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Silver vase bromeliad: Plant growth and mineral nutrition under macronutrients omission

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ABSTRACT

The present study aimed to evaluate the effects of N, P, K, Ca, Mg and S deficiencies on the growth, mineral contents of silver vase bromeliad [*Aechmea fasciata* (Lindley) Baker], a species native to Brazil. Plants were maintained on modified Hoagland & Arnon nutrient solution with omission of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S) or complete solution (CS) totalizing seven treatments. Leaf nutrient contents of the treatments were analyzed to confirm the deficiencies. The first leaf deficiency symptoms appeared in cultivated plants from which nitrogen (N) was omitted. In fact, nitrogen was found to be the growth-limiting nutrient of silver vase bromeliad. Phosphorus-deficient plants had reddish leaves and showed necrosis in young leaves. K, Ca, Mg and S deficiency can only be determined by foliar analysis. The limiting nutrients to silver vase bromeliad growth were N > P = K > Ca = Mg > S in ascending order.

1. Introduction

The bromeliad cultivation for commercial purposes is quite recent and there is a lack of knowledge to increase plant production and quality; consequently, it is challenging to establish a bromeliad production by potential producers. The ornamental bromeliad commerce could make significant contributions to rural areas economies and for the forest communitie in countries such as Brazil, Bolivia and Colombia (Negrelle et al., 2012). Silver vase bromeliad [*Aechmea fasciata* (Lindley) Baker] is endemic to Brazil. This beautiful and long lasting species was the first bromeliad to be cultivated in Europe (Samyn and Thomas, 1994). *A. fasciata* and *Guzmania lingulata* respond for 80% of the bromeliads marketed in Brazil (Anacleto and Negrelle, 2013).

In contrast to terrestrial plants, epiphytic tank-bromeliads uptake nutrients mainly from their tank leaf surface, which is determined by the source and the complex interplay among tank microorganisms (Inselsbacher et al., 2007). Tank-bromeliads as silver vase bromeliads have overlapping leaves forming a reservoir that can store water and organic matter, which are absorbed by special structures in leaf surfaces known as trichomes (Benzing et al., 1976). Leaf trichomes are as efficient as fine roots and play a role as nutrient uptake organs (Winkler and Zotz, 2010).

The horticultural aspects of growing bromeliads are quite complex since such species have adapted to different amounts of moisture, nutrients and light (Ertelt, 1992). The most important research studies on bromeliad nutrition had a physiological, biochemical or ecological standpoint, whereas the studies with a horticultural focus are scarce. Kämpf (1994) described the effect of different concentrations of N-P-K on silver vase bromeliad growth; Xavier et al. (2010) reported the effect of the mixture of ammonium sulfate and Peters® commercial formulation on *Alcantarea vinicolor*; Lin and Yeh (2008) determined the growth anatomy and macronutrients of *Guzmania lingulata* under various concentrations of K, and Vitória and Leite (2008) reported the effect of K on the growth of silver vase bromeliad.

The aim of this study was to characterize the deficiency symptoms as well as the yield of silver vase bromeliads by assessing their nutrient metabolism thus presenting an analysis of nutrient contents, plant growth and development of silver vase bromeliad grown in omitted macronutrient solutions.

2. Materials and methods

The plants for the experiment had the following measures on average: 17.61 cm leaf length, 7.86 leaves; 28.46 g leaf fresh mass; 2.83 g leaf dry mass; 2.83 g root fresh mass; 0.45 g root dry mass; 3.43 g stem fresh mass; 0.26 g stem dry mass and 11.57 mm in diameter. The plants were grown into 900 mL polyethylene pots with pine bark compost as substrate (pH – 3.50, Organic Matter 26.0%, C – 14%, C/N – 28/1, Humidity 65 °C – 57%, Macronutrients (%) N – 0.50, P_2O_5 – 0.1, K_2O < 0.1, Ca – 0.3, Mg – 0.1, and S – 0.3, Micronutrients (mg kg^{-1})

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Na – 129, Cu – 6, Fe – 3677, Mn – 52, and Zn – 13).

The experiment was carried out for a 10-month period, under greenhouse conditions with average temperature of 27 ± 3 °C. The treatments were based on HA nutrient solution number 1 (Hoagland and Arnon, 1950), composed of complete solution (CS) and modified solutions (Ferreira, 2012) with omitted nitrogen (-N), phosphorus (-P), potassium (-K), calcium (-Ca), magnesium (-Mg) or sulfur (-S). The pH of the solutions were adjusted to 5.8. We applied 50 mL of the solution into the bromeliad tank on a weekly basis, and plants irrigation were carried out weekly only on the substrate (water analysis: pH – 7.7; ions ($mmol_c\ L^{-1}$): K – 0.07; Ca – 0.320; Mg – 0.060; Cl – 0.960; Na – 0.100; CO_3^{-2} – 0.000; HCO_3- – 0.420, and EC – 0.080 $mS\ cm^{-1}$). The electrical conductivity of nutrient solutions were measured with a condutivitymeter (Marconi CA-150, Piracicaba, Brazil).

The experiment was conducted as a randomized block with 3 replications and 5 plants per plot (total of 105 plants). Plants were divided into leaves, stem and root system and weighted to obtain fresh mass of leaves (LFM), stem (SFM), roots (RFM) and total plant (TFM). The fresh material were dried in oven at 60 °C until constant weight to obtain leaves (LDM), stem (SDM), roots (RDM) and (TDM) total plant dry mass. Plant height (PH) and number of leaves (NL) were also evaluated.

The analysis of mineral elements was performed in triplicate of all leaves per plant. Phosphorus contents were determined by ammonium-metavanadate colorimetric method; potassium by flame spectrophotometer (600plus, Femto, São Paulo, Brazil); calcium, magnesium, zinc, iron, copper and manganese by atomic absorption spectrometer (2380, Perkin-Elmer, Norwalk, CT, USA), sulfur by turbidimetry of barium sulfate, nitrogen was evaluated by Kjeldahl method, and boron by the Azomethine-H method as described by Bataglia et al. (1983). Data were submitted to analysis of variance (F test), and the averages were compared by Tukey test at 5% probability.

3. Results and discussion

The treatment -N (nitrogen omission) resulted in the lowest values for fresh and dry mass of stems, roots, leaves, and total (Table 1). There was no significant difference among treatments for number of leaves and plants were shorter under treatment -N only in relation to treatment -S. The highest yield for total dry mass was obtained under CS, -Ca, -Mg and -S treatments, and intermediate values for -P and -K treatments. Our findings contrast with the effects of potassium fertilization in *Guzmania lingulata* (tank-bromeliad), in which stem and root dry mass were unaffected by K concentration in the nutrient solution (Lin and Yeh, 2008). The most prominent role of K^+ is its osmotic function, and K^+ can be partly replaced by other cations such as Mg^{2+}, Na^+ or Ca^{2+}; thus internal transfer to growing organs during periods of insufficient supply may allow the bromeliads to keep up growth for a considerable amount of time and can be considered a type of "luxury" consumption (Winkler and Zotz, 2010). As a consequence of constant exposure of leaves to nutrient solution in the bromeliad tank, the higher values of electrical conductivity of nutrient solution might explain our results for silver vase bromeliad cultivated with –S (1.24 $mS\ cm^{-1}$), –Ca (1.48 $mS\ cm^{-1}$) and –Mg (1.29 $mS\ cm^{-1}$) solutions which showed better growth parameters when compared to plants cultivated with Complete Solution (CS) (1.71 $mS\ cm^{-1}$). Higher percentage of base saturation and/or electrical conductivity of the nutrient solution can delay nutrient uptake by increasing osmotic pressure, while low percentages may positively affect plant health and crop production (Samarakoon et al., 2006). Sanches (2009) showed that silver vase bromeliad plants treated with 40% percent base saturation solution grew better and accumulated more nutrients than plants treated with 20%.

The limiting nutrients to silver vase bromeliad growth, in ascending order, were N > P = K > Ca = Mg > S, according to the dry mass of roots, stems, and leaves (Fig. 1). Nitrogen was the most limiting nutrient to silver vase bromeliad growth. These results are in accordance with Leroy et al. (2009), in which nitrogen is a major limiting nutrient to the growth of tank bromeliads. The base of tank bromeliad leaves is the main surface being exposed to nutrients, by playing the role of roots in nitrogen absorption, nitrate reduction and urea hydrolysis, since the roots have the main role in anchoring the bromeliad on the host plant rather than uptake nutrients (Takahashi and Mercier, 2011). Plant N:P ratios are diagnostic values to identify the limiting nutrient, N:P ratio > 16 indicates P limitation, while an N:P ratio < 14 indicates N limitation (Koerselman and Meuleman, 1996). The treatment CS showed a N:P ratio = 6.88 (Table 2), indicating that N is the main nutrient for silver vase bromeliad, and corroborate the plant growth and development data (Table 1).

Silver vase bromeliad cultivated under omission of nitrogen showed uniform chlorosis on the blade and petiole of all leaves (Fig. 2), and consequently losing the silvery appearance of leaves, followed by nutrient remobilization during leaf senescence, that is, from old leaves to young ones (Bausenwein et al., 2001). Nitrogen deficiency generally brings a decrease in protein in chloroplasts and a degradation of chloroplast fine structure (lamellar) which is associated with protein loss, leading to the loss of green color from nitrogen-deficient leaves (Barker and Pilbeam, 2007). Plants submitted to -P treatment showed reddish blade in all leaves (Fig. 3), followed by necrosis at the edge of older leaves (Fig. 4). Phosphorus deficiency reduces plant growth from the earliest stages of development and the older leaves turn purplish, due to the anthocyanin pigment accumulation, which progresses to necrosis (Adalberto et al., 2004). Bromeliad growers in Brazil (personal communication) also related these symptoms, increasing phosphorus fertilization when several varieties of bromeliads start to become reddish. However, and interestingly, most of the growers associated such symptoms with cold weather season in Brazil (June-August) and not with a nutritional deficiency. Plants submitted to the treatments -K, -Ca, -Mg and -S showed no visual symptoms in the leaves or leaf necrosis. Pineapple (Bromeliaceae) have a low requirement of Mg and S; in addition, Mg deficiency is pronounced prior floral differentiation (Malézieux and Bartholomew et al., 2002) and S deficiency is rare

Table 1
Plant height, number of leaves (NL), shoot (SFM), root (RFM), leaves (LFM), and total (TFM) fresh mass and shoot (SDM), root (RDM), leaves (LDM), and total (TDM) dry mass of silver vase bromeliads grown in complete solution (CS) of Hoagland and Arnon (1950) and under nutrient omission treatments.

Treatments	Plant Height (cm)	NL (un)	SFM (g)	RFM (g)	LFM (g)	TFM (g)	SDM (g)	RDM (g)	LDM (g)	TDM (g)
CS	27.03 ab	17.66 a	9.93 abc	4.73 bc	110.26 bc	124.76 bc	1.98 a	1.25 ab	20.86 ab	24.01 ab
-N	25.42 b	16.20 a	7.93 c	3.60 c	87.86 c	99.11 c	0.43 c	0.34 c	6.20 c	7.02 c
-P	30.44 ab	17.60 a	9.86 abc	5.26 abc	119.40 abc	134.24 abc	1.35 b	0.98 b	16.40 b	18.81 b
-K	29.36 abc	17.13 a	8.33 bc	5.93 abc	97.20 bc	111.36 bc	1.28 b	1.10 ab	15.93 b	18.20 b
-Ca	31.26 ab	19.00 a	11.00 abc	8.73 a	130.66 abc	150.46 ab	1.73 ab	1.50 ab	20.00 ab	23.10 ab
-Mg	30.94 ab	17.93 a	12.46 ab	7.86 ab	139.66 ab	159.95 ab	1.76 ab	1.45 ab	20.46 ab	23.59 ab
-S	32.33 a	19.33 a	13.46 a	8.60 a	158.93 a	180.96 a	1.83 ab	1.64 a	22.93 a	26.35 a

Means followed by the same letters in each column do not differ according to Tukey test ($P \leq 0.05$).