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Nature's Clean-Up Crew: Unlocking the Potential of Water Hyacinth as a Phytoremediation Wonder for Eutrophication Reduction in Aquatic Environments

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ABSTRACT

This study aims to determine whether water hyacinth can be a phytoremediation tool to mitigate eutrophication in water bodies. Specifically, it seeks to observe the morphological changes in the leaves and stems of water hyacinth in terms of length and width, to describe the similarities and differences of water hyacinth from eutrophic and normal water aquariums, and to determine the efficacy of water hyacinth in mitigating eutrophication. The research employed an experimental research design, which constitutes a structured set of protocols and procedures tailored for conducting experimental investigations scientifically, employing two distinct sets of variables. In conclusion, the study found significant changes in water hyacinth's morphology when exposed to eutrophic water, with signs of distress observed after ten days due to high nutrient levels. Despite this, the findings support the potential of water hyacinth to mitigate eutrophication in water bodies, offering promise for enhanced water quality management.

INTRODUCTION

Agriculture plays a crucial role in our society; in fact, nearly all the foods we consume, such as rice, oats, fruits, and vegetables like tomatoes, onions, and garlic, are products of agriculture. Farmers, as businesspeople, provide sustainable food sources in our communities. They continuously seek ways to improve farming quality and increase crop yields by utilizing various fertilizers, typically rich sources of nitrogen and phosphorus crucial for plant growth. Fertilizers significantly aid farmers in producing high-quality crops and boosting harvests. However, excessive levels of phosphorus and nitrogen in our environment can potentially harm aquatic ecosystems. According to the Environmental Protection Agency of the United States (2022), farmers apply nutrients to their fields in the form of chemical fertilizers and animal manure, which supply crops with the necessary nitrogen and phosphorus for growth and food production. However, if growing plants do not fully absorb these nutrients, they can be lost from the fields and adversely affect air and downstream water quality. This excess nitrogen and phosphorus can be washed from farm fields into waterways during rainfall or snowmelt, and it can also leach through the soil and into groundwater over time. Elevated levels of nitrogen and phosphorus can lead to eutrophication of water bodies, resulting in hypoxia ("dead zones"), fish kills, and a decline in aquatic life. Additionally, excess nutrients can trigger harmful algal blooms (HABs) in freshwater systems, disrupting wildlife and potentially producing toxins harmful to humans. Based on an article from Water Resources (2019), eutrophication is a natural process resulting from the accumulation of nutrients in lakes or other bodies of water. Algae, which thrive on these nutrients, can form unsightly scum on the water surface, reducing recreational value

and clogging water intake pipes. Decaying algae mats can produce foul tastes and odors in the water, while bacterial decay consumes dissolved oxygen, sometimes leading to fish kills. Human activities can exacerbate eutrophication by increasing nutrient input into water bodies. The availability of phosphate or nitrate typically constrains algal growth; a water body is considered nitrogen-limited if the ratio of nitrogen species to phosphorus species (N:P) is low, or phosphorus-limited if N:P is high.

LITERATURE REVIEW

This study draws from the review study conducted by Djihouessi *et al.* (2023), which highlights the theory and conceptual framework of biological invasions, noting that "most invasions fail, and only limited taxa succeed" in a natural environment (Moyle & Light, 1996; Williamson, 1996; Gurevitch *et al.*, 2011). Several authors underscore the significance of efficient nutrient utilization and solar energy absorption as key factors contributing to water hyacinth's success as an invasive species in tropical aquatic habitats. Notably, water hyacinth exhibits remarkable nutrient uptake rates, reaching 2200 mg N m⁻²day⁻¹ and 550 mg P m⁻²day⁻¹, significantly surpassing phytoplankton's optimum uptake rate (Reddy & Tucker, 1983; Rawson, 1992; Patel, 2012; Téllez *et al.*, 2008). Additionally, it demonstrates adaptability to a wide range of environmental conditions, thriving in freshwater with high organic matter and heavy metal concentrations, as well as brackish water environments with salinities <8 ppt (Brendonck *et al.*, 2003; Jayaweera *et al.*, 2008; Mahunon *et al.*, 2018; Li *et al.*, 2021; Gettys *et al.*, 2014).

Water hyacinth, an adaptable aquatic plant, has attracted considerable interest for its capacity to address urban and industrial wastewater challenges. The study by Rezanian (2015) revealed that water hyacinth is suitable

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for controlling urban and various types of wastewaters originating from industries. It also demonstrates that among aquatic plants, water hyacinth presents a viable and effective option for nutrient uptake and improving water quality.

Eutrophication poses a global challenge, including in the Philippines, exemplified by Pujada Bay in Mati, Davao Oriental. Recent nutrient mapping conducted by scientists at DOrSU underscores the bay's vulnerability to eutrophication due to elevated nitrate and sulfate levels, surpassing standard quality thresholds for coastal waters. High total dissolved solids (TDS) and low bicarbonate levels further indicate reduced productivity and declining marine life diversity (Zuasola, 2022).

Researchers continue to explore strategies for preventing or mitigating pollution's adverse effects on the environment. Plants like water hyacinth exhibit pollutant-absorbing capabilities, serving as phytoremediation tools to address various environmental issues. Auchterlonie *et al.* (2021) demonstrates water hyacinth's capacity to absorb phosphates and nitrates, suggesting its potential as a phytoremediation tool to mitigate eutrophication and reduce *Microcystis* blooms.

Phytoremediation, employing plants to purify polluted areas, offers promise in addressing heavy metal pollution. Yan *et al.* (2020) highlights its effectiveness in revegetating heavy metal-polluted soil, with numerous hyperaccumulator plants identified for this purpose. However, phytoremediation with natural hyperaccumulators faces limitations, including slow

growth rates and low biomass production. Enhancing plant performance is crucial for optimizing phytoremediation effectiveness in heavily contaminated sites.

Objectives of the Study

This study aims to investigate whether water hyacinth can serve as a phytoremediation tool to mitigate eutrophication in water bodies. Specifically, it seeks to accomplish the following:

1. To observe the morphological changes in the leaves and stems of water hyacinth in terms of length and width.
2. To describe the similarities and differences of water hyacinth from eutrophic water and normal water aquariums.
3. To determine the efficacy of water hyacinth in mitigating eutrophication.

MATERIALS AND METHODS

Research Design

The study employed an experimental research design, which constituted a framework of protocols and procedures crafted to conduct experimental research with a scientific approach, utilizing two sets of variables (Sirisilla, 2023). Moreover, it was characterized by two distinguishing features the conscious manipulation by the researcher of a treatment or, more generically, an independent variable of interest, and the random assignment of units to treatment and control groups (Munck and Verkuilen, 2005).

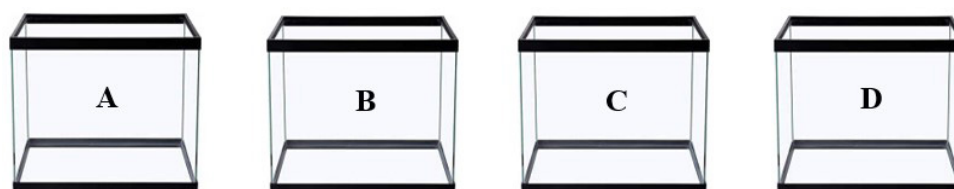


Figure 1: Four Transparent Glass Aquariums

- Aquarium A: River water and Water hyacinth
- Aquarium B: River water
- Aquarium C: River water with NPK fertilizer (Nitrogen, Phosphorus, and Potassium)
- Aquarium D: River water, NPK fertilizer (Nitrogen, Phosphorus, and Potassium), and Water hyacinth

To induce eutrophication, the researcher utilized four transparent glass aquariums labeled as containers A, B, C, and D, each filled with river water sourced near the public market of Bayambang, Pangasinan. The growth of algae in each aquarium was observed and documented daily using the camera of a mobile phone. Additionally, the researcher measured the length and width of water hyacinth leaves and stems using a ruler.

Instruments of the Study

The researcher procured four transparent glass aquariums labeled A, B, C, and D from Shopee, using a piece of bond paper and a marker to designate them. These aquariums

were then filled with river water. Other materials utilized in the study included water hyacinth, a ruler, NPK fertilizer, and a mobile phone for documentation.

Data Analysis of the Study

The researcher meticulously organized the data in alignment with the study's objectives, presenting and elaborating on it in a descriptive manner. Furthermore, to enhance clarity and provide visual insight, the documentation incorporated both photographs and tables. Additionally, measurements of the length and width of water hyacinth stems and leaves were recorded in millimeters to ensure precision.

RESULTS AND DISCUSSION

This section presents and discusses the data collected on the morphological changes of water hyacinth, the similarities and differences observed between water hyacinth placed in aquariums with river water and those

with river water and NPK (eutrophic water), and the relationship between eutrophication and water hyacinth.

Morphological Changes of Water Hyacinth

The objective of this study is to observe the morphological

changes in the leaves and stems of water hyacinth in terms of length and width. Table 1 displays the measurements of the leaves and stems of water hyacinth in terms of length and width after 10 days of the experiment.

Based on Table 1, there is an increase in water hyacinth leaf

Table 1: The length and width of water hyacinth before and after the experiment

	Day 0				Day 10			
	L (l)	L (w)	S (l)	S (w)	L (l)	L (w)	S (l)	S (w)
Aquarium A								
Water Hyacinth 1	34.67	56.33	65.67	11.67	35.67	58.67	71.67	14.33
Water Hyacinth 2	30	52.33	45.67	14.67	32.67	63	47	16.33
Aquarium D								
Water Hyacinth 1	37.67	54	49.67	12	26	47	49.67	10
Water Hyacinth 2	31	47.67	45.67	12.67	25	45.33	47.67	13.33

*Unit of measurement: millimeter (mm)

*L (l) - Leaf length

*L (w) - Leaf width

*S (l) - Stem Length

*S (w) - Stem Width

and stem size in terms of length and width in Aquarium A compared to Aquarium D. On day 0, Water Hyacinth 1 from Aquarium A had an average leaf length of 34.67 mm (35.67 mm on day 10) and a width of 56.33 mm (58.67 mm on day 10). The stem had an average length of 65.67 mm (71.67 mm on day 10) and a width of 11.67 mm (14.33 mm on day 10). Similarly, Water Hyacinth 2 had an average leaf length of 30 mm (32.67 mm on day 10) and a width of 52.33 mm (63 mm on day 10), with the stem measuring an average length of 45.67 mm (47

mm on day 10) and a width of 14.67 mm (16.33 mm on day 10). The leaves of the water hyacinth in Aquarium D become dry after day 10. This is supported by an article from the University of California Agriculture and Natural Resources (n.d.) that the presence of excess nitrogen can directly injure states plants. Excessive nitrogen can cause plants to grow excessively and develop overly succulent leaves and shoots, promoting outbreaks of certain sucking insects and mites. Fruit production and maturity can also be delayed, while fruit quality and yield may be reduced. Additionally, excess nitrogen can kill small roots and increase plants' susceptibility to damage by root-feeding nematodes and root decay pathogens. Overfertilization can cause leaves to turn brown, gray, dark green, or yellow at margins and tips or overall. Affected foliage may wilt temporarily or die and drop prematurely (see figure 1).



Chlorotic and necrotic leaf tips and margins due to nitrogen toxicity (University of California Agriculture and Natural Resources, n.d)



Leaves of water hyacinth after day 10

Figure 2: Leaves of the Water Hyacinth in Aquarium D after 10 days

Similarities and Differences in Water Hyacinth between Aquariums A and D

This study aims to describe the similarities and differences of water hyacinth from eutrophic water and normal water aquariums. Figure 2 depict the water hyacinth placed in Aquarium A and Aquarium D from day 0 to day 10. Due to the excessive nutrients (NPK) present in Aquarium D, the water hyacinth appeared unhealthy on

day 10, with its leaves turning light green and exhibiting dry tips or margins, and the stems becoming thinner compared to day 0. According to the article from Trifecta Natural (n.d.), nitrogen toxicity in plants can result in clawed, shiny, and abnormally dark green leaves, as well as slow growth and weak stems. Clawed leaves are bent at the tips with a talon-like shape and may exhibit cupping or curving. If left untreated, nitrogen toxicity can lead to

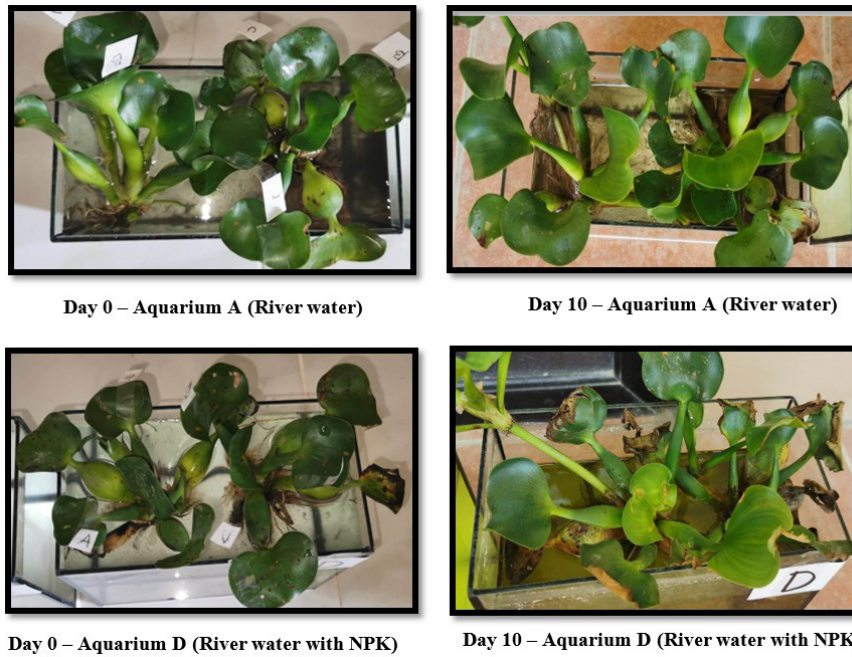


Figure 3: The water hyacinth placed in Aquarium A and Aquarium D from day 0 to day 10

yellowing and eventual death of the leaves. This toxicity is typically caused by an excessive nitrogen supply, which adversely affects photosynthesis. In cannabis plants, excess nitrogen can impede bud formation, reduce yields and potency, and result in inferior buds.

Water hyacinth and Eutrophication

This study aims to determine the efficacy of water hyacinth in mitigating eutrophication. Figure 3 show the growth of algae in each aquarium from day 0 to day 10. Visible indications of eutrophication include high turbidity

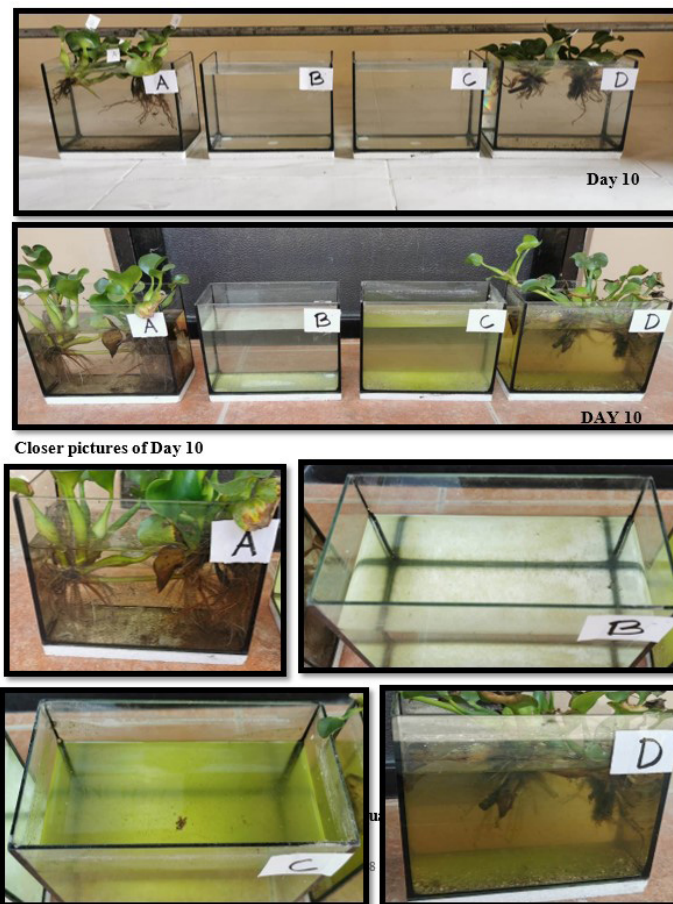


Figure 4: The growth of algae in each aquarium from day 0 to day 10.

caused by algal blooms, dense macrophyte growth, mass development of harmful cyanobacteria (blue-green algae), reduced species diversity, oxygen depletion, formation of hydrogen sulfide, fish kills, and odor nuisance (Hufper and Hilt, 2008). Based on figure 3, there is no visible growth of green algae in aquarium A (river water and water hyacinths), while there is a small amount of green algae growth in aquarium B (river water without water hyacinths). Furthermore, the water in container C (river water plus NPK without water hyacinths) becomes greenish in color, and there is visible algae growth inside the aquarium. On the other hand, there is less growth of green algae in container D (river water plus NPK) because water hyacinth consumes the nutrients present in the water, mitigating the eutrophication effect caused by excess nutrients, specifically nitrogen and phosphorus. The study by Ayana (2021) revealed that water hyacinth has the capacity to remove contaminants from polluted bodies of water (Chen *et al.*, 1989). Many contaminants, such as total suspended solids, dissolved solids, nitrogen, phosphorus, heavy metals, etc., as well as biochemical oxygen demand, have been minimized using WH (Gupta *et al.*, 2012). Nitrogen and phosphorus removal capacity from dairy wastewater was found to be fastest in WH, followed by *Lemna minor* and *Azolla pinnata* (Tripathi and Upadhyay, 2003). With the aforementioned results, water hyacinth can absorb excess nutrients such as nitrogen and phosphorus, which cause eutrophication in bodies of water.

CONCLUSIONS

1. The observations regarding the morphological changes in water hyacinth revealed significant differences between the specimens in aquariums A and D. While aquarium A exhibited robust growth, aquarium D displayed signs of stress and deterioration, likely due to the presence of excess nitrogen. This finding aligns with existing literature suggesting that excess nitrogen can adversely affect plant health, leading to various physiological disorders.

2. The comparison of water hyacinth between aquariums A and D highlighted the detrimental effects of eutrophic conditions on plant vitality. The excessive nutrients present in aquarium D led to observable changes in leaf color and texture, as well as reduced stem thickness. These symptoms are consistent with nitrogen toxicity, as indicated by previous research on plant responses to nutrient imbalances.

3. The investigation into the relationship between water hyacinth and eutrophication demonstrated the plant's potential to mitigate nutrient pollution in aquatic ecosystems. By absorbing excess nitrogen and phosphorus, water hyacinth can alleviate the adverse effects of eutrophication, as evidenced by the reduced algae growth observed in aquarium D compared to container C. This corroborates previous studies indicating the efficacy of water hyacinth in pollutant removal from contaminated water bodies.

RECOMMENDATIONS

1. Also measure the length of the water hyacinth's roots when observing its morphological changes.
2. Analyse the nitrogen, potassium, and phosphorus content absorbed by the water hyacinth after the experiment.
3. Include more water hyacinths as instruments in the study.

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