Water Hyacinth

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Introduction

The "beautiful blue demon" is classified as a perennial free-floating aquatic weed. *Eichhornia crassipes* (Mart.) Solms-Laubach, commonly referred to as water hyacinth, belongs to the *Pontederiaceae* family. It is recognized as one of the most problematic aquatic weeds globally and ranks among the most prolific plant species. These evergreen aquatic plants are indigenous to the Amazon River basin and have now spread to various regions worldwide. It is noteworthy that Lady Hastings, the spouse of a British governor, introduced Eichhornia crassipes in the 18th century. The British presented water hyacinth to the indigenous populations of India as a botanical gift. Its introduction was primarily motivated by the flower's aesthetic qualities, which have subsequently resulted in its proliferation in aquatic ecosystems. Its ecological niche encompasses tropical desert, subtropical desert, warm temperate desert, and rainforest biomes. It exhibits tolerance to a pH range from 5.0 to 7.5 and flourishes at temperatures between 21.1°C and 27.2°C. The average height of the plant ranges from 40 cm to 1 meter. The foliage is characterized by thick, broad, and dark-glossy green leaves. The roots can extend 2.45 cm below the surface of the water, exhibiting a dark purplish-black pigmentation.

In recent times, it has garnered significant scholarly attention due to its rapid proliferation and dense growth patterns. Its extensive coverage of natural water bodies leads to a substantial reduction in dissolved oxygen levels, thereby creating favorable conditions for mosquito breeding. Additionally, it obstructs sunlight, adversely affecting various aquatic organisms. The proliferation of water hyacinth can hinder activities such as fishing, river navigation, and recreational boating. Given its capacity to generate substantial biomass in a relatively short timeframe, it poses a potential risk of obstructing dams. Under optimal conditions, the biomass production can reach as high as 17.5 metric tons per hectare on a daily basis.

Water hyacinth can propagate via both sexual and asexual reproductive strategies. Asexual reproduction occurs through vegetative budding, while sexual reproduction takes place through seed germination. Although climatic factors and seasonal variations significantly influence growth, the species is capable of tolerating a broad temperature range of 13 to 40 °C, with optimal growth occurring between 25 and 30 °C. The species particularly flourishes in tropical and subtropical climates, which provide ideal conditions for the cultivation of water hyacinth.

Owing to their diverse applications in agriculture—such as mulching, biofertilizer production, energy generation, and wastewater treatment—these free-floating perennial aquatic weeds are esteemed as some of the most beneficial plants globally. Furthermore, they serve as valuable sources of both chemical and biological constituents.

Water hyacinth as a chemical and biological source

Cellulose diacetate is synthesized through the extraction and acetylation of cellulose derived from the water hyacinth. A research study indicates that water hyacinth can yield cellulose content of approximately 5.6%. This cellulose can further be employed in the fabrication of membranes. Furthermore, cellulose extracted from water hyacinth, with a concentration range of 0.03 to 2.70 percent w/w, serves as a significant source of shikimic acid. Shikimic acid, found predominantly in the aerial portions of the roots, exhibits a concentration range of 0.05–0.90% w/w. Given that water hyacinth fulfills the nutritional requirements of rhizobacteria, it is also utilized as a growth medium for rhizobacteria in its powdered and dried form. Moreover, water hyacinth tar can be transformed into carbon fiber through polymerization with formaldehyde and a catalyst such as hydrochloric acid, resulting in the production of carbon fiber as well. This carbon fiber exhibits axial modulus and tensile strength values of approximately 42 GPa and 600 MPa, respectively, which are comparable to those of commercial carbon fiber.

Water hyacinth as an energy resource

The potential of utilizing water hyacinth as an energy source for ethanol, biogas, and briquetting has been established. Ethanol is produced through the treatment of water hyacinth using acid, alkali, and biological methods. For the generation of biogas, a biological pre-treatment approach was employed on water hyacinth. Another methodology involved the incorporation of Bordetella muralis, Citrobacter werkmanii, and Paenibacillus sp., which expedite the hydrolysis process of water hyacinth.

Under optimal conditions conducive to maximizing biogas production from water hyacinth, earthworms rich in nitrogen were also observed. Within batch systems and mesophilic conditions (28–32 °C) maintained over a period of 15 days, the presence of earthworms tends to enhance biomethane potential production. The leaves of water hyacinth possess the capability to generate biomethane. In the presence of manure from pigs, elephants, and bats, the cellulose, hemicellulose, and lignin contents of water hyacinth were utilized in two alkaline solutions, namely sodium hydroxide and lime. Remarkably, a 63.65% increase in methane production was noted during the digestion of fresh water hyacinth leaves subjected to lime treatment. Investigations into the suitability of water hyacinth as a briquette component revealed that water hyacinth briquettes exhibited a calorific value of 14.55 MJ/kg.

Water hyacinth in wastewater treatment

Common parameters that are indicative of wastewater quality encompass biochemical oxygen demand over a five-day period (BOD5), levels of dissolved oxygen, temperature, pH, total suspended solids, chloride concentration, nitrogen, phosphorus, and the presence of hazardous substances. The cellulose and enriched fibrous materials found in the leaves of water hyacinth enhance the efficacy of an electrodeposition reactor in the purification of nickel electroplating effluent. As a result, the integration of water hyacinth leaves led to a decrease in nickel concentration. A comparative investigation of water hyacinth, reed, and duckweed was performed, focusing on five essential parameters: dissolved oxygen, biological oxygen demand, ammonia, phosphate, and total suspended solids. Consequently, the findings of these evaluations indicated that the effectiveness of water hyacinth and duckweed diminished, while the performance of reed demonstrated an enhancement during the summer season.

Water hyacinth for agricultural purposes The utilization of water hyacinth as compost represents one of the various applications of water hyacinth in agriculture. Composting has been extensively examined in numerous studies, particularly those involving the use of water hyacinth. The composting of water hyacinths emerges as a cost-effective solution to the challenges posed by abundance. The modification of water hyacinth in conjunction with zeolite facilitated enhanced degradation and diminished the bioavailability of heavy metals within a mixture of bovine dung and sawdust.

Water hyacinth was additionally utilized as an ingredient in rotating drum compost systems. The microbial flora present in water hyacinth plays a pivotal role in the active metabolic breakdown of organic materials. Water hyacinth is instrumental in the identification of specific bacterial species and in the remediation of heavy metals from aqueous environments.

Water hyacinth application as mulch material

Optimal moisture content ranging from 50% to 60% is recommended for the composting process. They further asserted that the moisture content of fresh water hyacinth is excessively high, thereby necessitating minimal water addition during composting. In arid regions, particularly where water hyacinths proliferate, the rates of evaporation are significant. Thus, composting water hyacinths does not pose considerable challenges due to their elevated moisture content. In tropical regions characterized by hot climates, the strategic positioning of composting operations is essential to mitigate moisture loss from compost piles. It may require up to 2700 liters of water to produce one ton of compost product. Composting can be conducted in either pits or piles. Composting in pits is feasible during dry seasons, while heaps may be employed during wet seasons to avert water stagnation. Furthermore, to minimize moisture loss, compost must be adequately protected from wind exposure.

Utilization of water hyacinths as green manure

Green manuring involves the application of plant materials with elevated nitrogen content to agricultural fields. Although values as low as 7.26% have been recorded, chemical analyses have demonstrated that water hyacinth possesses a high nutrient content, with a crude protein value of approximately 20%. They yield 140 tons of dry matter per hectare annually, rendering them suitable for application as green manure.

Prior to the initiation of cultivation in agricultural fields, water hyacinths are subjected to a drying process, primarily aimed at mitigating the potential risk of bilharzia and minimizing the labor requisite for their transportation. The process of drying may culminate in a depletion of vital nutrients, which could subsequently lead to a reduction in overall biomass. The foliar structures of water hyacinths exhibit a higher concentration of nutrients in comparison to other parts of the plant. Specifically, the leaves and stems exhibit nitrogen concentrations of 2.7% and 3.7%, respectively. Typically, the foliar and other delicate parts constitute the predominant components of the biomass. Hence, a diminution in the average nutritional profile, as determined by total dry matter, may ensue following the loss of leaves. It is noted that water hyacinths can achieve a maximum biomass of 25%.

Water hyacinth as pre-treatment

In the context of pre-treatment, fresh water hyacinths necessitate slicing to enhance bacterial accessibility to the plant material, thereby promoting effective composting. Prior to the composting process, water hyacinths were reduced into segments approximately 5 cm in length, which facilitated the decomposition process mediated by bacteria. Fresh water hyacinths were subjected to slicing prior to composting. Conversely, in instances where water hyacinths are composted without prior reduction in size, there may be a lower demand for labour and an increased necessity for construction materials.

Water hyacinth as a compost

An additional strategy for the management of water hyacinths involves aerobic decomposition, commonly referred to as composting. In developing nations, small-scale composting remains the primary focus due to limitations in infrastructure and resources. Composting is characterized by the generation of thermophilic temperatures resulting from the metabolic activity of living organisms. This process encompasses the biological decomposition and stabilization of organic substrates. The resultant product is expected to be stable, free from pathogens and viable plant seeds, and beneficial when applied to agricultural land. To mitigate evaporation and prevent nitrogen losses in the form of ammonia, compost can be covered with materials such as straw, grass, or plastic. Straw presents the advantage of being utilized by microorganisms as an energy source, capturing any released ammonia to fulfill their nitrogen requirements. Furthermore, straw acts as a barrier to precipitation, thus reducing nutrient loss when the compost pile is effectively covered.

Water hyacinth as a C/N ratio

The ideal carbon to nitrogen (C/N) ratio for microbial activity is situated within the range of 15 to 30. When the C/N ratio falls below this threshold, the composting process remains largely unimpeded; however, excessive nitrogen is released into the atmosphere through ammonia volatilization. A C/N ratio ranging from 20 to 40 is identified as optimal for the degradation processes mediated by bacteria. Microbial organisms necessitate a well-balanced supply of nutrients to facilitate the rapid progression of decomposition. The same group of researchers further identified that compost piles constructed using water hyacinth exhibited slower decomposition rates in comparison to those composed of cow dung and leaves, which were used as a control. They postulated that the primary constituent C/N ratio of 20 observed in water hyacinths may be attributed to the predominant elements found in leaves, specifically hemicellulose and cellulose, which are anticipated to be more abundant in leaf matter. The integration of cellulose-rich materials, such as leaves, is essential for water hyacinths to mitigate minimal ammonia losses during the microbial degradation process.

Application of water hyacinth

To mitigate nitrogen losses attributed to volatilization, it is recommended that plant material be adequately covered with soil during its distribution across the agricultural field. One of the most straightforward methods to achieve this involves planting water hyacinths within the furrows created by a plough and allowing subsequent furrow slicing to bury them. Given that the partially desiccated water hyacinths utilized as green manure continue to exhibit growth within the soil, it would be advantageous to somehow decompose the plants prior to their application. Such methods necessitate a certain degree of mechanization. In scenarios where all agricultural operations are conducted manually, water hyacinths may be incorporated into the soil to prepare it for seeding. Although the precise method would be contingent upon the degree of mechanization, it is crucial to devise a strategy that ensures the time spent on fieldwork does not substantially increase. During the process of nitrogen mineralization, nitrogen undergoes transformation from its organic form into inorganic forms, namely ammonium or nitrate, thereby rendering it accessible for plant uptake.

Evaluating the incubation of green manure legumes to investigate the mineralization of carbon and nitrogen, the nitrogen and lignin concentrations found in water hyacinths are comparable to those present in subterranean clover. The existing literature lacks information regarding the mineralization processes associated with dried water hyacinths. Furthermore, estimations of the nitrogen supplied by decomposing leguminous material to subsequent crops were conducted. Over the course of a 115-day incubation period, approximately 30–35% of the total nitrogen present in subterranean clover underwent mineralization.

Despite the fact that the specific procedure would depend on the extent of mechanization employed, the fields do not significantly expand. Nitrogen mineralization refers to the process of converting nitrogen from its organic state into inorganic forms. A strong correlation was observed between net nitrogen mineralization and the C/N ratio of legumes; species exhibiting elevated C/N ratios demonstrated reduced mineralization rates. Assessments of nitrogen mineralized from the same green manure legumes under field conditions indicated that the potential nitrogen mineralization (N0) decreased as the plants matured.

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