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IMPACT OF GROWING MEDIA WITH INDOLE-3-ACETIC ACID ADDITION ON THE DEVELOPMENT OF ROOT SYSTEM OF ORNAMENTAL PLANTS

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Abstract. The impact of the addition of indole-3-acetic acid (IAA) to three commercial growing media and three self-prepared growing media on rooting of cuttings of two ornamental plants: *Hydrangea* L. and poinsettia *Euphorbia pulcherrima* 'Prestige Early Red' was evaluated. According to the assessment of root system, length of roots, fresh and dry mass of roots, percentage of rooted cuttings the best rooting of cuttings of *Hydrangea* L. in Ceres and GM2 and of *Euphorbia pulcherrima* in Klasmann Steck Medium, GM2 and GM3 independent of the doses of IAA was observed. The addition of 200, 300 and 400 μg kg^{-1} IAA for GM2 and GM3 improved some of the parameters rooted cuttings of *Euphorbia pulcherrima*. The worst assessment of root system and percentage of rooted cuttings for both ornamental plants with the lowest pH in GM1 as compared to other growing media was shown. Furthermore, 400 μg kg^{-1} addition of IAA for Klasmann Steck Medium caused significant on higher length of roots and dry mass of roots of *Euphorbia pulcherrima*.

Key words: rooting of cuttings, growing media, IAA, *Hydrangea* L., *Euphorbia pulcherrima*

INTRODUCTION

Peat is known to be one of the most ideal materials for horticultural growing media based on its physical, chemical and biological characteristics. Growing medium has three main functions: i) supply roots with nutrients, air, and water, ii) allow for maximum root growth, and iii) physically support the plant. Modern technology in the horticultural production required substrates of a defined and repeatable quality. A good sub-

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strate facilitates the production of crops and helps to achieve even quality of the final product [Huttunen and Reinikainen 2000, Pudelski 2002, Schmilewski 2008].

Substrates used in modern commercial horticulture are becoming increasingly specialized and more there is demand for good raw materials in their manufacture. Features such as granulation, pore space, water capacity, weed risk etc. are critical to the success of high performance growing media. Many alternatives to peat have been evaluated and incorporated into growing media in recent years but for many commercial growers, peat remains the raw material of choice. The choice of substrate is one of the parameters that decides on final effect of ornamental plants cultivation. This is due not only to the requirements of the plant but also to the factors influencing the environment in which the root system is developing [Jackson et al. 2005].

Changes in root architecture can mediate the adaptation of plants to soils in which nutrient availability is limited by increasing the total absorptive surface of the root system. The ability of plants to respond appropriately to nutrient availability is of fundamental importance for their adaptation to the environment. Developmental processes, such as root-hair formation, primary root growth and lateral root formation, are particularly sensitive to changes in the internal and external concentration of nutrients. The responses of root architecture to nutrients can be modified by plant growth regulators, suggesting that the nutritional control of root development may be dependent on hormone synthesis and transport [López-Bucio et al. 2003]. The use of plant growth regulators is very important for rooting of cutting in ornamental plant production. Currently, ready-made substances containing auxins used for rooting of plant cuttings are available on the market. They are in powder form in which the base of the cutting is immersed before insertion [Szajdak and Nowak 2013].

The aim of the paper is to link the content of IAA and physical, chemical and biochemical properties of various types of organic growing media with morphological features of ornamental plants such as development of root system of rooted cuttings. The results of such comprehensive research should show the best growing media in production aspect.

MATERIAL AND METHODS

The effect of the IAA content in the different growing media for rooting of cuttings of ornamental plants: hydrangea *Hydrangea* L. and poinsettia *Euphorbia pulcherrima* 'Prestige Early Red' was evaluated. The experiment was carried out in cell trays on two dates: *Euphorbia pulcherrima* – from 28 June to 09 August 2011 and from 26 June to 07 August 2012, *Hydrangea* L. – from 21 April to 01 June 2011 and from 15 February to 28 March 2012 with the use of six growing media:

a) three commercial growing media of the factories: Hollas Sp. z o.o. Pasłęk; Ceres International Sp. z o.o., Pyzdry; Kronen Klasmann Sp. z o.o., Otrębusy, Poland;

b) three self-prepared growing media (GM1, GM2, GM3) by the Research Institute of Horticulture, Skierniewice, Poland (tab. 1).

Table 1. The composition of growing media for rooting of cuttings

Name of growing media	Factory	Composition of growing media	
		Organic	Mineral
Aura – commercial growing media for rooting of cuttings of ornamental plants	Hollas Sp. z o.o.	white peat mixture (H2-H3)	perlite and compound fertilizer, granulated, no chloride with microelements (YaraMila™ COMPLEX) used for ornamental plants. Nutrients content: nitrogen – 12% N (5.0% N-NO_3 and 7.0% N-NH_4), phosphorus – 11% P_2O_5, potassium – 18% K_2O, magnesium – 2.7% MgO, sulphur – 20% SO_3, boron – 0.015% B, iron – 0.2% Fe, manganese – 0.02% Mn, zinc – 0.02% Zn
Ceres – commercial growing media for rooting of cuttings	Ceres International Sp. z o.o.	weakly decomposed of white peat mixture and coco fibre	perlite, sand and compound fertilizer (PG-MIX™ 14-16-18 + MIKRO)
Klasmann Steck Medium – commercial growing media for rooting of cuttings	Kronen Klasmann Sp. z o.o.	weakly decomposed fine-grained of white peat mixture (H2-H3)	perlite and compound fertilizer (PG-MIX™ 14-16-18 + MIKRO) used for the preparation of peat substrates and mixes for the production of seedlings and potting soils. Nutrients content: nitrogen – 14% N (5.5% N-NO_3 and 8.5% N-NH_4), phosphorus – 16% P_2O_5, potassium – 18% K_2O, magnesium – 0.8% MgO, sulphur – 19% SO_3, boron – 0.03% B, copper – 0.12% Cu, iron – 0.09% Fe, manganese – 0.16% Mn, molybdenum – 0.20% Mo, zinc – 0.04% Zn
GM1	Lasland Sp. z o.o.	white peat (H3-H4; 70% vol.)	perlite (30% vol.) and compound fertilizer (PG-MIX™ 14-16-18 + MIKRO)
GM2	Agrohum	neutralized white peat (H3-H4; 70% vol.)	perlite (30% vol.) and compound fertilizer (PG-MIX™ 14-16-18 + MIKRO)
GM3	Hollas Sp. z o.o.	neutralized white peat (H3-H4; 70% vol.)	perlite (30% vol.) and compound fertilizer (PG-MIX™ 14-16-18 + MIKRO)

H2, H3, H4 – degree of decomposition (von Post 1922)
GM1, GM2, GM3 – self-prepared of growing media based on Polish white peats by Research Institute of Horticulture, Skierniewice, Poland

Growing media contained four concentrations of IAA: natural concentration and 200, 300, 400 μg kg^{-1} additionally. IAA obtained from Sigma-Aldrich factory (purity 98%, empirical formula $C_{10}H_9NO_2$, molecular weight 175.18 g mol^{-1}).

The temperature during the rooting plants ranged from 22 to 26°C, moisture maintained at 75–85%. Rooting of cuttings of ornamental plants was rooted in multi pots – each cell trays had a volume of 0.04 liters and spacing every two cell trays – 8 × 8 cm. It was rooted 40 rooting of cuttings of plants according to EPPO for each combination. All rooting of cuttings were evaluated to measure root length from base of shoot to the end of the longest root.

The physical properties of the substrates were determined according to the method adopted by the European Union [PN-EN 12579 2001, PN-EN 13040 2002, PN-EN 13041 2002]. Designations were made in the cylinders with a diameter of 10 cm and a height of 5 cm. Characteristic and the most important feature of this method is the way sample preparation relies on the free settling of the layer of a thickness 10 cm (the cylinder with extender) loose substrate with a potential aqueous -57 cm H_2O. Water-air capacity were determined on the camera sand 'Eijkelkamp' in the range of negative pressure 0–100 cm H_2O vacuum, using 24–hour equilibration of water at each of the 5 levels of negative pressure (-3.2, -10, -32, -50 and -100 cm H_2O). Shrinkage, bulk density and porosity were calculated using the formulas [PN-EN 13041 2002] (tab. 2).

IAA concentrations were assayed fluorimetrically [Szajdak and Maryganova 2009, Szajdak et al. 2011a]. The pH was measured in 1N KCl in air-dried of peat substrates using a 1:5 v/v soil solution suspension. The total organic carbon was analyzed on Total Organic Carbon Analyzer (TOC 5050A) with Solid Sample Module (SSM-5000A) produced by Shimadzu (Japan) and hot water extractable organic carbon by Smolander and Kitunen method [Smolander and Kitunen 2002] on TOC 5050A equipment (Shimadzu Japan). Ammonium and nitrate ions were measured by chromatographic method [Szajdak et al. 2011a]. Total nitrogen was determined by the Kjeldahl method.

The following enzymes activity were determined in growing media: urease (EC 3.5.1.5) by Hoffmann and Teicher method [Szajdak et al. 2011a, b], nitrate reductase (EC 1.7.99.4) by Kandeler method [Kandeler 1996, Szajdak and Gaca 2010, Szajdak et al. 2011b], phenol oxidase (EC 1.14.18.1) by Perucci method [Perucci et al. 2000, Szajdak et al. 2011a, b, c], peroxidase (EC 1.11.1.7) by Bartha and Bordeleau method [Szajdak et al. 2011a, b, c], xanthine oxidase (EC 1.17.3.2) by Krawczyński method [Krawczyński 1972, Szajdak et al. 2011a, b]. All determinations of enzyme activity in peat substrates were performed on a UV-VIS spectrophotometer Beckman DU®-68 USA from the early-prepared analytical curve according to the Lambert-Beer light absorption law by means of the least squares formulas.

The evaluation of cuttings of *Euphorbia pulcherrima* and *Hydrangea* L. was established after 42 days their rooting. Following features were estimated: root system (EPPO), length of roots (cm), dry and fresh mass (g $plant^{-1}$) and percentage of rooted cuttings. The experiments with cuttings rooting were in the line with EPPO norms (European and Mediterranean Plant Protection Organization – Guideline for the efficiency evaluation of plant growth regulators, Rooting of cuttings, PP 1/186(2)) according to which root system was assessed in scale from 1 to 5: 1 – very good rooting – produced bulk, 2 – good rooting, roots did not produce bulk, 3 – weak rooting, tips of roots or individual roots are

Table 2. Physical properties of growing media

Growing media	Shrinkage of soil (% by volume)	Bulk density (kg m^{-3})	Porosity (% by volume)	Fraction (% by volume)					Water potential (-cm H_2O)									
									water capacity (% by volume)					air capacity (% by volume)				
				> 10 mm	4–10 mm	2–4 mm	0.63–2 mm	< 0.63 mm	3.2	10	32	50	100	3.2	10	32	50	100
Aura	30.8	142.7	91.6	0.4	20	22	48	9.6	77.8	70.0	52.8	46.3	42.4	13.8	21.6	38.8	45.3	49.2
Ceres	25.6	85.3	95.0	–	2	20	78	–	79.8	71.8	44.5	39.0	36.9	15.2	23.1	50.4	56.0	58.1
Klasmann Steck Medium	37.8	119.6	92.7	–	16	44	40	–	81.4	72.0	53.0	46.9	44.7	11.3	20.6	39.7	45.8	48.0
GM1	22.0	150.8	92.2	8	10	28	48	6	76.4	60.3	46.2	42.2	39.3	15.8	31.9	46.1	50.1	53.0
GM2	19.2	188.5	89.6	–	10	34	52	4	71.8	62.8	46.7	41.8	40.7	17.8	26.8	42.9	47.8	48.9
GM3	19.8	134.5	93.0	1	10	22	66	1	73.5	62.6	45.3	40.5	39.6	19.5	30.5	47.7	52.6	53.4

visible, 4 – absence of roots or callus visible at the base of cutting's shoot, 5 – absence of roots, necrosis of the base of cutting's shoot.

The physical properties and development of root system were analyzed in four replications in growing media. Obtained results were subject to statistical analysis with ANOVA and significance of differences between means was established with Duncan's Multiple Range test at probability level of 95%. All chemical and biochemical analyzes were run in triplicate, and the results were averaged. The confidence intervals were calculated using the following formula: $\overline{x} \pm t_{\alpha \cdot (n-1)}$ SE, where: $\overline{x}$ – mean; $t_{\alpha \cdot (n-1)}$ – value of the Student test for $\alpha = 0.05$; n-1 – degree of freedom, SE – standard error. All the chemicals used in this study were of analytical grade of purity.

RESULTS AND DISCUSSIONS

Physical properties of growing media. Knowing the physical properties of growing media is important both in the selection of the growing media and in its management. The physical properties of growing media differ from those of soil and container production requires more attentive management. The highest shrinkage showed Klasmann Steck Medium and the lowest GM2 (tab. 2).

Highly porous media enhances gas exchanges (O_2 and CO_2) between the root zone and the environment. Therefore, in growing media with low bulk density there is considerably more oxygen available in the root zone, and considerably less CO_2 from root metabolism. High oxygen content has a positive effect on the growth rate of roots. Bulk density of all growing media has a distinct and negative relationship with total porosity. The lowest bulk density (85.3 kg m^{-3}), and the highest total porosity (95%) was determined for Ceres. Contrary was observed in GM2 with the highest bulk density (188.5 kg m^{-3}) and the lowest porosity (89.6%) (tab. 2).

All growing media characterized good structure which should allow rooting of cuttings. There was small fraction with texture more than 4 mm and below 0.63 mm (tab. 2). This texture has suitable effect on maintaining of normal air-water capacity of growing media. Independently of growing media the capacity of water and air at the water potential -10 cm H_2O was at the optimum level recommended for growing media for rooting of cuttings [Kipp et al. 1999].

Chemical properties of growing media. Soils contain compounds which exhibit strong auxin-like activity and differ in their IAA synthesizing capacity depending on the fertility status and organic matter content [Sarwar et al. 1992]. Many compounds are released by plant root exudates, including inorganic ions and organic substances: amino acids, amides, sugars, aliphatic acids, aromatic acids, vitamins, peptides, proteins, enzymes, ketones, urea, phytoalexins and plant hormones like IAA [Dundek et al. 2011]. Auxin is asymmetrically distributed in the root tip, with an apparent high concentration in the columella initial/quiescent center regions. High nitrate supply led to a decrease of IAA levels in roots, specifically in root sections (0–10 cm) close to the root tip, reducing the auxin gradient between the root tip and the more developed root zones. It has been reported that a decrease of auxin concentration in roots alters cell growth and reduces root elongation [Tian et al. 2008].

In the studied growing media the natural content of IAA ranged between 102.87 and 150.46 μg kg^{-1} before rooting of cutting of *Hydrangea* L. and *Euphorbia pulcherrima* (tab. 3 a–d).

pH is one of the most influential factors affecting the microbial community in soil. This parameter strongly influences abiotic factors, such as carbon and nutrient availability and the solubility of metals. Most native plants tend to grow best at pH levels between 5.5 and 6.5, although some species are more pH tolerant. The main effect of pH on plant growth is its control nutrient availability. In addition, soil pH may control biotic factors, such as the biomass composition of fungi, and bacteria in soils [Rousk et al. 2009]. All growing media represented strongly acidic to slightly acidic properties before rooting of cutting. pH in the growing media can be sort of ascending: Aura 4.88–5.02, Ceres 4.35–5.84, Klasmann Steck Medium 4.52–4.72, GM1 2.68–2.76, GM2 5.94–6.18, GM3 4.30–4.35 (tab. 3 a–d).

The addition of 200, 300 and 400 μg kg^{-1} IAA to the growing media for rooting of cuttings of *Hydrangea* L. and *Euphorbia pulcherrima* revealed significant effect on TOC, C_{HWE}, ammonium and nitrate ions and total nitrogen contents. The study showed significantly lower concentrations of TOC after rooting of cutting of *Hydrangea* L. (from 365.67 to 439.00 g kg^{-1}) than before (from 405.20 to 498.00 g kg^{-1}) for all growing media (tab. 3 a). However, opposite trend was observed for *Euphorbia pulcherrima* (tab. 3 c, d). TOC includes organic substances of well-known and unknown structure and different molecular weight. Therefore, the decrease of the concentrations of TOC after rooting of cuttings indicates that organic compounds are available source of carbon, which is taken by ornamental plants.

There was a significant decrease of C_{HWE} caused by rooting of cuttings of *Hydrangea* L. and the addition of different content of IAA. The results indicated that the contents of C_{HWE} were significantly lower after (from 9.37 to 10.28 g kg^{-1}) than before (from 10.92 to 11.55 g kg^{-1}) rooting of cuttings of *Hydrangea* L. in Ceres (tab. 3 a). These data indicate that the organic compounds were taken up by the plants and microorganisms. C_{HWE} is a food supplement, supporting plant growth and microorganisms and plays an important role in the global carbon cycle through the microbial loop.

Soil organic matter is a critical component of the soil-plant ecosystem. It constitutes the major part of organic carbon. There are different classes of biogenic, heterogeneous, dynamics and refractory organic compounds, characterizing various contents of carbon and nitrogen having molecular structure. A principal feature of organic matter is its ability to absorb and retain water molecules as well as to reduce soil biological and enzymatic activities [Ghani et al. 2003]. The rhizosphere effect can be measured by the ratio or difference between the numbers of microorganisms near the root compared with that in the bulk soil. In most cases this ratio is positive; however, there are exceptions. It is generally accepted that the rhizosphere effect exists thanks to root exudation of photosynthetically derived carbon sources and sloughing off of root cap cells and older sections of the cortex. The main source of root exudates is the root tip, while emergence of lateral roots also results in carbon losses [Semenov et al. 1999].

Among the chemical properties of organic soils, particular attention is paid to different forms of nitrogen. Variation in nitrogen gives these soils a specific character. Its content is important, as any quantitative and qualitative conversions as well as transformations in the

Table 3 a. Chemical and biochemical properties of commercial growing media before and after rooting of cutting of *Hydrangea* L.

Addition IAA ($\mu g\ kg^{-1}$)	IAA ($\mu g\ kg^{-1}$)	pH (KCl)	TOC ($g\ kg^{-1}$)	C_{HWE} ($g\ kg^{-1}$)	$N\text{-}NH_4^+$ ($mg\ kg^{-1}$)	$N\text{-}NO_3^-$ ($mg\ kg^{-1}$)	N_{total} ($g\ kg^{-1}$)	C/N	Urease activity ($\mu mol\ h^{-1}\ g^{-1}$)	Nitrate reductase activity ($nmol\ h^{-1}\ g^{-1}$)	Phenol oxidase activity ($\mu mol\ h^{-1}\ g^{-1}$)	Peroxidase activity ($nmol\ h^{-1}\ g^{-1}$)	Xanthine oxidase activity ($\mu mol\ h^{-1}\ g^{-1}$)
						Aura							
						before rooting of cutting							
0	106.91 ±29.51	4.88	498.00 ±4.22	9.98 ±0.16	18.88 ±0.19	63.77 ±2.23	9.14 ±0.22	54	21.69 ±3.88	0.55 ±0.07	4.01 ±0.33	0.75 ±0.04	5.38 ±0.71
200	114.83 ±14.32	4.92	497.40 ±3.50	10.27 ±0.17	19.43 ±0.12	34.55 ±2.18	8.92 ±0.21	56	25.37 ±2.04	0.72 ±0.07	4.54 ±0.83	1.13 ±0.16	5.13 ±0.92
300	126.71 ±17.04	4.88	496.60 ±2.48	9.75 ±0.20	12.47 ±0.16	55.93 ±3.19	9.07 ±0.19	55	19.44 ±2.14	0.63 ±0.09	4.77 ±0.78	1.08 ±0.18	3.96 ±0.42
400	130.67 ±34.07	4.91	492.90 ±2.73	9.43 ±0.18	11.76 ±0.11	60.20 ±3.13	8.64 ±0.17	57	14.97 ±1.34	0.55 ±0.06	4.30 ±0.89	1.04 ±0.07	3.81 ±0.15
						after rooting of cutting							
0	134.47 ±33.75	5.57	404.30 ±2.99	9.45 ±0.25	5.67 ±0.10	4.19 ±0.10	9.63 ±0.24	42	7.17 ±0.52	3.70 ±0.57	8.92 ±0.28	1.19 ±0.09	4.62 ±0.35
200	142.54 ±16.86	5.50	424.80 ±2.49	9.66 ±0.82	5.08 ±0.17	3.90 ±0.12	9.18 ±0.19	46	7.76 ±0.91	1.52 ±0.10	7.83 ±0.37	1.73 ±0.13	3.79 ±0.34
300	150.38 ±17.05	5.50	418.60 ±2.98	8.58 ±0.32	9.22 ±0.10	8.04 ±0.12	9.86 ±0.22	38	9.60 ±0.60	2.09 ±0.13	10.41 ±0.82	1.69 ±0.11	4.80 ±0.44
400	162.26 ±16.53	5.56	439.00 ±2.75	9.88 ±0.32	3.60 ±0.11	3.60 ±0.11	10.08 ±0.26	42	10.80 ±0.60	1.98 ±0.19	7.83 ±0.33	1.94 ±0.10	3.73 ±0.37
						Ceres							
						before rooting of cutting							
0	150.46 ±44.99	5.69	416.60 ±2.74	11.55 ±0.18	11.04 ±0.11	26.01 ±0.19	8.96 ±0.25	46	30.01 ±1.15	0.73 ±0.13	31.32 ±1.23	1.00 ±0.11	6.18 ±0.23
200	158.36 ±34.07	5.75	415.73 ±4.84	11.21 ±0.15	15.74 ±0.29	23.16 ±0.20	9.18 ±0.22	45	29.05 ±1.05	0.56 ±0.09	25.89 ±1.30	0.99 ±0.02	5.15 ±0.48
300	166.30 ±59.02	5.76	410.60 ±2.74	10.92 ±0.10	9.97 ±0.16	17.81 ±0.18	9.86 ±0.19	42	22.48 ±1.92	0.62 ±0.08	21.89 ±1.47	0.78 ±0.03	5.00 ±0.19
400	170.25 ±34.06	5.69	405.20 ±3.66	11.05 ±0.12	11.76 ±0.18	12.82 ±0.15	9.41 ±0.26	43	22.96 ±1.25	0.81 ±0.06	33.84 ±1.17	0.94 ±0.06	5.93 ±0.12
						after rooting of cutting							
0	122.59 ±16.16	6.66	407.90 ±2.73	10.08 ±0.47	3.90 ±0.19	3.60 ±0.10	8.29 ±0.24	49	18.25 ±1.58	6.34 ±0.81	28.17 ±1.60	1.34 ±0.09	3.37 ±0.10
200	122.79 ±17.05	6.73	392.35 ±7.83	10.28 ±0.67	3.60 ±0.15	5.08 ±0.15	9.63 ±0.25	41	17.53 ±1.88	2.14 ±0.24	21.79 ±1.31	1.45 ±0.10	3.32 ±0.13
300	154.42 ±16.30	6.78	398.07 ±2.31	9.94 ±0.70	4.49 ±0.18	4.49 ±0.16	8.51 ±0.19	47	17.85 ±1.81	2.24 ±0.68	19.43 ±1.65	4.20 ±0.19	3.21 ±0.14
400	166.30 ±18.31	6.83	381.50 ±4.72	9.37 ±0.94	3.90 ±0.17	3.90 ±0.18	9.41 ±0.21	41	16.01 ±1.82	3.58 ±0.33	21.79 ±1.30	4.36 ±0.13	3.01 ±0.17

						Klasmann Steck Medium before rooting of cutting							
0	142.54 ±28.01	4.68	474.73 ±3.63	13.57 ±0.23	14.25 ±0.54	10.91 ±0.31	8.51 ±0.11	56	27.05 ±1.50	2.27 ±0.14	11.26 ±0.49	1.27 ±0.12	6.77 ±0.28
200	142.64 ±34.05	4.52	457.90 ±5.22	11.60 ±0.17	15.49 ±0.54	24.94 ±0.22	9.41 ±0.13	49	25.29 ±3.00	1.79 ±0.07	12.08 ±0.73	1.12 ±0.07	7.13 ±0.22
300	150.46 ±34.07	4.63	474.80 ±2.86	12.07 ±0.28	14.96 ±0.17	23.51 ±0.27	9.18 ±0.25	52	22.81 ±2.39	1.84 ±0.12	14.83 ±0.40	1.10 ±0.13	8.45 ±0.42
400	158.37 ±29.25	4.67	480.40 ±6.46	12.93 ±0.21	16.39 ±0.19	16.74 ±0.14	9.40 ±0.27	51	25.53 ±2.06	2.20 ±0.15	17.51 ±0.55	1.43 ±0.14	12.38 ±0.70
						after rooting of cutting							
0	138.51 ±15.61	5.52	423.23 ±2.91	12.67 ±0.52	3.01 ±0.14	3.31 ±0.11	9.86 ±0.22	43	9.44 ±0.91	13.44 ±1.89	13.51 ±0.85	1.74 ±0.06	4.41 ±0.23
200	142.54 ±21.02	5.29	392.65 ±6.58	11.43 ±0.84	4.49 ±0.10	3.60 ±0.14	8.96 ±0.19	44	10.08 ±1.03	8.69 ±1.29	14.08 ±0.35	1.48 ±0.11	5.14 ±0.27
300	154.42 ±29.51	5.30	420.50 ±3.73	12.47 ±0.47	3.90 ±0.10	3.90 ±0.16	8.96 ±0.24	47	10.56 ±1.03	6.37 ±0.85	14.20 ±0.30	1.34 ±0.15	4.50 ±0.26
400	158.22 ±16.88	5.39	418.67 ±2.91	12.03 ±0.22	3.90 ±0.16	3.60 ±0.11	9.18 ±0.21	46	11.61 ±1.92	9.32 ±1.37	14.42 ±0.56	1.65 ±0.17	4.05 ±0.24

IAA – indole-3-acetic acid, TOC – total organic carbon, C_{HWE} – hot water extractable organic carbon, $N\text{-}NH_4^+$ – ammonium ions, $N\text{-}NO_3^-$ – nitrate ions, N_{total} – total nitrogen $\overline{X} \pm \Delta X$ – confidence interval of average at confidence level $\alpha = 0.05$ for n-1 degree of freedom

Table 3 b. Chemical and biochemical properties of self-prepared growing media (70% vol.) + perlit (30% vol.) before and after rooting of cutting of *Hydrangea* L.

Addition IAA (µg kg^{-1})	IAA (µg kg^{-1})	pH (KCl)	TOC (g kg^{-1})	C_{HWE} (g kg^{-1})	N-NH_4^+ (mg kg^{-1})	N-NO_3^- (mg kg^{-1})	N_{total} (g kg^{-1})	C/N	Urease activity (µmol h^{-1} g^{-1})	Nitrate reductase activity (nmol h^{-1} g^{-1})	Phenol oxidase activity (µmol h^{-1} g^{-1})	Peroxidase activity (nmol h^{-1} g^{-1})	Xanthine oxidase activity (µmol h^{-1} g^{-1})
						GM1							
						before rooting of cutting							
0	122.73 ±16.99	2.68	432.20 ±6.71	14.51 ±0.33	69.47 ±3.10	25.65 ±1.19	11.20 ±0.16	39	42.10 ±2.08	0.38 ±0.05	11.01 ±0.73	2.11 ±0.18	3.11 ±0.47
200	122.78 ±16.99	2.69	443.10 ±4.25	15.45 ±0.17	70.89 ±5.09	21.37 ±1.18	12.32 ±0.14	36	44.66 ±2.38	0.46 ±0.05	10.96 ±0.17	1.91 ±0.11	3.45 ±0.35
300	126.71 ±34.07	2.69	442.10 ±4.22	15.41 ±0.13	68.00 ±4.11	24.94 ±1.15	11.87 ±0.15	37	37.45 ±1.04	0.43 ±0.03	12.14 ±0.37	2.33 ±0.24	3.59 ±0.33
400	146.49 ±34.98	2.71	415.10 ±5.24	15.71 ±0.25	71.25 ±5.13	23.16 ±1.16	11.42 ±0.12	36	45.38 ±2.60	0.29 ±0.03	10.74 ±0.88	2.46 ±0.17	4.42 ±0.54
						after rooting of cutting							
0	102.87 ±34.04	3.26	398.10 ±4.75	16.06 ±0.45	23.69 ±2.05	4.79 ±0.27	9.41 ±0.11	42	16.09 ±0.80	0.06 ±0.02	7.20 ±0.50	1.82 ±0.17	2.81 ±0.18
200	106.91 ±33.74	3.23	390.27 ±7.63	16.22 ±0.27	19.24 ±1.35	5.38 ±0.10	10.75 ±0.14	36	12.24 ±0.75	0.09 ±0.02	8.23 ±0.82	1.41 ±0.16	2.46 ±0.12
300	110.85 ±29.51	3.22	369.20 ±2.24	13.83 ±0.55	18.97 ±1.13	5.08 ±0.19	10.08 ±0.16	37	13.45 ±1.58	0.12 ±0.05	8.80 ±0.59	1.55 ±0.11	2.98 ±0.16
400	122.59 ±16.36	3.39	377.60 ±5.96	13.27 ±0.15	17.49 ±2.07	4.79 ±0.18	9.63 ±0.15	39	13.21 ±0.28	0.07 ±0.03	8.37 ±0.46	1.13 ±0.11	2.31 ±0.17
						GM2							
						before rooting of cutting							
0	150.46 ±27.04	6.11	489.70 ±4.99	7.11 ±0.10	47.02 ±2.35	33.49 ±2.08	10.30 ±0.25	48	17.05 ±0.46	0.34 ±0.09	9.17 ±0.64	0.63 ±0.05	2.76 ±0.32
200	150.76 ±33.72	6.14	482.80 ±4.72	7.46 ±0.13	50.23 ±3.09	28.50 ±2.10	10.53 ±0.22	46	16.09 ±1.04	0.41 ±0.04	8.11 ±0.81	0.78 ±0.06	2.73 ±0.45
300	154.42 ±34.07	6.14	483.20 ±7.70	6.95 ±0.16	42.39 ±4.09	31.70 ±3.08	10.98 ±0.24	44	15.85 ±0.17	0.49 ±0.07	8.39 ±0.30	0.84 ±0.06	2.89 ±0.45
400	158.22 ±29.51	6.18	483.83 ±8.32	7.07 ±0.32	48.45 ±3.13	24.22 ±3.09	10.52 ±0.21	46	15.61 ±1.05	0.66 ±0.07	8.72 ±0.81	0.62 ±0.08	2.91 ±0.44
						after rooting of cutting							
0	126.63 ±33.60	6.34	422.23 ±3.90	6.92 ±0.75	5.97 ±0.15	6.85 ±0.14	9.18 ±0.17	46	8.88 ±0.15	1.68 ±0.16	12.87 ±0.64	2.13 ±0.14	1.88 ±0.17
200	134.47 ±33.89	6.26	428.97 ±2.81	6.73 ±0.70	12.17 ±0.17	8.63 ±0.18	9.86 ±0.14	44	9.12 ±0.92	1.42 ±0.18	11.98 ±0.55	2.03 ±0.18	1.80 ±0.10
300	138.51 ±16.89	6.36	424.57 ±3.06	6.31 ±0.20	10.56 ±0.18	6.26 ±0.17	8.51 ±0.12	50	11.28 ±0.14	1.50 ±0.24	13.14 ±0.35	3.46 ±0.15	2.08 ±0.22
400	146.35 ±34.28	6.22	413.53 ±5.89	6.50 ±0.12	16.90 ±0.12	9.61 ±0.28	8.29 ±0.15	50	10.08 ±1.57	1.12 ±0.18	12.99 ±0.62	1.44 ±0.16	2.94 ±0.15

						GM3 before rooting of cutting							
0	122.73 ±35.03	4.34	435.00 ±2.24	8.42 ±0.38	44.53 ±2.09	19.59 ±1.10	10.08 ±0.11	43	21.13 ±1.04	0.23 ±0.09	5.02 ±0.11	0.66 ±0.02	3.76 ±0.15
200	134.61 ±17.04	4.30	444.10 ±3.48	8.57 ±0.32	59.13 ±3.09	30.28 ±3.29	9.86 ±0.17	45	21.37 ±2.40	0.23 ±0.08	4.21 ±0.64	0.65 ±0.05	3.38 ±0.13
300	138.58 ±16.98	4.31	442.10 ±4.75	8.47 ±0.13	70.89 ±4.11	32.42 ±3.11	8.96 ±0.12	49	20.89 ±2.16	0.23 ±0.07	4.06 ±0.72	0.82 ±0.07	3.60 ±0.14
400	146.49 ±34.04	4.30	444.00 ±3.23	8.34 ±0.22	83.72 ±3.11	36.69 ±3.28	9.18 ±0.14	48	22.57 ±1.79	0.21 ±0.08	5.94 ±0.22	0.69 ±0.04	3.60 ±0.15
						after rooting of cutting							
0	106.91 ±29.51	5.20	386.75 ±8.07	8.56 ±0.37	12.76 ±0.10	7.44 ±0.17	7.62 ±0.11	51	13.20 ±2.60	2.87 ±0.15	8.45 ±0.84	2.92 ±0.17	2.43 ±0.15
200	114.75 ±16.88	5.35	379.90 ±4.99	7.62 ±0.82	9.81 ±0.17	12.17 ±0.15	7.39 ±0.14	51	14.09 ±1.40	3.43 ±0.18	6.24 ±0.60	3.30 ±0.15	2.17 ±0.29
300	126.63 ±16.88	5.15	365.67 ±3.32	8.97 ±0.37	10.40 ±0.18	10.99 ±0.11	7.84 ±0.13	47	12.48 ±1.28	1.41 ±0.06	9.17 ±0.26	4.94 ±0.17	3.25 ±0.35
400	138.51 ±33.60	5.22	378.40 ±6.96	8.45 ±0.79	8.63 ±0.15	8.64 ±0.15	7.39 ±0.12	51	13.21 ±1.55	1.56 ±0.10	6.13 ±0.15	5.49 ±0.16	2.45 ±0.13

IAA – indole-3-acetic acid, TOC – total organic carbon, C_{HWE} – hot water extractable organic carbon, $N\text{-}NH_4^+$ – ammonium ions, $N\text{-}NO_3^-$ – nitrate ions, N_{total} – total nitrogen $\overline{X} \pm \Delta X$ – confidence interval of average at confidence level $\alpha = 0.05$ for n-1 degree of freedom

nitrogen concentrations are distinctly reflected in chemical, and indirectly, in the physical, properties of soil transformation [Sokolov et al. 2008].

Our investigations showed a statistically significantly lower contents of $N\text{-}NH_4^+$ and $N\text{-}NO_3^-$ ions after than before rooting of cuttings of *Hydrangea* L. and *Euphorbia pulcherrima* in all growing media (tab. 3 a–d). *Euphorbia pulcherrima* cultivation reduced the content of ammonium ions from 66 to 95% and nitrate ions from 66 to 97% in all investigated growing media. Furthermore, the decrease of the contents of $N\text{-}NH_4^+$ after rooting of cuttings *Hydrangea* L. ranged from 26 to 90% and $N\text{-}NO_3^-$ from 60 to 94% in all tested growing media. The contents of ammonium and nitrate ions for *Hydrangea* L. are in line with TOC in all growing media (tab. 3 a–d).

The content of total nitrogen ranged from 8.51 to 12.32 g kg^{-1} before and from 7.39 to 10.75 g kg^{-1} after rooting of cuttings of *Hydrangea* L. for all growing media (tab. 3 a, b). Whereas, the concentration of total nitrogen ranged from 7.84 to 14.56 g kg^{-1} before and from 9.24 to 13.16 ±0.42 g kg^{-1} after rooting of cuttings of *Euphorbia pulcherrima* in growing media (tab. 3 c, d).

The results indicated significant lowering of total nitrogen amount (from 13 to 16% for GM1, from 6 to 23% for GM2 and from 13 to 25% for GM3) after rooted cuttings of *Hydrangea* L. (tab. 3 a, b). Furthermore, significant decrease of total nitrogen content from 21 to 27% for GM2 after rooting of cuttings of *Euphorbia pulcherrima* was observed (tab. 3 d). Low total nitrogen amount is in line with TOC, $N\text{-}NH_4^+$ and $N\text{-}NO_3^-$ concentration after rooting of cuttings of *Hydrangea* L. for GM1, GM2 and GM3.

However, some of the results reveal that the contents of total nitrogen were significantly higher from 12 to 21% for Aura and from 9 to 16% for Klasmann Steck Medium [Szajdak et al. 2013] after than before rooting of cuttings of *Euphorbia pulcherrima* (tab. 3 c, d). The increase of total nitrogen amount agrees with of TOC and C_{HWE} concentration under *Euphorbia pulcherrima* in these growing media.

The nitrogen concentration of organic residues, as reflected through the C/N ratio, is of primary importance in regulating the magnitude of the two opposing processes such as mineralization and immobilization [Goyal et al. 1993].

The results indicated that the C/N ratio was significantly lower after (from 17 to 24% for Aura and from 9 to 23% for Klasmann Steck Medium) than before rooting of cuttings for *Hydrangea* L. (tab. 3 a). The decrease of C/N value agrees with TOC, $N\text{-}NH_4^+$ and $N\text{-}NO_3^-$ concentration for these growing media. However, significant increase of C/N ratio from 3 to 18% for GM2 after rooting of cuttings of *Euphorbia pulcherrima* was observed (tab. 3 d). Moreover, the increase of C/N value agrees with TOC content under *Euphorbia pulcherrima* for Aura, Ceres, Klasmann Steck Medium and GM1.

Biochemical properties of growing media. The specific groups of bacteria, collectively known as rhizobia, induce the formation of root or stem nodules of leguminous plants and establish a nitrogen-fixing symbiosis. Apart from, nitrogen fixation, ammonia can be obtained from the other metabolic processes such as urease production and ammonification [Pongsilp and Boonkerd 2007]. The results of Yang et al. [2011] indicated that enzymes in rhizosphere soil play essential roles in soil processes such as nutrient cycling and energy transformation by catalyzing numerous chemical, physical and biological reactions. They are mainly exuded by roots and microorganisms and their

activities can also have significant effects contributing to the changes of nutrients. Szajdak and Maryganova [2009] suggested that the soil flora also produces appreciable amounts of auxin under natural condition, particularly when organic material is present to support microbial growth.

Statistically significant lower of urease activity was observed after rooting of cuttings of *Hydrangea* L. in all growing media (tab. 3 a, b). Results indicated that decrease activity of this enzyme was the highest in self-prepared growing media GM1 (from 62 to 73%) (tab. 3 b). The decrease of urease activity after rooting of cuttings of *Hydrangea* L. is in line with the concentration of TOC, ammonium and nitrate ions for all growing media and agrees with total nitrogen content in GM1, GM2 and GM3.

Furthermore, an opposite trend was showed for rooting of cuttings of *Euphorbia pulcherrima*. All growing media characterized by statistically significant increase of urease activity after rooting of cuttings of *Euphorbia pulcherrima* (tab. 3 c, d). The highest increase of urease was determined in commercial growing media Aura (about four times) (tab. 3 c). This data agrees with the increase of TOC amounts. The results suggest that the urease activity depends on ornamental plant and growing media.

Denitrification is one of the important causes of nitrogen loss in soil. Under anaerobic conditions, NO_3^- is reduced to NO_2^- by nitrate reductase [Ma 2000]. Potential for denitrification in soils is a complex interaction among aeration, nitrate availability, carbon substrate availability and other intrinsic soil factors as pH and temperature [Firestone 1982]. Our results showed statistically significant increase of nitrate reductase activity after rooted cuttings of both ornamental plants *Hydrangea* L. and *Euphorbia pulcherrima* (tab. 3 a–d). The highest nitrate reductase activity for rooting of cuttings of *Hydrangea* L. (before 0.21–0.23 and after 1.41–3.43 nmol h^{-1} g^{-1}) and *Euphorbia pulcherrima* (before 0.06–0.19 and after 9.51–14.00 nmol h^{-1} g^{-1}) in self-prepared growing media GM3 was determined (tab. 3 b, d). The increase of nitrate reductase activity after rooting of cuttings of ornamental plants is in line with TOC content and urease activity only for *Euphorbia pulcherrima* (tab. 3 c, d). However, statistically significant decrease activity of this enzyme (73–83%) was observed in self-prepared growing media GM1 for rooting of cuttings of *Hydrangea* L. (tab. 3 b). This media also was characterized by the lowest pH values. The decline of nitrate reductase activity in GM1 after rooting of cutting of *Hydrangea* L. agrees with the amount of TOC, $N\text{-}NH_4^+$, $N\text{-}NO_3^-$, total nitrogen and urease activity (tab. 3 a, b).

Phenolic compounds are integral component of plants, carrying out in the course of their viability various functions, including structural and basic. They are stimulators and growth inhibitors, and carrying out protective functions, show anti-oxidation, antibacterial, insecticidal activity [Tomson et al. 2010]. It is well known, that phenolic compounds are the component of auxin protectors and controllers of IAA activity. Phenolic content and IAA-oxidase (IAA-o) activity have been assayed in cells and medium of tobacco crown gall suspension culture in several stages of culture cycle. The highest content of total phenolics in the cells was found prior to cell division and in the middle stage of intensive growth. The beginning of intensive growth is accompanied by temporary reduction in phenolic level in the cells as well as their intensive secretion to the medium [Chirek 1990].

Table 3 c. Chemical and biochemical properties of commercial growing media before and after rooting of cutting of *Euphorbia pulcherrima*

Addition IAA ($\mu g\ kg^{-1}$)	IAA ($\mu g\ kg^{-1}$)	pH (KCl)	TOC ($g\ kg^{-1}$)	C_{HWE} ($g\ kg^{-1}$)	$N\text{-}NH_4^+$ ($mg\ kg^{-1}$)	$N\text{-}NO_3^-$ ($mg\ kg^{-1}$)	N_{total} ($g\ kg^{-1}$)	C/N	Urease activity ($\mu mol\ h^{-1}\ g^{-1}$)	Nitrate reductase activity ($nmol\ h^{-1}\ g^{-1}$)	Phenol oxidase activity ($\mu mol\ h^{-1}\ g^{-1}$)	Peroxidase activity ($nmol\ h^{-1}\ g^{-1}$)	Xanthine oxidase activity ($\mu mol\ h^{-1}\ g^{-1}$)
						Aura							
						before rooting of cutting							
0	114.75 ±33.74	4.99	414.10 ±2.73	8.30 ±0.44	17.45 ±0.19	26.47 ±1.14	11.20 ±0.70	37	4.72 ±0.13	0.19 ±0.03	4.54 ±0.78	1.31 ±0.13	3.74 ±0.19
200	118.79 ±16.87	5.02	411.80 ±3.49	8.64 ±0.77	19.89 ±0.18	33.47 ±2.12	10.64 ±0.52	39	5.04 ±0.21	0.23 ±0.04	4.76 ±0.46	1.24 ±0.09	3.81 ±0.14
300	127.70 ±19.18	5.00	407.60 ±2.99	7.88 ±0.49	26.92 ±0.35	31.79 ±2.10	11.76 ±0.43	35	4.72 ±0.18	0.30 ±0.12	4.57 ±0.22	1.12 ±0.08	3.69 ±0.16
400	134.47 ±26.81	5.00	405.50 ±2.73	8.47 ±0.26	22.33 ±0.13	28.89 ±1.18	10.92 ±0.55	37	5.36 ±0.23	0.37 ±0.15	4.81 ±0.55	0.88 ±0.06	3.87 ±0.12
						after rooting of cutting							
0	95.03 ±19.59	5.91	443.30 ±4.41	10.20 ±0.42	3.15 ±0.15	2.07 ±0.17	11.76 ±0.27	38	15.13 ±0.84	6.50 ±0.74	15.38 ±1.69	1.04 ±0.05	5.67 ±0.13
200	122.73 ±16.97	5.74	442.50 ±3.74	10.99 ±0.51	4.37 ±0.17	2.45 ±0.18	12.88 ±0.28	34	24.57 ±1.60	7.60 ±0.87	16.27 ±3.22	0.80 ±0.01	6.02 ±0.40
300	126.70 ±34.04	5.52	439.70 ±8.20	10.34 ±0.16	3.88 ±0.18	3.04 ±0.16	13.16 ±0.42	33	14.57 ±1.16	10.94 ±1.45	11.44 ±1.39	0.80 ±0.03	5.14 ±0.27
400	146.49 ±16.97	5.46	439.45±6.02	10.65 ±0.15	5.08 ±0.11	3.57 ±0.20	12.88 ±0.38	34	16.89 ±1.58	12.63 ±1.31	10.12 ±2.94	1.15 ±0.05	4.00 ±0.14
						Ceres							
						before rooting of cutting							
0	102.94 ±34.07	4.88	296.50 ±2.37	10.62 ±0.81	49.40 ±0.57	51.98 ±3.17	8.96 ±0.56	29	7.12 ±0.61	0.88 ±0.26	33.02 ±5.09	1.63 ±0.09	5.62 ±0.55
200	110.71 ±33.74	4.35	353.30 ±3.74	10.72 ±0.71	35.52 ±0.33	60.62 ±4.15	7.84 ±0.89	45	6.16 ±0.46	0.33 ±0.08	22.95 ±8.04	1.72 ±0.11	5.38 ±0.49
300	118.79 ±16.87	5.52	356.20 ±2.73	11.60 ±0.30	36.83 ±0.67	42.96 ±4.22	8.96 ±0.70	40	10.64 ±1.13	0.47 ±0.08	33.79 ±2.85	1.30 ±0.11	5.54 ±0.64
400	114.75 ±19.18	5.84	359.90 ±4.35	12.38 ±0.59	35.65 ±0.22	47.54 ±4.31	8.96 ±0.75	40	10.40 ±0.82	0.36 ±0.06	27.82 ±4.43	0.73 ±0.05	5.66 ±0.77
						after rooting of cutting							
0	110.85 ±34.04	6.37	342.35 ±9.07	9.17 ±0.29	8.52 ±0.20	4.59 ±0.23	9.52 ±0.28	36	25.53 ±1.34	23.64 ±1.50	60.83 ±4.83	1.26 ±0.09	8.06 ±0.15
200	114.75 ±17.02	5.82	371.55 ±8.82	12.48 ±0.30	6.35 ±0.14	2.06 ±0.12	9.52 ±0.68	39	18.01 ±0.77	24.16 ±1.40	60.47 ±5.10	1.06 ±0.06	7.91 ±0.16
300	126.70 ±16.87	6.37	385.20 ±6.71	10.31 ±0.16	7.45 ±0.18	3.34 ±0.15	10.64 ±0.49	36	28.49 ±1.17	22.13 ±1.35	48.12 ±2.07	1.05 ±0.02	8.17 ±0.20
400	134.61 ±16.97	6.53	360.65 ±2.86	9.17 ±0.19	5.49 ±0.16	3.13 ±0.15	10.08 ±0.42	36	26.97 ±1.24	27.66 ±1.45	61.57 ±5.78	2.16 ±0.09	9.32 ±0.25

Klasmann Steck Medium before rooting of cutting													
0	128.29 ±35.74	4.58	391.30 ±5.22	10.47 ±0.47	25.59 ±0.26	54.20 ±3.16	8.96 ±0.70	44	9.36 ±0.70	0.86 ±0.07	8.06 ±1.06	1.34±0.14	6.13 ±0.31
200	134.47 ±27.59	4.65	393.70 ±9.32	10.96 ±0.51	43.56 ±0.22	43.37 ±4.28	9.52 ±0.42	41	9.76 ±0.82	0.92 ±0.10	9.62 ±1.04	1.22±0.09	8.88 ±0.84
300	134.87 ±35.90	4.72	388.10 ±3.23	10.94 ±1.04	40.84 ±0.36	42.35 ±4.13	9.56 ±0.49	41	9.12 ±0.50	1.19 ±0.21	9.20 ±1.23	2.59±0.10	7.23 ±1.01
400	142.54 ±33.74	4.72	395.20 ±3.11	7.33 ±0.60	27.01 ±0.18	37.77 ±3.12	9.62 ±0.11	42	8.32 ±0.36	1.31 ±0.14	9.96 ±1.78	1.26±0.08	6.77 ±0.81
after rooting of cutting													
0	158.37 ±34.06	5.01	425.20 ±4.47	14.52 ±0.60	7.89 ±0.11	3.94 ±0.25	10.08 ±0.70	42	15.13 ±0.75	12.53 ±1.65	10.81 ±0.72	0.95 ±0.04	4.13 ±0.22
200	170.25 ±20.59	5.16	421.70 ±5.99	12.81 ±0.28	4.40 ±0.16	4.93 ±0.16	10.36 ±0.28	41	16.65 ±0.51	15.01 ±1.29	12.99 ±0.43	1.01 ±0.05	5.85 ±0.57
300	182.12 ±34.02	5.27	426.35 ±7.08	14.47 ±0.32	2.43 ±0.14	2.19 ±0.27	10.92 ±0.42	39	19.29 ±0.96	12.86 ±1.48	9.62 ±0.94	0.54 ±0.02	4.03 ±0.10
400	190.06 ±17.00	5.41	433.70 ±10.18	13.81 ±0.39	3.24 ±0.15	1.11 ±0.15	11.20 ±0.14	39	16.81 ±0.73	16.40 ±1.11	13.11 ±0.55	0.59 ±0.03	5.41 ±0.15

IAA – indole-3-acetic acid, TOC – total organic carbon, C_{HWE} – hot water extractable organic carbon, $N\text{-}NH_4^+$ – ammonium ions, $N\text{-}NO_3^-$ – nitrate ions, N_{total} – total nitrogen $\overline{X} \pm \Delta X$ – confidence interval of average at confidence level $\alpha = 0.05$ for n-1 degree of freedom

Table 3 d. Chemical and biochemical properties of self-prepared growing media (70% vol.) + perlit (30% vol.) before and after rooting of cutting of *Euphorbia pulcherrima*

Addition IAA ($\mu g\ kg^{-1}$)	IAA ($\mu g\ kg^{-1}$)	pH (KCl)	TOC ($g\ kg^{-1}$)	C_{HWE} ($g\ kg^{-1}$)	$N\text{-}NH_4^+$ ($mg\ kg^{-1}$)	$N\text{-}NO_3^-$ ($mg\ kg^{-1}$)	N_{total} ($g\ kg^{-1}$)	C/N	Urease activity ($\mu mol\ h^{-1}\ g^{-1}$)	Nitrate reductase activity ($nmol\ h^{-1}\ g^{-1}$)	Phenol oxidase activity ($\mu mol\ h^{-1}\ g^{-1}$)	Peroxidase activity ($nmol\ h^{-1}\ g^{-1}$)	Xanthine oxidase activity ($\mu mol\ h^{-1}\ g^{-1}$)
						GM1							
						before rooting of cutting							
0	118.79 ±14.72	2.76	359.50 ±8.65	15.35 ±0.38	75.39 ±8.23	61.72 ±1.17	9.52 ±0.70	38	8.36 ±0.84	0.07 ±0.02	10.62 ±1.41	1.84 ±0.10	2.31 ±0.11
200	126.63 ±24.59	2.76	369.40 ±2.68	16.84 ±0.63	80.95 ±6.31	76.84 ±2.13	10.08 ±0.28	37	9.60 ±0.72	0.06 ±0.02	11.98 ±1.94	1.62 ±0.08	2.81 ±0.15
300	130.67 ±16.87	2.76	366.50 ±11.06	14.33 ±0.38	72.56 ±6.79	61.41 ±2.25	9.52 ±0.42	38	8.64 ±0.66	0.06 ±0.02	13.77 ±1.35	2.94 ±0.16	2.01 ±0.11
400	138.51 ±16.87	2.76	360.20 ±6.21	16.40 ±0.47	68.90 ±5.85	55.91 ±1.14	9.52 ±0.48	38	7.78 ±0.44	0.07 ±0.02	12.56 ±0.73	2.43 ±0.17	2.92 ±0.16
						after rooting of cutting							
0	114.75 ±16.87	3.71	356.80 ±10.59	14.06 ±0.23	13.44 ±0.36	10.03 ±0.53	9.52 ±0.70	37	11.70 ±0.84	0.28 ±0.09	13.84 ±0.68	2.99 ±0.17	4.61 ±0.18
200	118.79 ±16.87	3.38	388.40 ±5.71	16.84 ±0.41	18.79 ±0.38	16.42 ±0.51	10.64 ±0.42	37	16.21 ±1.00	0.34 ±0.04	10.90 ±0.65	3.32 ±0.16	4.89 ±0.14
300	126.70 ±16.87	3.95	343.90 ±5.96	12.07 ±0.14	17.65 ±0.49	19.79 ±0.47	9.24 ±0.43	37	10.95 ±0.39	0.36 ±0.03	15.89 ±0.23	2.39 ±0.17	6.46 ±0.12
400	138.51 ±25.90	3.57	387.90 ±6.71	16.72 ±0.60	23.30 ±0.72	18.79 ±0.34	10.92 ±0.48	36	17.41 ±0.68	0.53 ±0.05	9.58 ±0.42	1.76 ±0.10	3.32 ±0.16
						GM2							
						before rooting of cutting							
0	142.54 ±19.77	5.95	411.30 ±6.75	6.91 ±0.39	62.35 ±1.18	63.13 ±2.28	14.56 ±0.70	28	3.75 ±0.13	0.12 ±0.04	8.52 ±0.43	1.84 ±0.10	3.43 ±0.17
200	142.74 ±16.87	5.94	409.20 ±10.21	6.77 ±0.55	55.91 ±3.81	62.46 ±4.16	13.44 ±0.42	30	3.65 ±0.15	1.07 ±0.14	8.61 ±0.45	1.20 ±0.05	2.99 ±0.12
300	148.48 ±14.75	5.95	417.10 ±2.12	6.88 ±0.60	57.72 ±4.86	59.04 ±3.27	14.56 ±0.56	29	4.13 ±0.20	1.33 ±0.24	8.54 ±0.59	1.48 ±0.08	3.03 ±0.16
400	162.26 ±25.90	5.96	415.00 ±7.33	6.72 ±0.32	50.37 ±3.57	60.42 ±4.32	14.56 ±0.70	29	3.84 ±0.15	1.27 ±0.33	9.01 ±0.21	1.15 ±0.04	3.04 ±0.16
						after rooting of cutting							
0	126.63 ±16.87	6.26	429.15 ±9.01	7.30 ±0.38	6.90 ±0.11	3.20 ±0.19	10.92 ±0.28	39	9.00 ±0.58	5.95 ±0.34	11.38 ±1.66	0.22 ±0.01	4.33 ±0.15
200	130.67 ±29.51	6.20	432.05 ±9.00	7.24 ±0.50	7.45 ±0.20	3.90 ±0.16	10.64 ±0.42	41	9.15 ±0.35	6.25 ±0.33	12.62 ±1.16	0.20 ±0.02	3.87 ±0.16
300	142.54 ±16.87	6.19	436.65 ±4.16	7.52 ±0.64	7.69 ±0.13	4.30 ±0.23	10.92 ±0.14	40	8.55 ±0.23	5.46 ±0.25	10.73 ±0.70	0.25 ±0.03	3.49 ±0.12
400	162.26 ±22.95	6.36	435.30 ±8.90	6.78 ±0.25	7.90 ±0.14	4.80 ±0.12	10.64 ±0.42	41	11.10 ±0.60	6.79 ±0.12	14.42 ±0.76	0.14 ±0.02	4.24 ±0.13

						GM3 before rooting of cutting						
0	102.87 ±33.73	4.35	384.80 ±7.46	8.72 ±0.68	34.65 ±0.74	23.20 ±0.11	9.52 ±0.70	40	5.19 ±0.45	0.06 ±0.02	4.60 ±0.50	1.31 ±0.05	5.37 ±0.11
200	110.71 ±33.74	4.35	378.50 ±5.59	7.97 ±0.26	21.59 ±0.45	18.45 ±0.17	10.64 ±0.28	36	5.47 ±0.32	0.19 ±0.09	4.41 ±0.43	1.30 ±0.04	3.56 ±0.18
300	122.73 ±29.51	4.35	389.90 ±8.97	8.66 ±0.57	26.48 ±0.58	19.62 ±0.12	9.52 ±0.42	41	8.16 ±0.38	0.13 ±0.04	4.45 ±0.31	1.66 ±0.05	3.69 ±0.15
400	130.67 ±17.04	4.35	390.70 ±7.83	7.94 ±0.68	32.04 ±0.44	19.47 ±0.28	9.52 ±0.56	41	9.89 ±0.37	0.19 ±0.05	4.89 ±0.84	1.46 ±0.08	3.69 ±0.16
						after rooting of cutting						
0	95.03 ±28.95	4.97	420.05 ±7.33	10.28 ±0.37	1.74 ±0.17	4.52 ±0.19	10.08 ±0.42	42	10.50 ±0.47	9.51 ±1.17	8.40 ±0.53	0.54 ±0.02	4.24 ±0.16
200	106.91 ±29.51	5.51	426.15 ±5.78	8.66 ±0.35	1.99 ±0.11	3.06 ±0.15	9.80 ±0.28	43	13.51 ±0.74	11.24 ±1.26	10.12 ±1.18	0.46 ±0.01	3.77 ±0.17
300	107.91 ±16.87	5.69	383.30 ±2.24	9.09 ±0.45	3.74 ±0.26	4.17 ±0.20	9.52 ±0.14	40	13.06 ±0.78	14.00 ±1.10	16.12 ±0.94	0.49 ±0.02	6.77 ±0.16
400	114.75 ±29.55	5.69	391.05 ±6.27	10.71 ±0.33	3.49 ±0.22	3.65 ±0.19	10.08 ±0.56	39	13.96 ±0.44	11.85 ±1.24	14.69 ±0.91	0.37 ±0.01	5.79 ±0.29

IAA – indole-3-acetic acid, TOC – total organic carbon, C_{HWE} – hot water extractable organic carbon, $N\text{-}NH_4^+$ – ammonium ions, $N\text{-}NO_3^-$ – nitrate ions, N_{total} – total nitrogen $\bar{x} \pm \Delta x$ – confidence interval of average at confidence level $\alpha = 0.05$ for n-1 degree of freedom

Oxidation of phenolic compounds to quinines catalyzes the phenol oxidase. The activity of extracellular phenol oxidases may therefore affect the retention of carbon in the litter and soil environment directly via the breakdown recalcitrant organic matter, and indirectly by releasing extracellular hydrolase enzymes from phenolic inhibition [Sinsabaugh 2010].

The addition of 200, 300 and 400 μg kg^{-1} IAA significantly increased phenol oxidase activity in Aura (from 72 to 122%), GM2 (from 40 to 57%) of *Hydrangea* L. and in Aura (from 111 to 242%), Ceres (from 42 to 163%), Klasmann Steck Medium (from 24 to 35%) [Szajdak et al. 2013], GM2 (from 26 to 60%) and GM3 (from 82 to 262%) of *Euphorbia pulcherrima* after rooting of cutting of plants than before planting (tab. 3 a–d). Opposite effect was noticed in Ceres and GM1 of *Hydrangea* L. Significant decrease of phenol oxidase activity ranged from 10 to 36% in Ceres and from 22 to 35% in GM1 after rooting of cutting of this plant (tab. 3 a, b). The highest activity of phenol oxidase from 48.12 to 61.57 μmol h^{-1} g^{-1} in Ceres after rooting of cuttings of *Euphorbia pulcherrima* and the lowest in Aura (from 4.01 to 4.77 μmol h^{-1} g^{-1}) before rooting of cuttings of *Hydrangea* L. was observed (tab. 3 a, c). Therefore, phenol oxidase activity is in line with the changes of TOC, C_{HWE}, $N\text{-}NH_4^+$, $N\text{-}NO_3^-$ urease activity in Ceres, nitrate reductase activity in Aura, GM2, GM3 and TOC, C_{HWE}, $N\text{-}NH_4^+$, $N\text{-}NO_3^-$, total nitrogen, urease and nitrate reductase activity in GM1 of *Hydrangea* L. Also, phenol oxidase activity agrees with the values of TOC, C_{HWE} in Aura, Klasmann Steck Medium, GM2, TOC, total nitrogen in Ceres, C_{HWE} in GM3 and urease and nitrate reductase activity in Aura, Ceres, Klasmann Steck Medium, GM2, GM3 of *Euphorbia pulcherrima*.

Peroxidases regulate growth in different ways, being associated with cell elongation processes but also with reactions that restrict growth. These enzymes can oxidize various phenolic substrates in the presence of H_2O_2-producting polymeric products such as lignin and suberin or cross-linking wall polymers leading to its stiffening and inhibition of elongation [Dragišić-Maksimović et al. 2008]. During recent years, extracellular peroxidases have been involved in cell wall phenolic cross-linking and probably also in IAA catabolism. In this case, these enzymes, which are constitutive enzymes of the cell wall and intercellular spaces, would apparently be regulated in both their catalytic activity and protein level during well-defined stages of plant cell growth [García-Florenciano et al. 1991]. Klisurska and Dencheva [1983] noted that the elucidation of the interrelationship between peroxidase and IAA-oxidase in the control of growth and differentiation of the plant cells concerns the question of the nature of the protein molecule residence of IAA-oxidase activity which is of a great theoretical and practical significance. They noted that increase of the peroxidase and IAA-oxidase activity in the differentiation zone of the primary root coincides with the accumulation of the greatest quantities, diversity in the composition of the phenol compounds in the end of the elongation zone.

The study showed that the addition of 200, 300 and 400 μg kg^{-1} IAA significantly increase the peroxidase activity in Aura (from 53 to 86%), Ceres (from 33 to 439%), GM2 (from 134 to 310%) and GM3 (from 342 to 692%) after rooting of cutting of *Hydrangea* L. (tab. 3 a, b). Opposite trend was confirmed in rooting of cuttings of *Euphorbia pulcherrima*. Peroxidase activity decreased significantly in Klasmann Steck Medium (from 17 to 79%) [Szajdak et al. 2013], GM2 (from 83 to 88%) and GM3 (from 59 to 75%) after rooting of cutting of this plant (tab. 3 c, d). However, the lowest activities of peroxidase were found in GM2 (from 0.14 to 0.25 nmol h^{-1} g^{-1}) of *Euphorbia pul-*

cherrima and the highest in GM3 (from 2.92 to 5.49 nmol h^{-1}) of *Hydrangea* L. after rooting of cutting of both plants (tab. 3 b, d).

For *Hydrangea* L. the peroxidase activity is in line with the changes of nitrate reductase activity in Ceres and Klasmann Steck Medium, nitrate reductase and phenol oxidase activity in Aura, GM2 and GM3. Furthemore, this enzyme activity agrees with TOC, $N\text{-}NH_4^+$, $N\text{-}NO_3^-$, activites of urease, nitrate reductase, phenol oxidase in GM1 of *Hydrangea* L. Additionally, peroxidase activity is in line with the values of $N\text{-}NH_4^+$, $N\text{-}NO_3^-$ in Klasmann Steck Medium, GM2 and GM3 of *Euphorbia pulcherrima*.

Xanthine oxidase catalyzes the oxidation of hypoxanthine to xanthine and next to the uric acid, although it has low substrate specificity, oxidizing also several purines and aldehydes at a lower rate [Masuoka and Kubo 2004]. According to Montalbini [1992] highly active purine biosynthesis and purine oxidative degradation are metabolic features of nodules-the specialized organs produced by symbiotic association of many plants and N_2-fixing bacteria.

The addition of 200, 300 and 400 μg kg^{-1} IAA indicated significant decrease of xanthine oxidase activity in Ceres (from 36 to 49%) and Klasmann Steck Medium (from 28 to 67%) after rooting of cuttings of *Hydrangea* L. (tab. 3 a, b). Opposite effect was noticed for rooting of cuttings of *Euphorbia pulcherrima*, where significant increase in xanthine oxidase activity in Ceres (from 43 to 65%), GM1 (from 42 to 222%), GM2 (from 15 to 39%) after rooting of cutting of this plant was observed (tab. 3 c, d). The lowest activity of this enzyme was in GM2 (from 1.80 to 2.94 μmol h^{-1} g^{-1}) after rooting of cuttings of *Hydrangea* L., but the highest in Klasmann Steck Medium (from 6.77 to 12.38 μmol h^{-1} g^{-1}) before rooting of cutting of this plant (tab. 3 a, b).

Moreover, for *Hydrangea* L. the xanthine oxidase activity is in line with the changes of TOC, C_{HWE}, $N\text{-}NH_4^+$, $N\text{-}NO_3^-$, urease and phenol oxidase activity in Ceres. However, for this plant xanthine oxidase activity agrees with TOC, $N\text{-}NH_4^+$, $N\text{-}NO_3^-$ and urease activity in Klasmann Steck Medium. It was documented that xanthine oxidase activity is in line with the changes of TOC, $N\text{-}NH_4^+$, $N\text{-}NO_3^-$, total nitrogen and activity of urease, nitrate reductase, phenol oxidase and peroxidase in GM1 of *Hydrangea* L. Furthermore, this enzyme activity agrees with the values of $N\text{-}NH_4^+$, $N\text{-}NO_3^-$ and peroxidase activity in Klasmann Steck Medium, TOC, activity of urease, nitrate reductase, phenol oxidase in Aura, Ceres, GM2, urease and nitrate reductase activity in GM1 of *Euphorbia pulcherrima*.

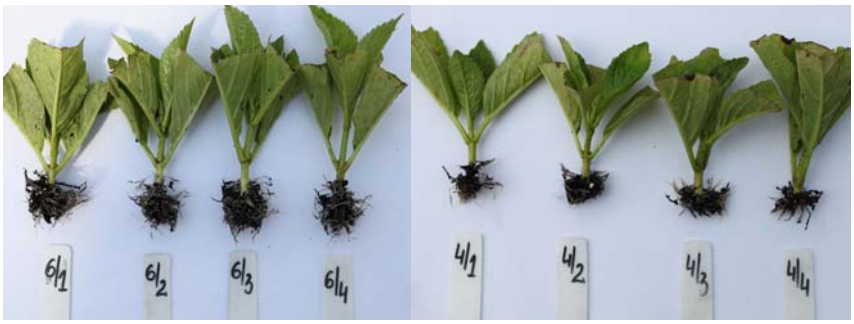
Evaluation of rooted cuttings of two ornamental plants. The study showed that adding of 200, 300 and 400 μg kg^{-1} IAA to the commercial and self-prepared growing media significantly influenced on rooting of cuttings of *Hydrangea* L. and *Euphorbia pulcherrima*. According to assessment of root system, length of roots, fresh and dry mass of roots the best rooting of cuttings of *Hydrangea* L. in neutralized white peat GM2 was observed (tab. 4, fig. 1). Also, it was determined 100% of rooted cuttings of *Hydrangea* L. with all addition of IAA in GM2 and the best assessment of root system was obtained with the addition of IAA 300 μg kg^{-1}. However, there was no significant effect of IAA doses on root system, length of roots, fresh and dry mass of roots in Ceres for rooting of cutting of *Hydrangea* L. In Ceres the percentage of rooted cuttings was between 80.0 and 97.5%.

The lowest assessment of root system was showed for rooting of cutting of *Hydrangea* L. in Klasmann Steck Medium, GM1, GM3 (except GM3 with 400 μg kg^{-1} IAA) (tab. 4,

Table 4. The impact of growing media with addition of IAA on rooting of cutting of *Hydrangea* L.

Growing media		IAA ($\mu g\ kg^{-1}$)	Assessment of root system (EPPO)	Length of roots (cm)	Fresh mass of roots (g $plant^{-1}$)	Dry mass of roots (g $plant^{-1}$)	% of rooted cuttings
Commercial growing media	Aura	0	2.39 ab	1.95 a–c	0.20 a–e	0.03 ab	97.5
		200	2.74 b–d	1.70 a	0.15 ab	0.02 a	87.5
		300	2.65 a–d	1.95 a–c	0.21 b–e	0.03 ab	92.5
		400	2.92 c–e	1.65 a	0.13 ab	0.02 a	77.5
	Ceres	0	2.46 a–c	2.25 bc	0.27 de	0.04 ab	97.5
		200	2.53 a–c	2.30 bc	0.26 c–e	0.07 b	87.5
		300	2.61 a–d	1.83 ab	0.21 b–e	0.02 a	80.0
		400	2.17 a	2.35 c	0.29 e	0.03 ab	95.0
	Klasmann Steck Medium	0	3.35 e	1.65 a	0.13 ab	0.03 ab	72.5
		200	3.10 de	2.00 a–c	0.15 a–c	0.03 ab	77.5
		300	2.89 b–e	1.85 a–c	0.16 a–d	0.03 ab	65.0
		400	3.08 de	1.55 a	0.09 a	0.02 a	75.0
Self-prepared growing media	GM1	0	3.07 c	2.25 c–f	0.27 de	0.03 bc	67.5
		200	2.98 c	1.70 a–c	0.25 c–e	0.02 a–c	82.5
		300	3.23 c	1.50 a	0.16 a–c	0.02 a	75.0
		400	3.20 c	1.45 a	0.18 a–d	0.02 a–c	65.0
	GM2	0	2.00 b	2.60 f	0.26 c–e	0.03 bc	100
		200	1.82 ab	2.45 ef	0.30 e	0.04 d	100
		300	1.54 a	2.25 c–f	0.21 b–e	0.03 cd	100
		400	2.05 b	1.65 ab	0.17 a–d	0.03 cd	100
	GM3	0	2.76 c	1.80 a–d	0.12 ab	0.02 a–c	87.5
		200	2.91 c	2.10 b–f	0.10 a	0.02 a	77.5
		300	2.82 c	1.90 a–e	0.11 ab	0.02 ab	87.5
		400	2.16 b	2.30 d–f	0.20 a–e	0.03 bc	100

Average designated with the same letters (a, b, c, d, e, f) are not significantly different at $\alpha = 0.05$, EPPO – Evaluation of the root system in a scale of 1–5, according to EPPO standards (European and Mediterranean Plant Protection Organization)



a) b)

Fig. 1. The effect of self-prepared (a) GM2 and GM1 (b) for rooting of cuttings of *Hydrangea* L. Explanations: 6/1, 4/1 – natural IAA content, 6/2, 4/2 – 200 µg IAA kg^{-1}, 6/3, 4/3 – 300 µg IAA kg^{-1}, 6/4, 4/4 – 400 µg IAA kg^{-1} added to the growing media (photo J.S. Nowak)

fig. 1). The doses of IAA caused significant decrease length of roots in GM1. The lowest percentage of rooted cuttings in Klasmann Steck Medium (from 65.0 to 77.5%) and GM1 (from 65.0 to 82.5%) was observed (tab. 4). However, in Aura was found that with increasing of IAA concentrations the quality of root system became worse.

Dąbski and Parzymies [2007] showed that auxins used in the experiment had a positive effect on rooting of shoots of *Hebe buchananii* and *Hebe canterburiensis* 'Prostrata' in vitro. On the media supplemented with IAA in concentrations of 2.5 and 5.0 mg dm^{-3}, indole-3--butyric acid (IBA) in concentration of 5 mg dm^{-3} and 1-naphthaleneacetic acid (NAA) in the concentration of 1 mg dm^{-3} 100% of rooted shoots of *Hebe canterburiensis* 'Prostrata' were obtained. The biggest number of roots occurred in media with 2.5 and 5.0 mg IAA dm^{-3}. Świstowska and Kozak [2004] observed significant influence of IAA, IBA or NAA in the concentrations 5, 10, 20, 40 µM on the growth of shoots, and the induction of roots. The shortest roots were obtained using IAA at the concentration of 5 µM.

The best rooting of cuttings of *Euphorbia pulcherrima* was observed in Klasmann Steck Medium, GM2 and GM3 (tab. 5). The rooted cuttings of *Euphorbia pulcherrima* in these growing media showed the biggest fresh and dry mass of roots and the highest length of roots (except GM2). In Klasmann Steck Medium, GM2 and GM3 percentage of rooted cuttings with the 200, 300 and 400 µg kg^{-1} addition of IAA ranged from 90 to 100. Furthermore, it was showed significant influence of IAA additions on the assessment of root system in GM2 and GM3 of this plant. The worst percentage of rooted cuttings was observed in white peat GM1 of *Euphorbia pulcherrima*. The results indicated no significant influence doses of IAA on assessment of root system, length of roots, fresh and dry mass of roots in this growing media. The lowest percentage of rooted cuttings from 25 to 45 was observed (tab. 5).

CONCLUSION

The study showed significant impact of commercial growing media (Hollas Sp. z o.o., Ceres International Sp. z o.o., Kronen Klasmann Sp. z o.o.) and three self-prepared growing

Table 5. The impact of growing media with addition of IAA on rooting of cutting of *Euphorbia pulcherrima*

Growing media		IAA (µg kg^{-1})	Assessment of root system (EPPO)	Length of roots (cm)	Fresh mass of roots (g plant^{-1})	Dry mass of roots (g plant^{-1})	% of rooted cuttings
Commercial growing media	Aura	0	2.07 bc	3.90 d–h	0.83 b–e	0.09 a–e	92.5
		200	2.15 b–d	4.75 h–j	1.05 d–f	0.10 a–e	92.5
		300	3.01 f	4.45 g–j	0.63 a–d	0.07 a–d	72.5
		400	3.58 g	4.75 h–j	0.88 b–e	0.09 a–e	45.0
	Ceres	0	2.87 ef	2.90 b–f	0.55 a–c	0.06 a–c	80.0
		200	3.06 f	2.65 a–d	0.51 a–c	0.06 a–d	77.5
		300	2.92 f	2.85 b–e	0.61 a–d	0.19 f	87.5
		400	3.58 g	2.45 a–c	0.32 a	0.04 a	52.5
	Klasmann Steck Medium	0	2.48 de	4.70 h–j	0.62 a–d	0.06 a–c	97.5
		200	2.30 cd	5.30 ij	0.75 a–e	0.06 a–d	100
		300	2.05 bc	5.70 j	1.19 ef	0.12 b–e	100
		400	2.45 cd	7.90 k	1.39 f	0.13 c–f	92.5
Self-prepared growing media	GM1	0	4.02 gh	2.00 ab	0.33 a	0.05 ab	32.5
		200	4.19 h	2.05 a–c	0.51 a–c	0.07 a–e	30.0
		300	4.04 gh	1.50 a	0.40 ab	0.05 ab	25.0
		400	3.77 gh	2.15 a–c	0.63 a–d	0.07 a–e	45.0
	GM2	0	3.11 f	4.90 h–j	0.89 c–e	0.12 c–f	75.0
		200	2.49 de	4.45 g–j	0.76 a–e	0.09 a–e	90.0
		300	2.27 cd	4.15 f–i	1.11 ef	0.11 a–e	90.0
		400	2.40 cd	3.90 d–h	0.86 b–e	0.10 a–e	95.0
	GM3	0	3.01 f	3.35 c–g	0.78 a–e	0.10 a–e	65.0
		200	2.19 b–d	4.10 e–i	1.06 d–f	0.11 ae	100
		300	1.49 a	5.30 ij	1.42 f	0.13 d–f	100
		400	1.86 b	5.40 ij	1.38 f	0.14 ef	97.5

Average designated with the same letters (a, b, c, d, e, f, g, h, i, j) are not significantly different at $\alpha = 0.05$, EPPO – Evaluation of the root system in a scale of 1–5, according to EPPO standards (European and Mediterranean Plant Protection Organization)

media by the Research Institute of Horticulture (GM1, GM2, GM3 Skierniewice, Poland) with 200, 300 and 400 μg kg^{-1} addition of IAA on quality for rooting of cuttings of *Hydrangea* L. and *Euphorbia pulcherrima*.

According to assessment of root system, length of roots, fresh and dry mass of roots, and percentage of rooted cuttings, the best rooting of cuttings of *Hydrangea* L. were obtained in Ceres and GM2. No significant impact of the different doses of IAA on the parameters rooted cuttings of *Hydrangea* L. in Aura, Ceres, Klasmann Steck Medium, GM2 and GM3 (except GM3 with 400 μg kg^{-1} IAA) was observed.

Klasmann Steck Medium, GM2 and GM3 are the best growing media for rooting of *Euphorbia pulcherrima* cuttings. However, 200, 300 and 400 μg kg^{-1} addition of IAA for GM2 and GM3 improved on some of the parameters rooted cuttings of *Euphorbia pulcherrima*. Furthermore, 400 μg kg^{-1} addition of IAA for Klasmann Steck Medium caused significant on higher length of roots and dry mass of roots of this plant.

The worst assessment of root system and percentage of rooted cuttings for both ornamental plants in GM1 was observed. The lowest pH of GM1 from all investigated growing media strongly impacts on abiotic parameters and limits the availability of mineral or organic nutrients for root system of plants.

The investigations after rooting of cuttings of *Hydrangea* L. showed significant decrease of the concentrations of TOC, $N\text{-}NH_4^+$, $N\text{-}NO_3^-$, urease activity. In case of *Euphorbia pulcherrima* decline refers to $N\text{-}NH_4^+$, $N\text{-}NO_3^-$ in all growing media. However, significant increase of nitrate reductase activity (except GM1) after rooting of cuttings of *Hydrangea* L. was observed. Besides in case of *Euphorbia pulcherrima* enhancement content of TOC, activity of urease, nitrate reductase and phenol oxidase (except GM1) in growing media was noticed.

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WPŁYW PODŁOŻA Z DODATKIEM KWASU INDOLO-3-OCTOWEGO NA ROZWÓJ SYSTEMU KORZENIOWEGO ROŚLIN OZDOBNYCH

Streszczenie. Oceniono wpływ dodawanych ilości kwasu indolilo-3-octowego (IAA) do trzech handlowych i trzech własnych podłoży na ukorzenienie dwóch roślin ozdobnych: *Hydrangea* L. i *Euphorbia pulcherrima* 'Prestige Early Red'. Zaobserwowano – na podstawie oceny systemu korzeniowego, długości, świeżej i suchej masy korzeni oraz procentu ukorzenionych sadzonek – że *Hydrangea* L. ukorzeniła się najlepiej w podłożu Ceres i GM2, natomiast *Euphorbia pulcherrima* w podłożu Klasmann Stek Medium, GM2 i GM3 niezależnie od dawek IAA. Dodanie 200, 300 i 400 μg kg^{-1} IAA do podłoży GM2 i GM3 przyczyniło się do polepszenia niektórych parametrów ukorzeniania sadzonek *Euphorbia pulcherrima*. Podłoże GM1 o najniższym pH najsłabiej ze wszystkich badanych wpływało na rozwój systemu korzeniowego i procent ukorzenionych sadzonek obu roślin ozdobnych. Ponadto dodanie 400 μg kg^{-1} IAA do podłoża Klasmann Stek Medium istotnie przyczyniło się do zwiększenia długości i suchej masy korzeni *Euphorbia pulcherrima*.

Słowa kluczowe: ukorzenianie sadzonek, podłoża, IAA, *Hydrangea* L., *Euphorbia pulcherrima*

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