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

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Abstract. Vegetation studies were conducted from 2002 to 2004, in two leading farms, located near Poznan where have obtained optimum anthurium (*Anthurium cultorum* Birdsey) yielding. Plants were grown in expanded clay with the application of fertigation with a standard nutrient solution (in 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}. Significant changes of macroelement contents were found in drainage water in comparison to nutrient solution. The most decreased contents (in %) of macroelements were found for phosphorus (51.2), potassium (26.7) and nitrogen (15.4). The EC value showed a downward trend of about 9.5%. Nutrients which concentration increased in drainage water were (in %): calcium (27.9), sulphur (14.3) and magnesium (5.5). The knowledge of variations of nutrient concentrations in drainage waters is the basis for the practical application of closed fertilization systems with the recirculation of nutrient solution.

Key words: anthurium, fertigation, macroelements, expanded clay, nutrient solution, drainage water

INTRODUCTION

Poland is a major anthurium producer in Europe; in terms of the volume of production it ranks second after Holland [Jabłońska 2005]. The cultivation of this species in our country has been developing systematically [Mojsiej 2002]. Recently its yield has grown significantly thanks to the application of inert media and fertigation [Komosa and Kleiber 2003], as well as greenhouse climate control [Treder 2005]. The inert medium most commonly used in anthurium growing in Poland is expanded clay [Komosa

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and Kleiber 2003]. The nutrient solution used in fertigation undergoes diversified changes in the root medium. Based on studies conducted so far Kleiber and Komosa [2004] were of the opinion that some components become more concentrated (e.g. calcium, magnesium), while others are significantly diluted (e.g. phosphorus).

The aim of the study was to determine changes in macroelement contents in drainage water, during the 3-year experiments, for anthurium grown in expanded clay. It is essential for the optimization of plant nutrition, and at the same time it is the basis for the development of fertigation systems with nutrient solution recirculation.

MATERIAL AND METHODS

The vegetation experiments were carried out in the years 2002–2004 in 2 farms specializing in anthurium growing, located in the vicinity of Poznań. Greenhouse facilities were equipped with the following systems: underplant sprinkling, shading, energy-saving curtains, climate control and monitoring. Six cultivars of anthurium *(Anthurium cultorum* Birdsey) were tested: 'Baron', 'Choco', 'Midori', 'Pistache', 'President' and 'Tropical'. Plants were grown in expanded clay using dripping line fertigation. Research was started on 15.01.2002 (2 years old plants), and finished on 30.11.2004 (5 years old). One cultural bed has dimension 1.2 × 46.0 m (55.2 m^2). There were growing 14 plants·m^2, it means 772 plants on the bed with one cultivar. During the experiment conducting the number of flowers was counted and appearance of leaves and flowers was observed.

Chemical analyses of drainage water were conducted prior to the preparation of nutrient solutions. In farm no. 1 water from municipal water mains was used, with the following chemical composition (in mg·dm^{-3}): NH_4 trace amounts, 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 trace amounts, pH 6.69, EC 0.59 mS·cm^{-1}. In farm no. 2 there were two sources of water: well and rainwater. Well water contained on average (in mg·dm^{-3}): N-NH_4 trace amounts, 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·cm^{-1}. Applied rainwater had the following chemical composition (in mg·dm^{-3}): N-NH_4 and N-NO_3 trace amounts, 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·cm^{-1}.

In the experiments the applied medium was a standard nutrient solution for anthurium growing in inert media (in 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} [Komosa 2000]. The frequency and duration of irrigation were dependent on the season of the year. In the summer, in the period of enhanced water and nutritional needs fertigation was applied 6–8 times, supplying 4–5 dm^3 nutrient solution·m^2, while in the winter it was 2–3 times, applying 2–3 dm^3. Approximately 20% nutrient solution was drained from the root medium. In order to maintain appropriate humidity and substrate moisture content, the cultivation was sprinkled with rainwater using microsprinklers.

Samples of nutrient solutions and drainage water were collected every 2 months, between the 14th and 16th day of a given month, in January, March, May, July, September and November in the years 2002–2004. Nutrient solution samples of 1 dm^3 were collected directly at dripping lines, while from the root medium drained drainage water was collected. Chemical analysis of nutrient solution and drainage water was conducted directly in the analyzed solutions (without their stabilization) using the following methods: $N\text{-}NH_4$ and $N\text{-}NO_3$ – by distillation according to Bremner as modified by Starck [Breś et al. 2003]; P – colorimetrically with ammonium vanadium molybdate; K, Ca, Na – by flame photometry; Cl – by nephelometry with $AgNO_3$; $S\text{-}SO_4$ – by nephelometry with $BaCl_2$; B – by colorimetry with curcumin; Mg, Fe, Mn, Zn, Cu – by atomic absorption spectrometry (AAS); EC – by conductometry; pH – by potentiometry. The analysis of variance was conducted, describing the relation between the applied nutrient solution and drainage water. Inference was carried out at the significance level $\alpha = 0.05$.

RESULTS

The yield of plant in the aspect of quantity and quality was on the optimum level. There was no observed any symptoms of deficiency or excess of nutrients.

A significant differences were shown for electrical conductivity (EC) between the nutrient solution supplied to plants and drainage water (tab. 1). A reduction of EC in drainage water was on average 9.5% in comparison to the supplied nutrient solution. This could have been caused by the application of underplant misting, increasing humidity and balancing substrate moisture content. Moreover, significant differences were also found between mean EC values of nutrient solutions and drainage water in successive years of the study and between the mean electrical conductivity of nutrient solutions and drainage water from the 3 years of the experiments within the analyzed farms. No significant differences were found in EC of nutrient solutions in farm no. 1 (1.43 $mS \cdot cm^{-1}$) and no. 2 (1.53 $mS \cdot cm^{-1}$).

Table 1. Differentiation of EC value in nutrient solution and drainage water ($mS \cdot cm^{-1}$)
Tabela 1. Zróżnicowanie EC pożywek i wód drenarskich ($mS \cdot cm^{-1}$)

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	1.36	1.42	1.49	1.43	1.48	1.76	1.36	1.53	1.48
Drainage water Wody drenarskie	1.22	1.19	1.32	1.24	1.26	1.54	1.51	1.44	1.34
$\bar{x}$ (B×C)	1.29	1.31	1.41	1.33	1.37	1.65	1.43	1.48	
$\bar{x}$ (B)	1.33				1.48				
$\bar{x}$ (C)	Year – Rok 2002 (I+II) 1.33			Year – Rok 2003 (I+II) 1.48			Year – Rok 2004 (I+II) 1.42		

n.d. – no differences; $LSD_{\alpha\ 0.05}$ for A = 0.10; $LSD_{\alpha\ 0.05}$ for B = 0.10; $LSD_{\alpha\ 0.05}$ for C = 0.11; $LSD_{\alpha\ 0.05}$ for A×B – n.d.; $LSD_{\alpha\ 0.05}$ for B×C = 0.16; $LSD_{\alpha\ 0.05}$ for A×B×C – n.d.
r.n. – różnice nieistotne, $NIR_{\alpha\ 0,05}$ dla A = 0,10; $NIR_{\alpha\ 0,05}$ dla B = 0,10; $NIR_{\alpha\ 0,05}$ dla C = 0,11; $NIR_{\alpha\ 0,05}$ dla A×B – r.n.; $NIR_{\alpha\ 0,05}$ dla B×C = 0,16; $NIR_{\alpha\ 0,05}$ dla A×B×C – r.n.

Opposite trends were shown for changes in pH values of drainage water in both farms (tab. 2). In farm no. 1 alkalization of drainage water was observed, while in farm no. 2 a decrease of pH values was recorded in the applied nutrient solution. Moreover, significant differences were found for mean pH values of nutrient solutions and drainage water in analyzed farms. A higher pH value was recorded in farm no. 1 (pH 6.30) in comparison to farm no. 2 (pH 5.55). No such differences were recorded for pH of nutrient solutions emited from dripping lines in the analyzed farms and between successive years of the study.

Table 2 Differentiation of pH value in nutrient solution and drainage water
Tabela 2. Zróżnicowanie pH pożywek i wód drenarskich

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	6.00	6.30	6.28	6.15	5.54	6.00	5.42	5.60	5.80
Drainage water Wody drenarskie	6.22	6.70	6.70	6.52	5.15	6.15	5.80	5.51	5.80
$\bar{x}$ (B×C)	6.10	6.52	6.40	6.30	5.30	6.07	5.52	5.55	
$\bar{x}$ (B)	6.30				5.55				
$\bar{x}$ (C)	Year – Rok 2002 (I+II) 5.54			Year – Rok 2003 (I+II) 6.22			Year – Rok 2004 (I+II) 5.80		

n.d. – no differences; $LSD_{\alpha\ 0.05}$ for A – n.d.; $LSD_{\alpha\ 0.05}$ for B – 0.01; $LSD_{\alpha\ 0.05}$ 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 – 0,01; $NIR_{\alpha\ 0,05}$ 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 3. Differentiation of nitrogen nitrate contents in nutrient solution and drainage water ($mg\ N\text{-}NO_3 \cdot dm^{-3}$)
Tabela 3. Zróżnicowanie zawartości azotu azotanowego w pożywkach i wodach drenarskich ($mg\ N\text{-}NO_3 \cdot dm^{-3}$)

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	101.2	97.5	115.0	104.5	99.1	105.5	95.1	99.9	102.2
Drainage water Wody drenarskie	84.5	78.1	89.8	84.1	90.4	83.9	92.2	88.8	86.5
$\bar{x}$ (B×C)	92.8	87.8	102.4	94.3	94.7	94.7	93.6	94.3	
$\bar{x}$ (B)	94.3				94.3				
$\bar{x}$ (C)	Year – Rok 2002 (I+II) 93.8			Year – Rok 2003 (I+II) 91.2			Year – Rok 2004 (I+II) 98.0		

n.d. – no differences; $LSD_{\alpha\ 0.05}$ for A = 7.8; $LSD_{\alpha\ 0.05}$ 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 = 7,8; $NIR_{\alpha\ 0,05}$ 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.

A significant decrease was shown for nitrate contents in drainage water – on average by 15.4% (tab. 3). Nitrate content in nutrient solutions in both farms was similar. No differences were observed between the years of the study.

Phosphorus turned out to decrease more considerably than it was found for nitrogen (tab. 4). Contents of this element decreased in drainage water on average by 51.2%. However, no significant differences were shown between farms or years of the study.

Table 4. Differentiation of phosphorus content in nutrient solution and drainage water (mg P·dm^{-3})
Tabela 4. Zróżnicowanie zawartości fosforu w pożywkach i wodach drenarskich (mg P·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	46.9	43.4	52.1	47.5	41.6	41.8	27.4	36.9	42.2
Drainage water Wody drenarskie	22.9	12.2	17.6	17.6	21.7	24.7	24.4	23.6	20.6
$\bar{x}$ (B×C)	34.9	27.8	34.9	32.5	31.7	33.2	25.9	30.3	
$\bar{x}$ (B)	32.5				30.3				
$\bar{x}$ (C)	Year – Rok 2002 (I+II) 33.3			Year – Rok 2003 (I+II) 30.5			Year – Rok 2004 (I+II) 30.4		

n.d. – no differences; $LSD_{\alpha\ 0.05}$ for A = 3.0; $LSD_{\alpha\ 0.05}$ for B – n.d.; $LSD_{\alpha\ 0.05}$ for C – n.d.; $LSD_{\alpha\ 0.05}$ for A×B = 4.2; $LSD_{\alpha\ 0.05}$ for B×C = 5.2; $LSD_{\alpha\ 0.05}$ for A×B×C = 7.3.
r.n. – różnice nieistotne; $NIR_{\alpha\ 0,05}$ dla A = 3,0; $NIR_{\alpha\ 0,05}$ dla B – r.n.; $NIR_{\alpha\ 0,05}$ dla C – r.n.; $NIR_{\alpha\ 0,05}$ dla A×B = 4,2; $NIR_{\alpha\ 0,05}$ dla B×C = 5,2; $NIR_{\alpha\ 0,05}$ dla A×B×C = 7,3.

Table 5. Differentiation of potassium content in nutrient solution and drainage water (mg K·dm^{-3})
Tabela 5. Zróżnicowanie zawartości potasu w pożywkach i wodach drenarskich (mg K·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	187.0	198.7	227.4	204.4	202.3	207.1	146.8	185.4	194.9
Drainage water Wody drenarskie	143.2	132.8	156.7	144.2	136.8	142.7	144.7	141.4	142.8
$\bar{x}$ (B×C)	165.1	165.8	192.1	174.3	169.6	174.9	145.8	163.4	
$\bar{x}$ (B)	174.3				163.4				
$\bar{x}$ (C)	Year – Rok 2002 (I+II) 167.4			Year – Rok 2003 (I+II) 170.4			Year – Rok 2004 (I+II) 168.9		

n.d. – no differences; $LSD_{\alpha\ 0.05}$ for A = 14.4; $LSD_{\alpha\ 0.05}$ 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 = 24.9; $LSD_{\alpha\ 0.05}$ for A×B×C = 35.2.
r.n. – różnice nieistotne; $NIR_{\alpha\ 0,05}$ dla A = 14,4; $NIR_{\alpha\ 0,05}$ 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 = 24,9; $NIR_{\alpha\ 0,05}$ dla A×B×C = 35,2.

Contents of potassium, similarly to nitrogen and phosphorus, decreased significantly in drainage water in comparison to the nutrient solution dripping from dripping lines (tab. 5). The mean decrease was 26.7%. Nutrient solutions dripping from dripping lines in both farms had similar contents of this element. Statistical analysis did not show significant differences between years of the study.

Table 6. Differentiation of calcium content in nutrient solution and drainage water (mg Ca·dm^{-3})
Tabela 6. Zróżnicowanie zawartości wapnia w pożywkach i wodach drenarskich (mg Ca·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	45.3	41.5	38.5	41.7	71.0	93.9	83.2	82.7	62.2
Drainage water Wody drenarskie	53.7	58.1	62.1	57.9	100.3	128.7	114.8	114.6	86.3
$\bar{x}$ (B×C)	49.5	49.8	50.3	49.8	85.7	111.3	99.0	98.7	
$\bar{x}$ (B)	49.8				98.7				
$\bar{x}$ (C)	Year – Rok 2002 (I+II) 67.6			Year – Rok 2003 (I+II) 80.5			Year – Rok 2004 (I+II) 74.6		

n.d. – no differences; $LSD_{\alpha\ 0.05}$ for A = 14.0; $LSD_{\alpha\ 0.05}$ for B = 14.0; $LSD_{\alpha\ 0.05}$ 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 = 14,0; $NIR_{\alpha\ 0,05}$ dla B = 14,0; $NIR_{\alpha\ 0,05}$ 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 7. Differentiation of magnesium content in nutrient solution and drainage water (mg Mg·dm^{-3})
Tabela 7. Zróżnicowanie zawartości magnezu w pożywkach i wodach drenarskich (mg Mg·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	30.7	34.2	37.0	34.0	31.7	34.0	29.5	31.7	32.8
Drainage water Wody drenarskie	33.6	40.4	39.5	37.8	31.2	32.4	30.3	31.3	34.6
$\bar{x}$ (B×C)	32.2	37.3	38.3	35.9	31.5	33.2	29.9	31.5	
$\bar{x}$ (B)	35.9				31.5				
$\bar{x}$ (C)	Year – Rok 2002 (I+II) 31.8			Year – Rok 2003 (I+II) 35.2			Year – Rok 2004 (I+II) 34.1		

n.d. – no differences; $LSD_{\alpha\ 0.05}$ for A – n.d.; $LSD_{\alpha\ 0.05}$ for B = 3.1; $LSD_{\alpha\ 0.05}$ 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 = 3,1; $NIR_{\alpha\ 0,05}$ 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.

In contrast to nitrogen, phosphorus and potassium, a significant increasing of calcium content was recorded in drainage water (tab. 6) – on average it amounted to 27.9%. Significant differences were shown between the analyzed farms in calcium content in nutrient solutions. A higher calcium content in farm no. 2 was the result of a higher content of this element in water used in fertigation.

An increase (on average by 5.5%) was recorded for magnesium content in drainage water in relation to the nutrient solution emited from dripping lines (tab. 7). However, this difference was not statistically significant. Moreover, no significant differences were shown between farm nos. 1 and 2 in terms of magnesium content in nutrient solutions.

Table 8. Differentiation of sulfur sulfate content in nutrient solution and drainage water (mg $S\text{-}SO_4 \cdot dm^{-3}$)
Tabela 8. Zróżnicowanie zawartości siarki siarczanowej w pożywkach i wodach drenarskich (mg $S\text{-}SO_4 \cdot dm^{-3}$)

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	26.5	56.4	47.5	43.5	71.6	107.4	72.3	83.7	63.6
Drainage water Wody drenarskie	29.1	54.0	60.3	47.8	80.1	114.2	98.5	97.6	72.7
$\bar{x}$ (B×C)	27.8	55.2	53.9	45.6	75.9	110.8	85.4	90.7	
$\bar{x}$ (B)	45.6				90.7				
$\bar{x}$ (C)	Year – Rok 2002 (I+II) 51.8			Year – Rok 2003 (I+II) 83.0			Year – Rok 2004 (I+II) 69.7		

n.d. – no differences; $LSD_{\alpha\ 0.05}$ for A – n.d.; $LSD_{\alpha\ 0.05}$ for B = 9.8; $LSD_{\alpha\ 0.05}$ for C = 12.0; $LSD_{\alpha\ 0.05}$ 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 = 9,8; $NIR_{\alpha\ 0,05}$ dla C = 12,0; $NIR_{\alpha\ 0,05}$ dla A×B – r.n.; $NIR_{\alpha\ 0,05}$ dla B×C – r.n.; $NIR_{\alpha\ 0,05}$ dla A×B×C – r.n.

No significant variation was shown in sulfate content in nutrient solutions and drainage water, although a distinct upward trend was found. The mean increase in sulfate content was 14.3% (tab. 8). Marked differences were observed between the years of the study and the farms.

DISCUSSION

Conducted investigations showed significant variation in contents of macroelements in drainage water in relation to applied nutrient solutions. Contents of phosphorus, nitrogen and potassium decreased, while those of calcium, magnesium and sulfates increased, primarily as a result of increasing concentration and selective ion uptake. Phosphorus content decreased most considerably, mainly as a result of retrogradation (transition into sparingly soluble compounds). It decreased on average by 51.2%. According to Kleiber and Komosa [2004] the retrogradation of this element is an advantageous phenomenon. Contents of potassium (26.7%) and nitrogen (15.4%) were reduced less significantly.

An increase in contents of calcium, magnesium and sulfates in drainage water may be the effect of many processes. The most important in this respect include the water transpiration process dominating over the rate of uptake of some nutrients and selective ion uptake. According to Komosa [2000], increasing the content of calcium and magnesium may be a significant cause of alkalization of the nutrient solution in anthurium growing on expanded clay. This process may also result from partial leaching of these components from expanded clay. Meinken [1997] was of the opinion that expanded clay exhibits slight sorption properties, which to a certain degree may protect the plant against damage, e.g. as a result of the application of a too concentrated nutrient solution in fertilization.

As a consequence of a bigger lowering of contents of nitrogen, phosphorus and potassium than the increase in contents of calcium, magnesium and sulfates electrical conductivity (EC) in drainage water was observed to decrease in comparison to the nutrient solution supplied to plants (on average by 9.5%). A reduction of contents of some components may also be caused by the dilution of drainage water as a result of the application of underplant sprinkling, which improved substrate moisture content conditions. The dilution of drainage water was confirmed in the study by Kleiber and Komosa [2004]. In turn, Őzçelik and Őzkan [2002] showed the effect of increased concentration of the nutrient solution in anthurium growing, conducted in the closed system with recirculation. According to those authors, that was caused by transpiration dominating over nutrient uptake and selective ion uptake by plants.

The concentration series (increasing concentration) of nutrients was determined in drainage water in relation to the nutrient solution supplied to plants, amounting to (in %): Ca 27.9 > S-SO_4 14.3 > Mg 5.5. The decreasing series was as follows: P 51.2 > K 26.7 > N 15.4, respectively.

Results of this study confirm the experiments of Kleiber and Komosa [2004], according to which the elements, which concentrations become most increased in drainage water in anthurium growing, include Ca, S-SO_4, Cu, B and Na. In turn, Chohura [2000] claimed that in cultivation of plants in expanded clay copper content increases most, while that of magnesium – the least. Iron, zinc, phosphorus and manganese did not increase in concentration.

The presented series of lowering or increasing concentrations of macroelements in drainage water are essential for the development of the anthurium growing method in closed systems with medium recirculation. Waechter-Kristensen et al. [1997] reported that the quality of plant yield in closed systems is comparable to that obtained from cultivation in open systems. Systems with medium recirculation have several other advantages, such as e.g. economical management of fertilizers and water, their more effective utilization and reduced pollution of the natural environment [Van Os 2001]. The above mentioned advantages were confirmed by Komosa [2004]. That author also emphasized the need to conduct research on the efficiency of the application of aeroponic systems in the closed system with medium recirculation, especially in case of epiphytes (e.g. anthurium), i.e. plants absorbing water and nutrients by aerial roots.

The investigations conducted in this study showed a high tolerance of anthurium to contents of calcium and sulfates (93.9 mg Ca·dm^{-3} and 107.4 mg S-SO_4·dm^{-3}, respectively). In nutrient solutions recommended for anthurium fertigation content of calcium is 60.0 mg·dm^{-3}, while that of sulfates is 48.0 mg·dm^{-3} [Breś et al. 2003].

So far numerous authors [Nowosielski 1988, Breś et al. 2003, Sonneveld and Voogt 1993] have considered anthurium a plant especially sensitive to salinity. This study showed high tolerance of these plants to EC, amounting up to 1.76 mS·cm^{-1}. No symptoms of nutrients excess or their toxicity were observed on plants, and their yield was correct. prawidłowe. Analyzed anthurium cultivars may be included in the group of plants with medium sensitivity to salt concentrations in substrate.

CONCLUSIONS

1. In drainage water diversified changes were recorded in nutrient contents in comparison to the nutrient solution supplied to plants. Contents of phosphorus, potassium and nitrogen decreased, while those of calcium, magnesium and sulfates increased.

2. The series of increasing concentration of nutrients in drainage water was as follows (in %): Ca (27.9) > S-SO_4 (14.3) > Mg (5.5), while the series of decreasing contents was (%): P (51.2) > K (26.7) > N-NO_3 (15.4), respectively.

3. No negative response was shown in anthurium cultivars 'Baron', 'Choco', 'Midori', 'Pistache', 'President' and 'Tropical' to high contents of calcium (93.9 mg $Ca \cdot dm^{-3}$) and sulfates (107.4 mg S-$SO_4 \cdot dm^{-3}$) in the nutrient solution. Analyzed cultivars may be considered to have medium sensitivity to salinity.

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

Streszczenie. Doświadczenia wegetacyjne przeprowadzono w latach 2002–2004 w dwóch wyspecjalizowanych gospodarstwach ogrodniczych położonych w okolicach Poznania, w których uzyskiwano optymalne plonowanie anturium *(Anthurium cultorum* Birdsey). Rośliny uprawiano w keramzycie, z zastosowaniem standardowej pożywki stosowanej w fertygacji kroplowej (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}. Stwierdzono zróżnicowanie zawartość składników w wodach drenarskich wyciekających z podłoża w stosunku do pożywki. Składnikiem, którego stężenie w wodach drenarskich obniżało się najsilniej, był fosfor (51,2%), następnie potas (26,7%) i azot (15,4%). Stwierdzono również obniżanie się przewodności elektrolitycznej (EC) – średnio o 9,5%. Składnikami, których zawartość w wodach drenarskich wzrastała były: wapń (27,9%), siarczany (14,3%) i magnez (5,5%). Znajomość zróżnicowania zawartości składników w wodach drenarskich stanowi podstawę do wdrażania w praktyce zamkniętych układów nawożenia z recyrkulacją pożywki.

Słowa kluczowe: anturium, fertygacja, makroelementy, keramzyt, pożywka, wody drenarskie

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