ACTA Acta Sci. Pol., Hortorum Cultus 9(3) 2010, 95-104

Phalaenopsis CULTIVATION IN DIFFERENT MEDIA. PART II. NUTRIENTS AND CHLOROPHYLL CONCENTRATION IN LEAVES AND ROOTS

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Abstract. Effect of growing media on macro- and microelements, as well as on chlorophyll concentration in *Phalaenopsis* orchids were investigated. In the years 2006–2008, an experiment on *Phalaenopsis* orchids cultivation was carried out. The plants were planted into New Zealand sphagnum moss, mixture of expanded clay pellets and New Zealand sphagnum moss (v:v = 1:1), or into expanded clay pellets only. Orchids were grown in translucent plastic pots. Total macro and micro elements concentration in leaves and roots were determined. Furthermore concentrations of chlorophyll a and chlorophyll b in leaves and roots were measured. Growing media exert a significant influence on the nutritional status of *Phalaenopsis* orchids. The highest concentration of magnesium, iron and copper was found in plants grown in expanded clay, less in orchids grown in the mixed medium and the least in plants grown in sphagnum moss. A higher concentration of nitrogen, phosphorus, potassium, calcium and manganese was found in leaves. Inversely, in roots, there was a higher concentration of magnesium, iron and zinc. Growing media did not affect chlorophyll concentration in leaves and roots of *Phalaenopsis*.

Key words: orchids, nutritional status, tissue analysis

INTRODUCTION

Phalaenopsis orchids have become more and more popular pot plants. The orchid cut-flower trade is also increasing steadily. Many publications presented the cultivation methods of these plants, however, they deal mainly with the usefulness of the applied media and with the effect of temperature and light on the growth and flowering of orchids. Only few publications deal with the mineral nutrition of these plants and particularly with the macro- and microelements concentration in orchid leaves and roots being responsible for the nutritional status of plants. The objective of the presented paper was the determination of macroelements, microelements and chlorophyll concentration in

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Phalaenopsis orchids grown in different media. The influence of media on the quality of these plants was presented in the paper published by Trelka et al. [2010].

MATERIAL AND METHODS

Seedlings (*ex in vitro*) of two *Phalaenopsis* cultivars 'Zagreb®' and 'Springfield®' were planted on 26.07.2006 into containers filled with different media: New Zealand sphagnum moss, mixture of expanded clay pellets (8–16 mm granulation) plus New Zealand moss (v:v = 1:1) and expanded clay pellets (8–16 mm granulation). Originally, orchids were grown in translucent plastic pots of 7 cm diameter (8,5 months). During cultivation plants were fertilized with nutrient solution (once a week 50 cm^3; chemical composition of solution is shown below). On the 15 March 2007 plants were transferred to translucent plastic pots of 11 cm diameter and 0.5 dm^3 capacity. and then, they were transferred to translucent plastic pots of 11 cm diameter and 0.5 dm^3 capacity. Orchids were additionally nourished, once in 2 weeks, with 100 ml of nutrient per plant which consisted of: N-NH_4 – 100; N-NO_3 – 120; P – 40, K – 230; Ca – 30; Mg – 20; Na – 10; Cl – 20; S-SO_4 – 40; Fe – 0.8; Mn – 0.4; Zn – 0.2; Cu – 0.07; B – 0.2 mg.dm^3; pH 6.6; EC – 1.8 mS· cm^{-1}. In December 2008, when the third flower opened in the inflorescence, the second well developed leaves and green root samples were collected. The total contents of macro- and microeleeements were determined in dried plant material after its mineralization in strong acids. The levels of K, Ca, Mg, Na, Fe, Mn, Zn and Cu were determined using atomic absorption spectrophotometer. For the analysis of P and B, spectrophotometric methods were applied. Total N was determined by micro-Kjeldahl procedure. Results were subjected to analysis of variance using Duncan's test at the significance level of $\alpha = 0.05$. Moreover, the concentrations of chlorophyll-a and chlorophyll-b in leaves and roots were spectrophotometrically determined. Extraction of pigments in dimethyl sulfooxide (DMSO) was applied [Hiscox and Israelstam 1979]. Calculation was carried out according to the modified Arnon's formulas presented in the paper by Wellburn [1994], results are given in milligrams per 1 g of fresh matter.

RESULTS AND DISCUSSION

Phalaenopsis orchids are grown in translucent plastic pots. Plants have three kinds of roots: aerial, prostrate epiphytic and substrate roots. The prostrate epiphytic root tips may be either green or purple and, like leaf pigmentation, they appear to be governed by a simple, probably single-allele inheritance pattern. Substrate roots usually lack pigment in the root tips [Christenson 2001].

In the presented experiments, leaves and green roots from medium were taken for chemical analyses. It was found that the concentrations of macro- and microelements in *Phalenopsis* organs are not equal (tab. 1–4). The concentration of nitrogen, phosphorus, potassium, calcium and manganese was higher in leaves, than in roots. Inversely, in roots, there was a higher concentration of magnesium, iron and zinc. Only sodium concentration in leaves and root tissues was similar. The presented results referred to both

Table 1. Macroelements concentration in leaves and roots of *Phalaneopsis* 'Springfield' grown in different media (% d.m.)
Tabela 1. Zawartość makroelementów w liściach i korzeniach *Phalaneopsis* 'Springfield' uprawianych w różnych podłożach (% s.m.)

	Medium – Podłoże (A)	Leaves – Liście (B)	Roots – Korzenie (B)	Mean A Średnia A
N	Sphagnum moss Mech torfowiec	1.61c	1.63c	1.62c
	Expanded clay pellets + sphagnum moss Keramzyt + mech torfowiec	1.52b	1.47b	1.49b
	Expanded clay pellets Keramzyt	1.47b	1.02a	1.24a
	Mean for B – Średnia dla B	1.53b	1.37a	
P	Sphagnum moss Mech torfowiec	0.28f	0.23e	0.25c
	Expanded clay pellets + sphagnum moss Keramzyt + mech torfowiec	0.19d	0.13b	0.16b
	Expanded clay pellets Keramzyt	0.16c	0.12a	0.14a
	Mean for B – Średnia dla B	0.21b	0.16a	
K	Sphagnum moss Mech torfowiec	4.63e	1.15a	2.89a
	Expanded clay pellets + sphagnum moss Keramzyt + mech torfowiec	5.38f	1.41b	3.40c
	Expanded clay pellets Keramzyt	4.32d	1.76c	3.04b
	Mean for B – Średnia dla B	4.78b	1.43a	
Ca	Sphagnum moss Mech torfowiec	3.54f	1.21b	2.38b
	Expanded clay pellets + sphagnum moss Keramzyt + mech torfowiec	3.31e	0.79a	2.05a
	Expanded clay pellets Keramzyt	2.76d	1.72c	2.24b
	Średnia dla B – Mean for B	3.20b	1.24a	
Mg	Sphagnum moss Mech torfowiec	0.69a	1.21d	0.95a
	Expanded clay pellets + sphagnum moss Keramzyt + mech torfowiec	0.77b	1.20d	0.99b
	Expanded clay pellets Keramzyt	0.83c	1.22d	1.03c
	Mean for B – Średnia dla B	0.76a	1.21b	

orchid cultivars. Slightly different effects were obtained by Poole and Sheehan [1982], who found in *Phalenopsis* leaves, grown in hydroponic culture, a higher content of K, Ca, Mn and B than in roots. However, more N, Mg, Fe and Zn was found in the roots. Kubota and Yoneda [1993] analyzed nutrient concentrations in different parts of *Phalaenopsis* during orchid cultivation (i.e. from flower stalks initiation to the full flowering stage). The total concentration of elements in both organs was variable, but in the full flowering stage, in leaves, there was distinctly more of N, K, Ca and Mg than in the roots, while the concentration of P was significantly higher in roots. Based on our research and the literature quoted one can be concluded, that concentration of potassium, calcium and manganese in the leaves is usually higher than in the roots. In case of roots, one can expect higher concentration of iron, zinc and probably of magnesium. Much more difficult is to assess nutritional status of plants. The discrepancies are too wide, they reach even 100%. For example, according to Poole and Sheehan [1982], magnesium concentration in roots of *Phalaenopsis* grown in hydroponic culture is contained in the range of 0.57–0.71, while in our own studies, the range was from 1.2 to 1.22% d.m. In leaves of mature plants cultivated in sphagnum moss, the concentration of magnesium determined by Kubota and Yoneda [1993] was in the range of 1.6–1.75, while in our experiment, it was 0.69–1.0% d.m.

Table 2. Microelements and sodium concentration in leaves and roots of *Phalaneopsis* 'Springfield' grown in different media (mg·kg^{-1} d.m.)
Tabela 2. Zawartość mikroelementów i sodu w liściach i korzeniach *Phalaneopsis* 'Springfield' uprawianych w różnych podłożach (mg·kg^{-1} d.m.)

	Medium – Podłoże (A)	Leaves – Liście (B)	Roots – Korzenie (B)	Medium A Średnia A
Fe	Sphagnum moss Mech torfowiec	44.33a	54.99b	49.66a
	Expanded clay pellets + sphagnum moss Keramzyt + mech torfowiec	43.59a	390.92c	217.26b
	Expanded clay pellets Keramzyt	52.63b	391.43c	222.03c
	Mean for B – Średnia dla B	46.85a	279.11b	
Zn	Sphagnum moss Mech torfowiec	32.42c	131.82e	82.12c
	Expanded clay pellets + sphagnum moss Keramzyt + mech torfowiec	23.64b	55.42d	39.53b
	Expanded clay pellets Keramzyt	18.28a	31.17c	24.73a
	Mean for B – Średnia dla B	24.78a	72.80b	
Cu	Sphagnum moss Mech torfowiec	38.37b	21.82a	30.10a
	Expanded clay pellets + sphagnum moss Keramzyt + mech torfowiec	47.21d	38.31b	42.76b
	Expanded clay pellets Keramzyt	56.09e	43.01c	49.55c
	Mean for B – Średnia dla B	47.22b	34.38a	
Mn	Sphagnum moss Mech torfowiec	249.16f	23.39a	136.28c
	Expanded clay pellets + sphagnum moss Keramzyt + mech torfowiec	102.82e	33.27b	68.04b
	Expanded clay pellets Keramzyt	63.46d	37.57c	50.52a
	Mean for B – Średnia dla B	138.48b	31.41a	
Na	Sphagnum moss Mech torfowiec	1.14a	0.79a	0.97a
	Expanded clay pellets + sphagnum moss Keramzyt + mech torfowiec	0.75a	0.85a	0.80a
	Expanded clay pellets Keramzyt	1.01a	0.80a	0.90a
	Mean for B – Średnia dla B	0.97a	0.81a	

Table 3. Macroelements concentration in leaves and roots of *Phalaneopsis* 'Zagreb' grown in different media (% d.m.)
Tabela 3. Zawartość makroelementów w liściach i korzeniach *Phalaneopsis* 'Zagreb' uprawianych w różnych podłożach (% s.m.)

	Medium – Podłoże (A)	Leaves – Liście (B)	Roots – Korzenie (B)	Mean A Średnia A
N	Sphagnum moss Mech torfowiec	1.41b	1.46bc	1.43b
	Expanded clay pellets + sphagnum moss Keramzyt + mech torfowiec	1.64d	1.54cd	1.59c
	Expanded clay pellets Keramzyt	1.19a	1.16a	1.18a
	Mean for B – Średnia dla B	1.41a	1.39a	
P	Sphagnum moss Mech torfowiec	0.20a	0.19a	0.20a
	Expanded clay pellets + sphagnum moss Keramzyt + mech torfowiec	0.15a	0.14a	0.15a
	Expanded clay pellets Keramzyt	0.27a	0.13a	0.20a
	Mean for B – Średnia dla B	0.21a	0.16a	
K	Sphagnum moss Mech torfowiec	3.74d	0.56a	2.15a
	Expanded clay pellets + sphagnum moss Keramzyt + mech torfowiec	5.16f	1.38c	3.27c
	Expanded clay pellets Keramzyt	4.84e	1.23d	3.04b
	Mean for B – Średnia dla B	4.58b	1.06a	
Ca	Sphagnum moss Mech torfowiec	3.18e	0.91a	2.05a
	Expanded clay pellets + sphagnum moss Keramzyt + mech torfowiec	2.36c	1.36b	1.86a
	Expanded clay pellets Keramzyt	2.76d	2.84de	2.80b
	Mean for B – Średnia dla B	2.76b	1.70a	
Mg	Sphagnum moss Mech torfowiec	0.81a	1.06d	0.94a
	Expanded clay pellets + sphagnum moss Keramzyt + mech torfowiec	0.91b	1.20e	1.06b
	Expanded clay pellets Keramzyt	1.00c	1.26f	1.13c
	Mean for B – Średnia dla B	0.91a	1.17b	

The next factor exerting an influence on the chemical composition of orchid plants was the medium type. The highest concentration of magnesium, iron and copper was found in plants grown in expanded clay, less in orchids grown in the mixed medium and the least in plants grown in sphagnum moss. An inverted dependence was shown in case of manganese and zinc. Growing medium did not affect sodium concentration. No fixed explicit tendencies were found for the remaining nutrients. The above described regularities referred to both cultivated orchid cultivars. The effect of potting media (tree fern, tree fern plus redwoood, fir bark, peat plus perlite) on the chemical composition of *Cattleya* was also examined by Poole and Sheehan [1977]. Differences in nitrogen, phosphorus and copper concentrations in leaves were small, however, significant differences referred to the concentrations of potassium, magnesium and iron, manganese and zinc. Peak et al. [1998] studied nutrient concentration in *Cymbidium goeringii* organs in 8 different media. The effect of media was very differentiated. For example, in plants grown in sphagnum moss, a higher concentration of P, K and Mg was found in roots, while in leaves, there was a higher concentration of N and Ca.

Table 4. Microelements and sodium concentration in leaves and roots of *Phalaneopsis* 'Zagreb' grown in different media ($mg \cdot kg^{-1}$ d.m.)
Tabela 4. Zawartość mikroelementów i sodu w liściach i korzeniach *Phalaneopsis* 'Zagreb' uprawianych w różnych podłożach ($mg \cdot kg^{-1}$ d.m.)

	Medium – Podłoże (A)	Leaves – Liście (B)	Roots – Korzenie (B)	Mean A Średnia A
Fe	Sphagnum moss Mech torfowiec	45.53b	65.99c	55.76a
	Expanded clay pellets + sphagnum moss Keramzyt + mech torfowiec	33.83a	356.67d	195.25b
	Expanded clay pellets Keramzyt	61.22c	420.01e	240.61c
	Mean for B – Średnia dla B	46.86a	280.89b	
Zn	Sphagnum moss Mech torfowiec	22.00ab	163.96d	92.98c
	Expanded clay pellets + sphagnum moss Keramzyt + mech torfowiec	16.01a	44.73c	30.37b
	Expanded clay pellets Keramzyt	18.33a	26.92b	22.63a
	Mean for B – Średnia dla B	18.78a	78.54b	
Cu	Sphagnum moss Mech torfowiec	9.91a	26.63b	18.27a
	Expanded clay pellets + sphagnum moss Keramzyt + mech torfowiec	24.77b	35.24c	30.01b
	Expanded clay pellets Keramzyt	35.85c	71.71d	53.78c
	Mean for B – Średnia dla B	23.51a	44.53b	
Mn	Sphagnum moss Mech torfowiec	290.48f	32.43b	161.45c
	Expanded clay pellets + sphagnum moss Keramzyt + mech torfowiec	71.73e	30.39a	51.06a
	Expanded clay pellets Keramzyt	65.24d	65.24c	65.24b
	Mean for B – Średnia dla B	142.48b	42.68a	
Na	Sphagnum moss Mech torfowiec	1.03b	1.08c	1.06b
	Expanded clay pellets + sphagnum moss Keramzyt + mech torfowiec	1.13e	0.93a	1.03a
	Expanded clay pellets Keramzyt	1.11d	1.08c	1.09c
	Mean for B – Średnia dla B	1.09b	1.03a	

According to Hew and Yong [2004], orchids are similar to other plants regarding their requirements, with the exception that they may need more time to show mineral deficiency symptoms. For example, in case of *Vanilla* grown in gravel culture, nitrogen deficiency occurs within three weeks, while phosphorus and potassium deficits appear after more than three months. A high influence of organic media on the nutritional status of *Phalaenopsis*, a differentiated accumulation of elements in plant organs and a delayed visual effect of component shortage could cause the diagnosis of nutritional disorders very difficult. It causes significant problem in horticultural practice. The quality of *Phalaenopsis* orchids grown in inert media, e.g. in expanded clay, is definitely inferior [Trelka et al. 2010].

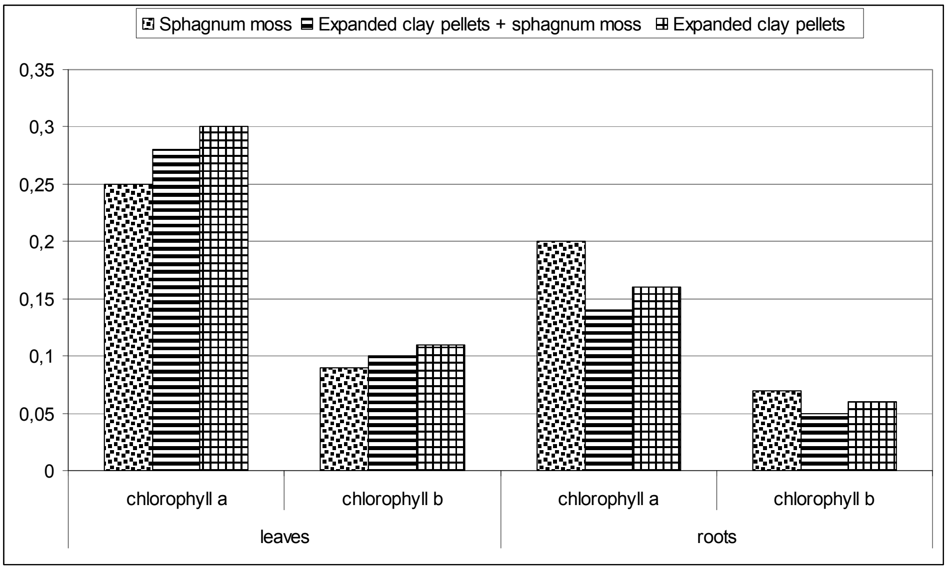

Fig. 1. Chlorophyll concentration in leaves and roots of *Phalaneopsis* orchid 'Sprigfield' grown in different media (mg·g^{-1} f.m.)

Rys. 1. Zawartość chlorofilu w liściach i korzeniach storczyka *Phalaneopsis* 'Sprigfield' uprawianego w różnych podłożach (mg·g^{-1} ś.m.)

As mentioned earlier, in the experimental orchid cultivation, translucent plastic pots were used. Christenson [2001] argued that the colour of plastic pots does not cause any effects on plant growth, with the exception of clear plastic which may possibly be seasonally beneficial for deciduous species from Himalayas. Those species show a significant photosynthetic activity in their roots and they may benefit from a lighted root zone provided by clear growing containers. Chlorophyll-a has approximate absorbance maxima of 430 nm and 662 nm (it corresponds to violet and red colours), while chlorophyll-b has approximate maxima of 453 nm and 642 nm (corresponding to blue and red colours). Ling and Subramaniam [2007], who studied leaves of 12 *Phalaenopsis violacea* orchids found that the concentration of chlorophyll-a is higher than the concentration of chlorophyll-b by about 100%. At the same time, they showed that orchid cultivars differ by chlorophyll a/b ratio. According to Lahai et al. [2003], a low ratio (< 2) of a/b chlorophyll is characteristic of orchids grown in shadowed areas. The men-

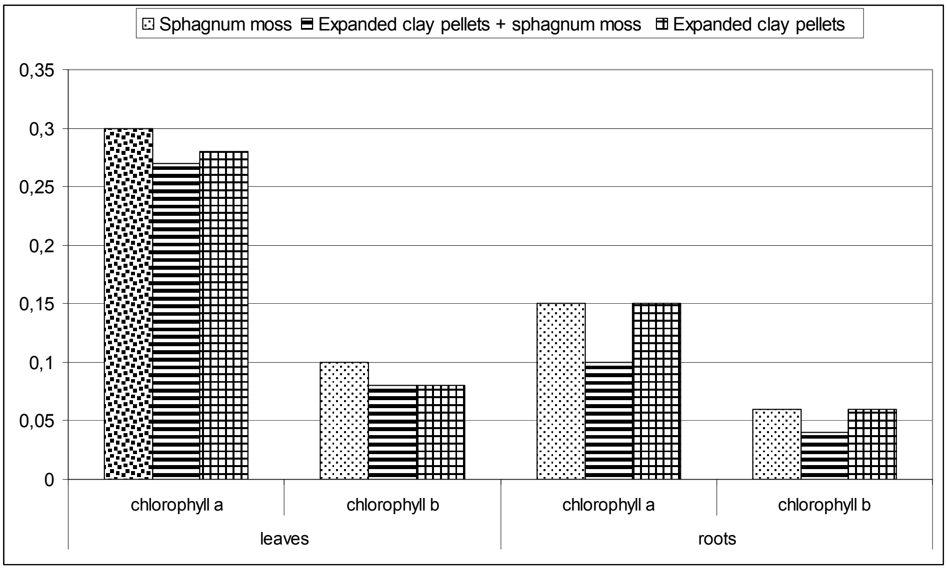

Fig. 2. Chlorophyll concentration in leaves and roots of *Phalaneopsis* orchid 'Zagreb' grown in different media (mg·g^{-1} f.m.)
Rys. 2. Zawartość chlorofilu w liściach i korzeniach storczyka *Phalaneopsis* 'Zagreb' uprawianego w różnych podłożach (mg·g^{-1} ś.m.)

tioned authors argued also that chlorophyll-b concentration may increase under stressful conditions.

In our experiments, chlorophyll-a and chlorophyll-b were measured as well. The ratio of chlorophyll-a/chlorophyll-b was higher than 2 (from 2.5 to 3.5). This regularity refers both to the concentration of pigments in leaves and in roots. This fact suggests that 'Springfield' and 'Zagreb' cultivars are adapted to be grown under high light exposure. Dale and Causton [1992] considered that the a/b chlorophyll ratio is physiologically flexible and it is only slightly influenced by soil magnesium status or water availability, and it is dissociated from patterns imposed by changes in leaf density. According to Ohtsuka et al. [1997], chlorophyll-b is released from light-harvesting chlorophyll a/b-protein complexes of photosystem II and it is converted to chlorophyll-a via 7-hydroxymethyl chlorophyll in the lipid bilayer and then, it is used for the formation of core complexes of photosystems. These mechanisms provide a fast and fine regulation of the photosynthetic apparatus during the construction of photosystems.

In the presented studies, no influence of media, used for *Phalaenopsis* cultivation, on chlorophyll concentration was observed. Leaves contained more chlorophyll-a and chlorophyll-b than roots (fig. 1 and 2). The concentration of magnesium and iron in roots were higher than in leaves, while more Mg and Fe in the plant tissue of *Phalaenopsis* were found in plants grown in expanded clay pellets and in the mixture of expanded clay pellets plus sphagnum moss. It can be connected with the presence of these elements in clay from which expanded clay pellets are produced.

CONCLUSIONS

1. Growing media exert a significant influence on the nutritional status of *Phalaenopsis* orchids what could cause the diagnosis of nutritional disorders very difficult.
2. Leaves and substrate roots of orchids differ significantly in reference to macro- and microelements accumulation: leaves accumulate more nitrogen, phosphorus, potassium, calcium and manganese, while roots accumulate more magnesium, iron and zinc.
3. Leaves of *Phalaenopsis* contain more chlorophyll-a and chlorophyll-b than roots, however, growing media did not affect chlorophyll concentration in leaves and roots.

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UPRAWA *Phalaeanopsis* W RÓŻNYCH PODŁOŻACH. CZEŚĆ II. ZAWARTOŚĆ SKŁADNIKÓW POKARMOWYCH ORAZ CHLOROFILU W LIŚCIACH I KORZENIACH

Streszczenie. Do badań dotyczących wpływu podłoży na zawartość składników pokarmowych oraz chlorofilu w liściach i korzeniach storczyka *Phalaenopsis* wybrano odmiany ‘Springfield’ i ‘Zagreb’. W roku 2006 rośliny sadzono do następujących podłoży: mech torfowiec (New Zealand sphagnum moss), mieszanka mchu torfowca z keramzytem (v:v = 1:1) oraz w keramzyt o granulacji 8–16 mm. Początkowo (8,5 miesiąca) storczyki rosły w doniczkach o średnicy 7 cm, następnie w przeźroczystych pojemnikach o średnicy 11 cm i pojemności 0,5 dm^3. Raz na dwa tygodnie rośliny dokarmiano pożywką o składzie: $N\text{-}NH_4$ – 100; $N\text{-}NO_3$ – 120; P – 40, K – 230; Ca – 30; Mg – 20; Na – 10; Cl – 20; $S\text{-}SO_4$ – 40; Fe – 0,8; Mn – 0,4; Zn – 0,2; Cu – 0,07; B – 0,2 $mg \cdot dm^{-3}$; pH 6,6; EC – 1,8 $mS \cdot cm^{-1}$. W roku 2008 (stadium kwitnienia) w liściach i korzeniach oznaczono całkowite zawartości makro- i mikroelementów oraz chlorofilu a i b. Podłoża wpływały na stan odżywienia roślin – najwyższą zawartość magnezu, żelaza, miedzi stwierdzono w organach roślin uprawianych w keramzycie, najmniejszą w storczykach uprawianych w mchu torfowcu. Jednocześnie zawartość cynku i manganu była najwyższa w roślinach uprawianych w mchu torfowcu. W liściach stwierdzono wyższą zawartość azotu, fosforu, potasu, wapnia i manganu, natomiast w korzeniach magnezu i żelaza i cynku. Ponadto liście zawierały więcej chlorofilu-a i chlorofilu-b w porównaniu z korzeniami.

Słowa kluczowe: storczyki, stan odżywienia roślin, analiza rośliny

Accepted for print – Zaakceptowano do druku: 8.06.2010