



Effectiveness of Water Hyacinth (*Eichhornia crassipes*) and Water Spinach (*Ipomoea aquatica*) to Reduce Nitrate and Phosphate Concentrations in Cimulu River Water, Tasikmalaya City, Indonesia

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Authors' contributions

This work was carried out in collaboration among all authors. Author HK designed the study, conducted the experiment, wrote the first draft of the manuscript, conducted data analysis and wrote the final manuscript. Author ZH provides guidance on literature search techniques, data analysis of experimental results and script writing. The author HH provides guidance in experimental and writing procedures. Author WL is total supervisor and ensures the accuracy of the results. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJFAR/2022/v18i530451

Open Peer Review History:

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: <https://www.sdiarticle5.com/review-history/89312>

Original Research Article

Received 14 May 2022
Accepted 18 July 2022
Published 27 July 2022

ABSTRACT

Water hyacinth and water spinach can be used as phytoremediation agents in the Cimulu River because these two plants can grow and adapt in the Cimulu River. This study compared the effectiveness of the two plants in reducing nitrate and phosphate in Cimulu river water. The research was conducted from September to October 2021. The research was conducted ex-situ and in-situ. Media retrieval from the Cimulu River was carried out in situ in the middle of the Cimulu River, Tawang District, Tasikmalaya City, Indonesia. aquatic plants, analysis of pH, temperature, and sampling were carried out ex-situ in the backyard of the house at the LIK Complex, Tasikmalaya City, Indonesia. Analysis of water samples such as DO, BOD, nitrate, and phosphate was carried out ex-situ at the Water Resources Management Laboratory of FPIK Padjadjaran University. The method used is an experimental method, with three treatments consisting of control treatment, treatment A (water hyacinth), and treatment B (water spinach). Each aquarium in

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treatments A and B contained aquatic plants weighing 200 g each. The results of the research conducted for 28 days showed that water hyacinth weighing 200 g was more effective in reducing nitrate and phosphate than water spinach with the same weight. Furthermore, water hyacinth can reduce nitrate by 61.72% and phosphate by 78.27% with the absorption rate of nitrate in one day reaching 0.006 g/m² and phosphate 0.038 g/m². The growth rates of water hyacinth in weeks I, II, III, and IV were 5.03±0.971%, 6.31±0.971%, 6.80±0.321%, and 7.18±0.277%. Meanwhile, other water parameters that can be reduced are BOD from 37.3 mg/L to 8.10 mg/L.

Keywords: *Eichhornia crassipes*; *ipomoea aquatic*; *phytoremediation*; *the rate of decrease in nitrates and phosphates*; *effectiveness*.

1. INTRODUCTION

The Cimulu River is a tributary of the Citanduy River in Tasikmalaya City, Indonesia. The area of the Cimulu River is 1546.2 hectares and passes through three sub-districts, namely Tawang, Cibereum, and Purbaratu [1]. Various uses of the Cimulu river include residential activities in the form of household activities, economic activities of traders on the banks of the river and capture fisheries activities, there is even a hospital industry [2]. This activity resulted in the Cimulu River being in a moderately polluted status [3].

Polluted waters can be overcome by treating water in an alternative that is natural, inexpensive and easy to use with aquatic plants. The processing is known as phytoremediation, which is a system that uses plants with the help of microorganisms to convert and destroy contaminants into harmless [4]. Phytoremediation has been carried out with various types of plants, such as water hyacinth and water spinach. Water hyacinth has a structure of tissues and organs that support the process of absorption of organic materials and other substances, such as having large stomata holes compared to most other plants and the distance between stomata is eight times the size of the holes [5]. Water spinach has a fairly high adaptability to the environment. Water spinach is a plant that is selective for certain nutrients, so it can absorb organic matter and other substances in water bodies [6].

2. METHODOLOGY

2.1 Research Sites

The study was conducted in September–October 2021. The time required for phytoremediation observations was 28 days. Analysis of water samples and weighing of aquatic plants were carried out once a week.

The place for taking phytoremediation water media comes from the Cimulu River, Tasikmalaya City, Indonesia. The research was carried out ex situ in the backyard of the house having the address at Komplek LIK Kota Tasikmalaya, Indonesia. Where the research was made like a green house covered by fiber glass with an area of 2m×1.2m. This is done so that water hyacinth and water spinach can be exposed to optimal sunlight and avoid rain. Analysis of pH, temperature and observations of aquatic plants were carried out directly at the research site, while for nitrate, phosphate, DO and BOD were carried out at the Water Resources Management Laboratory of FPIK Unpad.

2.2 Materials and Methods

The materials used in the study were water from the middle Cimulu river with the highest concentration, namely nitrate 0.128 mg/L, phosphate 0.635 mg/L and BOD 37.3 mg/L, water hyacinth 200 g with a size of 15-20 cm, water spinach 200 g with a size of 20-30 cm, distilled water, manganese sulfate solution, oxygen reagent solution, sulfuric acid solution, starch indicator, sodium thiosulfate, SnCl₂ solution, NH₄ molybdate solution, Phenol disulfonic acid solution, 10% NH₄OH solution. While the tools used in the study were jerry cans, dippers, 36 x 22 x 26 cm aquarium, sample bottles, litmus paper, thermometer, coolbox, digital scales, ruler, camera, spectrophotometer.

2.3 Methods and Data Analysis

The research method used is the experimental method. The experiment was carried out with three treatments and four replications. The treatments consisted of control, treatment A for water hyacinth and treatment B for water spinach. The data were analyzed using quantitative descriptive methods and a comparison of the effectiveness between treatments was carried out [7].

2.3.1 Growth rate and plant productivity

Biomass, growth rate, and biomass productivity can be obtained by collecting primary data results. The formula for finding the biomass growth rate is as follows [8]:

$$\mu = \left(\sqrt[t]{\frac{Bt}{Bo}} - 1 \right) \times 100\%$$

μ = growth rate of biomass (%)
 Bt = Final wet weight (g)
 Bo = Initial wet weight (g)
 t = Experimental Time (days)

Biomass productivity can be determined using the following formula [8]:

$$P = \frac{Bt - Bo}{A \cdot t}$$

P = Productivity of Biomass (g/m²/day)
 Bt = Final wet weight (g)
 Bo = Initial wet weight (g)
 A = Area of the Media Container (m²)
 T = Length of Experiment (days)

2.3.2 Nitrate and phosphate reducing rate

The rate of decrease in the concentration of phosphate and nitrate can be used by the formula, as follows [8]:

$$\mu = \left(\sqrt[t]{\frac{Ct}{Co}} - 1 \right) \times 100\%$$

μ = phosphate/nitrate decrease rate (%)
 Ct = Final concentration
 Co = Initial concentration
 T = Experiment Time

Determine the rate of absorption of the concentration of phosphate and nitrate can be used the formula [8] :

$$P = \frac{Ct - Co}{A \cdot t}$$

P = Absorption Rate (g/m²/day)
 Ct = Final Concentration (g)
 Co = Initial Concentration (g)
 A = Media Container Area (m²)
 T = Length of Experiment (days)

2.3.3 Effectiveness of reducing nitrate and phosphate

Effectiveness of nitrate and phosphate reduction on water hyacinth and water spinach [9]:

$$E_f = \frac{Ci - Ce}{Ci} \times 100\%$$

E_f = Efficiency/effectiveness (%)
 C_i = Initial concentration (mg/L)
 C_e = Final concentration (mg/L)

3. RESULTS AND DISCUSSION

3.1 Biomass, Growth Rate and Productivity

3.1.1 Biomass

Biomass is organic material resulting from the photosynthesis process which is expressed in units of weight [10].

Based on Fig. 1. the yield of water hyacinth and water spinach biomass growth week 0 weighed 200 g. Both treatments experienced an increase in weight from week 0 to week 4. Water hyacinth has a higher weight gain than water spinach, with the final weight of water hyacinth reaching 325 ± 5.887 g and water kangkung 321 ± 11.604 g. The growth ability of each plant is different, depending on several important factors such as light, growth regulators and nutrients [11].

Morphologically, water hyacinth has a network structure that supports the growth of water hyacinth faster than water spinach. One water hyacinth stem in 52 days can grow up to 1 m² [12]. Even water hyacinth root can help increase biomass. The results showed that water hyacinth had thicker and denser fibrous roots than water spinach which had tap roots.

The results showed that water hyacinth has thicker and denser fibrous roots, compared to water spinach which has tap roots. This is evidenced in Fig. 2. and Fig. 3.

The dense shape of the water hyacinth roots indicates that many rhizosphere microbes can degrade organic compounds for metabolic processes so that they can produce new cells and increase plant biomass [13].

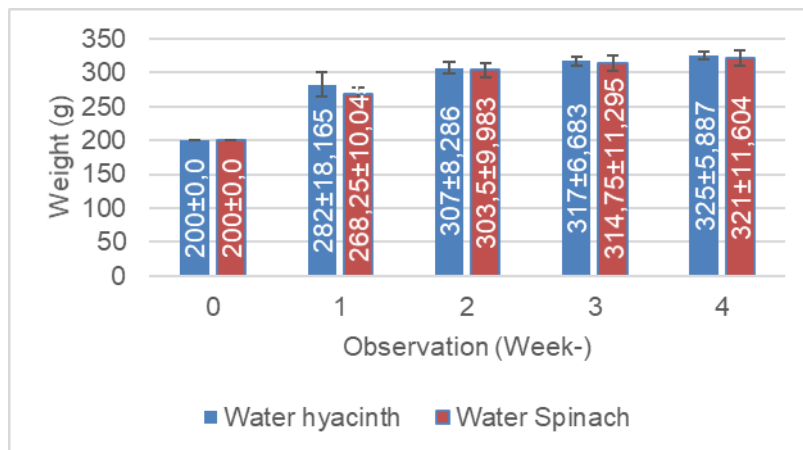


Fig. 1. The weight of water hyacinth and water spinach during the research



Fig. 2. Water hyacinth root



Fig. 3. Water spinach root

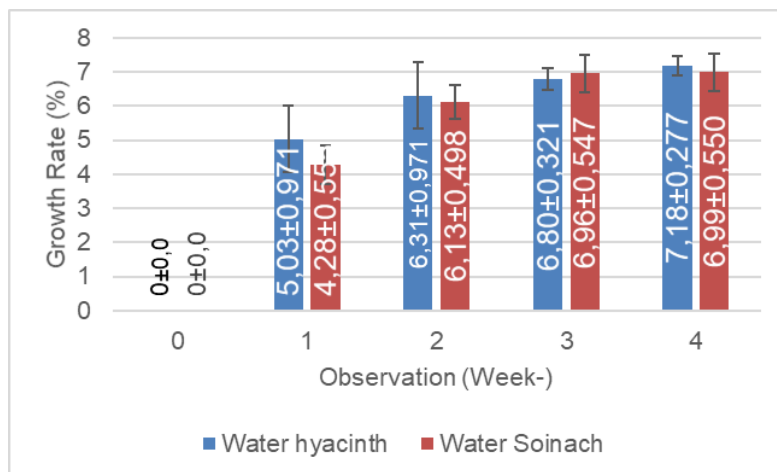


Fig. 4. Growth rate of water hyacinth and water spinach during research

3.1.2 Growth rate

Based on Fig. 4. Water hyacinth has a higher growth rate than water spinach. This is indicated by the growth rate of water hyacinth in the first week of $5.03 \pm 0.971\%$ and the last week reaching $7.18 \pm 0.277\%$, while water spinach was $4.28 \pm 0.55\%$ and the last week it was $6.99 \pm 0.550\%$.

The performance of the growth rate of the two plants in the third and fourth weeks of the increase was not too high, this was because some of the leaves and stems of the plants began to change color and wither due to a decrease in the nutrient content in the planting medium. Plant wilting is caused by a decrease in the ability to absorb organic matter because at the beginning of the study the absorption of organic matter was very high [5].

3.1.3 Productivity

Plant growth rate is related to biomass productivity because the calculation of biomass productivity can determine the growth of plant weight in the media every day. The productivity of water hyacinth and water spinach biomass is presented in Table 1.

In Table 1. the biomass productivity of the two plants shows that water hyacinth has a higher

productivity than water spinach. The productivity of water hyacinth is $9.70 \text{ g/m}^2/\text{day}$ while water spinach is $9.39 \text{ g/m}^2/\text{day}$. This is because the weight of water hyacinth increases faster than water spinach. The increase in wet weight of water hyacinth occurs because the water used in this research contains nutrients needed for the growth of water hyacinth, such as N and P [5].

3.2 Nitrate and Phosphate Degradation Rate

3.2.1 Nitrate (NO₃)

Based on Fig. 5 in the preliminary test week 0 to 4 in both plants there was a decrease, namely $0.128 \pm 0.00 \text{ mg/L NO}_3$ to $0.049 \pm 0.0009 \text{ mg/L NO}_3$ in water hyacinth treatment, while water spinach $0.054 \pm 0.0024 \text{ mg/L NO}_3$. This is because water hyacinth is able to properly absorb organic materials containing N nutrient compounds and store them in water hyacinth vascular tissue for metabolic processes that are used to multiply cells [14].

Plant age can affect the ability to reduce nitrate compounds. When the plant is still young, the ability to reduce nitrite, nitrate, ammonia and phosphate is higher. However, after reaching a certain size, its ability decreases [15].

Table 1. The productivity of water hyacinth and water spinach

	Productivity (g/m ² /day)
Water hyacinth	9,70
Water spinach	9,39

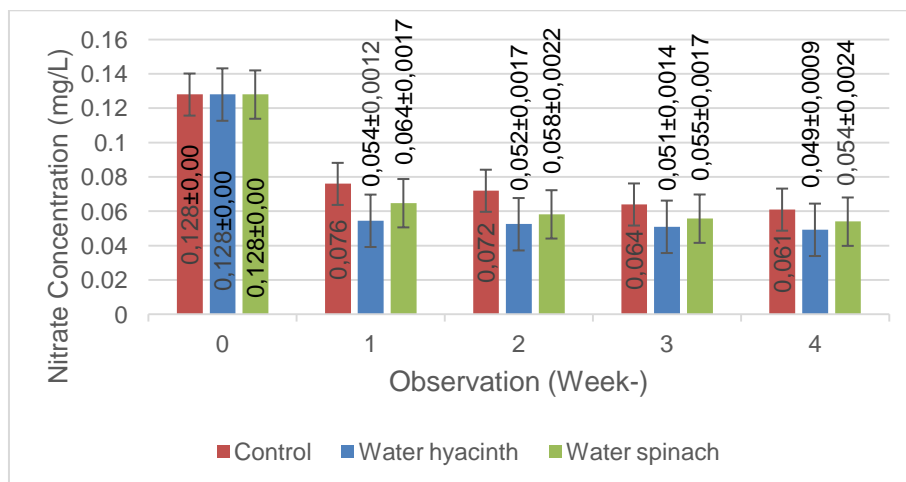


Fig. 5. Nitrate concentration during research

Table 2. Rate of Nitrate Reduction and Absorption in one day during research

	Rate of nitrate reduction in 1 day (%)	Rate of nitrate absorption (g/m ² /day)
Control	2,61	0,005
Water hyacinth	3,37	0,006
Water spinach	3,03	0,005

Based on the results of calculations, in Table 2 water hyacinth has a superior absorption percentage of 3.37% with an elimination rate of 0.005 mg/L NO₃ in 1 day, while water spinach is 3.03% at a rate of 0.005 mg/L NO₃ in 1 day.

Tissue structure in water hyacinth is very influential in the absorption process, because it has larger and wider leaves, so it can store a lot of nutrients and has large stomata holes, when compared to most other plants and the distance between stomata is eight times as large as the holes [5].

3.2.2 Phosphate (PO₄)

Based on Fig. 8. the preliminary test or week 0 is 0.635±0.00 mg/L PO₄. After doing the research from the first week to the fourth week, the three treatments decreased. Water hyacinth treatment succeeded in reducing the highest phosphate

from 0.635±0.00 mg/L decreased to 0.138±0.001 mg/L. Phosphate is the main inorganic nutrient needed for the growth of water hyacinth. Other nutrients, both organic and inorganic, have no effect such as nitrate and phosphate [12]. Therefore, during the study, the two treatment plants decreased, although the decrease in phosphate concentrations in the two plants was not much different.

The results of the calculation of the rate of decline and absorption in 1 day is that water hyacinth is able to absorb 5.30% in 1 day with an elimination rate of 0.038 mg/L PO₄ in 1 day, while in kale it is 4.74% with an elimination rate of 0.036 mg/L PO₄ in 1 day. The highest rate of decrease and absorption was found in the water hyacinth treatment because the large leaf width indicates a high chlorophyll content, relatively more phosphate is needed to store and transfer energy in the form of ATP and ADP [15].

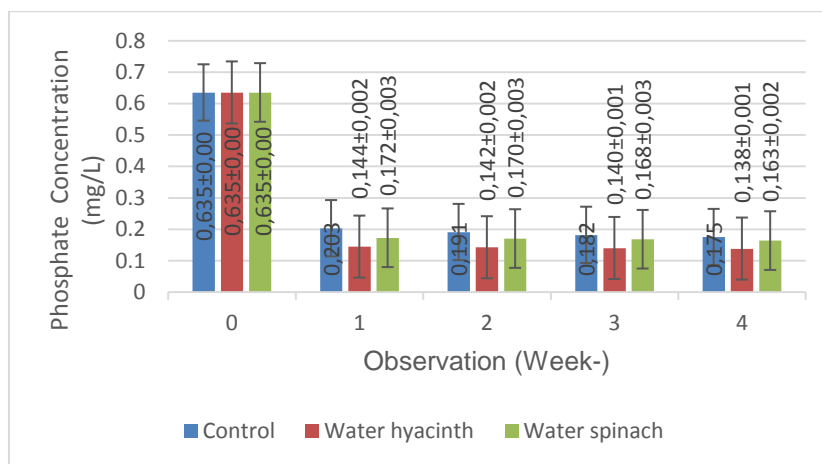


Fig. 6. Rate of phosphate Reduction and Absorption in one day during research

Table 3. Phosphate Depletion and Absorption Rate in one day during research

	Phosphate Reducing Rate/day (%)	Phosphate Absorption Rate (g/m ² /day)
Control	4,49	0,035
Water hyacinth	5,30	0,038
Water	4,74	0,036

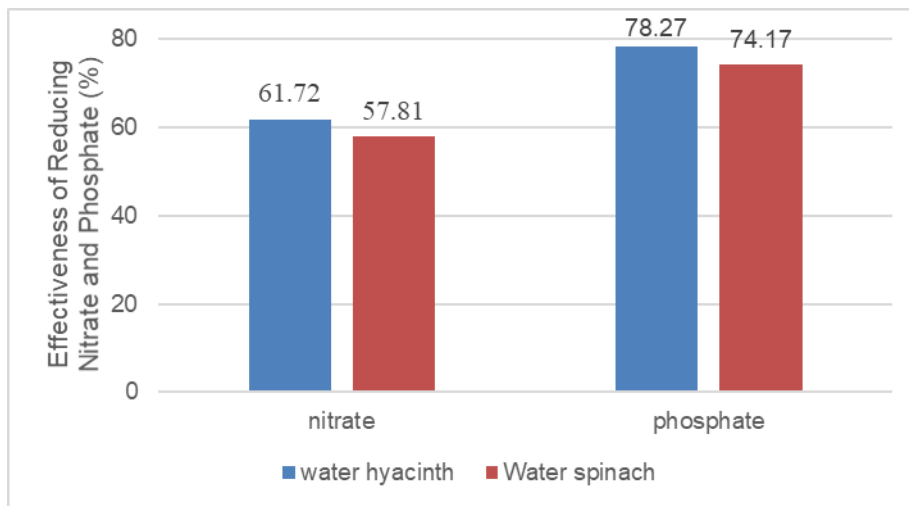


Fig. 7. Effectiveness of reducing nitrate and phosphate

3.3 Effectiveness of Reducing Nitrate and Phosphate

The results of the observations in Fig. 7 water hyacinth and water spinach were able to reduce the concentration of nitrate and phosphate. The results of the calculation of the effectiveness of nitrate and phosphate reduction showed that water hyacinth was more effective in reducing nitrate and phosphate, namely the concentration of nitrate could be decreased by 61.72% and phosphate by 78.27%. this is in accordance with previous research, in water hyacinth WWTP industrial wastewater efficiently reduces nitrate by 98.41% and phosphate by 86.14% [16]. Water hyacinth can reduce the concentration of phosphate in hospital industrial wastewater by 28.33% or 5.829 mg/L [17].

Water spinach with a weight of 200 g, effectively reduced the concentration of nitrate by 57.81%

and phosphate by 74.17%. This is in accordance with several previous studies, in water spinach laundry wastewater weighing 200 g in 10 days can reduce phosphate by 41.61% [18]. The concentration of nitrate in aquaponic system waste can be reduced by 58.57 mg/L water spinach [19].

3.4 Water Quality

3.4.1 Temperature

Based on Fig. 8 the temperature in the three treatments fluctuated. At the beginning of the research, the temperature was at 26°C and at the end of the fourth week of research the temperature was 27°C. The highest temperature was found in water spinach treatment. This was caused by leaf cover which was more tenuous, compared to water hyacinth leaf cover. It can be seen in Fig. 9 and Fig. 10.

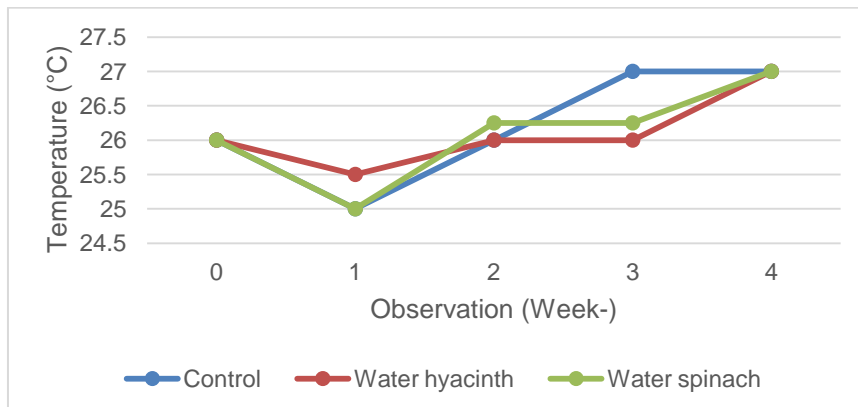


Fig. 8 Temperature during the research



Fig. 9. The density of water hyacinth leaves



Fig. 10 The density of water spinach leaves

Water hyacinth and water spinach can tolerate water hyacinth with a temperature of around 21–25.5°C, but water hyacinth grows optimally at a temperature of 27°C – 30°C [5]. and water spinach grows optimally. at a temperature of 25–30°C [5].

3.4.2 Power of hydrogen

Based on Fig. 11 the pH value of week 0 is 6 in all treatments, the first week to the fourth week for the control treatment has a stable value of 7.

The water hyacinth treatment has a stable pH value from the first to the third week with a value of 6.25 and decreases in the fourth week. with a pH value of 6, while in water spinach treatment the pH value fluctuated, in the first to second week, the pH was stable with a value of 6.5 and decreased in the third week to 6, but increased again in the fourth week with a value of 6.5. Plants can grow well at a pH of 5.5-7, because the process of absorption of nutrients from the waters can take place well [20].

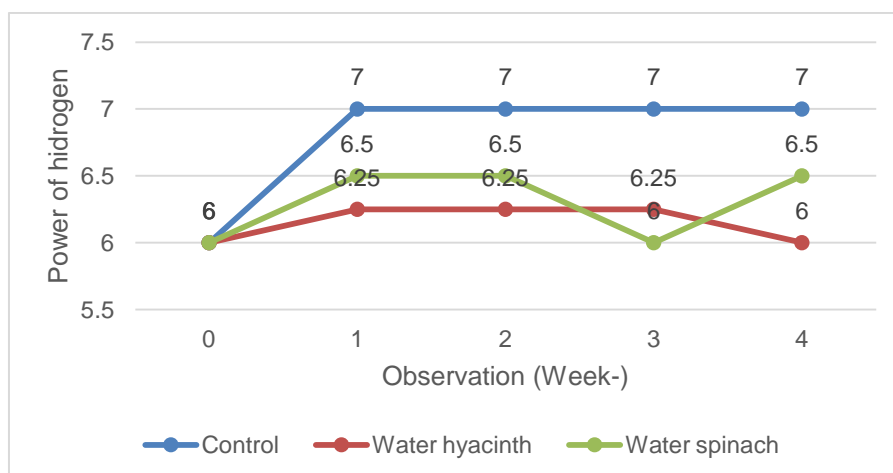


Fig. 11. pH value during the research

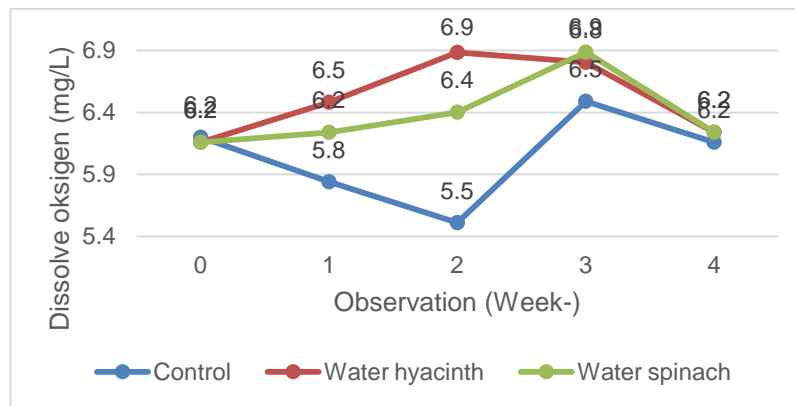


Fig. 12. Concentration of Dissolved Oxygen during the research

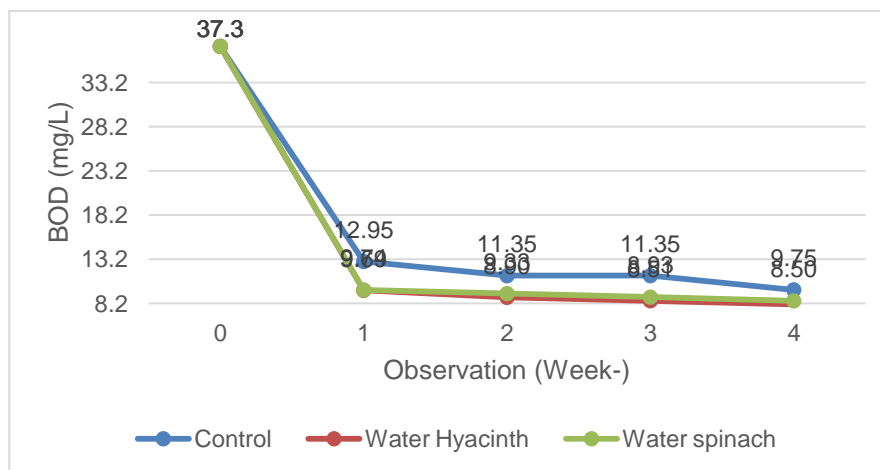


Fig. 13. BOD values during the research

3.4.3 Dissolve oksigen (DO)

Based on Fig. 12 Dissolved oxygen concentration week 0 is 6.2 mg/L. Dissolved oxygen concentration control treatment 0 to 4 weeks fluctuated. Water hyacinth experienced an increase in dissolved oxygen concentration in the 0 to the third week from 6.2 mg/L to 6.9 mg/L and decreased in the fourth week. Dissolved oxygen concentration in the 0 to 1 week water spinach treatment was stable and increased in the second to third weeks from 6.2 mg/L to 6.9 mg/L, but decreased in the fourth week. This happened because during the research there were several stalks of both dead and rotting plants. The decomposition of organic matter from decaying dead stalks can produce foul-smelling gases and cause a drastic drop in dissolved oxygen concentrations that are harmful to organisms.

3.4.4 Biological Oxygen Demand (BOD)

The results of the calculation of the BOD value in Fig. 13, week 0 reached 37.3 mg/L. All

treatments experienced a decrease in BOD values from week 0 to week four, except for the control treatment from week two to three, where the BOD value was stable at 11.35 mg/L. The BOD value decreased the most, namely in the treatment with water hyacinth in the fourth week reaching 8.10 mg/L.

The decrease in the BOD value in water hyacinth occurs due to the rhizofiltration process, namely the deposition of pollutants by the roots, then the absorbed nutrients will enter the stem through transport vessels and spread to all parts of the plant. Nutrients in stems that have undergone biological reactions and accumulate will be passed on to the leaves [21].

4. CONCLUSION

Based on the results of research that has been carried out for 28 days, water hyacinth weighing 200 g is more effective in reducing nitrate and phosphate than water spinach with the same

weight. Water hyacinth can reduce nitrate by 61.72% and phosphate by 78.27% with the rate of absorption of nitrate in one day reaching 0.006 g/m² and phosphate of 0.038 g/m². The growth rate of water hyacinth at weeks I, II, III and IV were 5.03±0.971%, 6.31±0.971%, 6.80±0.321% and 7.18±0.277%. Meanwhile, other water parameters that can be reduced are BOD from 37.3 mg/L to 8.10 mg/L.

ACKNOWLEDGEMENTS

Thank you to all those who have helped and encouraged me to complete this research.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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DOI: 10.32583/farmasetis.v8i2.599

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