity

The mosquito larvicidal property of the plant is highlighted as potential for vector control. *Eichhornia crassipes* has shown larvicidal activity and can be used to kill mosquito larvae (*Abdul Rahuman et al.,* 2008; *Lorrein et al.,* 2015).

The fact that it possesses mosquito larvicidal properties make it a prime candidate for new and green vector control tools. Mosquito-borne diseases (MBDs) are among the most important diseases globally, accounting for a significant burden of disease, especially in tropical and subtropical regions, including malaria, dengue, and chikungunya. Traditional chemical insecticides are potent, but their use raises ecological concerns, such as the emergence of resistance in mosquito populations and effects on non-target organisms. In this regard, bioactive compounds presented in *Eichhornia crassipes* can be a potential natural alternative.

Its phytochemicals, such as alkaloids, flavonoids, and saponins, have been identified in water hyacinth extracts and are believed to be related to their larvicidal activity. These larvicides interfere with the normal physiological functions of the mosquito larvae, resulting in death. For example, they can cause damage to the midgut lining of the larvae, disrupt molting and development, or block the pathways of important enzymes necessary for survival. The extracts of the plant have demonstrated great activity against the mosquito species Anopheles, Aedes and Culex that transmit malaria, dengue and filariasis, respectively (*Abdul Rahuman et al*. 2008). Moreover, the larvicidal potential of plants, such as Australian water hyacinth, responds to the integrated vector management principles, which stress the need for environmentally sound strategies to combat vector-borne diseases. Water hyacinth use to control the larval population not only tackles public health issues but also helps to mitigate overgrowth of the water hyacinth itself, as it is an invasive species in many areas. This dual reward makes it a valuable resource toward public health and environmental management programs. Further research essential to standardize extraction methods and assess long-term impact of Eichhornia crassipes-based larvicides on both target and many non-target species hopefully. Collaborative efforts between researchers public health officials and environmental agencies facilitate transition from laboratory studies towards real-world applications effectively nowadays. further research is needed to optimize the extraction and utilization of its bioactive compounds while mitigating its invasive impact.

5.Pharmaceutical Chemical Benefits

Water hyacinth has wide variety of chemical benefits as well as pharmaceutical benefits. It can be used for waste water treatment, bioenergy generation, and biopolymers. For example, its fibers have been used as reinforcement in tapioca starch composites which improves mechanical properties (*Abral et al* 2018). It also plays a crucial role in phytoremediation.

6.Biological Activity

Polysaccharides from Plant Sources: Polysaccharide Composition and Therapeutic Potential The plant polysaccharides have been eported as one of the major types of bioactive compounds with different therapeutic potential. Among these properties are its immunomodulatory and anti-inflammatory effects, which opens new pathways in drug exploration (*Arifkhodzhaev & Shoyakubov, et al.,* 1995).

Conclusion:

Water hyacinth, or *Eichhornia crassipes*, is an invasive aquatic plant with incredible industrial and therapeutic potential. It is rich in secondary metabolites such flavonoids, phenolics, tannins, and saponins and possesses larvicidal, antibacterial, antioxidant, anticancer, and immunomodulatory qualities. Its constituents effectively combat oxidative stress, inhibit the formation of cancer cells, and combat resistant microbial strains and mosquito larvae. It has ecological and industrial use in wastewater treatment, bioenergy production, and phytoremediation in addition to its medical uses. Its abundant biomass and versatile bioactive compounds present a long-term opportunity for therapeutic innovation while providing an environmentally safe means of reducing its environmental impact. Further research may unlock its full potential in the medical and environmental fields.

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