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Scientific Article

Effect of calcium fertilization on silver vase bromeliad (*Aechmea fasciata*)

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Abstract

The present study aimed to evaluate the effect of different concentrations of calcium on growth and development of silver vase bromeliad (*Aechmea fasciata*). Plants were fertilized three times a week with nutrient solutions formulated with HA solution (Hoagland and Arnon, 1950) modified with 0.25, 2.5, 5, 7.5, 10.0 or 12.5 mM Ca applied into the tank. After 90 days of experimentation, biometric and biomass measurements of root and shoot systems, and chemical analysis of leaves were assessed. The results showed that the concentration of 12.5 mM Ca in nutrient solution is recommended for silver vase bromeliad fertilization.
Keywords: Bromeliaceae, plant nutrition, fertilization, calcium nitrate.

Resumo

Efeito da adubação com cálcio na bromélia *Aechmea fasciata*

O presente estudo teve como objetivo avaliar o efeito de diferentes concentrações de cálcio no crescimento e desenvolvimento da bromélia ornamental *Aechmea fasciata*. As plantas foram fertilizadas três vezes por semana com soluções nutritivas de HA (Hoagland and Arnon, 1950) modificadas com 0,25; 2,5; 5; 7,5; 10,0 ou 12,5 mM de Ca aplicadas no tanque. Após 90 dias de experimentação, foram avaliadas as variáveis biométricas e de biomassa do sistema radicular e da parte aérea e teor de nutrientes na folha. Os resultados mostraram que a concentração de 12,5 mM de Ca na solução nutritiva é recomendada para a fertilização da bromélia ornamental *Aechmea fasciata*.
Palavras-chave: Bromeliaceae, Nutrição mineral, adubação, nitrato de cálcio.

Introduction

The importance of bromeliads as ornamental plants has increased in recent decades (Anacleto and Negrelle, 2009). Cultivated initially in botanical gardens, bromeliads have become very popular into worldwide as ornamental due to the beautiful shapes and colors of leaves and inflorescences, low maintenance and its use as vase plant or for landscape (Negrelle and Anacleto, 2012). However, there is a lack of information about plant nutrition, substrate and, insect and diseases control on the production of bromeliads for commercial purposes, which would promote an increase in productivity and quality of the crop.

The leaves of the bromeliads are adapted to absorb nutrients and water through structures such as hairs and foliar trichrome (Englert, 2000). The balanced fertilization on bromeliads produces better quality plants and resistance to diseases and pests (Kanashiro et al., 2007). Calcium is a crucial regulator of plants growth and development, and participates of numerous processes, involving almost all aspects in plant life (Hepler, 2005). Calcium is important on inflorescence differentiation and fruits development of bromeliads such as pineapple (*Ananas comosus* (L.) Merr.) and supports transpiration without loss of turgescence; while excessive levels of the element reduce potassium in leaves, initiate chlorosis and produce smaller plants (Paula et al., 1998). The first symptoms of calcium deficiency in *Ananas comosus* var. *erectifolius* initiate on new leaves, which develop light green color on the blade and edge of the leaves, along with reduction of plant height and size of leaves (Viégas et al., 2014). Pineapple plants demands high quantities of Ca; conversely, except in very poor and sandy soils deficiency rarely occurs (Py et al., 1987) and the most important effect of Ca is on fruit quality (Souza and Reinhard, 2007). The present study aimed to evaluate the effect of different concentrations of calcium on growth and development of silver vase bromeliad.

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Material and methods

The experiment was conducted at São Paulo City (23º30'S and 46º40'W), São Paulo State, Brazil, positioned 770 m over sea level. The plants used in the experiment were approximately 6 months old (average of 9.8 leaves, leaf length of 15.21 cm, root length of 5.84 cm, and 5.80 g of total fresh weight, n = 10) and were transplanted to 1.25 L black polyethylene pots, containing composted Pinus bark as substrate. The study was conducted in a greenhouse with a transparent polyethylene cover with average daily irradiance of 530 μmol $m^{-2} s^{-1}$ and irrigation through micro-sprinkler (NaanDanJain®, Modular Micro-Sprinkler 141 L h^{-1}) in two 15 minutes daily regimes. The analysis of irrigation water showed pH - 7.7; RAS (sodium absorption ratio) - 0.23; EC - 0.080 dS m^{-1}; ions in $mmol_c$ L^{-1}; K^+ - 0.07; Ca^{++} = 0.320; Mg^{++} = 0.060; Cl^- = 0.960; Na^+ = 0.100; CO_3^{-2} = 0.000 and HCO_3 - 0.420.

Plants were treated with HA solution (Hoagland and Arnon, 1950) modified with 0.25, 2.5, 5, 7.5, 10.0 or 12.5 mM Ca. The macronutrients concentrations were balanced to maintain the ions concentrations as in the HA solution (Table 1). The pH of the solutions was adjusted to 5.8, and the plants received 30 mL of the solution three times a week into the tank. The treatments were distributed in a completely randomized block design with four blocks containing 6 treatments each with 5 plants per plot, totaling 120 plants.

Table 1. Ions and source and concentrations in molarity units to formulate ionic balanced Hoagland and Arnon solution n.1 (1950) with 0.25, 2.5, 5, 7.5, 10 or 12.5 mM Ca.

Ion/source	Concentration (mM)					
	0.25	2.5	5.0	7.5	10.5	12.5
NO_3^--KNO_3	4.5	4.5	4.5	4.5	4.5	4.5
NO_3^--$Ca(NO_3)_2.4H_2O$	0.5	5.00	10.00	15.00	20.00	25.00
NO_3^--NH_4NO_3	12.5	10.25	7.75	5.25	2.75	0.25
NH_4^+-NH_4NO_3	12.5	10.25	7.75	5.25	2.75	0.25
N-total	30	30	30	30	30	30
PO_4^{3-}-KH_2PO_4	1.5	1.5	1.5	1.5	1.5	1.5
K^+-KNO_3	4.5	4.5	4.5	4.5	4.5	4.5
K^+-KH_2PO_4	1.5	1.5	1.5	1.5	1.5	1.5
K^+ total	6	6	6	6	6	6
Ca^{2+}-$Ca(NO_3)_2.4H_2O$	0.25	2.5	5.0	7.5	10.0	12.5
Ca^{2+}-total	0.25	2.5	5.0	7.5	10.0	12.5
Mg-$MgSO_4.7H_2O$	2.0	2.0	2.0	2.0	2.0	2.0
SO_4-$MgSO_4.7H_2O$	2.0	2.0	2.0	2.0	2.0	2.0

After 90 days of experimentation, plants were measured from substrate level to highest leaf (plant height) and measured diameter of the stem (substrate level). Plants were harvested from pots and sectioned into leaves, roots and stem. The width of the largest leaf was measured and number of leaves counted. The leaves, stem, root and total fresh mass were weighted, then dried at forced-air oven 70 °C until constant weight for dry mass.

The analysis of mineral elements was performed on all dried leaves that were powdered in mill according to Malavolta et al. (1997). Samples were subjected to nitric-perchloric acid digestion and phosphorus contents were determined by the metavanadate colorimetric method, potassium by flame spectrophotometry, calcium, magnesium, zinc, iron, copper and manganese by atomic absorption spectrometer and sulfur by turbidimetry of barium sulphate. Nitrogen contents were evaluated by Kjeldahl method and boron was assessed by the azomethine-H method.

For statistical analyses, data were analyzed by regression, and the adjustment degree of the models was evaluated by the significance of regression coefficients using F-test ($p \leq 0.05$) using Sisvar Software. When not statistically significant for first, second or third-degree regression, the data average ($\bar{y}$) with its value was inserted as a straight line in the graphic.

Results and discussion

The increase of Ca in HA modified solution had an increment effect on variables plant height ($p \leq 0.05$), stem diameter ($p \leq 0.05$), leave fresh ($p \leq 0.05$) and dry ($p \leq$

0.05) masses, and total plant fresh ($p \leq 0.05$) and dry ($p \leq 0.05$) masses of silver vase bromeliad. The optimum Ca concentration (maximum point) with highest stem diameter (22.21 millimeters) was 7.83 mM Ca (Figure 1A). Plant height (Figure 1B) significantly increased with the addition of calcium. Data for leaf width and number of leaves (Figures 1C and 1D) were not significant ($p > 0.05$) with increasing calcium concentration in silver vase bromeliad cultivation.

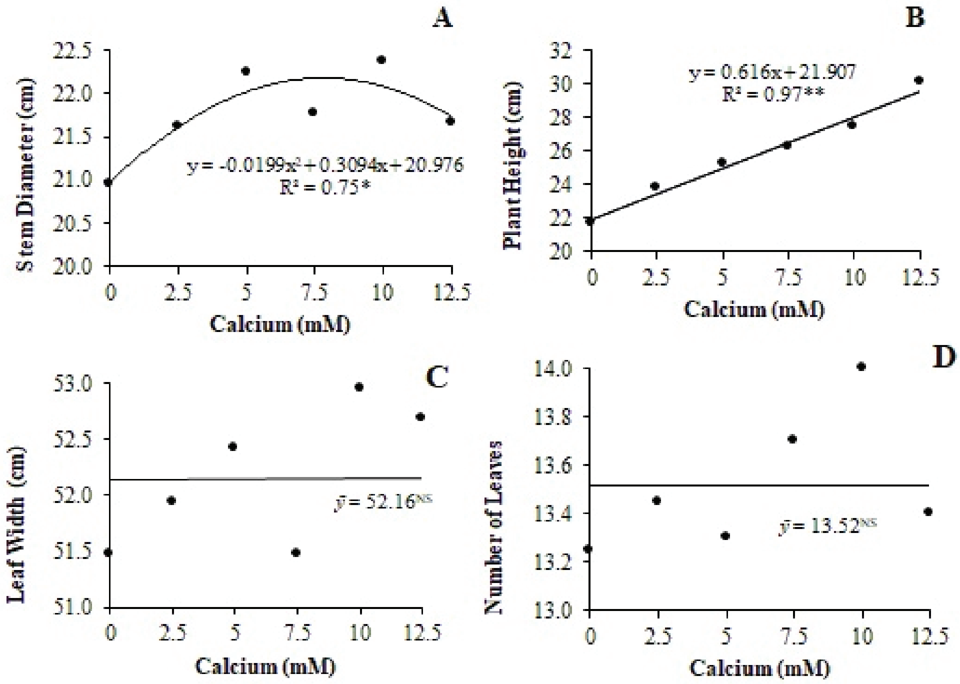

Figure 1. Averages and adjusted curve for variables stem diameter (A), plant height (B), leaf width (C), number of leaves (D) of silver vase bromeliad (*Aechmea fasciata*) cultivated on HA solution n.1 (Hoagland and Arnon, 1950) supplemented with 0.25, 2.5, 5.0, 7.5, 10.0 or 12.5 mM Ca. ** = ($0.01 < p \leq 0.01$); * = ($0.01 < p \leq 0.05$); NS = Not Significant.

Calcium is an important plant nutrient that affects the formation of cell membrane and plasma membrane and plays a fundamental role in plant growth, biomass production and function (Madani et al., 2015), which might explain the increase on mass production of silver vase bromeliad. In vitro cultivated bromeliads of Vriesea genus had significantly increase in fresh and dry masses as the calcium in solutions augmented; as Ca facilitated the absorption of other nutrients such N, K, Zn, Mn, and B resulting on better nutritional status consequently enhancing plant growth (Aranda-Perez et al., 2009). Calcium also have a major influence on cell metabolism, cell wall structure and integral part of the cell wall, it is involved in cross linkage of pectic molecules, promoting plant growth and development (Saikia et al., 2018). However, Aechmea blanchetiana cultivated in vitro under different calcium concentrations ($1.5 \leq Ca \leq 12$ mM) showed a decrease in root growth due to the presence of chlorine (Cl) on culture media (Kanashiro et al., 2009).

Leaf fresh (Figure 2A; $p < 0.01$) and dry (Figure 2B; $p < 0.05$) masses, and total fresh (Figure 2C; $p < 0.01$) and dry (Figure 2D; $p < 0.05$) masses increased as the concentration of calcium was raised in HA medium. Stem fresh (Figure 2E; $p > 0.05$) and dry (Figure 2F; $p > 0.05$) masses, root fresh (Figure 2G; $p > 0.05$) and dry (Figure 2H; $p > 0.05$) masses did not show significant difference with increasing concentrations of calcium. Fresh and dry root mass did not differ statistically (Figures 2E and 2F).

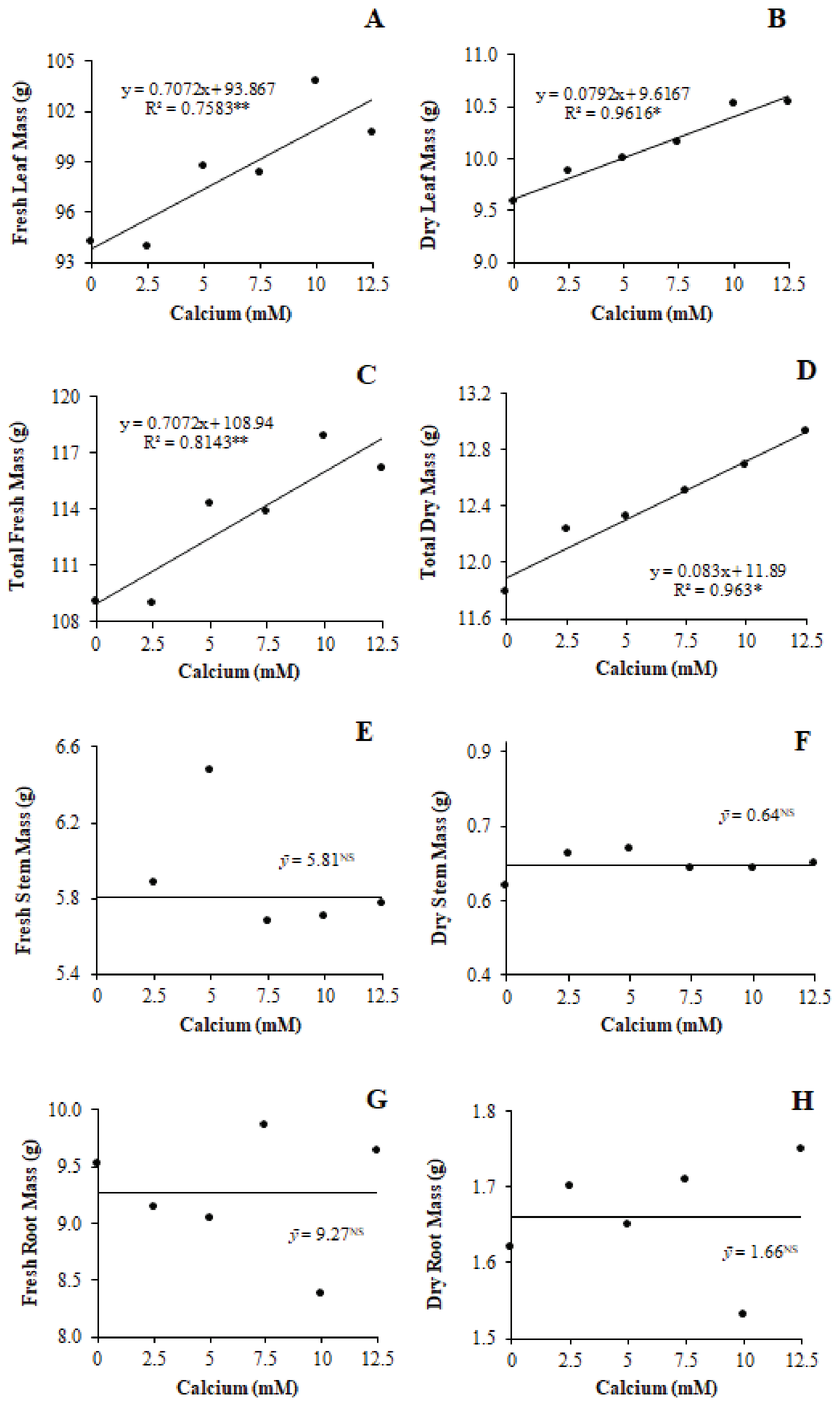

Figure 2. Averages and adjusted curve for variables fresh (A) and dry (B) leaf mass; fresh (C) and dry (D) total mass; fresh (E) and dry (F) stem mass; fresh (G) and dry (H) root mass of silver vase bromeliad (*Aechmea fasciata*) cultivated on HA solution n.1 (Hoagland and Arnon, 1950) supplemented with 0.25, 2.5, 5.0, 7.5, 10.0 or 12.5 mM Ca. ** = $(0.01 < p \leq 0.01)$; * = $(0.01 < p \leq 0.05)$; NS = Not Significant.

Aranda-Peres et al. (2009) observed the highest data for dry and fresh masses of Vriesea friburguensis, V. unilaterais and V. hieroglyphica (Bromeliaceae) in vitro cultured, when used 12 mM Ca in Murashige and Skoog (MS) media, and Aechmea blanchetiana plantlets cultured in vitro in MS modified media with 9.38 mM Ca had an increase in fresh and dry masses (Kanashiro et al., 2009). Silver vase bromeliad did not show visual symptoms of calcium deficiency in leaves (Figure 3).

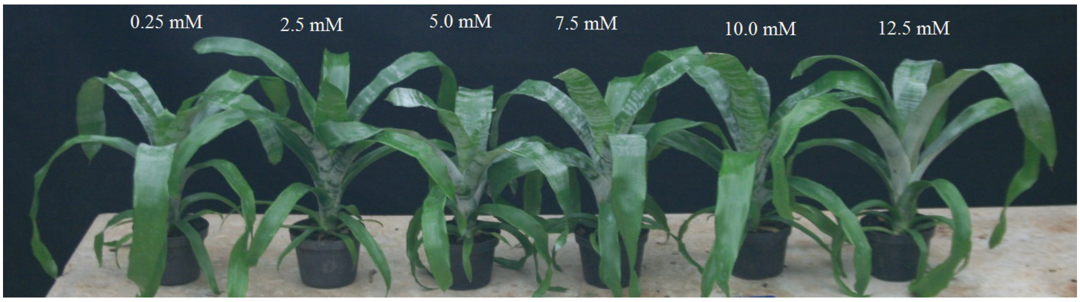

Figure 3. Silver vase bromeliad (*Aechmea fasciata*) fertilized with different calcium concentrations in HA solution n.1 (Hoagland and Arnon, 1950) modified with 0.25, 2.5, 5.0, 7.5, 10 or 12.5 mM Ca.

Silver vase bromeliads cultivated under Ca omission or complete Hoagland and Arnon medium (1950) did not show difference on plant growth and plants submitted Ca omission do not exhibit visual symptoms of Ca deficiency (Young et al., 2018), corroborating our results. Ca deficiency symptoms in pineapple initially are observed on the fruit because the demand for calcium is highest at the time of floral differentiation (Malézieux and Bartholomew, 2003).

The increase of Ca in fertilizer solutions also increase Ca contents in leaves of silver vase bromeliad; conversely, N, P and Mg contents in leaves decreased (Table 2), showing an antagonism effect. Young et al. (2018) observed lower values of Ca contents in leaves of silver vase bromeliads on treatment with Ca omission (3.66 g kg^{-1}) and the equivalent Ca content as observed on our data on complete treatment (13.00 g kg^{-1}).

Table 2. Macronutrients nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulfur (S), and micronutrients boron (B), cooper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) contents in leaves of silver vase bromeliad cultivated on HA solution n.1 (Hoagland and Arnon, 1950) supplemented with 0.25, 2.5, 5.0, 7.5, 10.0 or 12.5 mM Ca.

Ca (mM)	macronutrient (g kg^{-1})						micronutrient (mg kg^{-1})				
	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
0.25	21	2.4	22	9	4.8	0.8	26	5	143	368	27
2.5	20	2.3	22	9	4.3	0.8	26	5	116	357	29
5.0	19	2.1	23	9	4.0	0.7	24	5	195	302	36
7.5	18	2.1	22	10	4.3	0.8	23	5	126	345	22
10.0	17	2.0	22	11	3.8	0.8	24	5	132	324	23
12.5	17	1.8	22	13	3.8	0.8	23	5	192	340	22

The decrease of the average of P, Mg and B contents in plants is due to the antagonism between Ca and these nutrients, affecting their absorption (Malavolta, 1980). The interaction between calcium and phosphate is complex once both support and counteract each other, with simultaneous uptake and translocation of Ca and P and this effect is caused by precipitation of less soluble calcium phosphates at the area of nutrient-absorbing roots (Jakobsen, 1993). Increase of $CaCl_2$ and $CaSO_4$ concentrations in nutrient solution caused a decrease on Mg and an increase in Ca contents in cowpea (Vigna unguiculata) leaves and was attributed to an antagonistic effect of Ca on Mg (Guimarães et al., 2012). The liming increases the exchangeable Ca and Mg contents in the soil, which contributes to the increase in the leaf tissue of the pineapple (Veloso et al., 2001). The levels of boron (Table 2) contents in leaves of silver vase bromeliad decreased with augment of calcium concentrations in the solutions, showing the antagonistic effect. The copper content (Table 2) remained constant and the iron content (Table 2) showed a growth trend, showing the synergism effect. The macro e micronutrients contents in leaves of silver vase bromeliads are inside the range of chemical composition proposed by Poole and Conover (1976), exception for K contents that were almost three times higher in our study. Comparing our results with Mills and Jones (1996) recommendation silver vase bromeliads cultivated with 10.0 and 12.5 mM Ca presented Mg, B and Zn deficiency, and plants cultivated with 7.5 mM Ca were B and Zn deficient. Besides Ca concentrations, the Ca source is also important for Bromeliaceae, once large amounts of lime can raise soil pH to levels which increase the incidence of root and heart rot in pineapple while gypsum and basaltic dust do not increase soil pH and thus not affecting root health (Silva et al., 2006).

Conclusions

The data obtained in the experiment validate calcium as an important element to stimulate silver vase bromeliad growth. The concentration 12.5 mM Ca on nutrient solution is recommended for silver vase bromeliad fertilization.

Author Contribution

CBM 0000-0002-3657-4570: conception and design of the research, analyze and interpretation of data and critically analyses of manuscript. **VRS** 0000-0003-4202-9373: analyze and interpretation of data, statistical analysis, write and critically analyses of manuscript. **LHK** 0000-0003-0184-4873: analyze and interpretation of data, statistical analysis, write and critically analyses of manuscript. **RJK** 0000-0002-5810-406X: ionic balance calculations of nutrient solutions, conception, design and of the research, analyze and interpretation of data and critically analyses of manuscript. SK 0000-0003-0118-1723: conception and design of the research, obtaining data, analyze and interpretation of data, statistical analysis, write and critically analyses of manuscript. **ART** 0000-0001-6006-4741: conception and design of the research, obtaining data, analyze and interpretation of data, statistical analysis, write and critically analyses of manuscript and financial and obtaining funding.

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