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Ivy pelargonium response to media containing sewage sludge and potato pulp

Agnieszka ZAWADZIŃSKA*, Piotr SALACHNA

Department of Horticulture, West Pomeranian University of Technology in Szczecin, Szczecin, Poland
**Corresponding author: Agnieszka.Zawadzinska@zut.edu.pl*

ABSTRACT

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In a two-year pot experiment, the effect of five growing media on the growth, flowering, decorative value of *Pelargonium peltatum* cv. Maxime as well as on their uptake of the nutrients and heavy metals were studied. The media were prepared from four composts (made from: sewage sludge 70% or 35%, potato pulp 35%, straw 30% or sawdust 30%) and peat in 1:1, V:V ratio. In the 1st year of research 7-month-old composts and in the 2nd year 18-month-old composts were used. Plants cultivated in 7-month-old composts showed better growth-related parameters, created more inflorescences and were more decorative than those cultivated in 18-month-old ones. The medium with compost consisting of 70% sewage sludge and 30% straw gave the best results. Composts application increased nutrients and heavy metals content in pelargonium leaves. Heavy metals content was definitely lower than the value considered toxic to plants.

Keywords: ivy-leaf geranium; industries waste; organic material; peatland; toxic elements

Sphagnum peat is still a leading growing media product, widely considered to be the best mainly due to its excellent physical properties (Schmilewski 2008, Raviv 2013). Although, high costs of harvesting peatlands has made various countries set limits on its extraction (Fascella 2015). Growing pressure for more balanced use of natural resources, with future generations in mind, is an important issue on global scale. The global gardening market is becoming less and less dependent on peat, not only by the virtue of environmental issues, but also by the mere fact, that peat is a non-renewable material (Barrett et al. 2016). Those factors enforce a need to find new materials, which can fully or partially replace peat (Fascella 2015). Results of the global research prove that organic materials from agricultural, industrial and communal waste can be components of these new growing media (Raviv 2013). Sewage sludge, a source of organic matter, macro- and microelements, is one of those media (Usman et al. 2012). Chemical composition of potato pulp gives a prospect of using it as a natural source of potassium (Krzywy 2007). Composing these two products with other organic materials like bark, straw, sawdust, leaves etc. will, after a decomposition process, create nutrients appropriable for plants (Usman et al. 2012). The usage of composts for plants is limited, due to a high pH level, high salt and heavy metals content. Composts can be mixed with low pH and low salt content materials in different proportions, which gives the possibility of creating specific compounds for plants with different tolerance to salinity (Do and Scherer 2013). Ivy pelargonium, chosen for the study, is widely produced in peat media, in Europe and US for balcony decorating market. Nowadays, ivy pelargonium together with other pot pelargonium species is the fourth best-selling plant on Dutch stocks (Royal Flora Holland 2016). Therefore, the purpose of the study was to evaluate the influence of compost media containing sewage sludge, potato

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Table 1. Analysis of the raw material used in the preparation of composts

Raw material	pH	DM (%)	C_{org}	N_{tot}	P	K	Ca	Mg	S	C/N ratio	Cd	Cu	Mn	Ni	Pb	Zn
			(g/kg DM)								(mg/kg DM)					
Sewage sludge	7.6	18.2	305	37.5	16.5	5.25	12.5	2.95	10.0	8.10	3.4	47.0	187	36.0	60.5	260
Potato pulp	4.8	13.2	102	4.30	2.90	12.3	5.35	1.10	1.60	24.0	0.08	2.85	15.8	1.85	3.40	16.8
Rye straw	–	86.2	328	3.90	0.85	11.2	0.90	0.20	1.60	85.0	0.10	6.26	62.5	1.20	1.82	31.4
Sawdust	–	60.9	496	2.92	1.65	0.80	0.52	0.07	0.28	169.9	0.20	4.14	20.2	0.92	2.10	45.4

DM – dry matter

pulp and structuring components on the plants quality, its flowering, selected physiological parameters and nutrients and heavy metals content.

MATERIAL AND METHODS

Plant cultivation. In the experiment, rooted cuttings of ivy pelargonium cv. Maxime (Vitroflora nurseries, Poland) were placed in separate 1.0 L (14 cm in diameter) pots filled with prepared media. The plants were irrigated by tap water and watering frequency depended on field capacity, which was maintained at 70% based on tensiometer readings. The experiment was carried out from June 10th (1st year – experiment 1) or May 11th (2nd year – experiment 2) for 12 weeks in a double-layer, inflated, polyethylene greenhouse at the research centre of the Department of Horticulture in Szczecin (53°25'N, 14°32'E).

Media preparation and characterization. In this study, five growing media were examined. The control medium consisted of only sphagnum peat (P) neutralized with chalk and dolomite to pH of 5.8–6.0 (1:2, V:V) and supplemented with Azofoska (13.6% N, 2.79% P, 15.85% K, 2.71% Mg, 9.2% S, + micro) at a dose of 2.5 g/L. Azofoska 340 mg N/L, 70 mg P/L and 396 mg K/L were added to the peat. The growing media were made by mixing (in volume ratio 1:1, V/V) 50% sphagnum peat and 50% one of the four composts (CI–CIV) prepared with sewage sludge (sewage-treatment, Lobez, Poland), potato pulp (Nowamyl S.A., Lobez, Poland) and rye straw or coniferous sawdust. Composition of specific composts expressed in weight ratio in dry matter (DM) was as follows: CI – sludge 70%, straw 30%; CII – sludge 70%, sawdust 30%; CIII – sludge 35%, potato pulp 35%, straw 30%; CIV – sludge 35%, potato pulp 35%, sawdust 30%. Chemical characteristics of the raw materials (Table 1) and composts (Table 2) were made according to the Polish standard: pH – PN-75/C-04540/05/01 (1975); DM – PN-75/C-04616.01 (1975); organic C – according to the Lichterfeld as modified by Alten; total N – PN-75/C-04576/17 (1975); P – PN-98/C-04537-14 (1998); K, Ca and Mg – PN ISO 9964 (1994); S – by nephelometry; Cd, Cu, Mn, Ni, Pb and Zn – PN ISO 02/8288 (2002). In the first year, 7 month-old composts were used; in the second year the same composts were used but after 18 months of composting. The obtained composts showed an optimal degree of maturity (Table 2) according to their C/N ratio ≤ 12 (Bernai et al. 1998). Heavy metal concentration did not exceed limits specified in the Polish legislation (Regulation of the Minister for Agriculture and Rural Development, Journal of Law, No. 119, Item 765 (2008) and No. 137, item 924 (2010)). Chemical analysis of the media (pH and electrical conductivity (EC) (1:2, V/V), available form of nitrogen (NO_3^--N), P, K, Ca and Mg were performed at an accredited laboratory (Chemical and Agricultural Station, Szczecin, Poland). The elements were determined after extraction with 0.03 mol/L CH_3COOH using the universal method (1:10 leaching) as described by Nowosielski (1988). Recommendation for chemical composition of the substrate for growing pelargonium species (Komosa et al. 2012) are as follows (mg/L): NO_3^--N – 200–280; P – 180–250; K – 250–350; Ca – 500–1500; Mg – 200–250; Na < 50;

Table 2. C/N ratio of composts used in experiments 1 and 2

	CI	CII	CIII	CIV
Experiment 1	8.62	8.24	9.18	10.5
Experiment 2	9.42	9.45	12.6	10.6

CI – sludge 70%, straw 30%; CII – sludge 70%, sawdust 30%; CIII – sludge 35%, potato pulp 35%, straw 30%; CIV – sludge 35%, potato pulp 35%, sawdust 30%

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Table 3. Analysis of the growing media used in experiments

	Growing media	pH (1:2; V:V)	DM (%)	Bulk density (g/cm^3)	EC (1:2; V:V) (mS/cm)	NO_3^--N	P	K	Ca	Mg
						(mg/L)				
Experiment 1	P	3.6	59.8	0.18	0.22	17.0	20.0	6.0	42.0	27.0
	PCI	5.4	36.3	0.39	2.30	785	687	379	2265	500
	PCII	5.8	38.1	0.39	1.69	346	671	224	2690	309
	PCIII	5.8	44.8	0.36	0.90	386	518	644	1596	285
	PCIV	5.9	45.4	0.38	0.52	281	348	181	1625	202
Experiment 2	P	3.5	58.8	0.20	0.21	16.5	19.0	5.0	40.0	27.0
	PCI	5.4	36.8	0.28	2.11	330	810	845	3843	554
	PCII	5.3	36.6	0.34	2.09	379	620	226	3272	413
	PCIII	5.4	22.1	0.30	1.32	233	574	703	2121	306
	PCIV	5.9	24.5	0.37	1.67	248	449	295	3110	384

P – sphagnum peat; CI – sludge 70%, straw 30%; CII – sludge 70%, sawdust 30%; CIII – sludge 35%, potato pulp 35%, straw 30%; CIV – sludge 35%, potato pulp 35%, sawdust 30%; DM – dry matter; EC – electrical conductivity

Cl < 50; pH_{H_2O} 5.5–6.5; $EC_{1:2}$ < 1.9 mS/cm. On the basis of the chemical analysis (Table 3) in which the NO_3^--N and K contents were lower as recommended, these ingredients were supplemented up to the upper range (NO_3^--N – 280; K – 350 mg/L). No top-dressing fertilization was used.

Plant measurements. At the flowering stage, the number of stems per plant and the length of the longest stem were determined. Measurements of the greenness index of leaves were performed using the Chlorophyll Meter SPAD-502 (Konica Minolta, Osaka, Japan). Leaves per plant were counted and fresh matter of some leaves was weighed using thr RADWAG PS 200/2000/C/2 electronic scales. Leaves area per plant was measured using the Delta-T Image Analysis System Analyzer (DIAS, Delta-T Device Ltd., Cambridge, UK). The diameter of pelargonium inflorescence was measured in the first inflorescence. Number of inflorescences produced by the plant were counted and removed from the beginning of the flowering period to the end of the cultivation. Decorative value of plants was assessed using a five-score scale (1 – no ornamental value; 5 – the best value).

Analysis of plant methods. After 12 weeks of experiment, leaves were separated from shoots and dried at 60°C for 48 h; then DM was recorded. In the leaf samples, nutrients and heavy metals were determined. Total N was determined with the Kjeldahl method. Total P was determined with the colorimetric method according to Barton, K and Ca with the flame photometry. To indicate Mg, Cd, Cu, Mn, Ni, Pb and Zn, the atomic absorption spectrometry method was used.

Statistical analyses. The experiments were established in a complete randomization system with four replications, five plants in each. Collected data were statistically analysed by one-way analysis of variance (ANOVA) using the Statistica 13.0 (StatSoft, Cracov, Poland) software.

RESULTS AND DISCUSSION

Medium properties. New medium can be considered acceptable, if plants cultivated in it grow better or at the same level compared to the traditional media (Bilderback et al. 2013). In our experiments, applied compost media (Table 3) had pH level close both to optimum for ivy pelargonium (pH 5.5–6.0) and to acceptable level for perfect medium (pH 5.3–6.5) according to Abad et al. (2001). As recommended by Whipker (1998), electrical conductivity level for ivy pelargonium in a saturated-paste extract is 1.0–2.0 mS/cm. According to Komosa et al. (2012) pelargonium species require EC < 1.9 mS/cm (1:2, V/V). In our media, EC value measured by the same method was higher and did not exceed the value of 2.3 mS/cm. Substrates containing composts had a lower dry mass and higher bulk density in relation to the peat. The content of available nutrients, especially P, K and Ca in some substrates exceeded the values recommended for pelargonium species (Komosa et al. 2012). The excess of nutrients may adversely affect the growth, flowering of plants

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Table 4. Attributes of ivy pelargonium cv. Maxime cultivated in growing media

	Growing media	Stems number	Stem length (cm)	Leaf greenness index (SPAD)	Leaf area (cm^2/plant)	Leaf FM (g)	Inflor. diameter (cm)	Inflor. number per plant	Decorative value (score 1–5)
Experiment 1	P	4.7^{b}	36.4^{c}	35.8^{c}	1218^{d}	102.9^{c}	9.38^{a}	34.5^{c}	4.03^{c}
	PCI	5.7^{a}	46.2^{a}	46.6^{a}	1629^{a}	123.2^{b}	9.33^{ab}	42.0^{a}	4.25^{bc}
	PCII	4.5^{b}	37.3^{c}	42.9^{ab}	1542^{b}	135.5^{a}	8.33^{c}	37.5^{bc}	4.50^{ab}
	PCIII	4.8^{b}	42.2^{ab}	41.4^{b}	1531^{b}	136.0^{a}	8.95^{b}	41.0^{ab}	4.27^{bc}
	PCIV	4.3^{b}	39.8^{bc}	41.9^{b}	1449^{c}	121.1^{b}	9.40^{a}	40.0^{ab}	4.60^{a}
Experiment 2	P	5.2^{a}	25.4^{c}	46.5^{a}	887^{d}	71.90^{d}	8.36^{a}	22.0^{d}	3.83^{c}
	PCI	4.7^{b}	37.5^{a}	42.4^{b}	1230^{b}	117.0^{bc}	7.60^{b}	35.0^{a}	4.55^{a}
	PCII	4.2^{cd}	30.1^{abc}	40.9^{bc}	1339^{a}	127.0^{ab}	7.95^{ab}	25.0^{c}	3.88^{bc}
	PCIII	4.5^{bc}	34.7^{ab}	39.7^{c}	1203^{b}	102.3^{c}	7.53^{b}	28.0^{b}	4.43^{a}
	PCIV	3.8^{d}	26.8^{bc}	41.9^{b}	1021^{c}	142.3^{a}	7.58^{b}	23.0^{cd}	4.11^{b}

For each column values followed by the same letter do not differ significantly ($P \leq 0.05$) by the Duncan's test. P – sphagnum peat; CI – sludge 70%, straw 30%; CII – sludge 70%, sawdust 30%; CIII – sludge 35%, potato pulp 35%, straw 30%; CIV – sludge 35%, potato pulp 35%, sawdust 30%; FM – fresh matter

and disturb the ionic uptake (Biamonte et al. 1993, Whipker 1998).

Plant growth and decorative value. In experiment No. 1, the number of shoots of the ivy pelargonium cultivated in PCI medium was on average greater than those cultivated in a control medium (Table 4). Moreover, the shoots of plants from PCI and PCIII were longer than those from the control group, by 12.1 cm and 9.3 cm, respectively. However, in experiment No. 2 every plant cultivated in compost media produced significantly fewer shoots than those in the control group. Compost media caused more intensive greening, but only during the first year of the study, when 7-month old composts were used. In both experiments, all compost media had a great influence on development of total assimilation surface of leaves and total fresh weight of foliage, which were greater than in the control group. Similar results were obtained by Erdogan et al. (2011) and Iftikhar et al. (2012), who used sewage sludge as a part of the growing medium for ornamental plants. In both years, the largest inflorescences were produced by the plants cultivated in PCI medium. Using the 7-month-old compost media created a positive result on the number of inflorescences per plant, except those cultivated in PCII. However, more decorative plants grew out of PCII and PCIV media. When 18-month-old composts were used, plants cultivated in PCI medium had more inflorescences compared to those in the control group. Simultaneously, the plants cultivated in PCI and PCIII media were significantly more decorative. Satisfying results were also obtained by cultivating ivy pelargonium cvs. Beach and Boneta in the peat substrate with addition of 12.5% compost from sewage sludge and leaves (Zawadzińska and Salachna 2014).

Nutrient concentration in leaf tissues. Growing media containing composts had a significant influence on some nutrients content in pelargonium leaves (Table 5), namely on N, P and K, but not on Ca and Mg (data not shown). Plants cultivated in PCI or PCII medium contained more N in leaves than plants of the control group. Simultaneously, in both experiments total N content in the plant was in general below the level of deficiency (< 23.8 g/kg DM) defined for ivy pelargonium by de Kreij et al. (1990). Plants take up N most at the beginning of the growth period, and after time N uptake decreases (Kaplan et al. 2013). In this study, the determination of nutrients was made after 12 weeks of planting, when plants fully flowered, which is probably the reason that N content in leaves was smaller. In the first experiment, the foliage P content varied above optimum (4–7 g/kg DM) in plants cultivated in PCI and PCII media, according to Biamonte et al. (1993). In the second experiment, P content in the leaves of all the plants was also above optimum. In turn, foliage K content in both experiments was not in the optimum range (28–47 g/kg DM), but it was above the level

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Table 5. Nutrient content (g/kg dry matter) in the leaves of ivy pelargonium cv. Maxime cultivated in growing media

Growing media	Experiment 1			Experiment 2		
	N	P	K	N	P	K
P	12.3[d]	4.75[e]	9.66[a]	8.06[c]	4.00[c]	9.11[e]
PCI	14.7[a]	8.07[a]	9.29[b]	12.5[a]	9.61[a]	13.4[b]
PCII	14.3[b]	7.72[b]	8.82[c]	13.0[a]	9.55[a]	13.9[a]
PCIII	12.7[c]	6.21[d]	6.76[e]	10.2[b]	8.12[b]	9.42[d]
PCIV	12.0[e]	6.70[c]	7.70[d]	10.6[b]	8.14[b]	9.75[c]
Optimal range[1]	38–44	4–7	28–47			
Deficiency[2]	< 23.8	< 2.6	< 6.2			

[2]according to Biamonte et al. (1993) for ivy pelargonium; [2]according to De Kreij et al. (1990). For each column values followed by the same letter do not differ significantly ($P \leq 0.05$) by the Duncan's test. P – sphagnum peat; CI – sludge 70%, straw 30%; CII – sludge 70%, sawdust 30%; CIII – sludge 35%, potato pulp 35%, straw 30%; CIV – sludge 35%, potato pulp 35%, sawdust 30%

of deficiency (< 6.2 g/kg DM). Heavy metal concentration in leaf tissues. Accumulation of heavy metals in plants depends, among others, on pH level of a medium, composition of organic matter, the amount of absorbable forms of metals (Krzywy 2007, Komosa et al. 2012). The results of heavy metals toxic influence on plants are life processes disorders and abnormal growth (Biamonte et al. 1993). In both experiments, in any medium used, the accumulation of Cu, Ni and Zn in ivy pelargonium foliage was at a normal range, as elaborated by Chaney (1989). However, the uptake of Cd, Cu, Ni, Mn, Pb and Zn strongly depended on a given medium (Table 6). Cd and Pb contents in the control medium were at a normal range (Table 6), according to Chaney (1989). Plants cultivated in media with composts had substantially more Cd and Pb than the control group, but the level still did not reach point considered as toxic (> 5.0 mg Cd/kg DM and > 30 mg Pb/kg DM). In the first experiment, compost was added after 7 months of maturation; Mn content in leaves was above normal, but not toxic (> 400 mg Mn/kg DM). In the second experiment, with addition of 18-month-old composts, Mn content in foliage was normal. According to Orroño et al. (2009) *P. peltatum* is considered to be less tolerant to heavy metals than *P. zonale*. Plants usually produce less fresh weight

Table 6. Heavy metals content (g/kg dry matter) in the leaves of ivy pelargonium cv. Maxime cultivated in growing media

	Growing media	Cd	Cu	Mn	Ni	Pb	Zn
Experiment 1	P	0.64[c]	9.90[b]	79.1[b]	0.77[b]	1.32[b]	44.9[c]
	PCI	1.45[a]	12.0[a]	184[a]	1.15[a]	16.5[a]	57.1[b]
	PCII	1.49[a]	10.1[b]	174[a]	1.20[a]	16.6[a]	69.4[a]
	PCIII	1.37[b]	7.51[c]	196[a]	1.14[a]	16.6[a]	46.3[c]
	PCIV	1.31[b]	10.2[b]	179[a]	0.91[b]	16.6[a]	48.7[c]
Experiment 2	P	0.52[c]	8.51[a]	82.1[b]	0.64[b]	1.89[b]	59.0[c]
	PCI	1.57[a]	7.53[a]	118.0[a]	0.89[a]	11.1[a]	83.0[a]
	PCII	1.64[a]	7.84[a]	119.7[a]	0.88[a]	11.7[a]	85.1[a]
	PCIII	1.22[b]	6.14[b]	99.5[ab]	0.77[a]	10.3[a]	70.4[b]
	PCIV	1.19[b]	6.21[c]	95.2[b]	0.71[ab]	10.8[a]	70.3[b]
Normal range[1]		0.1–1.0	3.0–20.0	15.0–150	0.1–5.0	2.0–5.0	15.0–150
Phytotoxic range[1]		5.0–700	25.0–40.0	400–2000	50.0–100	30–300[2]	500–1500

[1]according to Chaney (1989); [2]according to Krzywy (2007). For each column values followed by the same letter do not differ significantly ($P \leq 0.05$) by the Duncan's test. P – sphagnum peat; CI – sludge 70%, straw 30%; CII – sludge 70%, sawdust 30%; CIII – sludge 35%, potato pulp 35%, straw 30%; CIV – sludge 35%, potato pulp 35%, sawdust 30%

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in the presence of high heavy metals concentrations. However, in our experiments a negative influence of heavy metals on leaf fresh weight and decorative value of plants was not observed. On the contrary, leaf fresh weight was greater by 17.7–32.2% (Exp. 1) and by 42.3–97.9% (Exp. 2).

Generally, alternative growing media are still not very popular in many countries. Defining the new growing medium, in which plants would develop acceptably, will help to reduce peat and mineral fertilizers consumption (Zawadzińska et al. 2015). It seems reasonable to say that composts after 7 months of decomposition were good enough to replace fertilizers in 50% mixed with peat for cultivation of ivy pelargonium. In both experiments, plants cultivated in a medium with compost made from sewage sludge and straw created longer shoots with greener foliage and bloomed more abundantly. Nonetheless, to introduce innovative growing media to the market successfully, education promoting ecology and principles of sustainable development is needed.

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