J. Elementol. 2010, 15(2): 301–311

DIFFERENTIATED MICROELEMENT CONTENT IN ANTHURIUM (*ANTHURIUM CULTORUM* BIRDSEY) LEAVES*

Tomasz Kleiber, Andrzej Komosa

Chair of Horticultural Plants Nutrition
Poznań University of Life Sciences

Abstract

The main objective of the study was to determine the nutritional status in terms of the content of microelements, such as iron, manganese, zinc, copper and boron in several standard cultivars of anthurium (*Anthurium cultorum* Birdsey) called Baron, Choco, Midori, Pistache, President and Tropical. The plants were grown in expanded clay (ř 8-18 mm) using drip fertigation with standard nutrient for anthurium grown in inert substrates with the following components: N-NH_4<1.0, N-NO_3 7.5, P 1.0, K 4.5, Ca 1.5, Mg 1.0, S-SO_4 1.5 (mmol dm^{-3}), Fe 15, Mn 3.0, Zn 3.0, Cu 0.5, B 20.0, Mo 0.5 (μmol dm^{-3}), pH 5.5-5.7, EC 1.5-1.8 mS cm^{-1}. Every two months, anthurium indicator parts were sampled for chemical analyses. The indicator parts included fully developed leaves from plants after freshly cut flowers. The average microelement content in the indicator parts showed the following values (in mg kg^{-1} d.m.): Fe 47.6-58.0, Mn 36.9-45.1, Zn 60.3-67.6, Cu 5.01-6.43, B 63.5--89.0. It was found that a significant effect on the nutritional status with respect to microelements was produced by the plant cultivar type. The highest content of iron in the indicator parts was found in cv. Baron; manganese was most abundant in cv. Choco; cv. Midori was the richest in zinc and boron appeared in the highest level in cv. Pistache. Coefficients of variability (*CV*) of the analyzed microelements were determined. The smallest variability during 3 years of studies was shown by copper (*CV* 15.4-24.3%), a mean value was found in boron (*CV* 20.9-26.7%) and in iron (*CV* 25.1-31.4%), while the highest values were shown by zinc (*CV* 39.7-44.7%) and by manganese (*CV* 40.4-58.5%).

Key words: tropical, plant analysis, microelement, coefficient of variability, inert substrate.

dr inż. Tomasz Kleiber, Chair of Horticultural Plants Nutrition, Poznań University of Life Sciences, ul. Zgorzelecka 4, 60-198 Poznań, e-mail: tkleiber@up.poznan.pl

*The study was co-financed by the State Committee for Scientific Research (KBN), grant No. 0381/P06/2004.

ZRÓŻNICOWANIE ZAWARTOŚCI MIKROELEMENTÓW W LIŚCIACH ANTURIUM (*ANTHURIUM CULTORUM* BIRDSEY)

Abstrakt

Głównym celem badań było określenie zróżnicowania stanu odżywienia mikroelementami: żelazem, manganem, cynkiem, miedzią i borem standardowych odmian anturium *(Anthurium cultorum* Birdsey): Baron, Choco, Midori, Pistache, President i Tropical. Rośliny uprawiano w keramzycie (ř 8-18 mm) z zastosowaniem fertygacji kroplowej pożywką standardową dla uprawy anturium w podłożach inertnych o następującej zawartości składników: $N\text{-}NH_4$<1.0, $N\text{-}NO_3$ 7.5, P 1.0, K 4.5, Ca 1.5, Mg 1.0, $S\text{-}SO_4$ 1.5 (mmol dm^{-3}), Fe 15, Mn 3.0, Zn 3.0, Cu 0.5, B 20.0, Mo 0.5 (μmol dm^{-3}), pH 5.5-5.7, EC 1.5-1.8 mS cm^{-1}. Co 2 miesiące pobierano do analiz chemicznych części wskaźnikowe anturium, którymi były w pełni wyrośnięte liście z roślin po świeżo ściętym kwiecie. Przeciętna zawartość mikroelementów w częściach wskaźnikowych była następująca (w mg kg^{-1} s.m.): Fe 47.6-58.0, Mn 36.9-45.1, Zn 60.3-67.6, Cu 5.01-6.43, B 63.5-89.0. Stwierdzono istotny wpływ odmian na stan odżywienia roślin mikroelementami. Największą zawartość żelaza w częściach wskaźnikowych stwierdzono u odmiany Baron, manganu i miedzi u Choco, cynku u Midori, a boru u Pistache. Wyznaczono współczynniki zmienności (*CV*) zawartości badanych mikroelementów. Najmniejszą zmienność w trakcie 3 lat badań wykazywała miedź (CV 15.4--24.3%), średnią bor (*CV* 20.9-26.7%) i żelazo (*CV* 25.1-31.4%), a największą cynk (*CV* 39.7--44.7%) i mangan (*CV* 40.4-58.5%).

Słowa kluczowe: anturium, mikroelementy, analiza roślin, współczynniki zmienności, podłoża inertne.

INTRODUCTION

Owing to a widespread use of inert media [mainly expanded clay] and fertigation, Poland is one of the main anthurium producer in Europe. In modern horticulture, an important role is played by controlled fertilization. In many cases, it is not enough to determine the content of components in a substrate or in a nutrient. In order to diagnose the nutritional status of plants, it is necessary to perform their chemical analyses. Usually, it is done by sampling plant indicator parts, which reflect most faithfully the differences in the component content under the influence of increasing fertilization (De Kreij et al. 1990). Mills, Scoggins (1998) proved that young, fully developed leaves, before developing a layer of suberine, are the best indicator parts for anthurium. Older leaves are not adequate for this purpose because their nutritive components are translocated to flowers.

Each year, a wide range of new commercial cultivars of the flower appear on the market. Meanwhile, many of the studies carried out so far concern cultivars of anthurium which are less popular in Poland (Higaki et al. 1992, Sonneveld, Voogt 1993, Mills, Scoggins 1998, Dufour, Guérin 2005).

The main objective of our present study was to determine the nutritional status in terms of iron, manganese, zinc, copper and boron in the most popular anthurium cultivars grown in Poland (*Anthurium cultorum* Birdsey), such as Baron, Choco, Midori, Pistache, President and Tropical, grown in expanded clay, as well as to determine the coefficients of variability and regression equations describing the dynamics of microelement content in leaves. These data are essential for the interpretation of the results of plant assays and for diagnosing their the nutritional status.

MATERIAL AND METHODS

A vegetation experiment was carried out at two speciality farms in Wielkopolska. Venlo type greenhouses were equipped with modern systems of fertigation, climate control and recording system, air humidity checks and energy-saving curtains. Anthurium cultivars (*Anthurium cultorium* Birdsey), such as Choco, Midori, Pistache, President and Tropical (Anthura B.V., Holland), grown in expanded clay (Ø 8-18 mm), underwent analyses. Cuttings grown in pots of mineral wool (75 cm^3) were planted into beds in the greenhouse between 8^{th} and 11^{th} August 2000. The analyses started on 15^{th} of January 2002 (on 2-year-old plants) and were terminated on 30^{th} November 2004 (4-year-old plants). One bed measuring 12 x 46 m covered 55.2 m^2. Fourteen plants were grown per 1 m^2 14. Agronomic treatments were carried out according to the current recommendations for anthurium. During the whole experiment, plant yielding was optimal regarding both the quantitative and qualitative values (Kleiber, Komosa 2007).

In the vegetation experiment, drip fertigation in a closed system was used without nutrient recirculation. The nutrient was distributed in beds through dripping lines with emitters spaced in 20cm intervals. The frequency and time of irrigation depended on the season of the year. In summer, fertigation was applied 6-8 times supplying 4-5 dm^3 of nutrient per 1 m^2, while in winter, it was done 2-3 times applying 2-3 dm^3. About 20% of nutrient exuded from the root zone. In order to provide an adequate air and substrate humidity, the culture was sprinkled with rain water using microsprinklers.

Before the preparation of nutrients, chemical analyses of water were carried out (Kleiber, Komosa 2006, 2008). In the experiments, the standard nutrient was used in drip fertigation for anthurium grown in inert substrates: N-NH_4<1.0, N-NO_3 7.5, P 1.0, K 4.5, Ca 1.5, Mg 1.0, S-SO_4 1.5 (mmol dm^{-3}), Fe 15, Mn 3.0, Zn 3.0, Cu 0.5, B 20.0, Mo 0.5 (µmol dm^{-3}), pH 5.5-5.7, EC 1.5-1.8 mS cm^{-1} (after Komosa 2000).

Samples of plant material were taken in the years 2002-2004 in two-month intervals, between 14^{th} and 16^{th} January, March, May, July, September and November. The indicator parts of anthurium consisted of fully developed leaves from plants after freshly cut flowers (De Kreij et al. 1990). Leaves were randomly sampled from the total area of beds from plants characteristic of a given cultivar, healthy, well yielding and without any symptoms of damages. One sample of a given cultivar consisted of 15-20 leaves sampled in both experimental farms. The details of chemical analyses of plant material were given previously (*Analytical methods*... 1972, KLEIBER et al. 2009).

Statistical analysis was carried out, with the calculation of variability coefficients and regression equilibrium coefficients and a description of the microelement content dynamics in the indicator parts, which changed with the age of plants. Conclusions were drawn at the significance level of $\alpha = 0.05$.

RESULTS AND DISCUSSION

The results of the chemical analyses of anthurium indicator parts are shown in Tables 1 and 2 and the dynamics of elements – in Figure 1. The plant cultivar and age of plants significantly modified the nutritional status of plants in terms of microelements. The mean iron content in the indicator parts was 47.6-58.0 mg Fe kg^{-1} (Table 1). The least amount of Fe was found in the youngest plants (in 2002), while the 3-4-year-old plants were characterized by significantly higher values (in 2003-2004). The Fe content tended to increase with the aging of plants (Figure 1), which was proven by a regression equation in the form of $y = 0.011x^3 - 0.2829x^2 + 2.4241x + 45.50$, where: y – expected Fe content in a given term; x – the term of sampling (1-18; from Jan. 2002 to Nov. 2004; 3 years 6 terms = 18). For example, in the 4th term of sampling (July 2002), the Fe content was $y = 0.011\ 4^3 - 0.2829\ 4^2 + 2.4241 \cdot 4 + 45.50 = 50.74$ mg Fe kg^{-1} 50.7 mg Fe kg^{-1}. The cultivar Baron showed the highest Fe content in the indicator parts (53.9--67.2 mg Fe), while cv. Choco was characterized by the smallest Fe content (38.3-53.9 mg Fe). Some earlier studies by KLEIBER, KOMOSA (2004) showed that the year of experiments can produce a considerable effect on the iron content.

The mean content of manganese in plant indicator parts ranged from 36.9mg (4-year-old plants) to 45.1 mg Mn kg^{-1} d.m. (3-year-old plants). Differences between the successive years have not been statistically proven. KLEIBER and KOMOSA (2004) confirmed significant differentiation of Mn in indicator parts in the particular years of studies. The cultivar Choco showed the highest Mn content (41.5-68.8 Mn), while cv. President was characterized by the smallest manganese content (22.1041.3 mg Mn kg^{-1} d.m.).

The mean content of zinc in the indicator parts of the analyzed cultivars was 60.3-67.6 mg Zn kg^{-1} (Table 2). The youngest plants (in 2002) were characterized by a significantly higher zinc content. The Zn content declined drastically in 3-year-old plants. In zinc, the tendencies in the plant indicator

Table 1

Coefficients of variability (*CV*) and mean content of iron and manganese in anthurium indicator parts

Cultivar		mg Fe kg^{-1} d.m.			mg Mn kg^{-1} d.m.		
		year					
		2002	2003	2004	2002	2003	2004
Baron	$\overline{x}$	53.9*a*	67.2*a*	58.3*a*	43.6*a*	38.7*b*	37.8*b*
	min	37.3	57.1	48.5	21.9	30.6	18.1
	max	64.8	83.9	69.3	65.9	52.1	49.6
	CV (%)	25.1	18.8	22.3	36.9	20.7	27.2
Choco	$\overline{x}$	38.3*c*	45.8*b*	53.9*ab*	41.5*a*	68.8*a*	60.3*a*
	min	28.0	36.9	39.4	20.3	61.7	25.6
	max	45.3	51.1	87.4	62.9	80.3	79.0
	CV (%)	19.5	13.5	36.1	39.5	11.8	29.2
Midori	$\overline{x}$	42.9*c*	47.8*b*	49.2*b*	49.1*a*	38.8*b*	49.9*ab*
	min	28.2	34.4	37.7	16.9	22.1	16.8
	max	57.6	64.2	62.9	90.4	67.6	90.9
	CV (%)	29.6	24.8	29.8	51.8	43.8	60.4
Pistache	$\overline{x}$	44.7*bc*	61.5*a*	55.9*ab*	29.6*a*	37.4*b*	29.4*bc*
	min	38.6	46.6	46.3	12.4	32.4	17.4
	max	53.3	84.1	63.3	45.6	43.1	45.2
	CV (%)	17.0	28.6	21.9	40.5	10.5	32.2
President	$\overline{x}$	53.9*a*	64.1*a*	50.9*ab*	41.3a	32.7*b*	22.1*c*
	min	31.5	51.8	35.2	27.6	22.6	6.7
	max	78.3	78.8	70.2	68.8	39.5	43.8
	CV (%)	31.9	15.7	29.5	31.2	19.0	56.3
Tropical	$\overline{x}$	51.9*ab*	61.7*a*	56.4*ab*	41.8*a*	54.6*a*	22.1*c*
	min	30.7	50.6	42.7	24.6	25.1	16.8
	max	66.6	71.5	68.4	60.2	94.1	30.8
	CV (%)	37.1	18.2	24.6	31.5	43.9	21.5
Mean		47.6*c*	58.0*a*	54.1*b*	41.2*a*	45.1*a*	36.9*a*
CV (%)		31.4	25.1	28.1	42.8	40.4	58.5

Mean values in columns marked with the same letter do not differ significantly.
Mean values from all the tested varieties (in rows) marked with the same letter do not differ significantly.

Table 2

Coefficients of variability (*CV*) and mean content of zinc. copper and boron in anthurium indicator parts

Cultivar		mg Zn kg^{-1} d.m.			mg Cu kg^{-1} d.m.			mg B kg^{-1} d.m.		
		year								
		2002	2003	2004	2002	2003	2004	2002	2003	2004
Baron	$\overline{x}$	55.4 *c*	58.5 *a*	64.5 *a*	5.94 *b*	6.44 *a*	5.03 *ab*	63.0 *a*	85.2 *a*	65.1 *a*
	min	49.3	40.6	34.1	4.84	3.88	4.14	39.0	72.9	44.0
	max	61.3	73.9	92.0	4.90	7.22	5.82	90.5	111.4	81.5
	CV (%)	35.7	49.7	50.2	13.8	23.5	13.4	31.4	19.9	21.1
Choco	$\overline{x}$	70.7 *b*	60.0 *a*	60.4 *a*	6.72 *a*	6.98 *a*	5.48 *a*	62.1 *a*	89.3 *a*	67.3 *a*
	min	61.9	42.3	47.7	5.61	4.73	4.26	42.8	73.0	49.6
	max	82.8	78.5	70.0	7.84	8.30	6.39	79.8	116.9	80.5
	CV (%)	33.5	36.4	31.0	13.4	25.4	18.4	20.6	25.5	21.7
Midori	$\overline{x}$	80.5 *a*	61.8 *a*	68.0 *a*	5.98 *b*	6.42 *a*	4.58 *b*	67.7 *a*	91.4 *a*	74.4 *a*
	min	67.0	48.7	34.8	5.68	4.33	3.70	52.7	72.6	70.5
	max	96.0	71.9	93.7	6.34	9.22	5.70	80.6	115.8	82.9
	CV (%)	32.8	34.4	41.4	9.8	25.9	18.0	18.6	20.9	14.4
Pistache	$\overline{x}$	55.0 *c*	56.6 *a*	49.3 *c*	5.39 *b*	5.82 *b*	5.44 *a*	65.1 *a*	90.8 *a*	79.7 *a*
	min	45.5	43.3	29.3	4.91	3.99	4.90	53.5	74.8	72.0
	max	71.0	67.3	64.8	6.20	7.34	6.07	77.9	117.8	88.1
	CV (%)	40.8	46.9	41.4	13.0	20.7	20.3	21.6	19.5	13.9
President	$\overline{x}$	75.0 *ab*	62.6 *a*	59.1 *b*	6.09 *b*	6.43 *a*	4.71 *b*	57.3 *a*	91.1 *a*	63.0 *a*
	min	61.7	49.5	50.8	5.31	4.50	3.71	40.2	77.8	54.0
	max	93.7	73.9	76.1	6.66	7.56	5.61	70.4	114.7	80.1
	CV (%)	42.8	44.2	44.4	17.7	24.3	27.3	35.6	21.9	17.2
Tropical	$\overline{x}$	69.3 *bc*	62.5 *a*	64.9 *a*	6.02 *b*	6.47 *a*	4.85 *b*	65.7 *a*	86.4 *a*	61.1 *a*
	min	53.9	49.8	43.1	5.26	5.05	3.78	51.5	59.0	45.4
	max	91.2	70.5	98.7	6.58	7.63	5.69	74.7	105.6	80.8
	CV (%)	36.8	20.7	47.5	14.5	21.4	22.1	27.4	22.4	23.4
Mean		67.6 *a*	60.3 *b*	61.1 *b*	6.02 *b*	6.43 *a*	5.01 *c*	63.5 *b*	89.0 *a*	68.4 *b*
CV (%)		39.9	39.7	44.7	15.4	24.3	21.4	26.7	21.9	20.9

Explanations see Table 1

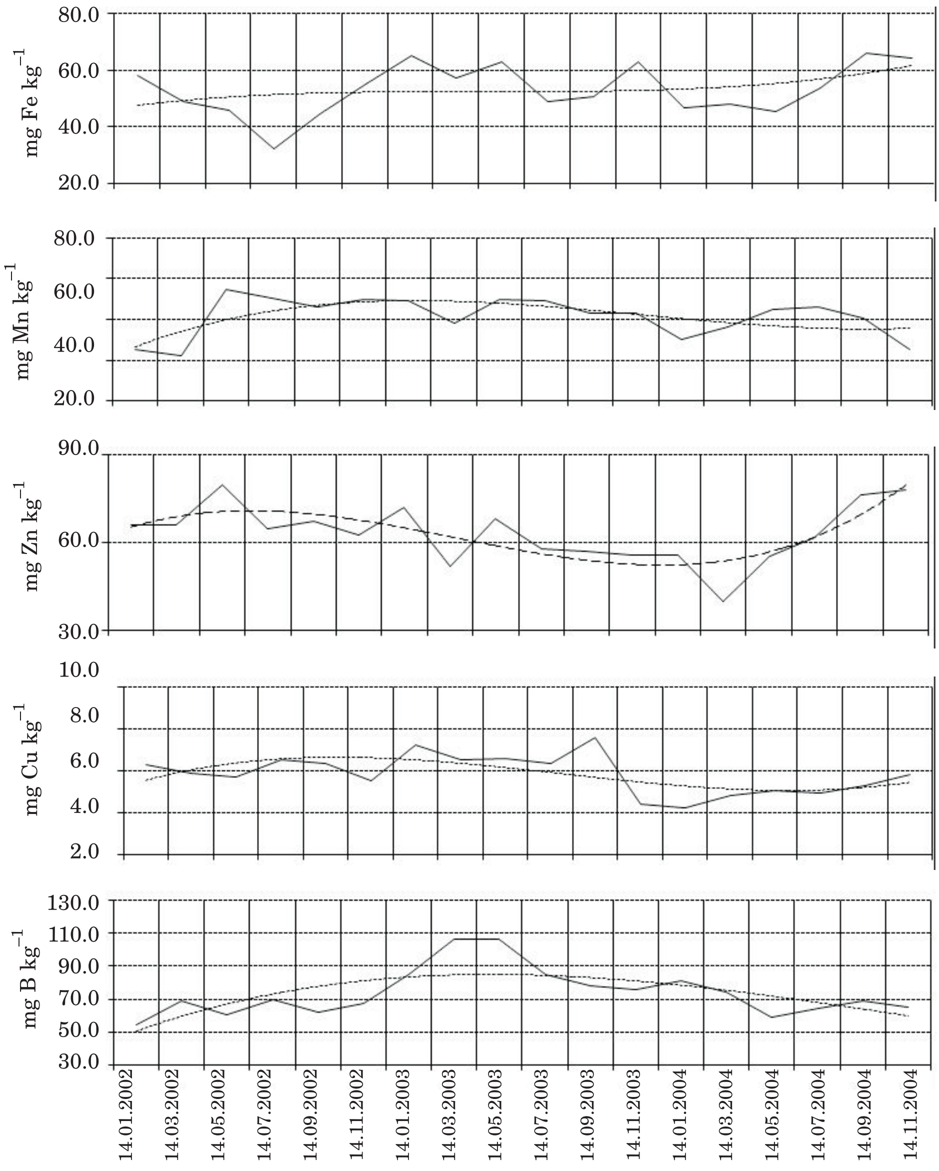

Fig. 1. Dynamics of microelements contents in the indicator parts of anthurium (means from 6 cultivars and 2 farms)

parts are described by the equation: $y = 0.0505\ x^3 - 1.2304\ x^2 + 6.9172x + 59.47$. KLEIBER, KOMOSA (2004) showed that the zinc content tended to decrease during a growing season. In the present tests, significant differences were shown in the Zn content among the analyzed cultivars. The highest Zn content was found in cv. Midori (61.8-80.5 mg Zn), while the lowest Zn value was shown in cv. Pistache (49.3-56.6 mg Zn kg^{-1} d.m.).

The mean content of copper, depending on the year of the experiment, varied between 5.01 and 6.43 mg Cu kg^{-1} d.m. in the plant indicator parts (Table 2). Three-year-old plants (in 2003) showed significantly the highest Cu content, while the two- and four-year-old plants (in 2002 and 2004) were characterized by smaller amounts of Cu. Significant differences among the analyzed cultivars were found. The smallest mean Cu content (5.39-5.82 mg Cu) was shown in cv. Pistache, while cv. Choco showed the highest Cu content (5.48-6.98 mg Cu). Regression equation in the form: $y = 0.003x^3 - 0.0936x^2 + 0.7326x + 4.90$ described the dynamics of the Cu content changing with the aging of plants. KLEIBER, KOMOSA (2004) found high differentiation of the copper content in the successive years of studies.

The mean boron content in plant indicator parts showed the values of 63.5-89.0 mg B kg^{-1} d.m. Analogously to copper, significantly the highest B content was shown in 3-year-old plants (in 2003). The dynamics of B in plant indicator parts is described by the equation: $y = 0.0157x^3 - 0.859x^2 + 11.48x + 39.67$. KLEIBER, KOMOSA (2004) found an unstable boron nutritional status of plants in the successive years of studies. The smallest mean content of boron was found in cv. President (57.3-91.1 mg B), while the highest B content was shown in cv. Pistache (65.1-90.8 mg B kg^{-1} d.m.).

The content of microelements found in the present study were compared with the content ranges recommended by other authors (Table 3). A high degree of agreement was found in the content of iron in the indicator parts of plants with the data reported in the literature (Table 3). In contrast to iron, the content of manganese showed little correspondence to the ranges reported in literature. Available references reported much higher Mn content in plant indicator parts. Regarding zinc, the assessed levels coincided with the ranges reported by CHEN et al. (2003). The copper content was within the ranges given by MILLS, SCOGGINS (1998) and by CHEN et al. (2003). A much higher copper content was reported by MILLS, SCOGGINS (1998). The content of boron in most of the cultivars was similar to that reported by UCHIDA (2000) and by CHEN et al. (2003). The smallest content of B appears in a paper by MILLS, SCOGGINS (1998).

Coefficients of variability

Coefficients of variability (*CV*) indicating the content of microelements in the plant indicator parts were determined (Tables 1, 2). They include the total effect of a series of factors modifying amounts of components in plants, including the cultivar type, growing conditions, light conditions. It was found

Table 3

Recommended content of microelements in indicator parts of anthurium according to different authors

Nutrient	Recommended values (mg kg^{-1} d.m.)	% of results in the recommended range		
		2002	2003	2004
Anthura (1998)				
Fe	28.0 - 112.0	98.6	84.7	100.0
Mn	38.0 - 109.0	58.3	52.8	36.1
Zn	46.0 - 131.0	68.1	66.7	62.5
Cu	6.3 - 12.7	37.5	43.1	12.5
B	54.0 - 76.0	51.4	29.2	50.0
Mills, Scoggins (1998)				
Fe	20.7 - 90.0(*a*)	95.8	56.9	95.8
Mn	41.0 - 237.0	41.7	44.4	36.1
Zn	41.0 - 98.1	66.7	66.7	58.3
Cu	10.3 - 25.0	0.0	0.0	0.0
B	12.0 - 25.0	0.0	0.0	0.0
Mills, Scoggins (1998)				
Fe	28.0 - 76.6 (*b*)	81.9	30.6	68.1
Mn	44.0 - 193.3	38.9	36.1	30.6
Zn	17.0 - 57.5	41.7	50.0	51.4
Cu	4.0 - 13.8	100.0	43.1	81.9
B	11.0 - 27.0	0.0	0.0	0.0
Uchida (2000)				
Fe	50.0 - 400.0	77.8	100.0	93.1
Mn	50.0 - 1500.0	27.8	30.6	22.2
Zn	-	-	-	-
Cu	-	-	-	-
B	25.0 - 135.0	100.0	95.8	100.0
Chen et al. (2003)				
Fe	50.0 - 400	77.8	100.0	93.1
Mn	40.0 - 500.0	41.7	47.2	36.1
Zn	20.0 - 200.0	100.0	98.6	100.0
Cu	5.0 - 40.0	87.5	84.7	51.4
B	20.0 - 100.0	97.2	68.1	98.6

a – young leaves, ripe in 90%, pale-green, 10 days before full maturity
b – mature leaves, dark green, with a growing and in 3/4 mature flower

that a significant effect was produced by the year of experiment and the analyzed cultivar on the coefficient of microelement content variability in the indicator parts, although there is no general tendency describing these effects. During the three years of trials, copper showed the smallest variability (*CV* 15.4%-24.3%). Moderate variability was found for iron (*CV* 25.1--31.4%) and boron (CV 20.9-26.7%), while the highest variability was achieved for manganese (*CV* 40.4-58.5%) and zinc (*CV* 39.7-44.7%). In the analyzed cultivars, differentiation of the variability coefficients was found. For example, the CV of iron in 2002 for cv. Choco cultivar was 19.5%, while for cv Midori, it reached 29.6%. This indicates that there was significant variability in the iron content in the indicator parts of cv. Midori. Considering the variability coefficients for microelement content which indicate deviations in their content versus the mean value for the total population enables researchers to attain a more precise interpretation of leaf analysis for diagnostic purposes.

CONCLUSIONS

1. Significant effect of a cultivar and the age of plants was found to be produced on the content of iron, manganese, zinc, copper and boron in leaves of anthurium.

2. The mean content of microelements in the analyzed cultivars was as follows: Fe 51.8-54.6, Mn 41.1-158.6, Zn 43.2-82.8, Cu 5.35-6.29, B 73.3--73.9 mg kg^{-1} d.m. in indicator parts.

3. The highest iron content in plant indicator parts was found in the cultivar Baron; manganese and copper showed the highest value in cv. Choco; the zinc content was the highest in cv. Midori while the boron content was the highest in cv. Pistache.

4. A significant effect on the coefficient of variability (*CV*) in the microelement content of plant indicator parts was found to be exerted by the cultivar type and plant age. Copper showed to be a component with the lowest variability (*CV* 15.4%-24.3%); boron was moderately variable (*CV* 20.9-26.7%); iron was also characterized by a medium value of variability (*CV* 25.1-31.4%), while zinc (*CV* 39.7-44.7%) and manganese (*CV* 40.4-58.5%) showed the highest variability.

REFERENCES

Analytical methods in agricultural-chemistry stations. IUNG 1972. Part II. *Plant analyses.* IUNG, Puławy (Poland), 25-83.

CHEN J., MCCONNELL D.B., HENNY R., EVERITT K.C. 2003. *Cultural guidelines for commercial production of interiorscape anthurium*. Environ. Hort. Dept. Florida Coop. Ext. Serv., Univ. of Florida, ENH, 956.

De Kreij C., Sonneveld C., Warmenhoven M.G., Straver N. 1990. *Guide values for nutrient element contents of vegetables and flowers under glass*: 23.

Dufour L., Guérin V. 2005. *Nutrient solution effects on the development and yield of Anthurium andreanum* Lind. *In tropical soilless conditions*, Sci. Horticult., 105: 269-282.

Higaki T., Imamura J.S., Paull R.E. 1992. *N, P and K rates and leaf tissue standards for optimum Anthurium andreanum flower production*. Hort Sci., 27 (8): 909-912.

Kleiber T., Komosa A. 2004. *Porównanie dynamiki zawartości makro- i mikroelementów w różnych latach uprawy anturium. [Comparison of dynamics of macro- and microelement contents in different years of anthurium growing],* Rocz. AR. Poznań. Ogrodn., 37: 95-101. (in Polish)

Kleiber T., Komosa A. 2006. *Differentiation of macroelement contents in nutrient solution and drainage water in growing of anthurium (Anthurium cultorum* Birdsey*) in expanded clay*. Acta Sci. Pol., Hortorum Cultus, 5(2): 69-78.

Kleiber T., Komosa A. 2007. *Plonowanie anturium (Anthurium cultorum* Schott*) uprawianego w keramzycie*. Rocz. AR Poznań, Ogrodn., 41: 57-61.

Kleiber T., Komosa A. 2008. *Differentiation of microelements contents in nutrient solution and drainage water in growing of anthurium (Anthurium cultorum* Birdsey*) in expanded clay*. Acta Sci. Pol., Hortorum Cultus, 7(1): 53-62.

Kleiber T., Komosa A., Krzyszkowska J., Moliński K. 2009. *Seasonal changes in the nutritional status and yielding of Anthurium cultorum* Birdsey. Part II. *Microelements*. Fol. Horicult. (in press).

Komosa A. 2000. *Plant and substrate analyses as the indicator of nutrient status of anthurium*. V Anthurium Growers Conf., ISiK Skierniewice, 12-13.04.2000; 24-30.

Komosa A., Kleiber T. 2003. *Zawartość składników pokarmowych w anturium uprawianym w podłożach inertnych.* Cz. II. *Mikroelementy [Content of nutrients in anthurium grown in inert substrates].* Rocz. AR. Poznań, Ogrodn., 36: 55-63. (in Polish)

Mills H.A., Scoggins H.L. 1998. *Nutrional levels for anthurium: young versus mature leaves*. J. Plant Nutr., 21(1): 199-203.

Sonneveld C., Voogt W. 1993. *The concentration of nutrients for growing Anthurium andreanum in substrate*. Acta Hort., 342: 61-67.

Uchida R. 2000. *Recommended plant tissue nutrient levels for some vegetable, fruit and ornamental foliage and flowering plants in Hawaii*. Plant nutrient management in Hawaiis Soils., 57-64.