Use Of Waterhyacinths To Remove Nitrogen And Phosphorus From Eutrophic Waters

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ABSTRACT

Greenhouse studies indicated that waterhyacinths [*Eichhornia crassipes* (Mart.) Solms] accounted for large losses of NH_4^+- and NO_3^--N and lesser amounts of PO_4^{-3}-P from 6 liters of water containing either 0.3 g (50 ppm), 0.6 g (100 ppm), or 1.5 g (250 ppm) of N or P. Ammonium -N at 0.3 and 0.6 g was completely gone from the water in 15 and 21 days, while NO_3^--N at the 0.3 g level was completely removed within 23 days. Large losses of NH_4^+- and NO_3^--N also occurred within 35 days at the higher concentrations. At the three P concentrations, about 80, 150 and 210 mg of PO_4^{-3}-P were removed from the water. Field experiments at two locations indicated that the waterhyacinths increased the rate at which NH_4^+-N was lost from the pond waters but were completely ineffective in increasing NO_3^--N disappearance. Results obtained on PO_4^{-3}-P losses with the plants showed minimal P losses at both locations.

INTRODUCTION

Waterhyacinth is a pest plant species which often abounds in inland waters of tropical and subtropical regions throughout the world. Because of its abundance, several workers have suggested that it might have some value in animal feeds or as a green manure (2, 4, Chaturvedi[1]). Waterhyacinths are capable of rapid growth and multiplication (7, 8, 10) and absorb large quantities of some plant nutrients (3, 6, 9). Therefore, several researchers have proposed this species as a nutrient scavenger plant in eutrophic waters and waste effluents (3, 6, 10, 11).

The present study was conducted in a greenhouse and in the field to ascertain the ability of waterhyacinths to reduce high concentrations of NH_4^+-, and NO_3^--N and PO_4^{-3}-P in eutrophic waters.

METHODS AND MATERIALS

Waterhyacinths still possessing float cells were gathered from a shallow bayou in Ascension Parish near Sorrento, La. They were transported to the test sites in tubs containing the bayou water and were used within a few hours after removal from their natural habitat. In the greenhouse tests, glazed clay pots (four replicates) were filled with 6 liters of tap water containing either 0, 0.3 g (50 ppm), 0.6 g (100 ppm), or 1.5 g (250 ppm) of the N or P as NH_4Cl-N, KNO_3-N or KH_2PO_4-P. Tap water was added every 3 to 4 days to maintain the 6 liter volume. In the first tests, one waterhyacinth was placed in each pot and the N or P concentrations were determined weekly. A second experiment was conducted similarly at a later date without the inclusion of any waterhyacinths in order to determine whether nutrient losses from the water were attributable solely to plant uptake. Ammonium-N was determined by Nesslerization, NO_3^--N by the phenoldisulphonic acid method and PO_4^{-3}-P by the molybdate-ascorbic acid method (1).

Field studies were conducted in two farm ponds, one located at Baton Rouge and the other at St. Gabriel, La. These ponds were selected because the sediments possessed different textural characteristics and organic matter contents. The Baton Rouge sediment was a silt loam with 1.3% organic matter while the St. Gabriel sediment was a heavier textured clay loam with 0.8% organic matter. Thirteen 220 liter bottomless barrels were painted with an inert epoxy paint and set firmly into the pond sediment. Because of the difficulty in setting some of the barrels in the sloping pond bottoms, the contained waters varied slightly in volume but averaged about 150 liters per barrel. They then had either NH_4Cl, KNO_3 or KH_2PO_4 added to four of the barrels. Quantities were calculated so as to bring the water in each barrel to about 6 g in either N or P. The thirteenth barrel served as a control for the natural N and P content of the water. Waterhyacinths were brought to the test sites, weighed and three uniformly-sized plants were then added to two of the four barrels containing each nutrient. Every 2 to 4 days 10 ml water samples were removed from each barrel and the water depth within each barrel was measured to the nearest cm. This allowed nutrient concentrations to be expressed in g of N or P in the barrels which were continually losing water from evaporation and evapotranspiration. Tests were conducted for four weeks at each site. The plants which had multiplied prolifically during both test periods were then gathered from the barrels and reweighed. In the work at St. Gabriel, the final number of plants per barrel were counted.

RESULTS AND DISCUSSION

In the greenhouse tests large quantities of NH_4^+-N were

[1]Chaturvedi, H. S. 1933. Economic utilization of waterhyacinth in Louisiana with particular reference to its use as a source of potash salts. M.S. Thesis. Louisiana State University, Baton Rouge.

removed from the waters due to the presence of the waterhyacinths (Figure 1). There were also NH_4^+ losses from the pots which did not contain plants, but these values did not approach the magnitude observed in the waters with plants. No explanations can be given for the NH_4^+ losses from pots without plants. Final pH values were in the range 6.9 to 7.2, and therefore one would not expect loss via volatilization of ammonia. It is possible that some NH_4^+ was slowly adsorbed onto the glazed clay, perhaps through minute cracks in the pots, or possibly microbial contaminations under the greenhouse conditions resulted in some NH_4^+ immobilization. Regardless, it appeared that the waterhyacinth plants were responsible for greatly increasing the losses of NH_4^+-N from the waters.

Nitrate-N losses were also quite high. Although the rates of loss appeared slower than NH_4^+-N losses when plant data alone were viewed, these losses are actually greater than they appear because there was almost no NO_3^{-3}-N loss from the waters of pots without plants.

The PO_4^{-3}-P losses from the waters were smaller than either of the N losses. Data from the pots without plants indicated that there were no P losses from precipitation or other mechanisms and therefore the average losses of 80, 150, and 210 mg per pot with waterhyacinths were considered to be due to plant uptake. At the highest level,

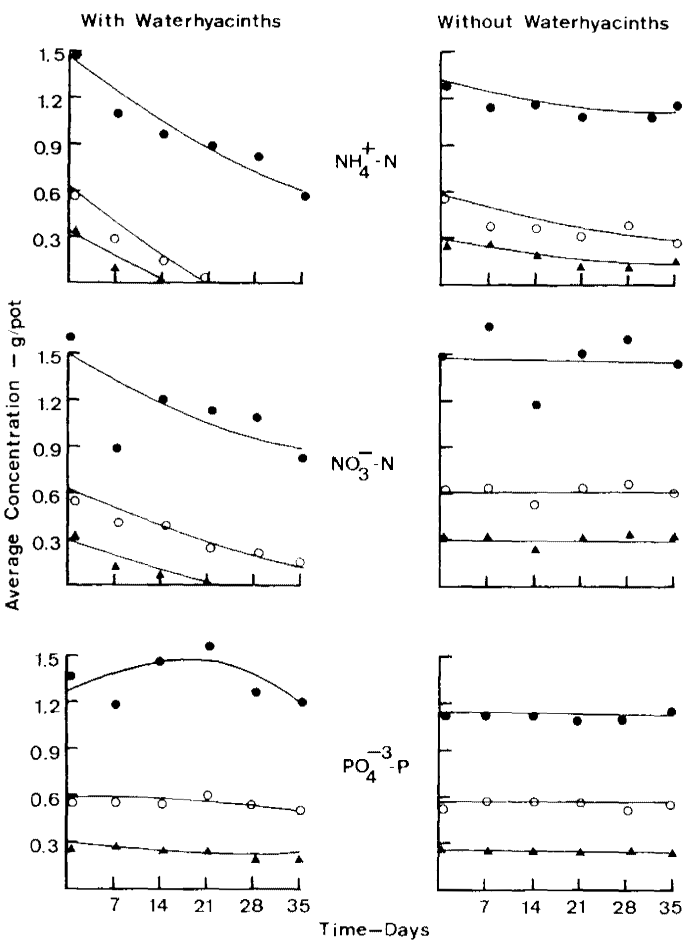

Figure 1. The average change in the grams of NH_4^+- and NO_3^--N and PO_4^{-3}-P in 6 liters of water, with and without one waterhyacinth plant grown in a greenhouse.

P was apparently released to the water during the first three weeks of the experiment. Rogers and Davis (9) reported a similar P release in 4-day experiments using 10 and 25% Hoagland's nutrient solution. They attributed this to a physiological adjustment of the plant when transferred from full strength Hoagland's solution to a solution much lower in P. The plants used in our study were selected for uniform size and age and were removed from their natural environment only hours before transfer to the more concentrated P solutions. It appeared that our P losses involved other than physiological adjustments, and we can presently offer no explanation for the temporary P release.

Calculations were made to determine the average daily ratio of N (NH_4^+- + NO_3^--N) to P losses from the water. These values were determined to be 6, 6 and 5 to 1 (N to P) at the 0.3, 0.6, and 1.5 g/pot concentrations. The values are in agreement with those of Boyd (3) and Rogers and Davis (9). From this, one could predict much lower P. losses than N losses via waterhyacinths uptake.

Criticism could be made that the N and P levels used in the greenhouse experiments were excessively high and that other essential nutrients were absent from the waters. The high levels of nutrient were chosen in order that changes in levels of nutrient concentration could be observed over an exceedingly broad range of N and P values. This also permitted analytical determinations to be made on very small volumes of the solutions, thus minimizing nutrient losses due to sample removals. Also preliminary tests by us not reported on herein, had indicated that the inclusion of other nutrients in the form of one-half strength Hoagland's nutrient solution had no effect on either NH_4^+-N or PO_4^{-3}-P losses by waterhyacinths over a 4-week-period. Nitrogen and P losses in that experiment corresponded quite closely to those seen in Figure 1.

The N and P losses found in the greenhouse tests were considered of sufficient magnitude to warrant field tests during the summer of 1974. These data on NH_4^+- and NO_3^--N, and PO_4^{-3}-P losses are presented in Figure 2.

Results indicated that waterhyacinths caused increased losses of NH_4^+-N from waters at both Baton Rouge and St. Gabriel. However, it appeared that the plants were completely ineffective in contributing to the loss of NO_3^--N and were of minimal value in PO_4^{-3}-P losses at both locations. Nitrate and PO_4^{-3} decreased in concentration due to other mechanisms however, (i.e. denitrification, adsorption, etc.). In view of the results from the greenhouse tests and the rapid proliferation of the plants during the pond tests, (Table 1) it was surprising to see that the plants were so ineffective under the field conditions. Although the results varied at the two locations, the weight gains were considered quite high with plant weight increases ranging from about 300 to 450% over the starting weights. The data gathered at St. Gabriel indicated a 400 to 500% increase in average number of plants per barrel over the 28 day test. Other work by Dunigan (5) indicated that the waterhyacinth roots were populated by large numbers of denitrifying microorganisms. Apparently, they were of no help in lowering NO_3^--N concentrations in the waters containing the plants.

TABLE 1. THE AVERAGE WEIGHT GAIN AND PLANT INCREASE OF WATERHYACINTHS GROWN IN THE N OR P AMENDED WATERS OF TWO FARM PONDS.[a]

Average Plant Parameters	Location					
	Baton Rouge			St. Gabriel		
	NH_4^+-N	NO_3^--N	PO_4^{-3}-P	NH_4^+-N	NO_3^--N	PO_4^{-3}-P
Original weight - (g)	358	383	343	355	355	340
Final weight - (g)	1618	1695	1445	1070	1225	1278
Gain in weight - %	452	443	421	301	345	376
Final number of plants[b]	—	—	—	13	12	15

[a] Test duration: 28 days.
[b] Three plants were placed in each barrel on day 0.

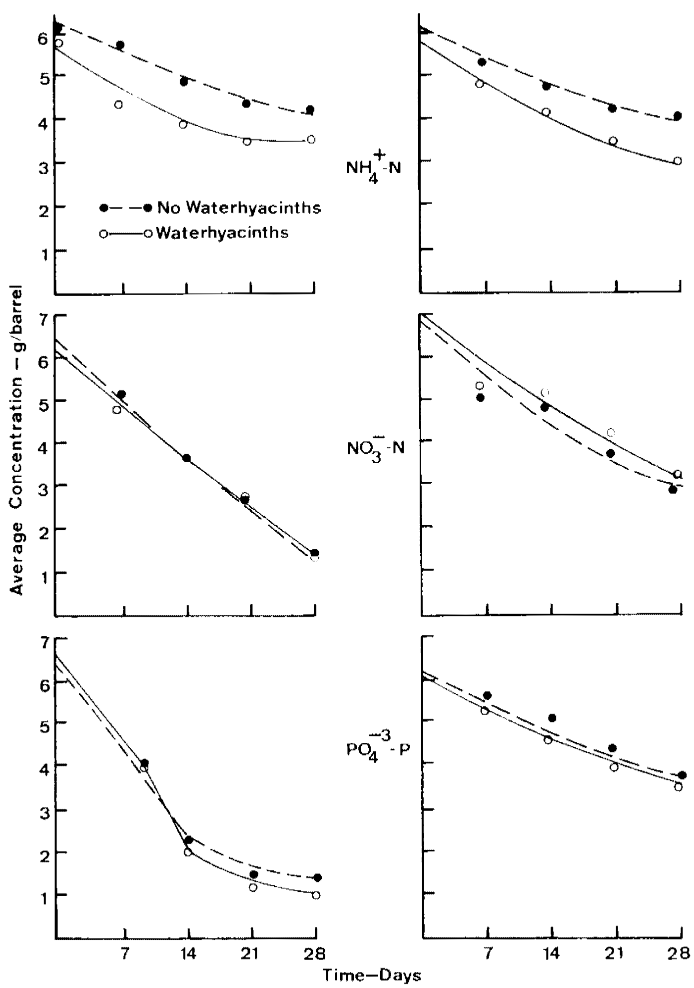

Figure 2. The average change in grams of NH_4^+- and NO_3^--N and PO_4^{-3}-P in 220 liter bottomless barrels with and without waterhyacinth plants grown in two farm ponds.

In conclusion, waterhyacinths were shown to be capable of helping in the removal of NH_4^+-N from water in both greenhouse and field tests. Although they aided in NO_3^--N and PO_4^{-3}-P removal from waters in greenhouse tests, they were of no value in NO_3^--N removal in field tests and were responsible for only minor PO_4^{-3}-P removal from water at the two field locations. Further field tests are needed to elucidate their value with respect to PO_4^{-3}-P uptake.

LITERATURE CITED

1. American Public Health Assoc. and Others. 1971. Standard methods for the examination of water and wastewater. 13th ed. Amer. Public Health Assoc., Inc. N.Y., N.Y. 874 p.
2. Boyd, C. E. 1969. The nutritive value of three species of water weeds. Econ. Bot. 23:123-127.
3. Boyd, C. E. 1970. Vascular aquatic plants for mineral nutrient removal from polluted waters. Econ. Bot. 24:95-103.
4. Boyd, C. E. and D. H. Vickers. 1971. Variation in the elemental content of *Eichhornia crassipes*. Hydrobiol. 38:409-414.
5. Dunigan, Edward P. 1974. Some preliminary observations on the nitrogen utilizing microorganisms on the roots of waterhyacinths. Proc. La. Acad. Sci. 37:22-24.
6. Haller, William T. and D. L. Sutton. 1973. Effect of pH and high phosphorus concentrations on growth of waterhyacinth. Hyacinth Contr. J. 11:59-61.
7. Penfound, W. T. 1956. Primary production of vascular aquatic plants. Limnol. Oceanogr. 1:92-101.
8. Penfound, W. T. and T. T. Earle. 1948. The biology of the waterhyacinth. Ecol. Monogr. 18:447-472.
9. Rogers, H. H. and D. E. Davis. 1972. Nutrient removal by waterhyacinth. Weed Sci. 20:423-428.
10. Sahai, R. and A. B. Sinha. 1969. Contribution to the ecology of Indian aquatics. I. Seasonal changes in biomass of waterhyacinths [*Eichhornia crassipes* (Mart.) Solms]. Hydrobiol. 35:376-382.
11. Steward, K. K. 1970. Nutrient removal potentials of various aquatic plants. Hyacinth Contr. J. 8:34-35.
12. Yount, J. L. and R. A. Crossman, Jr. 1970. Eutrophication control by plant harvesting. J. Water Pollution Control Fed. 42:173-183.