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# Effect of Nitrogen Sprays on Biomass Production and Phosphorus Uptake in Waterhyacinth[1]

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## ABSTRACT

Nitrogen (N) was applied as foliar sprays to determine the effects of different (N) concentrations on the productivity of waterhyacinth [*Eichhornia crassipes* (Mart.) Solms]. Increases in N concentration in sprays up to 30 X $10^3$ mg $l^{-1}$ resulted in increases in biomass production with significant increases in shoot growth. Higher concentrations, however, caused burning of leaf margins and eventual death of the plants. Variation in P concentration did not affect growth significantly since all P concentrations were higher than the minimum required for waterhyacinth. Increases in N concentration in sprays up to 15 X $10^3$ mg $l^{-1}$ resulted in linear increases in P uptake in all plants, irrespective of P concentration. When N concentrations greater than 15 X $10^3$ mg $l^{-1}$ were used, plants growing in media containing 7 mg $l^{-1}$ P still showed an enhanced P uptake; however lowering the P concentration of growth media to 5 and 3.1 mg $l^{-1}$ P depressed N-dependent P uptake. These results have important implications on maximizing production of waterhyacinth biomass, particularly in nitrogen deficient sewage effluent.

## INTRODUCTION

Waterhyacinth [*Eichhornia crassipes* (Mart.) Solms] is being studied extensively for biomass production and fuel conversion because of its potential high productivity. This species is also being used for the removal of excess nutrients from polluted waters and sewage effluents. Many investigators have reported on high productivity (7, 9, 12) and nutrient removal capabilities of waterhyacinth (5, 6, 9, 11). Yount and Crossman (12), and Ryther et al. (7), reported mean annual biomass productions of 45, and 88 mt dry wt $ha^{-1}$ $year^{-1}$ for waterhyacinth, respectively.

Rogers and Davis (6) reported that a single waterhyacinth has the capability of removing more than 3 mg P and over 20 mg N per day from solution. Scarsbrook and Davis (8) reported an uptake of 2.87 g of P, 6.03 g of N, and 8.73 g of potassium (K) by waterhyacinth during a 23-wk growth period in sewage effluent. Steward (10) found that waterhyacinths have a greater potential than submersed aquatic plants in absorbing N and P from the water. Haller and Sutton (3) found a positive correlation between P concentration of the growth media and the P concentration of the waterhyacinth tissues. When the P concentration was increased from zero to 40 mg $l^{-1}$ in the growth media, P of the tissues increased from 0.98 to 9.07 mg $g^{-1}$ dry wt. Gossett and Norris (1) obtained similar results for both P and N in waterhyacinth.

In earlier work it was determined that N concentration affects the P uptake in waterhyacinth (9). When P concentrations in growth media were high increases in N concentration enhanced the P uptake. However, when the P concentrations in growth media were low, reductions in N concentration resulted in increases in P uptake, while higher concentrations of N reduced P uptake.

The objectives of this study were to determine the effect of various N concentrations on biomass production when N is supplied as foliar sprays on waterhyacinth, and also to determine the effects of different N sprays on P uptake from media containing different P concentrations.

## MATERIALS AND METHODS

Seventy liters of 10% Hoagland's solution minus N (4) were prepared in containers with a surface area of 0.12 $m^2$ and a depth of 60 cm. Urea solutions [$CO(NH_2)_2$] provided N concentrations of zero, 5X, 10X, 15X and 20 X $10^3$ mg $l^{-1}$ in the spray. One ml spreader-sticker (Chase & Company, Sanford, Florida) was added to each liter of urea spray solution. The P concentration of this series of containers was 3.1 mg $l^{-1}$. Two other series of containers were prepared in the same manner except that in the second series the concentration of P was adjusted to 5 mg $l^{-1}$ and in the third series to 7 mg $l^{-1}$. Five uniform plants (approximately 10 cm long) were transfered to each container on 14 September, 1979. The containers were located in an open field under a clear plastic canopy in order to prevent the urea from being washed from the leaf surface by rainfall. Three replicates for each treatment were prepared, and each treatment was sprayed with urea solution containing different N concentrations. The plant tops were sprayed to saturation at the beginning of the experiment and also 2 weeks after growth in the containers. Plants were harvested 2 weeks after the second spray.

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In another experiment, 10% Hoagland solution minus N was adjusted to provide P concentrations of 0.5 mg $l^{-1}$ in one series and 5 mg $l^{-1}$ in another series. Nitrogen concentration in the growth media of both series was adjusted to 0.5 mg $l^{-1}$. Four uniform plants (approximately 15 cm long) were transferred to each container on 18 October, 1979. Three replicates for each treatment were prepared, and each treatment was sprayed as before with urea solutions containing zero, 15X, 20X, 25X, or 30 X $10^3$ mg $l^{-1}$ N. Again, plants were harvested 2 weeks after the second spray, or 4 weeks after initiation of the experiment for the measurement of dry weight and P uptake. Dry weight and P content of the tissues were measured as previously described (9).

## RESULTS AND DISCUSSIONS

Increases in P concentrations from 3.1 to 5 or 7 mg $l^{-1}$ in growth media did not affect the growth of waterhyacinth significantly when the N concentration was held constant (Table 1). Since these P concentrations were much higher than 0.1 mg $l^{-1}$, the critical P concentration for maximum waterhyacinth growth (2), the excess P taken up by waterhyacinth was luxury consumption and hence did not increase growth. Increasing the N concentration in urea sprays up to 30 X $10^3$ mg $l^{-1}$ increased the biomass yield (Tables 1 and 2). The increase was especially significant for shoots,

TABLE 1. THE EFFECT OF NITROGEN AS A FOLIAR SPRAY ON THE GROWTH OF WATERHYACINTH (G DRY WT/PLANT) IN SOLUTIONS OF VARIOUS PHOSPHORUS CONCENTRATIONS.[a]

| Nitrogen concentration mg $l^{-1}$ X $10^3$ | Phosphorus concentration[b] (mg $l^{-1}$) | | |
|---|---|---|---|
| | 3.1 | 5 | 7 |
| 0 | 2.6a | 2.9a | 2.9a |
| 5 | 3.5a | 3.6ab | 3.8a |
| 10 | 4.5b | 4.6bc | 5.0b |
| 15 | 5.6c | 5.5cd | 5.2b |
| 20 | 6.7d | 6.6d | 5.9b |

[a] Phosphorus was added to the growth medium whereas nitrogen was supplied from urea in two foliar sprays.
[b] Values in a column followed by the same letter are not significantly different at 5% level as determined by Duncan's Multiple Range Test. Each value is the mean of three replicates, with each replicate containing five plants.

whereas increases in N concentration in excess of 30 X $10^3$ mg $l^{-1}$ caused burning at the margins of the leaves and still higher concentrations killed the plants. Foliar application of various N-containing sprays resulted in no consistent difference between the root dry weight productions of plants in 0.5 mg $l^{-1}$ P and those in 5.0 mg $l^{-1}$ P. The application of nitrogenous foliar sprays enhanced the dry weight production in the plant top, with either 0.5 or 5.0 mg $l^{-1}$ P in the growth medium (Table 2). At both levels of P, growth increases depended upon increases in N concentration of the sprays. At the 5.0 mg $l^{-1}$ P level, the two 30 X $10^3$ mg $l^{-1}$ N sprays caused a doubling of the shoot dry weights; however, the N sprays had less promotive effect on top growth when the P concentration of the growth medium was 0.5 mg $l^{-1}$. In this case, the maximum enhancement in dry weight production was 56%. It is thought that the P in

TABLE 2. THE EFFECT OF FOLIAR APPLIED NITROGEN ON THE GROWTH OF WATERHYACINTH (G DRY WT/PLANT) IN SOLUTIONS OF 0.5 AND 5.0 MG $l^{-1}$ P.[a]

| Nitrogen concentration mg $l^{-1}$ X $10^3$ | Phosphorus concentration[b] (mg $l^{-1}$) | | | |
|---|---|---|---|---|
| | 0.5 | | 5.0 | |
| | Root | Shoot | Root | Shoot |
| 0 | 2.8a | 5.4a | 3.4a | 4.8a |
| 15 | 3.3a | 6.2ab | 3.7a | 8.1b |
| 20 | 3.2a | 7.6bc | 3.3a | 8.1b |
| 25 | 3.1a | 8.4c | 4.0a | 9.3b |
| 30 | 3.8a | 8.1c | 3.6a | 9.9b |

[a] Phosphorus was added to the growth medium whereas nitrogen was supplied from urea for both growth medium (0.5 mg $l^{-1}$) and the foliar sprays.
[b] Values in a column followed by the same letter are not significantly different at 5% level as determined by Duncan's Multiple Range Test. Each value is the mean of three replicates, with each replicate containing four plants.

growth medium (P = 0.5 mg $l^{-1}$) was consumed during the growth period and reached a critical point which resulted in less growth in comparison to the plants grown in media containing greater P but receiving the same amount of N.

Increase in N concentrations in sprays resulted in increases in P uptake by the plants grown in media containing 3.1, 5, and 7 mg $l^{-1}$ P (Figure 1). The increases were linear up to 15 X $10^3$ mg $l^{-1}$ N for all three levels of P. However, when the N concentration was increased from 15 X $10^3$ mg $l^{-1}$ to 20 X $10^3$ mg $l^{-1}$, P uptake was decreased in plants grown in medium containing 3.1 mg $l^{-1}$ P. In the

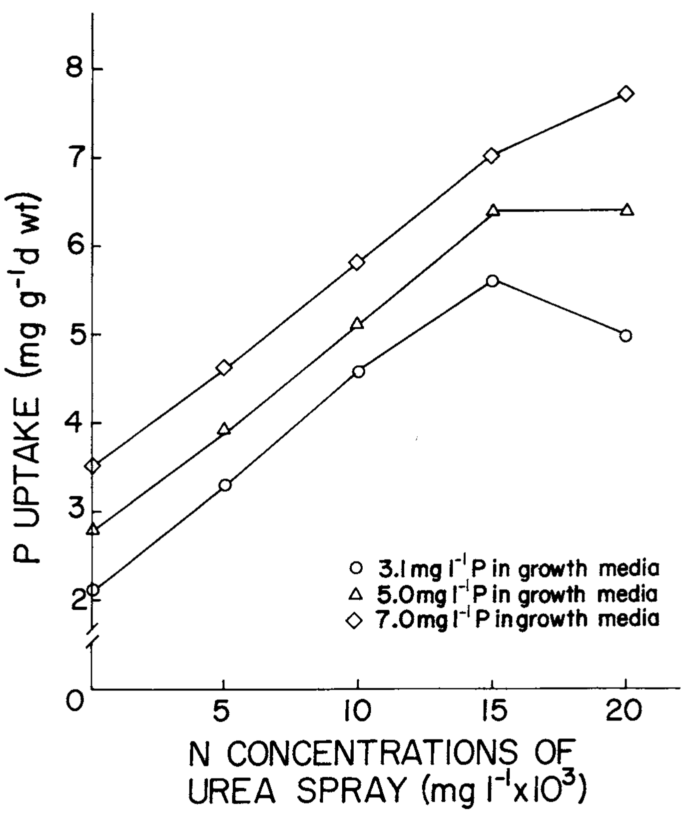


Figure 1. The effect of various N concentrations of urea spray on P uptake from growth media after 4 weeks.

presence of 5 mg $l^{-1}$ P, increasing the N concentration of urea spray from 15 X $10^3$ mg to 20 X $10^3$ mg $l^{-1}$ had no effect on P uptake, while increasing N concentration in the presence of 7 mg $l^{-1}$ P resulted in additional P uptake from the medium. These results confirm the previous findings (9) that when the concentration of P is high in a growth medium P uptake can be promoted by the application of higher N concentrations, and when the P concentration is low in a growth medium, an increase in N concentration can depress P uptake.

When the N concentration was adjusted to 0.5 mg $l^{-1}$ in two series of growth media, one containing 0.5 mg $l^{-1}$ P and another 5 mg $l^{-1}$ P, addition of nitrogenous foliar sprays containing larger than 15 X $10^3$ mg $l^{-1}$ N caused a decrease in P uptake by waterhyacinth growing in medium containing 5 mg $l^{-1}$ P (Figure 2). However, when the concentration of P in the growth medium was 0.5 $l^{-1}$, an increase in the N concentration of the foliar spray resulted in practically no change in P uptake. Inasmuch as the amount of P in the growth medium was low, the plants with the different N treatments absorbed all the available P and did not show differences in P uptake (Figure 2).

Increases in P concentration in growth media resulted in increases in P uptake as long as the N concentration remained the same for each treatment. (Figures 1 and 2). Similar results have been reported by Haller and Sutton (3) and Haller et al. (2). In our studies, when the P concentration was high in the growth media, smaller percentages of available P were absorbed from the media than when lower amounts of P were present (Table 3). These results are in

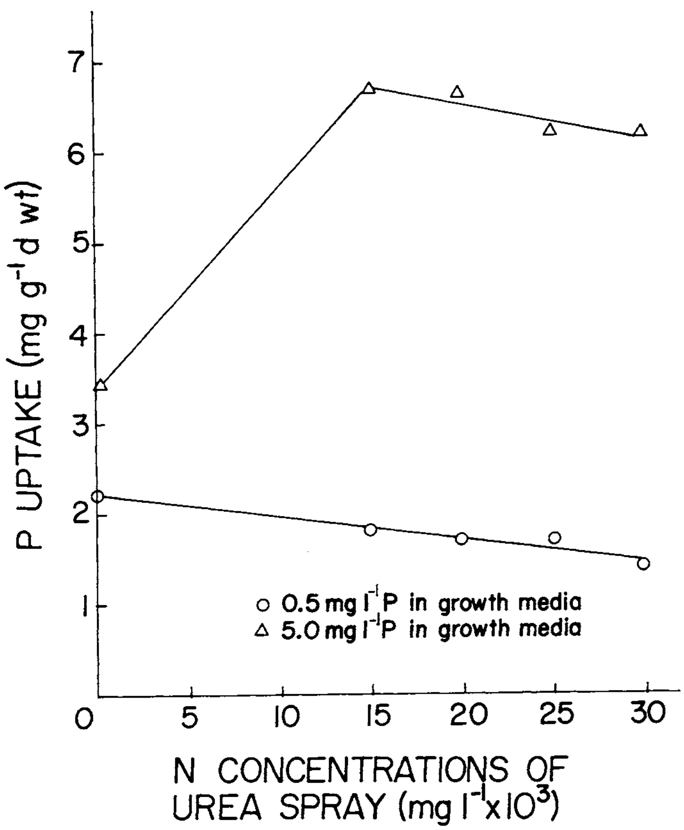


Figure 2. Effect of high N concentrations of urea spray on P uptake from growth media after 4 weeks.

TABLE 3. THE EFFECT OF NITROGEN CONCENTRATION ON PHOSPHORUS UPTAKE BY WATERHYACINTH.[a]

| Nitrogen concentration mg $l^{-1}$ X $10^3$ | % Available phosphorus taken up[b] Phosphorus concentration (mg $l^{-1}$) 3.1 | 5 | 7 |
|---|---|---|---|
| 0 | 13±1 | 11±3 | 10±1 |
| 5 | 27±2 | 20±2 | 18±2 |
| 10 | 48±3 | 34±6 | 31±2 |
| 15 | 73±11 | 51±5 | 36±4 |
| 20 | 78±10 | 60±6 | 46±7 |

[a] Phosphorus was added to the growth medium whereas nitrogen was supplied from urea in two foliar sprays.
[b] Each value is the mean of three replicates, with each replicate containing five plants.

agreement with Haller et al. (2) although the P concentrations they used were much lower (from 0.01 to 0.6 mg $l^{-1}$).

Distributions of P in roots and shoots on a percentage basis were about equal for all P concentrations in growth media when no N was applied as urea spray (Table 4). However, the percentage P accumulated in shoots increased in almost all cases when the N concentration was increased by foliar sprays.

TABLE 4. THE DISTRIBUTION OF PHOSPHORUS IN WATERHYACINTH ROOTS AND SHOOTS AS A FUNCTION OF FOLIAR APPLICATION OF NITROGEN.[a]

| Nitrogen concentration mg $l^{-1}$ X $10^3$ | Phosphorus distribution (%)[b] Phosphorus concentration (mg $l^{-1}$) 3.1 | | 5 | | 7 | |
|---|---|---|---|---|---|---|
| | Root | Shoot | Root | Shoot | Root | Shoot |
| 0 | 43±2 | 47±2 | 42±1 | 58±1 | 50±3 | 50±3 |
| 5 | 31±3 | 69±3 | 41±3 | 59±3 | 31±2 | 69±2 |
| 10 | 28±2 | 72±2 | 25±2 | 75±2 | 29±5 | 71±5 |
| 15 | 23±1 | 77±1 | 21±1 | 79±1 | 20±1 | 80±1 |
| 20 | 25±2 | 75±2 | 20±1 | 80±1 | 16±1 | 84±1 |

[a] Phosphorus was added to the growth medium whereas nitrogen was supplied from urea in two foliar sprays.
[b] Each value is the mean of three replicates, with each replicate containing five plants.

From the data obtained here, it is recommended that when waterhyacinth is being used for large scale biomass production, and adjustment of N in growth media is not feasible, plants can be sprayed with urea solution containing proper concentrations of N for enhancement of growth. The same method can be applied for maximum P uptake from sewage effluents and other wastewaters. When P concentration is very low and N is not a limiting factor in a growth media, application of N for the enhancement of P removal is not recommended. Further research on the use of foliar fertilization of waterhyacinths is warranted. It is likely that any nutrient deficiencies in sewage effluent can be corrected by appropriate foliar sprays, thus providing adequate nutrients for maximum biomass production and nutrient removal without addition to the media.

During this study we have been interested in the waterhyacinth as a potential nutrient sink for the treatment of nutrient rich water as well as a potential biomass source for energy producing systems. Our data suggests that this aquatic plant has promise in both roles, singularly or in combination. The enhancement of biomass production and the accompanying increase in P uptake in response to foliarly-applied N (urea) may offer an opportunity to produce a highly nutritional biomass that may be used for production of fuels, feeds, compost, and perhaps other energy forms.


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