***WFL* Publisher**
Science and Technology
Meri-Rastilantie 3 B, FI-00980
Helsinki, Finland
e-mail: info@world-food.net

Journal of Food, Agriculture & Environment Vol.10 (2): 546-550. 2012
www.world-food.net

Symptoms, growth, nutritional status and accumulation of nutrients in young *Zingiber spectabile* plants subjected to restriction of macronutrients

Ismael de Jesus Matos Viégas [1]*, Sabrina Santos de Lima [1], Allan Klynger da Silva Lobato [2], Sávia Poliana da Silva [1], Heráclito Eugênio Oliveira da Conceição [1], Diocléa Almeida Seabra Silva [1], Dilson Augusto Capucho Frazão [3], Cândido Ferreira de Oliveira Neto [2] and Dionilson Cardozo da Cunha [1]

*[1] Instituto de Ciências Agrárias, Universidade Federal Rural da Amazônia, Pará, Brasil. [2] Núcleo de Pesquisa Vegetal Básica e Aplicada, Universidade Federal Rural da Amazônia, Paragominas, Pará, Brasil. [3] Federação da Agricultura do Estado do Pará, Pará, Brasil. *e-mail:ismael.viegas@ufra.edu.br, candido.neto@ufra.edu.br*

Received 21 January 2012, accepted 2 May 2012.

Abstract

Aim of this study was to characterize the symptoms produced by nutrient omission and evaluate the effects on growth, nutritional status, and accumulation of nutrients in young *Zingiber spectabile* plants subjected to restriction of macronutrients. The experimental design was completely randomized with seven treatments (N, P, K, Ca, Mg and S deficiencies, and control) and 5 replicates. Visual symptoms linked to restrictions of macronutrients were, in general, easily characterized and appeared in the following order of treatments K, N, Mg, Ca, P and S restrictions. Individual restrictions of N, P, K, Ca, Mg and S reduced the content of these nutrients, when compared to the control treatment. The order of the accumulation of nutrients was the same observed in contents of macronutrients, being control>N>K>Ca>Mg>P>S. The accumulations of nitrogen, phosphorus, and potassium were 855.0, 90.0 and 672.5 mg plant^{-1} in control plants. The restriction of all macronutrients limited the plant growth in relation to the control, in which potassium followed by magnesium were most limiting nutrients.

Key words: *Zingiber spectabile*, mineral nutrition, nutritional deficiency, ornamental plants.

Introduction

The species *Zingiber spectabile* (ornamental ginger) is an ornamental plant with greater potential of production for Brazil, mainly in the North and Northeast regions due to adequate edaphic-climatic conditions such as temperature, soil, water and lower incidence of diseases and pests. These factors contribute directly on product quality, decrease in production costs, and consequently competitive prices in international market.

The productivity of tropical flowers specifically in Northern region of Brazil has considerably increased, with an estimated annual production of 1.5 million commercial stems, the state of Pará being the largest producer with 38.1% of this production. In the segment of ornamental plants for landscaping and gardening the production was 2.5 million of plants by year, this state being responsible by 54.4% of regional production [1].

Several factors have contributed to this increase, including some research, whose results have given basis to different production components, specifically on breeding, pests, disease, and water supply. However, works on the nutritional requirements of *Zingiber spectabile* plants are limited, despite recent research projects carried out in Pará State has generated fundamental results on other species such as *Heliconia psittacorum* [4] and *Heliconia spathocircinata* [2], *Heliconia* spp. [3] and *Alpinia purpurata* [5].

Adequate concentrations of essential nutrients to plant must be investigated considering requirement for an optimal growth rate [6]. The definition of nutritional deficiency in plants is characterized by lower element concentration in substrate or when the chemical element is present in unavailable form for plant absorption. When deficiencies are sufficiently severe, the symptoms are manifested by more intense form, but in field or light deficiency this work is difficult. Therefore, description of visual symptoms can help farmers and experts in this species to identify nutritional deficiencies.

In general, deficiency or restriction of nutrients negatively affects the growth of higher plants, because several reactions are depending on essential nutrients [7]. On the other hand, growth parameters like number of leaves, plant height and plant dry matter and yield are normally influenced by the availability of nutrients [8, 9]. Therefore, studies on morphological responses and accumulation of nutrients are fundamental aiming to define the mineral requirements of *Zingiber spectabile*.

Aim of this study was (i) to characterize the symptoms produced by nutrient omission, and (ii) evaluate the effects on growth, nutritional status, and accumulation of nutrients in young *Zingiber spectabile* plants subjected to restriction of macronutrients.

Materials and Methods

Experimental conditions and plant material: Experiment was conducted under greenhouse conditions at Embrapa Amazônia Oriental, Belém City, Pará State, with temperatures oscillating from 25°C to 32°C. *Zingiber spectabile* rhizomes came from

Empresa Brasileira de Pesquisa Agropecuária (Embrapa) located in Benevides City, Pará State.

Recipients and plant obtaining: Rhizomes were placed in recipient with dimensions of 40 cm x 20 cm x 10 cm (length×width×height, respectively), containing a mixture of sand and sawdust in the ratio of 3:1, respectively. Twenty days after rhizomes were placed in recipients; these were transplanted to plastic bags. Seedlings with approximately 30 cm of height were selected. Their roots were washed with running water and subsequently with distilled water to eliminate any residue of the substrate and transplanted into plastic pots with a capacity of 5 L containing washed silica (sort zero thick). The vessels were drilled next to the base and painted externally with aluminized paint to reduce the direct passage of sunlight, thus avoiding algae blooms within the containers. A segment of flexible plastic hose was connected to the drilling of each pot connecting the inside of each one with the entrance of the plastic bottles with a capacity of 1 L, also painted with aluminized paint and all bottles were placed in a lower level of the vessels.

Experimental design: The experimental design was completely randomized with seven treatments (N, P, K, Ca, Mg and S deficiencies and control) and 5 replicates, totaling 35 experimental units, each experimental unit being composed of one plant per pot. These treatments included complete nutrient solution for control and omissions of individual nutrients for nitrogen, phosphorus, potassium, calcium, magnesium and sulphur.

Plant acclimation: Rhizomes were initially acclimated for a period of 75 days in nutritive solution of Hoagland *et al.* [10] diluted in the proportion of 1:10, having salts as source for analysis. Solution was supplied to plants by percolation in vessels, being irrigated and drained plants by periods of 9 and 15 hours during morning and afternoon, respectively. Young *Zingiber spectabile* plants, reached 30 cm of height, were treated with nutrient solution 1:1 supplied by leaching in plastic pots by renewing the solution every 15 days, with pH retained around ± 5.5. Daily, the level of the solution in the glass collectors was observed, filling until 1 L for each plant.

Symptoms description and harvest: The symptoms of deficiencies in macronutrients were characterized, described and photographed. The plants were collected and separated in leaves, stems and roots. The collected material was washed with deionised water, packed in paper bags and placed in drying oven with forced air at 70°C until constant weight.

Determination of dry matter and relative growth: After drying the material was weighed, measuring dry matter of leaves, stem and root and also shoot dry matter (leaf+stem) and total dry matter (leaf+stem+root). After weighing, the material was ground in Wiley mill to perform chemical analysis of plant tissue. The relative growth (RG) was calculated by the formula:

RG (%) = (PDMDN / PDMCT) X 100

where PDMDN = plant dry matter obtained in each deficiency of nutrients and PDMCT = plant dry matter in control treatment.

Determination of nutrients : Macronutrients such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulphur (S) were determined using methods described by Malavolta *et al.* [11]. Considering data obtained from leaf dry matter and nutrient contents accumulation of nutrients was determined.

Data analysis: The data were subjected to variance analysis and significant differences between means were determined by Tukey's test at 5% level of error probability. The statistical procedures were carried out with the STAT software.

Results and Discussion

Visual symptoms linked to restriction of macronutrients: Symptoms induced by restriction of nitrogen in plants of *Zingiber spectabile* were manifested 60 days after initiation of treatment. There was reduction in plant height, smaller size of leaves, and older leaves were presenting light green color, when compared to control (Fig. 1A). Nitrogen is a mineral nutrient most required by plants and is important component of amino acids, proteins, nucleic acids, plant hormones and chlorophyll formations. Studies have suggested that the yield and flower quality of *Chrysanthemum moriforlium* are more affected by nitrogen deficiency, if compared to phosphorus and potassium. In addition, nitrogen nutrition plays a key role in the biosynthesis of enzymes[12]. Therefore, nitrogen deficiency in general will limit plant growth. Light green color in older leaves has been a characteristic of nitrogen deficiency in ornamental plants such as *Alpinia purpurata* [5].

Symptoms of phosphorus restriction were more intense in 90th day after experiment implementation, with older leaves presenting dark green color accompanied by a reduction in plant height (Fig. 1B). The dark color of the leaves is probably due to a greater relative concentration of chlorophyll. Mengel *et al.* [13] reported that plants deficient in phosphorus have decreased growth, synthesis of protein and nucleic acids, reduced tillering, delayed flowering and growth and dormancy of lateral buds and lower number of fruits and seeds. In ornamental plants as such *Tagetes patula* and *Euphorbia pulcherrima* phosphorus proved to be important, according to research conducted by Mirkohi *et al.* [14]. Ferreira *et al.* [15] described that the application of phosphorus along with nitrogen and potassium promoted increase in production of inflorescences of *Heliconia* spp. Minor plant growth and dark green leaves were visual symptoms of phosphorus omission observed by Jeong *et al.* [16] on *Rosa hybrida*, agreeing with symptoms observed in this study. The reduced growth, common to many species with P deficiency, can also be explained by reduction in cell division [17].

Symptoms of potassium deficiency were the first to appear, 25 days after treatments, showing that this nutrient is quite limiting to *Zingiber spectabile* plants. This limitation is probably due to the essentiality of potassium in osmotic processes, in protein synthesis, translocation of sugars, in membrane permeability, and activities of several enzymes involved in respiration and photosynthesis. Slight chlorosis from the margins to the apex of leaf, followed by necrosis was observed in older leaves of *Zingiber spectabile*. In addition there was reduction in plant height and number of leaves, compared to control treatment (Fig. 1C). Typical symptoms of potassium deficiency as chlorosis and subsequent necrosis are due to accumulation of putrescine

Figure 1. Visual symptoms linked to restriction of nitrogen (A), phosphorus (B), potassium (C), calcium (D), magnesium (E) and sulphur (F) in shoot and leaf of young *Zingiber spectabile* plants.

(tetramethylenediamine) [18]. Similar symptoms were seen by Viégas *et al.* [5] in *Alpinia purpurata* plants. Normally soils from Pará State have low available potassium level, and this fact promotes manifestation of symptoms linked to nutrient deficiency with higher intensity, if not provided an adequate potassium supply. In fact, it has been observed typical symptoms of potassium deficiency in *Zingiber spectabile* plants cultivated in areas localized in Pará state.

The symptoms provoked by calcium deficiency were manifested after 70 days, and it is characterized by reduction in plant height, inadequate formation of new leaves, chlorosis in margins and apices with subsequent necrosis (Fig. 1D). According to Marschner [19], new leaves and other young tissues develop quickly symptoms of calcium deficiency, because this nutrient is not remobilized in the plant. Calcium deficiencies in young tissues causing gelatinous appearance on leaf tips and growing points are due to necessity of calcium pectate for formation of cell wall. In ornamental plants as *Viola x wittrockiana*, *Petunia x hybrida hort*, and *Gerbera jamesonii* the symptoms of calcium deficiency have been reported by Krug *et al.* [20] as chlorosis, curling of young leaves followed by necrosis. Similar results are described in this research.

Symptoms of magnesium deficiency were manifested in same time with those of nitrogen restriction during 60 days after initiation of treatments. Chlorotic bands were observed between the secondary veins in older leaves, while the main vein remained green (Fig. 1E). This pattern of chlorosis in this treatment is explained by Taiz *et al.* [21] as consequence of chlorophyll into vascular bundles remains unchanged for higher period, when compared with chlorophyll in cells between bundles, and if the deficiency is severe, leaves may become yellowish or white, a fact that also occurred with *Zingiber spectabile* leaf. The yellowish is associated with lower production of chlorophyll, which contains magnesium in molecule center. Magnesium is very mobile in phloem and thus easily redistributes in older leaves and tissues to areas of greatest needs, such as meristems and reserve organs [6], explaining the fact that the deficiency symptoms in *Zingiber spectabile* appear first in older leaves. Chlorosis between veins of older leaves is a characteristic of magnesium deficiency and has also been observed by Castro *et al.* [22] on *Heliconia psittacorum* and Viégas *et al.* [5] on *Alpinia purpurata* plants.

Symptoms of sulfur restriction were last to appear 190 days after starting treatments, and showed that this plant is not sensitive to sulfur deficiency. It is characterized by mild chlorosis in young leaves, reduced plant height and leaf narrowing, as compared to control treatment (Fig. 1F). According to Malavolta [23], the symptoms of sulfur deficiency is due to fact that this nutrient is absorbed by plants as SO_4^{-2} and it conducted from base in direction to apical part. In addition, this has low mobility being normally observed in younger organs, such as upper leaves. However, in many plant species, chlorosis due to lack of sulfur can occur simultaneously on all leaves or start in older leaves [21]. Jeong *et al.* [16] also observed in *Rosa hybrida* chlorosis in young leaves as characteristic of sulfur deficiency.

Production of dry matter: Treatments with restriction of macronutrients, except sulfur in stem dry matter and shoot dry matter limited the production of dry matter in other parts of plant, in relation to control (Table 1). The major limitations on the plant dry matter occurred under restriction of potassium, about 78.8% in relation to control, indicating that *Zingiber spectabile* is highly exigent of this nutrient. In *Etlingera elatior* the dry matter production has also been limited by omission of potassium, and was surpassed only by restriction of boron [24].

Table 1. Leaf dry matter, stem dry matter, root dry matter, shoot dry matter, plant dry matter, and relative growth in young *Zingiber spectabile* plants exposed to restriction of macronutrients.

Treatment	LDM*	SDM	ShDM	RDM	PDM	RG
	------------------------(g plant^{-1})------------------------					(%)
Control	36.52 a	30.94 a	67.46 a	44.24 a	111.70 a	100.00 a
N restriction	17.25 c	14.12 b	31.37 b	29.00 c	60.37 c	54.04 c
P restriction	13.12 d	12.88 b	26.00 b	18.62 e	44.62 d	39.94 d
K restriction	10.12 e	5.28 c	15.40 c	8.32 f	23.72 f	21.23 f
Ca restriction	15.95 c	12.90 b	27.66 b	23.12 d	50.78 cd	45.46 d
Mg restriction	12.33 d	11.48 b	23.80 bc	10.80 f	34.60 e	30.97 e
S restriction	30.13 b	31.42 a	62.16 a	33.80 b	100.96 b	90.38 b
CV	4.70	13.85	12.56	5.87	8.17	7.18
DMS	1.82	4.72	4.55	2.90	9.98	3.91

*Averages followed by the same letter in columns do not differ at Tukey's test at 5% level of error probability.

The second nutrient most limiting on plant dry matter was magnesium, with a reduction of 69% compared with the control. Limitation on growth caused by restriction of potassium and magnesium is relevant, because the several cultivated areas with *Zingiber spectabile* present Yellow Latosol with medium texture, and this soil type has low level of these nutrients. In this case, special attention should be paid to potassium and magnesium fertilization for growing *Zingiber spectabile*.

The sequence linked to relative growth followed the order of treatments control>S>N>Ca>P>Mg>K restrictions. Castro *et al.* [22] found reduction in flower dry matter of *Heliconia psittacorum* under individual omission of potassium. Oliveira *et al.* [25] observed an increase of inflorescences in *Heliconia bihai* grown in Yellow Latosol of medium texture with the application of nitrogen, phosphorus and potassium, showing the importance of these nutrients in tropical ornamental plants.

Content and accumulation of leaf nutrients: Individual restrictions of N, P, K, Ca, Mg and S reduced the content of these nutrients, when compared to the control treatment (Table 2). Levels of macronutrients in control plants were N = 22.6, P = 2.4, K = 18.2, Ca = 16.2, Mg = 3.1, S = 2.2, and under restriction individuals the values of N = 15.2, P = 1.1, K = 6.8, Ca = 3.3, Mg = 1.6 and S = 1.1.

Similar to observed with foliar content, the restriction of each macronutrient also limited the accumulation of nitrogen, phosphorus, potassium, calcium, magnesium and sulfur in leaves (Table 3), when compared with control treatment. Those results demonstrate the importance of macronutrients for cultivation of *Zingiber spectabile*. The order of the accumulation of nutrients in leaf of control plants was the same observed in content of macronutrients, being N>K>Ca>Mg>P>S. The accumulations of nitrogen, phosphorus, and potassium were 855.0, 90.0 and 672.5 mg plant^{-1} in control plants.

Table 2. Content of macronutrients in leaf of young *Zingiber spectabile* plants exposed to restriction of macronutrients.

Treatment	N*	P	K	Ca	Mg	S
			(g Kg^{-1})			
Control	22.6 c	2.4 d	18.2 d	16.2 b	3.1 d	2.2 c
N restriction	15.2 d	5.1 a	21.2 bc	14.2 b	5.2 c	4.6 a
P restriction	27.3 ab	1.1 e	23.4 ab	16.6 b	4.6 c	2.6 b
K restriction	26.4 abc	4.6 b	6.8 e	26.6 a	9.7 a	2.5 b
Ca restriction	28.9 a	3.3 c	22.6 ab	3.3 c	7.1 b	2.5 b
Mg restriction	25.9 abc	4.4 b	25.1 a	14.6 b	1.6 e	2.7 b
S restriction	23.1 bc	3.3 c	18.4 cd	23.4 a	4.9 c	1.1 d
CV	8.55	3.97	6.67	12.02	12.56	5.82
DMS	2.07	0.13	1.29	1.97	0.65	0.15

*Averages followed by the same letter in columns do not differ at Tukey's test at 5% level of error probability.

Table 3. Accumulation of macronutrients in leaf of young *Zingiber spectabile* plants exposed to restriction of macronutrients.

Treatment	N*	P	K	Ca	Mg	S
			(mg plant^{-1})			
Control	855.0 a	90.0 a	672.5 a	595.0 b	115.0 b	82.5 a
N restriction	197.5 e	65.0 b	272.5 e	180.0 d	67.5 d	57.5 b
P restriction	482.5 c	20.0 d	412.5 c	292.5 c	85.0 cd	47.5 bc
K restriction	265.0 de	47.5 c	67.5 f	262.5 c	95.0 bc	27.5 e
Ca restriction	455.0 c	55.0 bc	357.5 cd	52.5 c	112.5 b	40.0 cd
Mg restriction	322.5 d	52.5 c	307.5 de	180.0 d	20.0 e	35.0 de
S restriction	707.5 b	100.0 a	565.0 b	715.0 a	150.0 a	32.5 de
CV	8.63	8.33	8.25	10.04	11.23	10.32
DMS	92.40	11.76	71.90	75.11	23.79	10.93

*Averages followed by the same letter in columns do not differ at Tukey test at 5% level of error probability.

Table 4 shows the comparison between foliar concentrations obtained in the control treatment of this study on *Zingiber spectabile* plants and those obtained by Viégas *et al.* [5] on *Alpinia purpurata* and Mills *et al.* [26] on *Zingiber officinale* plants. Concentrations of macronutrients in *Alpinia purpurata* presented higher values, with exception of calcium, comparing with *Zingiber spectabile* in this research. This fact reveals greater nutritional requirement of *Alpinia purpurata*. In relation to foliar content of *Zingiber officinale* except for potassium and calcium, other being compatible with the results obtained in this research.

Table 4. Comparison of macronutrients in leaf of young *Zingiber spectabile* plants with *Zingiber officinale* and *Alpinia purpurata*.

Source	Species	N	P	K	Ca	Mg	S
In this study	*Zingiber spectabilis*	22.0	2.4	18.2	16.2	3.1	2.2
Viégas *et al.* [5]	*Alpinia purpurata*	25.1	5.1	36.1	5.9	5.6	4.1
Mills *et al.* [26]	*Zingiber officinale*	23.4	2.6	24.4	4.0	3.2	2.2

Conclusions

Potassium and nitrogen were the first nutrients to show visual symptoms induced by restriction, followed by magnesium, calcium, phosphorus, and sulfur. The nutrient most limiting for growth of *Zingiber spectabile* plants was potassium, followed by magnesium. In addition, production of dry matter in leaf, stem, shoot, root and whole plant was affected by the omission of macronutrients, except sulfur in dry matter of stem and shoot. Individual restrictions of nitrogen, phosphorus, potassium, calcium, magnesium and sulfur promoted reduction in contents and accumulation in leaf of *Zingiber spectabile*.

References

[1]Serviço de Apoio às Micro e Pequenas Empresas. 2010. Executive summary about the study competitiveness and efficiency of the Amazonian flowers and ornamental plants supply chain. SEBRAE, Manaus, 98 p.

[2]Batista, K. T. 2006. Evaluation of Nutrient Solutions in Plants of *Heliconia psittacorum* L. x *Heliconia spathocircinata Arist* cv. Golden Torch. MSc. thesis, Universidade do Estado do Pará, Brasil, 45 p.

[3]Oliveira, R. F., Viégas, I. J. M., Conceição, H. E. O., Frazão, D. A. C., and Chagas, J. H. 2006. Flower production of *Heliconia bihai* with mineral and organic fertilization. Embrapa Amazônia Oriental, Belém, 5 p.

[4]Sousa, G. O.,Viégas, I. J. M. and Frazão, D. A. C. 2009. Growth of *Heliconia psittacorum* cv. Golden Torch in function of dolomitic

calcarium levels. Revista de Ciências Agrárias **52**:49-59.
[5]Viégas, I. J. M., Naif, A. P. M., Conceição, H. E. O., Lobato, A. K. S., Frazão, D. A. C., Oliveira Neto, C. F. and Cordeiro, R. A. M. 2011. Visual symptoms, growth and nutrients of *Alpinia purpurata* plants exposed to N, P, K, Ca, Mg and S deficiencies. Journal of Food, Agriculture & Environment **9**(3&4):1048-1051.
[6]Epstein, E. and Bloom, A. J. 2005. Mineral Nutrition of Plants: Principles and Perspectives. Sinauer, Sunderland, 400 p.
[7]Nayyar, H. and Kaushal, S. K. 2002. Alleviation of negative effects of water stress in two contrasting wheat genotypes by calcium and abscisic acid. Biologia Plantarum **45**:65-70.
[8]Cruz, F. J. R., Lobato, A. K. S., Costa, R. C. L., Lopes, M. J. S., Neves, H. K. B., Oliveira Neto, C. F., Silva, M. H. L., Santos Filho, B. G., Lima Junior, J. A. and Okumura, R. S. 2011. Aluminum negative impact on nitrate reductase activity, nitrogen compounds and morphological parameters in sorghum plants. Australian Journal of Crop Science **5**:641-645.
[9]Marques, D. J., Broetto, F., Silva, E. C., Freitas, J. M. N., Lobato, A. K. S. and Alves, G. A. R. 2011. Changes in leaf proline and fruit production induced by potassium stress in eggplant. Journal of Food, Agriculture & Environment **9**(2):191-194.
[10]Hoagland, D. R. and Arnon, D. I. 1950. The Water Culture Method for Growing Plants without Soils. Califórnia Agricultural Experimental Station, Berkeley, 347 p.
[11]Malavolta, E., Vitti, G. C. and Oliveira, S. A. 1997. Evaluation of the Nutritional State of Plants: Principles and Applications. Potafos, Piracicaba, 319 p.
[12]Liu, W., Zhu, D. W., Liu, D. H., Geng, M. J., Zhou, W. B., and Mi, W. J. 2010. Influence of nitrogen on the primary and secondary metabolism and synthesis of flavonoids in *Chrysanthemum morifolium* Ramat. Journal of Plant Nutrition **33**:240-254.
[13]Mengel, K. and Kirkby, E. A. 2001. Principles of Plant Nutrition. International Potash Institute, Bern, 849 p.
[14]Mirkohi, A. K. and Schenk, M. K. 2009. Phosphorus efficiency of ornamental plants in peat substrates phosphorus stress. Journal of Plant Nutrition and Soil Science **172**:369-377.
[15]Ferreira, L. B. and Oliveira, S. A. 2003. Study of fertilization NPK in the growth variable and inflorescences productivity of *Heliconia* sp. Revista Brasileira de Horticultural Ornamental **9**:121-127.
[16]Jeong, K. Y., Whipker, B. E., Mccall, I. and Gunteret, C. C. 2011. Characterization of nutrient disorders of pot rose Karina parade. Acta Horticulturae **891**:125-133.
[17]Chiera, P., Thomas, J. and Rufty, T. 2002. Leaf initiation and development in soybean under phosphorus stress. Journal of Experimental Botany **53**:473-481.
[18]Silveira, R. L. V. A., Malavolta, E. and Broetto, F. 2001. Effect of potassium on dry matter production and concentration of putrescine, spermidine and spermine in *Eucalyptus grandis* progenies. Scientia Forestalis **59**:13-25.
[19]Marschner, H. 1995. Mineral Nutrition of Higher Plants. Academic Press, New York, USA, 889 p.
[20]Krug, B. A., Whipker, B. E., Jonathan, F. and Mccall, I. 2009. Characterization of calcium and boron deficiency and the effects of temporal disruption of calcium and boron supply on pansy, petunia, and gerbera plugs. Hortscience **44**:1566-1572.
[21]Taiz, L. and Zeiger, E. 2009. Plant Physiology. Artmed, Porto Alegre, 848 p.
[22]Castro, A. C. R., Loges, V., Costa, A. S., Castro, M. F. A., Aragão, A. S., and Willadino, L. G. 2007. Flower stems postharvest characteristics of helicônia under macronutrients deficiency. Pesquisa Agropecuária Brasileira **42**:1299-1306.
[23]Malavolta, E. 2006. Manual of Plant Mineral Nutrition. Livroceres, São Paulo, Brasil, 638 p.
[24]Frazão, J. E. M., Carvalho, J. G., Pinho, P. J., Oliveira, N. P., Coelho,V. A. T. and Melo, S. C. 2010. Nutritional deficiency in torch ginger (*Etlingera elatior* (Jack) R. M. Smith): Effect on dry matter production and biometrical. Ciência Agrotécnica **34**:294-299.
[25]Oliveira, R. F., Viégas, I. J. M. and Chagas, J. H. 2006. Effect of organic fertilization in flower production of *Heliconia bihai*. Embrapa Amazônia Oriental, Belém, 3 p.
[26]Mills, H. A. and Jones Jr., J. B. 1996. Plant Analysis Handbook II. Micromacro Publishing, Athens, Greece, 422 p.