Ornamental Horticulture
ISSN 2447-536X | HTTPS://ORNAMENTALHORTICULTURE.EMNUVENS.COM.BR/RBHO
SBFPO Sociedade Brasileira de Floricultura e Plantas Ornamentais

SCIENTIFIC ARTICLE

Nutrients uptake by silver vase bromeliad roots

Jorge Luiz Marx Young[1], Matheus Casarini Siqueira[1], Shoey Kanashiro[1], Emerson da Silva[1], Armando Reis Tavares[2]

[1] Instituto de Pesquisas Ambientais, São Paulo-SP, Brazil.
[2] Instituto Agronômico, Jundiaí-SP, Brazil.

Abstract

The bromeliads are desirable vase plants because of the flowering bract and the usually large, bold, colored and exotic format of the leaves that forms a cistern. The main function of epiphytic bromeliads roots is the fixation on the substrate, while water and nutrients uptake are performed mainly by leaves. However, recent studies have shown that the roots of epiphytic bromeliads can also help in the absorption of water and nutrients, contributing to plant growth and development. The present study aimed to evaluate the importance of the root system in the mineral nutrition of an epiphytic ornamental bromeliad silver vase bromeliad (*Aechmea fasciata*) that occurs in Brazil. 80 plants were cultivated for 240 days in plastic pots (900 mL) containing composted pine bark and were subjected to 5 treatments with 50 mL of 0% (control), 25%, 50%, 75% and 100% Hoagland & Arnon (HA) nutrient solution, applied twice a week only onto the substrate. Biometric and biomass variables of root and shoots, as well as macro- and micronutrients content in silver vase bromeliad leaves were evaluated. Results showed that all biometric and biomass parameters increased with the application of increasing HA solution concentrations, while the nutritional content in leaves showed different responses, with increase in nitrogen and potassium, decrease in calcium, phosphorus, magnesium, manganese, copper, sulfur, iron and zinc. We conclude that silver vase bromeliad grows better when fertilized with 75% or 100% HA solution on the substrate. We emphasize that the roots of the epiphytic silver vase bromeliad are functional and plays important roles in its nutrition and growth.
Keywords: Bromeliaceae, nutrient solution, root system, substrate.

Resumo

Absorção de nutrientes pelas raízes da bromélia *Aechema fasciata*

As bromélias são desejáveis como plantas de vaso devido as brácteas floridas e formato geralmente grande, colorido e exótico das folhas que formam uma cisterna. A principal função das raízes de bromélias epifíticas é a fixação no substrato, enquanto a captação de água e nutrientes é realizada principalmente pelas folhas. Porém, estudos recentes têm demonstrado que as raízes das bromélias epífitas também podem auxiliar na absorção de água e nutrientes, contribuindo para o crescimento e desenvolvimento das plantas. O presente estudo teve como objetivo avaliar a importância do sistema radicular na nutrição mineral da bromélia ornamental epifítica *Aechmea fasciata* que ocorre no Brasil. Oitenta plantas foram cultivadas por 240 dias em vasos plásticos (900 mL) contendo casca de pinus compostada e foram submetidas a 5 tratamentos com 50 mL de 0% (controle), 25%, 50%, 75% e 100% da solução nutritiva de Hoagland & Arnon (HA), aplicada duas vezes por semana somente sobre o substrato. Foram avaliadas as variáveis biométricas e de biomassa da raiz e da parte aérea, bem como o teor de macro e micronutrientes nas folhas de *A. fasciata*. Os resultados mostraram que todos os parâmetros biométricos e de biomassa aumentaram com a aplicação de concentrações crescentes da solução de HA, enquanto o conteúdo nutricional nas folhas apresentou diferentes respostas, com aumento de nitrogênio e potássio, diminuição de cálcio, fósforo, magnésio, manganês, cobre, enxofre, ferro e zinco. Concluímos que *A. fasciata* cresce melhor quando fertilizada com solução de AH 75% ou 100% no substrato. Ressaltamos que as raízes da bromélia epifítica *A. fasciata* são funcionais e desempenham importante papel na sua nutrição e crescimento.
Palavras-chave: Bromeliaceae, sistema radicular, substrato, solução nutritiva.

Corresponding Author: atavares2005@yahoo.com.br

https://doi.org/10.1590/2447-536X.v28i3.2460
Received Dec 07, 2021 | Accepted June 22, 2022 | Available online July 25, 2022

Area Editor: Petterson Baptista da Luz

Introduction

Brazil is the most diverse country for bromeliads, with more than 50% of the species of this diversified and adapted fascinating plant family of the Neotropics (Palma-Silva and Fay, 2020). With more than 3 thousand species distributed in 76 genera, Bromeliaceae family occupy a wide range of habitats and are one of the most distinguishing plants of Neotropical forests (Versieux et al., 2020). Popularly known as silver vase bromeliad, *Aechmea fasciata* is a Bromeliaceae epiphytic plant native to Brazilian Atlantic Forest, which has great ornamental value and an increasingly commercialization popularity on gardening and landscaping (Martinelli et al., 2008). The attractive stripy and silver-grey foliage, and the flower stalk, which emerges from the tight center rosette of leaves composed of a cluster of rosy pink bracts with blue flowers that change to rose, making silver vase bromeliad an attractive ground cover or container plant (Gilman et al., 2018).

Commercialization of bromeliad plants are increasing in the past decades due to their attractive shapes and colors, low maintenance and adaptability to different environments. There is an emphasize to develop more suitable techniques cultivation of bromeliads, once the demands of the increasingly competitive floriculture market (Negrelle et al., 2012). Bromeliads are well established in the flowering potted plant floriculture industry with 60 million plants sold each year, 65% being *Guzmania* hybrids (Vanhoutte et al., 2016). Adequate fertilization is essential for the correct growth and development of bromeliads, but the most studied and explored fertilization technique for producers is foliar fertilization (Amaral et al., 2019).

Epiphytic bromeliads, such as silver vase bromeliad, presents aphyllotaxis that creates a leaf tank which promotes water retention, and also have leaf trichomes that help absorb water and nutrients stored in this tank (Males, 2016). In nature, the detritus (mainly dead leaves) that are deposited into the tanks is the main source of nutrients (Corbara et al., 2018). In contrast, recent studies have shown that some epiphytic species are also able to uptake water and nutrients through their root system (Leroy et al., 2019; Gomes et al., 2021), and the adequate root uptake of nutrients can improve growth, development and enhance biomass production (Carvalho et al., 2017). The root capacity to uptake nutrients in epiphytic bromeliads is likely due to a uniseriate layer of root epidermis, which confers structural characters that allow water and nutrient intake (Kowalski et al., 2019). The ability to uptake nutrients from the roots of epiphytic bromeliads is due to velamen, a structure found in roots of epiphytic orchids (Carvalho et al., 2017).

Despite the great interest in cultivation and commercialization of ornamental plants, there are lacks in knowledge about mineral nutrition and fertilization of ornamental epiphytic bromeliads, since most studies with Bromeliaceae species focus on ecological aspects (Negrelle et al., 2012). Accordingly, this study aims to investigate the capacity of silver vase bromeliad root system to uptake nutrients and its contribution to bromeliad growth, biomass production and mineral nutritional balance.

Material and Methods

Experimental conditions and design

The experiment was carried out at the Department of Biodiversity and Conservation of Instituto de Pesquisas Ambientais, São Paulo State, Brazil. Six-month-old silver vase bromeliad plants (17.61 cm height, 11.57 cm diameter, 8 leaves, 28.46 g leaves FW, 3.43 g stem FW, 2.83 g roots FW, 2.83 g leaves DW, 0.26 g stem DW and 0.45 g roots DW) were transplanted into 900 mL polyethylene pots with pine bark as substrate (Table 1) and cultivated over benches in a glass greenhouse without temperature control (27 ± 3 °C during experimentation) and 292.45 µmol m² s¹ P.A.R. (Photosynthetic Active Radiation).

Table 1. Chemical composition of pine bark used as substrate.

O.M.	P_2O_5	K_2O	Ca	Mg	S	M-65ºC	C	C/N	pH	Na	Zn	Cu	Fe	Mn
--------------------------------natural %--------------------------------										--------------mg/Kg natural-------------				
26	0.1	ND	0.3	0.1	0.3	57.0	14	28/1	3.5	129	13	6	3677	52

ND: Not detected, M: Moisture, O.M.: Organic Matter

The plants were fertirrigated twice a week with 50 mL of 0% (control), 25%, 50%, 75% or 100% HA (Hoagland & Arnon, 1950) complete solution with pH adjusted to 5.8, applied only on the substrate (roots). The plants were also irrigated with tap water using a watering can one day before and one after the fertirrigations. The water was applied into the cistern and on the substrate (± 200 mL)

The experimental design adopted was a completely randomized blocks, comprising 4 blocks, 5 treatments and 4 plants per replication, totaling 80 plants.

Growth parameters

After 240 days of experimentation the biometric parameters plant height (cm), stem diameter (mm) and number of leaves were evaluated. The plants were removed from the pots and sectioned into leaves, stems and roots, and weighed for fresh biomass assessment. Subsequently, the leaves, stems and roots were dried in oven at 60 °C until constant weight, obtaining the dry biomass. Total fresh and dry biomass were established as a result of the sum of the biomass of plant organs (leaves + stem + roots).

Macro- and micronutrient content in leaves

The dried leaves were milled in a knife mill to obtain a homogeneous powder. The macronutrients nitrogen (N), phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg) and sulfur (S), and micronutrients iron (Fe), manganese (Mn), boron (B), copper (Cu) and zinc (Zn) contents in silver vase bromeliad leaves were analyzed. N was evaluated by the Kjeldahl method after sulfuric digestion; P by the ammonium metavanadate colorimetric method; K, Ca, Mg, Fe, Cu, Mn and Zn by atomic absorption spectrophotometry (AAS) after nitric-perchloric digestion; sulfur (S) by the turbidimetric method ($BaCl_2 \cdot 2H_2O$) after nitric-perchloric digestion; and B by the colorimetric method (azomethine-H) after incineration (Malavolta, 1997).

Statistical analyses

Data were submitted to Shapiro-Wilk normality test and Brown-Forsythe homoscedasticity test using the statistical software GraphPad Prism v9.0. The data were determined to meet assumptions of normality and homogeneity of variance, and then submitted to regression analysis calculated for linear and quadratic equations with an acceptance level corresponding to a significance level of 1% of probability with the F test.

Results

Macro- and micronutrient content in leaves

The leaves of silver vase bromeliad showed an increase in nitrogen and potassium (linear regressions, $p \leq 0.05$) contents as the HA concentration augmented in the solution (Figures 1A, 1C). The contents of phosphorus, magnesium, sulfur, manganese and zinc (linear regressions, $p \leq 0.05$) contents as the HA concentration augmented in the solution (Figures 1B, 1E, 1F, 1H, 1K). The contents of calcium, boron, copper and, iron (polynomial regression regressions, $p \leq 0.05$) contents as the HA concentration augmented in the solution (Figures 1D, 1G, 1I, 1J). The lowest concentrations of calcium, boron, copper and, iron in the leaves of silver vase bromeliad were observed on the concentrations 81.25%, 85.91%, 79.17% and 83.88 % HA, respectively.

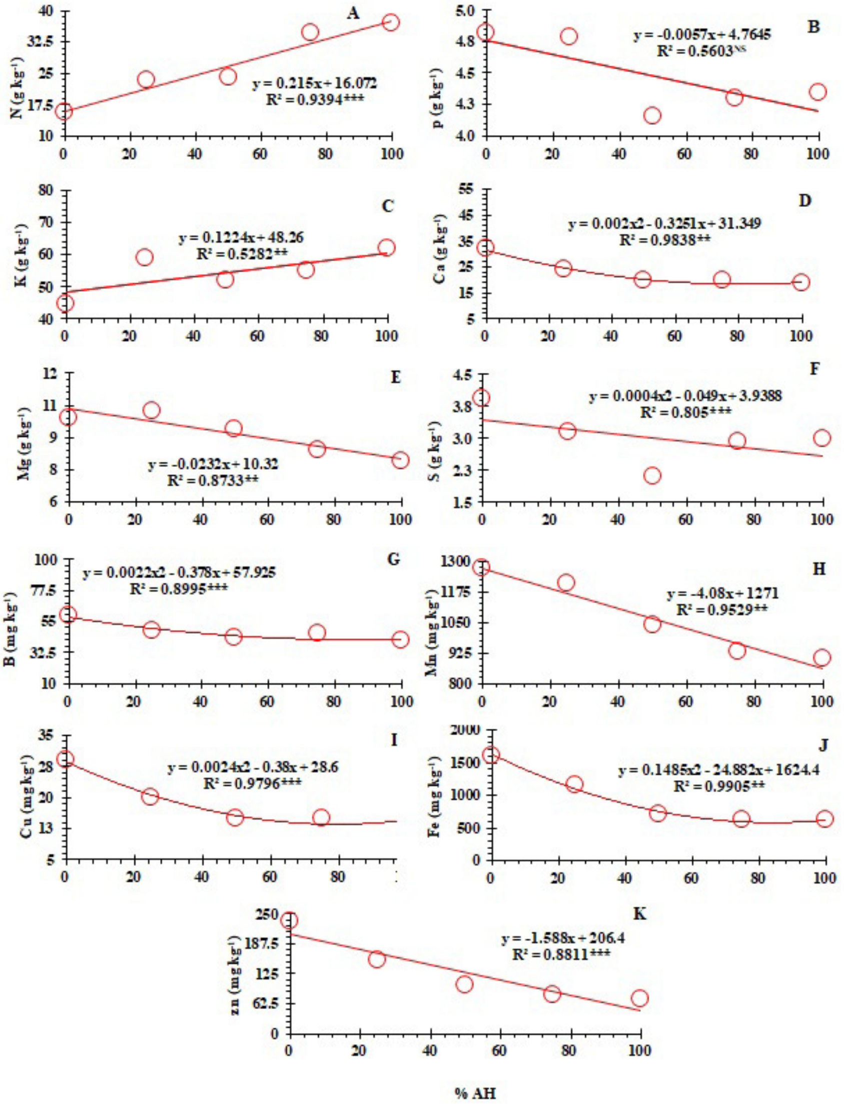

Figure 1. Macro- and micronutrient content in *A. fasciata* leaves. Lowercase letters compare treatments and means followed by same letters do not differ by Tukey's test at 5% probability.

Biometric and biomass

Silver vase bromeliad showed an increase in height, stem diameter and number of leaves as the concentration of the HA solution applied into the substrate augmented (linear regressions, $p \leq 0.05$, Figure 2).

Silver vase bromeliad showed an increase in fresh and dry biomass of leaf, stem, root and total as the concentration of the HA solution applied to the substrate augmented (linear regressions, $p \leq 0.05$, Figure 3).

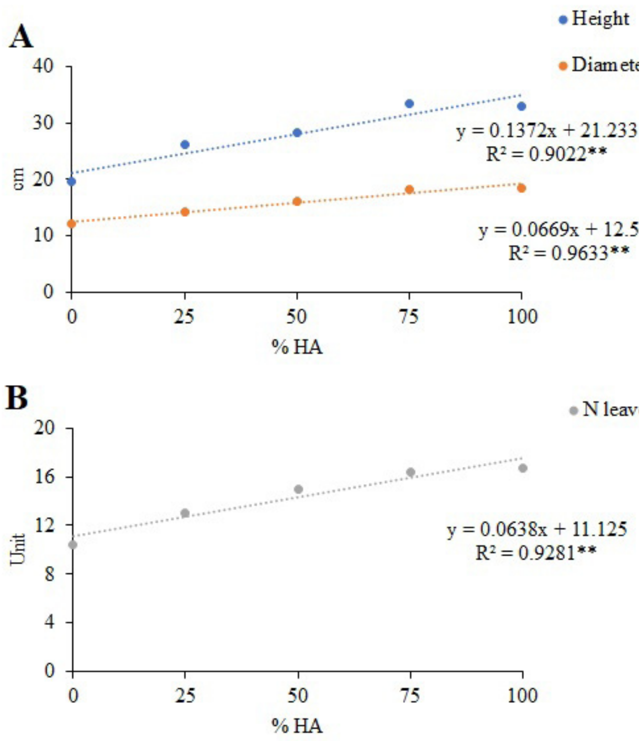

Figure 2. Height, stem diameter and number of leaves of *A. fasciata*.

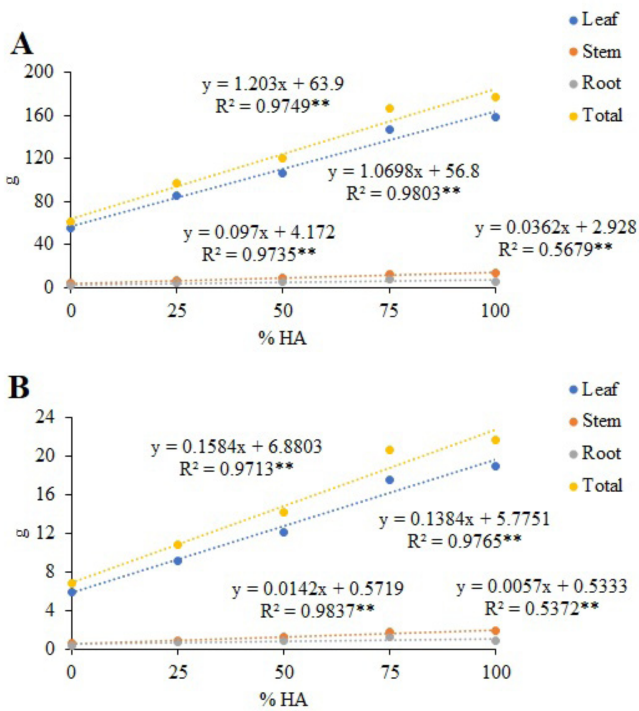

Figure 3. Silver vase bromeliad fresh (A) and dry biomass (B) of leaves, stem, roots and total. Lowercase letters compare treatments within each organ. Means followed by same letters do not differ by Tukey's or Dunn's test at 5% probability.

Discussion

The increase of HA concentration in the solution applied on the substrate increased the nitrogen and potassium contents in the leaves of silver vase bromeliad. It was already demonstrated that root system of epiphytic bromeliads is functional for nitrogen uptake and, bromeliads fertilized in roots have higher nitrogen use efficiency (NUE), than those fertilized only in the tank (Silva et al., 2018). Also, silver vase bromeliad improved uptake and physiological incorporation of inorganic N compared to organic N, regardless if supplemented into the tank or on substrate (Gomes et al., 2021).

K is a highly mobile element and required in large amounts to maintain the physiological functions in plants (Srivastava et al., 2020), and is essential for width expanding of leaves and enhance leaf thickness in the epiphytic bromeliad *Guzmania lingulata*, and contribute to increase tissue water storage, which is essential for the survival of the species (Lin and Yeh, 2008). The fertilization with K increases leaf length, number of roots and enhance the biomass production of leaves, stem and roots on *Aechmea blanchetiana* (Tavares et al., 2012). In our study, the increase in N and K contents in silver vase bromeliad leaves demonstrate that these nutrients were effectively uptake by roots, translocated and incorporated into the leaves. There was a decrease in calcium, phosphorus, magnesium, sulfur, copper, iron, manganese and, zinc contents in silver vase bromeliad leaves. In contrast, silver vase bromeliad showed higher biomass production of all tissues, with more and extended leaves, and increase stem diameter. This inverse relationship between increase growth and decrease in nutrient content is a phenomenon known as dilution effect, and is observed when biomass production increases at a faster rate than the uptake and incorporation of these mineral nutrients in the tissue (Jarrell and Beverly, 1981).

The antagonism between nutrients is another side-effect that can occur in several fertilized plants, where some elements compete for uptake and translocation channels within the plant and can lead to a decrease in other elements, especially for divalent cations such as calcium, magnesium and manganese (Rietra et al., 2017). This was already observed in epiphytic bromeliad *A. blanchetiana* when fertilized with high potassium concentration showing a decline in calcium, magnesium and sulfur contents in leaves, as result of antagonism effects (Tavares, et al., 2012).

As epiphytic tank bromeliads are adapted to low and intermittent nutrient supply; consequently, exposure bromeliads to a high and constant nutrient source, especially heavy metals, can be detrimental and cause nutritional imbalances (Winkler and Zotz, 2009). Copper, iron and zinc are essential micronutrients but also hazardous heavy metals, which in high concentrations negatively affect plant physiology and may trigger oxidative damages (Hirve et al., 2020).

Plants can limit translocation of these potentially toxic elements to leaves by storing them in the root system as defense mechanism (Kumar et al., 2016). Therefore, the dilution effect, antagonistic relationships between nutrients, and metal accumulation strategies in roots, can describe the decrease/stability of nutrients in silver vase bromeliad leaves.

Silver vase bromeliad increased all biometric parameters (Figures 2A and 2B) and increased leaf, stem, root and total biomass production (Figures 3A and 3B) with the augment of HA concentration in the solution (Figure 4). Associated with plant growth, there was a significative increase in nitrogen and potassium contents in leaves. Adequate mineral nutrition is a fundamental factor for bromeliads growth and development in all life stages (Tamaki et al., 2011).

Figure 4. Silver vase bromeliads treated with 0% (A, control), 25% (B), 50% (C), 75% (D) or 100% (E) HA (Hoagland & Arnon, 1950) at the end of experimentation.

Nitrogen, phosphorus and potassium are the most limiting elements for growth and biomass production of silver vase bromeliad, once the omission of these elements causes great decrease in biometric parameters (Young et al., 2018). Furthermore, epiphytic bromeliads fertilized in the roots (substrate) have a greater investment in biomass than when fertilized only in the tanks (Silva et al., 2018). Thus, the nutritional improvement of the main macronutrients is a major reason for the increase in all biometric and biomass parameters showed by silver vase bromeliad cultivated in complete HA solution (100%). This demonstrates that the addition of nutrients to the substrate was effective and enhance growth and development of silver vase bromeliad.

Conclusions

We show that the addition of nutrient solution to the substrate enhance growth of silver vase bromeliad. Our results pointed that silver vase bromeliad roots are functional and play significative roles in nutrient uptake which contributes for plant growth and development.

Author Contribution

JLMY: implementation of experiments, maintenance of the experimental area, data collection, data analysis, article writing; **MCS**: data collection, data analysis, article writing; **SK**: implementation of experiments, data analysis, review of article writing; **ES**: data collection, data analysis, article writing; **ART**: implementation of experiments, maintenance of the experimental area, data collection, data analysis, article writing; review of article writing.

References

AMARAL, T.L.; JASMIM, J.M.; NAHOUM, P.I.; FREITAS, C.B.; SALES, C.S. Nitrogen and potassium fertilization of Bromeliaceae grown in coconut fiber and cattle manure. **Horticultura Brasileira**, v.27, n.3, p.286-289, 2019. https://doi.org/10.1590/S0102-05362009000300004

CARVALHO, J.L.; HAYASHI, A.H.; KANASHIRO, S.; TAVARES, A.R. Anatomy and function of the root system of bromeliad *Nidularium minutum*. **Australian Journal of Botany**, v.65, n.7, p.550-555, 2017.https://doi.org/10.1071/BT17121

CORBARA, B.; BONHOMME, C.; CARRIAS, J.F.; CEREGHINO, R.; DÉZERALD, O.; LEROY, C. Tank bromeliads: aquatic life at the heart of plants. **Espèces-Revue d'Histoire Naturelle**, n.29, p.38-47, 2018.

GILMAN, E.F.; KLEIN, R.W.; HANSEN, G. ***Aechmea fasciata*: Silver Vase**. Available at: https://edis.ifas.ufl.edu/pdf/FP/FP01600.pdf. Accessed on: 10th Oct 2021.

GOMES, L.D.; FERREIRA, M.L.; KANASHIRO, S.; TAVARES, A.R. Nitrogen uptake by ornamental bromeliad: leaf and root efficiency. **Plant and Soil**, v.466, p.293-302, 2021.https://doi.org/10.1007/s11104-021-05013-9

HIRVE, M.; JAIN, M.; RASTOGI, A.; KATARIA, S. Heavy metals, water deficit, and their interaction in plants: an overview. In: TRIPATHI, D.K.; SINGH, V.P.; CHAUHAN, D.K.;

HOAGLAND, D.R.; ARNON, D.I. **The water-culture method for growing plants without soil**. Berkeley: California Agricultural Experiment Station, 1950. 40p.

JARRELL, W.M.; BEVERLY, R.B. The dilution effect in plant nutrition studies. **Advances in Agronomy**, v.34, p.197-224, 1981. https://doi.org/10.1016/S0065-2113(08)60887-1

KOWALSKI, V.K.; OLIVEIRA, F.M.C.; VOLTOLINI, C.H.; TARDIVO, R.C.; MOURÃO, K.S.M. Velamen or uniseriate epidermis? Root apices in Bromeliaceae Juss. **Flora**, v.250, p.9-17, 2019. https://doi.org/10.1016/j.flora.2018.11.010

KUMAR, R.; MISHRA, R.K.; MISHRA, V.; QIDWAI, A.; PANDEY, A.; SHUKLA, S.K.; PANDEY, M.; PATHAK, A.; DIKSHIT, A. Detoxification and tolerance of heavy metals in plants. In: Ahmad, P. **Plant Metal Interaction**. Cambridge: Elsevier, 2016. p.335-359.

LEROY, C.; GRIL, E.; OUALI, L.S.; COSTE, S.; GÉRARD, B.; MAILLARD, P.; MERCIER, H.; STAHL, C. Water and nutrient uptake capacity of leaf-absorbing trichomes vs. roots in epiphytic tank bromeliads. **Environmental and Experimental Botany**, v.163, p.112-123, 2019. https://doi.org/10.1016/j.envexpbot.2019.04.012

LIN, C.Y.; YEH, D.M. Potassium nutrition affects leaf growth, anatomy, and macroelements of *Guzmania*. **HortScience**, v.43, p.146-148, 2008. https://doi.org/10.21273/HORTSCI.43.1.146

MALAVOLTA, E. **Avaliação do estado nutricional das plantas**. Piracicaba: POTAFOS, 1997. 319p.

MALES, J. Think tank: water relations of Bromeliaceae in their evolutionary context. **Botanical Journal of the Linnean Society**, v.181, n.3, p.415-440, 2016. https://doi.org/10.1111/boj.12423

MARTINELLI, G.; VIEIRA, C.M.; GONZALEZ, M.; LEITMAN, P.; PIRATININGA, A.; COSTA, A.F.D.; FORZZA, R.C. Bromeliaceae da Mata Atlântica brasileira: Lista de espécies, distribuição e conservação. **Rodriguésia**, v.59, p.209-258, 2008. https://doi.org/10.1590/2175-7860200859114

NEGRELLE, R.R.B.; MITCHELL, D.; ANACLETO, A. Bromeliad ornamental species: conservation issues and challenges related to commercialization. **Acta Scientiarum. Biological Sciences**, v.34, n.1, p.91-100, 2012. https://doi.org/10.4025/actascibiolsci.v34i1.7314

PALMA-SILVA, C.; FAY, M.F. Bromeliaceae as a model group in understanding the evolution of Neotropical biota. **Botanical Journal of the Linnean Society**, v.192, p.569-586, 2020. https://doi.org/10.1093/botlinnean/boaa003

RIETRA, R.P.; HEINEN, M.; DIMKPA, C.O.; BINDRABAN, P.S. Effects of nutrient antagonism and synergism on yield and fertilizer use efficiency. **Communications in soil Science and Plant Analysis**, v.48, n.16, p.1895-1920, 2017. https://doi.org/10.1080/00103624.2017.1407429

SILVA, K.G.D.; FERREIRA, M.L.; SILVA, E.A.D.; KANASHIRO, S.; CAMARGO, P.B.D.; TAVARES, A.R. Nitrogen efficiency indexes for evaluating nitrogen uptake and use in ornamental bromeliad's root system and tank. **Pesquisa Agropecuária Brasileira**, v.53, p.703-709, 2018.

SRIVASTAVA, A.K.; SHANKAR, A.; NALINI CHANDRAN, A.K.; SHARMA, M.; JUNG, K.H.; SUPRASANNA, P.; PANDEY, G.K. Emerging concepts of potassium homeostasis in plants. **Journal of Experimental Botany**, v.71, n.2, p.608-619, 2020.

TAMAKI, V.; PAULA, S.M.; NIEVOLA, C.C.; KANASHIRO, S. Soluções nutritivas alternativas para o cultivo de bromélias ornamentais. **O mundo da Saúde**, v.35, n.1, p.91-97, 2011.

TAVARES, A.R.; KANASHIRO, S.; JOCYS, T.; RIBEIRO, R.C.S.; GONÇALVES, A.N. Effect of potassium on growth and nutrients contents in ornamental bromeliad cultured in vitro. **Acta Horticulture**, v.938, p.315-320, 2012. https://doi.org/10.17660/ActaHortic.2012.938.41

VANHOUTTE, B.; CEUSTERS, J.; DE PROFT, M.P. The 'tubing' phenomenon in commercial cultivation of *Guzmania*: morphology, physiology and anatomy. **Scientia Horticulturae**, v.205, p.112-118, 2016. https://doi.org/10.1016/j.scienta.2016.04.008

VERSIEUX, L.M.; PALMA-SILVA, C.; WENDT, T.; MERCIER, H. Report from the 2nd World Congress of Bromeliaceae Evolution–BromEvo II (Natal, Brazil, 2018). **Botanical Journal of the Linnean Society**, v.192, n.4, p.587-588, 2020. https://doi.org/10.1093/botlinnean/boaa002

WINKLER, U.; ZOTZ, G. Highly efficient uptake of phosphorus in epiphytic bromeliads. **Annals of Botany**, v.103, n.3, p.477-484, 2009. https://doi.org/10.1093/aob/mcn231

YOUNG, J.L.M.; KANASHIRO, S.; JOCYS, T.; TAVARES, A.R. Silver vase bromeliad: plant growth and mineral nutrition under macronutrients omission. **Scientia Horticulturae**, v.234, p.318-322, 2018. https://doi.org/10.1016/j.scienta.2018.02.00