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Research Article

GROWTH, FLOWERING AND PHOTOSYNTETIC PIGMENTS OF *PELARGONIUM* × *HORTORUM* L.H. BAILEY 'SURVIVOR HOT PINK' AND 'GRAFFITI FIRE' GROWN IN SUBSTRATES CONTAINING SEWAGE SLUDGE COMPOST

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ABSTRACT
The aim of this study was to assess usability of composts made of sewage sludge and either straw or leaves used as substrates for growing zonal pelargoniums. The study plants 'Hot Pink' cv. of Survivor group and 'Fire' cv. of Graffiti group were grown in 5 different substrates. The control substrate was high peat (100%) deacidified with chalk and dolomite up to pH 5.8–6.0 and supplemented with 2.5 g·dm^{-3} of Azofoska multi-component fertilizer. The other four substrates contained two types of composts: SSRS – sewage sludge, straw (1:1, v/v) and SSL – sewage sludge, leaves (1:1, v/v), mixed with high peat at two different proportions, 1:3 (v/v) and 1:7 (v/v). Chemical composition of the substrates was investigated and they were supplemented with nitrogen and potassium as recommended for pelargoniums. Plant morphological parameters were evaluated during flowering. They included plant height and diameter, number of shoots and leaves, leaf assimilation area and leaf weight. Leaf chlorophyll and carotenoid content was also estimated. Inflorescence related parameters included inflorescence diameter and inflorescence stem length, number of flowers per inflorescence and flower diameter. All inflorescences formed over 10 weeks of flowering were counted. Plant ornamental value was assessed using a five-score bonitation scale. The investigated composts were found to be useful components of the substrates for zonal pelargonium production. Irrespective of the compost share, the tested substrates significantly affected most of the evaluated morphological traits. The substrate containing the compost made of sewage sludge and straw (SSRS) and peat (1:3, v/v) was found the most beneficial for pelargonium foliage, i.e. the number of leaves, their fresh weight and assimilation area. Leaf chlorophyll and carotenoid content in the pelargoniums grown in the substrates containing either dose of SSRS compost did not differ from the control plants. Substrate type did not affect bonitation score of 'Survivor Hot Pink' cultivar. The bonitation score of 'Graffiti Fire' cultivar was the highest for plants growing in the substrates with either SSRS or SSL compost plus peat in 1:3 ratio (v/v).

Keywords: bedding plants, sphagnum peat, rye straw, waste material.

INTRODUCTION

Research literature clearly indicates a huge potential connected with using waste products from various fields of industry as components of substrates for growing ornamental plants [Nascimento et al. 2002, Vabrit et al. 2008, Zheljazkow et al. 2008, Tariq et al. 2012]. Some industrial waste products reported as useful for this purpose include potato pulp [Krzywy et al. 2007], cotton waste [Papafotiou et al. 2001], wood fibers [Lopez et al. 2008] or even glass-based aggregate [Evans 2011] and waste tire pellet [Newman et al. 1997]. Municipal sewage sludge is a type of waste that is produced in huge quantities worldwide and its utilization is difficult and expensive [Mininni et al. 2014].

The problem of municipal sewage sludge disposal becomes more and more pressing in Poland and other countries of the European Union [Fytili et al. 2008, Eurostat 2011]. In 2010, the production of sewage sludge in Poland was 895,000 tons of dry weight (d.w.), of which 526,700 tons were produced in municipal wastewater treatment plants. This amount is estimated to grow and reach 707 000 tons (d.w.) in 2018 [Bauman-Kaszubska and Sikorski 2011]. In recent years, the municipal sewage sludge management included storage, using in agriculture and incinerating [Krzywy and Iżewska 2004, Bień et al. 2011, Jakubus 2013]. Since 2013 unconditional storage of municipal sludge has been no longer possible [Regulation … 2005]. According to the National Waste Management Plan [2014], this type of waste should be mainly disposed of by thermal decomposition. In 2018, the share of sludge disposed of by means of thermal utilization is expected to reach 60%.

Using the municipal waste for environmentally friendly purposes seems to be one of the most reasonable ways of its disposal [Ciecko and Hanisz 2002, Liu et al. 2009]. High fertilization potential of the municipal sludge makes it a good organic fertilizer, provided the requirements set out in the Act on Fertilizers and Fertilization [2007] are met. The most reasonable solution in the agriculture is composting the municipal waste with different structural materials, such as bark, leaves, straw or sawdust [Kosobucki and Buszewski 2003, Raviv 2013]. However, such factors as elevated pH or high concentration of salts and heavy metals may limit the usability of the composts as growth media [Abad et al. 2001, Moore 2004, Perez Murcia et al. 2005, Fornes et al. 2007]. Mixing the municipal waste or composts containing it with other components with lower pH and salinity, e.g. peat, improves their physical and chemical properties [Fitzpatrick 2001, Moore 2005]. Ornamental plants intended for growing in such compost substrates should be tolerant to soil conditions and higher concentration of some nutrients and microelements, including heavy metals [Fornes et al. 2007]. Zonal pelargonium is considered to salt tolerant ornamental plants [White 1993]. This African native taxon popular in Europe and the USA is used for seasonal decoration of balconies, terraces and green areas [Zawadzińska et al. 2015]. In 2013, sixteen million of pelargonium plants were sold on the Dutch market for 27 million euro, which means they were the most popular garden plants that year [Flora Holland 2013]. Such a large number of pelargonium plants sold each year indicates great economic importance of this taxon in Europe.

The aim of the study was to evaluate the usefulness of composts made of sewage sludge and either straw or leaves for preparing growth media for pelargoniums belonging to two different breeding groups.

MATERIAL AND METHODS

The study was conducted at research centre of the West Pomeranian University of Technology in Szczecin (53° 25' N, 14° 32' E). The plant material included rooted cuttings of zonal pelargoniums of two breeding groups: 'Hot Pink' of Survivor group (Dümmen) and 'Fire' of Graffiti group (Syngenta). Survivor group is characterized by strong growth and semi-double flowers, while typical traits of Graffiti group are stellar shaped flowers and palmate leaves with a dark zone.

Single cuttings were planted on 29th April 2010 in pots (12 cm in diameter, 0.75 dm^3), containing five different substrates. A control substrate was high peat deacidified with chalk (93% $CaCO_3$) and dolomite (45% CaO+MgO) up to pH 5.8–6.0 and supplemented with 2.5 $g \cdot dm^{-3}$ of Azofoska multicomponent fertilizer containing 13.6% N, 6.4% P_2O_5, 19.1% K_2O, 4.5% MgO, 23.0% SO_3, 0.045% B, 0.18% Cu, 0.17% Fe, 0.27% Mn, 0.04% Mo, and 0.045% Zn. The other substrates contained two types of composts, SSRS – sewage sludge, straw (1:1, v/v) and SSL – sewage sludge, leaves (1:1, v/v). The composts were obtained from the municipal sewage treatment plant in Stargard Szczeciński and their maturation period was 14 months. Chemical analysis of the composts was performed at an accredited laboratory of the Chemical and Agricultural Station in Szczecin and its results are showed in Table 1. The composts were mixed with high peat in two proportions 1:3 (v/v) and 1:7 (v/v). Given the results of the chemical analysis of the growth media carried out at an accredited laboratory (Table 2), nitrogen and potassium deficiency was supplemented with ammonium nitrate (34% N) and potassium sulphate (50% K_2O) up to the level recommended for pelargonium [Komosa 2003]. The plants were grown under a plastic tunnel in the conditions rec-

Table 1. Chemical characteristic of composts used to preparing of media

Designation	Unit	Compost SSRS (sewage sludge, rye straw 1:1,v/v)	Compost SSL (sewage sludge, leaves, 1:1 v/v)
pH_{H2O} (1:2, v/v)		8.6	7.3
EC (1:2, v/v)	$mS \cdot cm^{-1}$	3.8	3.3
Dry matter	%	26.5	26.2
Organic C		17.4	19.4
N	$g \cdot kg^{-1}$ d.m.	16.1	16.6
P		11.1	12.5
K		6.02	4.32
Ca		40.7	29.4
Mg		4.18	3.57
S		3.75	4.13
Fe	$mg \cdot kg^{-1}$ d.m.	11.0	11.9
Cu		97.5	105.7
Mn		29.2	30.6
Ni		61.3	65.8
Zn		375.4	361.4
Pb		42.4	59.0
Cd		0.675	0.988
Cr		22.6	16.8
C:N ratio		1:10.8	1:11.6

ommended for pelargonium over the entire study period [Biermann et al. 1995]. From 21st June to 14th August 2010 the plants were fertilized once a week with 0.15% (w/v) solution of Peters Professional Foliar Feed multicomponent fertilizer (100 ml per plant) containing 27% N, 6.5% P, 10% K, 0.15% Fe, 0.07% Mn, 0.03% B, 0.07% Cu, 0.001% Mb, and 0.07% Zn. The plants were watered 2–3 times a week. Watering frequency depended on field capacity, which was maintained at 70% (water potential – 30 kPa) based on tensiometer readings [Startek et al. 2006].

The experiment was fully randomized and run in four replicates, three plants per replicate. Morphological traits were measured at the flowering stage, on 20th July 2010, when at least two inflorescences were blooming. The traits concerned plant habit (height and diameter and shoot number), foliage (number of leaves, assimilation area and leaf fresh weight), and flowering parameters (diameter of flowers and inflorescences, number of flowers per inflorescence and length of inflorescence stem). The inflorescences were counted every 10 days over ten weeks of flowering and they were removed after withering. Leaf assimilation surface was measured with Delta-T Image Analysis System analyzer (DIAS, Delta-T Device Ltd., Cambridge, Great Britain). The device records images by means of a special analog to digital converter coupled to a PC. The same leaves were counted and their fresh weight was determined using RADWAG PS 200/2000/C/2 electronic scales (0.001 g accuracy). Chlorophyll a and b content was estimated as described by Arnon et al. [1956] and modified by Lichtenthaler [1987] and carotenoids were determined according to Schnarrenberg and Mohr [1970]. Pelargonium bonitation value was assessed using a five-score bonitation scale. The highest score (5) was given to the pelargoniums with the highest ornamental value, and the lowest (1) to the plants showing no such value.

Measurement results, bonitation score and physiological parameters were statistically analyzed by subjecting them to one-way analysis of variance using Statistica 10 (Statsoft, Poland).

Table 2. Chemical properties of the substrate media used for the cultivation of pelargonium

Media	pH_{H2O}	Content ($mg \cdot dm^{-3}$)						Salinity $g\ NaCl \cdot dm^{-3}$
		$N\text{-}NO_3$	P	K	Ca	Mg	Cl	
1^x	4.6	22^A	32	26	490	92	37	0.24
2	6.6	18^N	778	430	1294	201	69	1.65
3	5.8	26^N	335	225^K	702	136	45	0.82
4	7.5	17^N	582	398	2698	368	82	2.18
5	6.4	15^N	376	272^K	1581	221	55	1.31

Explanations:

^{x} 1 - sphagnum peat 100%; 2 - SSRS compost, sphagnum peat (1:3, v/v); 3 - SSRS compost, sphagnum peat (1:7, v/v); 4 - SSL compost, sphagnum peat (1:3, v/v); 5 - SSL compost, sphagnum peat (1:7, v/v)

SSRS – sewage sludge, rye straw (1:1, v/v); SSL – sewage sludge, leaves (1:1, v/v)

^{A} media supplemented with Azofoska 2.5 $mg \cdot dm^{-3}$; ^{N} media supplemented with nitrogen to the level of 280 mg $N\text{-}NO_3 \cdot dm^{-3}$; ^{K} media supplemented with potassium to the level of 350 mg $K \cdot dm^{-3}$

Significance of mean values was verified by Duncan's test at a significance level P≤0.05.

RESULTS AND DISCUSSION

Horticultural substrates containing composts made of municipal sewage sludge and structural components were used for growing ornamental plants [Ozdemir 2004, Wraga and Zawadzińska 2007, Macias et al. 2010, Erdogan et al. 2011, Zawadzińska and Salachna 2014a,b,c] and a few vegetable species [Perez-Murcia et al. 2006, Cai et al. 2010]. The impact of this type of growth media on plant development and ornamental value depended on the composition and proportion of a compost and tolerance of the investigated species to salinity and elevated content of certain microelements [Grigatti et al. 2007, Zawadzińska and Janicka 2007a,b]. Our study involved composts containing municipal sewage sludge and either straw or leaves. The straw-based compost was characterized by higher pH and salinity and greater share of dry weight than leaf-based one (Table 1). On the other hand, the leaf-based compost contained more organic carbon, nitrogen, phosphorus, sulfur and heavy metals, mainly lead and cadmium. Compost maturity and stability of organic matter is determined by its C:N ratio, the recommended range of which is 20-30:1 [Davidson et al. 1994, Kosobucki et al. 2000, Krzywy 2007]. C:N ratio in the investigated composts ranged between 10.8:1 and 11.6:1 (Table 1) and met the requirements for substrates used for the production of ornamental plant seedlings [Dudka et al. 1998]. Heavy metal content did not exceed the values set out in Polish regulations [Regulation… 2008; Regulation… 2010]. The substrates with nitrogen and potassium content insufficient for pelargonium production [Komosa 2003] were supplemented with appropriate mineral fertilizers.

The examined substrates containing composts made of municipal sewage sludge and either straw (SSRS) or leaves (SSL) significantly affected height and diameter of pelargonium plants and the number of shoots (Table 3). Height of 'Survivor Hot Pink' pelargoniums growing in the substrate 2, containing SSRS compost and peat (1:3), was similar to the control plants. The greatest plant diameter in this cultivar was observed in the substrate 2. Pelargoniums grown in the substrate 3 had a smaller number of shoots and did not differ in this respect from the plants grown in the media containing SSL compost (substrate 4 and 5). 'Graffiti Fire' pelargoniums were the highest when grown in peat (substrate 1) and in the media containing SSRS or SSL compost mixed with peat at 1:3 ratio. The smallest plant diameter was noticed in the individuals growing in the substrate 3 containing SSRS compost and peat in the proportion 1:7. 'Graffiti Fire' pelargoniums grown in the substrates 3 and 5, containing the composts

Table 3. The effect of different substrates on plant height and diameter and the number of shoots in zonal pelargonium of 'Survivor Hot Pink' and 'Graffiti Fire' cultivars

Media	Heigth of plants (cm)		Diameter of plants (cm)		Number of shoots	
	Cultivar					
	'Survivor Hot Pink'	'Graffiti Fire'	Survivor Hot Pink	'Graffiti Fire'	'Survivor Hot Pink'	'Graffiti Fire'
1[x]	11.7 ± 0,49[y] a[z]	12.4 ± 0.94 a	22.7 ± 0.24 b	22.0 ± 0.82 a	2.26 ± 0.25 a	2.40 ± 0.41 ab
2	12.7 ± 1.15 a	13.2 ± 0.35 a	25.3 ± 0.91 a	22.5 ± 0.85 a	2.26 ± 0.43 a	2.75 ± 0.25 a
3	10.5 ± 0.80 b	10.4 ± 0.46 b	22.6 ± 0.64 b	19.5 ± 1.01 b	1.38 ± 0.41 b	1.75 ± 0.25 c
4	10.2 ± 0.80 b	12.7 ± 0.70 a	21.7 ± 1.45 b	22.2 ± 0.81 a	1.76 ± 0.43 ab	2.60 ± 0.41 a
5	10.5 ± 0.70 b	10.6 ± 0.98 b	21.9 ± 1.31 b	21.5 ± 0.58 a	1.76 ± 0.25 ab	2.14 ± 0.21 bc
Effect significance	***	***	***	***	**	***

Explanations:

[x] 1 - sphagnum peat 100%; 2 - SSRS compost, sphagnum peat (1:3, v/v); 3 - SSRS compost, sphagnum peat (1:7, v/v); 4 - SSL compost, sphagnum peat (1:3, v/v); 5 - SSL compost, sphagnum peat (1:7, v/v); SSRS – sewage sludge, rye straw (1:1, v/v); SSL – sewage sludge, leaves (1:1, v/v)

[y] values represent the means of four replications ± standard deviations;

[z] Mean values followed by the same letter in each column do not differ significantly at P≤0.05 by Duncan's multiple range test;

* effect significance at the level P ≤ 0.05; **P ≤ 0.01; ***P ≤ 0.001; ns – not significant.

and peat in the proportion 1:7, had the lowest number of shoots.

The growth media affected also pelargonium foliage (Table 4). ‘Survivor Hot Pink’ plants had more leaves and greater assimilation area when grown in the substrate containing higher dose of SSRS compost (substrate 2) or in the control substrate. Pelargoniums of this cultivar grown in the substrate 2 had the greatest leaf fresh weight. Leaf fresh weight in the plants grown in the substrate 3 was nearly two times lower than in those grown in the substrate 2. Contrary to that, ‘Graffiti Fire’ plants grown in this substrate developed the greatest number of leaves with the greatest assimilation area and fresh weight (Table 4). Foliage development and low leaf fresh weight of the plants grown in the substrate 3 was probably related to too low calcium content in this media (Table 2). Calcium deficiency in ivy pelargonium (*Pelargonium peltatum* (L.) L’Her.) was manifested by a decrease in the number of shoots and inflorescences and the weight of shoots, leaves and inflorescences [Mikesell 1992]. Additionally, calcium shortage caused strong reduction of the root system and poor growth of adventitious roots. Our study indicated that some symptoms of calcium deficiency were more noticeable in ‘Graffiti Fire’ than ‘Survivor Hot Pink’ plants.

In both cultivars, flower diameter and number of flowers per inflorescence largely depended on the substrate (Table 5). The greatest flower diameter was observed in ‘Survivor Hot Pink’ plants growing in the substrates 3, 4, and 5. The highest number of flowers per inflorescence was noticed in the plants grown on both substrates containing SSRS compost and the control plants.

‘Graffiti Fire’ plants produced flowers of the greatest diameter when they were grown in the substrates supplemented with SSRS or SSL compost and peat in the proportion 1:7 (substrates 3 and 5). The highest number of flowers per inflorescense, on average 10 more than in control, was found in the plants growing in the substrate supplemented with higher dose of SSRS compost.

In neither of the cultivars, the substrates affected inflorescence diameter (Table 6). The longest inflorescence stems were seen in the pelargo-

Table 4. The effect of different substrates on leaf number, fresh weight and assimilation area in zonal pelargonium of ‘Survivor Hot Pink’ and ‘Graffiti Fire’ cultivars

Media	Number of leaves		Fresh matter of leaves (g)		Area of leaves (cm²)	
	Cultivar					
	‘Survivor Hot Pink’	‘Graffiti Fire’	‘Survivor Hot Pink’	‘Graffiti Fire’	‘Survivor Hot Pink’	‘Graffiti Fire’
1	36.1 ± 2.04 a	41.0 ± 6.08 b	62.3 ± 4.15 b	51.7 ± 7.25 b	839.0 ± 37.3 ab	711.0 ± 92.3 b
2	36.1 ± 2.90 a	55.0 ± 8.10 a	68.5 ± 1.30 a	73.4 ± 8.83 a	924.3 ± 65.3 a	912.0 ± 59.2 a
3	25.5 ± 1.45 b	31.5 ± 0.61 c	34.6 ± 0.45 e	31.3 ± 2.56 d	501.7 ± 80.4 d	443.3 ± 23.2 d
4	24.4 ± 2.72 b	46.5 ± 5.31 b	55.4 ± 2.91 c	37.0 ± 5.22 cd	758.0 ± 76.3 bc	503.0 ± 84.9 cd
5	22.5 ± 2.29 b	31.5 ± 8.07 c	46.4 ± 3.25 d	44.6 ± 6.11 bc	671.0 ± 21.9 c	633.0 ± 102 bc
Effect significance	***	***	***	***	***	***

Explanations: see table 3.

Table 5. The effect of different substrates on flower diameter and number of flowers per inflorescence in zonal pelargonium of ‘Survivor Hot Pink’ and ‘Graffiti Fire’ cultivars

Media	Diameter of flower (cm)		Number of flowers in inflorescence	
	Cultivar			
	‘Survivor Hot Pink’	‘Graffiti Fire’	‘Survivor Hot Pink’	‘Graffiti Fire’
1	3.90 ± 0.17 c	4.03 ± 0.14 bc	38.8 ± 2.92 a	40.9 ± 3.41 bc
2	4.15 ± 0.15 bc	3.97 ± 0.12 cd	42.4 ± 4.44 a	50.9 ± 2.70 a
3	4.42 ± 0.29 ab	4.19 ± 0.14 ab	39.4 ± 3.69 a	33.7 ± 3.81 d
4	4.26 ± 0.08 ab	3.78 ± 0.17 d	31.0 ± 3.06 b	43.7 ± 7.28 b
5	4.48 ± 0.25 a	4.34 ± 0.13 a	23.2 ± 2.51 c	35.2 ± 3.56 cd
Effect significance	**	***	***	***

Explanations: see table 3.

niums growing in the substrate 2. Plants of both cultivars produced more inflorescences when grown in the control medium and the substrates with compost:peat ratio of 1:3 (substrates 2 and 4) than in the substrates with compost:peat ratio of 1:7 (substrates 3 and 5). Grigatti et al. [2007] reported beneficial effects of supplementing growth media with 25% of municipal sewage sludge on the flowering of *Begonia semperflorens*, *Mimulus* sp., *Salvia splendens* and *Tagetes* 'Zenith Lemon Yellow' taxa, which is consistent with the outcomes of this study. However, the number of flowers in the four examined taxa decreased when the share of the municipal sewage sludge increased from 25 to 100%.

The highest content of chlorophyll a was found in the leaves of 'Survivor Hot Pink' plants growing in the substrates 1, 2, and 3. Substrate type did not affect chlorophyll a content in 'Graffiti Fire' cultivar. No differences were observed in both pelargonium cultivars between leaf content of chlorophyll b and carotenoids in the plants grown in the control substrate and in the substrate 2 and 3 containing SSRS compost (Table 7).

The type of substrate affected the ornamental value of the cultivars in a different manner (Figure 1). The examined substrates did not affect the ornamental value of 'Survivor Hot Pink' cv. Contrary to that, the highest bonitation score in 'Graffiti Fire' cv. was obtained in the plants growing on SSRS or SSL compost and peat (1:3), and it was impaired by the substrates 3 and 5.

Contrasting results were obtained for ivy pelargonium grown in substrates of the same qualitative and quantitative composition [Zawadzińska and Salachna 2014c]. Two ivy pelargonium cultivars, 'Beach' and 'Boneta' grew better in the substrate containing sewage sludge compost and leaves mixed with peat in a ratio of 1:7 (v/v). The number of inflorescences in these cultivars was independent of the compost type or dose. According to Biamonte et al. [1993] zonal pelargoniums have higher requirements than ivy pelargoniums. This is probably why our study revealed better growth and development of zonal pelargonium in the substrates with higher compost content.

Table 6. The effect of different substrates on inflorescence diameter, inflorescence stem length and total number of inflorescences developed by zonal pelargonium of 'Survivor Hot Pink' and 'Graffiti Fire' cultivars

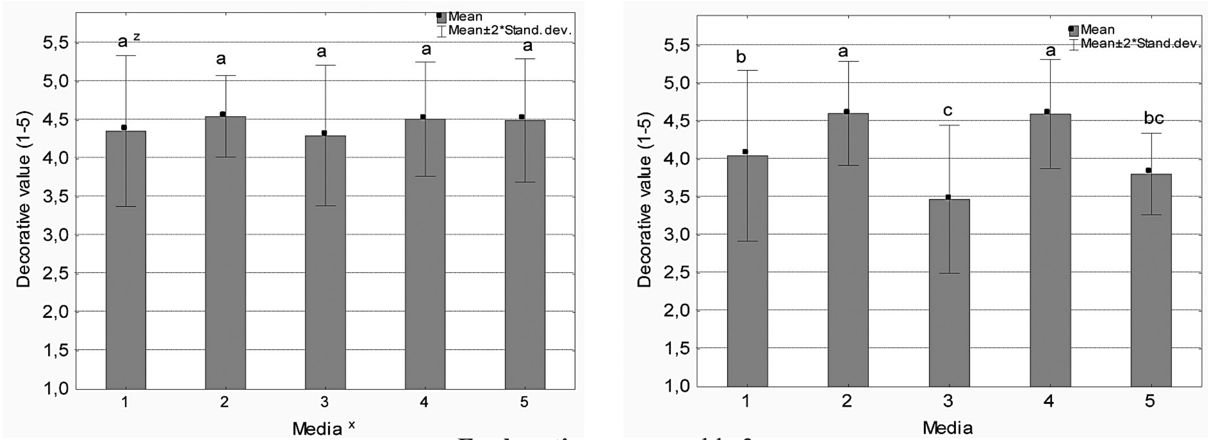
Media	Diameter of inflorescence (cm)		Length of inflorescence stem (cm)		Total inflorescences per plant	
	Cultivar					
	'Survivor Hot Pink'	'Graffiti Fire'	'Survivor Hot Pink'	'Graffiti Fire'	'Survivor Hot Pink'	'Graffiti Fire'
1	10.4 ± 0.56 a	8.61 ± 0.14 a	15.4 ± 0.71 c	15.2 ± 0.78 b	12.8 ±1.26 a	16.1 ± 2.06 ab
2	11.2 ± 0.66 a	8.49 ± 0.35 a	18.8 ± 1.43 a	17.5 ± 0.51 a	12.1 ±1.87 ab	18.3 ± 3.33 a
3	10.8 ± 0.50 a	8.43 ± 0.69 a	16.7 ± 0.66 b	15.5 ± 0.25 b	10.6 ±0.99 b	12.8 ± 1.74 c
4	10.5 ± 0.13 a	8.43 ± 0.36 a	15.0 ± 0.89 c	15.0 ± 1.68 b	10.9 ±0.51 ab	17.3 ± 3.13 ab
5	10.8 ± 0.89 a	8.81 ± 0.55 a	16.8 ± 0.89 b	15.0 ± 0.69 b	10.4 ±1.44 b	15.4 ± 2.02 b
Effect significance	ns	ns	***	**	**	**

Explanations: see table 3; FM – fresh matter.

Table 7. The effect of different substrates on the content of chlorophyll a and b and carotenoids in fresh leaves of zonal pelargonium of 'Survivor Hot Pink' and 'Graffiti Fire' cultivars

Media	Chlorophyll *a* ($\mu g \cdot g^{-1}$ FM)		Chlorophyll *b* ($\mu g \cdot g^{-1}$ FM)		Carotenoids ($\mu g \cdot g^{-1}$ FM)	
	Cultivar					
	'Survivor Hot Pink'	'Graffiti Fire'	'Survivor Hot Pink'	'Graffiti Fire'	'Survivor Hot Pink'	'Graffiti Fire'
1	1097.8 ± 75.9a	1038.0 ± 37.1a	499,5 ± 25.7a	482,6 ± 25.1a	528,4 ± 38.3a	505,1 ± 24.7a
2	1040.6 ± 37.7a	1031.1 ± 43.3a	456,4 ± 3.53ab	469,8 ± 11.4ab	506,3 ± 8.48a	494,7 ± 18.7ab
3	1086.3 ± 41.4a	1059.9 ± 89.3a	467,5 ± 58.7ab	493,4 ± 14.8a	516,4 ± 54.7a	512,7 ± 21.8a
4	788.4 ± 22.2b	946.5 ± 11.5a	395,5 ± 32.5b	432,5 ± 0.70bc	383,4 ± 2.68b	459,2 ± 1.06b
5	837.4 ± 27.2b	946.0 ± 0.80a	387,6 ± 21.6b	424,8 ± 8.90c	406,2 ± 21.0b	451,7 ± 5.60b
Effect significance	**	ns	*	*	*	*

Explanations: see table 3; FM – fresh matter.



Explanations: x,z see table 3

Figure 1. The effect of different substrates on the ornamental value (1-5 bonitation scale) of Pelargonium hortorum 'Survivor Hot Pink' (left) and 'Graffiti Fire' (right)

The study results indicated that the substrates supplemented with composts containing sewage sludge can be used for the production of both examined pelargonium cultivars. The composts accounted for 25% of compost-peat mixtures and pelargoniums cultivated in them presented high decorative value. Replacing 12.5–25% of high peat with compost allows for a significant drop in peat consumption. This is one of the reasons for undertaking studies on alternative substrates that can replace peat, the extraction of which is regulated in Europe [Ostos et al. 2008]. Additionally, it is one of the most reasonable ways of dealing with problematic waste. Plants grown in these types of substrates can be cultivated in green areas, flowerbeds, the places transformed as a result of construction works and degraded areas whose original function is to be restored [Zawadzińska et al. 2015].

CONCLUSIONS

1. Composts made of municipal sewage sludge and straw or leaves are useful components of substrates for the production of pelargoniums of Survivor and Graffiti groups.
2. Irrespective of the compost dose, compost containing substrates significantly affected the examined morphological features of zonal pelargonium, except for inflorescence diameter.
3. The substrate containing the compost made of sewage sludge and straw (SSRS) and peat (1:3, v/v) was found to be the most beneficial for pelargonium foliage, i.e. the number of leaves, their fresh weight and assimilation area.
4. The substrate containing SSRS compost (sewage sludge and straw) and peat in a ratio of 1:7 (v/v) provided the least favorable effect on the habit of both pelargonium cultivars. This compost mixed with peat in a ratio of 1:3 (v/v) stimulated elongation of pelargonium inflorescence stems.
5. Leaf chlorophyll and carotenoid content in the pelargoniums grown in the substrates containing either dose of SSRS compost did not differ from the control plants.
6. The substrate type did not affect bonitation score of 'Survivor Hot Pink' cultivar. 'Graffiti Fire' plants were more decorative and achieved higher bonitation score when grown in the substrates with higher compost share.

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