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Initial growth of *Brachiaria subquadripara* (Trin.) Hitchc. plants under different nutritional conditions

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Urochloa subquadripara
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eutrophication
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A B S T R A C T

The objective of this study was to evaluate the initial growth of emergent plants of *Brachiaria subquadripara* under different conditions of availability levels of the nutrients nitrogen (N), phosphorus (P), and potassium (K) provided to the plants via nutrient solution in a greenhouse. The treatments consisted of five concentrations of N (0, 42.0, 84.0, 126.0, and 168.0 mg L^{-1}), five concentrations of P (0, 6.2, 12.4, 18.6, and 24.8 mg L^{-1}) and five concentrations of K (0, 46.8, 93.6, 140.4, and 187.2 mg L^{-1}) which were adapted from a base solution. The results showed that the initial growth of plants was slow up to 21 days after transplantation (DAT) and it increased in accordance with increments in N, P, and K concentrations in the nutrient solution up to the end of the study (35 DAT). The Relative Growth Rate and the Net Assimilation Rate of the *B. subquadripara* plants were larger when the N, P, and K concentrations were of 84.0, 18.6, and 46.8 mg L^{-1}, respectively. These results suggest that this species can develop in environments considered hypereutrophic.

Palavras-chave:
Urochloa subquadripara
Urochloa arrecta
planta aquática
planta daninha
eutrofização
reservatórios hidrelétricos

Crescimento inicial de *Brachiaria subquadripara* (Trin.) Hitchc. em diferentes condições nutricionais

R E S U M O

Propôs-se, neste trabalho, avaliar o crescimento inicial emergindo *Brachiaria subquadripara* em diferentes condições de disponibilidade dos nutrientes nitrogênio (N), fósforo (P) e potássio (K) via solução nutritiva em casa-de-vegetação. Os tratamentos se constituíram de cinco doses de N (0, 42,0, 84,0 126,0 e 168,0 mg L^{-1}), cinco doses de P (0, 6,2, 12,4, 18,6 e 24,8 mg L^{-1}) e cinco doses de K (0, 46,8, 93,6, 140,4 e 187,2 mg L^{-1}) adaptadas a solução base. Os resultados demonstraram que o crescimento inicial das plantas foi lento até os 21 dias após o transplante (DAT) e crescente de acordo com os aumentos das concentrações de N, P e K em solução nutritiva até o final do experimento (35 DAT). A Taxa de Crescimento Relativo e a Taxa de Assimilação Líquida da *B. subquadripara* foram maiores nas concentrações de 84,0, 18,6 e 46,8 mg L^{-1} de N, P e K, respectivamente. Esses resultados sugerem que esta espécie pode se desenvolver em ambientes considerados hipereutróficos.

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Introduction

Trophic conditions of rivers, lakes, and reservoirs mainly in the South and Southeast regions of Brazil have been altered principally by the influx of nutrients from agricultural activities, urban sewage, and industrial residues (Bini et al., 1999; Cavenaghi et al., 2003). Consequently, the intense colonization of polluted water bodies by aquatic plants has increasingly become a real possibility due to the favorable conditions for plant growth brought about by the increased availability of nutrients (O'Hare et al., 2010).

Due to the unpredictable growth shown by aquatic plants in reservoirs, several studies have been carried out to understand their biology and distribution as along with alternative control methods to find more appropriate management of these plants (Bini et al., 1999; Martins et al., 2009). One of these studies identified 39 species belonging to 21 families found in five hydrographic basins of the state of São Paulo, Brazil. *Brachiaria subquadripara* (Trin.) Hitchc. was among them and was one of the more frequent in the evaluated reservoirs (Martins et al., 2008).

B. subquadripara (= *Urochloa subquadripara*) is a member of the Poaceae family and it is native to Africa. Its characteristics are of a perennial plant which easily colonizes wet environments, mainly the margins of water bodies and rice producing areas. It shows high efficiency in the use of environmental resources and it grows quickly. It is resistant to temporary flooding and all those characteristics make it an aggressive invader of several environments (Kissmann & Groth, 1997; González & Morton, 2005; Mormul et al., 2010).

The success with which *B. subquadripara* plants colonize several aquatic environments may be ascribed to the allocation of biomass and nutrients for specific organs of the plant (stem, leaves, roots), the fragmentation of these vegetative organs is the main propagation means of this species as well as the formation of plant coverings which depends on nutritional resources stored in the plant (Barrat-Segretain et al., 1998). These characteristics are thought to be responsible for *B. subquadripara* being capable of suppressing other competitors (Thomaz & Bini, 1998; Domingos et al., 2011).

Notwithstanding all this accumulated amount of knowledge about this species, in Brazil few are the studies concerning *B. subquadripara* biology and growth pattern as influenced by non biotic factors such as N, P, and K concentrations in the water. It is though believed that the growth analysis by means of physiological indices may be used for the evaluation of the productivity ecological adaptation in addition to the interference potential in eutrophic environments (Thomaz et al., 2007; Henry-Silva et al., 2008) and, consequently, provide subsidies for the development of integrated and sustainable management methods for the control of this species.

So, the objective of this research work was to evaluate the initial growth of greenhouse-grown *B. subquadripara* plants under different availability levels of N, P, and K in a nutrients solution.

Material and Methods

B .subquadripara plants were collected at their occurrence environment at the Barra Bonita Hydroelectric Power Plant at Barra Bonita city (latitude of 22° 46' 4" S, longitude of 48° 9' 41" WGr. and at a mean altitude of 457 m above sea level), state of São Paulo, Brazil. The period of the experiment was 2006-2007. The plants were multiplied in a greenhouse in fifty plastic pots (13.8 x 28.3 x 11.8 cm) filled with a soil classified as a dark Red Latosol with a medium texture showing the following characteristics: pH ($CaCl_2$) = 4.1; organic matter (g dm^{-3}) = 18.0; P (mg dm^{-3}) = 8.0; H + Al, K, Ca, Mg, SB, and CTC (cation exchange capacity) ($mmol_c$ dm^{-3}) = 67.0, 0.1, 1.0, 1.0, 2.0, and 68.0, respectively; V% = 3.0.

In each pot was transferred 1 plant with three internodes in the stem, two to three open leaves starting from the apex and no roots. The plants remained in the pots above a water depth of 5 cm. For better standardization of the seedlings before transplanting in pots with nutrient solution, the plants were kept in the pots for 48 days and received an application of 30 mL pot^{-1} at 15 day intervals of a urea solution with a concentration of 4.5% of N. During this period there were two pruning to avoid tillering.

A preliminary study was undertaken to find out the most adequate nutrients solution (base solution) for the growth of *B. subquadripara* plants. To find the base solution, the nutrients solution Sarruge (1975) was diluted several times. Results showed that diluting Sarruge´s solution to 20% of its original concentration yielded the best solution for the nutritional demand of *B. subquadripara* plants. This base solution had concentrations of 168.0, 24.8, 187.2, 160.0, 38.4, and 51.2 mg L^{-1} of, respectively, N, P, K, Ca, Mg, and S. It also had concentrations of 4, 0.4, 0.4, 0.0016, and 0.0008 mg L^{-1} of Fe-EDTA, B, Mn, Zn, Cu, and Mo, respectively. The solution pH was of 6.0 ± 0.5. The treatments consisted of five concentrations of N (0, 42.0, 84.0, 126.0, and 168.0 mg L^{-1}), five concentrations of P (0, 6.2, 12.4, 18.6, and 24.8 mg L^{-1}) and five concentrations of K (0, 46.8, 93.6, 140.4, and 187.2 mg L^{-1}) which were adapted from a base solution. These concentrations correspond to hypereutrophic environment (Toledo Júnior, 1990).

The plants were transplanted to plastic recepients containing 1 L of the basic solution with the respective treatments. A plant was understood as including part of a tiller with three internodes in the stem, two to three open leaves starting from the apex and no roots. These plants were fixed in phenolic foam which was embedded in expanded polystyrene which was perforated to fix the air distributing tube stopped with a cotton wad to avoid the entrance of light and the consequent algae proliferation. The nutrient solution was renewed at each 7 days and the pH of the solution was daily adjusted to 6.0 ± 0.5 during the whole experimental period.

Evaluations began 7 days after the transplantation (DAT) of the plants to the nutrient solution and that date was considered as 0 DAT. The growth analysis of *B. subquadripara* plants was based on plants collected at 7, 14, 21, 28, and 35 DAT. The growth analysis was based on the evaluation of the following biometric parameters: leaf area, leaves, roots, and the whole plant (leaves, stem, and roots) dry matter. To determine the physiological indices, the following characteristics were estimated: relative growth rate (RGR), leaf area ratio (LAR), and net assimilation rate (NAR) in relation to the DAT, which were established by the ANACRES program (Portes & Castro Júnior, 1991).

The study was carried out according to a completely random design with six replications. The treatments with levels of N, P, and K were individually analysed in a factorial scheme 5 x 5 (5 nutrient concentration levels in the nutrient solution and 5 collecting times). The results were submitted to the analysis of variance by the F test ($p \leq 0.05$) whereas the means were submitted to a regression analysis. The statistical program 'SigmaStat 2.0' was used. The regression model was chosen on the basis of coefficient of determination, regression significance ($p \leq 0.05$), and the normality test.

The results of the physiological indices estimated by the ANACRES program, since they are calculated values, do not obey the basic assumptions for the analysis of variance. So, the indices were presented graphically for the evaluation of the growth curves behavior (Portes & Castro Júnior, 1991).

Results and Discussion

The analysis of variance results show that there was a significant interaction between the nutrients N, P, and K concentrations and the collect times for leaf dry matter, plant dry matter, and leaf area (Table 1).

At 35 DAT *B. subquadripara* showed increasing accumulation of dry matter in leaves and plant (total) to 50% of the concentration used of N, P and K. From that level upwards for each nutrient there was a severe reduction mainly in the concentrations of 168.0, 24.8, and 187.2 mg L^{-1} of N, P, and K, respectively (Figure 1). A similar behavior was observed when plant leaf area was examined (Figure 2).

Thus, at the end of the study, the highest amounts of accumulated dry matter as determined by N were observed when the concentrations of this element were of 42.0, 84.0, and 126.0 g L^{-1} with means of 6.1 ± 0.4, 11.1 ± 1.4, and 10.1 ± 0.7 of dry matter in g $plant^{-1}$, respectively (Figure 3A). When phosphorus is examined, it is seen that the highest amounts of accumulated dry matter were of 7.5 ± 0.3, 8.5 ± 0.2, and 7.9 ± 0.5 g $plant^{-1}$ when P concentrations were, respectively, of 6.2, 12.4, and 18.6 mg L^{-1} (Figure 3B). K, at the concentrations of 46.8, 93.6, and 140.4 mg L^{-1}, resulted in the highest amounts of accumulated dry matter, that is, 7.7 ± 0.8, 9.8 ± 0.7, and 8.7 ± 0.9 g $plant^{-1}$, respectively (Figure 3C). It was verified that the concentrations of 168.0, 24.8, and 187.2 mg L^{-1} of N, P, and K resulted in the lowest amounts of plant accumulated dry matter. These results were similar to those produced by the control treatment (without the addition of nutrients).

The amounts of accumulated dry matter by the leaves and the plants leaf area were similar to those of plants accumulated dry matter (Figure 4).

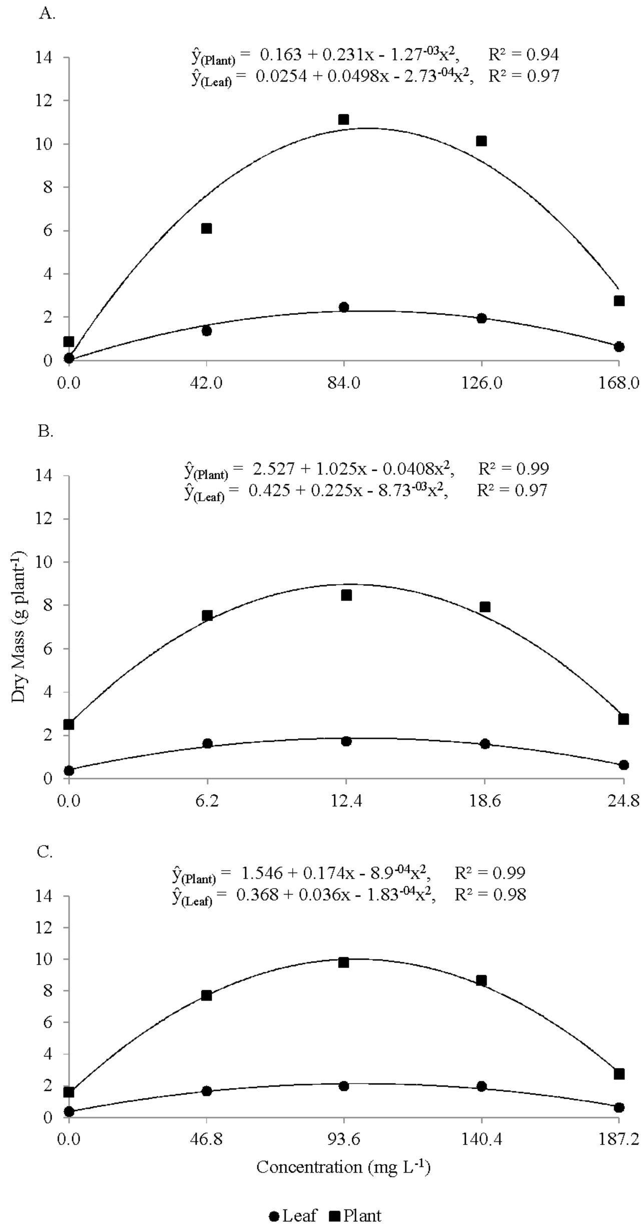

Figure 1. Leaves and plants dry mass, 35 days after seedling transplant, of *B. subquadripara* plants under different nitrogen (A), phosphorus (B), and potassium (C) concentrations

Table 1. F values of the analysis of variance for nitrogen (N), phosphorus (P), and potassium (K); N = 150 (for each nutrient)

Sources of variation	Leaf dry mass	Plant dry mass	Leaf area
		N	
Concentrations (C)	24.167 (P < 0.001)	34.040 (P < 0.001)	34.886 (P < 0.001)
Time (T)	104.420 (P < 0.001)	130.330 (P < 0.001)	109.704 (P < 0.001)
C x T	10.172 (P < 0.001)	14.205 (P < 0.001)	13.300 (P < 0.001)
		P	
Concentrations (C)	18.133 (P < 0.001)	24.318 (P < 0.001)	34.892 (P < 0.001)
Time (T)	89.968 (P < 0.001)	173.002 (P < 0.001)	163.807 (P < 0.001)
C x T	5.831 (P < 0.001)	9.961 (P < 0.001)	10.058 (P < 0.001)
		K	
Concentrations (C)	16.076 (P < 0.001)	16.136 (P < 0.001)	23.278 (P < 0.001)
Time (T)	105.660 (P < 0.001)	123.532 (P < 0.001)	176.641 (P < 0.001)
C x T	7.049 (P < 0.001)	10.575 (P < 0.001)	13.520 (P < 0.001)

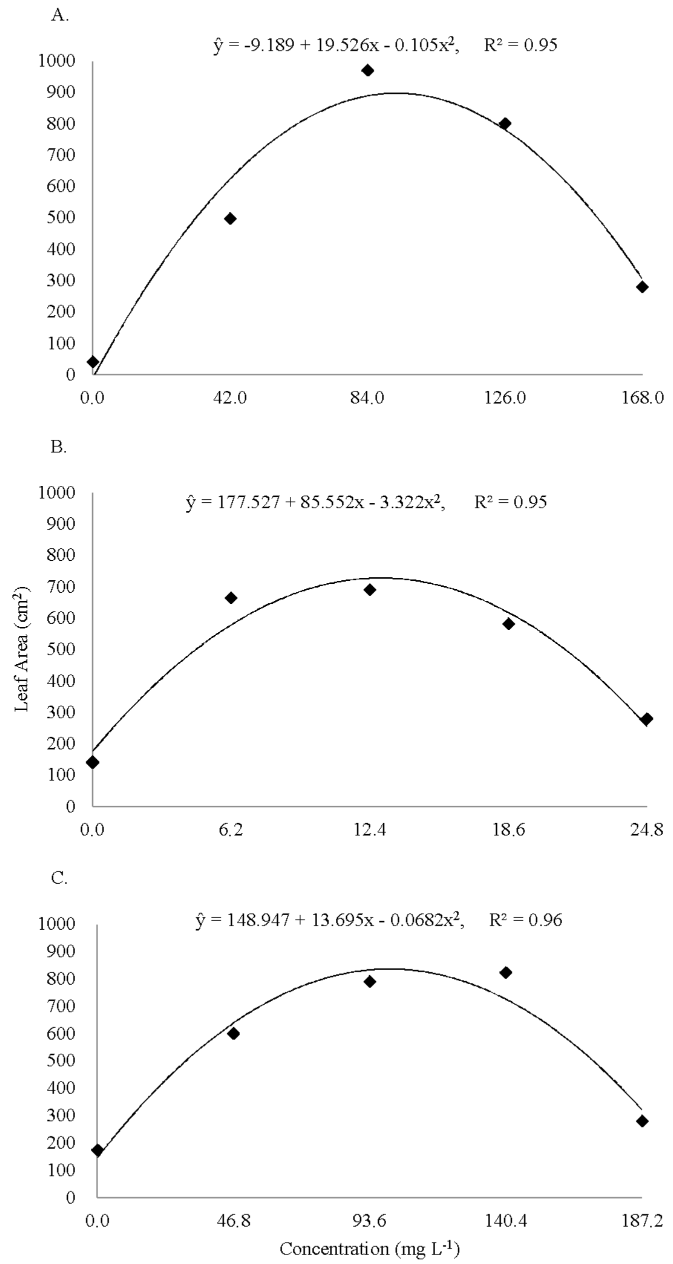

Figure 2. Leaf area, 35 days after seedling transplant, of *B. subquadripara* plants under different nitrogen (A), phosphorus (B), and potassium (C) concentrations

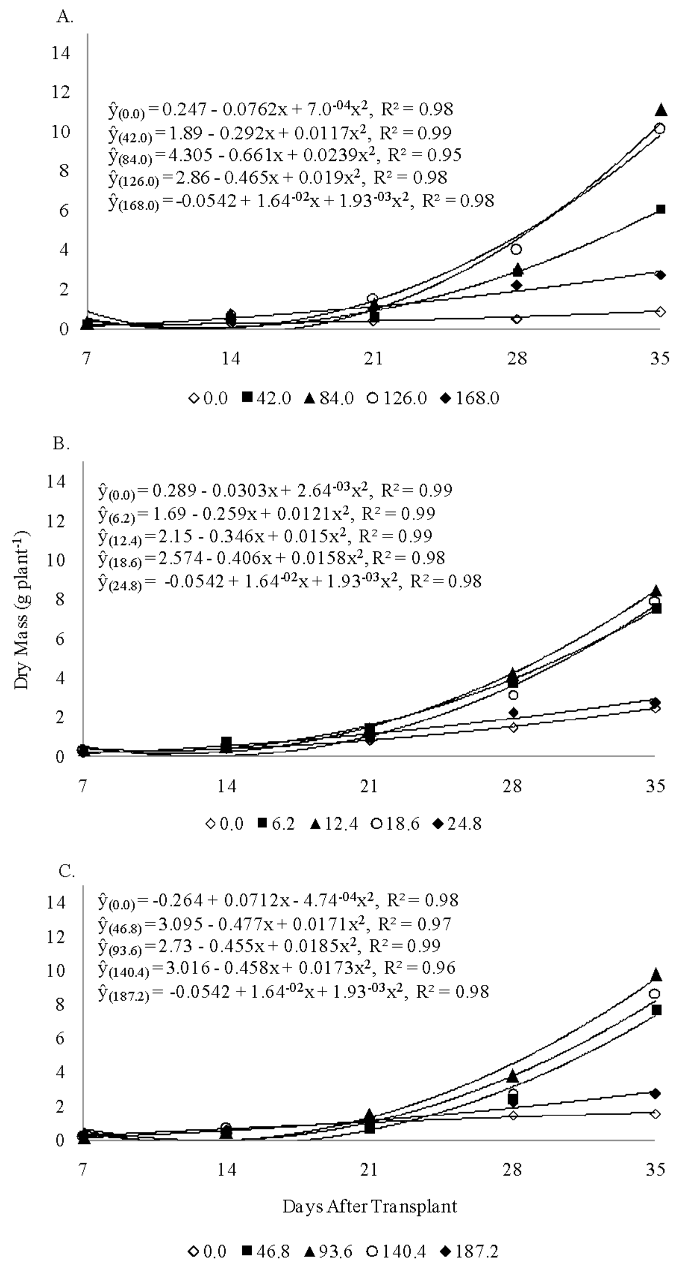

Figure 3. Dry mass of *B. subquadripara* plants under different nitrogen (A), phosphorus (B), and potassium (C) concentrations during a period of 35 days after seedling transplant

The relative growth rate (RGR) is a measure of the increment in dry weight of a plant or of any organ of that plant during a period of time. In Figure 5A it is seen that the *B. subquadripara* plants showed increasing RGR values as N concentrations increased, mainly at the concentrations of 42.0, 84.0, and 126.0 mg L^{-1}.

The concentration of 0 mg L^{-1} of N in the nutrient solution resulted in RGR relatively constant during the evaluation period with a mean of 0.05 g g^{-1} d^{-1} respectively (35 DAT). On the other hand, at the concentration of 168.0 mg L^{-1} of N in the nutrient solution the RGR values underwent a decrease as the evaluation period increased.

The concentration of 84.0 mg L^{-1} of N was considered a limit concentration for the RGR; increments above that value may cause reductions in RGR readings during plant growth.

The results for the concentrations of P (Figure 5B) show that the RGR values increased at the concentrations of 6.2, 12.4, and 18.6 mg L^{-1} during the evaluation period in which the means were of 0.14, 0.15, and 0.17 g g^{-1} d^{-1}, respectively, at 35 DAT. On the other hand, at the P concentrations of 0 and 24.8 mg L^{-1} reductions in RGR, were observed as the plants developed.

For the concentrations of K (Figure 5C) it was observed that the highest RGR value resulted when the K concentration was of 46.8 mg L^{-1} with an average of 0.21 g g^{-1} d^{-1} at 35 DAT.

It was observed a general tendency of decreasing leaf area ratio (LAR) as the plants grew. The N concentration of 168.0 mg L^{-1} caused the highest LAR with a mean of 1.0 dm^2 g^{-1} at 35 DAT (Figure 6A).

When the P effects are analysed, it is seen that the maximum LAR was reached at 21 DAT and, after that period, LAR decreased for the concentrations of 6.2, 12.4, and 18.6 mg L^{-1} (Figure 6B).

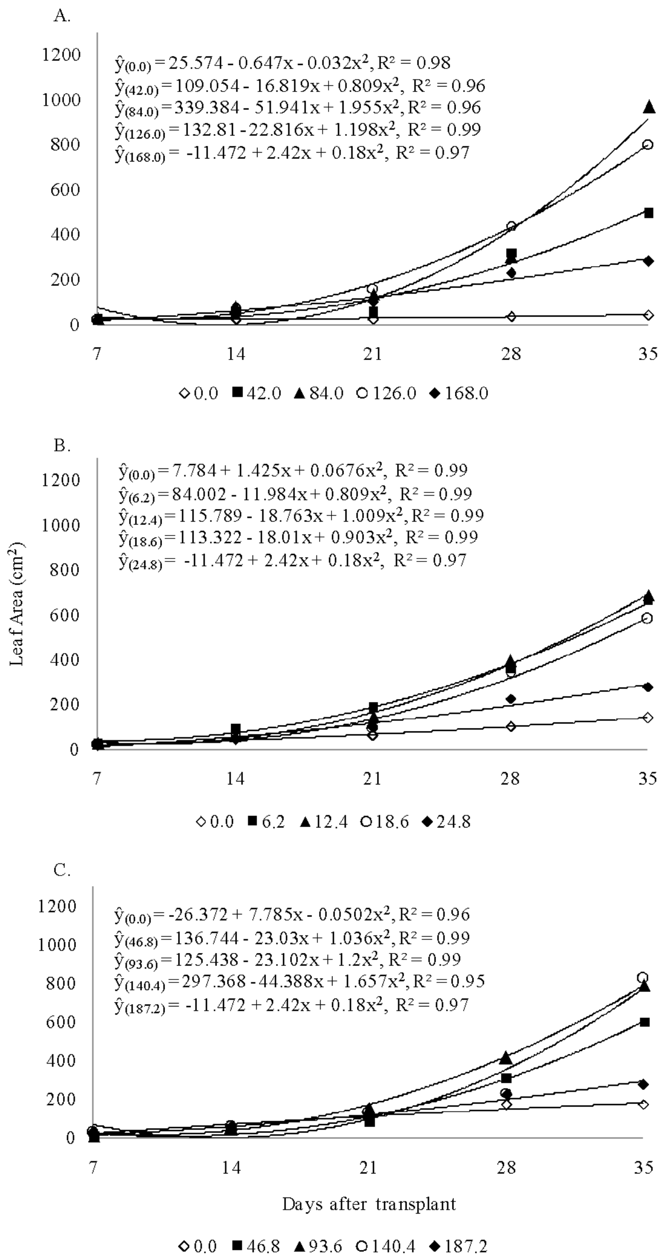

Figure 4. Leaf area of *B. subquadripara* plants under different nitrogen (A), phosphorus (B), and potassium (C) concentrations during a period of 35 days after seedling transplant

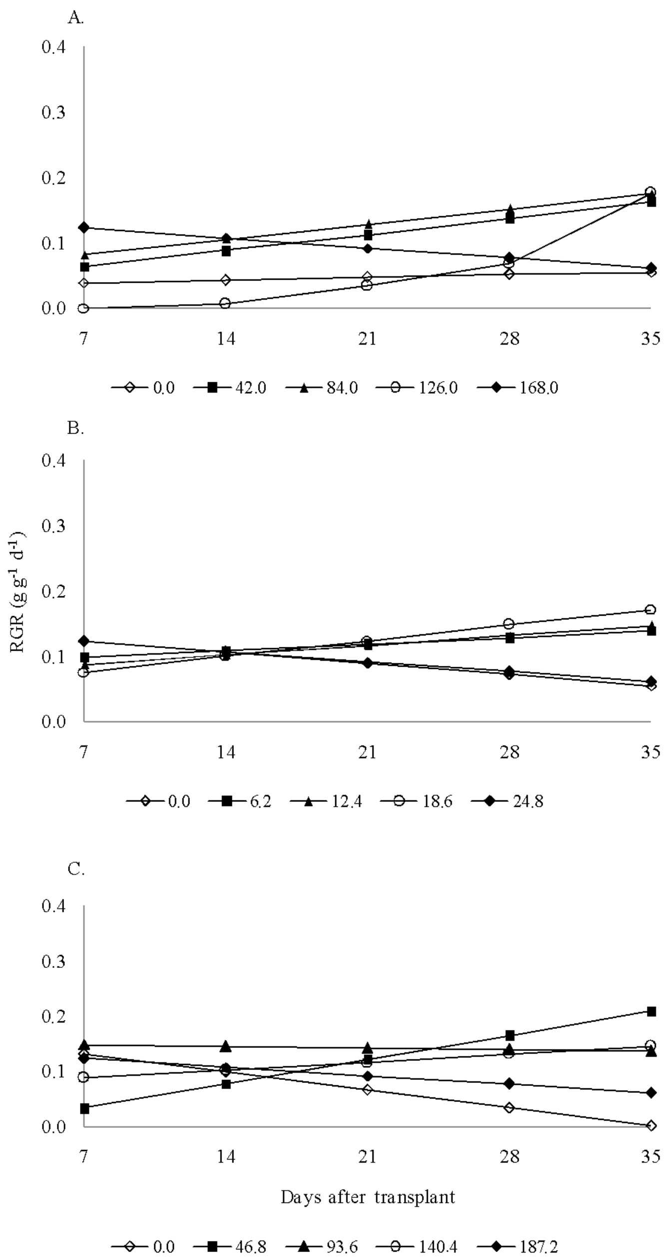

Figure 5. Relative growth rate (RGR) of *B. subquadripara* plants under different nitrogen (A), phosphorus (B), and potassium (C) concentrations during a period of 35 days after seedlings transplant

LAR values for the K concentrations of 46.8 and 93.6 mg L^{-1} of K in the nutrient solution were highest at 21 DAT. But, at the end of the experiment the observed values were close to those observed at the beginning of the evaluations (Figure 6C).

The efficiency in the use of solar radiation or net assimilation rate (NAR) by *B. subquadripara* plants at the first week is observed to increase with N concentration, except the concentration of 126.0 mg L^{-1} (Figure 7A). But, the mean NAR value at 35 DAT were of 0.18, 0.23, and 0.20 g dm^3 correspondents to the N concentrations of 42.0, 84.0, and 126.0 mg L^{-1}, respectively. When the N concentration in the nutrient solution was of 168.0 mg L^{-1}, decrease in NAR values were observed during the experimental period.

The P concentration in the nutrient solution of 18.6 mg L^{-1} resulted in the highest NAR value at 35 DAT (Figure 7B). But, at 7 DAT the P concentration of 24.8 mg L^{-1} led to the highest NAR values. But as time passed by, significant reductions in NAR values were observed. When P was absent, NAR values were practically constant during the evaluated period.

As to K (Figure 7C), it was observed that in the absence of this nutrient the assimilating system was significantly affected since NAR showed drastic reductions during the evaluation period. On the other hand, the K concentration of 46.8 mg L^{-1} was enough to result in the highest values of that parameter at 35 DAY, although the values observed in the first week were lower than those of the other evaluated concentrations.

In the Barra Bonita hydroelectric power plant reservoir, Domingos et al. (2011) reported to have found nitrogen (N total), phosphorus (PO_4^{3-}), and potassium (K) concentrations in the water of 55,2; 77,5, and 17.2 mg L^{-1}, respectively.

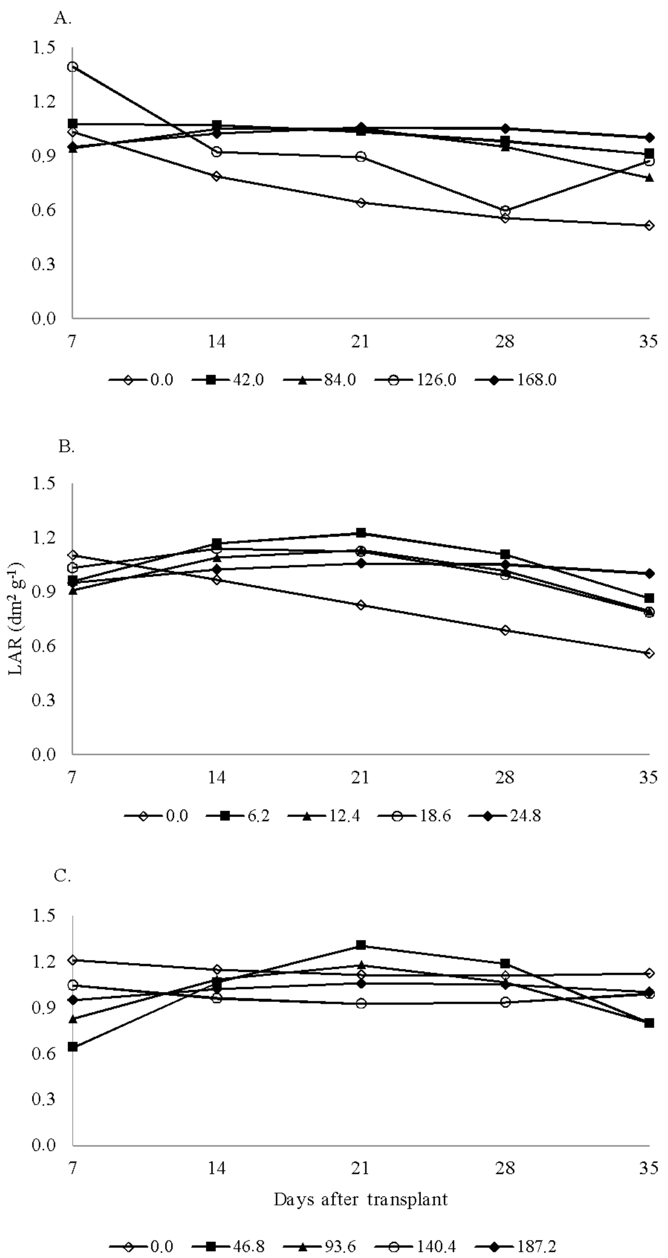

Figure 6. Leaf area ratio (LAR) of *B. subquadripara* plants under different nitrogen (A), phosphorus (B), and potassium (C) concentrations during a period of 35 days after seedlings transplant

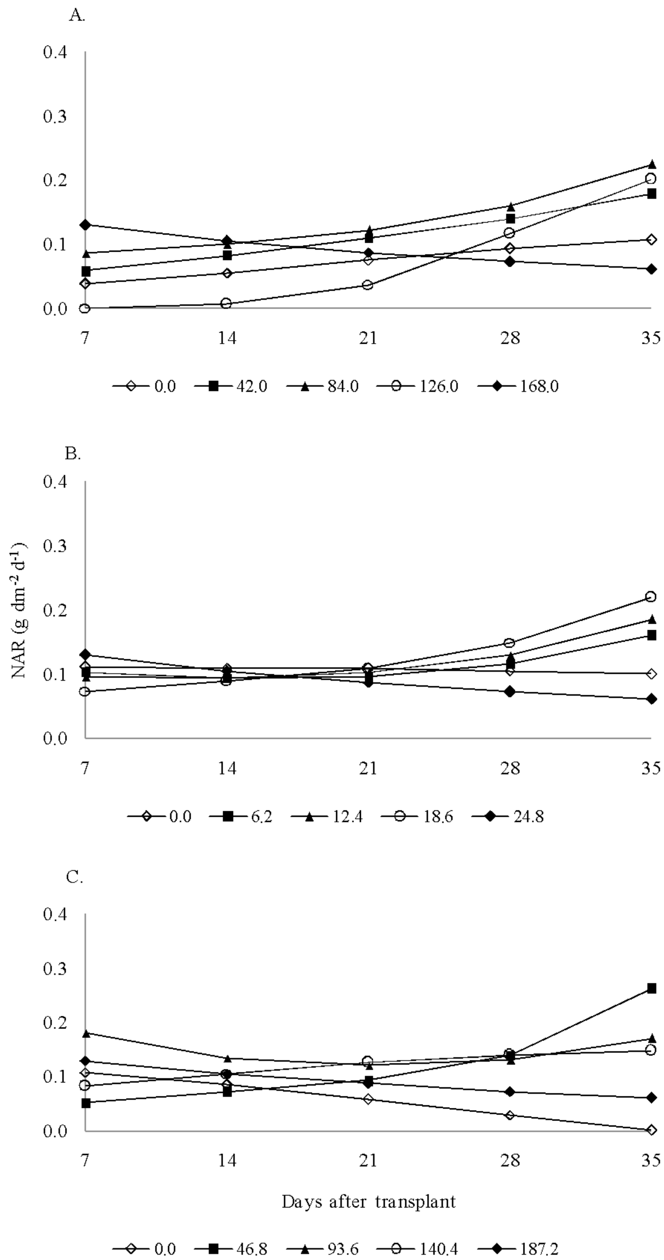

Figure 7. Net assimilation rate (NAR) of *B. subquadripara* plants under different nitrogen (A), phosphorus (B), and potassium (C) concentrations during a period of 35 days after seedling transplant

Cavenaghi et al. (2003) observed correlation of these nutrients with the occurrence of large infestations of *B. subquadripara*, in five reservoirs of the Tietê watershed (São Paulo, Brasil) used to produce electrical energy.

In the present study, the initial growth of *B. subquadripara* plants increased in agreement with the increasing concentrations of N, P, and K in the nutrients solution. But, in the highest concentrations of these nutrients, reductions in the leaves dry mass, of the whole plant as well as in leaf area were observed, showing that, when the concentrations of these elements are in excess (168.0, 24.8, and 187.2 mg L^{-1} of N, P, and K, respectively), they may act as a limiting factor for the establishment of plants of that species in aquatic environments.

It is noteworthy that this condition may represent the maximum tolerated hypertrophication by plants of *B. subquadripara* and that probably this condition was negative interaction of N, P and K with the absorption of micronutrients by the plant. But is still not clear the mechanism that allows the plant *B. subquadripara* tolerate high levels of nutrients dissolved in water. These results confirm those reported by Lacoul & Freedman (2006).

Xie et al. (2004) verified that *Eichhomia crassipes* plants growth and propagation are stimulated when N and P availability in the medium where the plants are is regularly augmented. It is, nonetheless, necessary to emphasize that the concentrations used by those authors (0 to 1 mg L^{-1} of P and 0 to 10 mg L^{-1} of N) may be considered low in comparison with those used in this work.

Nothwithstanding the difficulties in establishing the concentration limits which characterize mesotrophic, eutrophic and hypereutrophic conditions (Tundisi et al., 2008) it can be concluded that *B. subquadripara* plants exhibited good development under hypereutrophic conditions (42.0 to 126.0 mg L^{-1} of N, 6.2 to 18.6 mg L^{-1} of P and 46.8 to 140.4 mg L^{-1} of K) although they did not tolerate conditions considered extremely hypereutrophic in the experiment (168.0 mg L^{-1} of N, 24.8 mg L^{-1} of P, and 187.2 mg L^{-1} of K).

Conclusions

1. The plant growth of *B. subquadripara* responded to the quadratic model with increased levels of N, P and K in the nutrient solution, as well as the evaluated physiological indices.
2. Under conditions of excess or deficiency of these nutrients in the nutrient solution, relative growth rate and net assimilation rate tend to undergo reductions during the initial growth of the plants.

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