Removal Of Phosphorus From Static Sewage Effluent By Waterhyacinth[1]

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ABSTRACT

Waterhyacinth [*Eichhornia crassipes* (Mart.) Solms] was grown in static sewage effluent during May to July 1974 in outdoor concrete containers with a capacity of 760 liters and a surface area of 1.66 m^2. The plants were removed weekly from one-half of the surface area of the containers during 5-wk growth periods. Tissue phosphorus (P) and nitrogen (N), plant productivity, and some parameters of water quality were measured. A maximum uptake of 5,500 μg of P/g dry weight of plant material occurred when the level of orthophosphate phosphorus (available P) in the effluent was 1.1 μg/ml. Phosphorus in the effluent was reduced from an initial concentration of 1.4 μg/ml to 0.2 μg/ml by the end of the 5-wk period with an 80% decrease occurring during the first 3 wk. Productivity as measured by dry weight was maximum after 1 wk, but productivity in terms of number of plants was maximum after 2 wk. Crude protein of the plants harvested after 1 wk was 20%, but decreased to 9% by the end of the growth period.

INTRODUCTION

Utilization of various aquatic macrophytes to remove nutrients from domestic sewage and other types of waters high in nutrients has been suggested as a possible tertiary treatment method. Rogers and Davis (8); Knipling, et al. (6); and Sheffield (11) all have reported on the high growth rates and nutrient removal capabilities of waterhyacinth. Scarsbrook and Davis (10) reported that waterhyacinth absorbed 2.87 g of P, 6.93 g of N, and 8.73 g of potassium (K) during a 23-wk period when grown in sewage effluent contained in pools 2.7 m in diameter by 0.7 m in depth. Dry weight of these plants increased about 30-fold.

The purposes of this experiment were to determine the rate of uptake of P by waterhyacinth grown in a static municipal sewage effluent and to suggest a schedule of harvests that would take advantage of the productivity and nutrient removal capabilities of waterhyacinth.

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METHODS AND MATERIALS

Waterhyacinth plants were collected from roadside canals near the Agricultural Research Center in Fort Lauderdale, Florida. The plants were transported to the Research Center and placed in outdoor concrete tanks containing 760 liters of pond water. Effluent, collected weekly from the City of Fort Lauderdale's Treatment Plant A (an activated sludge secondary treatment system), was transported to the Research Center and placed into additional concrete tanks. A total of eight tanks was set up from May 1974 through July 1974. Each tank contained 30 young plants (18/m^2) of uniform size and 760 liters of effluent with a surface area of 1.66 m^2. The plants were harvested weekly by removing the vegetation contained within one-half the surface area. Plants were air dried for approximately 3 hr, then placed in paper bags and put into a forced-draft oven for 7 days at 65 C. Dried samples were weighed, then ground in a Wiley mill to pass a 40 mesh screen. Phosphorus in the samples was determined after digestion with nitric and perchloric acids (5) using the colorimetric method described by Boyd (4). Crude protein was determined using the macro-Kjeldahl (N X 6.25) method (2).

Some parameters of effluent quality were monitored weekly by analyzing for pH, conductivity, total phosphate phosphorus (total P), and available P. Total P and available P were analyzed by the stannous chloride extraction procedure (1).

RESULTS AND DISCUSSION

The highest dry weight yield of waterhyacinth plants grown in sewage effluent was 97 g/m^2 after 1 wk (Figure 1). This represented a 45% increase in tissue dry weight in 1 wk when compared to the initial weight of 67 g/m^2. Knipling, et al. (6) reported a 39% increase in fresh weight after 8 days in P concentrations of 0.075 to 0.60 ppm. The daily increment factor (3) for dry weight during the first wk was 1.05 g dry wt/m^2 per day. This value was similar to that found by Bock (3) during a 7-day period in August 1964 in a natural environment. A gradual decrease in dry weight yield occurred after the 1-wk harvest until only 35 g/m^2 was measured at the end of the 5-wk growth period.

After 1 wk of growth in the sewage effluent, 34 waterhyacinth plants per m^2 were harvested; this was a 90% increase over the initial number of plants placed in the

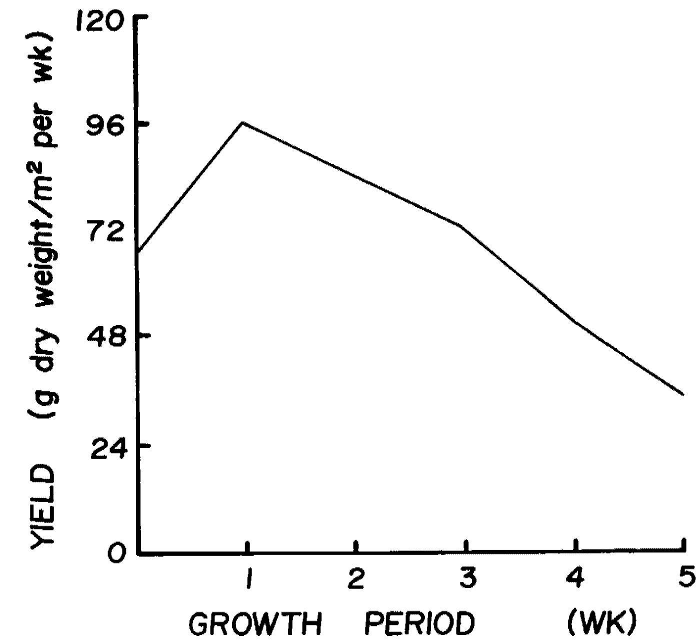

Figure 1. Waterhyacinth yield as dry weight per m^2 from weekly harvests of one-half of the area of concrete containers filled with sewage effluent. Each value is the mean of eight containers.

containers (Figure 2). This was equivalent to 1.9 daughter plants produced per parent plant per wk. Rushing (9) found 1.9 to be a medium rate of production from field sites in Puerto Rico. The daily increment factor for plant number during the first wk was 1.1 plants/m^2 per day. The maximum number of plants produced was 41/m^2 after 2 wk, representing a 108% increase over the initial number of plants. The daily increment factor from wk 1 to wk 2 of 1.03 plants/m^2 per day is similar to that found by Bock (3) in a natural area for a 7-day period in August 1964. Perkins (7) also reported similar increment factors from various locations throughout the world. The number of plants produced after the 2-wk harvest decreased to a low of 16/m^2 for the last 7 days of the 5-wk growth period.

At the beginning of the study the waterhyacinth plants contained 20.6% crude protein (Figure 3). After 1 wk, the protein content was essentially the same as the initial plants, but the levels in the plants collected at the remaining harvest times were lower. The greatest decrease in crude protein occurred from wk 2 to wk 3 representing a 31% decrease. No change in crude protein occurred from wk 4 to wk 5. At wk 5 the crude protein content was 9.1% which represented a 55% decrease in crude protein over the 5-wk period. Knipling, et al. (6) reported an average of 1.75% N (10.9% crude protein) in waterhyacinth from a lake in Gainesville, Florida.

Tissue P showed a similar trend to that of crude protein (Figure 4). The P level did not change from the initial value to wk 1. A 17% decrease occurred from wk 1 to wk 2 followed by a decrease of 18% from wk 2 to wk 3. No changes occurred from wk 3 to wk 5.

The sewage effluent contained an average of 1.42 μg available P/ml at the beginning of the growth period. After 1 wk the level decreased 32% to 0.97 μg P/ml. At wk 2 the level was 0.41 μg P/ml; this was a 58% decrease from wk 1. At wk 3, 4, and 5 the levels were 0.28, 0.26, and 0.20 μg P/ml, respectively. Thus, 71% of the P was removed during the first 2 wk of growth. The trend of total P in the effluent was essentially the same as that of available P except that the values were slightly higher.

A regression analysis indicated that maximum uptake of P by waterhyacinth occurred when the available P in the effluent was at 1.1 μg/ml (Figure 5). This relationship of the available P in the sewage effluent as the in-

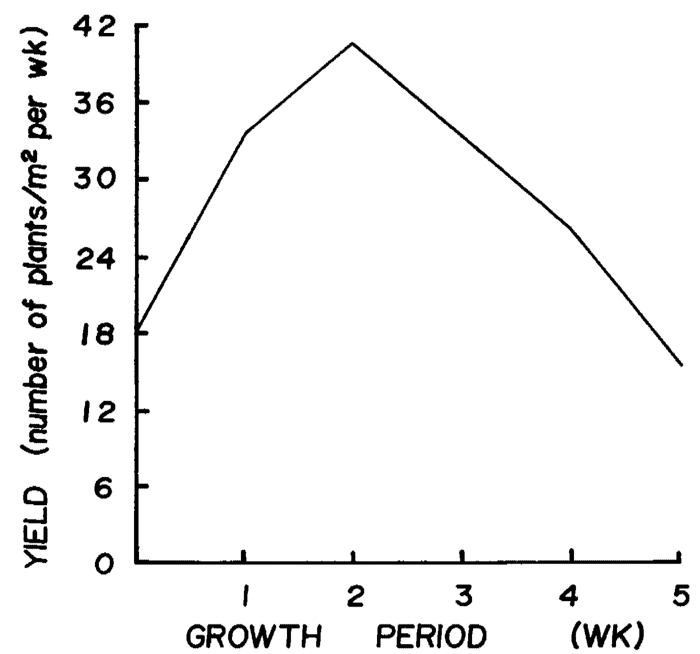

Figure 2. Waterhyacinth yield as number of plants produced per m^2 from weekly harvests of one-half of the area of concrete containers filled with sewage effluent. Each value is the mean of eight containers.

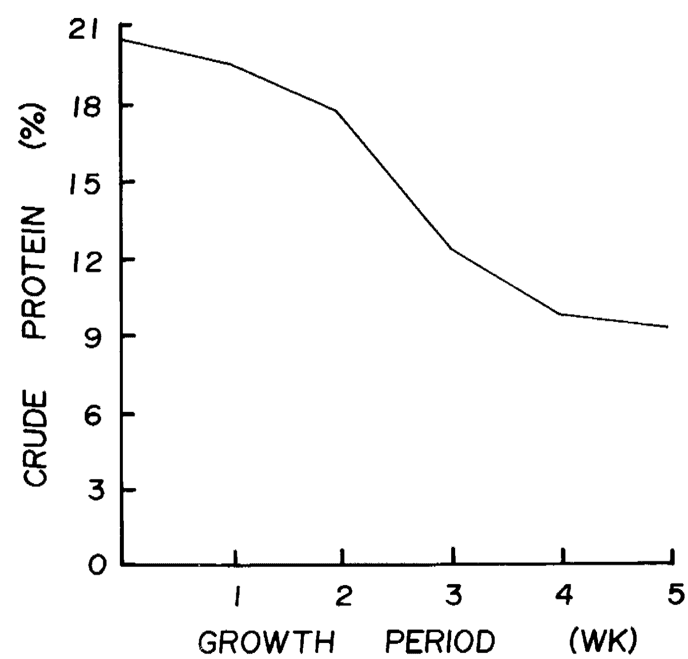

Figure 3. Crude protein of waterhyacinth plants harvested weekly from concrete containers filled with sewage effluent. Each value is the mean of eight containers.

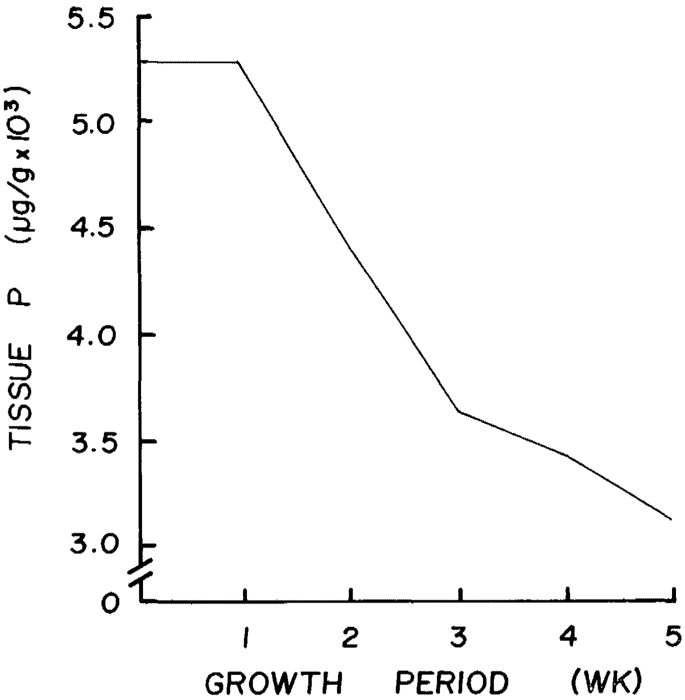

Figure 4. Phosphorus content of waterhyacinth plants harvested weekly from concrete containers filled with sewage effluent. Each value is the mean of eight containers.

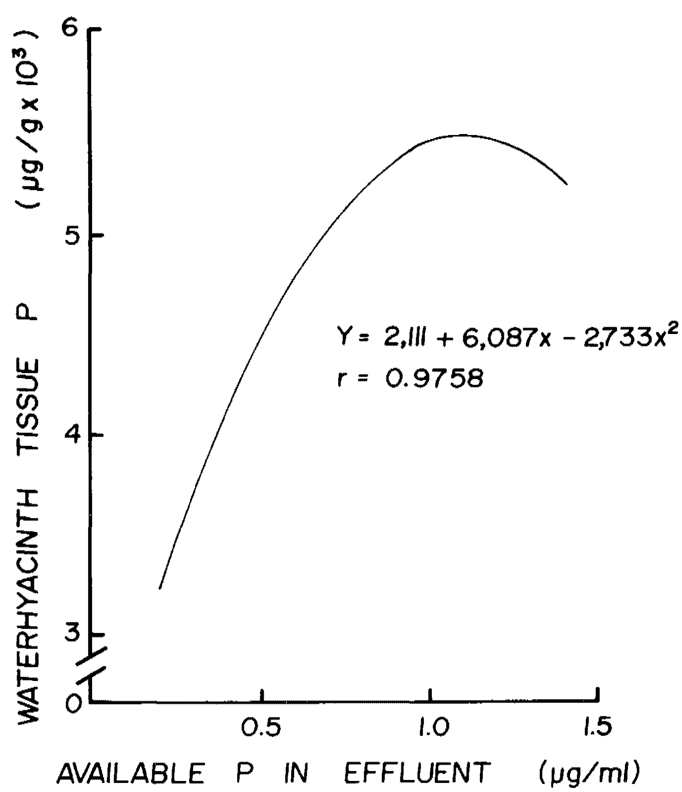

Figure 5. Phosphorus content of waterhyacinth plants (Y) harvested weekly as related to available P in the sewage effluent (x). Each value is the mean of eight containers.

dependent variable (x) and the P content of the waterhyacinth tissue as the dependent variable (Y) is significant at the 1% level, and would be useful in predicting P levels in waterhyacinth based on available P in the water.

The pH of the sewage effluent initially averaged 6.9 followed by a gradual increase with time until the pH of the water was 8.0 by the end of the 5-wk growth period. Conductivity of the sewage effluent at the beginning of the study was 2,074 μmho/cm, but was reduced 25% by the end of the 5-wk period.

This study indicated that waterhyacinth could be used to reduce P in sewage effluent to low levels. However, the length of time involved may not make this a practical method because of the space required to hold the sewage effluent under static conditions. For example, to hold the sewage effluent from 1 day's production of a treatment plant processing 3.8 million liters per day would require a surface area of 8,190 m² with a depth of 0.5 m. A more practical approach would be to grow the plants in the sewage lagoon and then harvest when growth and nutrient content of the waterhyacinth is maximum. This study suggests that weekly harvests of waterhyacinths for 1 year from sewage effluent renewed weekly would result in growth of 5 kg dry weight/m². Based on this amount of dry weight, these plants would contain 0.9 kg of crude protein and 22 g of P. These plants could then be used as a mulch, soil amendment, or for other purposes.

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LITERATURE CITED

1. American Public Health Association. 1971. Standard Methods for the Examination of Water and Wastewater. 13th ed. New York. 874 pp.
2. Association Official Agricultural Chemist. 1965. Methods of Analysis. Assoc. Official Agri. Chem., Washington, D.C. 957 pp.
3. Bock, J. H. 1966. An ecological study of *Eichhornia crassipes* with special emphasis on its reproductive biology. Ph.D. dissertation. University of California. Berkeley. 175 pp.
4. Boyd, C. E. 1966. Elemental composition of several fresh water algae. Ph.D. dissertation. Auburn University. Auburn. Alabama. 67 pp.
5. Johnson, C. M. and A. Ulrich. 1959. II. Analytical methods for use in plant tissue analysis. Pages 52-53 *in* Calif. Agric. Exp. Sta. Bull. 766.
6. Knipling, E. B., S. H. West, and W. T. Haller. 1970. Growth characteristics, yield potential, and nutritive content of waterhyacinths. Proc. Soil and Crop Science Soc. of Florida 30:51-63.
7. Perkins, B. D. 1972. Potential for waterhyacinth management with biological agents. Pages 53-64 *in* Proceed. of Ann. Tall Timbers Conf. on Ecol. Animal Control by Habitat Management. Vol. 4.
8. Rogers, H. H. and D. E. Davis. 1972. Nutrient removal by waterhyacinth. Weed Science 20:423-428.
9. Rushing, W. N. 1974. Waterhyacinth research in Puerto Rico. Hyacinth Contr. J. 12:48-52.
10. Scarsbrook, E. and D. E. Davis. 1971. Effect of sewage effluent on growth of five vascular aquatic species. Hyacinth Contr. J. 9:26-30.
11. Sheffield, W. C. 1967. Waterhyacinth for nutrient removal. Hyacinth Contr. J. 6:27-30.