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The diverse applications of water hyacinth with main focus on sustainable energy and production for new era: An overview

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ABSTRACT

Water hyacinth was introduced as an ornamental crop in many countries more than a century ago, due to its attractive appearance and aesthetical value in the environment. Unfortunately, the flowers developed into invasive species due to their adaptability for a wide range of fresh water ecosystems and their interference with human activities. In the 21st century, they were considered as an alternative to fossil fuels, as many researchers found them capable of converting their content into fuel energy at less cost and recognized as an eco-friendly product. As water hyacinth is among the group of fastest growing plants, its biomass has the potential to become a potential renewable energy source and replace conventional fossil fuels, perhaps during the next decade. This is an essential mission to overcome the depletion of energy sources and also to fulfill the increasing demand of world energy. Instead of fuel energy, the dried biomass can also be fabricated as briquettes, which is suitable as co-firing agent in coal power plant. Thus, in future compacted biomass residues produced in the form of briquettes may decrease the dependence of coal to provide more energy The other application of water hyacinth into a co-compost material such as soil amendment to the sandy soil, can improve hydro-physical, chemical parameters of soil and will supply the growing crops with several nutrients. Water hyacinth has also drawn attention due to its bioremediation ability, capable of removing pollutants from domestic and industrial waste water effluents. Thus, the issue of water hyacinth should be evaluated from energy, engineering as well as environmental perspectives. In this review, the potential uses of water hyacinth are being classified and discussed.

Contents

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1. Introduction

Water hyacinth (*Eichhornia crassipes*) is a noxious weed that has attracted worldwide attention due to its fast spread and crowded growth, which leads to serious problems in navigation, irrigation, and power generation. It is also renowned as a non-native, invasive and free-floating aquatic macrophyte. Moreover, water hyacinth due to their abundant and uncontrolled growth in open pond, irrigation and other water bodies, are frequently noted in the literature as one of the world's most problematic weeds [1]. It is a free floating aquatic plant well known for its production abilities and exclusion of pollutants from water. It is able to rapidly grow to very high density of (over 60 kg/m^2); this means entire clogging of water bodies can occur, which in turn may have unfavorable effects on the environment, human health and economic development [2–4].

The shoot system covers the surface of water body to capture the sunlight thereby obstructing the entry of sunlight into water, which is required by algae and other organisms present in the water to survive. This leads to a reduction in the growth of algal population and thus disturbs the ecological balance [5]. The mature plant consist of long, pendant roots, rhizomes, stolons, leaves, inflorescences and fruit clusters. The plants are up to 1 m high although; 40 cm is the usual measured height. The inflorescence allows 6–10 lily-like flowers, each one being 4–7 cm in diameter. The stems and leaves contain air-filled tissue which provides the plant its substantial buoyancy. The vegetation reproduction is asexual and takes place at a rapid rate under superior conditions [6]. It can tolerate drought conditions well because it can survive in moist sediments up to several months [7]. At an average the annual productivity of 50 kg/m^2 dry water hyacinth (ash-free) is in tones per hectare per year [8] and water hyacinth is one of the most productive plants in the world [2]. It can double its size within five days and a mat of medium sized plants may contain two million plants per hectare and can weigh approximately 270–400 t. Also [9] investigated that the growth rate of water hyacinth under favorable conditions can reach up to 17.5 metric tons per hectare per day. These figures also indicate that the plant may interfere with the localized problems, such as navigation, recreation, irrigation, and power generation [10].

The water hyacinth replicates sexually by seeds and vegetatively with the help of budding and stolen production. For rapid spreading, the vegetative promulgation is more important [11]. Daughter plants grow from the stolons and the doubling times have been reported of about 6–18 days. Under favorable conditions of temperature and nutrient availability, the vegetative propagation is very fast. There are seven species of water hyacinth available including: *E. azurea* – anchored water hyacinth, *E. crassipes* – common water hyacinth, *E. diversifolia* – variable leaf water hyacinth, *E. paniculata* – Brazilian water hyacinth. Clonal plants such as *E. crassipes* might enhance light interception via horizontal growth of stolons or rhizomes and a situation of new ramets, in less shaded microsites [12]. Water hyacinth is successful owing to their life cycle and survival strategy that gives it a competitive edge over other species. Its adaptability at various ecological conditions makes obliteration of this plant virtually impossible [13].

The plant has black, tough roots and when it irregularly becomes stranded in sludge it may appear rooted. Its growth rate is amongst the highest of any plant known, and its population can double in as low as 12 days [14]. A study in Louisiana in 1948, showed that ten plants were able to vegetatively replicate 1610 plants in three months [15] also the growth rate has been calculated in other countries to be an increase in biomass of 400–700 t per hectare per day, or an increase in water area coverage by a factor of 1.012–1.077 per day. Surroundings for water hyacinth have ranged from low temporary ponds, marshes and sluggish flowing waters to large lakes, rivers and reservoirs [1].

The water hyacinth plants can withstand both high acidic and alkaline conditions, but more effervescent growth is supported by neutral water bodies [1]. As assumed by Aquatic Ecosystem Restoration Foundation [16] there is a logistic growth model in the analysis of water hyacinth population dynamics at temperate and tropical zones. Their results revealed that the growth rate in temperate regions differ with seasons. In tropical zones the intrinsic rate of growth for the weed was estimated in the range 0.04–0.08 dry weight per m^2 per day. It grows over a wide variety of wetland types and prefers nutrient-enriched waters. However, it can tolerate considerable variation in nutrients, temperature and pH levels. The optimum pH for growth of water hyacinth is 6–8. It can grow in wide range of temperatures ranging from 10 to 40 °C (optimum growth at 25–27.5 °C) but it is also thought to be cold-sensitive [17]. Salinity is the main obstacle for the growth of water hyacinth in coastal areas [18]. High level of salinity in wastewater can limit the growth of water hyacinth and other aquatic macrophytes [19]. Research performed by De Casabianca et al. [20] showed that water hyacinth would tolerate salinity at less than 10 ppt. In rural areas, water hyacinth could be used as an integrated approach for decentralized wastewater treatment systems coupled to biogas and compost production from the consequential biomass production [8].

Water hyacinth harvests have been put into different valuable uses in several countries. Methods of converting the plant material into valuable products have emerged [19]. This review paper highlights water hyacinth function with the ultimate attention on its utilization for energy and engineering fields conducted in the last three decades. Based on these noteworthy research realizations it is desirable to recognize as an administration strategy to adjust in the commercial activities.

2. Characteristics of water hyacinth

Fresh plant of water hyacinth contains 95.5% moisture, 0.04% nitrogen, 1.0% ash, 0.06% P_2O_5, 0.20% K_2O and 3.5% organic matter. On zero-moisture basis, it has 75.8% organic matter, 1.5% nitrogen and 24.2% ash. The ash contains 28.7% K_2O, 1.8% Na_2O, 12.8% CaO, 21.0% Cl, and 7.0% P_2O_5. The crude protein (crude protein = amount of nitrogen × 6.25) using Kjeldahl method contains, per 100 g, 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 [21].

3. Application of water hyacinth

Water hyacinth consisting of high percentage of water, fibrous tissue, high energy and protein content can be used for a variety of useful applications. A number of possible uses of the plant