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EFFECT OF FERTILIZATION THROUGH GEOCOMPOSITE ON NUTRITIONAL STATUS OF *Hosta* 'HALCYON' PLANTS GROWN IN CONTAINERS

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Abstract. Geocomposite (GC) with hydrophilic polymer is an innovative method of superabsorbent application. The aim of the conducted research was to assess the usefulness of the geocomposite for the fertilization of *Hosta* with liquid fertilizer in comparison with soluble fertilizer (SF) and controlled release fertilizer (CRF). Plants were grown in containers filled with peat substrate, in a plastic tunnel and regularly feed with two doses of the fertilizers (according to N supply: 0.36 or 0.72 $g \cdot plant^{-1}$). Hostas responded positively to GC application: plants were higher and wider and their fresh weight increased respectively by 15 and 22% in comparison with SF and CRF application. The yield of dry matter was also higher. Plant nutrient status was better in case of P, K and Mg, but the N leaf content was lower. Lower electrical conductivity of the substrate at the end of cultivation with GC, alongside with intensive growth of plants proved high utilization of nutrients. The experiment confirmed usefulness of geocomposite for ornamental plant fertilization.

Key words: hydrophilic polymers, plant nutrition, ornamental perennials, nursery production

INTRODUCTION

One of the major issues related to the fertilization of ornamental plants is a sustainable production system, which is based, among others, on the assumption of efficient management of natural resources and protecting the environment from pollution [Bolques et al. 2011]. The crucial elements in the sustainable production is the need to achieve possibly high utilization of nutrient from applied fertilizers. The effectiveness

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of applied fertilizers depends, among others, on the sorption capacity of the soil or growing medium. The higher it is, the lower the nutrient losses. In container cultivation peat based substrates characterised by optimal water and air conditions are usually used. Effective cation exchange capacity (CEC_{eff}) of sapric peat is 123 ±12 $mmol_c \cdot kg^{-1}$ [Mouvenchery et al. 2013]. Depending on the type of substrate, it may be significantly limited or even completely reduced, as it is in the case of inert substrates [Bilderback 2001]. One of the ways to reduce the losses of nutrients from fertilizers is provided by CRF. The aim of their activity is to reduce leaching of nutrients from the substrate through their gradual release, adapted to the needs of plants during vegetation period. Works on the improvement of the CRF technology, including the modification of the coating composition so as to further improve the efficient use of nutrients and prevent environmental pollution are still in progress [Liang et al. 2007, Corradini et al. 2010]. Also, controlled release coated urea fertilizers (CRCU), recommended mainly for agricultural cultivation, are available on the market. They were created in order to limit nitrogen losses resulting from leaching, evaporation and denitrification [Azeem et al. 2014]. Hydrophilic polymers have also been used in order to improve the properties of CRF [Xie et al. 2011, Zhong et al. 2013]. At the same time, studies are conducted on the improvement of the properties of horticultural substrates, with the objective to intensify production and optimise the fertilization and hydration of plants e.g. via incorporation of superabsorbents. Hydrophilic polymers (HPs, superabsorbents – SAPs, hydrogels, agrogels) are commonly used in agricultural and horticultural plant production. SAPs are loosely cross-linked polymers, characterised by high water and water-based solutions retention capacity. Plants may use the retained water as a result of the difference in osmotic pressure between hydrogel and plant roots [Zohuriaan-Mehr et al. 2010]. SAPs can be also used as a carrier of nutrients and/or chemical substances as well as a shell component of controlled release fertilizers. However, the presence of mineral salts in the soil or hydration solution limits the ability of SAPs to adsorb and retain water [Foster and Keever 1990, Sita et al. 2005, Ghebru et al. 2007]. Cations, especially multivalent, strongly inhibit hydration of SAP as compared to anions, whereas contribution of urea in deterioration of SAP swelling is very little [Mikkelsen 1994].

Superabsorbents may be manufactured from synthetic components or natural elements such as starch. They are insoluble in water, easy to apply and not toxic for plants [Mikkelsen 1994, Elliott 2004, Kiatkamjornwong 2007, Zohuriaan-Mehr et al. 2010]. In the hydrated phase they take the form of gel and in dry state they exist in the form of granules, fibres or powder. Several methods of application of SAPs may be distinguished, including direct mixing with soil, injection into the soil or soaking roots in gel. Recently a new method of application of hydrogels in form of geocomposite has been invented [Orzeszyna et al. 2006]. The sorbing material is surrounded by nonwoven geotextile and placed inside a frame structure providing the space for free swelling. In container production, this additionally prevents "bursting" of the soil resulting from excessive swelling of the gel, so that significantly higher amounts of SAP may be applied than the recommended 2–6 $g \cdot dm^{-3}$ of the soil [Martyn and Szot 2001]. The capacity of the hydrogel placed inside the geocomposite to absorb nutrients [Sita et al. 2005] and to increase the water retention capacity of the substrate [Jobin et al. 2004, Ghebru et al. 2007, Ekebafe et al. 2011, Yang et al. 2015] can be very important for the production of ornamental plants in container nurseries.

The aim of the present study was to evaluate the usability of geocomposite as a carrier of liquid multi-component fertilizer for the nutrition of *Hosta* 'Halcyon' in comparison to commonly used fertilization methods (soluble and controlled release fertilizers) in container plant production.

MATERIALS AND METHODS

The experiment was established in Psary (long. 17º00'E; lat. 51º05'N), at the research station of Wrocław University of Environmental and Life Sciences, Poland, in May of the years 2010–2012. Plants of *Hosta* 'Halcyon' were planted in 1.5 dm^3 containers with peat substrate, in 0.4 × 0.3 m spacing. Two-factorial experiment was established in completely randomized design, with three replications, 8 plants in each. The first factor was the type of fertilization; the second factor was the dose of fertilizer according to N dose.

Experiment conditions. Three types of fertilization were applied:

1. GC: geocomposite + multi-component fertilizer Insol U (12:4:6), made by Fertilizer Research Institute, Puławy, Poland;
2. SF: soluble fertilizer YaraMila Complex (12:11:18) produced by Yara International ASA;
3. CRF: controlled release fertilizer Osmocote Exact Standard 3–4M (16:12:12) by Scotts (tab. 1). The doses of fertilizers were calculated to cover equal N doses: 0.36 and 0.72 $g \cdot plant^{-1}$.

Table 1. Composition characteristic of fertilizers (%)

Nutrients	Geocomposite + Insol U (GC)	YaraMila Complex (SF)	Osmocote 3-4M (CRF)
N-NO_3	2.0	5.0	7.1
N-NH_4	–	7.0	8.9
Urea	10.0	–	–
P (P_2O_5)	4.0	11.0	12.0
K (K_2O)	6.0	18.0	12.0
Mg	–	2.7	2.0
S	–	8.0	–
B	0.01	0.015	0.03
Cu	0.01	–	0.03
Fe	0.02	0.02	0.08
Mn	0.01	0.02	0.06
Mo	0.005	–	0.02
Zn	0.01	0.02	0.015

Superabsorbent (potassium salt of cross-linked polyacrylic acid), placed inside a geotextile cylinder, served as the geocomposite. Plastic frame maintained its shape and provided the space for free HP swelling. Geocomposite element containing 5 g of HP absorbed 300 cm^3 of distilled water. Plant roots could overgrow geotextile, obtaining access to water absorbed by HP. To avoid excessive HP swelling, restraint GCs were soaked in Insol 0.8% and Insol 1.6%, absorbing about 250 cm^3 of solution. After soaking the GC element was placed on the bottom of each container before plants were planted inside it. The lacking nutrients (0.5 and 1.0 cm^3, respectively) were supplemented in four weekly injections directly into GCs to provide total 2.5 and 5.0 cm^3 Insol U per plant, respectively. SF (3 and 6 g) was applied twice in two equal doses (1.5 or 3.0 g per each treatment) at a monthly interval onto the surface of substrate CRF (2.25 or 4.50 g) was applied once and mixed with the growing medium before planting. The plants were cultivated in a shaded (59%) plastic tunnel and irrigated with tap water according to their requirements: plants were watered by sprinklers, 2–7 times a week according to weather conditions, receiving 200 $cm^3 \cdot plant^{-1}$ per each irrigation.

Measurements and analyses. Plant growth was assessed after 12 weeks of experiment on the basis of the height and diameter of plants, the number of leaves and the fresh and dry weight of above-ground parts of plants. Mineral nutrient contents in leaves were also determined. The index parts were composed of well-developed leaves taken once after 12 weeks of cultivation. Six leaves from each replication were sampled, dried at 60°C and milled. To determine P and Mg colorimetric method was used with ammonium molybdate and thiazole yellow, respectively [Nowosielski 1974]. K and Ca content of leaves were examined by the flame photometry method (using Carl-Zeiss-Jena model) [Faithfull 2002]. In order to determine N content Kjeldahl method with sulfosalicylic acid was used. The chlorophyll content of the leaves was determined after extraction in 80% acetone [Arnon 1949]. Absorption was measured using a spectrophotometer (WPA, S106), at 645 and 663 nm and chlorophyll content (in $mg \cdot g^{-1}$ f.w.) was calculated according to the equation: chlorophyll a + b = 8.02 (A_{663}) + 20.21 (A_{645}). Electrical conductivity (distilled water to growing medium ratio 2:1, V/V) of the growing medium were measured at the end of experiment using Orion EC meter model 142. Moisture of the medium were measured every 7 days, 24 h after watering, with ProCheck, Decagon Devices including the digital ECHO-TE and EC-H2O sensors. Results of the experiment were statistically elaborated according to the method of analysis of variance (ANOVA) for two-factorial experiment, at significance level $P \leq 0.05$. Data concerning dry weight content were formerly transformed according to Bliss function (table presents the real data). To estimate the significance of differences t-Duncan test was used. The means in the tables were calculated over three years.

RESULTS

Plant growth. Plants fertilized with use of geocomposite containing Insol U achieved increased height and diameter (tab. 2). They also grew fewer leaves, compared to SF fertilization, yet their fresh weight yield was higher. This shows that the weight of a single leaf blade was higher. Plants fertilized with SF were also lower and had a smaller diameter. The disadvantageous influence on the number of leaves was observed after CRF and GC fertilization. The number of leaves after CRF and GC treatment did not differ significantly. None of the fertilization methods affected the percentage share of dry weight in the overground parts of plants (tab. 2) while in case of geocomposite usage the yield of dry matter was greater. After application of higher dose of fertilizers the plants produced increased biomass although higher percentage share of dry weight was observed in hostas fertilized with lower dose of fertilizers. The interaction between factors of the experiment did not cause modifications to the growth of plants. However higher dose of Insol U with geocomposite stimulated the increase of their fresh weight yield.

Table 2. The influence of fertilization and geocomposite on biometric traits, fresh and dry weight, chlorophyll content of leaves of *Hosta* 'Halcyon' grown in containers

		Plant height (cm)	Plant diameter (cm)	Leaf number (no·plant^{-1})	Fresh weight (g·plant^{-1})	Dry weight (g·plant^{-1})	Dry weight (%)	Chlorophyll (mg·g^{-1} f.w.)
Treatment	GC + 0.36 N	13.50	26.60	10.1 b	34.82 a	10.69	30.75	0.77 a
	GC + 0.72 N	12.26	26.00	9.8 ab	46.43 b	12.07	25.98	1.24 c
	SF + 0.36 N	12.11	24.43	9.9 ab	31.92 a	8.59	26.83	0.93 ab
	SF + 0.72 N	11.49	24.63	11.7 c	34.80 a	8.87	25.56	1.12 b
	CRF + 0.36 N	12.02	24.24	9.4 a	35.25 a	9.71	27.62	1.18 c
	CRF + 0.72 N	11.86	24.70	10.1 b	35.39 a	8.84	24.99	1.11 bc
Means for fertilizer forms	GC	12.88 b	26.30 b	9.9 a	40.63 b	11.38 b	28.37	1.01
	SF	11.80 a	24.53 a	10.8 b	33.36 a	8.73 a	26.20	1.03
	CRF	11.95 a	24.47 a	9.7 a	35.32 a	9.27 a	26.30	1.15
Means for doses	0.36 N	12.54 b	25.09	9.8 a	34.00 a	9.66	28.40 b	0.96 a
	0.72 N	11.87 a	25.11	10.5 b	38.87 b	9.93	25.51 a	1.16 b

GC – geocopmposite + Insol U; SF – soluble fertilizer; CRF – controlled release fertilizer. Means followed by the same letters in the columns are not significantly different at $P \leq 0.05$. Not-marked values in the columns do not differ significantly from each other at $P \leq 0.05$

Table 3. The influence of fertilization and geocomposite on the macroelement content (% d.w.) in leaves and electrical conductivity (mS·cm^{-1}) of substrate after container cultivation of *Hosta* 'Halcyon'

		N	P	K	Mg	Ca	EC
Treatment	GC + 0.36 N	1.59 a	0.52	2.20	0.55	3.03	0.18 a
	GC + 0.72 N	1.98 c	0.39	2.53	0.50	3.19	0.29 ab
	SF + 0.36 N	1.83 b	0.31	2.12	0.42	3.48	0.25 ab
	SF + 0.72 N	2.13 d	0.32	2.34	0.38	3.33	0.68 c
	CRF + 0.36 N	2.20 d	0.39	2.03	0.40	2.70	0.72 c
	CRF + 0.72 N	2.19 d	0.35	2.10	0.28	2.95	0.36 b
Means for fertilizer forms	GC	1.78 a	0.46 c	2.37 b	0.53 c	3.11 b	0.23 a
	SF	1.98 b	0.32 a	2.23 a	0.40 b	3.40 c	0.47 b
	CRF	2.20 c	0.37 b	2.07 a	0.34 a	2.82 a	0.54b
Means for doses	0.36 N	1.87 a	0.41	2.12 a	0.45 b	3.07	0.38
	0.72 N	2.10 b	0.35	2.33 b	0.39 a	3.16	0.44

For explanations: see Table 2

Plant material analysis. The content of chlorophyll in hosta leaves did not vary significantly depending on the applied type of fertilizer (tab. 2), while higher dose of fertilizers positively influenced its level. The joint influence of the type and dose of fertilizer also led to differences in chlorophyll content. It was the lowest in plants cultivated with geocomposite and a lower dose of Insol U, while the richest content was observed in plants fertilized with a higher dose of the same fertilizer, as well as those fertilized with CRF. Plants fertilized with geocomposite, irrespective of fertilizer dose, had a higher level of P, K and Mg nutrients (tab. 3), while the N content was the poorest. Fertilization with SF had a beneficial influence on Ca content, level of P was decreased. After CRF fertilization, the content of Mg and Ca was the lowest but the leaves contained the highest level of N. The content of K in leaves of hostas fertilized with SF and CRF did not differ significantly. It was noted that, regardless of the dose of fertilizers, the content of P and Ca in hosta leaves remained the same, whereas plants treated with higher doses of fertilizer were better nourished with N and K. The opposite reaction was observed in the case of Mg. It's content in hosta leaves was greater when lower fertilizer doses had been applied. The tests did not indicate a significant influence of interaction between the factors on the degree of nourishment of *Hosta*. The nitrogen level, which was the highest after the application of a higher dose of YaraMila Complex and of Osmocote Exact was an exception. The lowest nitrogen concentration was found in plants treated with a lower dose of Insol U applied in the geocomposite.

DISCUSSION

The conducted experiment confirmed the beneficial effects of fertilization with use of geocomposite on the growth of *Hosta* 'Halcyon' plants. After the application of geocomposite plant fresh weight grew by 21.8 and 15.0% in comparison to plants fertilized with SF and CRF, respectively. Even more significant rise in fresh weight yield (by 46%) was noted in spider plants (*Chlorophytum comosum* (Thunb.) Jacques) cultivated with a 10-percent addition of hydrogel [Wang and Boogher 1987], while in Boston fern (*Nephrolepis exaltata* (L.) Schott) the addition of the same amount of agrogel did not influence the fresh weight yield of plants. The addition of agrogel to the soil also stimulated the increase in fresh weight yield in numerous species of grass [de Varennes et al. 2010, Islam et al. 2011a], in particular those cultivated on light soils. In *Agrostis stolonifera* L. cultivated on sandy soil the weight increase was 4-fold [Agaba et al. 2011]. More prolific growth of *Hosta* plants may be explained by constant availability of nutrients that had been absorbed by the geocomposite throughout the vegetation period. Gradual release of nutrients from the CRF fertilizer did not prove as effective. This may be connected with the fact that the release of nutrients from CRF depends on temperature and water content of the substrate, which in turn means varied microbiological activity [Hicklenton and Cairns 1992, Cabrera 1997, Huett and Gogel 2000, Azeem et al. 2014]. The pace of releasing nutrients from CRF in the conducted experiment might have been inadequate to the plant metabolism [Azeem et al. 2014]. This is also confirmed by analyses of the substrate, which have shown that the EC of the growing medium after the end of production was the highest in the case of CRF (tab. 3). Less intense plant growth during last few weeks of experiment (data not shown), which resulted in lower demand for water and nutrients could contribute to this phenomenon. At the end of the vegetation period, the moisture of the substrate (fig. 1) treated with CRF was higher than in pots containing geocomposite, which also might have accelerated the pace of releasing nutrients. It is likely that the plants used the elements from the applied fertilizer more effectively, as Mikkelsen [1994] suggests, although, according to Liang et al. [2007] the temperature of substrate significantly modifies the pace of releasing NPK from fertilizers absorbed by superabsorbents with an addition of kaolinite-P (acrylic acid-co-acrylamide)/kaolin P (P(AA-co-AM)/kaolin). Another cause of the increased growth of plants fertilized with geocomposite and Insol U might have been the increased nutrient retention capacity in the substrate-geocomposite complex, as well as nitrogen form. Insol U contains N mostly in the form of urea. Maybe this form of N was beneficial to hosta growth because of longer nitrogen availability. HPs have the capacity to adsorb and retain ions that may be used by the plants due to negatively charged functional groups in HPs structural frame [Mikkelsen 1994, Sita et al. 2005]. This property allows them to prevent leaching nutrients. Thus, they constitute a reservoir of nutrients that the plant can access in amounts depending on growth intensity, so that the geocomposite may be more useful than CRF as a carrier of nutrients. Previous research has shown that the reduction in leaching NH_4^+ ions may reach 60% in substrate consisting of coarse silica sand and Decatur silt loam [Mikkelsen 1994] and 20–40% in substrate consisting of pine bark [Ghebru et al. 2007], depending on the type and dose of HPs. In the case of K^+, retention may increase by 20% [Mikkelsen 1994].

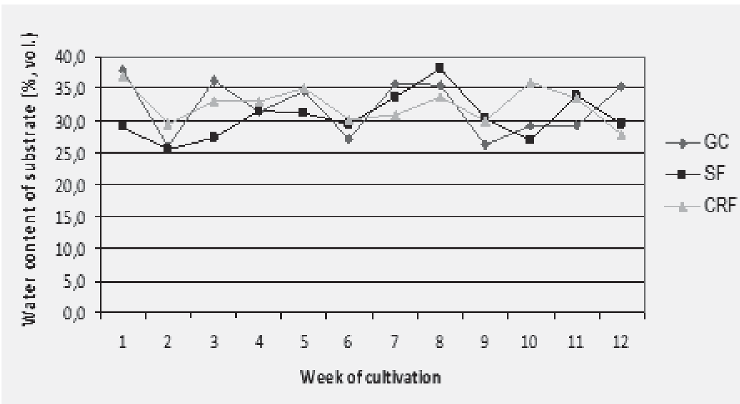

Fig. 1. The influence of the type of fertilization on substrate water content during cultivation period of *Hosta* 'Halcyon' (means of two years)

The influence of agrogel on dry weight content depends on the level of soil or substrate water content. In optimum medium moisture conditions the content of dry weight in plants cultivated with the addition of hydrogels is lower or the same as in control group plants [Boatright et al. 1997, Islam et al. 2011b]. In corn (*Zea mays* L.), dry weight of the overground part after the application of SAPs was higher only in water stress conditions, but in optimal substrate moisture conditions the application of HPs negatively influenced both the yield of dry weight and its percentage content in the plant [Islam et al. 2011b]. In *Chrysanthemum* × *grandiflorum* it was noted that the dry weight achieved by plants was the lower, the higher the dose of applied agrogel [Sita et al. 2005]. In the case of insufficient substrate water content, *Lolium perenne* L. responded to the addition of polymer to the substrate with an increase in dry weight [de Varennes et al. 1999]. In the experiment discussed here, the fertilization method influenced the yield of dry weight: plants responded positively to the application of geocomposite containing Insol. These results are contrary to previous findings as the moisture of substrate remained optimal (fig. 1).

The nitrogen leaf content was the lowest in cultivation with geocomposite. Plants fertilized in this way were characterised by increased growth pace (data not shown) and they produced more fresh weight yield than in the other treatments. Thus, the content of nitrogen in the tissues of *Hosta* 'Halcyon' might have been diluted as a result of Piper-Steenbjerg effect [Marschner 2012]. This happens when, on intense growth of plants, the level of an element decreases together with increased yield [Wikström 1994]. Results obtained by de Varennes et al. [1999] demonstrated that the total nitrogen content in perennial ryegrass plants decreases after the application of polymers. Jobin et al. [2004] documented that the nitrogen level in *Petunia* × *hybrida* either remained the same or decreased in comparison to control objects after adding hydrogels. That characteristics was more strongly modified by the type of substrate than by the presence of hydrogel. Opposite to N, the content of P, K and Mg was higher in plants fertilized with the use of geocomposite containing Insol U, what is contrary to previous reports [Taylor and Halfacre 1986].

In numerous analyses of the EC of the substrate mixed with superabsorbent the salinity was usually higher than in control objects [Bhat et al. 2009, Bai et al. 2010, Dorraji et al. 2010]. The results of the present study showed lower EC of the substrate after cultivation of plants fertilized with geocomposite. The fundamental difference depended on the presence of HP particles in the substrate, while in the case of geocomposite application, only the substrate, without SAPs, was analysed. Low EC of substrate containing GC may also indicate that nutrients did not get through substrate and were absorbed directly from the geocomposite. Furthermore, the plants might use nutrients more efficiently. Hydrogels retain mineral salts inside their structure so they act not only as 'miniature water reservoirs' [Zohuriaan-Mehr et al. 2010] but also as nutrient reservoirs. The form of application of agrogel will also play an important role in cultivation of ornamental plants. During replantation to the final destination the geocomposite may be successfully placed inside the soil, where it can continue to perform its functions. Apart from the fact that the GC contains a desired dose of SAP and that it can be placed exactly at the accurate depth in the soil, it can also be easily removed, even after many years of cultivation [Orzeszyna et al. 2006]. The GC is one of the easier methods of the application of HPs and it provides a chance to optimise cultivation conditions, including optimised fertilization.

CONCLUSIONS

1. The plants grown with geocomposite were higher and wider, produced more fresh and dry mass, what contributed to increased decorative value of the plants.

2. The highest content of P, K, Mg of the hosta leaves indicated more efficient utilization of the nutrients from the substrate with geocomposite by the plants while the greatest N and Ca content of the leaves was elicited by controlled release fertilizer and soluble fertilizer treatment, respectively.

3. The influence of the dose of fertilization was equivocal, thus the higher dose of fertilizers does not seem to be advisable.

4. Geocomposite can be an alternative and efficient method of ornamental plant fertilization in comparison to commonly used soluble and controlled release fertilizers in plant nurseries.

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WPŁYW NAWOŻENIA GEOKOMPOZYTEM NA ODŻYWIENIE FUNKII 'HALCYON' UPRAWIANEJ W POJEMNIKACH

Streszczenie. Geokompozyt (GC) z hydrofilowym polimerem jest innowacyjnym sposobem aplikacji supersorbentów. Celem prowadzonych badań było określenie przydatności geokompozytu do nawożenia funkii płynnym nawozem w porównaniu z nawozami rozpuszczalnymi (SF) i o kontrolowanym uwalnianiu składników (CRF). Rośliny uprawiano w pojemnikach na podłożu torfowym w tunelu foliowym. Funkia była nawożona dwiema dawkami nawozów (na podstawie zawartości N: 0,36 lub 0,72 g·roślina^{-1}). Rośliny pozytywnie zareagowały na zastosowanie nawożenia w formie GC: były wyższe, miały większą średnicę oraz większą świeżą masę odpowiednio o 15 i 22% w porównaniu z roślinami nawożonymi SF i CRF. Plon suchej masy w tej kombinacji był również większy. Stan odżywienia roślin uprawianych z geokompozytem był lepszy w przypadku P, K, Mg, natomiast zawartość N w liściach była mniejsza. Niższe zasolenie podłoża z GC po uprawie, w połączeniu z intensywnym wzrostem roślin, dowodzi dobrego wykorzystania składników pokarmowych przez rośliny. Badania potwierdziły przydatność GC do nawożenia roślin ozdobnych.

Słowa kluczowe: polimery hydrofilowe, żywienie roślin, byliny ozdobne, produkcja szkółkarska

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