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Documentation on Several applications of Waterhyacinth : A Review

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Abstract :

An account of the several activities and applications of waterhyacinth are included in this review. Globally, water hyacinth is a known invasive species that predominantly threatens the pillars of sustainability. The cost of controlling these invasive plants is high. Despite this challenge, there is valuable resource recovery from water hyacinth which can be used to make financial and environmental returns. the current paper is an attempt to discuss the beneficial use of water hyacinth.

Keywords: Eichhornia crassipes., Pesticides, Organic garment fibre, Mushroom harvesting, Biopolymers, Insulation board, Biogas

Taxonomy: Waterhyacinth, a member of the pickerelweed family (Pontederiaceae) , is indigenous to South America, particularly to the Amazonian basin . Waterhyacinth has invaded freshwater systems in over 50 countries on five continents and, according to recent climate change models, its distribution may expand into higher latitudes as temperatures rise. Waterhyacinth is especially pervasive throughout Southeast Asia, the South Eastern United States, Central and Western Africa and Central America .

The English common names of E. crassipes (family Pontederiaceae; sub-family Trollioideae; tribe Eichhornieae 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.

With broad, thick, glossy, oval leaves, hyacinth can rise up to 1 meter above the surface of the water. The leaves are 10–20 cm wide and float above the surface of the water. Hyacinth is also one of the favourite plants to be included in an aquatic garden. However, in addition to its ability to add beauty to your water garden, it actually comes with lots of benefits. These plants are hydrophytes plants, the plants are not edible, even become weeds for other plant life and the lives of other animals. These plants which have the property as a nuisance plant play an important role in reducing the levels of the heavy metals in water, such as iron, zinc, copper, and mercury, and the plants have high cellulose content and are usually used as an alternative fuel.

Waterhyacinth grows in all types of freshwater, lentic and lotic. Plant growth is described in two ways either by reporting the percentage of water surface covered in a period of time or by reporting the plant density in units of wet plant mass per unit of surface area [14]. The plant might be exceptionally productive since it is a warm water species with submerged roots and aerial leaves like emergent macrophytes [13]. So, under normal conditions, loosely packed waterhyacinth can cover the water surface at relatively low plant density (10 kg/m2 wet weight) and can reach maximum density of 50 kg/m2 wet weight before growth ceases [15]. Growth of waterhyacinth depends on various ecological factors. The chief limiting factors for regular plant growth and development are the ability of the plant to use solar energy, the nutrient composition of the water, cultural methods, environmental factors [16], salinity, temperature, nutrients, disturbance, natural enemies [17], and pH levels [18]. Waterhyacinth can tolerate salinity up to 1.3-1.9 ppt and even below 1ppt [19]. The plant grows fast at temperatures from 20 to 30°C, but growth fully stops at temperatures from 8 to 15°C [20]. It can withstand near freezing temperature .

Measures to remove the hyacinth have mostly been either through chemical treatments or manual removal. Either way, they have proven extremely ineffective and expensive. For instance, the municipal corporation in Ooty spent millions to clean the lakes in the tourist town, only to find it growing back. In Bengaluru, the Indian Army deployed 7,000 of its personnel to clean the Ulsooru lake, and their efforts had proved futile.

"Efforts to control the growth of water weeds were attempted by methods such as physical removal, chemical and biological control, but all of them have failed miserably," said G. Nagendra Prabhu, associate professor, PG Department of Zoology and principal investigator, Centre for Research on Aquatic Resources (CRAR) of Sanatana Dharma College, Alappuzha. "People have realized that the only hope lies in the economic utilization of these 'natural resources' by economically viable techniques – the concept of eradication through utilization. In fact, many researchers across the world have been striving to make use of these aquatic weeds for creative purposes," he added.

The need to deal with the water hyacinth problem is immediate in Alappuzha. Known as the Venice of India, the town is located on the banks of the Vembanad lagoon, an expansive network of estuaries and canals. In the recent years, tourism has become a major income earner for the people of Alappuzha. When the water bodies are choked with water hyacinth, it could adversely impact on the aesthetics, biodiversity and in turn tourism revenue.

Disease spreading vector species of mosquitoes breed freely in the static waters. The decomposition of the dead plants results in an obnoxious smell, decreases the clarity of water and depletes the dissolved oxygen content of the water, making it unsuitable for human use. Local fishermen have found it impossible to cast their nets into water covered with dense mats of these weeds.

According to Prabhu, estimates show that more than 0.2 million hectares of water bodies are infested with aquatic weeds. Their mat-forming nature severely impacts biodiversity by preventing the entry of sunlight and oxygen to the bottom waters. Also, their growth prevents the natural flow of water in irrigation channels, obstructs smooth navigation and interferes with hydroelectric power generation.

In 2011, an initiative around the Harike Wildlife Sanctuary (the largest wetland in northern India in the border of Tarn Taran Sahib district and Ferozepur district of Punjab), undertaken by World Wide Fund for Nature-India (WWF-India) altered the scenario. As part of the project, WWF selected two villages in proximity to the sanctuary to promote handicrafts created from water hyacinth.

Following that project, many others have followed suit. Recently, the Kapra lake in Hyderabad got a new lease of life, after the discovery of the accelerated anaerobic composting (AAC) technology**.** According to Dr A Gangagni Rao, senior principal scientist, the Indian Institute of Chemical Technology (CSIR-IICT), Hyderabad, this is a joint operation by KHAR Energy Optimisers and CSIR-IICT and has been implemented for the first time at Kapra Lake in Hyderabad to clean hyacinth from the lake.

Essentially, it aims at conversion of green waste – in this case the leaves, stems and roots of water hyacinth – into good quality organic fertilizer within a span of 28 days. The roots and stems are separated, and chopped before pushing through the AAC process. The anaerobic culture developed by CSIR-IICT is blended with water hyacinth stem and leaves, and appropriate mixing results in an organic fertilizer which is subsequently dried to marketable fertilizer. Similarly, roots can be put through the AAC process to generate organic fertilizer, which can be used as compost.

Making organic compost is one of the most economical solutions and can prove to be a permanent solution for most of the lakes that are polluted. “Based on the necessity, water hyacinth could be exploited in many ways,” Rao said.

The AAC process is suitable for all kind of lakes filled with water hyacinth. However, since the composition of water in lakes differ the characteristics of water hyacinth also changes. “The utility of the product changes based on the composition of the water hyacinth,” Rao explained.

In yet another instance, Prabhu and his team have put together techniques for the production of cellulase enzyme from bacteria using common aquatic weeds such as water hyacinth and water moss (*Salvinia molesta*). He believes that through research, the plant could be efficiently used to make biomass briquettes and as a bedding material for mushroom cultivation and modified hydroponics.

“Two methods for obtaining the industrially useful enzyme *cellulase* from bacteria through the solid state fermentation fermentation were standardized,” Prabhu said. Additionally, his team have also begun to focus on developing rural technologies for utilization of these weeds in a manner that is easily acceptable to the rural population and implementable at the village level, and in an environment friendly manner .

Three different species of mushrooms were cultivated in these weeds under different conditions oyster mushroom (*Pleurotus florida*), pink mushroom (*P. eous*) and white elm oyster mushroom (*Hypsizygus ulmarius*). The left over bedding material after harvest of the mushrooms can be used as organic manure. Scale-up studies are needed to undertake this at a larger scale, Prabhu added.

Mushroom grown on a water hyacinth bed. Photo by G. Nagendra Prabhu.

Prabhu’s team has also developed a range of products from the pulp obtained from water hyacinth leaves and stem along with small amounts of used newspaper and appropriate binders. The products include disposable plates, ready-to-plant biodegradable nursery pots, egg and fruit trays, cartoon models, toys, file boards, multi-purpose boards, special canvas for paintings etc. The team also blended coir industry waste fibres popularly known as “baby fibres” along with water hyacinth pulp to prepare unique canvas for paintings.

Disposable plates made out of water hyacinth pulp. Photo by G. Nagendra Prabhu.

The way ahead

Currently, CSIR-IICT and KHAR Energy Optimisers are working together to take the technology from the laboratory to the land and optimize the composting method to blend with local needs. Lakes polluted with water hyacinth that are under the supervision of Greater Hyderabad Municipal Corporation (GHMC) – such as the Gangaram lake in Chandanagar – would be considered for the adoption of the AAC technology.

CRAR too has taken up several national, state and regional level Initiatives in solving the problem of aquatic weeds through value addition. Prabhu feels that since the technologies developed by him and his team are easily adoptable, cheap and eco-friendly, they can be replicated on a pan-India basis.

Removal of Pesticides

Water hyacinth is considered as the only water plant that can remove pesticides dissolved in water. Sari (2007) reported that water hyacinth was able to increase DO (dissolved oxygen) in river water that had been polluted by detergents and was able to reduce BOD (biological oxygen dissolved). Water hyacinth is able to increase DO of 8.05 mg/kg and decrease the BOD of 52.119 mg/kg (Moenandir and Hidayat, 1993). According to Pitrawijaya (1992) water hyacinth also has the capacity as bioaccumulator that is able to absorb anion or cation in the waste and able to grow quickly and can survive in poor condition. The leaf stalks are efficacious as medicines for swelling. The leaves contain saponins, flavonoids, tannins and polyphenols. Agricultural waste is the source of organic matter available in large quantities and is produced continuously, but has not been used optimally and is generated during the production process in field, during harvest and post harvest. It contains organic materials that contain primary metabolite and secondary metabolite compounds. Induced Water hyacinth with Purple roots (PRWH) exerts a significant inhibitory effect on the growth of blue-green algae. The wide type water hyacinth (WTWH) and purple rootwater hyacinth (RTWH) were collected from the Dianchi Lake in Yunnan Province of China. The air dried roots (100 g) were powered and extracted with 90% aqueous MeOH (300 mL) three times by heat reflux extraction method. Their organic phase were evaporated to dryness under reduced pressure at 50°C.. The obtained crude methanol extracts (CME) were stored in a 20 °C for further analysis. Some CME from the roots of PRWH was then redissolved in 100m L water and partitioned with ethyl acetate (EA) to yield ethyl acetate fraction (EAE) and water fraction (WF). (Gui-Guang Cheng, Ya -Ping Liu, Ji Gu, Sheng Yan Qian, Hong -Jun Yang, Zhong-Yuan Na, and Xiao-Dong Luo).

Water Hyacinth, the New Organic Garment Fibre

Scientists and researchers are always on the lookout for new fibre sources and better methods of sustainable processing. The goal is to provide an all-natural and preferably organic fibrous material that can be used in the textile industry for use in clothing, interiors and upholstery. Hyacinth fabric is not yet available in local stores or markets but keeps your eyes open for this innovative step in sustainable apparel technology.

Water Purification

Hyacinth plays a very important role in pollution mitigation by absorbing various types of pollutants including heavy metals present in water. This plant has been used for pre-treatment in a drinking water treatment plant. Hyacinth can absorb minerals and inorganic substances from sewage. It can be grown rapidly in all types of conditions. As a result, after it is used to clean sewage it is brought in for use as an organic fertilizer such as compost or mulching. Hyacinth can absorb suspended particles, algae, dissolved impurities, nitrogen, phosphorus and other nutrients. It has been used in advanced water treatment in sewage and in the treatment of hospital wastewater.

For Healthy Digestion

Fried hyacinth beans can actually make digestion smoother! The old Chinese medicine uses Eichhornia beans to keep the spleen healthy. The herb is also known to treat nausea, upset stomach, intestines, diarrhoea, worms, etc.

Makes Skin Healthy

Many skincare products contain hyacinth. The use of water hyacinth and its antimicrobial, antifungal, antibacterial properties make it a perfect choice for treating many skin related problems.

Powerful Anti-inflammatory

People in the Philippines like to use hyacinth as an anti-inflammatory agent. It can be included as one of the list of herbal plants found in the Philippines. They make juice from hyacinth, mix it with lemon juice which is rich in vitamin C, and then apply it topically to the boil. As a result, it relieves inflammation and reduces abscess.

Especially for Women

Women can actually use this plant to get a healthy body! In Kenya, some women use this water Hyacinth plant to promote lactation. A new mother can consume boiled hyacinth to get the most out of it. On the other hand, its flowers can help women suffering from irregular periods

Note:

Hyacinth beans should never be eaten raw. Raw Eichhornia beans are considered toxic and can cause stomach problems. Therefore, it is advisable to boil the dried hyacinth seeds so that the poison inside is released and is safe for consumption. Also, be sure to change the water used for boiling. This will further help in flushing out the toxic content of the beans.

Animal feed

Researchers have promoted the use of water hyacinth as animal feed as it has high water and mineral content,which suggests that the nutritional value may be appropriate for certain animals. Nevertheless, with the mixture of carbohydrate additives such as molasses and rice bran, the nutritional content can be fortified. Mahmood et al. [27] assessed the potential of water hyacinth as food on the development and digestibility of grass carp (Ctenopharyngodon idella) fingerlings. Three diets were prepared with water hyacinth for feeding grass carp juveniles, namely, whole plant meal (WP), leaf meal (LM), and roots meal (RM). While LM had the highest weight gain (7.14 g) and digestibility of protein (72.5 _ 1.6%), WP had 6.87 g and 64.13 _ 0.2%, and RM had the lowest at 2.10 g and 45.54 _ 4.8% respectively. Protein digestibility is a significant factor to evaluate the dietary quality of a food; high digestibility rate signifies high nutrients use. However, histology assessment revealed that the kidneys of the fish had degeneration of renal tubules, necrotic damage in tubular epithelial cells, and tubular lysis. There was no report of toxicity in the study of [26], which was aimed at substituting Tifton-85 hay used in sheep diet with water hyacinth as the globulin concentrations were suitable. It is evident that E. crassipes is used as animal feed, however, it calls for suitable precautious procedures such as pre-treatment before use to reduce its toxicity and seed viability.

Bio-fertilisers

The use of bio-fertilisers for agriculture has sustainable benefits compared to chemical fertilisers as they increase the quality of the soil and concurrently decrease the build-up of nitrate in the soil. Eichhornia crassipes contains high nitrogen, phosphorus, and potassium elements which makes it appropriate for use as mulch [28], compost [29], or vermicomposting [46]. It has been established that water hyacinth compost is viable to replace peats, and consequently reduce the quick exhaustion of peatlands [30].

Insulation Boards

The use of water hyacinth in developing thermal insulation particle board as investigated by Salas-Ruiz et al. [32] has shown the viable performance of the aquatic plant in the construction sector. The study exposed the microstructure and chemical composition of the aquatic weed which the authors consider will boost its application as a bio-based building material.

Enzyme Production

The production of enzymes involves a high cost because of the carbon source. studies on developing alternative methods to minimise such costs are carried out as its use in the industries are a_ected. Water hyacinth has been utilised as a carbon source to create enzymes such as cellulase [33,34] and xylanase [35]. The high lignocellulosic content of water hyacinth biomass is suitable as a growth medium for enzyme production. These enzymes are sustainable substitutes to conservative technique as their use ensures a cost-e_cient and energy e_cient process, reduced waste generation, and high-value products. Enzymes have gained attention because of their wide range of applications in the pharmaceutical, food and beverage, detergents, textile, and pulp and paper industries. For example, in the food industry, cellulase and xylanase are recognised as enzymes that disrupt the structural cell walls of plants and improve extraction of fruit juices by increasing yield, reducing viscosity, and enhancing cloud stability.

Biopolymers

Water hyacinth is the subject of attention because of its cellulosic content and proliferation rate. Cellulose from water hyacinth Sustainability **2020**, 12, 9222 11 of 20 has been used to make polyhydroxybutyrate (PHB), a resource for bioplastics. Nanomaterials fabricated from water hyacinth have been applied in wound dressings [36], biodegradable packaging films [37,48], control release technology (hydrogel) [38]. However, there is a need for further investigation on the wound healing attributes of the aquatic weed.

Biogas

Much research has shown an extensive disparity in biogas yield from anaerobic degradation of water hyacinth under di_erent investigational situations [43,44,50]. This is because the technology is reliant on the activities of the microbial consortium, which consecutively depends on several parameters. E_orts have been made in increasing the biogas yield by pre-treatment [42], optimising the process parameters, appropriate digester design, stimulating the microbial communities,and co-digestion [41,45].

Briquettes

Briquettes are densified agricultural products such as sawdust, palm kernels, and husks from cowpeas, rice. They are alternatives to fuelwoods, charcoal, and paraffin, as they are known for their high calorific value, expediency, requires little storing capacity, and they do not release smoke. Eichhornia crassipes can be utilised in the production of briquettes; although its calorific value is lower than coal, it could be co-fired to reduce the greenhouse gases released by coal-fired power plants. The use of binders is recommended for optimal burning time; however, such binders should be sustainable and cost-effective. The result of the investigation on the use of water hyacinth and empty fruit brunch fibres (25:75) as briquettes indicated 17.17 MJ/kg calorific rate and 3.73% low ash content [39]. Bioethanol is made from the fermentation of biomass and is a promising alcoholic biofuel existing in the market today because of its clean combustion. The structural features of monosaccharide and polysaccharide in E. crassipes make it viable for bioethanol production. Its polymeric carbohydrate is predominantly cellulose and hemicellulose. While the cellulose contains glucosemonomers, hemicellulose contains various polymers such as xylose, arabinose, galactose, and mannose [40,49]. Amongst the di_erent stages in the breakdown of lignocellulose to fermentable sugars, the saccharification stage is considered a limiting stage [12]; however, the emergence of economical bioprocess technology has brought hope to the industry. Furthermore, the high cost of an enzyme such as cellulase is seen as a major hurdle for the optimisation and a_ordability of bio-ethanol. Nevertheless, some studies have reported high bioethanol yield in the absence of cellulase [12,40]. While Madian et al. [12] explored the use of Candida tropicalis Y-26 in producing bioethanol from water hyacinth hydrolysate, Zhang et al. [40] involved the use of Phanerochaete chrysosporium, Phanerochaete chrysosporium combined with dilute acid, and Phanerochaete chrysosporium combined with dilute alkaline. Both studies revealed the highest bioethanol production from the fermentation of both acid- and fungal-treated hydrolysate.

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