Influence of Potassium Supply on Growth and Nutrient Storage by Water Hyacinth


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Abstract

The net productivity and nutrient storage of potassium (K), nitrogen (N), and phosphorus (P) by water hyacinth (Eichhornia crassipes [Mart.] Solms) were evaluated at several K concentrations in the culture medium (between 2 and 52 mg K liter⁻¹) using 1000-liter outdoor tanks for a period of about 4 months. Maximum plant biomass (31 kg (dw) m⁻²) was reached at culture medium K concentrations of 12–52 mg K liter⁻¹. Potassium storage in water hyacinth tissue steadily increased at K supplies of up to 52 mg K liter⁻¹ with a maximum tissue K content of 72 mg K g⁻¹. Maximum N and P storage in the plant biomass was reached at K concentrations of 12 and 22 mg K liter⁻¹, respectively; further increases in K concentration did not increase either N or P storage.

Key words: Aquatic plant, biomass production, nutrient uptake, wastewater treatment.

INTRODUCTION

Potassium (K) is one of the major plant nutrients that can potentially limit the growth and nutrient uptake by water hyacinth (Eichhornia crassipes [Mart.] Solms), especially when cultured in wastewaters containing low levels of K. Under natural conditions, K is not likely to be the limiting growth factor of water hyacinth, because either N or P are present in low enough concentrations to limit its growth. Water hyacinth has one of the highest K tissue concentrations when compared with other aquatic plants (Lawrence, 1968; Boyd, 1969a, b, 1970a, b; Knipling et al., 1970; Boyd & Vickers, 1971; Scarsbrook & Davis, 1971; Parra & Hortenstine, 1974; JAAS, 1982; Sutton & Portier, 1983; Madsen & Adams, 1988), ranging from 10 to 83 mg K g⁻¹. Such a wide range of tissue K content suggests that water hyacinth has a high K requirement, and a high K uptake capability. In spite of the fact that water hyacinth has been successfully employed for treating polluted water (Stewart, 1979; Stowell et al., 1981; Duffer, 1982; DeBusk et al., 1983; Reddy & Sutton, 1984; Tchobanoglous, 1987), and for producing biomass for beneficial purposes (Parra & Hortenstine, 1974; Abbasi, 1987; Hayes et al., 1987; Salati, 1987), little data are available on the response of water hyacinth to K supply, and its interacting effects with other plant nutrients and plant density. Optimal concentrations of K to achieve maximum growth and nutrient uptake need to be established to optimize water hyacinth-based wastewater treatment systems.

The objectives of the present study were to determine: (i) the effect of the K supply on water hyacinth growth, and (ii) the interacting effects of the K supply and plant density on growth and nutrient storage in the plant tissue.

METHODS

Water hyacinth plants were collected from the St Johns River near Sanford, Florida, and cultured in outdoor tanks for a period of 2 weeks. The experimental period was from 3 April 1984, to 25 July 1984. The maximum–minimum ambient air temperature and solar radiation measured at the experimental site are presented in Fig. 1. Water hyacinth plants were placed in 1000-liter concrete
Plant tissue was analyzed for total K and P after digestion with nitric-perchloric acid (Jackson, 1958) followed by analysis on an atomic absorption spectrophotometer and an autoanalyzer (APHA, 1985), respectively. Total N was determined by digestion (Bremner & Mulvaney, 1982) followed by analysis on an autoanalyzer (APHA, 1985). Solar radiation was continuously monitored at the experimental site using a solar monitor with an integrator. Maximum and minimum air temperatures were monitored using a recording hygrothermograph.

RESULTS AND DISCUSSION

The biomass accumulation of water hyacinth was affected by the K supply (Fig. 2). Maximum water hyacinth biomass (3.1 kg (dw) m⁻²) was reached at a K concentration of 52 mg K liter⁻¹. Differences in the biomass accumulation of water hyacinth plants at varying K levels were evident 6 weeks after the study was initiated, and continued to increase throughout the study.

Maximum net productivity of 33 g (dw) m⁻² day⁻¹ was reached for the plants cultured at K concentrations of 12–52 mg liter⁻¹ (Table 1). Net productivity was highest within the initial 10 weeks of the study, and declined at a plant density greater than 1.8 kg (dw) m⁻². Wooten and Dodd (1976) in Iowa, reported a maximum productivity of 29 g (dw) m⁻² day⁻¹ during the summer months for hyacinths cultured in sewage effluent. Reddy and DeBusk (1984) in Orlando, Florida, reported maximum productivity in the range of 37–52 g (dw) m⁻² day⁻¹ in hyacinths maintained at optimal plant densities (<2.0 kg (dw) m⁻²) grown in nutrient solution during the summer months. The present study was conducted during the season of maximum productivity for water hyacinth in Central Florida. The solar radiation showed very little or no temporal variation during the study period. Similarly, the maximum and minimum temperatures were optimal for maximum growth. Thus, the confounding effect of solar radiation and temperature on biomass yields as influenced by K loading was minimal. The variation in growth rates reported in the literature is a function of latitude (temperature and solar radiation), growth season, plant density, pest population, and nutrient availability (Center & Spencer, 1981; DeBusk et al., 1981; Reddy, 1984, 1988). A significant relationship between water hyacinth growth and mean daily air temperature

vaults (1.7 m² surface area) containing 900 liters of nutrient medium at a starting plant density of 4.5 kg (fresh weight) m⁻². Potassium was added as KCl at 2, 4, 7, 12, 22 and 52 mg K liter⁻¹. The treatment with no K could not be included because the tap water used contained 2 mg K liter⁻¹. Nitrogen and P were added at 20 mg N liter⁻¹ and 3 mg P liter⁻¹, respectively. Nitrogen was added as ammonium nitrate, while P was added as sodium phosphate. The N and P supply at these levels was found to be adequate to achieve maximum growth and uptake (Reddy et al., 1989, 1990). Secondary and minor nutrients were added at levels reported by Reddy and DeBusk (1984). Nutrient medium was replaced weekly. Water in the vaults was mixed constantly with submersible pumps to avoid stratification. Two Vexar mesh baskets (0.25 m², 3-cm openings) stocked with water hyacinths were placed in each vault. The density within the baskets was the same as outside the baskets. Each week baskets were removed from the vaults, drained for 5 min, weighed, and placed back in their respective vaults. This procedure was repeated until the plants in the vaults achieved maximum density, and no significant additional growth was recorded. Each vault contained two baskets; therefore, the productivity data were based on duplicate measurements from each replication.

Two plants (rosette with its ramets) were obtained randomly from outside the baskets from each vault once a week and fresh weights were recorded. Plant samples were dried at 70°C for a period of 72 h and dry weights were recorded.

Fig. 1. Maximum and minimum ambient air temperature (a) and solar radiation (b) for the study location (University of Florida's Central Florida Research and Education Center in Sanford, Florida) during the study period (3 April 1984–25 July 1984).
was shown for field cultures of water hyacinth with maximum growth observed in the temperature range of 27–30°C (Reddy, 1988). Knippling et al. (1970) showed significant interactions between light, temperature and water hyacinth growth.

The K content of plant tissue was related to the K supply (Fig. 3) with values in the range of 10–72 mg K g⁻¹. For plants grown under low K conditions (≤70 mg liter⁻¹), the K content of the tissue remained at 18 ± 5 mg K g⁻¹ throughout the study period. The effect of the K supply on plant tissue K content was evident 6 weeks after the study was initiated (14 May 1984), therefore statistical analysis was conducted on the data collected from 14 May to 25 July 1984 (using ANOVA t test (LSD), SAS (1985)). Two distinctly different response curves were observed for the relationship between productivity and K storage in the tissue (Fig. 4). During the first 70 days of the growth period, maximum net productivity was reached when the plant tissue K content increased to 52 mg K g⁻¹; a further increase in tissue-K content represented luxury consumption. When plant densities approached near maximum (70–114 days), productivity significantly decreased.

In studies conducted in China (JAAS, 1982), the tissue-K concentration of water hyacinth ranged from 50 to 83 mg K g⁻¹. Parra and Hortonstine (1974) sampled water hyacinths from 19 various water bodies in Florida and found a range of tissue-K content of 10–65 mg K g⁻¹. Similarly, Boyd and Vickers (1971) sampled water hyacinth from 17 sites around central Florida, and found a range of tissue-K concentration of 16–67 mg K g⁻¹, with a coefficient of variation of 32%. The wide range of tissue-K content found in water hyacinths at the various sites illustrates the adaptability of these plants to extreme water quality conditions. Boyd and Vickers

![Graphs showing biomass yield vs time for different K concentrations](image)

**Fig. 2.** The effect of potassium (K) loading to the culture medium at different concentrations (2–52 mg K liter⁻¹) on the biomass yields of water hyacinth plants. The LSD for the slopes of the power function curves were calculated to be 0.063.

<table>
<thead>
<tr>
<th>K-supply (mg liter⁻¹)</th>
<th>0–41 (g (dw) m⁻² day⁻¹)</th>
<th>41–70 (g (dw) m⁻² day⁻¹)</th>
<th>70–114 (g (dw) m⁻² day⁻¹)</th>
</tr>
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<tbody>
<tr>
<td>2</td>
<td>18.2c</td>
<td>18.2b</td>
<td>12.2cd</td>
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<td>20.0bc</td>
<td>21.2b</td>
<td>8.8d</td>
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<tr>
<td>12</td>
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<td>32.7a</td>
<td>22.8a</td>
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<tr>
<td>52</td>
<td>23.4a</td>
<td>32.6a</td>
<td>25.0a</td>
</tr>
<tr>
<td>LSD</td>
<td>2.8</td>
<td>7.9</td>
<td>5.5</td>
</tr>
</tbody>
</table>

*Means in the same column with the same letter are not significantly different at P = 0.05 (ANOVA t test (LSD), (SAS, 1985).
Maximum plant tissue-K storage of 212 g K m\(^{-2}\) was measured at a K supply of 52 mg K liter\(^{-1}\). Boyd and Vickers (1971) estimated maximum plant tissue-K storage at 86 g K m\(^{-2}\), based on the maximum plant biomass values of 1.3 kg (dw) m\(^{-2}\) found by Penfound (1956). The K storage value in the present study surpassed their value by about 2.5-fold, which was reasonable since the biomass value measured in the present study also was about 2.5-fold higher.

The nitrogen content of hyacinth tissue was inversely related to the K-supply rates (Fig. 5). The range of tissue-N content was 16.6–24.6 mg N g\(^{-1}\) for plants treated at K concentrations in the culture medium between 52 and 2 mg K liter\(^{-1}\), respectively. The optimal tissue-N concentration for water hyacinth (16 mg N g\(^{-1}\)) (Reddy et al., 1989) was surpassed in hyacinths grown at all K loading rates, indicating non-N limiting conditions in the culture medium.

The tissue-P content was also reduced in plants grown in culture medium supplied with high concentrations of K (≥ 12 mg K liter\(^{-1}\)) for longer than 6 weeks (Fig. 5). The range of tissue-P concentrations was 3.6–5.6 mg P g\(^{-1}\). Although the P supply (3.1 mg P liter\(^{-1}\) or 227 mg P m\(^{-2}\) day\(^{-1}\)) surpassed that required for maximum biomass yields (80 mg P m\(^{-2}\) day\(^{-1}\)) (Reddy et al., 1990), the critical tissue-P concentration of 43 mg P g\(^{-1}\)

(1971) found deviation in the linear correlation between water hyacinth tissue-K and water-K concentrations extrapolated over a wide range of nutrient concentrations in natural water bodies, due to the effects of plant density (competition for limited nutrients), and the effects of some elemental concentrations in the water which may play a role in K uptake or may be limiting to hyacinth growth. Tissue nutrient concentration may also be affected by season, with higher nutrient concentrations found during season of low growth (Boyd & Blackburn, 1970; Trevidy & Gopal, 1981; Tucker & DeBusk, 1981). Plant morphology also affects nutrient concentration of water hyacinth. For example, Knipling et al. (1970) found maximum N, P, K concentrations in the leaf, stem, and root tissue of water hyacinth, respectively.

Fig. 5. Nitrogen (a) and phosphorus (b) tissue concentrations in the water hyacinth plants between 41 and 114 days after treatment with increasing potassium concentrations in the culture medium. The bars shown with the same letter are not significant at \(P=0.05\). The LSD for N and P content was 1.63 and 0.639, respectively, at \(P=0.05\).
was not attained in hyacinths grown at K concentrations in the culture medium greater than 12 mg K liter\(^{-1}\), suggesting some interaction effects between K concentrations in the culture medium and P uptake.

In conclusion, water hyacinth biomass quantity and quality were significantly affected by the K supply. The potassium supply of 12–52 mg K liter\(^{-1}\) resulted in maximum productivity. The optimal tissue-K content required to achieve maximum productivity was 51.6 mg K g\(^{-1}\), and this concentration was achieved by hyacinths grown at a K supply of 22 mg K liter\(^{-1}\). These results suggest that when water hyacinths are cultured in K-limited water, such as sewage effluent (Reddy et al., 1985), the addition of K could potentially improve the productivity thus improving the water quality.

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REFERENCES


