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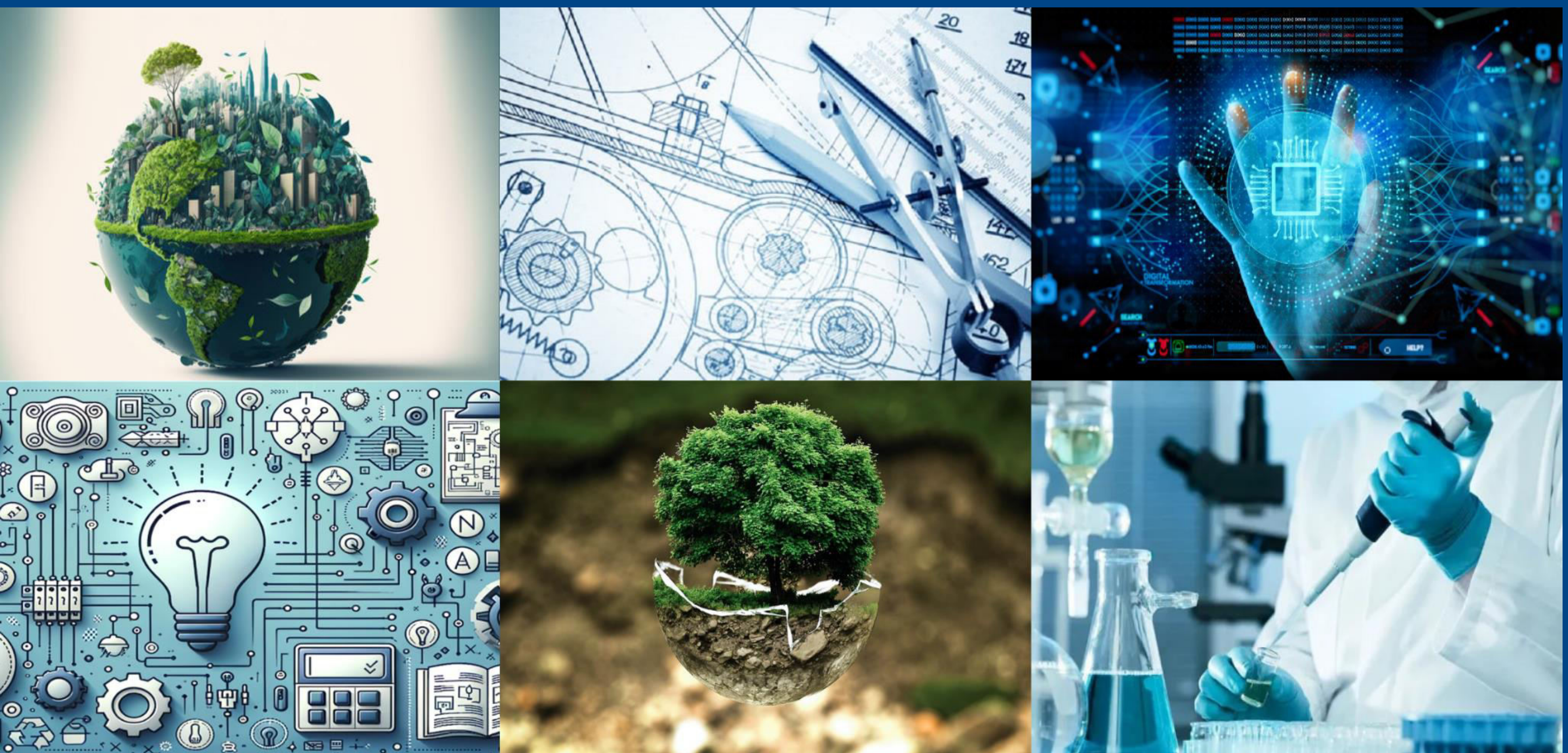

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Potential of Water Hyacinth (Eichhornia crassipes) as Compost and its Effect on Soil and Plant Properties: Review

Shifadjzic Khan

Master of Agriculture Candidate, Department of Food Security and Agricultural Development, Kyungpook National University, Daegu South Korea

ORCID Number: 0009-0000-5994-5920

ABSTRACT: Water hyacinth (*Eichhornia crassipes*), an invasive aquatic weed, poses significant environmental and economic challenges due to its rapid proliferation in water bodies. However, its high biomass production and rich organic content make it a promising raw material for composting. This study explores the potential of water hyacinth compost (WHC) as an alternative organic fertilizer and its effects on soil properties and plant growth. The composting process enhances nutrient availability, improving soil fertility by increasing organic matter, nitrogen, phosphorus, and microbial activity. WHC has been found to enhance soil aeration, water-holding capacity, and cation exchange capacity (CEC), leading to improved crop productivity. Additionally, it contributes to sustainable weed management by converting an invasive species into a valuable agricultural input. However, challenges such as high moisture content, heavy metal accumulation, and proper composting techniques must be addressed for effective utilization. The study highlights the need for further research on optimizing water hyacinth composting methods and integrating it into sustainable farming practices. By converting this noxious weed into a beneficial soil amendment, water hyacinth composting presents a dual solution—environmental management and agricultural enhancement. The findings suggest that water Hyacinth Compost can be a viable organic alternative to synthetic fertilizers, promoting eco-friendly and cost-effective farming practices.

KEYWORDs: Water hyacinth, composting, soil fertility, plant growth, sustainable agriculture.

I. INTRODUCTION

Eichhornia crassipes, sometimes known as water hyacinth, is classified as a detrimental invasive alien species (IAS). E. crassipes, originally from the Amazon basin in South America, has spread widely worldwide. It poses a significant risk to biodiversity, the functioning of the environment, human health, socio-economic development, and the livelihoods and income creation of impoverished individuals. As a result, African nations were compelled to endorse many international environmental agreements and thereafter establish their own national strategies to address the impact of these infestations on their own localities(Ilo et al., 2020).

The water-hyacinth is a well-recognized invasive plant that poses a significant challenge to the fundamental principles of environmental sustainability on an international level. The expense associated with managing these invasive species is substantial, and several Southern African nations are ill-prepared to handle this responsibility due to the time-consuming nature of the operation. Notwithstanding this obstacle, water hyacinth presents a significant opportunity for resource extraction that may provide both economic and ecological benefits(Ilo et al., 2020).

The fast expansion of E. crassipes leads to alterations in water chemistry and disturbance of the aquatic ecosystem, thereby causing a significant escalation in water loss via evapotranspiration. The weed's impact on biodiversity has been characterized as concerning, and recently, there has been a growing interest in exploring its potential for many additional applications. The presence of the weed may have a detrimental effect on the well-being of aquatic ecosystems and pose substantial ecological and environmental hazards. However, the plant may be used for a multitude of advantageous purposes(Ayanda et al., 2020).

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Water hyacinth, scientifically known as Eichhornia crassipes, is being utilized more frequently as a source of nutrients in composted form. Similar to other natural sources composts, it enhances the physical and biological capacity for storing nutrients, holding water, facilitating cation exchange, promoting micro aggregation in soils, and mitigating the negative impact of excessive fertilization through the gradual release of nutrients. The application of water hyacinth composting in the cultivation of fruit and leaf crops has been shown to enhance crop output. Water hyacinths possesses a significant capacity to provide nitrogen, as they may retain up to 3.2% of nitrogen in their dry mass. Additionally, they often exhibit a carbon to nitrogen ratio (C/N) ranging from 8 to 15(Mashavira et al., 2015). The plant may be used for a multitude of advantageous applications. The biomass of plants serves various purposes, including bioremediation and metabolism of harmful pollutants and metals, the generation of biogas and biofuel, provision of feed for fish and animals, carbon supply for microbial metabolism, vermicomposting, compost production, and various other crucial applications(Ayanda et al., 2020).

Water hyacinth**(Eichhornia crassipes)** is classified as follows: (Mahmood et al., 2010)

- Domain: Eukaryota
- Kingdom: Plantae
- Phylum: Spermatophyte
- Subphylum: Angiospermae
- Class: Monocotyledonae
- Order: Pontederiales
- Family: Pontederiaceae
- Genus: Eichhornia
- Species: *Eichhornia crassipes*

Parameters (%)	References					
	[13]	[14]	[15]	[16]	[17]	[18]
Hemicellulose	33.4	-	30.0	30.0	20.82	-
Cellulose	19.7	-	24.8	24.0	30.65	-
Lignin	9.27	-	5.6	16.0	2.01	-
Crude protein	20.0	10.01	-	-	5.90	-
Carbon	-	-	31.5	38.4	37.80	14.4
Nitrogen	-	-	2.80	2.9	0.90	-
Oxygen	-	-	31.7	28.1	-	49.5
Hydrogen	-	-	6.2	5.85	5.30	-
Sulphur	-	-	-	0.47	0.10	-
Phosphorus	0.53	0.28	-	0.77	-	-
Calcium	0.58	3.08	-	1.32	-	4.73
Magnesium	0.17	0.65	-	-	-	1.96
Potassium	-	4.13	-	2.78	-	8.26
Sodium	-	0.13	-	1.44	-	0.58

Table: 1 BIOCHEMICAL COMPOSTION OF WATER HYACINTH (Eichhornia crassipes)
Source: (Abdelhamid & Gabr, 1991)

The table above illustrates the biochemical makeup of water hyacinth, highlighting notable levels of hemicellulose (20.82%–33.4%) and cellulose (19.7%–30.65%). This suggests that it could serve as a valuable source of fibrous biomass.

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The lignin content ranges from 2.01% to 9.27%, indicating a level of structural rigidity that is quite moderate. This material is rich in important nutrients, including crude protein (as much as 20%), carbon (ranging from 14.4% to 38.4%), and key elements like nitrogen, phosphorus, calcium, potassium, and magnesium. This makes it a great choice for composting and creating bio fertilizers. Moreover, the elevated levels of oxygen (31.7%–49.5%) and hydrogen (5.35%–6.2%) suggest exciting possibilities for use in bioenergy and bioremediation efforts.

II. METHODOLOGY

This review paper conducted a comprehensive literature search using databases like Google Scholar, ScienceDirect, Scopus, and Semantic Scholar, focusing on water hyacinth composting, soil fertility, and plant growth. Only peer-reviewed articles, conference papers, and reports from the last 15 years were considered. Studies were selected based on their relevance to nutrient composition, soil improvement, and plant response, while irrelevant and duplicate papers were excluded. Key themes analyzed included composting processes, soil enhancement, plant yield, adoption challenges, and sustainable applications. The data were synthesized to identify trends, research gaps, and potential improvements in water hyacinth composting. Comparisons were made between studies to assess the effectiveness of WHC as an organic fertilizer in sustainable agriculture. This methodology ensured a comprehensive and unbiased review process.

III. COMPOST USING WATER HYACINTH (EICHHORNIA CRASSIPES)

Research was conducted in Nepal to examine the use of Heap/Pile as a method for compost Water hyacinth. The findings of this study suggest that the nutritional content of compost is advantageous in comparison to farmyard waste. The concentrations of nitrogen (N), phosphorus (P), and potassium (K) in typical compost types are often seen to be 1.0%, 0.5%, and 1.0% respectively. According to the Regional Soil Test Laboratory of Pokhara, Nepal, the amounts of nitrogen (N), phosphorous (P), and potassium (K) levels detected in the farmyard manure fall within the specified ranges of 0.5-0.0%, 0.5%, and 0.5-0.0% respectively. The laboratory test results demonstrate that the compost produced from Water hyacinth exhibits a content of nitrogen (N), phosphorus (P), potassium (K), and pH that meets the required standards. Therefore, it is appropriate for use on land utilized for agricultural production(Kafle et al., 2009b).

S.N.	Material	Quantity (Kg)	Material %
1	Water hyacinth	85	70
2	Farm yard manure	10	8
3	Mustard cake	10	8
4	Agricultural lime	1.5	1
5	Dry leaf/forage	5	4
6	Green leaf of Jatropha	10	8
7	Wood ash	0.5	0.4

Table 2: Composition materials for composting with Water hyacinth (Eichhornia crassipes)

Source: (Kafle et al., 2009b)

The table above shows what makes up a mixture that mainly consists of water hyacinth (70%), along with a mix of different organic and inorganic materials. Farmyard manure, mustard cake, and green Jatropha leaves each add 8%, probably boosting nutrient content and aiding decomposition. Agricultural lime at 1% and wood ash at 0.4% are added, likely to help balance pH levels and enhance the availability of minerals. This blend seems to be crafted for composting or creating biofertilizer, with water hyacinth serving as the primary biomass ingredient.

S.N.	Nutrient Elements	Amount in %
1	Nitrogen (N)	1.78
2	Phosphorus (P)	0.93
3	Potassium (K)	0.75

Table 3: Macro Nutrient (NPK) composition in the compost of Water hyacinth
Source: (Kafle et al., 2009b)

The table above presents the nutrient composition of macro nutrients from compost of Water Hyacinth, highlighting the presence of nitrogen (1.78%), phosphorus (0.93%), and potassium (0.75%). The high nitrogen content suggests that the material is beneficial for plant growth, promoting leaf and stem development. The phosphorus and potassium levels indicate its potential to support root development, flowering, and overall plant health. This composition suggests the material could be useful as a biofertilizer or compost additive for sustainable agriculture.

IV. IMPORTANCE OF WATER HYACINTH (EICHHORNIA CRASSIPES) IN AGRONOMIC PRACTICES

4.1 Animal Feed

The need to provide food security while minimizing the impact on global land usage for agricultural activities has prompted the exploration of cost-effective, easily available, and nutritionally beneficial supplements. The use of the water hyacinth as food for animals has been advocated by researchers due to its elevated water and mineral composition, indicating that its nutrient content may be suitable for certain animal species. However, by including carbohydrate additions like glucose and rice bran, it is possible to enhance nutritional composition. Evaluating the viability of water hyacinth as a food source for grass carp in terms of its impact on their growth and digestion(Mahmood et al., 2018).

4.2 Bio-Fertilizer

Utilizing bio-fertilizers in agriculture offers sustainable advantages over chemical fertilizers by enhancing soil quality and simultaneously reducing nitrate accumulation in the soil. Eichhornia crassipes has elevated levels of nitrogen, phosphorus, and potassium elements, making it suitable for use as mulch, compost, or the composting process material. Water hyacinth compost has been shown to be a viable alternative to peats, thereby mitigating the rapid depletion of peatlands.
(Goswami et al., 2017; Hernández-Shek et al., 2016).

4.3 Bioenergy

The recognition of climate change has necessitated the implementation of measures to provide energy security, reduce emissions of greenhouse gases, and promote environmental well-being. The request has resulted in a notable transition from petroleum and coal to sustainable energy alternatives, namely biomass. Water hyacinth does not pose a threat to land resources or food security due to its quick growth, abundant availability, and biodegradability. These characteristics provide it a viable biomass option for the production of bioenergy. Nevertheless, a significant limitation of this technology is its high water content of 95%, resulting in an increased cost for the generation of bioenergy(Yan et al., 2017)

4.4 Briquettes

Briquettes refer to compacted agricultural commodities, including saw dust, kernels from palms, and husk derived from cowpeas and rice. They serve as substitutes for fuelwoods, charcoal, and paraffin because to their notable calorific value, efficiency, minimal storage requirements, and absence of smoke emission. Eichhornia crassipes has the potential to be used in the manufacturing of briquettes. Despite its comparatively lower calorific value in comparison to coal, it can be co-fired as a means to mitigate the greenhouse gas emissions associated with coal-fired power plants. It is advisable to use binders to get the best burning time. However, it is important that these binders be both sustainable and cost-effective. The result of the study on the utilization of water hyacinth and devoid fruit brunch fibers(Setyaningsih et al., 2019).

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4.5 Bioethanol

Bioethanol is derived via the process of biomass fermentation and is now regarded as a very promising alcoholic biofuel due to its environmentally friendly combustion characteristics. The viability of E. crassipes for bioethanol production is attributed to its structural characteristics including monosaccharide and polysaccharide components. The primary constituents of its polymeric carbohydrate composition are cellulose and hemicellulose. Cellulose is composed of glucose monomers, while hemicellulose is composed of a diverse range of polymers including xylose, arabinose, galactose, and mannose. The scarification step is widely recognized as a critical stage in the conversion of lignocellulose into fermentable sugars. Nevertheless, the advent of cost-effective bioprocess technology has provided optimism for the sector(Madian et al., 2019; Rezania et al., 2016).

4.6 Biogas

Biogas is produced by anaerobic digestion which takes place in a reactor or digester (an air tight container usually situated below ground) and the usable product is methane gas which can be used as fuel for cooking, lighting or for powering an engine to provide shaft power. The residue from the digestion process provides a fertilizer rich in nutrients. In this method water hyacinth is shredded into slurry and digest in a continuous process, as cow dung is customarily used [8]. Experiment will need a digestion tank (known as the Digester), shredders, gas holders, pipes and fittings, a supply of water hyacinth, cow dung and catalyst. A blend of Water hyacinth and Cow dung in the ratio of 2:3 by weight is most suitable for biogas production. Addition of very little amount of lower volatile fatty acid, particularly acetic acid facilitates the gas production. This technique is very much helpful at the village level of Bangladesh for the farmers using biogas plants. The rate of production of biogas from Water hyacinth is higher as compared to Cow dung slurry. The digested slurry (residue) can be used as useful chemical free eco-friendly manure(Nahar, 2012). Biogas is a highly esteemed energy resource that is very efficient in generating heat, power, and transportation fuel. Digestate, derived from anaerobic digestion, serves as a biofertilizer in addition to biogas(Barua et al., 2018; Sarto et al., 2019).

4.7 Phytoremediation

Aquatic plants have a notable capacity for effectively removing both organic and inorganic contaminants that are found inside water bodies. E. crassipes is a very efficient method for treating wastewater and eliminating pollutants. The existence of metals such as mercury in aquatic or terrestrial environments poses a significant risk to all forms of life, including the human population. Phytoremediation has been recognized as a financially viable environmentally friendly solution that has long-lasting relevance. E. crassipes is renowned for its exceptional capacity to accumulate harmful metals such as Cu, Co, Ni, Cr, Zn, Pb, As, and Cd via phyto-accumulation. Upon the conclusion of the phyto-accumulation process, the biomass derived from the plant material may be effectively used as a primary resource to produce bioenergy. Consequently, this serves as a preventive measure against the introduction of contaminated plants or their harmful constituents into the food chain(Wu & Ding, 2020).

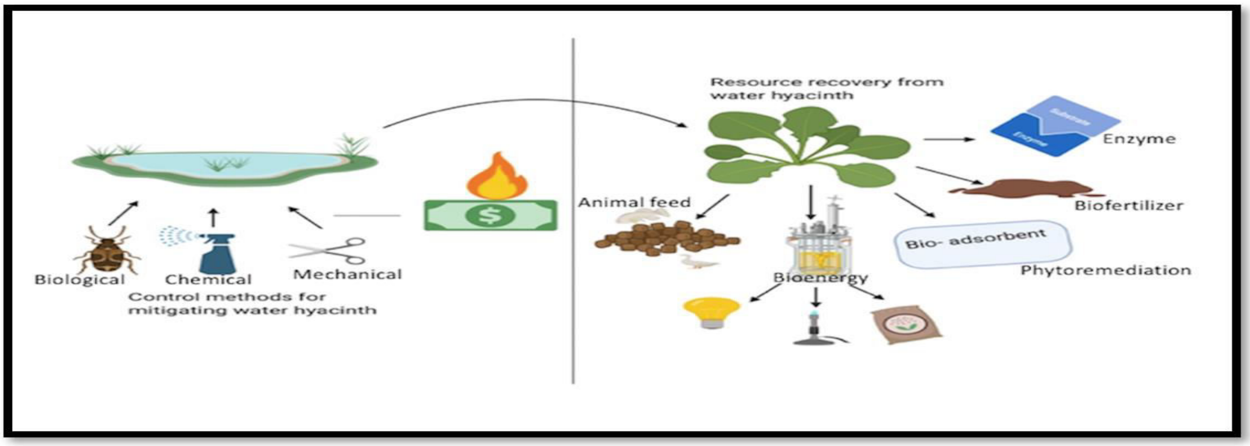

Fig 1: Illustration of Water Hyacinth as a Substitute for Agro Chemicals
Source: (Ilo et al., 2020)

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Figure 1: illustrates both the control methods and resource recovery options for water hyacinth. On the left, biological, chemical, and mechanical approaches are shown as strategies to mitigate the plant's overgrowth in water bodies. On the right, water hyacinth is depicted as a valuable resource, being utilized for bioenergy, bio-adsorbents, biofertilizer, enzymes, animal feed, and phytoremediation. This highlights the dual nature of water hyacinth, which is both an invasive species and a potential resource for sustainable applications.

V. COMPOSTING PROCESS OF WATER HYACINTH

Composting water hyacinth (Eichhornia crassipes) is an effective waste management strategy for this invasive aquatic plant (Samuel et al., 2022). The process typically involves mixing water hyacinth with cattle manure and other materials like sawdust or rice husk in various proportions (Prasad et al., 2013; Sarika et al., 2014; Singh et al., 2012) Rotary drum composters and agitated pile methods have been used successfully (Prasad et al., 2013; Singh et al., 2012). During composting, organic matter, lignin, cellulose, and hemicellulose are reduced, while nutrients like nitrogen, phosphorus, sodium, potassium, calcium, and magnesium increase (Prasad et al., 2013; Sarika et al., 2014). Key factors influencing the process include aeration, moisture content, and composting duration (Samuel et al., 2022). Stability parameters such as CO_2 evolution rate, oxygen uptake rate, and chemical oxygen demand decrease as composting progresses (Prasad et al., 2013)The resulting compost is nutrient-rich and can potentially reduce the need for chemical fertilizers in agriculture (Prasad et al., 2013).

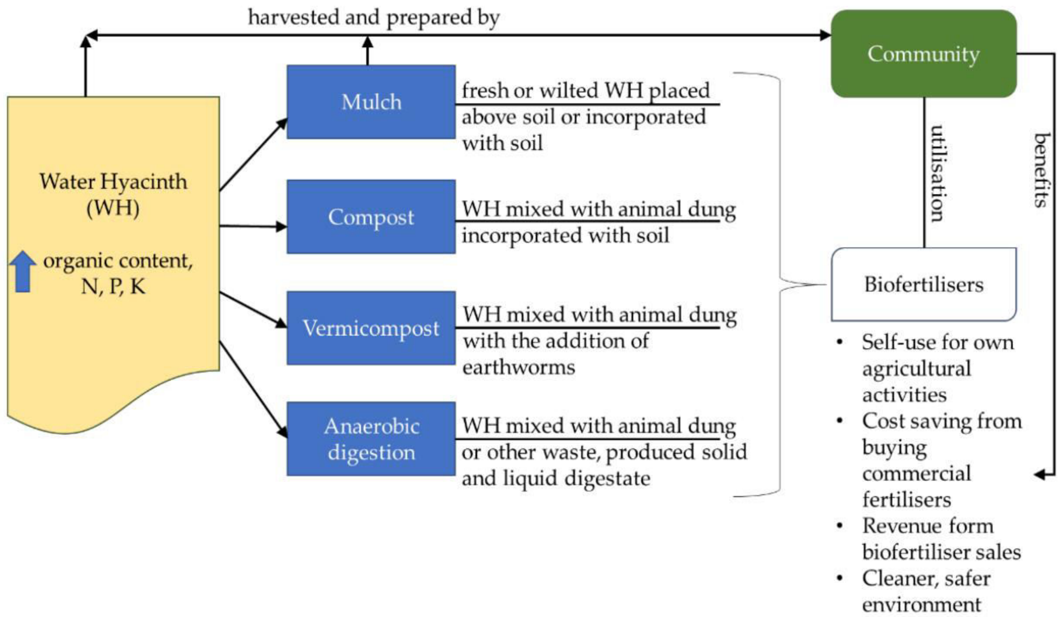

Figure 2: Sustainable Organic Model using Water Hyacinth as Organic Compost
Source:(Harun et al., 2021)

Figure 2 shows how we can manage and make the most of water hyacinth, an invasive plant that grows quickly when the conditions are just right. There are various ways to manage its overgrowth, including mechanical, physical, chemical, and biological methods. Rather than focusing on eradication, we can embrace sustainable management practices that transform harvested biomass into valuable products such as animal feed, biofertilizer, bioenergy, crafts, and even solutions for phytoremediation. This holistic approach fosters community strength, nurtures a sustainable microeconomic model, and inspires environmentally friendly actions, resulting in a thriving community.

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VI. METHODS OF COMPOSTING (TRADITIONAL, VERMICOMPOSTING, AEROBIC, ANAEROBIC)

Water hyacinth, an invasive aquatic plant, can be effectively managed through composting and vermicomposting, producing valuable organic fertilizers. Traditional composting methods require crushing the plant material and can take several months (Labrador et al., 2015). Vermicomposting, using earthworms like Eisenia fetida, has shown greater effectiveness in processing water hyacinth, resulting in stable and mature compost within 110 days (Labrador et al., 2015). Rotary drum reactors can be used for vermicomposting water hyacinth mixed with poultry litter, producing compost with balanced nutrient content in 45 days (Patil, 2012). Both compost and vermicompost from water hyacinth can be used as growing media for plants like lilies, with lower percentages of vermicompost showing better results for plant growth and vase life (Alami et al., 2021). A novel method called Novcom composting has demonstrated rapid biodegradation of water hyacinth, producing high-quality compost within 21 days. This method shows potential for large-scale adoption among farmers due to its speed and lack of infrastructural requirements (Dolui et al., 2014). These approaches offer sustainable solutions for managing water hyacinth while creating valuable agricultural resources.

VII. FACTORS AFFECTING DECOMPOSITION (MOISTURE, TEMPERATURE, MICROBIAL ACTIVITY)

Decomposition of organic matter is influenced by multiple interacting factors, primarily temperature, moisture, and microbial activity. Higher temperatures generally increase decomposition rates (Roberts, 2011; Sierra et al., 2015) while moisture effects are more complex. Optimal moisture levels vary, with both very low and very high moisture potentially inhibiting decomposition (Bartholomew et al., 1947; Roberts, 2011). Microbial composition plays a crucial role in decomposition and can interact with environmental factors to affect decomposition rates (Matulich & Martiny, 2015). The quality of the substrate also impacts decomposition, with higher quality substrates often decomposing faster (Roberts, 2011). Environmental changes can alter microbial community composition, which in turn affects decomposition rates (Matulich & Martiny, 2015). The interaction between microbial composition and environmental factors is particularly strong for changes in nitrogen availability (Matulich & Martiny, 2015). Understanding these complex interactions is essential for predicting decomposition rates under changing environmental conditions (Sierra et al., 2015).

VIII. ROLE OF ADDITIVES (MICROBIAL INOCULANTS, CO-COMPOSTING WITH OTHER MATERIALS)

Research has shown that microbial inoculants and co-composting can enhance the utilization of water hyacinth as a biofertilizer and energy source. Microbial inoculants, including bacteria, actinomycetes, and fungi, can accelerate composting and stimulate plant growth when applied to water hyacinth compost (Martínez-Nieto et al., 2011). Co-composting water hyacinth with vegetable waste and goat dung improves maize growth and soil fertility (Ali et al., 2024). Water hyacinth compost treated with yeast culture can serve as an effective carrier for Rhizobium inoculants, enhancing nodulation and yield in faba bean plants (Mohamed & Abdel-Moniem, 2010). Additionally, inoculum derived from anaerobically digested water hyacinth can significantly increase methane production during anaerobic digestion of fresh water hyacinth, while also improving the digester's potential as a soil ameliorant (Mohamed & Abdel-Moniem, 2010)These findings demonstrate the versatility of water hyacinth as a valuable resource when combined with appropriate additives and co-composting materials.

IX. EFFECT OF WATER HYACINTH (EICHHORNIA CRASSIPES) ON SOIL PROPERTIES

Compost manure is a primary contributor of organic matter to the soil, containing abundant plant nutrients and enhancing the soil's physico-chemical and biological characteristics(Van Haute, 2014). A study was done to investigate the capacity of E. crassipes to restore macronutrients, especially nitrogen, phosphorus, and potassium (NPK), in a soil that is low in these essential elements. Experimental research was conducted to investigate the properties of water hyacinth by comparing two conditions: (1) the use of sundried compost and (2) the use of fresh compost in soil. The duration of composting spanned a period of 31 days, which was sufficient for the decomposition of water hyacinth. The collected data was then subjected to univariate analysis of variance (ANOVA). The findings demonstrated an increase in NPK levels from low to medium and high. Significant impacts were seen in the nitrogen and phosphorus levels of sundried and freshwater hyacinth composts. While some individuals do not exhibit substantial variations in NPK content before to and during composting, all nutrient levels demonstrate an increase(C. Bondoc, 2020).

In the context of agricultural areas, the use of E. crassipes biomass as composting for soil nutrient management is being explored, with a focus on assessing microbial features as possible indicators. According to the research, water hyacinth has been identified as a promising organic substrate that could enhance the variety of microbial populations in agricultural soils. Overall, the mulched plots exhibited substantially higher levels of soil respiration and microbial diversity compared to the control group ($p < 0.05$)(Balasubramanian et al., 2013b). Eichhornia crassipes can generate compost that is high in pathogens, hence enhancing soil fertility and ultimately improving soil fertility. The use of agricultural leftovers, such as water hyacinth residues, has been shown to have advantageous outcomes.(Widjajanto, 2001).

Research findings indicate that the application of several types of water hyacinth as soil mulch resulted in a significant augmentation of fungal and bacterial populations when compared to control plots. Similarly, the soil respiration rate demonstrated a higher level of microbial activity in plots that were mulched with water hyacinth compared to the control plots. The phenomenon of substrate-induced soil respiration in grassland soils was also documented by (Hassink, 1993).. The impact of water hyacinth mulch, which is rich in quickly decomposable organic matter, on microbial populations was evident. This, in turn, resulted in increased levels of microbial nutrients (namely carbon, nitrogen, and phosphorus) across all treatments(Hassink, 1993).

The current study findings corroborate the results, indicating a considerable increase in the amount of soil organic matter in the plots that were mulched with water hyacinth. This finding provides more evidence that water hyacinth compost has the potential to serve as a nitrogen source for lowland rice growing systems in humid tropical regions. The plots treated with vermicompost mulch exhibited higher levels of microbial biomass phosphorus (P) compared to the plots treated with compost and green mulch. This finding indicates that vermicompost derived from water hyacinth have a larger capacity for phosphorus absorption. However, variations in the amount and quality of the substrate, as well as the nutritional condition of the soil, may also contribute to the higher microbial biomass(Haron et al., 1998).

X. EFFECT OF WATER HYACINTH (EICHHORNIA CRASSIPES) ON PLANT PROPERTIES

The use of water hyacinth as a biofertilizer demonstrated that the integration of water hyacinth into the soil crop system resulted in enhanced wheat plant performance. According to Majid's (1983) findings, the application of water hyacinth compost resulted in an increase in crop production per plant for rice, maize, sesame, brinjal, onion, and gourd(Majid et al., 1980).

The use of water hyacinth compost resulted in greater development of common beans. Hence, this serves as an indication of enhanced crop productivity when effective agricultural practices are used under optimal environmental circumstances. Water Hyacinth has favorable performance in crop yield; yet its detrimental impact on the soil and ecosystem renders its use undesirable. While the field findings suggest that it is feasible to produce common beans without the use of fertilizers on some fields, there is concern that without replenishing, the macronutrients may be exhausted, resulting in reduced yields. It is recommended that farmers operating within the Lake Victoria basin use compost derived from water hyacinth, a readily accessible, abundant, and cost-effective organic soil amendment, in order to enhance the productivity of common bean cultivation(Osoro et al., 2014).

The findings of the research indicate that the use of water hyacinth manure had a notable impact on the growth characteristics and productivity of the wheat plant in comparison to the control group. A notable augmentation was seen in the germination %, fresh weight, dry weight, biomass, as well as root and shoot length, in comparison to the control group(Vidya & Girish, 2014). All measures exhibited elevated values in comparison to the control group for both wheat plants and soil.

Table 1: Physical Parameters of Wheat Plant

Sr. No	Sample Pot	% Germination	Fresh Wt. (gm)	Dry. Wt. (gm)	Biomass	Shoot Length (cm)	Root Length (cm)	Root/Shoot Ratio (cm)
1	Expt.	44/50	13.85	1.24	12.59	15.99	14.75	0.922
2	Control	18/50	4.65	0.533	4.12	13.58	10.83	0.797

Source: (Vidya & Girish, 2014)

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XI. CASE STUDIES ON USE OF WATER HYACINTH (EICHHORNIA CRASSIPES) AS COMPOST

Water hyacinth (Eichhornia crassipes) compost has shown significant potential in improving soil properties and plant growth. Studies have demonstrated that its application enhances soil organic matter, physical structure, nutrient availability, and microbial activity (Begum et al., 2021; Muktamar et al., 2017). The compost increases total soil organic carbon, microbial biomass carbon, pH, available phosphorus, and exchangeable potassium in various soil types (Muktamar et al., 2017). It also stimulates microbial population growth and soil respiration(Balasubramanian et al., 2013a). Water hyacinth compost has been found to replenish macronutrients (NPK) in nutrient-depleted soils, with sundried compost showing significant effects on nitrogen and phosphorus levels (C. C. Bondoc, 2020). These improvements in soil properties contribute to enhanced plant growth parameters and yield (Begum et al., 2021). Despite challenges such as heavy metal accumulation and harvesting difficulties, water hyacinth compost presents a promising alternative to inorganic fertilizers for sustainable soil management (Begum et al., 2021).

Water hyacinth (Eichhornia crassipes), an invasive aquatic plant, can be effectively transformed into valuable compost and vermicompost for agricultural use. Studies have shown that water hyacinth compost and vermicompost can serve as suitable growing media for plants like lilies, with 25% vermicompost yielding optimal results for plant growth and vase life (Alami et al., 2021). Composting water hyacinth with cattle manure and sawdust significantly increases nutrient content and stability while reducing pathogens (Singh & Kalamdhad, 2015). In the Lake Victoria Basin, various water hyacinth compost treatments demonstrated high levels of essential nutrients and alkaline pH, making it an effective soil amendment (John, 2016). In Spain, both composting and vermicomposting techniques were successfully employed to bio transform water hyacinth biomass, with vermicomposting showing greater effectiveness and no phytotoxicity in plant growth tests (Labrador et al., 2015).

Studies have demonstrated the potential of water hyacinth compost as a nutrient-rich soil amendment across different regions. In Sri Lanka, composting water hyacinth with leaf litter produced high-quality compost suitable for field application (Amarasinghe, 2021). Research in India showed that agitated pile composting of water hyacinth with cattle manure and sawdust resulted in increased nutrients and improved stability parameters (Singh & Kalamdhad, 2015). In Iran, water hyacinth compost and vermicompost were successfully used as growing media for lily plants, partially replacing peat moss (Alami et al., 2021). Similarly, in the Lake Victoria Basin, various water hyacinth compost treatments exhibited high levels of essential nutrients, making it an effective soil nutrient replenishment(John, 2016).

An experiment was conducted on making compost from the invasive water hyacinth weed in the Begnas and Rupa Lake areas of Pokhara, Nepal, with funding support from Toyota. The water hyacinth invaded the wetland in Nepal which in turn proved to be a valuable resource for sourcing nutrients(Kafle et al., 2009a). These studies highlight the versatility and benefits of water hyacinth compost across different regions.

XII. ENVIRONMENTAL AND ECONOMIC PERSPECTIVES

12.1 Potential for sustainable waste management.

Sustainable waste management is crucial for environmental protection and economic benefits. While a significant portion of global waste is still landfilled (Castaldi, 2014),there's growing recognition of waste streams as valuable resources for energy and materials recovery. An integrated approach to municipal solid waste management can maximize usable materials and produce energy as a by-product (Kaosol, 2009). The adoption of circular economy principles in waste management can minimize resource depletion, reduce environmental pollution, and create economic opportunities through innovation and new business models (Aiguobarueghian et al., 2024). However, challenges persist, including lack of public awareness and inadequate infrastructure. Increasing public awareness about proper waste management practices and involving informal garbage collectors can improve environmental sustainability while providing economic benefits (Sahar & Ahmad, 2019). Policymakers should focus on developing regulatory frameworks that incentivize circular practices and foster collaboration among stakeholders to create a more sustainable and economically viable approach to waste management.

Water hyacinth, an invasive aquatic plant, can be transformed from an environmental nuisance into a valuable resource. It has potential applications in phytoremediation, effectively removing pollutants such as suspended solids, biological

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oxygen demand, and heavy metals from wastewater (Ajayi & Ogunbayo, 2012). The plant can be utilized as animal feed due to its high protein content and beneficial amino acid profile (Rajan et al., 2022). Water hyacinth also shows promise in biogas production, offering a renewable energy source for rural communities while simultaneously managing its proliferation in water bodies (Kamau et al., 2015). Furthermore, it can be used to manufacture various products, including paper, cardboard, and disposable items (Rajan et al., 2022). By harnessing its multifaceted functions, water hyacinth can contribute to environmental sustainability, addressing issues such as pollution remediation and global warming mitigation (Xu et al., 2022)This approach aligns with the concept of turning waste into wealth for sustainable development.

12.2 Cost-effectiveness of using water hyacinth (Eichhornia crassipes) in agriculture
Water hyacinth-based composts have shown promising results as effective fertilizers for crop production. Studies have demonstrated that these composts contain substantial amounts of nitrogen, phosphorus, and potassium, which can boost crop yields (Beesigamukama et al., 2018; Dennis et al., 2018). Experiments with maize crops revealed that water hyacinth compost mixed with poultry manure applied at 3 t ha-1 was most effective for grain yield (Dennis et al., 2018). Additionally, water hyacinth can be used for silage production and as a soil conditioner, with economic benefits possible after five years of operation(Polprasert et al., 1994). Research in Ethiopia has shown that water hyacinth compost has acceptable pH, moisture content, and nutrient levels, with heavy metal concentrations below permissible limits (Tibebe et al., 2022). Converting water hyacinth into compost offers a sustainable solution to manage its invasive growth while providing agricultural benefits (Tibebe et al., 2022).

Water hyacinth composting offers a sustainable alternative to chemical fertilizers, addressing both waste management and soil fertility issues. Studies have shown that water hyacinth compost, when mixed with cattle manure and sawdust, increases nutrient content and improves compost stability (Prasad et al., 2013; Singh & Kalamdhad, 2015) . Field trials demonstrated that water hyacinth compost significantly enhanced bean nodulation and yield, comparable to di-ammonium phosphate fertilizer (Kawaka et al., 2018). Furthermore, phosphor-compost prepared from water hyacinth and enriched with single super phosphate proved to be a cost-effective alternative to conventional phosphorus fertilizers, especially when combined with phosphate solubilizing bacteria (D et al., 2022). The composting process also effectively reduced pathogens, as indicated by decreased coliform counts (Singh & Kalamdhad, 2015). These findings suggest that water hyacinth compost can reduce fertilizer costs while improving soil fertility and crop productivity.

XIII. CHALLENGES OF USING WATER HYACINTH (EICHHORNIA CRASSIPES) IN AGRICULTURE

13.1 Potential risks (heavy metal accumulation, allopathic effects).
Water hyacinth (Eichhornia crassipes) poses significant environmental challenges due to its rapid growth and negative impacts on aquatic ecosystems (Su et al., 2018). However, it also offers potential benefits in agriculture and environmental remediation. Water hyacinth can be utilized as compost, improving soil properties and plant growth parameters (Begum et al., 2021). It also shows promise in phytoremediation, particularly for heavy metal accumulation in contaminated water bodies (Carrión et al., 2012). Studies have demonstrated its ability to absorb various heavy metals, including Pb, Cu, Zn, Cd, and Co, with higher concentrations typically found in the roots (Buta et al., 2011). Despite its potential uses, challenges remain, such as difficulties in harvesting, potential ecological risks, and the need for proper management to prevent heavy metal contamination (Begum et al., 2021; Su et al., 2018).Further research is needed to develop efficient harvesting techniques and assess the long-term impacts of water hyacinth utilization.

Water hyacinth (Eichhornia crassipes) demonstrates significant potential for phytoremediation of heavy metals in aquatic environments. Studies have shown its ability to accumulate various metals, including cadmium, zinc, chromium, copper, and lead (El-Gendy et al., 2006; Mishra & Tripathi, 2009). The plant's roots generally accumulate higher concentrations of metals compared to its shoots (Carrión et al., 2012). Water hyacinth can remove up to 95% of zinc and 84% of chromium from aqueous solutions within 11 days (Mishra & Tripathi, 2009). However, high concentrations of certain metals, such as chromium, may cause toxicity symptoms in the plant (Mishra & Tripathi, 2009). The effectiveness of metal accumulation varies with initial metal concentration, exposure time, and pH levels (El-Gendy et al., 2006; Xu et al., 2022). While water hyacinth shows promise for treating metal-contaminated waters, regular removal of the plants is necessary to prevent metal re-release into the environment (Carrión et al., 2012).

13.4 Farmer Adoption Challenges

Water hyacinth compost has shown potential as an effective organic fertilizer, improving soil properties and plant growth (Begum et al., 2022).Studies have demonstrated its positive effects on common bean production, enhancing nodulation and yield (Kawaka et al., 2018). The Novcom composting method has been found to produce high-quality compost from water hyacinth within 21 days, making it suitable for large-scale adoption among farmers (Dolui et al., 2014). However, challenges in adopting compost technology persist, with knowledge being a critical factor affecting adoption rates (Mustafa-Msukwa et al., 2011). Farmers generally have a positive perception of compost manure technology, believing it improves soil productivity (Mustafa-Msukwa et al., 2011). Despite these benefits, difficulties in harvesting, potential heavy metal accumulation, and limited awareness remain obstacles to widespread utilization of water hyacinth compost (Begum et al., 2022). Addressing these challenges could promote water hyacinth compost as an alternative to expensive inorganic fertilizers.

Some studies caution that composting may not eliminate the risk of seed spread, with low germination rates (1-3.5%) observed in compost-treated seeds (Albano Pérez et al., 2015). Alternative management strategies, such as using water hyacinth as sheep fodder, have shown promise in completely destroying seed viability through digestion (Albano Pérez et al., 2015)While composting can be an effective method for managing water hyacinth, careful monitoring of temperature and duration is crucial to ensure complete inactivation of seeds and propagules(Meier et al., 2014).

XIV. FUTURE PRSPECT OF USING WATER HYACINTH (EICHHORNIA CRASSIPES) IN AGRICULTURE

The fast reproductive capacity of this organism has a multitude of prospects for its use as a sustainable resource. In this context, water hyacinth presents more than just an environmental concern, since its significant intrinsic benefit may be harnessed for the purpose of fostering economic development(Onyango & Ondeng, 2015). The process of valuing water hyacinth is not a recent development; its potential is wide-ranging, spanning several industries like agriculture, energy, metallurgy, construction, pharmaceuticals, arts and craft, material science, and others(Ilo et al., 2020; Li et al., 2021).

The implementation of contemporary traditional high-input agriculture has resulted in several issues across all agricultural systems, including those found in nature. This phenomenon mostly occurs because of diminished biological content, imbalanced soil nitrogen levels, inadequate irrigation practices, and increased formation of biomass waste. Consequently, these factors contribute to the loss of agricultural land and a decline in crop output(Dissanayaka et al., 2022; Mengqi et al., 2021). Eichhornia crassipes is a plant that has both attractive qualities and is well recognized for its use as a phytoremediation plant, a biomass energy source, and a vital resource for animal feed, building, handicraft, paper, and board production(Jafari, 2010).

Eichhornia crassipes, also known as water hyacinth, is a buoyant plant that thrives in tropical aquatic environments. The presence of this invasive plant presents a variety of risks including ecological, economic, and social dimensions. It poses a threat to biodiversity, leads to eutrophication, provides a habitat for pests, obstructs freshwater channels, impacts agriculture and aquaculture, and impedes shipping and recreational activities. The current control approaches have shown to be inadequate in effectively mitigating the aggressive spread of the phenomenon.

(Wu & Ding, 2020). In recent times, there has been a growing anticipation that the effective exploitation of this particular plant has the potential to address the many challenges related with it. There is speculation on the potential use of the substantial biomass in various applications such as waste water treatment, remediation of heavy metals and dyes, production of bioethanol and biogas, generation of electricity, industrial applications, human nutrition and antioxidants, pharmaceuticals, animal feed, agriculture, and sustainable development(Patel, 2012). The use of water hyacinth in craft manufacturing has significant promise. The dried plant and its fiber may serve as a valuable raw material for the production of various objects such as purses, handbags, wallets, pots for flowers, fashion accessories, mats, and many other products(Haron et al., 1998; Punitha et al., 2015).

The versatility of water hyacinth is shown in its many applications. It may be used as a fresh feed source, incorporated into silage via its combination with manure, urea, molasses, straws, and other substances. Additionally, water hyacinth can be composted or utilized as hay for animal feed in dry or wilted states(Bai et al., 2011; Islam et al., 2009). Extensive research has been conducted on the nutritional composition and possible use of water hyacinth as a feed source for cattle,

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poultry, and fish. The nutritional characteristics of this substance, such as its high levels of cellulose, hemicellulose, and crude protein, provide it a viable option for incorporation as a replacement or supplement in animal feed formulations(Wimalarathne & Perera, 2019).

14.2 Policy and regulatory considerations

Water hyacinth (Eichhornia crassipes) is an invasive aquatic plant that poses environmental and economic threats to water bodies (Nega et al., 2024). However, it can be effectively managed through composting, which not only addresses the invasive species problem but also produces valuable horticultural products (Montoya et al., 2011).Large-scale composting of water hyacinth with other organic materials can reach temperatures high enough to inactivate seeds and propagules, ensuring safe utilization (Montoya et al., 2011).The resulting compost improves soil properties, including structure, nutrient availability, and microbial activity, leading to enhanced plant growth and yield (Audah et al., 2023) water hyacinth in circular bio economy, transforming this environmental challenge into sustainable growth opportunities (Nega et al., 2024).

XV. CONCLUSION

The management of water hyacinth should be integrated with its usage as a valuable resource. This has the potential to not only transform trash into valuable resources and address the issue of water hyacinth proliferation, but it might also provide economic and ecological advantages. In general, the process of composting water hyacinth has the potential to enhance the NPK level within soil. Utilizing sundried water hyacinth for composting has the potential to replenish a substantial quantity of nitrogen and phosphorus in a soil that lacks essential nutrients. The aquatic weed, in addition to its detrimental impact on nutrient-rich water bodies, serves as a cost-effective substitute for organic fertilizer that is readily available. The herbaceous plant has the capacity to absorb nitrogen, phosphorus, and potassium from the surrounding water, so serving as a viable substrate for composting processes. Water hyacinth is recognized for its potential as a nutrient source via composting. Various composting procedures may be used to produce compost from water hyacinth. Water hyacinth, as an organic source, contributes to the accumulation of soil organic matter, hence playing a crucial role in enhancing the physical, chemical, and biological qualities of the soil. Conducting capacity-building workshops on composting techniques may solve the challenge of farmers adopting water Hyacinth as an organic manure for agricultural production. The application of water hyacinth compost has been shown to enhance many soil qualities, including the aggregation of soil particles, porosity, density, water holding capacity, nutrient availability, cation exchange capacity, pH, and soil microorganisms. Water hyacinth may be used as an organic fertilizer to support sustainable farming practices via the reduction of reliance on synthetic inputs.

RECOMMENDATION

- Water hyacinth compost improves soil fertility, structure, and moisture retention, especially in nutrient-depleted or sandy soils.
- To ensure crop and soil safety, compost must be well-decomposed to remove toxins and pathogens before application.
- To avoid nutrient imbalances, farmers should add compost at the right rate depending on crop nutrient needs and soil testing.
- Water hyacinth compost should be used with crop rotation and integrated pest management to boost agricultural yield.
- To evaluate long-term benefits and optimize treatment procedures, soil and crop response should be monitored regularly.

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