Revista Ciência Agronômica, v. 46, n. 2, p. 258-265, abr-jun, 2015
Centro de Ciências Agrárias - Universidade Federal do Ceará, Fortaleza, CE
www.ccarevista.ufc.br

Artigo Científico
ISSN 1806-6690

Macronutrients deficiency in *Heliconia psittacorum* x *Heliconia spathocircinata* 'Golden Torch'[1]

Deficiência de macronutrientes em *Heliconia psittacorum* x *Heliconia spathocircinata* cultivar Golden Torch

Ana Cecília Ribeiro de Castro[2]*, Lilia Gomes Willadino[3], Vivian Loges[3], Mario Felipe Arruda de Castro[3] e Fernando Antonio Souza de Aragão[2]

ABSTRACT - The objective of this study was to characterize nutritional deficiencies in *Heliconia psittacorum* x *Heliconia spathocircinata* 'Golden Torch', through growth indicators, symptomatology and macronutrients contents in leaves and underground plant part. The experiment was carried out in a greenhouse, with eight treatments comprising complete nutrition solution (N, P, K, Ca, Mg, S), solution with individual nutrient omission of N, P, K, Ca, Mg or S and solution lacking all nutrients. The symptoms of nutrients deficiency appeared in the following occurrence order: N, K, P, Mg and S. Deficiency symptoms were: general chlorosis to - N omission; slight chlorosis to - P and - S; dark green leaves and necrosis to - K; marginal chlorosis and necrosis to - Mg. Calcium omission did not cause any visual symptom. Deficiencies in N and P affected more intensely shoot number, leaf dry mass production, total leaf number and leaf area. Among the evaluated leaves, there was a tendency of a highest decrease in the contents in the third leaf.

Key words: Heliconia. Symptomatology. Nutrition. Tropical flowers.

RESUMO - O objetivo deste estudo foi caracterizar deficiências nutricionais em *Heliconia psittacorum* x *Heliconia spathocircinata* cultivar Golden Torch, por meio de indicadores de crescimento, sintomatologia e teores de macronutrientes nas folhas e parte subterrânea. O experimento foi conduzido em casa de vegetação, com oito tratamentos, sendo solução completa (N, P, K, Ca, Mg, S) e com a omissão individual de N, P, K, Ca, Mg ou S e ausência completa de nutrientes. Os sintomas de deficiência dos nutrientes surgiram na seguinte ordem de ocorrência: N, K, P, Mg e S. Os sintomas foram: clorose generalizada em - N; clorose em - P e em - S; folhas verde-escuras e necrose em - K e; clorose ao longo dos bordos com necrose em - Mg. A omissão de Ca não acarretou sintomas visíveis. As deficiências de N e P afetaram mais intensamente o número de perfilhos, produção de massa seca das folhas, número total de folhas e área foliar. Entre as folhas avaliadas, houve tendência à redução destes teores de forma mais acentuada na 3ª folha.

Palavras-chave: Helicônia. Sintomatologia. Nutrição. Flores tropicais.

DOI: 10.5935/1806-6690.20150005
*Autor para correspondência
[1]Recebido para publicação em 07/08/2013; aprovado em 17/01/2015
Parte da Tese de Doutorado do primeiro autor, apresentada ao Programa de Pós-Graduação em Botânica da Universidade Federal Rural de Pernambuco, Recife-PE, Brasil
[2]Laboratório de Melhoramento e Recursos Genéticos Vegetais, Embrapa Agroindústria Tropical, Fortaleza-CE, Brasil, 60.511-110, cecilia.castro@embrapa.br, fernando.aragao@pq.cnpq.br
[3]Laboratório de Floricultura, Universidade Federal Rural de Pernambuco, Recife-PE, Brasil, 52.171-900, willadino.lilia@gmail.com, vloges@yahoo.com, mariocastro@alldeia.com.br

INTRODUCTION

The heliconias belongs to Zingiberales Order, Heliconiaceae family that presents a single genus, *Heliconia*. Among the more commercially cultivated genotypes, one of the most important the natural hybrid is *Heliconia psittacorum* x *Heliconia spathocircinata* Aristeguieta 'Golden Torch' (ROCHA *et al*., 2010).

Nutritional deficiency affects heliconia cut flower production and the success of its commercialization. Relative to other floricultural crops, heliconia in cultivation generally requires high rates of macro-elements, particularly N. There is a great variation in heliconia management in farm production, mainly concerning fertilization (CASTRO *et al*., 2011).

Appropriate fertilization programs must be used in commercial cut flower production, in order to guarantee productivity, quality and post-harvest durability of the floral stem. The scarcity of a nutrient can cause visible abnormalities, which are characteristic to each element (MALAVOLTA, 2006).

Nevertheless, many times growth and production can be already affected before the appearing of visual deficiency symptom (EPSTEIN; BLOOM, 2006). Plant nutritional deficiency is the expression of metabolic disturbances resulting from the deficient supplying of one or more mineral nutrients. These disturbances are related to the functions performed by nutrients in the plant metabolism (TEWARI *et al*., 2004).

Plant nutritional status can be determined through visual diagnosis or leaf analysis (EPSTEIN; BLOOM, 2006). The selection of the indicator leaf to be used in leaf analysis, that better expresses the nutritional status of the crop, is important in order to determine the deficient elements when these had not yet caused visual symptoms or when the symptoms of different deficiencies are similar.

Aspects of nutritional requirements of these plants have not been studied comprehensively and little published researches are available (CASTRO *et al*., 2011), fundamental informations are needed, regarding several aspects of the heliconia production, specially concerning to mineral nutrition. The objective of this study was to characterize nutritional deficiencies in plants of *Heliconia psittacorum* x *H. spathocircinata* 'Golden Torch', trough growth indicators, symptomatology and macronutrients contents in leaves and underground plant part.

MATERIAL AND METHODS

The experiment was carried out in a greenhouse in Recife-PE, Brazil. Rhizomes from *Heliconia psittacorum* x *H. spathocircinata* Aristeguieta 'Golden Torch' were used, selected with 30 cm long and approximately 120 g of fresh mass. The rhizomes were cleaned; the roots were removed and after washing in demineralized water, were air dried. Although fresh mass and length of the rhizomes are approximate, it is possible the occurrence of variation in vigor, dry mass and macronutrient content. Previously, the macronutrient contents were determined in 10 rhizomes possessing fresh mass, size and source similar to the used in the experiment. The rhizomes presented the following average macronutrient concentrations (g kg^{-1} fresh mass): N (18.2), P (2.7), K (23.8), Ca (3.7), Mg (1.1) and S (9.9). A completely randomized experimental design was used, with 10 replications, being 5 replications randomly collected for each analyzed development stage (vegetative and reproductive), and the experimental unit was one rhizome per pot.

The rhizomes were planted in 12-liter plastic black pots, containing substrate composed exclusively by washed quartz sand and sifted in 2mm mesh, covered by a 3mm gravel layer in order to reduce the superficial evaporation. Initially, the rhizomes were daily irrigated exclusively with distilled water for 30 days. After this period, were applied the treatments that consisted of ½-strength modified Hoagland solution (HOAGLAND; ARNON, 1950) and the other treatments constituted by the same nutrition solution with lack of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) or sulfur (S) and absence of macronutrients (water). Nutrient solutions were formulated to eliminate particular specified nutrients, without changing other nutrient concentration (FERREIRA, 2012).

In order to avoid salt accumulation or nutrients depletion, treatments were daily irrigated with volume of solution equivalent to the pot capacity until obtaining of drained liquid. Every seven days, pots were irrigated with water in a volume approximately twice the pot capacity. The pH of solutions was maintained near 5.5 using NaOH or HCl.

All the shoots were weekly identified and, in the same occasion, evaluations were done, analyzing nutritional deficiency by means of description of the visual symptomatology and the following growth indicators: emitted shoot number, leaf number, length and width of leaves. Leaf area was estimated by multiplying by 0.4 the product of length and width of leaves, modified from (FARIAS *et al*., 2013).

The first harvest occurred at 90 days after the beginning of treatments, in the vegetative phase, and the second was done from 150 days on, in the reproductive phase. Plants were individually washed in water and leaves

and underground part (rhizomes and roots) were separated. The identified parts of the plants were dried at 70 ºC, in forced convection oven, until constant weight. Then, dry mass was determined to each plant part.

For macronutrients analysis, the following components of the first shoot were used: leaves (first, second and third, completely expanded, numbered from the apex) and underground plant part (roots and rhizome). Samples were ground in a Wiley-type mill equipped with a 20 mesh screen, and disposed in craft paper bags. Samples of leaves were submitted to sulfuric digestion for N analysis and to nitro-perchloric digestion to analyze the other elements. Nitrogen determination was done by Kjeldahl Method in Kjeltec Auto-analyzer; Ca, Mg and S contents were measured by Atomic Absorption Spectrometry (AAS); K trough Flame Photometry; and P content was determined by the colorimetric vanadate-molybdate method.

Data were submitted to analysis of variance and the treatments averages were compared using the Tukey Test at 5% probability, using a software package for analysis in experimental statistics (CRUZ, 2013).

RESULTS AND DISCUSSION

The visible symptoms of different macronutrients were essentially similar to those available in the literature. In the experimental conditions of this work, visual nutrient deficiency symptoms (Figure 1) appeared in the following occurrence order: N, Mg, K, P and S. More drastic nutritional deficiency symptoms are conditioned to a more time growing under nutrient omission conditions.

The growth indicators were different between treatments (Table 1), and the plants cultivated in solution with omission of at least one macronutrient presented distinct concentration from that cultivated in complete nutrition solution. However, do not decreased dry matter yields and nutrient concentration in plants significantly in all treatments. These alterations occurred in both phases - flowering and non-flowering - in the two evaluated parts of the plants, leaves and underground (Table 2).

Regarding nutrients lack, it was observed that the third leaf presented lower nutrient contents in their respective omission treatments, except for Ca that has a low mobility and, therefore, it is expected a lowest content in the recently expanded leaf (Tables 3 and 4). This tendency was detected in both developing phases of the plants.

Plants with N-deficiency presented generalized chlorosis, starting in the older leaves, which gradually had changed its color from green to pale-green (Figure 1). Chlorosis is associated to a reduction on chlorophyll contents and Rubisco activity, what causes low photosynthesis rates (HERMANS *et al*., 2006). When supply is insufficient, the N of old leaves is translocated to new leaves, due to its high mobility in the phloem (MARSCHNER, 2012).

Nitrogen was the nutrient that more limited plant growth. The N-deficiency generally inhibits the plant growth, causes chlorosis in leaves, specially in the older, reduces leaves and shoot production, besides decreasing leaf area) and, consequently, the leaf surface

Figure 1 - Leaves of *Heliconia psittacorum x Heliconia spathocircinata* 'Golden Torch' plants cultivated under complete nutrition solution, with omission of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulfur (S) and macronutrients absence (water), at 150 days after planting - DAP (reprodutive phase)

for light absorption for photosynthesis (HERMANS *et al.*, 2006). Reduction nearly 60% in the number of emitted shoots, 66% in the average leaf dry mass production, and 50% in the underground dry mass, 35%

Table 1 - Average shoot number, dry mass production of leaves and underground plant part (g/plant), leaf total number and leaf area (cm^2) of *Heliconia psittacorum* x *H. spathocircinata* 'Golden Torch', cultivated in complete solution, with omission of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulfur (S) and macronutrients absence (water), harvested at 150 days after planting - DAP (reprodutive phase)

Treatment	Nº of shoots	Leaves dry mass (g)	Underground part dry mass (g)	Nº of leaves	Foliar área (cm^2)
Complete	9.40 a	83.62 ab	64.51 ab	31.60 d	299.10 d
- N	3.80 b	28.72 cd	31.92 bc	20.60 e	217.50 g
- P	4.00 b	33.18 bcd	51.55 abc	20.20 e	256.20 e
- K	10.60 a	77.79 abc	81.85 a	36.00 c	244.30 f
- Ca	8.60 a	107.46 a	66.22 ab	39.20 b	310.10 c
- Mg	9.40 a	85.62 ab	58.43 abc	37.40 bc	388.20 a
- S	10.80 a	113.46 a	69.65 ab	44.00 a	323.30 b
Water	2.20 b	8.06 d	19.73 c	9.20 f	115.50 h
CV%	27.12	32.26	35.00	26.42	14.68

*Means followed by the same capital letter in the column and small letter in the line did not differ by Tukey Test (P<0,05)

Table 2 - Mean values for each nutrient extracted from heliconias, in g kg^{-1} of dry mass, in the non-flowering - NFL (90 days after planting) and flowering - FL (150 days after planting) phases, for each part of the plant (leaf and underground part), cultivated in complete solution, omission of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulfur (S) and macronutrients absence (water)

Nutrient	N		P		K		Ca		Mg		S	
	NFL	FL	NFL	FL	NFL	FL	NFL	FL	NFL	FL	NFL	FL
leaf												
Complete	17.1 c	24.4 a	1.6 b	1.3 ab	35.9 c	12.9 bc	9.3 ab	5.2 cd	2.7 ab	1.0 c	5.9 c	4.6 cd
- N	7.4 e	5.2 c	7.9 a	3.6 a	68.2 a	22.0 a	9.6 ab	4.8 d	1.1 ab	2.4 bc	4.3 d	4.2 d
- P	17.5 bc	20.3 b	0.7 bc	0.5 cd	35.9 c	15.2 abc	8.4 b	7.1 bc	2.3 ab	1.6 c	5.0 cd	6.9 ab
- K	18.2 bc	25.6 a	0.8 bc	1.5 bc	3.3 f	3.6 d	11.1 a	11.7 a	3.3 a	5.3 a	8.1 b	3.9 d
- Ca	9.9 d	26.1 a	0.7 bc	1.4 bcd	25.1 d	15.0 abc	3.6 c	0.8 e	0.5 b	1.2 c	10.0 a	7.7 a
- Mg	19.4 ab	25.0 a	1.6 b	1.3 bcd	46.2 b	16.6 ab	9.4 ab	7.3 b	0.7 ab	0.6 c	5.3 cd	5.9 bc
- S	20.7 a	24.1 a	1.3 b	2.0 b	7.8 ef	8.5 bcd	9.1 b	9.8 a	0.7 ab	4.7 ab	1.8 e	1.0 e
Water	9.6 de	7.4 c	0.3 c	0.3 d	14.2 e	7.7b cd	8.1 b	5.9 cd	0.5 b	2.6 bc	1.3 e	2.1 e
underground part												
Complete	11.6 a	14.6 a	3.7 b	5.2 ab	49.1 ab	83.6 a	7.1 ab	3.5 bc	4.4 b	3.7 bc	2.9 c	3.6 b
- N	7.4 bc	4.7 c	8.9 a	5.8 a	33.5 d	80.1 a	5.9 b	3.0 cd	3.9 bc	3.1 bc	4.7 ab	2.3 bc
- P	12.9 a	10.5 b	1.5 d	1.5 d	42.3 bc	55.0 c	7.1 ab	5.5 ab	4.5 b	2.9 bc	3.5 bc	1.7 cd
- K	11.7 a	15.1 a	2.0 cd	3.4 c	4.3 f	0.8 f	7.7 ab	5.5 ab	8.0 a	13.4 a	2.9 c	2.7 bc
- Ca	8.9 b	12.3 b	1.9 cd	5.0 ab	51.7 a	64.5 b	2.6 c	1.3 d	1.4 c	1.2 c	5.7 a	7.0 a
- Mg	11.5 a	11.9 b	2.5 c	3.2 c	52.1 a	77.9 a	6.4 b	5.7 a	2.7 bc	1.5 c	3.6 bc	3.4 b
- S	12.3 a	11.7 b	2.2 cd	4.5 b	36.8 cd	41.6 d	8.9 a	4.7 abc	10.2 a	12.1 a	0.8 d	0.7 d
Water	6.1 c	3.7 c	2.0 cd	2.4 cd	22.0 e	12.0 e	8.5 a	3.3 cd	3.8 b	5.3 b	2.3 c	1.4 cd
CV%	8.92		20.34		14.86		16.93		21.93		18.97	

*Means followed by the same letter in the column and small letter in the line did not differ by Tukey Test (P<0,05)

in leaf number and 27% in leaf area were observed, when compared to growth indicators of the complete treatment (Table 1). Similar decreases in growth were also observed in other ornamental Zingiberales, as *Zingiber spectabilis*, in macronutrients deficiency experiment (COELHO *et al*., 2012).

Nitrogen omission caused decrease in the concentration of this nutrient in the evaluated organs, in both phases, when compared to the complete treatment. An increase on K contents was observed in leaves, in the two analyzed phases, and in P contents in the vegetative phase. A decrease on S contents occurred in leaves, in the vegetative phase. In the underground part, increase in P and S and decrease in K were observed, in the vegetative phase.

In plants with P-deficiency, visual symptoms were not well defined, chlorosis being observed (Figure 1). *Spathiphyllum wallissii* plants cultivated under P-omission conditions presented leaf symptoms similar to those observed in the present work, visible only when compared to plant cultivated in complete solution (YEH; LIN; WRIGHT, 2000). It's important to note that visual symptoms are no always observable. Besides that, under P-omission conditions it was verified reduction on shooting, leaf number and leaf area, when compared to plants treated with complete solution (Table 1). The inhibition of leaf expansion and shooting reduction is a direct effect of P-deficiency by the restriction on cell expansion and decreased root elongation (POTTERS *et al*., 2007). The reduced growth, observed in many species submitted to P deficiency, also occurs due to the reduction in cell divisions (CHIERA; THOMAS; RUFTY, 2002).

P-omission did not alter the nutrient contents observed in leaves, comparatively to the complete treatment, in the vegetative phase. In the reproductive phase, decrease in N and S and increase in Ca occurred (Tables 3 and 4). In the underground plant part, P omission did not present difference to the other elements when compared to the complete treatment, in the vegetative phase, but decrease in N, K and S occurred in the reproductive phase (Table 2). According to De Groot *et al*. (2003), there are several possible causes to the decrease in N concentration caused by P omission. At first, can be due to the biomass allocation from organs with high N concentration to organs with low N concentration.

Table 3 - N, P, K, Ca, Mg, S contents (g Kg^{-1}) in the leaves 1, 2 and 3 of the first shoot of *Heliconia psittacorum* x *H. spathocircinata* 'Golden Torch', cultivated under complete solution and omission of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulfur (S), harvested at 90 days after planting (vegetative phase)

Nutrient	Leaf	Complete	Nutrient suppressed						CV (%)
			-N	-P	-K	-Ca	-Mg	-S	
	1	23.48 Aa	8.52 Ac	14.81 Bb	22.60 Aa	16.19 Ab	20.08 Ba	22.56 Aa	
N	2	17.15 Bb	8.72 Ad	15.30 ABbc	16.74 Bbc	13.28 Bc	24.18 Aa	17.39 Bb	11.09
	3	16.28 Bb	7.87 Ac	17.55 Aab	18.21 Bab	10.07 Cc	19.63 Bab	20.54 Aa	
	1	2.54 Ab	5.73 Ba	1.00 Ac	1.32 Abc	1.30 Abc	1.72 Abc	1.84 Abc	
P	2	1.62 Ab	7.36 Aa	0.73 Ab	0.83 Ab	0.58 Ab	1.43 Ab	1.33 Ab	26.56
	3	1.49 Ab	7.84 Aa	0.68 Ab	0.78 Ab	0.68 Ab	1.53 Ab	1.22 Ab	
	1	36.91 Abc	71.72 Aa	32.57 Abc	9.32 Ad	38.59 Abc	42.44 Ab	24.37 Acd	
K	2	36.49 Ab	70.11 Aa	36.10 Ab	5.70 Ad	26.48 ABbc	38.54 Ab	12.11 ABcd	19.94
	3	32.68 Abc	74.46 Aa	36.68 Abc	3.26 Ad	25.29 Bc	46.03 Ab	7.73 Bd	
	1	3.83 Bab	4.65 Bab	6.93 Aa	7.71 Ba	1.52 Ab	7.10 Aa	7.59 Aa	
Ca	2	5.88 ABab	4.83 Bab	7.32 Aa	8.77 ABa	2.75 Ab	8.30 Aa	7.48 Aa	19.71
	3	8.76 A a	11.11 Aa	8.78 Aa	11.41 Aa	3.38 Ab	9.80 Aa	9.05 Aa	
	1	1.29 Aab	1.26 Aab	2.20 Aab	2.66 Aa	0.56 Ab	0.86 Ab	1.90 Bab	
Mg	2	1.43 Abc	0.93 Ac	2.02 Abc	2.90 Aab	0.47 Ac	0.86 Ac	3.98 Aa	24.37
	3	1.75 Aabc	1.09 Abc	2.28 Aab	3.21 Aa	0.49 Ac	0.70 Abc	0.69 Bbc	
	1	4.63 Bb	3.63 Ab	4.31 Ab	5.27 BB	8.05 Aa	5.19 Ab	3.05 Ab	
S	2	7.76 Aab	4.54 Acd	5.45 Abc	7.34 ABab	8.74 Aa	4.18 Acd	1.85 Ad	18.86
	3	6.00 ABbc	4.42 Acd	5.12 Ac	8.10 Aab	9.31 Aa	5.10 Ac	1.82 Ad	

*Means followed by the same capital letter in the column and small letter in the line did not differ by Tukey Test (P<0,05)

Table 4 - N, P, K, Ca, Mg, S contents (g Kg^{-1}), in the leaves 1, 2 and 3 of the first shoot of *Heliconia psittacorum* x *H. spathocircinata* 'Golden Torch', cultivated under complete solution and omission of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulfur (S), harvested at 150 days after planting - DAP (reprodutive phase)

Nutrient	Leaf	Complete	Nutrient suppressed						CV (%)
			- N	- P	- K	- Ca	- Mg	- S	
N	1	32.50 Aa	9.00 Ae	17.90 ABd	23.8 AC	30.70 Aa	30.50 Aab	26.70 Abc	13.82
	2	27.80 Ba	8.36 ABc	15.60 Bb	24.2 AA	25.90 Ba	25.40 Ba	19.60 Bb	
	3	24.40 Ca	5.32 Bc	20.40 Ab	25.4 AA	26.40 Ba	25.30 Ba	23.80 Aab	
P	1	2.05 Acd	3.58 Aa	0.36 Ae	2.07 Acd	2.36 Abc	1.82 Ad	2.77 Ab	22.17
	2	1.53 Bcd	3.23 Ba	0.37 Ae	1.97 Abc	2.21 Ab	1.39 Bd	1.82 Bbcd	
	3	1.32 Bc	3.57 Aa	0.46 Ad	1.50 BC	1.31 Bc	1.29 Bc	2.03 Bb	
K	1	15.80 Ac	25.50 Aa	15.80 Ac	4.47 AD	22.00 Aab	24.30 Aa	19.10 Abc	17.50
	2	13.40 Ab	25.20 ABa	13.30 Ab	4.09 AC	16.50 Bb	15.60 Bb	16.20 Ab	
	3	12.90 Abc	22.10 Ba	15.30 Ab	3.50 AD	14.80 Bb	16.50 Bb	8.51 Bc	
Ca	1	5.39 Aab	3.20 Abc	4.44 Bab	6.84 BA	0.55 Ac	5.33 Aab	4.11 Cab	28.22
	2	4.39 Aab	3.61 Ab	5.00 ABab	5.57 Bab	0.54 Ac	6.95 Aa	6.50 Ba	
	3	4.58 Ac	4.74 Ac	7.04 Abc	12.00 AA	0.97 Ad	7.22 Abc	9.45 Aab	
Mg	1	1.32 Ac	2.37 Abc	2.49 Abc	3.58 Bab	1.29 Ac	1.35 Ac	4.86 Aa	22.29
	2	0.97 Ab	1.95 Ab	1.53 Ab	4.96 Aa	1.05 Ab	0.70 Ab	3.91 Aa	
	3	0.98 Abc	2.30 Ab	1.57 Abc	5.28 Aa	1.17 Abc	0.62 Ac	4.42 Aa	
S	1	5.33 Aab	2.90 Ab	5.39 ABab	4.32 Ab	7.76 Aa	5.36 Aab	2.84 Ab	18.32
	2	5.17 Aab	4.32 Abc	3.53 Bbc	3.21 Abc	7.99 Aa	4.29 Abc	0.92 Ac	
	3	4.44 Ab	4.26 Abc	6.29 Aab	3.86 Abc	7.94 Aa	4.98 Aab	1.00 Ac	

*Means followed by the same capital letter in the column and small letter in the line did not differ by Tukey Test (P<0,05)

The second possibility is an inhibition of the absorption in response to the N accumulation in the roots. Besides that, N absorption can be reduced due to a decrease in the available energy, what is indicated by the lowest root growth and/or reducing in the concentration.

Plants with K deficiency presented dark-green color in all the leaves, apical necrosis in the older and leaves with more evident leaf veins, resembling a chartaceous texture. It was not observed decreases in shooting and dry mass production of leaves and underground plant part. An increase in leaf number occurred, when compared to plants treated with complete solution, but this is not necessarily beneficial to plant once a reduction in leaf area occurred (Table 1). Similar results were obtained by Yeh; Lin and Wright (2000), in *Spathiphyllum wallissii* submitted to K omission treatment, who observed increase in leaf number, but without increase in leaf area.

Plants cultivated under K omission conditions presented increase in Mg and Ca contents in leaves, in the reproductive phase, when compared to the complete treatment. In the underground plant part, only Mg increase occurred, in both phenological phases (Table 2). These results show the competitive K inhibition in the absorption of Mg and Ca, as related by Epstein; Bloom (2006).

Plants cultivated under Ca omission conditions did not present visible symptoms (Figure 1). The omission of this nutrient in some plants do not revealed initially any visible nutritional deficiency symptom in the plant (CASTRO *et al*., 2007; RAMOS *et al*., 2009), even after one year under nutrient omission conditions, in *Anthurium andraeanum* for an example (IMAMURA; HIGAKI, 1984). The low Ca concentration in the plant tissues can no cause symptoms until that certain phase or physiological condition starts metabolic processes that expresses the deficiency, as flowering and post-harvest durability (CASTRO *et al*., 2007). In plants cultivated with Ca omission, no significant decrease occurred neither in shooting, nor in dry mass production of leaves and underground part, when compared to plants treated with complete solution (Table 1). Leaf number and leaf area were higher when compared to the treatment with complete solution, although the lack of this nutrient affect growth points in plants (EPSTEIN; BLOOM, 2006). Increase in dry mass production in plants with deficiencies

of nutrients with low mobility in the phloem, like Ca, was also observed in *Spathiphyllum wallissii* (YEH; LIN; WRIGHT, 2000). According to Marschner (2012), the requirement in Ca for growth is lower in monocotyledons than in dicotyledons species.

The treatment with Ca omission caused decrease in N and K and increase in S contents, in leaves, in both analyzed phases. In the underground plant part, decrease in N, P and Mg and increase in S occurred, in the vegetative phase. In the reproductive phase, reduction in N and K and increase in S occurred (Table 2). The Ca effect on ions flux through membrane is connected to their role in integrity and stability of the membrane, that once damaged lost their selectivity (MARSCHNER, 2012).

Under Mg omission in the nutrient solution, plants presented marginal chlorosis in the older leaves and necrosis in the leaf blade borders and in the leaf apex (Figure 1). These symptoms are identical to the reported by Broschat (1992), who describes deficiency symptomatology in species from Zingiberales Order, including heliconias. Although plants with Mg deficiency showed very evident visual symptoms, there were no significant differences in shooting and dry mass production of leaves and underground plant parts, in regard to plants treated with complete solution. Leaf number and leaf area were higher to the plants treated with complete solution (Table 1).

The Mg contents observed in plants under complete treatment did not present differences, when compared to treatments with Mg omission (Table 2). This fact suggests that rhizomes apports sufficient Mg to supply plant until the beginning of flowering. Besides the Mg contained in rhizomes be enough to supply plants until the beginning of the reproductive phase, it was observed that in the treatment with Mg absence, the Ca contents increased, as in leaves as in underground parts, characterizing the competitive inhibition effect. It is interesting to emphasize that in *Spathiphyllum wallissii* leaves, significantly higher Mg contents were observed in plants treated with Mg omission than in plants treated with complete nutrient solution (YEH; LIN; WRIGHT, 2000). Plants from Mg omission treatment also presented increase in N and K contents in leaves, in the vegetative phase. In the underground plant part, a decrease in P content occurred, in the vegetative phase. In the reproductive phase, decrease in N and P occurred (Table 2).

Plants cultivated under S omission presented an uniform chlorosis in younger leaves (Figure 1). This is due to the fact of S do not be easily carried from the older to the younger leaves. However, shooting and leaves and roots dry mass production were no different of plants treated with complete solution. On the other hand, these plants presented higher leaf number and leaf area than plants treated with complete solution (Table 1). Antagonistic results were observed in other Zingiberales ornamental as *Etlingera elatior* and *Zingiber spectabilis*, planted by seed and subjected to nutritional stress, while growth compromised (COELHO *et al*., 2012; FRAZÃO *et al*., 2010).

The difference is that in this experiment, the heliconias had the input of nutrients from rhizome. Heliconias are plants that grow very rapidly and have in their rhizomes a great amount of carbohydrates and transfer a great percentage of biomass from the underground parts into the leaves (CASTRO *et al*., 2011).

Plants cultivated under S omission presented increase in N and decrease in K contents, in leaves in the vegetative phase, and in the reproductive phase increase in Ca and Mg contents occurred. In the underground plant parts, reduction in P and K and increase in Mg contents occurred in the vegetative phase. In the reproductive phase, N and K decrease and Mg increase were observed (Table 2).

The lack of this nutrient cannot cause the immediate appearing of visual symptoms, being possible initially occur a reduction in growth (hidden hunger) and later chlorosis and necrosis could appears (EPSTEIN; BLOOM, 2006).

Heliconias submitted to nutritional stress may even present growth indicators, macronutrient concentrations and initial production of flowers similar to a plant with proper nutrition, but decrease productivity throughout the development and impair the postharvest longevity of inflorescences (CASTRO *et al*., 2007).

The characterization of growth indicators can be useful in the diagnosis of nutritional disturbances, although more intense nutritional deficiency symptoms are conditioned to highest time of growth under omission of these nutrients, when the culture may already be endangered.

CONCLUSIONS

1. Macronutrients omission, except Ca, causes changes that are translated as visible symptoms of nutritional deficiency to each nutrient;
2. Among the macronutrients, N and P deficiencies affect more intensely shoot number, leaf dry mass production, total leaf number and leaf area;
3. More evident symptoms of nutritional deficiency are conditioned to a highest time growing under nutrient omission conditions, because of the amount of nutrients from rhizome.

ACKNOWLEDGMENTS

The authors thank to Capes for supporting this work and Capes for the scholarship to the first author.

REFERENCES

BROSCHAT, T. K. Nutrition of heliconias and related plants. **Bulletin Heliconia Society International,** v. 6, n. 1/2, p. 20-21, 1992.

CASTRO, A. C. R. *et al*. Hastes florais de helicônia sob deficiência de macronutrientes. **Pesquisa Agropecuária Brasileira**, v. 42, n. 9, p. 1299-1306, 2007.

CASTRO, A. C. R. *et al*. Macronutrients contents in two development phases of *Heliconia psittacorum* x *H. spathocircinata* 'Golden Torch'. **Acta Horticulturae**, v. 886, p. 283-286, 2011.

CHIERA, P.; THOMAS, J.; RUFTY, T. Leaf initiation and development in soybean under phosphorus stress. **Journal of Experimental Botany**, v. 53, n. 368, p. 473-481, 2002.

COELHO, V. A. T. *et al*. Caracterização de sintomas visuais de deficiências de macronutrientes e boro em plantas de gengibre ornamental. **Revista Brasileira de Horticultura Ornamental**, v. 18, n. 1, p. 47, 2012.

CRUZ, C. D. GENES - a software package for analysis in experimental statistics and quantitative genetics. **Acta Scientiarum. Agronomy**, v. 35, n. 3, p. 271-276, 2013.

DE GROOT, C. C. *et al*. Interaction of nitrogen and phosphorus nutrition in determining growth. **Plant and Soil**, v. 248, n. 1/2, p. 257-268, 2003.

EPSTEIN, E; BLOOM, A. **Nutrição mineral de plantas:** princípios e perspectivas. Londrina: Editora Planta, 2006. 401 p.

FARIAS, A. P. *et al*. Produtividade da *Heliconia psittacorum* x *Heliconia spathocircinata* cv. Golden Torch sob diferentes fontes de adubação orgânica. **Revista Brasileira de Engenharia Agrícola e Ambiental,** v. 17, n. 7, p. 713–720, 2013.

FERREIRA, M. M. M. Sintomas de deficiência de macro e micronutrientes de plantas de milho híbrido BRS 1010. **Revista Agro@mbiente On-line**, v. 6, n. 1, p. 74-83, 2012.

FRAZÃO, J. E. M. *et al*. Deficiência nutricional em bastão-do-imperador (*Etlingera elatior* (Jack) R. M. Smith): efeito na produção de matéria seca e índices biométricos. **Ciência e Agrotecnologia**, v. 34, n. 2, p. 294-299, 2010.

HERMANS, C. *et al*. How plants respond to nutrient shortage by biomass allocation? **Trends in Plant science**, v. 11, n. 12, p. 610-617, 2006.

HOAGLAND, D. R.; ARNON, D. I. **The water-cultured method for growing plants without soil**. California Agricultural Experiment Station, 1950. 34 p. (Circular).

IMAMURA, S. J.; HIGAKI, T. **Nutrient deficiency in anthuriums**. HTAHR: University of Hawaii, 1984. 15 p.

KAVANOVA, M. *et al*. Phosphorus deficiency decreases cell division and elongation in grass leaves. **Plant Physiology**, v. 141, n. 2, p. 766-775, 2006.

MARSCHNER, H. **Mineral nutrition of higher plants**. 3nd ed. London: Academic Press, 2012. 651 p.

MALAVOLTA, E. **Manual de nutrição mineral de plantas**. São Paulo: Editora UFV, 2006. 638 p.

RAMOS, M. J. M. *et al.* Sintomas visuais de deficiência de macronutrientes e de boro em abacaxizeiro "imperial"**. Revista Brasileira de Fruticultura,** v. 31, n. 1, p. 252-256, 2009.

ROCHA, F. H. A. *et al*. Genetic study with *Heliconia psittacorum* and interspecific hybrids. **Crop Breeding and Applied Biotechnology**, v. 10, n. 4, p. 282-288, 2010.

POTTERS, G. *et al*. Stress-induced morphogenic responses: growing out of trouble? **Trends in Plant Science,** v. 12, n. 3, p. 98-103, 2007.

TEWARI, R. K. *et al*. Macronutrient deficiencies and differential antioxidant responses influence on the activity and expression of superoxide dismutase in maize. **Plant Science**, v. 166, n. 3, p. 687-694, 2004.

VIÉGAS, I. J. M. *et al.* Efeito da omissão de macronutrientes e boro no crescimento, nos sintomas de deficiências nutricionais e na composição mineral de plantas de camucamuzeiro. **Revista Brasileira de Fruticultura,** v. 26, n. 2, p. 315-319, 2004.

YEH, M. D.; LIN, L.; WRIGHT, C. J. Effects of mineral nutrient deficiencies on leaf development, visual symptoms and shoot-root ratio of *Spathiphyllum*. **Scientia Horticulturae**, v. 86, n. 3, p. 223-233, 2000.