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Nitrogen uptake by ornamental bromeliad during atmospheric and tank developmental stages

Captación de nitrógeno por las bromelias ornamentales durante las etapas de desarrollo atmosférico y de tanque

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ABSTRACT

The aim of this study was to evaluate the growth of atmospheric (tankless-bromeliad) and tank (tank-bromeliad) developmental stages of silver vase bromeliad (Aechmea fasciata) as a function of nutrition with different sources and concentrations of nitrogen. The experiment consisted of the fertilization of atmospheric and tank stages of silver vase bromeliad with 50 mL of Hoagland and Arnon n. 1 (1950) solution, supplemented with 0, 15, 30 or 45 mM N of urea, ammonium nitrate or glutamine as nitrogen sources. After 210 days of experimentation, tank and atmospheric stages of silver vase bromeliad did not show significant differences for the variables plant height, rosette and stem diameter, leaf and total fresh mass, and root, leaf and total dry matter masses. Both stages have grown better with 15 mM N of ammonium nitrate and urea, while 45 mM of all N sources were deleterious. Glutamine in the tank occasioned the presence of a film and dark spots lowing the ornamental quality. The agronomic nitrogen use efficiency showed that tank stage use N more efficiently, when fertilized with inorganic form, while atmospheric stage is indifferent for N source.
Keywords: urea, nitrate, glutamine, Bromeliaceae, floriculture, mineral nutrition, Aechmea fasciata.

RESUMEN

El objetivo de este estudio fue evaluar el crecimiento de bromelia fasciata (Aechmea fasciata) en etapa atmosférica (periodo en ausencia de tanque y utilización de agua o humedad disponible en el aire) y etapa con presencia de tanque (estructuras desplegadas para captar el agua de lluvia o condensación) en función de la nutrición con diferentes fuentes y concentraciones de nitrógeno. El experimento consistió en fertilizar ambas etapas de la planta con 50 ml de Hoagland y Arnon n. 1 solución (1950), suplementada en concentraciones de 0, 15, 30 y 45 mM N, con urea, nitrato de amonio y glutamina como fuentes nitrogenadas. Después de 210 días del inicio del experimento, no se observaron diferencias significativas para las variables de altura de planta; diámetro de roseta; diámetro del tallo; masa fresca total de hojas y raíces; masas secas de raíces, hojas y materia seca total. Ambas etapas se han desarrollado mejor con 15 mM N de nitrato de amonio y urea, mientras que 45 mM de todas las fuentes de N fueron perjudiciales. La glutamina en el tanque, producto de la fertilización, ocasionó la presencia de una membrana y manchas oscuras que disminuyeron la calidad ornamental. La eficiencia del uso agronómico de nitrógeno mostró que la etapa de tanque usa N de modo más eficiente, cuando se fertiliza con manera inorgánica, mientras que la etapa atmosférica es indiferente para la fuente de N.
***Palabras clave:** urea, nitrato, glutamina, Bromeliaceae, floricultura, nutrición mineral, Aechmea fasciata.*

Introduction

Silver vase bromeliad (*Aechmea fasciata* (Lindl.) Baker) is the most commercialized bromeliad in floriculture markets, followed by *Guzmania* (var. Compacta, Empire, Magenta, Cherry and Denise), *Vriesea* sp. var. Charlote, *V. splendens* and *Neoregelia carolinae* as potted plants for indoor environments, and *Vriesea regina*, *Aechmea blanchetiana*, *Neoregelia compacta* and *Alcantarea imperialis* for landscape use (Vitari, 1994). Silver vase bromeliad is a native bromeliad from Espírito Santo and Rio de Janeiro State, Brazil. The specie has beautiful foliage and inflorescence, and can reach 40 cm height; its coriaceous leaves are arranged as an open rosette forming a tank

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(cistern), with transverse silver bands on leaf blades (Reitz 1983, Wanderley, 1999).

Leaves constitute a major part of bromeliads and are considered the main organs for nutrients and water uptake and organic compounds storage, and can be divided into apical and basal regions (Takahashi *et al.*, 2007). The basal region of the tank is in contact with the solution present into the tank and can uptake water and nutrients by structures termed trichomes or scales that are common on the leaf surface (Benzing, 1990, Takahashi *et al.*, 2007).

The first stage that seedlings of bromeliads develop into so-called atmospherics and presents narrow leaves, which latter change into plants forming the tank by overlapping the broad leaf bases (Meisner *et al.*, 2013). The stages atmospheric and tank show considerable morpho-anatomical and physiological differences, with small juveniles having morphological characteristics of atmospherics (non-impounding rosettes of small and linear leaves), whereas larger conspecifics leaves form a tank (overlap broad leaves basally forming water-filled chambers) (Zotz *et al.*, 2004). In relation to water and nutrients supply the small atmospheric plants lack a tank and are "pulse supplied" compared to larger more "continuous supplied" bromeliads with tanks (Zotz and Hietz, 2001). Bromeliads tends to transfer water and nutrient uptake from root towards to tank during plant development from atmospheric to tank stage, even though there is differences in the balance of roots vs. tank uptake among bromeliad cultivars (Vanhoutte *et al.*, 2017).

Bromeliads have a long cultivation cycle as compared to other ornamental horticultural crops. The cultivation cycle of silver vase bromeliad from seeds takes 2 years and 2 months (780 days), divided into 5 phases: sowing (240 days), 34 cells trays (120 days), pot n. 11 (120 days), pot n. 15 (180 days), pot n. 17 (120 days) and another 120 days to flourish and be marketed (Sanches, 2009). Consequently, studies on mineral nutrition of bromeliads are essential to accelerate plant development, reduce production costs such as time in greenhouse, irrigation, man labor, phytosanitary treatments, among others.

Therefore, we aimed to study the effect of nitrogen doses and sources on growth and development of silver vase bromeliad during the atmospheric and tank stages. This knowledge will contribute to a more comprehensive understanding of how to manage the fertilization of bromeliads in horticultural conditions, improving plant growth, and reducing N losses.

Material and methods

The experiment was carried out in a greenhouse with irradiance of 500 µmol m^{-2} s^{-1}, daily average temperature of 27.5 ºC and watered using micro-sprinklers irrigation (Modular NaanDanJain® Microaspersor, flow rate 141 L h^{-1}) on two periods during 15 min daily. The analysis of irrigation water showed: pH - 7.7; K - 0.07 mM; Ca - 0.320 mM; Mg - 0.060 mM; Cl - 0.960 mM; Na - 0.100 mM; CO_3 - 0.000 mM; HCO_3^- - 0.420 mM; SAR (Sodium Absorption Ratio) - 0.23 and EC - 0.080 dS m^{-1}.

Silver vase bromeliads with atmospheric (without tank, 7.4 leaves, 2.76 mm of stem diameter, 6.73 cm of plant height, 3.02 cm of root length, 0.06522 g of total dry mass, n = 10), and tank (11.6 leaves, 6.18 mm stem diameter, 9.97 cm of plant height, 6.97 cm root length, 0.30504 g of total dry mass, n = 10) stages were used in experiment (Figure 1).

The plants were transplanted into black polypropylene pots with a volumetric capacity of 0.45 L. The substrate used was *Pinus* bark substrate (composted; granulation 6-10 mm; N - 0.50%, P_2O_5 - 0.1%, K_2O - Undetected; Ca - 0.3%, Mg - 0.1%, S - 0.3%, O.M. - 26.0% and C - 14.0 % and 129, 6, 3.68, 52, 13 mg kg^{-1} of Na, Cu, Fe, Mn and Zn, respectively; C/N - 28/1 and pH - 3.5).

The plants were fertilized three times a week with 50 mL of solution of ion balanced Hoagland and Arnon n. 1 (1950) modified solution with 0, 15, 30 or 45 mM N of urea, ammonium nitrate or glutamine as nitrogen sources.

Figure 1. Tank (A) and atmospheric (B) stages of silver vase plant.

After 210 days of experimentation the variables plant height and rosette diameter, stem diameter, width of leaf and number of leaves were evaluated. Plants were sectioned into roots, stem and leaves and weighted for fresh mass and dried in air-forced oven at 60 ºC until constant weight was reached for dry mass.

Nitrogen Agronomic Efficiency index was calculated as follows:

Nitrogen Agronomic Efficiency (NAE, g g^{-1}) = (Total plant dry mass with fertilization - total plant dry mass without fertilization) / (Applied Nitrogen) (adapted from Fageria, 1998);

The experimental design was randomized blocks and consisted of three blocks and twenty four treatments in a factorial scheme of 2 x 3 x 4 (plant stages x nitrogen sources x nitrogen doses). Each plot was composed of five plants, making three hundred and sixty plants, of which 180 tank and 180 atmospheric plant stage. Data were submitted to analysis of variance (F test) and the means were compared by the Tukey test ($p \leq 0.05$) using the SISVAR statistical program (Ferreira, 2000).

Results and discussion

Tank and atmospheric stages of silver vase bromeliad did not show significant differences ($p \leq 0.05$) for the variables plant height, rosette and stem diameter, leaf and total fresh mass, and root, leaf and total dry matter masses (Table 1). Despite the tank plants were almost five times heavier (0.305 g DW) than atmospheric plants (0.065 g DW) at the begin of experimentation, in the end both stages had the same weight ($p \leq 0.05$). This response may be related to the rapid growth of the atmospheric stage plants to establish the tank, while the tank stage plants invested in the developmental structures (e.g. trichomes and scales) in detriment to plant growth. Tank establishment in *Guzmania monostachia* was positively associated with the emergence of morphological compartmentalization along the leaf blade that facilitates CO_2 uptake by the photosynthesizing cells improving carbon assimilation when stomata are closed (Rodrigues *et al.*, 2016). Atmospheric stages of bromeliads *Guzmania monostachia, Guzmania lingulata*, and *Werauhia sanguinolenta* showed photosynthetically active chlorenchyma cells embedded into an upper and lower hydranchyma, which decreases in size as plant stage the tank (Beltran *et al.*, 2013). Water and nutrient uptake by two *Vriesea* cultivars was shown to be dependent of the growth stage; total uptake of water and nutrients (roots + trichomes) per gram of fresh weight of both cultivars was higher in young plants (Vanhoutte *et al.*, 2017). In addition, the roots of atmospheric stage of *Vriesea gigantea* has an important role on nutrient uptake, while the plants develop the tank on the base of the leaves undertake the uptake function, as the roots decrease its capacity for nitrogen uptake (Takahashi, 2014). On the other hand, for Meisner *et al.*, (2013), the changes from atmospheric to tank stage are gradual and primarily related to size and not to the abrupt switch in habit or stage.

Higher concentrations of glutamine, urea and nitrate were detrimental for silver vase bromeliad growth and development, showing the best results at 15 mM N for all N sources. Epiphytic species are exposed to a constant nutritional stress in their natural habitat, thus these plants have a

Table 1. Biometric and biomass variables of silver vase bromeliad during tank and atmospheric stages.

	Height (cm)	Rosette diameter (cm)	Stem diameter (mm)	Stem fresh mass (g)	Root fresh mass (g)	Leaf width (mm)	Number of leaves (un)
Tank	21.8 a	32.43 a	15.24 a	3.46 a	1.64 a	45.48 a	9.1 b
Atmospheric	22.5 a	33.68 a	15.39 a	2.59 b	0.84 b	43.67 b	9.8 a
	Stem dry mass (g)	Root dry mass (g)	Leaf dry mass (g)	Total fresh mass (g)	Leaf dry mass (g)	Total dry mass (g)	
Tank	0.37 a	0.32 a	51.45 a	56.55 a	5.42 a	6.12 a	
Atmospheric	0.32 b	0.30 a	51.24 a	54.67 a	5.69 a	6.31 a	

Means followed by the same letter within a column are not differ significantly from each other at a 5% probability level by the Tukey test.

great efficiency for nitrogen uptake and reach the maximum of its growth potential with low levels of N (Santos *et al*., 2012). *Aechmea blanchetiana* seedlings growing *in vitro* in Murashige and Skoog (MS) (1962) medium modified with different nitrogen concentrations, decreased plant height linearly as N concentration increased, supporting the hypothesis of low nutrient requirement and slow growth of bromeliads in nature (Kanashiro *et al*., 2007). Fertilization with high concentrations of glutamine showed to be deleterious, mainly for tank plants; however, phytotoxic and detrimental effects of glutamine fertilization in plants were not found in literature. Silver vase bromeliad submitted to high concentrations of glutamine showed a darkening solution into the tank and the formation of a dark film adhered to the central leaves of the tank, which was not observed in urea and ammonium nitrate treatments. The dark solution into the tank and the film adhered to leaves had an impact on ornamental characteristics of the leaves, showing a "dirty" appearance. In addition, the 45 mM glutamine treatment showed the presence of fly larvae (Tipulomorpha infraorder, family Limonidae) inside the tank of all plants. Probably, the glutamine fermentation inside the tank, became a propitious site for attraction, emergence and development of the Diptera larvae.

Stem, root, leaf and total fresh mass variables of atmospheric and tank stages had the lowest mass as N concentrations increase in urea and ammonium nitrate treatments. Whereas for glutamine bromeliads with tank presented a deleterious effect at 45 mM N, while bromeliads without tank did not showed those characteristics. As regards for dry mass, roots were more responsive to the fertilization with high dose of N (45 mM) for all sources, when compared to leaves. Leaves and total dry masses also showed a decrease in the concentration of 45 mM N in all the sources, except for glutamine in atmospheric stage plants (Table 2). Nitrogen isotopic study showed that N source shift as plants age and grow, though small bromeliads depend upon atmospheric inputs, and tank bromeliads reflect the isotopic composition of the leaf litter (Reich *et al*., 2003). *Neoregelia cruenta* require 300 days to show the effects of urea fertilization, which is due to the time of the seedlings demand to use nitrogen for amino acid and protein synthesis and as the seedlings reach full vegetative development, they initiate to respond better to urea fertilization in an increasing linear mode (Ferreira *et al*., 2007). *Aechmea blanchetiana* seedlings fertilized with potassium nitrate, had the lowest values of leaf length, length of the largest root, number of leaves, dry and fresh masses and percentage of live plants on higher concentrations (Tavares *et al*., 2008). Studies by Hamasaki *et al*., (2005) showed that concentrations of 32 mM glutamine was inhibitory and lead to a strong reduction on the frequency of regeneration in pineapple, even though, glutamine is a fast and easy source of nitrogen, and glutamine and glutamate are the main endogenous amino acids involved in plant metabolism.

The chemical analysis of the leaves of silver vase bromeliad (Table 3) showed that there was N uptake for all nitrogen sources used in the experiment, with an increase of N contents in the leaves of all treatments. Epiphytic tank bromeliads tend to prefer an organic nitrogen source, while terrestrial such as pineapple would prefer inorganic nitrogen (Enders and Mercier, 2001, Romero *et al*., 2006). Atmospheric stage of *V. gigantea* were able to uptake and assimilate inorganic nitrogen rapidly in the 1st hour of the experimental time, while the tank stages absorbed nitrate slowly at the end of the experiment (Takahashi, 2014). Small plants of *Vriesea sanguinolenta* responded more strongly to increases of water and NPK fertilizer (18-14-18, formulated with ammonium and nitrate), than larger plants (Laube and Zotz, 2003). Although silver vase bromeliad is an epiphytic bromeliad, our data did not shown a preference for organic or inorganic N source; besides glutamine had the highest concentrations in leaves of atmospheric and tank stages, it showed to be deleterious in relation

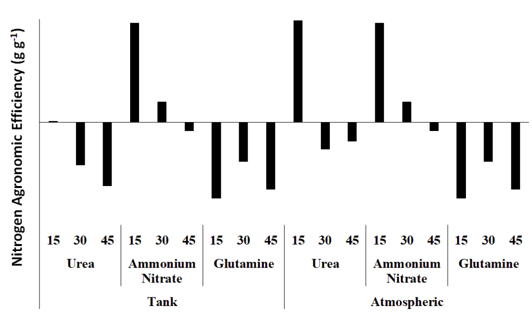

Figure 2. Agronomic efficiency of nitrogen use of tank and atmospheric stages of *Aechmea fasciata* submitted to 15, 30 or 45 mM of urea, ammonium nitrate or glutamine.

Table 2. Biometric and biomass variables of silver vase bromeliad during tank and atmospheric stages submitted to treatments with glutamine, ammonium nitrate and urea at concentrations of 0, 15, 30 or 45 mM N.

	N Source	N (mM)	H (cm)	RD (cm)	SD (mm)	LW (mm)	NL (un)	FSM (g)	FRM (g)	FLM (g)	TFM (g)	SDM (g)	RDM (g)	LDM (g)	TDM (g)
Atmospheric	Glutamine	0	24.0 a	32.5 a	15.92 a	48.23 a	10.53 a	2.97 a	0.93 a	55.76 a	59.66 a	0.34 a	0.37 a	5.10 a	6.54 a
		15	22.5 ab	34.5 a	15.21 a	44.80 ab	9.60 a	2.78 a	1.10 a	56.57 a	60.45 a	0.33 ab	0.30 ab	6.02 a	6.65 a
		30	19.8 b	32.4 a	13.18 a	38.76 b	9.67 a	1.67 b	0.76 a	40.09 a	42.52 a	0.21 b	0.24 b	4.50 a	4.95 a
		45	21.5 b	32.6 a	14.17 a	38.83 b	10.53 a	2.36 ab	0.62 a	44.71 a	47.69 a	0.30 ab	0.25 b	5.10 a	5.66 a
	Ammonium nitrate	0	25.6 a	37.4 a	18.47 a	52.80 a	10.07 a	3.61 a	0.94 ab	66.35 a	70.90 a	0.43 a	0.45 a	7.64 a	8.53 a
		15	24.0 ab	36.0 a	17.02 ab	48.07 ab	9.80 a	2.88 ab	1.28 a	62.41 a	66.57 a	0.34 ab	0.35 ab	6.61 ab	7.30 ab
		30	22.6 ab	32.0 a	15.99 ab	43.24 bc	9.73 a	2.93 ab	0.77 ab	54.50 ab	58.20 ab	0.37 ab	0.31 b	6.29 ab	6.97 ab
		45	20.8 b	32.8 a	14.46 b	52.80 c	9.67 a	2.18 b	0.49 b	42.06 b	44.73 b	0.28 b	0.25 b	4.99 b	5.52 b
	Urea	0	23.5 ab	33.9 a	16.11 a	46.49 a	9.60 a	2.96 a	1.06 a	51.14 ab	55.15 ab	0.32 a	0.32 ab	5.32 ab	5.96 ab
		15	24.2 a	37.2 a	15.50 ab	46.45 a	9.47 a	2.73 ab	0.87 a	58.46 a	62.06 a	0.33 a	0.35 a	6.75 a	7.44 a
		30	21.4 ab	31.6 a	13.81 ab	40.21 ab	9.33 a	2.21 ab	0.53 a	41.65 b	44.40 ab	0.28 a	0.22 b	4.66 b	5.16 b
		45	20.4 b	31.3 a	13.09 b	37.81 b	9.60 a	1.83 b	0.71 a	41.20 b	43.75 b	0.25 a	0.24 b	4.62 b	5.11 b
Tank	Glutamine	0	24.2 a	33.3 a	17.12 a	52.71 a	8.87 a	4.18 a	2.75 a	62.50 a	69.43 a	0.43 a	0.35 a	5.95 a	6.73 a
		15	22.9 a	32.0 a	14.93 ab	45.75 ab	8.67 a	2.98 a	1.52 b	49.29 ab	53.79 ab	0.33 ab	0.30 ab	4.99 a	5.63 ab
		30	19.2 b	28.4 ab	13.21 bc	38.97 b	8.93 a	2.29 a	1.52 b	39.55 bc	43.11 bc	0.29 ab	0.29 ab	5.01 ab	5.59 ab
		45	15.7 c	23.1 b	12.06 c	31.42 c	9.13 a	1.63 a	0.81 b	44.71 c	31.23 c	0.22 b	0.22 b	3.34 b	3.79 b
	Ammonium nitrate	0	23.2 ab	32.1 b	17.02 a	49.42 ab	9.40 a	4.12 a	2.47 a	56.70 a	63.29 ab	0.39 a	0.45 a	5.62 a	6.46 a
		15	24.1 a	38.4 a	17.67 a	53.44 a	9.40 a	3.79 a	1.78 ab	69.39 ab	74.96 a	0.43 a	0.36 ab	7.12 a	7.91 a
		30	23.5 a	35.7 ab	16.33 a	48.07 ab	9.53 a	3.56 a	1.37 b	55.73 ab	60.67 ab	0.42 a	0.31 b	6.33 a	7.05 a
		45	20.0 b	34.4 ab	15.83 a	42.39 b	9.53 a	3.24 a	1.08 b	47.07 b	51.39 b	0.44 a	0.26 b	5.39 a	6.09 a
	Urea	0	24.8 a	35.9 a	18.49 a	54.21 a	9.33 a	4.80 ab	2.39 a	63.27 a	70.47 a	0.49 a	0.37 a	6.17 a	7.04 a
		15	23.5 ab	35.1 a	16.2 ab	48.04 ab	9.27 a	6.27 a	1.78 a	64.64 ab	72.69 a	0.46 a	0.31 a	6.29 a	7.05 a
		30	21.2 bc	33.0 ab	14.16 b	45.00 b	9.20 a	3.04 bc	1.67 a	46.90 bc	51.61 b	0.36 ab	0.37ab	5.06 ab	5.79 ab
		45	19.2 c	27.8 b	11.61 c	36.30 c	9.33 a	1.65 c	0.73 b	33.56 c	35.94 b	0.23 b	0.22 b	3.82 b	4.26 b

Means followed by the same letters within a column, from each fertilizer source, are not differ significantly from each other at a 5% probability level by Tukey test, being H, height; RD, rosette diameter; SD, stem diameter; LF, leaf width; NL, number of leaves; FSM, fresh stem mass; FRM, fresh root mass; FLM, fresh leaf mass; TFM, total fresh mass; SDM, stem dry mass; RDM, dry mass of the roots; LDM, leaf dry mass and TDM, total dry mass.

to plant quality. Nutrients Ca, S, P, Cu, Fe and B contents did not change with higher doses of N for atmospheric or tank plants. The K, Mg and Mn contents decrease as N levels on treatments increases for both stages of bromeliads. Nitrogen fertilization may result in a dilution effect; in another word, when mineral-element concentrations in shoots decrease as shoot-dry-matter accumulation increase (Riedell, 2010). Such effect may be the main reason why plants did not increase nutrients contents in leaves, besides the fast and vigorous growth of atmospheric and tank stages of *A. fasciata* under nitrogen fertilization. Differently, *Vriesea sanguinolenta* showed marked increases in N and P content in all plant size classes, pointing to both "luxury" consumption and storage of N and P, such increase in P concentration, reflecting the switch from vegetative growth to storage and reproductive stage (Zotz *et al.*, 2004).

Conclusions

The results corroborate the data observed for plant growth and development, once the best results were obtained at low N concentrations; moreover, the results also showed that tank bromeliads become

Table 3. Macro and micronutrients content averages of in the leaves of silver vase bromeliad during tank and atmospheric stages submitted to treatments with glutamine, ammonium nitrate and urea at concentrations 0, 15, 30 or 45 mM N.

Treatment			N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
N source (mM)			g kg^{-1}					mg kg^{-1}					
Tank	Urea	0	13	2.1	55	5	3.0	1.6	39	3	179	248	23
		15	25	3.2	53	5	2.7	1.6	36	3	177	169	23
		30	31	3.3	48	5	2.5	1.6	34	2	161	127	20
		45	35	3.0	46	4	1.8	1.6	30	2	163	115	18
	Ammonium nitrate	0	14	3.1	59	6	2.9	1.6	33	2	135	238	22
		15	23	3.1	55	4	2.9	1.6	32	2	122	154	25
		30	25	3.1	48	4	2.2	1.5	29	2	117	185	21
		45	30	2.8	42	4	2.2	1.5	26	2	144	156	19
	Glutamine	0	15	2.9	60	5	2.8	1.6	28	2	119	247	19
		15	35	3.1	42	6	2.7	1.6	32	2	198	165	22
		30	29	3.0	48	5	2.2	1.6	30	2	153	142	17
		45	28	2.9	39	5	1.9	1.7	29	2	201	123	14
Atmospheric	Urea	0	12	2.7	59	5	3.5	1.6	28	2	102	196	26
		15	26	2.6	43	4	2.3	1.5	29	2	128	125	19
		30	32	2.7	49	5	2.7	1.6	30	2	162	161	31
		45	23	3.0	52	4	2.3	1.6	31	3	164	155	18
	Ammonium nitrate	0	10	3.0	51	5	3.4	1.6	31	3	104	177	30
		15	21	2.8	54	4	2.8	1.5	30	3	107	162	24
		30	24	2.7	46	4	2.3	1.5	31	3	114	135	25
		45	32	2.7	48	4	2.3	1.5	33	3	152	148	26
	Glutamine	0	11	3.0	58	6	3.5	1.5	33	5	121	261	28
		15	27	3.3	55	5	2.8	1.5	34	4	172	183	24
		30	32	3.1	49	5	2.5	1.5	34	3	126	162	24
		45	34	3.0	46	6	2.3	1.7	32	3	149	167	23

more efficiently with inorganic N, while atmospheric bromeliads are indifferent about N source. The agronomic efficiency of nitrogen use shows that the tank stage was more efficient on concentration of 15 mM of ammonium nitrate, and 15 mM urea and 30 mM ammonium nitrate doses similarly resulted on positive efficiency. The atmospheric stage was more efficient on concentrations of 15 mM of urea and ammonium nitrate, and the dose of 30 mM of ammonium nitrate was also efficiently. Glutamine was a deleterious nitrogen source for bromeliads at all concentrations.

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