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Research Article

EFFECT OF SUBSTRATES CONTAINING COMPOSTS WITH THE PARTICIPATION OF MUNICIPAL SEWAGE SLUDGE ON FLOWERING AND MACRONUTRIENT CONTENT IN THE LEAVES OF GARDEN PANSY (*VIOLA* × *WITTROCKIANA* GAMS.)

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ABSTRACT
The aim of the study was to assess the impact of substrates containing composts made from municipal sewage sludge and straw or sawdust on flowering, leaf greenness index and macronutrient content in the leaves of 'Fancy Carmine with Blotch' garden pansy. Two composts, with the following compositions: K I – 70% municipal sewage sludge, 30% rye straw; K II – 70% municipal sewage sludge, 30% coniferous tree sawdust, were used for the preparation of substrates. Six substrates of peat and compost at 25, 50 and 75% (by volume) were prepared. The control object was a peat substrate, pH 5.8–6.0, supplemented with Azofoska at 2.5 g·dm^{-3}. It has been found that leaf greenness index of pansy increased with an increasing share of compost. Composts involving municipal sewage sludge at the level of 50% had a more positive influence on the abundance of pansy flowering than at 25 and 75%. The content of total nitrogen, phosphorus, potassium and sulfur in the leaves increased with increasing the dose of compost. The content of total phosphorus in the leaves at the end of pansy cultivation in compost substrates ranged optimally for this species. In the experiment conducted in 2006, pansies contained more total nitrogen, potassium and sulfur than the flowering pansies planted in 2005.

Keywords: municipal sewage sludge, composts, SPAD, pansy, *Viola* × *wittrockiana* Gams.

INTRODUCTION

Garden pansy (*Viola* × *wittrockiana* Gams.) is a temperate climate plant and belongs to one of the most popular early spring and late summer ornamental plants in Europe, USA and Japan [Kessler 1998; Startek 2001; Wade and Thomas 2012]. For the cultivation of garden pansy, peat substrates are usually recommended, their physical properties are most suitable [Startek 2001; Di Benedetto et al. 2010]. Due to a large use of peat as a substrate for the cultivation of ornamental plants, including pansy, it is necessary to replace this material with alternative substrates, thanks to which one can reduce the use of peat [Chavez et al. 2008; Di Benedetto et al. 2010]. Previous studies indicate that pansy develops normally also in the substrate with the participation of clay and pine bark with nitrogen fertilizer [Anserimino et al. 1995; Sloan et al. 2004], in the substrate with rice husk in different proportions [Evans and Gauchukia 2004; Currey et al. 2010], and also in the substrate with the participation of coconut fiber [Janicka 2010]. In Poland, the possibility of using some of waste, such as dried shrimp [Placek 2009], municipal sewage sludge, potato pulp [Zawadzińska and Janicka 2007], as a substrate component for growing pansy was studied. Dried shrimp proved to be useful only in the case of putting a small part of it into the substrate, while the substrate containing composts with the participation of municipal sewage sludge in certain proportions turned out to be useful for the growing of cultivars of pansy of Thapsus group.

Municipal sewage sludge can be used naturally after having met the conditions contained in the Polish legislation [Regulation… 2008; Regulation… 2010]. Composts with the participation of municipal sewage sludge contain a lot of organic matter and are very rich in macro- and micronutrients [Kalembasa and Kuziemska 1999; Baran 2004]. However, the elevated pH and excessive salinity limit their use in the cultivation of ornamental plants [Abad et al. 2001; Moore 2004]. Mixing these composts with the ones containing a small amount of nutrient components, such as peat, reduces the salinity of the substrates. The use of composts as a component of substrates for the cultivation of ornamental plants has ecological and economic aspects, as it creates a nuisance to dispose of waste, while limiting the use of mineral fertilizers [Ribeiro et al. 2000; Zubilaga and Lavado 2001; Karoń and Pietr 2006].

The aim of this study was to evaluate the effect of substrates containing peat moss and two types of composts prepared from municipal sewage sludge and structure-forming components – straw and sawdust – on the leaf greenness index, flowering and macronutrient content in the leaves of the 'Fancy Carmine with Blotch' garden pansy.

MATERIAL AND METHODTS

The study was conducted in 2005–2006 in a plastic tunnel of West Pomeranian University of Technology in Szczecin. Plant material was 'Fancy Carmine with Blotch' garden pansy seedling from a German company Benary, it was obtained from sowing seeds on 1 June 2005 (for flowering during late summer) and 1 September 2005 (the spring blooming). Seeds were sown in peat substrate, following the instructions given in Startek's [2001] paper. After 4–5 weeks, the seedlings were quilted to substrates prepared 4 weeks earlier. For the preparation of substrates, two types of compost were used, after 7 and 12 months of decomposition. The process of composting is given in Krzywy et al. [2007] paper. The material composition of compost in dry weight was as follows: K I – 70% municipal sewage sludge, 30% rye straw; K II – 70% municipal sewage sludge, 30% coniferous tree sawdust. Six substrates based on peat moss and compost in three proportions by volume were prepared: 1 – 25% compost I + 75% sphagnum peat; 2 – 50% compost I + 50% sphagnum peat; 3 – 75% compost I + 25% sphagnum peat; 4 – 25% compost II + 75% sphagnum peat; 5 – 50% compost II + 50% sphagnum peat; 6 – 75% compost II + 25% sphagnum peat. The physical and chemical analysis of peat and substrates is shown in Table 1 and 2. Basing on the results, substrates too acidic for pansy were neutralized with chalk and dolomite to pH 5.8–6.0. Substrates with low potassium content were completed to the level of 300 mg $K \cdot dm^{-3}$, using potassium sulfate. The control object was sphagnum peat neutralized with chalk and dolomite to pH of 5.8–6.0, with the addition of Azofoska (13.6N+2.8 P+15.8K), at a dose of 2.5 $g \cdot dm^{-3}$.

Pansy seedlings were planted in prepared substrates into pots with a diameter of 10 cm and grown on tables in a plastic tunnel. In the cultivation, top

Table 1. Physical and chemical properties of substrates for garden pansy *(Viola × wittrockiana* Gams.*)* prepared for planting in 2005–2006

Substrate	2005				2006			
	PH_{H2O}	Dry matter (%)	Density ($g \cdot cm^{-3}$)	Salinity NaCl ($g \cdot dm^{-3}$)	PH_{H2O}	Dry matter (%)	Density ($g \cdot cm^{-3}$)	Salinity NaCl ($g \cdot dm^{-3}$)
Peat	3.60	59.8	0.18	0.35	3.60	59.8	0.18	0.35
1	4.50	36.9	0.26	2.85	4.45	36.8	0.26	2.98
2	5.35	36.3	0.39	3.50	5.15	36.3	0.38	3.66
3	5.70	45.2	0.40	4.34	5.40	45.1	0.38	4.37
4	5.25	38.8	0.33	1.55	5.10	37.5	0.31	1.65
5	5.80	38.1	0.39	1.69	5.80	36.1	0.39	1.69
6	6.30	70.8	0.42	1.78	6.20	59.0	0.40	1.66

Explanations: Composition of substrates: 1 – 25% compost I + 75% peat; 2–50% compost I + 50% peat; 3 – 75% compost I + 25% peat; 4 – 25% compost II + 75% peat; 5 – 50% compost II + 50% peat; 6 – 75% compost II + 25% peat.

Composition of composts: compost I – 70% sewage sludge, 30% rye straw; compost II – 70% sewage sludge, 30% saw dust from coniferous tree.

Table 2. Chemical characteristic of substrates for garden pansy *(Viola × wittrockiana* Gams.*)* prepared for planting in 2005–2006

Substrate	Total form content ($g \cdot kg^{-1}$ d.m.)						Available form content ($mg \cdot dm^{-3}$)				
	N	P	K	CA	MG	S	$N\text{-}NO_3$	P	K	CA	MG
2005											
Peat	8.90	1.60	1.60	2.10	0.30	0.50	17.0	20.0	6.00	42.0	27.0
1	15.9	13.3	2.20	5.70	0.55	4.20	252	340	398	1144	322
2	17.4	18.3	3.65	7.70	0.62	5.20	465	735	370	2110	430
3	22.4	19.3	3.80	7.90	0.65	6.80	590	850	360	2780	470
4	15.1	8.80	2.10	4.50	0.48	2.20	230	410	140	1225	270
5	15.3	12.0	2.20	6.10	0.60	4.50	332	540	256	2508	278
6	18.6	14.3	2.80	7.00	0.58	6.20	710	602	302	2996	366
2006											
Peat	8.90	1.60	1.60	2.10	0.30	0.50	17.0	20.0	6.00	42.0	27.0
1	16.3	15.3	2.40	5.70	0.56	4.00	364	460	289	1132	303
2	17.6	17.3	3.70	7.70	0.63	5.30	785	687	379	2265	500
3	25.2	19.1	3.70	8.10	0.64	6.70	800	847	385	3478	580
4	16.1	8.70	1.30	5.60	0,50	2.20	326	419	139	1430	236
5	16.6	13.0	2.20	6.70	0.56	4.70	346	671	224	2690	309
6	20.8	15.3	2.90	7.10	0.59	6.10	945	741	256	3080	327

Explanations: see table 1.

dressing was not used. Each experimental object occurred in four replications, 5 plants in each.

The air temperature while growing pansy in the summer months (VII–VIII) was controlled by intense airing and shading plants. While wintering, minimum air temperature in the plastic tunnel (I–III), as recommended, ranged from 2 to 5 °C.

At the beginning of the generative phase, the pansy leaf greenness index was measured with an optical device Chlorophyll Meter SPAD-502 (Minolta). According to the literature [Loh et al. 2002, Altland et al. 2003], leaf greenness index is highly correlated with chlorophyll content. This measurement method is frequently used to assess the degree of crop nutrition [Loh et al. 2002, Altland et al. 2003, Larcher et al. 2011]. This device performs a non-invasive measurement of the area of 6 mm^2 in SPAD (Soil Plant Analysis Development) units. Four measurements were performed on each mature pansy leaf, in the middle of the leaf blade. The results were averaged for each replication. In both years of the study, for 8 weeks of flowering, flowers were counted and then removed. The numbers of flowers are given per one plant.

After the cultivation, the total contents of nitrogen, phosphorus, potassium, calcium, magnesium and sulfur were determined in pansy leaves. Plant material for the analysis was obtained by taking samples from two replicates of each object, and then drying them at 60 °C. After grinding the material in a laboratory mill macronutrients were determined in them in two replications. Total nitrogen was determined with the Kjeldahl method after prior digestion of samples in concentrated sulfuric acid (VI) with the addition of a selenium mixture, total phosphorus with colorimetric method according to Barton, potassium and calcium with flame photometry and total sulfur with macro-sulfur elemental analyzer VarioMax. For the determination of total magnesium, the method of atomic absorption spectrometry (AAS) was used, after prior digestion of samples in a mixture of nitric acid (V) and chlorine acid (VII) in a 1:1 ratio.

The results concerning the number of flowers, SPAD readings and the total form of macronutrient content in the leaves were verified using the ANALWAR 4.0 analysis of variance for multifactor experiments. The significance of the average values was verified with Tukey's range test at a level of $\alpha = 0.05$.

RESULTS AND DISCUSSION

Garden pansy according to Hamrick [2003] has secondary cultivation requirements. The substrate for seeding as well as further cultivation of pansy should have good air-water properties.

As recommended by Kessler [1998] and Bailey [1998], the substrate pH for pansy is 5.4–5.8, while the pH recommended by German companies specializing in the cultivation and production of pansy is 5.5–6.2 [www.benary.com]. In our study, in the prepared substrates, the pH was adjusted according to the breeder of the tested cultivar – Benary (Table 1). Although pansy is produced in large quantities in Poland and in the world, in the available literature, there is no information about the limit numbers relating to the content of nutrients in substrates for its cultivation. In the fertilization of pansy, the form of nitrogen provided with a mineral fertilizer is important [www.benary.com]. Excess nitrogen in ammonium form can adversely affect the plant when it is grown at higher temperatures [Hamlin et al. 1999; Hamlin and Mills 2001]. The content of nitrate (V) and other components, especially phosphorus, potassium and calcium in the prepared substrates was quite high (Table 2), and in some, exceeded the recommended value for ornamental plants with high nutritional requirements [Strojny 1996]. Salinity of substrates (2.85–4.37 g KCl $\cdot dm^{-3}$) was significantly higher in objects containing compost I with the participation of municipal sewage sludge (70%) and straw (30%) than in the substrates containing compost II (municipal sewage sludge 70%, sawdust 30%) – Table 1. Despite the enhanced performance of substrates containing composts with municipal sludge, in a number of scientific studies in Poland and abroad [Ramahsamay 2004; Vabrit et al. 2007; Wraga and Zawadzińska 2007; Ahmad et al. 2012], it was demonstrated that ornamental plants grown in such substrates can grow and develop normally.

In the first year, the leaf greenness index of garden pansy in the early stages of flowering was higher in objects with substrates containing compost I, with 70% of the municipal sewage sludge and 30% of straw (Table 3). Most greenness was observed in pansies in objects containing 50%

Table 3. Leaf greenness index (SPAD) of 'Fancy Carmine with Blotch' garden pansy grown in substrates containing compost with municipal sewage sludge

Dose of compost in substrate [%]		2005			2006		
		Type of compost*		Mean	Type of compost		Mean
		K I	K II		K I	K II	
0		26.8	26.3	26.5	48.4	47.7	48.0
25		25.3	20.9	23.1	47.9	43.5	45.7
50		32.9	30.4	31.7	49.0	47.6	48.3
75		37.0	27.9	32.4	48.9	49.1	49.0
Mean		30.5	26.3	28.4	48.5	47.0	47.7
$LSD_{0,05}$ for:	compost	1.52			n.s.		
	dose	2.88			n.s.		
	compost × dose	3.05			n.s.		
	dose × compost	4.07			n.s.		

Explanations: see table 1; n.s. – no significant differences.

Table 4. Number of flowers of 'Fancy Carmine with Blotch' garden pansy grown in substrates containing compost with municipal sewage sludge

Dose of compost in substrate [%]		2005			2006		
		Kind of compost*		Mean	Kind of compost		Mean
		K I	K II		K I	K II	
0		31.7	31.3	31.5	32.4	32.0	32.2
25		23.6	21.6	22.6	28.8	25.9	27.3
50		30.6	29.1	29.8	30.5	30,8	30.6
75		25.9	22.0	24.0	30,0	26.7	28.3
Mean		27.9	26.0	27.0	30.4	28.9	29.6
$LSD_{0,05}$ for:	compost	n.s.			n.s.		
	dose	5.167			4.085		
	compost × dose	n.s.			n.s.		

Explanations: see table 1; n.s. – no significant differences.

and 75% of the compost in the substrate – respectively, 31.7 and 32.4 SPAD. In 2006, pansies in spring had a greater leaf greenness index than at the same stage of development in 2005. The type of compost and compost dose applied to the substrate did not affect leaf greenness index of pansy. Beneficial effects of the substrate with an addition of municipal sewage sludge or composts with the participation of municipal sludge on the leaf greenness index were demonstrated in experiments with geranium (*Pelargonium × hortorum*), chrysanthemum (*Chrysanthemum × grandiflorum*), impatiens (*Impatiens walleriana*) and small-sized pansies (*Viola × wittrockiana*) [Dudka et al. 1998; Wraga and Zawadzińska 2007; Zawadzińska and Janicka 2007; Zawadzińska and Dobrowolska 2009].

In both years of the study, the type of compost used for the preparation of substrates to grow pansy did not affect the number of flowers (Table 4). The influence of compost in the substrate on pansy flowering was shown. In the first year of the study, more flowers were obtained in the control object and objects containing compost at 50% - respectively, 31.5 and 29.8 of the flower.

In the second year of the study, most flowers were on the control plants (32.2 of the flower), but a lot of flowers were also present in the objects, where compost was at the level of 50% and 75% of the volume of the substrate (Table 4). Limitations on the number of flowers per plant by increasing the participation of municipal sludge in the substrate (from 25 to 100%) were observed in the Grigatti et al. [2007] study of constantly thriving begonia (*Begonia semperflorens*), *Mimulus hybridus*, sage (*Salvia splendens*) and marigold (*Tagetes* 'Zenith Lemon Yellow'). A positive effect on the flowering of the above-mentioned taxa was achieved by the lowest dose of municipal sludge. In our study, no interaction between the type of compost and its participation in the substrate was observed. In the spring term in 2006, pansies developed 9.6% more flowers than in the fall of 2005 (Table 4).

The type of compost and participation of compost in the substrate contributed to the total nitrogen content in the leaves of garden pansy in the first year of cultivation (Table 5). Pansies grown in the substrate containing compost II (70% municipal sewage sludge, 30% sawdust) had significantly more nitrogen in the leaves of the objects containing compost I (70% municipal sewage sludge, 30% straw). The greatest amount of total nitrogen was present in the leaves of pansy grown in the substrate containing 75% of compost. In 2006, pansies were not significantly different in nitrogen content in the objects containing composts. The least amount of nitrogen was present in the control object. Pansies flowering in 2006 contained more nitrogen in the leaves, on average by 46.3% compared to 2005. In both years, the interaction between the type of compost and its participation in the substrate occurred. Kessler [1998] reported that the nitrogen content in the leaves of a properly fertilized pansy should be 3.5–4.5% N d.m. On the other hand, according to Whipker et al. [2003], the total nitrogen content in the leaves of well-fertilized pansies ranges from 2.5 to 4.5% N d.m.. The authors probably studied nitrogen content in the indicator leaves, but this information was not included. In our study, the total nitrogen content was determined in all leaves at the end of the cultivation. In each test year, the total nitrogen content was lower than that recommended by the above-mentioned authors, but symptoms of nitrogen deficiency were seen only in plants flowering in 2005.

In both years of the study, the type of compost and compost content in the substrate affected the phosphorus content in the leaves of pansy (Table 5). More phosphorus was present in the plants grown in objects containing compost II (municipal sewage sludge 70%, sawdust 30%), 0.76–0.77% P d.m., than when the sawdust in the compost was replaced with straw - an average of 0.70% P d.m. The phosphorus content in a well-fertilized pansy according to Bailey [1998] and Whipker et al. [2003] is 0.25–1.00% P d.m., and according to Kessler (1998) 0.3–1.0% P d.m. In our study, the phosphorus content determined in all the leaves of the plant was within the range recommended by the above-mentioned authors.

The potassium content in the leaves of pansy in the first and second years of the study depended on both of the studied factors (Table 5). In the first year, pansies had more potassium in the leaves in the objects with compost II (municipal sewage sludge 70%, sawdust 30%) than those in the objects with compost I (municipal sewage sludge 70%, straw 30%). Most potassium was found in the leaves of pansy in the objects with the highest content of composts (1.32% K d.m.) and the lowest at the control object (0.76% K d.m.). In the second year of the study, most of potassium was present in the leaves of pansy grown in the substrate containing compost I. Pansy did not significantly differ in the potassium content between objects that contained composts, but in the control objects, plants contained the least potassium. Pan-

Table 5. The content of total nitrogen, phosphorus and potassium in the 'Fancy Carmine with Bloch' garden pansy leaves depending on the type and dose of compost in the substrate after cultivation

Dose of compost in substrate [%]		2005			2006		
		Total N [% d.m.]					
		Type of compost*		Mean	Type of compost		Mean
		K I	K II		K I	K II	
0		0.710	0.708	0.709	1.019	1.015	1.017
25		0.791	0.834	0.812	1.387	1.365	1.376
50		0.811	1.011	0.911	1.350	1.385	1.367
75		0.872	1.314	1.093	1.365	1.431	1.398
Mean		0.796	0.967	0.881	1.280	1.299	1.289
$LSD_{0,05}$ for:	compost	0.016			n.s.		
	dose	0.032			0.038		
	compost × dose	0.033			0.039		
	dose × compost	0.046			0.054		
Dose of compost in substrate [%]		P [% d.m.]					
		Type of compost		Mean	Type of compost		Mean
		K I	K II		K I	K II	
0		0.42	0.42	0.42	0.56	0.57	0.57
25		0.67	0.81	0.74	0.70	0.80	0.75
50		0,76	0.93	0.84	0.74	0.88	0.81
75		0.96	0.90	0.93	0.78	0.81	0.80
Mean		0.70	0.76	0.73	0.70	0.77	0.73
$LSD_{0,05}$ for:	compost	0.018			0.019		
	dose	0.035			0.037		
	compost × dose	0.035			0.038		
	dose × compost	0.049			0.052		
Dose of compost in substrate [%]		K [% d.m.]					
		Type of compost		Mean	Type of compost		Mean
		K I	K II		K I	K II	
0		0.76	0.76	0.76	1.44	1.44	1.44
25		0.90	1.21	1.05	1.71	1.62	1.67
50		1.18	1.24	1.21	1.75	1.63	1.69
75		1.29	1.35	1.32	1.71	1.70	1.70
Mean		1.03	1.14	1.09	1.65	1.60	1.62
$LSD_{0,05}$ for:	compost	0.023			0.018		
	dose	0.045			0.035		
	compost × dose	0.045			0.036		
	dose × compost	0.063			0.050		

Explanations: see table 1; n.s. – no significant differences.

sy blooming in spring 2006 contained more potassium in leaves – an average of 48.6% more than in 2005. In both years, the potassium content in the leaves of pansy was not within the range of 2.5–5.0% K d.m. as recommended by Bailey [1998] and Whipker et. al. [2003] and within the range of 3.0–4.5% K d.m. as given by Kessler [1998].

In 2005 and 2006, the examined factors did not affect the content of calcium and magnesium in the leaves of pansy (Table 6). Slightly more calcium in the leaves was present in the case of flowering pansies grown in 2005. The magnesium content in the leaves of pansy in the studied period was similar. In both years, the calcium content in all leaves ranged below the range of 0.6–3.0% Ca d.m. given by Bailey [1998] and Whipker et al. [2003], and 0.6–1.2% Ca d.m. given by Kessler [1998]. The magnesium content in the leaves of pansy was less than the optimal recommended by Bailey [1998] and Whipker et al. [2003].

The amount of total sulfur in the leaves of pansy did not depend on the type of compost (Table 6). The dose of compost affected the sulfur content in the leaves in both years of the study. In 2005, most sulfur (0.068% S d.m.) was present in the leaves of pansy grown in the substrate containing 75% of composts, while in 2006, there were no significant differences in the sulfur content between objects containing compost. In 2006, the plants contained an average of almost three times more sulfur than in 2005 in the leaves. According to Bailey [1998], in the properly nourished pansy, the sulfur content in the leaves should be within the range 0.2–0.7% S d.m. In the two years of study, the sulfur content was less than the optimum range recommended for pansy.

The applied substrates with the participation of composts were very rich in nutrients (Table 2). The small content of total nitrogen, potassium, calcium, magnesium and sulfur may be due to ion imbalance between the studied elements of the substrate and their antagonistic effects on one another, particularly between calcium and magnesium [Marschner 1993; Bailey et al. 1995;

Table 6. Calcium, magnesium and sulfur content in the leaves of 'Fancy Carmine with Blotch' garden pansy depending on the type and dose of compost in the substrate after cultivation

Dose of compost in substrate [%]		2005			2006		
		Ca [% d.m.]					
		Type of compost*		Mean	Type of compost		Mean
		K I	K II		K I	K II	
0		0.132	0.129	0.130	0.089	0.097	0.093
25		0.135	0.135	0.135	0.121	0.122	0.121
50		0.132	0.144	0.138	0.121	0.119	0.120
75		0.135	0.144	0.139	0.122	0.111	0.117
Mean		0.133	0.138	0.136	0.113	0.112	0.113
$LSD_{0,05}$ for:	compost	n.s.			n.s.		
	dose	n.s.			n.s.		
	compost × dose	n.s.			n.s.		
Dose of compost in substrate [%]		Mg [% d.m.]					
		Type of compost		Mean	Type of compost		Mean
		K I	K II		K I	K II	
0		0.087	0.086	0.086	0.079	0.075	0.077
25		0.085	0.084	0.084	0.087	0.087	0.087
50		0.086	0.082	0.084	0.087	0.085	0.086
75		0.087	0.087	0.087	0.083	0.086	0.084
Mean		0.086	0.084	0.085	0.084	0.083	0.083
$LSD_{0,05}$ for:	compost	n.s.			n.s.		
	dose	n.s.			n.s.		
	compost × dose	n.s.			n.s.		
Dose of compost in substrate [%]		S [% d.m.]					
		Type of compost		Mean	Type of compost		Mean
		K I	K II		K I	K II	
0		0.027	0.022	0.025	0.099	0.098	0.098
25		0.037	0.046	0.042	0.121	0.131	0.126
50		0.044	0.044	0.044	0.126	0.135	0.130
75		0.085	0.051	0.068	0.124	0.141	0.132
Mean		0.048	0.041	0.044	0.117	0.125	0.122
$LSD_{0,05}$ for:	compost	n.s.			n.s.		
	dose	0.010			0.026		
	compost × dose	0.010			n.s.		
	dose × compost	0.013			n.s.		

Explanations: see table 1; n.s. – no significant differences.

Lis-Krzyścin 2007; Francke 2010]. For pansy, the optimum ratio of Ca: Mg should be 5:2. The higher the ratio of these elements, the more their collection is hampered, and boron deficiency occurs [Laffe and Styer 1989; Bailey et al. 1995]. In compost substrates for growing pansy, the ratio Ca: Mg was much greater than 5:2, as recommended by Bailey et al. [1995]. The optimal macronutrient content provided by American researchers has probably been developed on the indicator leaves of pansy, for diagnostic purposes. Our study examined the content in all leaves, after completion of cultivation. This might be the reason for lower macronutrient content. Similar results with regard to the content of macronutrients in the leaves were obtained by Zawadzińska and Salachna [2013] in the experiment with *Impatiens walleriana* 'Fiesta Lavendr Orchid' grown in substrates with composts containing municipal sewage sludge.

In the control substrate, after pansy cultivation, the ingredients have been used for the construction of vegetative mass and the production of flowers. In the control object, pansies bloomed profusely. In addition, in 2006, pansies were better fed than in 2005. The research of Harris et al. [1998] and Hamlin and Mills [2001] shows that pansies grown at lower temperatures (12 ºC) are better fed and their leaves contain more nutrients than pansies grown at higher temperatures (22 ºC). In our own study, pansies blooming in spring in 2006 had more flowers, greater leaf greenness index, and a 46.3% increase in total nitrogen content in the leaves. In addition, in 2006, pansies were characterized by a 48.6% increase in the content of total potassium and contained almost three times more sulfur. Phosphorus and magnesium contents in the analyzed period were similar.

CONCLUSIONS

Composts of municipal sewage sludge (70%) and straw (30%) or sawdust (30%) mixed with peat substrate at a dose of 50–75% favourably influenced the intensity of leaf colour 'Fancy Carmine with Blotch' garden pansy. Leaf greenness index (SPAD) of plants while flowering increased with increasing the participation of composts in substrates. Composts added to the peat substrate at 50% had a more positive influence on the abundance of garden pansy flowering than composts at 25% and 75%.

Type of compost and percentage of compost in the substrate affected the content of total nitrogen, phosphorus, potassium and sulfur in the leaves of garden pansy. The content of total nitrogen, phosphorus and sulfur increased when increasingly higher doses of compost were used. Total phosphorus content in the leaves of garden pansy, after growing in the compost substrates, varied within the optimal range for this species.

In the experiment conducted in spring 2006 pansies better advantage of the nutritional components of substrates than in summer 2005. The contents of total nitrogen, potassium and sulhur in the leaves of pansies was greater in 2006.

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