ACTA Acta Sci. Pol., Hortorum Cultus 7(1) 2008, 53-62

DIFFERENTIATION OF MICROELEMENTS CONTENTS IN NUTRIENT SOLUTION AND DRAINAGE WATER IN GROWING OF ANTHURIUM (*Anthurium cultorum* Birdsey) IN EXPANDED CLAY

Tomasz Kleiber, Andrzej Komosa
Agricultural University in Poznań

Abstract. Vegetative experiments were carried out in the years 2002–2004 in two specialistic horticultural farms growing the most popular in Poland and in the Netherlands cultivars of anthurium (*Anthurium cultorum* Birdsey): 'Baron', 'Choco', 'Midori', 'Pistache', 'President' and 'Tropical'. Plants were grown in expanded clay with the use of drop fertigation with standard nutrient for anthurium in inert substrates (in $mg \cdot dm^{-3}$): $N\text{-}NH_4$ < 14.0, $N\text{-}NO_3$ 105.0, P 31.0, K 176.0, Ca 60.0, Mg 24.0, $S\text{-}S0_4$ 48.0, Fe 0.840, Mn 0.160, Zn 0.200, B 0.220, Cu 0.032, Mo 0.048, pH 5.5–5.7, EC 1.5 – 1,8 $mS \cdot cm^{-1}$. Subject of studies was the differentiation of microelement content in drainage waters driped from the substrate in relation to the supplied nutrient. Manganese was the nutrient wich was most intensely decreased (by –65.5%), followed by iron (by –51.9%) and zinc (by –45.2%). On the other hand, an increase was found in copper (by +11.1%) and in boron (by +16.6%). The recognition of changes in the contents of nutritive components in the drainage waters is a basis for the elaboration and implementation into the horticultural practice of closed fertigation systems with nutrient recirculation.

Key words: anthurium, microelements, nutrient solution, drainage water, expanded clay, closed fertigation system

INTRODUCTION

The present horticulture under covers inevitably tends towards closed fertigation systems. They permit significant limitation of the applied water and mineral fertilizers, as well as their more efficient utilization [Magen 1999]. Van Os [2001a] reports that the greatest number of this type cultivations can be found in the Netherlands (about 70%), where legal regulations prohibit to discharge drainage waters containing remainders of mineral fertilizers and plant protection agents directly into the soil [Runia and Amsing

Corresponding author – Adres do korespondencji: Tomasz Kleiber, Andrzej Komosa, Department of Horticultural Plants Nutrition, Agricultural University in Poznań, ul. Zgorzelecka 4, 60-198 Poznań, e-mail: tkleiber@au.poznan.pl, ankom@au.poznan.pl

2001]. Also the British (50%) and German (40%) gardeners are the leading ones in the field of ecology. In the nearest future, also in Poland, it will be necessary to eliminate completely any discharges of surplus nutrients from cultivated fields. A chance for a complete elimination of undesired discharges is offered by the elaboration and implementation of the closed fertigation systems. Significantly simpler, although, so far not practically applied, is the accumulation of drainage waters and their reutilization for sprinkling irrigation for other cultivations (the so called closed systems without nutrient recirculation). More complicated but technically and scientifically more advanced are the closed systems with nutrient recirculation. In the latter ones, the excess of nutrient exuding from the beds is collected and subsequently, after adequate conditioning (enriched by missing nutrients and disinfected), it is reused for fertigation [Van Os 2001a, Treder 2000]. There exist effective methods of nutrient disinfection as for example the thermic method [Van Os 1988; Runia and Amsing 2001]; with UV radiation [Benoit and Ceustermans 1995]; by inverse osmosis [Wohlanka 1990]; or by chemical agents such as hydrogen peroxide [Van Os 2001b] or by ozone [Runia and Amsing 1996]. Effective disinfection of nutrient, in spite of being essential, is not sufficient for correct functioning of closed fertigation system with recirculation. A necessary condition for the elaboration and implementation into horticultural practice is the knowledge of the content of nutritive components in the drainage waters exuding from the root zone in relation to the nutrient applied to the plants from the point of view of their repeated application in the fertilization systems [Treder 2000].

Anthurium cultorum Birdsey is a plant with a high economic importance in Poland. The total area of this plant cultivation is estimated for about 40 ha. Regarding anthurium production, Poland belongs to the leaders in Europe [Jabłońska 2005]. In the cultivation, there dominate inert substrates such as polyphenolic foam and expanded clay [Komosa and Kleiber 2003]. Expanded clay is characterized by physical properties particularly favourable for the growing of epiphytes, among others because of a very large air capacity [Anthura 1998]. It forces the necessity of a more frequent,than in case of rockwool, application of fertigation which increases the amount of drainage waters exuding from the cultivation beds. It limits the excessive concentration of nutritive components and facilitates effective functioning of the system with nutrient circulation for the cultivation of anthurium on expanded clay.

The objective of studies carried out in the years 2002–2004 was the determination of changes in microelement contents in the drainage waters in relation to the sprinkler, for the cultivation of anthurium in expanded clay from the point of view of their reutilization for plant fertigation.

MATERIALS AND METHODS

Vegetation experiments were carried out in the years 2002–2004, in two specialistic production farms in the region of Poznań. The greenhouse objects (of Dutch production; 'Venlo' type) were equipped with modern systems of sprinkling fertigation, control and climate recording (among others: thermal screens, energy saving curtains and mist generationg systems). All agrotechnical treatments were carried out according to the actual recommendations. Throughout the whole period of studies, the yieldidng of plants was optimal regarding the quantity and quality.

Subject of studies were the most popular in Poland and in the Netherlands cultivars of anthurium (*Anthurium cultorum* Birdsey): 'Baron', 'Choco', 'Midori', 'Pistache', 'President' and ''Tropical' (Anthura B.V.). Cuttings grown in pots of rockwool (75 cm^3) were planted in the greenhouse into beds on the 8th–11th of August 2000. One bed of 1.2×46 m included 55.2 m^2. On 1 m^2, 14 plants were planted in standard spacing giving 772 plants on one bed. Plants were grown in expanded clay (ø 8–18 mm.) with the application of fertigation with standard nutrients. Studies were started on 2-year old plants (14.01.2002) and they were terminated on 5-year old plants (14.11.2004).

Before the preparation of nutrients applied for fertigation, chemical analyses of water were carried out on the content of macro- and microelements. In farm I, tap-water was used with the following chemical composition (in $mg \cdot dm^{-3}$): NH_4 traces, N-NO_3 1.0, P 0.8, K 2.4, Ca 58.1, Mg 20.3, S-SO_4 7.9, Fe 0.015, Mn 0.025, Zn 0.358, B 0.008, Cu traces, pH 6.69, EC 0.59 $mS \cdot cm^{-1}$. In farm II, there were two independent water sources: well water and rain water. Water from own deep water intake contained (in $mg \cdot dm^{-3}$): N-NH_4 traces, N-NO_3 2.2, P 1.2, K 1.3, Ca 141.4, Mg 8.1, S-SO_4 98.7, Fe 0.678, Mn 0.322, Zn 0.034, B 0.020, Cu 0.002, pH 7.46, EC 0.934 $mS \cdot cm^{-1}$, and rain water (in $mg \cdot dm^{-3}$): N-NH_4 and N-NO_3 traces, P 0.2, K 0.2, Ca 5.0, Mg 0.1, S-SO_4 0.4, Fe 0.062, Mn 0.022, Zn 0.933, B 0.003, Cu 0.005, pH 6.46, EC 0.060 $mS \cdot cm^{-1}$. In the experiments, standard nutrient was used for sprinkling fertigation for anthurium grown in inert substrates (in $mg \cdot dm^{-3}$): N-NH_4 < 14.0, N-NO_3 105.0, P 31.0, K 176.0, Ca 60.0, Mg 24.0, S-SO_4 48.0, Fe 0.840, Mn 0.160, Zn 0.200, B 0.220, Cu 0.032, Mo 0.048, pH 5.5–5.7, EC 1.5–1.8 $mS \cdot cm^{-1}$ [after Komosa 2000]. 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 m^2, on the other hand, in winter, it was done 2–3 times applying 2–3 dm^3. About 20–30% of nutrient exuded from the root zone. In order to maintain an adequate air humidity and substrate moisture, the culture was sprinkled with rain water using microsprinklers.

Samples of nutrients and drainage waters were taken systematically between the 14th and the 16th day of the given month, in January, March, May, July, September and November in the years 2002, 2003 and 2004. Each time, the samples of nutrients were taken in the volume of 1 dm^3 from the emitters distributed on the sprinkling lines and from the drainage waters. Chemical analysis of nutrients and drainage waters was carried out directly in the studied solutions (without their stabilization) by the following methods: B – colorimetrically with curcumin, Fe, Mn, Zn, Cu – by atomic spectrometry absoption method (ASA) on Carl Zeiss Jena apparatus. Study results were statistically elaborated using 3-factorial analysis of variance. Conclusions were drawn at the significance level of $\alpha = 0.05$.

RESULTS

Iron content, similarly as the contents of manganese and zinc were significantly decreased in the drainage waters in relation to the nutrient exuded from the sprinklers (tab. 1). The decrease was on the average 51.9%. No significant differences were found in the content of iron between the studied farms and between the particular study years.

A significant effect was exerted by the sampling place on the content of manganese (tab. 2). This component was decreased in the drainage waters on the average by 65.5%, mainly because of fixation. Significant differences were shown in the retardation of manganese between the studied farms. Such differences were not found in the successive years of studies.

The content of zinc, similarly as the already mentioned manganese and iron, was significantly decreased in the drainage waters in relation to the applied nutrient (tab. 3). The studied component was decreased on the average by 45.2%. Significant differences were found between the years of studies.

An increase of copper content was found in the drainage waters (tab. 4). However, its concentration (on the average increased by 11.1%) was not statistically proven. On the other hand, statistical differences were found in the mean content of copper in the nutrients and in the drainage waters of the studied farms. Such differences were not found in the successive years of studies.

Statistically significant differences were found between the contents of boron in the nutrient solutions and in the drainage waters (tab. 5). The mean concentration was 16.6%. Differences in the content of this component were found in the successive years of studies. No significant effect was exerted by the particular farm on the content of boron in the nutrient solutions and in the drainage waters.

DISCUSSION

In our own studies, multidirectional changes have been found in the microelement contents in the drainage waters exuding from the root zone of plants in relation to the applied nutrient solution. Some components were decreased while others were concentrated. Manganese was the component which was the most intensively decreased in the drainage waters. Its decrease amounted to 65.5%. Iron content decreased in a lesser degree (by –51.9%), as well as zinc (by –45.2%). Components whose content increased (they became more concentrated) in the drainage waters included copper (by +11.1%) and boron (by +16.6%).

According to Komosa [2000], in anthurium grown in expanded clay, there follows a strong retardation of manganese and iron. Changes in the contents of nitrates, sulphates, zinc and chlorides are not significant. However, the author recorded a significant increase of the concentration of mangesium, calcium, boron and copper. The main reason of nutrient alcalization was the increase of the content of calcium and magnesium which exerted an effect on the creation of sparingly soluble calcium phosphates, magnesium and manganese. In order to limit the retardation of iron and manganese, it is purposeful to use their chelated forms. In turn, Kleiber and Komosa [2004] reported that in the growing of anthurium in expanded clay, copper, boron and sodium concentrated most intensively in the drainage waters in relation to the nutrient exuding from the sprinkler. The content of manganese, iron and zinc decreased. Similar tendencies of nutrient contents were confirmed by Savvas and Manos [1999] in their cultivation of roses.

Table 1. Differentiation of iron content in nutrient solution and drainage water (mg Fe·dm^{-3})
Tabela. 1. Zróżnicowanie zawartości żelaza w pożywkach i wodach drenarskich (mg Fe·dm^{-3})

Place of sampling Miejsce pobrania próby (A)	Farm – Gospodarstwo I (B)				Farm – Gospodarstwo II (B)				$\bar{x}$ (A)
	year – rok (C)				year – rok (C)				
	2002	2003	2004	$\bar{x}$ (A×B)	2002	2003	2004	$\bar{x}$ (A×B)	
Nutrient solution – Pożywka	1.49	1.58	1.34	1.47	1.42	2.57	1.23	1.74	1.60
Drainage water – Drenaż	0.79	0.88	0.92	0.86	0.70	0.70	0.65	0.68	0.77
$\bar{x}$ (B×C)	1.14	1.23	1.13	1.16	1.06	1.63	0.94	1.21	
$\bar{x}$ (B)	1.16				1.21				
$\bar{x}$ (C)	year – rok 2002 (I + II) 1.10			year – rok 2003 (I + II) 1.43			year – rok 2004 (I + II) 1.03		

n.d. – no differences; $LSD_{\alpha 0.05}$ for A = 0.39; $LSD_{\alpha 0.05}$ for B – n.d.; $LSD_{\alpha 0.05}$ for C – n.d.; $LSD_{\alpha 0.05}$ for A×B – n.d.; $LSD_{\alpha 0.05}$ for B×C – n.d.; $LSD_{\alpha 0.05}$ for A×B×C – n.d.
r.n. – różnice nieistotne; $NIR_{\alpha 0,05}$ dla A = 0,39; $NIR_{\alpha 0,05}$ dla B – r.n.; $NIR_{\alpha 0,05}$ dla C – r.n.; $NIR_{\alpha 0,05}$ dla A×B – r.n.; $NIR_{\alpha 0,05}$ dla B×C – r.n.; $NIR_{\alpha 0,05}$ dla A×B×C – r.n.

Table 2. Differentiation of manganese content in nutrient solution and drainage water (mg Mn·dm^{-3})
Tabela 2. Zróżnicowanie zawartości manganu w pożywkach i wodach drenarskich (mg Mn·dm^{-3})

Place of sampling Miejsce pobrania próby (A)	Farm – Gospodarstwo I (B)				Farm – Gospodarstwo II (B)				$\bar{x}$ (A)
	year – rok (C)				year – rok (C)				
	2002	2003	2004	$\bar{x}$ (A×B)	2002	2003	2004	$\bar{x}$ (A×B)	
Nutrient solution – Pożywka	0.27	0.28	0.34	0.29	0.28	0.32	0.24	0.28	0.29
Drainage water – Drenaż	0.04	0.03	0.07	0.05	0.13	0.15	0.17	0.15	0.10
$\bar{x}$ (B×C)	0.15	0.16	0.20	0.17	0.20	0.23	0.20	0.21	
$\bar{x}$ (B)	0.17				0.21				
$\bar{x}$ (C)	year – rok 2002 (I + II) 0.18			year – rok 2003 (I + II) 0.20			year – rok 2004 (I + II) 0.20		

n.d. – no differences; $LSD_{\alpha 0.05}$ for A = 0.04; $LSD_{\alpha 0.05}$ for B = 0.04; $LSD_{\alpha 0.05}$ for C – n.d.; $LSD_{\alpha 0.05}$ for A×B = 0.05; $LSD_{\alpha 0.05}$ for B×C – n.d.; $LSD_{\alpha 0.05}$ for A×B×C – n.d.
r.n. – różnice nieistotne; $NIR_{\alpha 0,05}$ dla A = 0,04; $NIR_{\alpha 0,05}$ dla B = 0,04; $NIR_{\alpha 0,05}$ dla C – r.n.; $NIR_{\alpha 0,05}$ dla A×B = 0,05; $NIR_{\alpha 0,05}$ dla B×C – r.n.; $NIR_{\alpha 0,05}$ dla A×B×C – r.n.

Table 3. Differentiation of zinc content in nutrient solution and drainage water (mg Zn·dm^{-3})
Tabela 3. Zróżnicowanie zawartości cynku w pożywkach i wodach drenarskich (mg Zn·dm^{-3})

Place of sampling Miejsce pobrania próby (A)	Farm – Gospodarstwo I (B) year rok (C)				Farm – Gospodarstwo II (B) year – rok (C)				$\bar{x}$ (A)
	2002	2003	2004	$\bar{x}$ (A×B)	2002	2003	2004	$\bar{x}$ (A×B)	
Nutrient solution – Pożywka	0.39	0.35	0.33	0.36	0.63	0.33	0.49	0.48	0.42
Drainage water – Drenaż	0.23	0.12	0.07	0.14	0.45	0.17	0.34	0.32	0.23
$\bar{x}$ (B×C)	0.31	0.24	0.20	0.25	0.54	0.25	0.41	0.40	
$\bar{x}$ (B)	0.25				0.40				
$\bar{x}$ (C)	year – rok 2002 (I + II) 0.42				year – rok 2003 (I + II) 0.24		year – rok 2004 (I + II) 0.31		

n.d. – no differences; LSD$_{\alpha 0.05}$ for A = 0.11; LSD$_{\alpha 0.05}$ for B = 0.11; LSD$_{\alpha 0.05}$ for C = 0.14; LSD$_{\alpha 0.05}$ for A×B – n.d.; LSD$_{\alpha 0.05}$ for B×C – n.d.; LSD$_{\alpha 0.05}$ for A×B×C – n.d.
r.n. – różnice nieistotne; NIR$_{\alpha 0,05}$ dla A = 0,11; NIR$_{\alpha 0,05}$ dla B = 0,11; NIR$_{\alpha 0,05}$ dla C = 0,14; NIR$_{\alpha 0,05}$ dla A×B – r.n.; NIR$_{\alpha 0,05}$ dla B×C – r.n.; NIR$_{\alpha 0,05}$ dla A×B×C – r.n.

Table 4. Differentiation of copper content in nutrient solution and drainage water (mg Cu·dm^{-3})
Tabela 4. Zróżnicowanie zawartości miedzi w pożywkach i wodach drenarskich (mg Cu·dm^{-3})

Place of sampling Miejsce pobrania próby (A)	Farm – Gospodarstwo I (B) year – rok (C)				Farm – Gospodarstwo II (B) year – rok (C)				$\bar{x}$ (A)
	2002	2003	2004	$\bar{x}$ (A×B)	2002	2003	2004	$\bar{x}$ (A×B)	
Nutrient solution – Pożywka	0.07	0.08	0.11	0.08	0.09	0.11	0.11	0.10	0.09
Drainage water – Drenaż	0.09	0.09	0.08	0.08	0.15	0.09	0.09	0.11	0.10
$\bar{x}$ (B×C)	0.08	0.08	0.09	0.08	0.12	0.10	0.10	0.11	
$\bar{x}$ (B)	0.08				0.11				
$\bar{x}$ (C)	year – rok 2002 (I +II) 0.10				year – rok 2003 (I +II) 0.09		year – rok 2004 (I + II) 0.10		

n.d. – no differences; LSD$_{\alpha 0.05}$ for A – n.d.; LSD$_{\alpha 0.05}$ for B = 0.02; LSD$_{\alpha 0.05}$ for C – n.d.; LSD$_{\alpha 0.05}$ for A×B – n.d.; LSD$_{\alpha 0.05}$ for B×C – n.d.; LSD$_{\alpha 0.05}$ for A×B×C – n.d.
r.n. – różnice nieistotne; NIR$_{\alpha 0,05}$ dla A – r.n.; NIR$_{\alpha 0,05}$ dla B = 0,02; NIR$_{\alpha 0,05}$ dla C – r.n.; NIR$_{\alpha 0,05}$ dla A×B – r.n.; NIR$_{\alpha 0,05}$ dla B×C – r.n.; NIR$_{\alpha 0,05}$ dla A×B×C – r.n.

Table 5. Differentiation of boron content in nutrient solution and drainage water ($mg\ B \cdot dm^{-3}$)
Tabela 5. Zróżnicowanie zawartości boru w pożywkach i wodach drenarskich ($mg\ B \cdot dm^{-3}$)

Place of sampling Miejsce pobrania próby (A)	Farm – Gospodarstwo I (B)				Farm – Gospodarstwo II (B)				$\bar{x}$ (A)
	year – rok (C)				year – rok (C)				
	2002	2003	2004	$\bar{x}$ (A×B)	2002	2003	2004	$\bar{x}$ (A×B)	
Nutrient solution – Pożywka	0.22	0.24	0.25	0,24	0,23	0,26	0,24	0,24	0,24
Drainage water – Drenaż	0.26	0.27	0.28	0,27	0,29	0,29	0,27	0,29	0,28
$\bar{x}$ (B×C)	0.24	0.26	0.26	0,25	0,26	0,28	0,26	0,26	
$\bar{x}$ (B)	0.25				0.26				
$\bar{x}$ (C)	year – rok 2002 (I + II) 0.25			year – rok 2003 (I + II) 0.27			year – rok 2004 (I + II) 0.26		

n.d. – no differences; $LSD_{\alpha 0.05}$ for A = 0.01; $LSD_{\alpha 0.05}$ for B – n.d.; $LSD_{\alpha 0.05}$ for C = 0.01; $LSD_{\alpha 0.05}$ for A×B – n.d.; $LSD_{\alpha 0.05}$ for B×C – n.d.; $LSD_{\alpha 0.05}$ for A×B×C – n.d.
r.n. – różnice nieistotne; $NIR_{\alpha 0,05}$ dla A = 0,01; $NIR_{\alpha 0,05}$ dla B – r.n.; $NIR_{\alpha 0,05}$ dla C = 0,01; $NIR_{\alpha 0,05}$ dla A×B – r.n.; $NIR_{\alpha 0,05}$ dla B×C – r.n.; $NIR_{\alpha 0,05}$ dla A×B×C – r.n.

Chohura [2000] reported that in the growing of plants in expanded clay, copper content increased most intensively, while the content of manganese showed the lowest increase. On the other hand, no concentration was shown by iron, zinc, phosphorus and manganese. When we compare the changes in the chemical composition of nutrient in the root zone of plants grown in rockwool with plants grown in expanded clay, one must stress that in rockwool, there is a higher concentration of nutritive components [Komosa and Breś 1996; Komosa 2000]. In the studies of the mentioned authors, the greatest increase was shown by the contents of sodium, calcium, potassium, nitrates, zinc, boron, copper, magnesium and chlorides. No increase was recorded in the contents of ammonium, phosphorus, iron and manganese.

On the basis of the obtained results of our own studies, we can present a series of microelements whose contents were decreased (in %) in relation to the nutrient supplied to the plants: Mn –66.5 < Fe –51.9 < Zn – 45.2. The concentration of components in the drainage waters showed the following range (in %): Cu +11.1 < B +16.6. Detailed changes in macroelement contents in the drainage waters in relation to the applied nutrient in the period of 3-year cultivation of anthurium are presented by Kleiber and Komosa [2006].

The presented series of decreases and concentrations of microelements in drainage waters in relation to the nutrient have a significant importance for the elaboration of horticultural plants fertilization conceptions in closed fertigation systems with nutrient recirculation. The quality of plant yield in closed systems is comparable with that obtained in open systems [Waechter-Kristensen et al. 1997]. The possibility of growing plants with the application of nutrient recirculation has been confirmed among others by Choi et al. [2001], Dhakal et al. [2005], Pergola et al. [1994], Raya et al. [2005]. It indicates the need to elaborate and to implement into horticultural practice this type of solutions in case of anthurium grown in expanded clay.

CONCLUSIONS

1. Multidirectional changes of microelement contents have been found in comparison with the nutrient supplied to plants.
2. The series of nutritive components concentration in drainage waters ranged in the following way (in%): Cu +11.1 < B +16.6, while the series of content decrease (in %) was: Mn –65.5 < Fe –51.9 < Zn –45.2.
3. The recognition of changes in the content of nutritive components in drainage waters in relation to the applied nutrient permits to elaborate a fertilization program.

REFERENCES

Anthura, 1998. Cultivation guide Anthurium. Anthura, 43.

Benoit F., Ceustermans N., 1995. Horticultural aspects ecobiological soilless growing methods. Acta Hort. 396, 11–19.

Chohura P., 2000. Zawartość składników pokarmowych w strefie korzeniowej, stan odżywienia i plonowanie pomidora szklarniowego w podłożach inertnych. Praca doktorska, 13.

Choi, S. Y., Lee, Y. B., Kim J. Y., 2001. Nutrient uptake, growth and yield of cucumber cultivated with different growing substrates under a closed and an open system. Acta Hort., 548, 543–550.

Dhakal U., Salokhe V., Tantau H., Max J., 2005. Development of a Greenhouse Nutrient Recycling System for Tomato Production in Humid Tropics. Agricultural Engineering International: the CIGR Ejournal. Manuscript BC 05 008. Vol. VII.

Jabłońska L., 2005. Development of Polish floriculture in the last 15 years. Proceedings from the National Conf. „Progress in the production of ornamental plants". 11–12.

Kleiber T., Komosa A., 2004. Dynamika zawartości składników pokarmowych w liściach oraz zmiany składu chemicznego pożywki w uprawie anturium. IX Konferencja dla Producentów Anturium, ISiK Skierniewice, 12–20.

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.

Komosa A., 2000. Analiza podłoża i roślin jako wskaźniki odżywiania anturium. V Konferencja dla Producentów Anturium, ISiK Skierniewice, 24–30.

Komosa A., Breś W., 1996. Recyrkulacyjny system zamknięty – nowa technologia nawożenia roślin ogrodniczych. Sprawozdanie z projektu badawczego. Katedra Nawożenia Roślin Ogrodniczych Akademii Rolniczej Poznań, 27–31.

Komosa A., Kleiber T., 2003. Anthurium – podłoża i odżywianie. VIII Konferencja dla Producentów Anturium, ISiK Skierniewice, 5–15.

Magen H., 1999. Recirculating nutrient solutions in greenhouse production. 9th IPI-ISSAS Regional Workshop, December 5–8, 1999, Haikoy, Hainan, PRC. Dostępne website: http://www.ipipotash.org/presentn/rnsigp.html.

Pergola G., Oggiano N., Serra F., Lupetti A., 1994. Water and nutrints absorption for growing *Oreopanax capitatus* in expanded clay with recirculated solution. Acta Hort. 361, 509–512.

Raya V., Díaz M.A., Mansito P., Socorro A.R., Cid, M.C., 2005. Recirculating nutritive solution in soilless culture of rose using alkaline water. Acta Hort. 697, 33–41.

Runia W.TH., Amsing J.J., 1996. Disinfestation of nematode infested recirculation water by ozone and activated hydrogen peroxide. Proc. of 9th International Congress on Soilless Culture St. Helier, Jersey 12–19.04.1996.

Runia W.TH., Amsing J.J., 2001. Disinfection of recirculation water from closed cultivation systems by heat treatment. Acta Hort. 548, 215–222.

Savvas D., Manos G. 1999. Automated composition control of nutrient solution in closed soilless culture systems. J. Agric. Eng. Res. 73, 29–33.

Treder W., 2000. Obieg zamknięty pożywki w uprawie anturium. V Konferencji dla Producentów Anturium, ISiK Skierniewice, 39–43.

Van Os E.A., 1988. Heat treatment for disinfecting draincoater technological and economic aspects. Proc. 7th Int. Congr. Soilless Culture. Flevohof, 353–359.

Van Os E.A., 2001a. New developments in recircualtion systems and disinfection methods for greenhouse crops. Hort. Eng. 16(2), 2–5.

Van Os E.A., 2001b. Design of sustainable hydroponic systems in relation to enviroment-friendly disinfection methods. Acta Hort. 548, 197–205.

Waechter-Kristensen B., Sundin P., Berkelmann-Loehnertz B., Wohlanka W., 1997. Management of microbial factors in the rhizosphere and nutrient solution of hydroponically grown tomato. Acta Hort. 450, 335–339.

Wohlanka W., 1990. Wasserentkeimung. Taspo – Praxis 18. 73–81.

ZRÓŻNICOWANIE ZAWARTOŚCI MIKROELEMENTÓW W POŻYWKACH I WODACH DRENARSKICH W UPRAWIE ANTURIUM (*Anthurium cultorum* Birdsey) W KERAMZYCIE

Streszczenie: Doświadczenia wegetacyjne przeprowadzono w latach 2002–2004 w dwóch specjalistycznych gospodarstwach ogrodniczych uprawiających najpopularniejsze w Polsce odmiany anturium (*Anthurium cultorum* Birdsey): 'Baron', 'Choco', 'Midori', 'Pistache', 'President' i 'Tropical'. Rośliny uprawiano w keramzycie, z zastosowaniem fertygacji kroplowej pożywką standardową dla anturium w podłożach inertnych (w mg·dm^{-3}): N-NH_4 < 14,0, N-NO_3 105,0, P 31,0, K 176,0, Ca 60,0, Mg 24,0, S-SO_4 48,0, Fe 0,840, Mn 0,160, Zn 0,200, B 0,220, Cu 0,032, Mo 0,048, pH 5,5–5,7, EC 1,5–1,8 mS·cm^{-1}. Badano zróżnicowanie zawartości mikroelementów w wodach drenarskich wyciekających z podłoża w stosunku do dostarczanej roślinom pożywki. Składnikiem, którego zawartość ulegała najsilniejszemu obniżeniu (w %) był mangan (-65.5), następnie żelazo (-51.9) i cynk (-45.2), wzrastała z kolei zawartość miedzi (+11.1) i boru (+16.6). Znajomość zmian zawartości składników pokarmowych w wodach drenarskich stanowi podstawę do opracowania i wdrażania do praktyki ogrodniczej układów zamkniętych z recyrkulacją pożywki.

Słowa kluczowe: anturium, mikroelementy, pożywka, wody drenarskie, keramzyt, system zamknięty

The research was supported by the State Committee for Scientific Research (KBN), grant No. 0381/P06/2004/26

Accepted for print – Zaakceptowano do druku: 19.03.2008