Growth, nutrient accumulation and export by heliconia 'Red Opal'[(1)]

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ABSTRACT

Synchronizing the timing of fertilizer applications with plant nutrient demand increases the nutritional efficiency and decrease the cost of production. The objective of this study was to determine the growth and the nutrient uptake and export by heliconia 'Red Opal'. The experiment was carried out in a shade house and *Heliconia psittacorum* 'Red Opal' rhizomes were planted in soil classified as Arenic Kandinstults. The experimental design was completely randomized with nine plant sampling (zero; 30; 90; 150; 210; 270; 330; 390 and 450 days after planting) and five replicates. Leaves, sheathing leaf bases, flower stem, rhizomes and roots were collected every sampling and dry mass and nutrients accumulation were determined. Heliconia plants showed slow initial development but from the 210 days of planting, which corresponds with the beginning of the flower stem harvest there is a marked increase in dry mass accumulation. Nutrient accumulation followed the decreasing order: K > N = Ca > P = Mg > S > Fe = Mn > Zn > Cu = B. Potassium and calcium were the most exported macronutrients by heliconia flower stem and among the micronutrients, manganese was the most exported.

Keywords: *Heliconia psittacorum* 'Red Opal', nutrient cycling, tropical floriculture.

RESUMO

Crescimento, acúmulo e exportação de nutrientes pela helicônia 'Red Opal'

A sincronização da aplicação dos fertilizantes com a época de demanda de nutrientes aumenta a eficiência nutricional da planta e diminui os custos de produção. Objetivou-se com o trabalho determinar o desenvolvimento e a marcha de absorção de nutrientes pela helicônia 'Red Opal'. O experimento foi conduzido em telado e rizomas de *Heliconia psittacorum* 'Red Opal' foram plantados em Argissolo Vermelho-Amarelo. O delineamento experimental foi o inteiramente casualizado com nove épocas de amostragem (zero; 30; 90; 150; 210; 270; 330; 390 e 450 dias após o plantio) e cinco repetições. Folhas, bainhas, hastes, rizomas e raízes foram coletadas a cada época de amostragem e a massa seca e o acúmulo de nutrientes foram determinados. As plantas de helicônia apresentaram desenvolvimento lento, mas a partir dos 210 dias do plantio, época que corresponde ao início da colheita das hastes, houve aumento acentuado no acúmulo de massa seca da planta. O acúmulo de nutrientes seguiu a ordem decrescente: K > N = Ca > P = Mg > S > Fe = Mn > Zn > Cu = B. O potássio e o cálcio foram os macronutrientes mais exportados pelas hastes de helicônia e dentre os micronutrientes, o manganês foi o mais exportado.

Palavras-chave: *Heliconia psittacorum* 'Red Opal', ciclagem de nutrientes, floricultura tropical.

1. INTRODUCTION

Synchronizing the timing of fertilizer applications with plant nutrient demand is critical for any crop production. When this aim is reached, the nutritional efficiency increases and the cost of production decreases. For most of the crops the dry mass and the nutrient accumulation dynamics are well established but for ornamental plants are rare, especially for tropical flowers. In fact, studies related to mineral nutrition of ornamental plants are scarce as floriculture is a relatively recent economic activity when compared to other commercial crops (FURTINI NETO et al., 2015).

Different NPK formulations are frequently used by the heliconia growers, but the development phase (vegetative or reproductive), seasonality or highest flowering periods are not considered when fertilizations are planned (CASTRO et al., 2011). Responses to fertilization vary even within the *Heliconia* species (FERREIRA and OLIVEIRA, 2003; MACHADO NETO et al., 2011).

Heliconia require a large amount of nutrient and the response to fertilization are often found (CLEMENS and MORTON, 1999; ALBUQUERQUE et al., 2010; MACHADO NETO et al., 2011; CARVALHO et al., 2012; SUSHMA et al., 2012; FARIAS et al., 2013; BECKMANN-CAVALCANTE et al., 2015; 2016; NAIK, 2015). Besides the inflorescence production, fertilization also influences the heliconia flower stem quality (CASTRO et al., 2007; MACHADO NETO et al., 2011; AMARAL et al., 2015).

The objective of this study was to determine the growth and the nutrient uptake and export by heliconia 'Red Opal' grown under shade house conditions.

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2. MATERIALS AND METHODS

The experiment was carried out in a shade house located at the Embrapa Tropical Agroindustry Experimental Field (Pacajus, Ceara State, Brazil). The region climate is Aw (hot climate, rainy summer and dry winter) according to Köppen classification and average annual rainfall of 931.3 mm (EMBRAPA, 2001). The shade house covering was a black shade cloth of 50% transmittance and the average temperature and humidity were 26.3 ºC and 77%, respectively.

The soil was classified as Arenic Kandinstults, according to Lima et al. (2002). Soil samples from 0 to 0.2 m layer were collected for chemical analysis and the results were: pH H_2O = 6.2; O.M. = 9.2 g kg^{-1}; P = 2.0 mg dm^{-3}; Ca^{2+} = 13.6 $mmol_c$ dm^{-3}; Mg^{2+} = 9.7 $mmol_c$ dm^{-3}; Na^+ = 1.0 $mmol_c$ dm^{-3}; K^+ = 1.4 $mmol_c$ dm^{-3}; H+Al = 13.2 $mmol_c$ dm^{-3}; sum of bases = 25.7 $mmol_c$ dm^{-3}; cation exchange capacity = 38.9 $mmol_c$ dm^{-3} and bases saturation = 66.0%. According to the soil results and the liming recommendation for ornamental plants and flowers (RAIJ et al., 1996), lime was not necessary.

The experimental design was completely randomized with nine plant sampling (zero, 30, 90, 150, 210, 270, 330, 390 and 450 days after planting) and five replicates. Prior to planting *Heliconia psittacorum* 'Red Opal' rhizomes were selected, standardized and cleaned, roots were removed and air dried after washing in tap water. Rhizomes were planted at 1.0 m between plants and 2.0 m between rows. Fertilization consisted of 20-10-20 + 2% S (200 g per plant each fertilization) at 60, 90 and 120 days after planting and single application of fritted trace elements containing 9% of Zn; 1.8% of B; 0.8% of Cu; 0.1% of Mo; 3% of Fe and 2.0% of Mn (50 g per plant at 60 days after planting). During the experiment was not given any pesticide sprays, plants were watered daily through a drip irrigation system (from 2.2 to 2.5 mm per day, according to GONDIM et al., 2008) and weeds were manually removed.

Every plant sampling leaves, sheathing leaf bases (including petioles), flower stem (from 210 days after planting), rhizomes and roots were collected, washed with hydrochloric acid solution 3% (v:v) and deionized water and dried in an oven at 65 °C until constant weight. Hereinafter, leaves, sheathing leaf bases and flower stem and rhizomes and roots will be referred to as leaves and rhizomes, respectively. Afterwards, shoot and rhizomes dry mass were determined and ground to pass through a 1 mm sieve. Macronutrients and micronutrients were determined, as procedures described in Miyazawa et al. (2009).

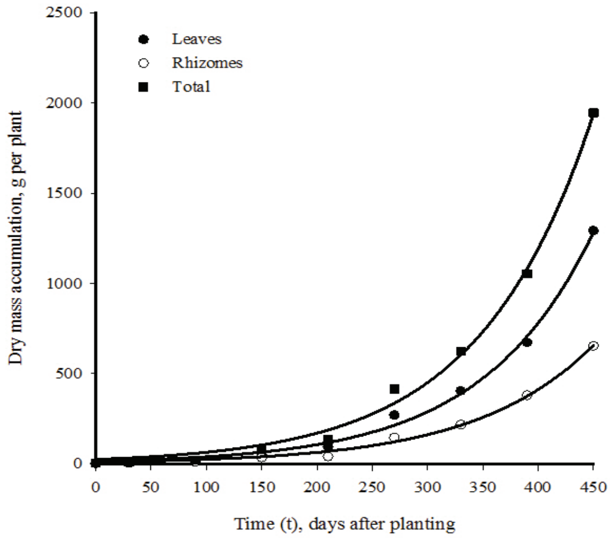
Flower stems were harvested when the inflorescences had two open bracts. Plants were cut at the soil surface, leaves blades removed and petioles preserved (Figure 1), as recommended by Mosca et al. (2004). Flower stems and removed leaves blades followed the cleaning and nutrients determination procedures described above.

Figure 1. Heliconia 'Red Opal' flower stem after post-harvest handling. Pacajus, 2015.

The data obtained were subjected to variance analysis using SAS program and means were fitted to an exponential model (SAS, 2012).

3. RESULTS AND DISCUSSION

The R^2 values higher than 0.9421** indicate that the exponential model can explain most of the variability of heliconia 'Red Opal' leaves, rhizomes and total (leaves + rhizomes) dry mass (Figure 2). Heliconia plants showed slow initial development, with low leaves, rhizomes and total dry mass until 90 days after planting. At this stage, the slow development could be attributed to the beginning of the roots growth, leaves expansion and shoot emission. From 90 to 210 days after planting, an increase in all growth parameters were found, however, considering the evaluation period (450 days), the total dry mass production at that stage accounted for only 9.7% of the accumulated dry mass. From the 210 days of planting, when heliconia flower stem began the harvest (Figure 3), there was a marked increase in dry mass accumulation until the end of the evaluation period.



Leaves $L = 14.5663.e^{0.0099.t}$ ($R^2 = 0.9895^{**}$)

Rhizomes $R = 9.7708.e^{0.0093.t}$ ($R^2 = 0.9421^{**}$)

Total $T = 24.2590.e^{0.0097.t}$ ($R^2 = 0.9803^{**}$)

Figure 2. Leaves, rhizomes and total dry mass production of heliconia 'Red Opal', as affected by cultivation time. Pacajus, 2015.

Heliconia inflorescence production was less than one stem per plant per month, however, from 271 to 390 days after planting the average was two stems per plant per month (Figure 3). From 391 to 450 days of planting, the average production was four stems per plant per month.

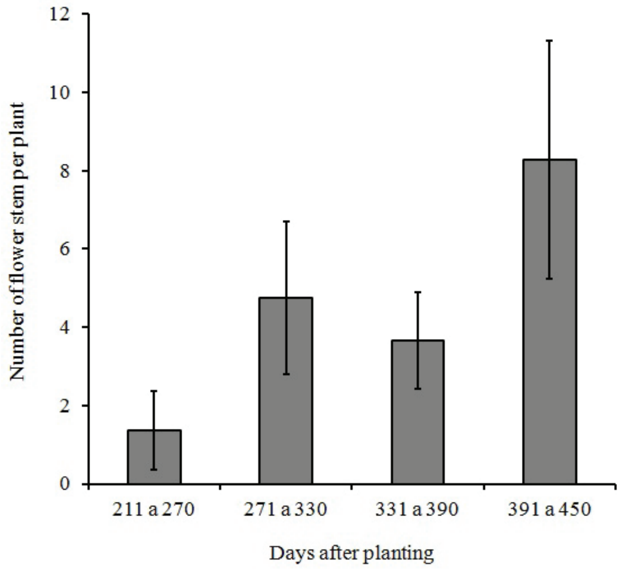


Figure 3. Heliconia 'Red Opal' flower stem production, as affected by cultivation time. Pacajus, 2015.

Rhizomes accounted for more than 80% of plant dry mass at planting (Figure 4). Rhizomes contribution in the total dry matter accumulation decreased as the plant developed and at 90 days after planting, rhizomes and leaves ratio was equivalent. From the 210 days after planting, rhizomes distribution ranged from 30 to 40% of the total dry mass, which corresponds with the beginning of the flower stem harvest.

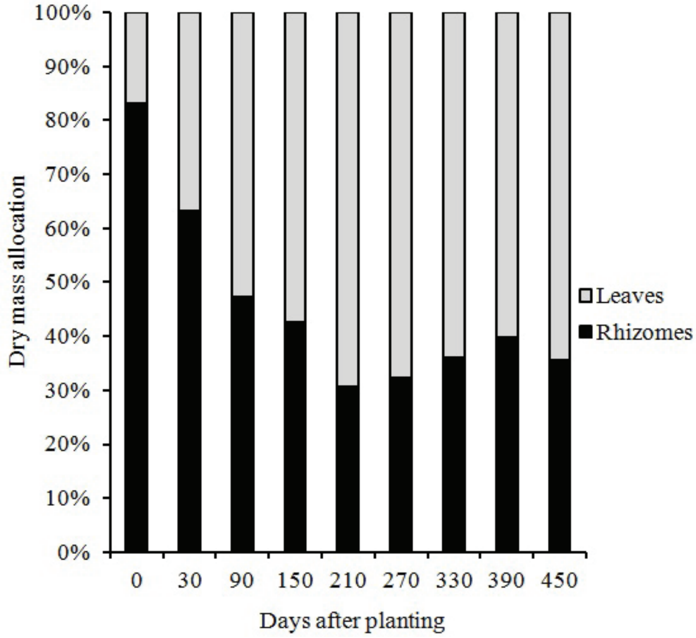


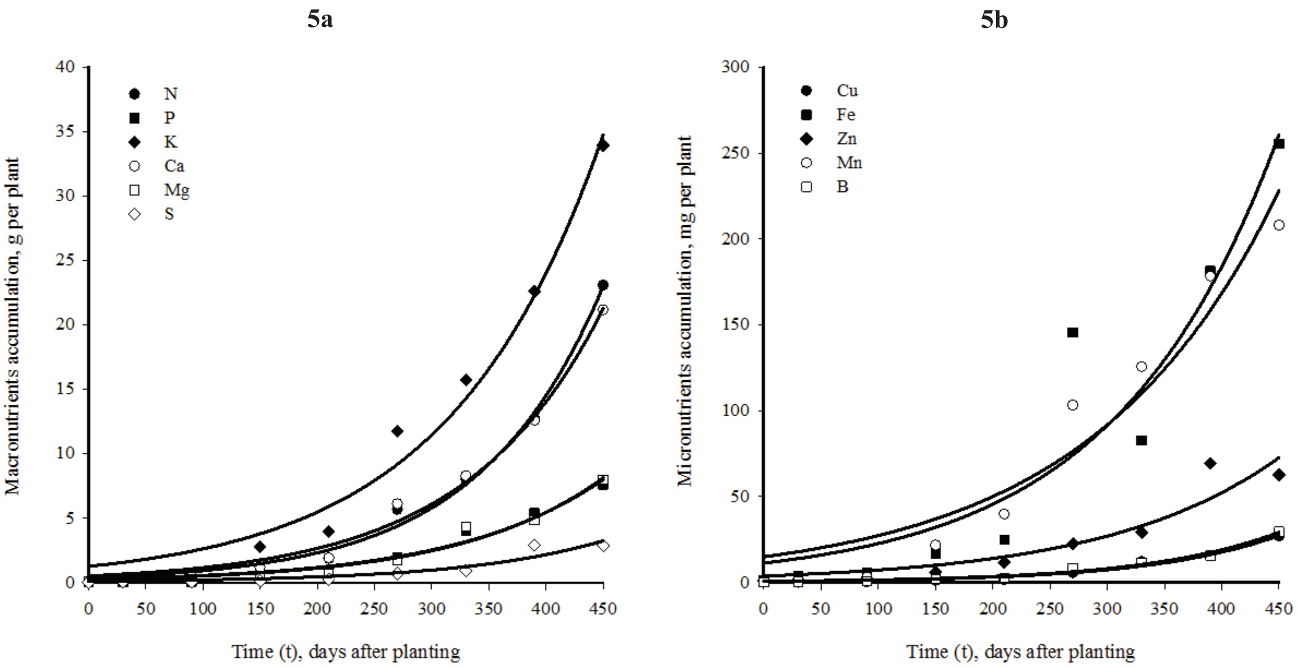
Figure 4. Leaves and rhizomes dry mass allocation in heliconia 'Red Opal', as affected by cultivation time. Pacajus, 2015.

Nutrients accumulation in heliconia plants followed the trend of dry mass production (Figure 5 and Table 1). For macronutrients, the accumulation followed the decreasing order: K > N = Ca > P = Mg > S, while for micronutrients Fe = Mn > Zn > Cu = B. Nitrogen was the nutrient that most limited the development of *Heliconia psittacorum* x *H. spathocircinata* Aristeguieta 'Golden Torch', resulting in decreased by 60% the shoots number and 66% in leaves dry mass production (CASTRO et al., 2015). In addition to nitrogen, Viégas et al. (2014) also pointed out magnesium as a limiting nutrient to the development of heliconia 'Golden Torch'. According to Clemens and Morton (1999), nitrogen and potassium fertilizers directly affects the development of heliconia 'Golden Torch': high N rates and high N:K ratio favor the biomass production, while moderate N rates and low N:K ratio favor the inflorescences production. In addition to plant development decreasing, nitrogen, phosphorus and potassium deficiency in heliconia 'Golden Torch' resulted in flower stem length and diameter modification, post-harvest durability and carbohydrate content of flower stem alteration (CASTRO et al., 2007).

Potassium and calcium were the nutrient most exported by heliconia flower stem (Figure 6) and among the micronutrients, manganese was the most exported. Leaf blades, which are removed at the flower stem post-harvest handling, have considerable amounts of nitrogen, potassium, calcium, manganese and iron (Figure 7). These results agree with Criley (1989), who found that the macronutrients which have higher contents in six heliconia species were nitrogen, potassium and calcium, while for the micronutrients, manganese and iron. The return of the leaf blades to the cultivation area are cycling about 82% of N; 57% P; 42% K; 68% Ca; 63% Mg; 81% S; 62% Cu; 30% Fe; 34% Zn; 11% Mn and 53% B exported by the plant (flower stems + leaf blades). Nutrient availability in this plant residue is dependent on abiotic factors and microorganism activity in the soil. The possibility of nutrient cycling could decrease the fertilizer input, lowering the production costs and the environmental risks associated with their unnecessary application.

Based on these results, it is observed that heliconia 'Red Opal' fertilization management should be planned to provide nutrients in sufficient quantities to enable the rapid root system development and the plant establishment in the field. After this period the supply of nutrients must be in greater quantity and frequency, due to the continuing shoots emission and inflorescence formation and harvest. Nitrogen, potassium and calcium were the most accumulated nutrients and exported by heliconia and particularly in relation to the latter, appropriate levels in the soil or the lime application before planting the rhizomes guarantee the supply of this nutrient for plants. With the beginning of the reproductive phase, fertilization with nitrogen and potassium should be intensified in order to meet the need of the plant to ensure the vegetative growth and the nutrients exported by the plant. Furthermore, leaf blades removed at the post-harvest handling, can return to the cultivation area, allowing the nutrients cycling and consequently, decreasing fertilizer application.

Studies have shown the effects of inorganic (CLEMENS and MORTON, 1999; SUSHMA et al., 2012; BECKMANN-CAVALCANTE et al., 2015; 2016; NAIK, 2015) and/or organic fertilizers (ALBUQUERQUE et al., 2010; MACHADO NETO et al., 2011; CARVALHO et al., 2012; FARIAS et al., 2013) on different heliconia species, however, more studies are needed to define the timing of fertilizer applications.



Nitrogen	$N = 0.3636.e^{0.0092.t}$ ($R^2 = 0.9825^{**}$)	Copper	$Cu = 0.5301.e^{0.0088.t}$ ($R^2 = 0.9703^{**}$)
Phosphorus	$P = 0.2485.e^{0.0077.t}$ ($R^2 = 0.9673^{**}$)	Iron	$Fe = 11.2430.e^{0.0070.t}$ ($R^2 = 0.9186^{**}$)
Potassium	$K = 1.2421.e^{0.0074.t}$ ($R^2 = 0.9706^{**}$)	Zinc	$Zn = 3.7105.e^{0.0066.t}$ ($R^2 = 0.9187^{**}$)
Calcium	$Ca = 0.4968.e^{0.0084.t}$ ($R^2 = 0.9769^{**}$)	Manganese	$Mn = 14.8493.e^{0.0061.t}$ ($R^2 = 0.9527^{**}$)
Magnesium	$Mg = 0.2233.e^{0.0080.t}$ ($R^2 = 0.9616^{**}$)	Boron	$B = 0.6140.e^{0.0086.t}$ ($R^2 = 0.9754^{**}$)
Sulfur	$S = 0.0838.e^{0.0081.t}$ ($R^2 = 0.9269^{**}$)		

Figure 5. Macronutrients (5a) and micronutrients (5b) accumulation in heliconia 'Red Opal', as affected by cultivation time. Pacajus, 2015.

Table 1. Macro and micronutrients accumulation in heliconia 'Red Opal', as affected by cultivation time. Pacajus, 2015

Days after planting	N	P	K	Ca	Mg	S	Cu	Fe	Zn	Mn	B
	-- % --										
0-90	1	1	1	2	1	1	1	2	3	2	2
91-210	8	10	11	9	8	8	6	9	18	18	8
211-270	26	27	35	30	22	26	22	56	34	51	30
271-390	56	75	71	63	64	104	62	78	121	90	56
391-450	100	100	100	100	100	100	100	100	100	100	100

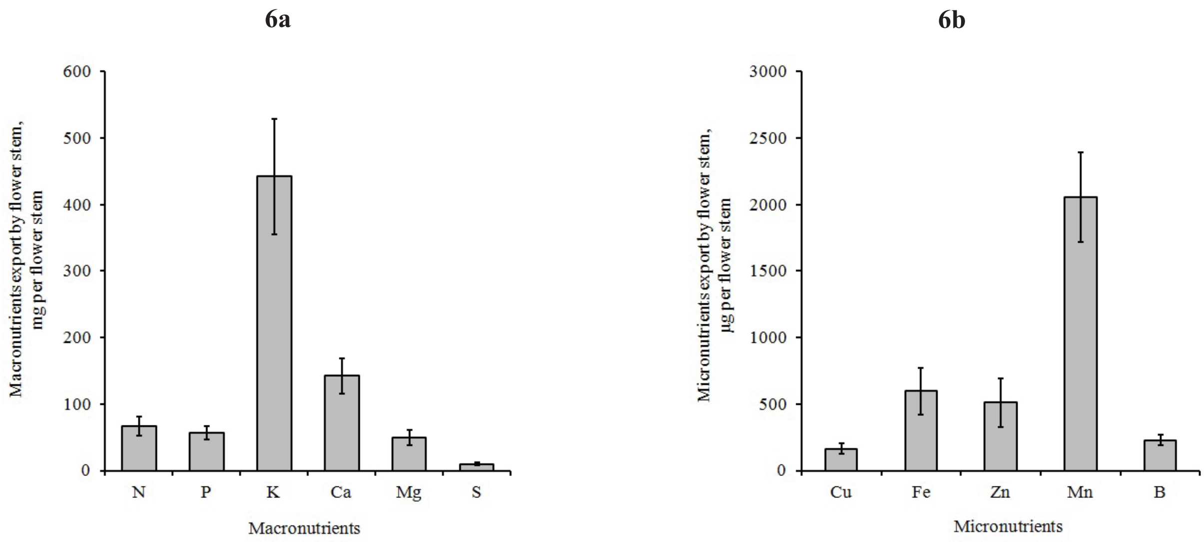


Figure 6. Macronutrients (6a) and micronutrients export (6b) by heliconia 'Red Opal' flower stem. Pacajus, 2015.

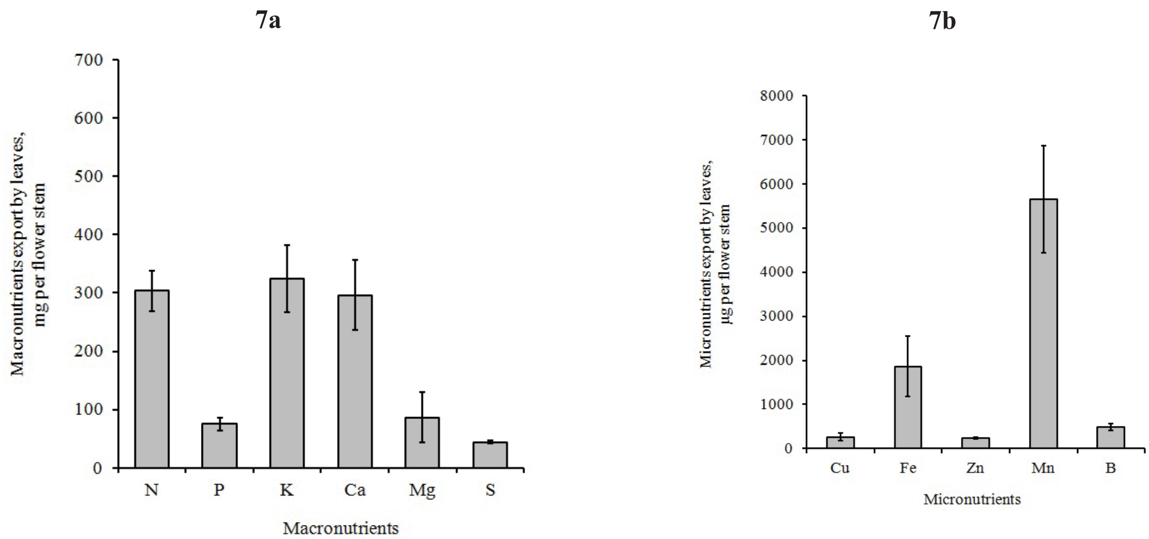


Figure 7. Macronutrients (7a) and micronutrients export (7b) by heliconia 'Red Opal' leaves. Pacajus, 2015.

4. CONCLUSIONS

Heliconia plants show slow initial development but from the 210 days of planting, which corresponds with the beginning of the flower stem harvest there is a marked increase in dry mass accumulation. Nutrient accumulation followed the decreasing order: K > N = Ca > P = Mg > S > Fe = Mn > Zn > Cu = B. Potassium and calcium were the macronutrients most exported by heliconia flower stem and among the micronutrients, manganese was the most exported.

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