Effect Of PH And High Phosphorus Concentrations On Growth Of Waterhyacinth[1]

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ABSTRACT

Growth of waterhyacinth (*Eichornia crassipes* (Mart.) Solms) plants was unaffected by a range of pH values which includes the pH of most natural bodies of water. Maximum growth of waterhyacinth occurred in acid (pH 4.0) to slightly alkaline (pH 8.0) water. Under high levels of phosphorus fertilization, waterhyacinth plants exhibited luxury consumption of phosphorus. Maximum growth of waterhyacinth occurred in water with a phosphorus concentration of 20 ppm. As the phosphorus content of the water was increased from 0 to 40 ppm, waterhyacinth plants absorbed greater amounts of phosphorus. Phosphorus absorbed by these plants became more uniformly distributed in the leaves, stems, and roots when the phosphorus concentration was increased in the nutrient solution.

INTRODUCTION

Many studies have been conducted to determine the nutritive value of aquatic plants, including waterhyacinth. Aquatic plants generally have a low percentage of dry matter, produce a large mass of vegetation, and have a nutritive content that varies with the time of the year and maturity of the plants (2, 3, 4).

The possible use of aquatic plants to remove nutrients from waste effluents and eutrophic water has received considerable attention in recent years. Waterhyacinth plants have received primary attention because of their spreading growth habit and high productivity (6, 11, 14, 17). A single waterhyacinth plant reportedly can absorb over 3 mg of phosphorus per day (13). In this same comprehensive study of nutrient removal by waterhyacinth plants, 1.0 ha of waterhyacinth was estimated to have the capability of removing from water the annual nitrogen and phosphorus output of slightly over 800 people (13).

This paper describes experiments designed to (a) evaluate pH effects on the productivity of waterhyacinths, (b) measure the maximum amount of phosphorus absorbed by waterhyacinth plants, and (c) determine the distribution of the absorbed phosphorus in the plants.

METHODS AND MATERIALS

Culture of plants during experimental periods. Waterhyacinth plants 10 to 18 cm in height were collected from canals in the vicinity of Fort Lauderdale, Florida. Algae and senescent root tissue were removed from these plants. Plants were selected for uniform size, weighed, and placed three each in polyethylene containers with 11 liters of 0.5-strength Hoaglands nutrient solution (9). Sequestrene 330 Fe[3] was added to the basic nutrient solution as an iron source at a rate of 5 mg/l. The plants remained in a screened growthhouse for a period of 4 weeks for each of the following experiments.

pH experiment. Before placing the weighed plants in containers, the pH levels of the nutrient solutions were adjusted to 2, 4, 6, 7, 8, 10, and 12 with 3 M hydrochloric acid (HCI) or 3 M sodium hydroxide (NaOH) as required. Each nutrient solution at the various pH levels was replicated three times. Distilled water was added to the containers weekly to replace water lost through evapotranspiration. After 2 weeks, the plants were removed from the containers, and the pH of the nutrient solutions checked and returned to their original levels. The plants were returned to the containers and allowed to grow an additional 2 weeks after which they were harvested, dried, and weighed. The final pH of the nutrient solutions was also determined.

Phosphate experiment. Nutrient solutions were prepared with 0.5-strength Hoaglands nutrient solution, minus phosphate. Phosphate in the form of phosphoric acid (H_3PO_4) was added as required to attain concentrations of 0, 5, 10, 20, 40, 80, 160, and 320 ppm of elemental phosphorus. Each phosphorus concentration was replicated three times. Solution pH was maintained between 5.0 and 6.0 by the addition of 3 M NaOH as necessary. The solutions were brought to volume weekly with distilled water and the pH was checked and adjusted if necessary after 2 weeks. After 4 weeks, the plants were harvested, rinsed, dried, weighed, and ground in a Wiley mill through a 40 mesh screen. Plant tissue was analyzed for phosphorus content by the procedure described by Boyd (1).

RESULTS AND DISCUSSION

Waterhyacinth plants grew over a pH range of 4.0 to 10.0 (Table 1) which includes most natural bodies of water (10). Maximum growth of these plants occurred in acid to slightly alkaline water. The addition of 3 M NaOH

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[3]Sodium ferric diethylenetriamine pentaacetate with 14.2% iron as Fe_2O_3. Mention of a trademark name or proprietary product does not constitute a guarantee or warranty of the product by the University of Florida and does not imply its approval to the exclusion of other products that also may be suitable.

TABLE 1. EFFECT OF pH ON DRY WEIGHT OF WATERHYACINTH PLANTS DURING A 4-WEEK PERIOD.

pH		
Initial	After 4 weeks	Plant dry weight (g)[a]
2.0	1.9	0.0 a
4.0	4.6	18.3 c
6.0	6.8	15.4 c
7.0	7.6	13.3 bc
8.0	7.3	14.5 bc
10.0	8.7	9.4 b
12.0	9.4	-2.1a[b]

aValues in a column followed by the same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test. Each value is the mean of three replications.

bNegative value indicates a decrease in the weight from the estimated dry weight of plants originally placed in the containers.

to the nutrient solution at pH 12 produced a precipitate which probably included many of the essential nutrients required for growth and may be the reason for the death of the waterhyacinth plants when placed in this solution.

The final pH values of the nutrient solutions are presented to show the influence of the waterhyacinth plants on pH levels in water. The free diffusion of carbon dioxide with the atmosphere and the uptake of nutrient salts by plants affect the pH level. Measurements of the initial and final pH levels indicated that waterhyacinth plants growing in either acid or alkaline water had a tendency to change the pH towards neutrality.

Growth of waterhyacinth as determined by dry weight was higher when grown in a medium of 20 ppm phosphorus than when grown in 0, 5, 10, or 40 ppm concentrations (Table 2). Phosphorus concentrations higher than 40 ppm were toxic to waterhyacinth. At the higher phosphorus concentrations, the neutralization of phosphoric acid with sodium hydroxide resulted in solutions with salinities toxic to waterhyacinth.[4] Reduced growth in the 40 ppm solution was probably a reflection of high salinity, not high enough to be toxic, but sufficient to reduce growth.

Separation of the plants into leaves, stems, and roots shows that the weights of the leaves and stems followed a pattern of growth similar to the whole plant. Weight of the roots growing in the 0 ppm phosphorus nutrient solution was nearly twice the weight of roots growing in the other solutions. Lack of phosphorus in the nutrient solution apparently stimulated root growth of these plants. The more extensive growth of roots would present a larger surface area for absorption of solutes than for plants growing in the other nutrient solutions. Roots of plants growing in nutrient solutions containing phosphorus were a normal, grey-black color, but roots of plants in the nutrient solution without phosphorus were an iridescent blue, indicative of anthracyanin production and phosphorus deficiency (16).

Table 2 indicates that 20 ppm of phosphorus resulted in a higher mass of leaves and stems produced than for the other concentrations. However, the percent of leaves and stems produced in the 20 ppm phosphorus solution is no different than for the other phosphorus concentrations, except that the 0 ppm phosphorus solution caused an increase in root growth and consequently reduced the percent weight in the leaves and stems.

As the phosphorus content of the water was increased from 0 ppm to 40 ppm phosphorus, the phosphorus content of the plant parts increased. However, the increase was not proportional to the phosphorus content in the water (Table 3). The phosphorus content of the leaves was higher than the roots or stems at the lower phosphorus concentrations, but as the concentration of phosphorus was increased in the water, the distribution of phosphorus in the plants became more uniform. Phosphorus content of the whole plants increased with each increase in the phosphorus content of the water. As the phosphorus content of the water was increased from 20 to 40 ppm, growth of the waterhyacinth plants decreased from 32.4 to 23.2 g (Table 2); however, the phosphorus content of the plants increased from 7.22 to 9.06 mg phosphorus per gram dry weight. Luxury consumption, or an increase in nutrient uptake without an accompanying increase in growth, has been reported for waterhyacinth, but the upper magnitude of phosphorus absorption is not known (8).

Plotting the phosphorus content of the plants versus the phosphorus content of the water indicates graphically that a maximum accumulation of phosphorus in waterhyacinth is being approached in the 40 ppm phosphorus solution. This implies that water with higher phosphorus content will not increase the amount of phosphorus

[4]Haller, W. T. and D. L. Sutton. 1972. Unpublished data.

TABLE 2. DRY WEIGHT OF WATERHYACINTH PLANTS GROWN IN NUTRIENT SOLUTIONS WITH DIFFERENT PHOSPHORUS CONCENTRATIONS.

Phosphorus concentration (ppm)	Plant dry weight (g)[a]			
	Leaf	Stem	Root	Total
0	4.4 a	6.0 a	6.8 b	17.2 a
5	7.8 b	10.9 b	3.5 a	22.2 b
10	9.2 b	12.6 b	3.9 a	25.6 b
20	11.7 c	16.5 c	4.4 a	32.6 c
40	8.6 b	10.7 b	3.9 a	23.2 b

a Values in a column followed by the same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test. Each value is the mean of three replications.

TABLE 3. PHOSPHORUS CONTENT OF THE LEAVES, STEMS, AND ROOTS OF WATERHYACINTH PLANTS GROWN IN NUTRIENT SOLUTIONS WITH DIFFERENT PHOSPHORUS CONCENTRATIONS.

Phosphorus concentration (ppm)	Phosphorus content (mg/g dry plant wt)[a]			
	Leaf	Stem	Root	Total
0	1.17 a	0.71 a	0.96 a	0.98 a
5	4.96 b	3.00 b	1.97 b	3.77 b
10	6.77 c	4.80 c	3.12 c	5.52 c
20	8.16 d	6.73 d	6.05 d	7.22 d
40	8.80 d	9.30 e	9.26 e	9.07e

a Values in a column followed by the same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test. Each value is the mean of three replications.

b Phosphorus content of the whole plants was calculated using the percent of plant weight in the leaves, stems, and roots and the phosphorus content of these parts as a weighted average.

absorbed by the plants. Although research has indicated that other plants exhibit luxury consumption of phosphorus, waterhyacinth plants in this study absorbed four times more phosphorus than the plants previously studied (5, 7, 12). Seedlings and young immature plants have a higher phosphorus content by weight than mature plants (15). The high levels of phosphorus absorbed by waterhyacinth depend on the phosphorus content of the water, but a more important factor may be the continual production of new shoots and daughter plants.

High phosphorus absorption, complimented with the high productivity of waterhyacinth, indicates that waterhyacinth plants could be beneficial in removing large amounts of nutrients from eutrophic waters by mechanical harvesting. Presently, the cost of mechanically harvesting waterhyacinth is prohibitive, but it would be worthwhile to know the value of removing nutrients from a body of water and then including this value in determining the economic feasibility of the operation.

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