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CHANGES IN THE CHEMICAL COMPOSITION OF ORGANIC MEDIA USED IN CULTIVATION OF GARDEN HORNED VIOLET (*VIOLA CORNUTA* L.) FROM THE PATIOLA F1 GROUP

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Abstract

Compost substrates based on sewage deposits, tannery sludge as well as coconut fiber can become an alternative for peat substrates in the cultivation of ornamental plants. The use of municipal deposit composts to fertilise soils increases their organic mass content, which, as a result of the humidification processes, improves their physical properties, sorptive capacity, creates a lumpy structure and enhances the microbiological activity in soils. The aim of the research was to assess the use of nutrients contained in substrates produced with the use of municipal sewage deposits and coconut fibre in the cultivation of the horned violet. In 2005-2007, experiments were conducted using six horned violet cultivars (*Viola cornuta)* from the Patiola F1 group. Four organic substrates were used in the research: I - sphagnum peat, II – coconut fibre, III – peat and compost substrate 1 (1:1 v/v), IV – peat and compost substrate 2 (1:1 v/v). Compost 1 was prepared from municipal sewage sludge (35%), potato pulp (35%) and straw (30%). Compost 2 was made from municipal sewage sludge (35%), potato pulp (35%) and sawdust (30%). Both of them were composted for 10 months. The following chemical analyses of the composts, their components and substrates after plant cultivation were performed: pH; dry matter content, total nitrogen, total phosphorus, total potassium, calcium and total magnesium, cadmium, copper, manganese, nickel, lead, total zinc.

The compost substrates made from municipal sewage deposits were rich in nutrients and provided the plants with their appropriate amounts. The composts from municipal sewage waste also contained considerable amounts of heavy metals; however, their levels did not exceed the concentrations allowable in mineral soils intended for cultivations and lands.

Key words: coconut fibre, compost, heavy metals, sewage sludge, sphagnum peat.

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ZMIANY SKŁADU CHEMICZNEGO PODŁOŻY ORGANICZNYCH ZASTOSOWANYCH W UPRAWIE FIOŁKA ROGATEGO (*VIOLA CORNUTA* L.) Z GRUPY PATIOLA F1

Abstrakt

W uprawie roślin ozdobnych alternatywą substratów torfowych mogą stać się podłoża kompostowe z osadów ściekowych, a także włókno kokosowe. Zastosowanie kompostów z osadu komunalnego do nawożenia gleb powoduje wzbogacenie ich w masę organiczną, która w następstwie procesów humifikacji poprawia właściwości fizyczne, pojemność sorpcyjną, tworzy strukturę gruzełkowatą i intensyfikuje aktywność mikrobiologiczną w glebach. Celem badań była ocena wykorzystania składników pokarmowych zawartych w podłożach z udziałem komunalnego osadu ściekowego, a także włókna kokosowego w uprawie bratka ogrodowego. W latach 2005-2007 badano 6 odmian bratka ogrodowego z grupy Patiola z zastosowaniem 4 podłoży organicznych: I – torfu wysokiego, II – podłoża z torfu i kompostu 1, III – podłoża z torfu i kompostu 2, IV – włókna kokosowego. Kompost 1 sporządzono z komunalnego osadu ściekowego (35%), wycierki ziemniaczanej (35%) i słomy (30%), kompost 2 – z komunalnego osadu ściekowego (35%), wycierki ziemniaczanej (35%) i trocin (30%). Do badań użyto kompostów po 12 miesiącach kompostowania.

Podłoża kompostowe z komunalnego osadu ściekowego były zasobne w składniki pokarmowe i zapewniały odpowiedni ich poziom uprawianym roślinom. Komposty z komunalnego osadu ściekowego zawierały także znaczne ilości metali ciężkich, jednak ich wartości nie przekraczały dopuszczalnych stężeń dla gleb mineralnych przeznaczonych pod uprawę oraz ziem.

Słowa kluczowe: kompost, metale ciężkie, osad ściekowy, torf wysoki, włókno kokosowe.

INTRODUCTION

Sphagnum peat is the basic substrate in the cultivation of ornamental plants and also the main component of garden substrates; however, other substrates which could at least partially replace it are being searched for (Dobrowolska, Startek 2003, Dobrowolska et al. 2007). Compost substrates based on sewage deposits, tannery sludge as well as coconut fibre can become an alternative to peat substrates in the cultivation of ornamental plants (Czuchaj, Szczepaniak 2005, Krzywy et al. 2007, Tudunwada et al. 2007). The use of municipal deposit composts to fertilise soils increases their organic mass content, which, as a result of the humidification processes, improves their physical properties, sorptive capacity, creates a lumpy structure and enhances the microbiological activity in soils (Krzywy et al. 2004, Harrison et al. 2006). Sewage deposits are characterised by a high content of organic substances, owing to which soil properties can be improved, including its density, porosity or water and nutrient absorption capacity (Krzywy et al. 2004). Research shows an advantageous plant response to the use of municipal deposits as a substrate or substrate component (Andre et al. 2002, Nascimento et al. 2002). The most frequently occurring elements include nitrogen, phosphorus, magnesium, calcium and, to a lesser extent, potassium; therefore, if sewage deposits are used for substrate production, it is necessary to add potassium in the form of mineral fertilizers (Maćkowiak 2001, Krzywy et al. 2000a). Toxic substances are a hazard when sewage deposit-based composts are used. Industrial waste and stormwater flowing down from streets or other hardened surfaces are often dischared into the municipal sewage system, which may result in numerous harmful substances entering the sewage, including detergents and crop protection products (Sommers et al. 1976).

Considerable diversity of sewage deposits produced at various wastewater treatment plants, which are used for compost production, makes it necessary to examine them thoroughly in respect of their chemical composition before they are introduced into the soil. Their characteristics depend on wastewater treatment processes and on deposit processing. Generally, sewage deposits are rich in organic substances; they contain macro- and micronutrients, trace amounts of metals, including heavy metals, as well as organic impurities, including microorganisms (Kulling 2001).

The aim of the research was to assess the use of nutrients contained in substrates produced with the use of municipal sewage deposits and coconut fibre in the cultivation of the horned violet.

MATERIAL AND METHODS

Research shows that organic substrates influence the growth and development of plants as well as causing changes in the chemical properties of substrates during plant cultivation. Experiments with horned violet cultivars (*Viola cornuta* L.) from the Patiola F1 group: Patiola Pure Yellow, Patiola Pure Violet, Patiola Violet with Yellow Face, Patiola Pure Light Blue, Patiola Pure Lemon Yellow and Patiola Tangerine (Syngenta Seeds), were conducted in 2005-2007. Four substrates were used in the experiment: I – sphagnum peat (control), II – substrate from peat and compost 1 (1:1 v/v), III – substrate from peat and compost 2 (1:1 v/v), IV – coconut fibre. Compost 1 was prepared using municipal sewage sludge (35%), potato pulp (35%) and straw (30%). Compost 2 was prepared using municipal sewage sludge (35%), potato pulp (35%) and sawdust (30%). After 10 months of composting, the composts were submitted to the research, and the methods of their preparation were described by Krzywy et al. (2000). Osmocote Exact Hi-Start (15+10+10+) fertiliser in the amount of 5 g dm^{-3} was added to the substrates with peat and coconuts fibre. Substrates with the addition of compost were supplemented with ammonium nitrate (NH_4NO_3) and potassium sulphate (K_2SO_4), and nutrients were provided in amounts necessary to ensure their following levels in substrates: N – 250 mg dm^{-3} and K_2O – 300 mg dm^{-3}.

From September 1 to September 10, pansy seeds were sown into a sphagnum substrate. They were sown spot-wise, at a distance of 2 cm x 0.5 cm. After the seeds were sown, the substrate was sprayed with a fungicidal agent Previcur 607 SL in the concentration 0.15%, covered with perforated film to retain the moisture and placed in a greenhouse with moderately high air temperature 18-20°C. The plants were transplanted between October 11 and October 20, at a 2- 4-leaf phase, into 0.4 l pots filled with the tested substrates. The plants were sprayed with Previcur 607 SL (0.2%) to prevent disease, and then placed on tables in an unheated, plastic film tunnel at distances of 10 x 10 cm. From 11 to 20 April in all the years of the research, pansies from the pots were placed in a plastic tunnel on 120-cm wide beds, at distances of 20 x 15 cm. Regardless of the year, the experiments were terminated between 11 and 20 June.

Chemical analyses of compost from the municipal wastewater treatment plant in Stargard Szczeciński and substrates after plant cultivation included determinations of pH, dry matter content, total nitrogen, total phosphorus, total potassium, calcium and total magnesium, cadmium, copper, manganese, nickel, lead, total zinc. All determinations were performed in accordance with the Polish Standards using the methods specified below. The organic carbon content was determined using the Lichterfeld method as modified by Alten; the total nitrogen was assessed using the Kjeldahl method after wet mineralisation in concentrated H_2SO_4 and a selenium mixture; the total phosphorus was tested using the spectrometric method with ammonium molybdate (according to Barton); assimilable phosphorus was determined calorimetrically, while potassium, calcium and assimilable magnesium were determined using the atomic absorption spectroscopy procedure (ASA) after mineralisation in a mixture of perchloric and nitric acids at a 1:1 ratio; total sulphur was determined using the nephelometric method after mineralisation in a mixture of perchloric acid(VII) and nitric acid(V) at a 1:1 ratio.

The results of chemical composition determinations were analysed statistically using a one-factor and two-factor variance analysis in the Statistica 10 programme. The Tukey's test was used for the verification of statistical significance between the means at the significance level of $\alpha = 0.05$. In the tables, means marked with the same letter do not differ significantly. The results of chemical analyses of substrates used for planting are presented in Table 1. The content of macro- and microelements in sphagnum peat, coconut fibre and both composts 10 months after composting is presented in Table 2.

RESULT AND DISCUSSION

In cultivation of garden pansy and horned violet, seeds as well as proprely prepared, nutrient-rich soil have great impact on the plant quality (Rosińska, Hołubowicz 2008). The nutritional requirements of ornamental plants are quite well known (Strojny 1993); therefore, after performing chemical analyses of composts from municipal sewage deposits, potato pulp and bulk components (straw, sawdust), it was found that they could be used as

Table 1

Chemical composition of components of compost – in 2004-2006

Specification	2004				2005				2006				Aggregated for 2004-2006			
	components of composts															
	MSS*	PP	RS	S	MSS	PP	RS	S	MSS	PP	RS	S	MSS	PP	RS	S
Content of macroelements (g kg^{-1} d.m.)																
C org.	328*c***	110*a*	294*c*	185*b*	267*c*	99*a*	334*d*	188*b*	295*c*	98*a*	342*c*	201*b*	297*c*	102*a*	323*c*	191*b*
N	36.54*c*	5.86*b*	3.45*ab*	1.97*a*	37.56*c*	5.66*b*	4.06*ab*	2.03*a*	40.05*b*	5.72*a*	3.53*a*	2.31*a*	38.05*b*	5.75*a*	3.68*a*	2.10*a*
P	20.16*b*	3.08*a*	2.98*a*	2.86*a*	23.98*b*	4.52*a*	3.45*a*	3.51*a*	23.36*b*	4.12*a*	3.65*a*	3.85*a*	22.50*b*	3.90*a*	3.36*a*	3.41*a*
K	6.24*b*	9.68*c*	7.89*bc*	1.24*a*	5.54*b*	12.42*d*	8.85*c*	1.56*a*	4.67*b*	10.91*c*	7.96*bc*	1.11*a*	5.48*b*	11.00*c*	8.23*bc*	1.30*a*
Ca	19.22*c*	5.47*b*	0.85*a*	0.34*a*	15.26*c*	7.43*b*	0.94*a*	0.53*a*	14.12*c*	6.48*b*	0.93*a*	0.94*a*	16.20*c*	6.46*b*	0.91*a*	0.60*a*
Mg	2.14*c*	1.02*b*	0.19*a*	0.08*a*	2.88*c*	1.25*b*	0.24*a*	0.06*a*	2.84*b*	0.88*a*	0.22*a*	0.18*a*	2.62*c*	1.05*b*	0.22*a*	0.11*a*
S	12.84*c*	1.26*b*	1.52*b*	0.21*a*	9.70*c*	1.76*b*	1.37*b*	0.33*a*	8.21*c*	1.42*b*	1.41*b*	0.29*a*	10.25*c*	1.48*b*	1.43*b*	0.28*a*
C:N	8.97	18.77	85.00	94.00	7.11	17.49	82.00	93.00	7.36	17.13	97.02	87.00	7.81	17.80	88.01	91.30
Content of microelements (mg kg^{-1} d.m.)																
Cd	5. 34*b*	0.11*a*	0.12*a*	0.24*a*	4.23*b*	0.07*a*	0.09*a*	0.19*a*	4.96*b*	0.07*a*	0.09*a*	0.16*a*	4.84*b*	0.08*a*	0.10*a*	0.20*a*
Cu	51.5*b*	2.51*a*	4.98*a*	3.26*a*	42.6*b*	2.23*a*	4.52*a*	3.08*a*	36.4*b*	2.20*a*	4.38*a*	2.86*a*	43.50*b*	2.31*a*	4.63*a*	3.07*a*
Mn	345.1*c*	16.2*a*	72.3*b*	27.1*a*	270.5*c*	14.9*a*	65.4*b*	25.8*b*	234.8*c*	13.8*a*	60.5*b*	26.2*b*	283.5*c*	15.0*a*	66.1*b*	26.4*a*
Ni	28.6*c*	1.95*b*	1.21*ab*	0.78*a*	32.2*c*	1.68*b*	0.89*a*	0.65*a*	33.1*c*	1.61*b*	0.86*a*	0.60*a*	31.30*c*	1.75*b*	0.99*a*	0.68*a*
Pb	49.21*c*	3.58*b*	1.62*a*	2.01*a*	41.33*b*	3.32*a*	1.41*a*	1.88*a*	45.50*c*	3.41*b*	1.25*a*	1.76*a*	45.35*c*	3.44*b*	1.43*a*	1.89*a*
Zn	240.2*c*	12.8*a*	28.5*ab*	44.6*b*	202.4*c*	10.6*a*	25.4*ab*	42.3*b*	166.4*c*	12.3*a*	24.1*ab*	41.8*b*	203.0*c*	11.9*a*	26.0*ab*	42.9*b*

* MMS – municipal sewage sludge, PP – potato pulp, RS – rye straw, S – sawdust;
** Means marked with the same letter do not differ significantly at $\alpha = 0.05$ according to the Tukey's test.

Table 2

Content of macro- and microelements in sphagnum peat, coconut fibre and two composts after 10-month composting (years 2005-2007)

Specification		Components of composts and composts															
		2005				2006				2007				aggregated for 2005-2007			
		1*	2	3	4	1*	2	3	4	1*	2	3	4	1*	2	3	4
pH		3.74*a***	6.02*b*	7.24*c*	7.03*c*	3.47*a*	5.93*b*	6.87*bc*	6.72*c*	3.51*a*	5.76*b*	6.96*c*	6.74*c*	3.57*a*	5.90*b*	7.02*c*	6.83*c*
Content of macroelements ($g\ kg^{-1}$ d.m.)	N	1.44*a*	6.06*b*	20.60*d*	17.20*c*	1.30*a*	5.43*b*	17.40*c*	15.80*c*	1.18*a*	4.86*b*	16.60*c*	15.30*c*	1.31*a*	5.45*b*	18.20*c*	16.10*c*
	P	1.69*a*	4.48*b*	15.90*c*	15.61*c*	1.56*a*	3.89*b*	15.46*c*	15.30*c*	1.64*a*	3.86*b*	15.71*c*	14.39*c*	1.63*a*	4.08*b*	15.70*c*	15.10*c*
	K	1.26*a*	12.52*c*	10.42*bc*	7.98*b*	1.10*a*	11.66*c*	10.22*c*	7.82*b*	1.12*a*	11.23*c*	8.94*b*	7.24*b*	1.16*a*	11.80*c*	9.86*bc*	7.68*b*
	Ca	3.02*a*	3.90*a*	7.42*b*	6.88*b*	2.88*a*	4.01*a*	6.85*b*	6.80*b*	2.58*a*	3.72*a*	6.76*b*	6.68*b*	2.83*a*	3.88*a*	7.01*b*	6.79*b*
	Mg	0.33*a*	0.72*b*	1.66*c*	1.62*c*	0.42*a*	0.56*a*	1.52*b*	1.48*b*	0.29*a*	0.76*b*	1.55*c*	1.51*c*	0.35*a*	0.68*b*	1.58*c*	1.54*c*
Content of microelements ($mg\ kg^{-1}$ d.m.)	Cd	0.11*a*	0.25*a*	2.04*b*	1.85*b*	0.14*a*	0.31*b*	1.68*c*	1.52*c*	0.10*a*	0.22*a*	1.76*b*	1.48*b*	0.12*a*	0.26*a*	1.83*b*	1.62*b*
	Cu	1.28*b*	0.36*a*	34.20*d*	30.20*c*	1.47*b*	0.47*a*	31.60*d*	27.80*c*	1.24*b*	0.38*a*	30.09*d*	27.51*c*	1.33*b*	0.40*a*	32.00*d*	28.50*c*
	Mn	17.1*a*	114.2*b*	201.6*c*	183.7*c*	14.6*a*	108.4*b*	162.4*c*	170.2*c*	15.1*a*	110.4*b*	170.1*c*	162.1*c*	15.6*a*	111.0*b*	178.0*c*	172.0*c*
	Ni	1.74*a*	1.26*a*	18.60*b*	17.50*b*	2.11*a*	1.44*a*	15.50*b*	19.80*c*	1.62*a*	1.43*a*	16.60*b*	14.11*b*	1.82*a*	1.38*a*	16.90*b*	17.10*b*
	Pb	1.36*a*	16.85*b*	23.24*c*	23.60*c*	2.32*a*	20.64*b*	21.03*b*	20.20*b*	2.21*a*	16.86*b*	21.72*b*	21.40*b*	1.96*a*	18.13*b*	22.00*b*	21.70*b*
	Zn	9.58*a*	19.54*b*	240.7*c*	231.2*c*	7.34*a*	22.74*b*	230.2*c*	221.6*c*	9.78*a*	20.04*b*	183.2*c*	216.2*d*	8.90*a*	20.77*b*	218.0*c*	223.0*c*

* 1 – sphagnum peat, 2 – coconut fibre, 3 – compost 1 (municipal sewage sludge 35%, potato pulp 35%, rye straw 30%), 4 – compost 2 (municipal sewage sludge 35%, potato pulp 35%, sawdust from coniferous trees 30%);

** Means marked with the same letter do not differ significantly at $\alpha = 0.05$ according to the Tukey's test.

garden substrates. In the authors' own research, municipal sewage deposit composts were mixed with sphagnum peat. Thus, it is possible to obtain substrates with optimal physicochemical properties for individual plant species (Gouin 1992, Klock-Moore 1999, Zubillaga, Lavado 2001). During the composting process, some organic substances undergo mineralisation to carbon dioxide, ammonia and water, while the remaining organic matter is transformed into humus substances, which are very similar to those present in the soil in terms of their structure (Hernanez-Apaolaza et. al. 2000). The use of composts made from municipal sewage deposits as material appropriate for plant cultivation is also justified economically, as it lowers the substrate costs (Ingelmo et al. 1998).

Research performed by some authors confirms the high content of N, P and even K in sewage deposits, which is even higher than in garden soil. This shows that they can be used as a source of nutrients for plants as well as in the stabilisation process of soil structural properties (Kumar et al. 2008).

Before substrate preparation, chemical analyses of individual components used in the composts as well as analyses of peat, coconut fibre and both composts were performed (Tables 1, 2). It was shown that municipal sewage deposits contained large amounts of N, P and Ca and that it was characterised by a low potassium content. Potato pulp had a relatively high nitrogen and potassium content. Composts obtained after 10-month fermentation were also rich in N, P and Ca; however, before planting, the substrates had to be supplemented with N and K in the form of a mineral fertiliser. The pH of the sewage deposit was high (7.75), but when mixed it was with a bulk component and composted, its pH was reduced to neutral. Sewage deposits contain nitrogen and phosphorus, hence the incorporation of such deposits into the soil offers excellent fertilisation benefits, because the macronutrients they contain are necessary for plant cultivation. Substrates were prepared by mixing the composts obtained with acidic compost in appropriate proportions, which lowered the pH of the substrates to a slightly acidic level.

The analyses performed after the completion of the experiments showed that the substrates used for the cultivation of the horned violet differed in terms of chemical composition (Tables 2-6). The lowest total nitrogen content after the termination of the experiment was found in coconut fibre, especially if it was used for the cultivation of Patiola Pure Lemon Yellow horned violets. The highest amount of nitrogen after the experiment was found in the substrate with the addition of compost I. The P content also differed, depending on the substrate use; the highest amount of this nutrient after the experiment was found in the substrate with the addition of compost II, while it was the lowest in the coconut fibre. Coconut fibre was also relatively poor in calcium (Ca), which is confirmed by research results of Startek et al. (2006). Our study revealed a low potassium content in the peat substrate as well as in substrates with the addition of composts, with the largest amount

Table 3

Changes in the chemical composition of media used for cultivation horned violet from the Patiola F1 group after the end of plant cultivation in 2005

Medium		Cultivars from Patiola F1 group						**Mean**
		Pure Yellow	Violet with Yellow Face	Pure Light	Pure Violet	Tange-rine	Pure Lemon Yellow	
		content (g kg^{-1} d.m.)						
N	Sphagnum peat	9.84	10.25	6.12	8.55	7.36	3.69	**7.64***ab******
	Coconut fibre	7.42	5.54	6.52	5.69	7.68	4.52	**6.23***a***
	Medium with compost 1	10.68	9.56	12.02	13.56	4.65	5.23	**9.28***c***
	Medium with compost 2	9.24	9.88	8.96	10.14	5.74	4.97	**8.16***b***
	Mean	**9.30***c***	**8.81***c***	**8.41***c***	**9.49***c***	**6.36***b***	**4.60***a***	
P	Sphagnum peat	4.56	5.23	2.44	2.16	2.28	1.95	**3.10***ab***
	Coconut fibre	4.21	2.38	1.96	2.21	2.31	2.17	**2.54***a***
	Medium with compost 1	5.26	0.84	5.21	4.56	4.01	3.62	**3.92***b***
	Medium with compost 2	5.05	3.12	4.36	4.78	3.95	4.85	**4.35***c***
	Mean	**4.77***b***	**2.89***a***	**3.49***ab***	**3.43***ab***	**3.14***a***	**3.15***a***	
K	Sphagnum peat	3.18	1.65	2.67	3.52	2.96	2.6	**2.76***ab***
	Coconut fibre	5.16	5.68	4.21	4.26	5.54	5.03	**4.98***c***
	Medium with compost 1	4.02	4.11	3.58	3.02	3.82	3.14	**3.62***b***
	Medium with compost 2	1.42	5.11	1.35	1.62	2.03	1.78	**2.22***a***
	Mean	**3.45***b***	**4.14***c***	**2.95***a***	**3.11***ab***	**3.59***b***	**3.14** *ab*	
Ca	Sphagnum peat	18.2	12.69	15.14	13.65	15.07	14.32	**14.85***b***
	Coconut fibre	4.23	5.84	5.34	5.26	5.62	5.38	**5.28***a***
	Medium with compost 1	15.88	16.52	16.47	15.01	16.11	13.22	**15.54***b***
	Medium with compost 2	14.12	16.74	11.84	13.45	13.45	14.96	**14.09***b***
	Mean	**13.11***b***	**12.95***ab***	**12.20***a***	**11.84***a***	**12.56***a***	**11.97***a***	
Mg	Sphagnum peat	0.64	0.36	0.72	0.42	0.63	0.48	**0.54***a***
	Coconut fibre	0.52	0.42	0.49	0.66	0.51	0.42	**0.50***a***
	Medium with compost 1	0.48	0.46	0.56	0.47	0.63	0.44	**0.51***a***
	Medium with compost 2	0.51	0.48	0.51	0.52	0.52	0.47	**0.50***a***
	Mean	**0.54***a***	**0.43***a***	**0.57***a***	**0.52***a***	**0.57***a***	**0.45***a***	
S	Sphagnum peat	2.46	2.54	2.13	2.14	1.15	1.16	**1.93***a***
	Coconut fibre	2.98	1.86	1.88	2.12	1.89	2.11	**2.14***a***
	Medium with compost 1	2.45	2.36	2.51	2.45	0.94	0.96	**1.95***a***
	Medium with compost 2	2.65	3.05	1.97	1.85	1.67	1.11	**2.05***a***
	Mean	**2.64***b***	**2.45***b***	**2.12***ab***	**2.14***ab***	**1.41***a***	**1.34***a***	
C org.	Sphagnum peat	364	241	215	295	255	152	**254***ab***
	Coconut fibre	286	237	341	266	297	325	**292***b***
	Medium with compost 1	252	265	361	296	120	145	**240***ab***
	Medium with compost 2	202	315	221	210	144	135	**205***a***
	Mean	**276***b***	**265***ab***	**285***b***	**267***ab***	**204***a***	**189***a***	

* Means marked with the same letter do not differ significantly at $\alpha = 0.05$ according to the Tukey's test.

Table 4

Changes in the chemical composition of media used for cultivation horned violet from the Patiola F1 group after the end of plant cultivation in 2006

Medium		Cultivars from Patiola F1 group						Mean
		Pure Yellow	Violet with Yellow Face	Pure Light	Pure Violet	Tange-rine	Pure Lemon Yellow	
		content (g kg^{-1} d.m.)						
N	Sphagnum peat	7.42	10.11	5.86	8.92	5.98	5.38	**7.28***ab******
	Coconut fibre	6.56	6.38	6.85	7.03	7.94	4.79	**6.59***a***
	Medium with compost 1	8.72	10.11	11.47	12.48	4.42	5.11	**8.72***b***
	Medium with compost 2	7.55	7.56	8.42	9.82	5.23	4.75	**7.22***ab***
	Mean	**7.56***ab***	**8.54***b***	**8.15***ab***	**9.56***c***	**5.89***a***	**5.01***a***	
P	Sphagnum peat	4.06	4.86	2.16	2.31	2.46	2.04	**2.98***ab***
	Coconut fibre	3.98	2.71	2.3	2.01	2.22	2.22	**2.57***a***
	Medium with compost 1	4.68	0.75	4.63	4.26	3.78	3.41	**3.59***bc***
	Medium with compost 2	4.89	2.81	3.65	4.66	3.87	4.61	**4.08***c***
	Mean	**4.40***b***	**2.78***a***	**3.19***a***	**3.31***a***	**3.08***a***	**3.07***a***	
K	Sphagnum peat	3.33	1.94	2.88	3.11	3.52	2.55	**2.89***b***
	Coconut fibre	6.47	6.5	4.86	4.62	4.86	4.56	**5.31***c***
	Medium with compost 1	2.89	3.26	3.26	2.77	3.51	2.86	**3.09***b***
	Medium with compost 2	1.31	4.38	1.17	1.53	1.84	1.58	**1.97***a***
	Mean	**3.50***a***	**4.02***c***	**3.04***ab***	**3.01***a***	**3.43***b***	**2.89***a***	
Ca	Sphagnum peat	16.7	13.45	13.34	14.92	14.73	15.11	**14.71***b***
	Coconut fibre	5.82	5.49	4.25	5.62	5.89	5.55	**5.44***a***
	Medium with compost 1	15.03	15.93	15.62	14.22	15.21	12.54	**14.76***b***
	Medium with compost 2	14.02	16.04	10.86	13.22	12.95	14.58	**13.61***a***
	Mean	**12.89***a***	**12.73***a***	**11.02***a***	**12.00***a***	**12.20***a***	**11.95***a***	
Mg	Sphagnum peat	0.59	0.41	0.56	0.38	0.42	0.64	**0.50***a***
	Coconut fibre	0.43	0.51	0.64	0.48	0.41	0.48	**0.49***a***
	Medium with compost 1	0.44	0.49	0.47	0.42	0.47	0.43	**0.45***a***
	Medium with compost 2	0.43	0.43	0.43	0.33	0.41	0.44	**0.41***a***
	Mean	**0.47***a***	**0.46***a***	**0.53***a***	**0.40***a***	**0.43***a***	**0.50***a***	
S	Sphagnum peat	2.89	2.11	1.56	2.22	1.38	1.15	**1.89***a***
	Coconut fibre	2.11	1.54	2.02	2.02	2.04	1.87	**1.93***a***
	Medium with compost 1	2.11	2.02	1.82	2.21	0.78	0.74	**1.61***a***
	Medium with compost 2	1.14	2.75	1.87	1.66	1.44	0.96	**1.64***a***
	Mean	**2.06***ab***	**2.11***b***	**1.82***ab***	**2.03***ab***	**1.41***a***	**1.18***a***	
C org.	Sphagnum peat	298	224	234	315	221	168	**243***ab***
	Coconut fibre	224	242	301	222	324	352	**278***b***
	Medium with compost 1	234	242	298	324	146	120	**227***ab***
	Medium with compost 2	184	289	182	236	137	140	**195***a***
	Mean	**235***ab***	**249***ab***	**254***ab***	**274***b***	**207***a***	**195***a***	

* Means marked with the same letter do not differ significantly at α = 0.05 according to the Tukey's test.

Table 5

Changes in the chemical composition of media using to cultivation horned violet from the Patiola F1 group after the end of plant cultivation in 2007

	Medium	Cultivars from Patiola F1 group						Mean
		Pure Yellow	Violet with Yellow Face	Pure Light	Pure Violet	Tange-rine	Pure Lemon Yellow	
		content (g kg^{-1} d.m.)						
N	Sphagnum peat	8.68	9.29	5.92	6.71	6.91	4.86	**7.06***ab******
	Coconut fibre	6.35	5.84	6.76	5.42	8.18	4.68	**6.21***a*
	Medium with compost 1	9.87	8.87	10.76	12.38	4.38	4.99	**8.54***b*
	Medium with compost 2	6.77	7.94	7.65	9.37	4.96	4.66	**6.89***ab*
	Mean	**7.92***c*	**7.99***c*	**7.77***c*	**8.47***c*	**6.11***b*	**4.80***a*	
P	Sphagnum peat	3.76	4.78	2.36	2.48	2.36	2.06	**2.97***ab*
	Coconut fibre	4.38	2.02	1.82	1.99	2.16	2.08	**2.41***a*
	Medium with compost 1	4.88	0.69	3.89	3.85	3.59	3.23	**3.36***ab*
	Medium with compost 2	4.76	2.68	3.68	4.48	3.76	4.51	**3.98***b*
	Mean	**4.45***b*	**2.54***a*	**2.94***a*	**3.20***a*	**2.97***a*	**2.97***a*	
K	Sphagnum peat	3.21	1.76	3.34	3.48	3.16	2.47	**2.90***ab*
	Coconut fibre	5.72	6.12	4.58	4.75	5.16	5.01	**5.22***c*
	Medium with compost 1	2.85	3.62	2.96	2.58	3.52	3.05	**3.10***b*
	Medium with compost 2	1.04	4.24	0.96	1.32	1.79	1.53	**1.81***a*
	Mean	**3.21***ab*	**3.94***b*	**2.96***a*	**3.03***a*	**3.41***ab*	**3.02***a*	
Ca	Sphagnum peat	16.1	13.72	13.68	14.79	14.36	14.43	**14.51***b*
	Coconut fibre	5.11	5.54	5.21	5.33	5.57	5.44	**5.37***a*
	Medium with compost 1	14.67	15.24	15.64	14.01	14.02	11.97	**14.26***b*
	Medium with compost 2	13.01	16.69	10.61	12.95	12.86	14.56	**13.45***b*
	Mean	**12.22***ab*	**12.80***b*	**11.29***a*	**11.77***a*	**11.70***a*	**11.60***a*	
Mg	Sphagnum peat	0.74	0.54	0.61	0.4	0.72	0.67	**0.61***a*
	Coconut fibre	0.46	0.36	0.68	0.59	0.44	0.45	**0.50***a*
	Medium with compost 1	0.46	0.49	0.46	0.45	0.32	0.41	**0.43***a*
	Medium with compost 2	0.42	0.44	0.44	0.43	0.42	0.43	**0.43***a*
	Mean	**0.52***a*	**0.46***a*	**0.55***a*	**0.47***a*	**0.48***a*	**0.49***a*	
S	Sphagnum peat	2.24	2.14	1.82	2.43	1.33	1.25	**1.87***a*
	Coconut fibre	1.21	1.88	1.68	2.11	1.92	1.75	**1.76***a*
	Medium with compost 1	1.34	1.57	1.68	2.04	0.75	0.65	**1.34***a*
	Medium with compost 2	0.85	2.7	1.65	1.69	1.48	0.87	**1.54***a*
	Mean	**1.41***a*	**2.07***b*	**1.71***ab*	**2.07***b*	**1.37***a*	**1.13***a*	
C org.	Sphagnum peat	328	218	208	291	237	178	**243***bc*
	Coconut fibre	292	194	281	258	290	311	**271***c*
	Medium with compost 1	246	237	286	288	101	151	**218***ab*
	Medium with compost 2	170	306	167	217	125	106	**182***a*
	Mean	**259***b*	**239***ab*	**236***ab*	**264***b*	**188***a*	**187***a*	

* Means marked with the same letter do not differ significantly at $\alpha = 0.05$ according to the Tukey's test.

Table 6

Changes in the chemical composition of media used for cultivation horned violet from Patiola F1 group after the end of plant cultivation (years 2005-2007)

Medium		Cultivars from Patiola F1 group						Mean
		Pure Yellow	Violet with Yellow Face	Pure Light	Pure Violet	Tange-rine	Pure Lemon Yellow	
		content (g kg^{-1} d.m.)						
N	Sphagnum peat	8.65	9.88	5.97	8.06	6.75	4.64	**7.33***ab******
	Coconut fibre	6.78	5.92	6.71	6.05	7.93	4.66	**6.34***a*
	Medium with compost 1	9.76	9.51	11.4	12.8	4.48	5.11	**8.84***b*
	Medium with compost 2	7.86	8.46	8.34	9.78	5.31	4.79	**7.42***ab*
	Mean	**8.26***c*	**8.44***c*	**8.11***c*	**9.17***c*	**6.12***b*	**4.80***a*	
P	Sphagnum peat	4.13	4.96	2.32	2.32	2.37	2.02	**3.02***ab*
	Coconut fibre	4.19	2.37	2.02	2.07	2.23	2.16	**2.51***a*
	Medium with compost 1	4.94	0.76	4.58	4.22	3.79	3.42	**3.62***bc*
	Medium with compost 2	4.90	2.87	3.90	4.64	3.86	4.66	**4.14***c*
	Mean	**4.54***b*	**2.74***a*	**3.21***a*	**3.31***a*	**3.06***a*	**3.07***a*	
K	Sphagnum peat	3.24	1.78	2.96	3.37	3.21	2.54	**2.85***ab*
	Coconut fibre	5.78	6.10	4.55	4.54	5.19	4.87	**5.17***c*
	Medium with compost 1	3.25	3.66	3.27	2.79	3.62	3.02	**3.27***b*
	Medium with compost 2	1.26	4.58	1.16	1.49	1.89	1.63	**2.00***a*
	Mean	**3.38***ab*	**4.03***b*	**2.99***a*	**3.05***ab*	**3.48***ab*	**3.02***a*	
Ca	Sphagnum peat	17.0	13.3	14.05	14.5	14.7	14.6	**14.69***b*
	Coconut fibre	5.05	5.62	4.93	5.40	5.69	5.46	**5.36***a*
	Medium with compost 1	15.2	15.9	15.9	14.4	15.1	12.6	**14.85***b*
	Medium with compost 2	13.7	16.5	11.1	13.2	13.1	14.7	**13.70***b*
	Mean	**12.7***a*	**12.8***a*	**11.5***a*	**11.9***a*	**12.1***a*	**11.8***a*	
Mg	Sphagnum peat	0.66	0.44	0.63	0.40	0.59	0.60	**0.55***a*
	Coconut fibre	0.47	0.43	0.60	0.58	0.45	0.45	**0.50***a*
	Medium with compost 1	0.46	0.48	0.50	0.45	0.47	0.42	**0.46***a*
	Medium with compost 2	0.45	0.45	0.46	0.43	0.45	0.45	**0.45a**
	Mean	**0.51***a*	**0.45***a*	**0.55***a*	**0.47***a*	**0.49***a*	**0.48***a*	
S	Sphagnum peat	2.53	2.26	1.84	2.26	1.29	1.19	**1.90***a*
	Coconut fibre	2.10	1.76	1.86	2.08	1.95	1.90	**1.94***a*
	Medium with compost 1	1.97	1.98	2.00	2.23	0.82	0.78	**1.63***a*
	Medium with compost 2	1.55	2.83	1.83	1.73	1.53	0.98	**1.74***a*
	Mean	**2.04***ab*	**2.21***b*	**4.42***c*	**4.47***c*	**4.38***c*	**1.21***a*	
C org.	Sphagnum peat	330	228	219	300	238	166	**247***bc*
	Coconut fibre	267	224	308	249	304	329	**280***c*
	Medium with compost 1	244	248	315	303	122	139	**229***ab*
	Medium with compost 2	185	303	190	221	135	127	**194***a*
	Mean	**257***b*	**251***b*	**258***b*	**268***b*	**200***a*	**190***a*	

* Means marked with the same letter do not differ significantly at $\alpha = 0.05$ according to the Tukey's test.

of this element found in coconut fibre (Table 2). As quoted in the literature, sewage deposits often contain small amounts of this element and potassium supplementation is required when they are used in substrate components (Krzywy et al. 2000, Maćkowiak 2001). The Mg content in all the analysed substrates was at a similar level, ranging from 0.45-0.55 g kg^{-1} in dry matter. The highest S content, on the other hand, was found in the substrate with the addition of compost I; it was over three-fold higher than in the remaining substrates (Tables 2-6). All of the analysed substrates were organic substrates with a high organic carbon content. After the cultivation period, its amount was approximately 200-280 g kg^{-1} in dry matter. Coconut fibre was characterised by the highest organic carbon content.

Research conducted by other authors also confirmed that composts made from municipal sewage deposits, which were used as a component of substrates for cultivation of bedding plants, had a positive influence on plants, provided that they were used in appropriate amounts for a given species (Andre et al. 2002, Dobrowolska et al. 2007, Vabrit et al. 2007). Czyżyk et al. (2002) showed that long-term composting of sewage deposits resulted in progressive mineralisation of the compost mass and a reduction in the content of nearly all mineral ingredients. However, despite nutrient depletion, composts made from sewage deposits maintain a high fertilising balance, even after two years of storage. Other authors claim (Zawadzińska et al. 2009) that sewage deposit-based composts may have too low a content of nutrients available for plants, especially for plants with high nutritional requirements, such as New Guinea impatiens (Startek, Dobrowolska 2002).

Numerous elements, such as boron, iron, copper, manganese, zinc, molybdenum and chlorine (B, Fe, Mn, Cu, Zn, Mo, Cl) are micronutrients necessary for the proper functioning of plants. Heavy metals in soils can be a potential hazard for plants and groundwater and, as a result, also for animals and people (Karczewska et al. 2008). Their elevated concentration can be frequently observed in sewage deposits (Warman, Termeer 2005). Due to physicochemical processes occurring actively in sewage, heavy metals tend to accumulate in existing sewage and in its deposits. A high content of metals such as zinc (Zn), copper (Cu), nickel (Ni), cadmium (Cd), lead (Pb), mercury (Hg) and chromium (Cr) is usually a factor limiting the use of sewage deposits for agricultural purposes (Hsiau, Lo 1998). Heavy metal concentrations in sewage deposits can differ considerably, depending on the sources of contamination.

In the authors' own research, the presence of heavy metals was found in sewage sludge, in composts with the addition of sewage sludge and in substrates with the addition of composts made from municipal waste deposits (Tables 1, 2, 7, 8). The sewage sludge had a high content of Mn and Zn. A relatively high content of Mn was also found in rye straw and a high content of Zn appeared in sawdust (Table 1). Among the substrates used for the cultivation, coconut fiber was characterised by a high concentration of Mn (111 mg kg^{-1} in dry matter) and Pb (18.13 mg kg^{-1} in dry matter), which accounted, respectively, for over 60% and 80% of the content of these elements in composts made from sewage sludge (Table 2). Regardless of the substrate used, after the end of plant cultivation, Zn (*ca* 250 mg kg^{-1} in dry matter) and Mn (*ca* 140 mg kg^{-1} in dry matter) and Pb (26-32 mg kg^{-1} in dry matter) were found to be present in the largest amounts. Out of the heavy metals under analysis, Cd was obserevd in the lowest amount of Cd (0.35-0.36 mg kg^{-1} in dry matter) was observed (Tables 7, 8).

However, despite the high accumulation of heavy metals, their content in the soil did not exceed the allowable concentrations (*Regulation* ... 2002).

The heavy metal content underwent significant changes both in the process of composting, and during plant cultivation (Figure 1). It was found

Table 7

Content of heavy metals in media with addition of composts after the end of plant cultivation in 2005-2007

Specification		Medium with compost 1						Medium with compost 2					
		Cd	Cu	Mn	Ni	Pb	Zn	Cd	Cu	Mn	Ni	Pb	Zn
		content (mg kg^{-1} d.m.)						content (mg kg^{-1} d.m.)					
2005	Pure Yellow	0.41	24.8	142	12.3	38.3	258	0.39	27.3	141	14.0	26.8	266
	Violet with Yellow Face	0.40	28.3	136	16.8	28.5	258	0.38	28.6	106	12.2	22.6	269
	Pure Light Blue	0.42	25.6	115	12.5	44.3	256	0.27	24.5	123	17.2	22.9	225
	Pure Violet	0.39	19.6	183	16.5	28.8	244	0.43	23.5	166	16.8	40.4	256
	Tangerine	0.44	15.2	171	13.1	32.6	302	0.37	13.9	189	17.3	25.6	294
	Pure Lemon Yellow	0.33	18.8	156	11.8	28.6	238	0.42	20.2	174	14.5	29.5	279
	Mean	**0.40***a******	**22.1***a*	**151***a*	**13.8***a*	**33.5***b*	**259***a*	**0.38***a*	**23.0***a*	**150***a*	**15.3***b*	**28.0***a*	**265***b*
2006	Pure Yellow	0.37	20.6	121	11.7	36.7	284	0.39	24.1	129	12.3	24.3	248
	Violet with Yellow Face	0.37	27.1	128	15.3	26.3	243	0.36	28.2	101	10.7	22.1	245
	Pure Light Blue	0.36	23.2	99	11.3	41.7	231	0.22	24.1	108	17.1	20.6	216
	Pure Violet	0.36	17.5	159	15.8	27.6	226	0.39	22.2	152	16.5	37.2	248
	Tangerine	0.41	14.6	162	11.9	30.8	275	0.36	12.8	177	15.8	28.3	257
	Pure Lemon Yellow	0.32	18.6	151	11.3	24.3	223	0.44	18.6	158	14.0	25.2	280
	Mean	**0.37***a*	**20.3***a*	**137***a*	**12.9***a*	**31.2***b*	**247***a*	**0.36***a*	**21.7***a*	**138***a*	**14.4***b*	**26.3***a*	**249***a*
2007	Pure Yellow	0.31	19.6	117	10.5	37.6	204	0.34	23.7	121	10.7	20.3	240
	Violet with Yellow Face	0.35	23.9	126	16.2	25.6	261	0.31	24.6	101	9.1	20.7	223
	Pure Light Blue	0.34	22.6	94	10.9	37.2	226	0.25	23.1	114	14.3	21.6	184
	Pure Violet	0.34	17.9	165	15.7	23.2	235	0.32	20.1	139	15.1	37.9	262
	Tangerine	0.39	12.8	157	11.1	32.2	274	0.37	12.7	150	15.6	26.2	249
	Pure Lemon Yellow	0.27	18.6	138	10.3	26.2	202	0.35	17.6	165	12.8	23.6	254
	Mean	**0.33***a*	**19.2***a*	**133***a*	**12.5***a*	**30.3***b*	**234***a*	**0.32***a*	**20.3***a*	**132***a*	**12.9***a*	**25.1***a*	**235***a*

* Means marked with the same letter do not differ significantly at $\alpha = 0.05$ according to the Tukey's test.

Table 8

Content of heavy metals in media with addition of composts after the end of plant cultivation (data aggregated for 2005-2007)

Media	Cultivars from Patiola F1 group	Cd	Cu	Mn	Ni	Pb	Zn
		content (mg kg^{-1} d.m.)					
Medium with compost 1	Pure Yellow	0.36	21.7	127	11.5	37.5	249
	Violet with Yellow Face	0.37	26.4	130	16.1	26.8	254
	Pure Light Blue	0.37	23.8	103	11.6	41.1	238
	Pure Violet	0.36	18.3	169	16.0	26.5	235
	Tangerine	0.41	14.2	163	12.0	31.9	284
	Pure Lemon Yellow	0.31	18.7	148	11.1	26.4	221
	Mean	**0.36a***	**20.5a**	**140a**	**13.1a**	**31.7b**	**245a**
Medium with compost 2	Patiola Pure Yellow	0.37	25.0	130	12.3	23.8	251
	Patiola Violet with Yellow Face	0.35	27.1	103	10.7	21.8	246
	Patiola Pure Ligt Blue	0.25	23.9	115	16.2	21.7	208
	Patiola Pure Violet	0.38	21.9	152	16.1	38.5	255
	Patiola Tangerine	0.36	13.1	172	16.2	26.7	267
	Patiola Pure Lemon Yellow	0.40	18.8	166	13.8	26.1	271
	Mean	**0.35a**	**21.6a**	**140a**	**14.2a**	**26.4a**	**249.4a**

* Means marked with the same letter do not differ significantly at $\alpha = 0.05$ according to the Tukey's test.

that during the composting process of sewage sludge and straw, potato pulp or sawdust, the content of heavy metals – except Zn – decreased by 15-60%. The addition of peat and cultivation itself caused a further decline of these elements. Only the share of Pb and Zn grew larger in the media (Figure 1.)

The research performed by Fuentes et al. (2004) showed that the heavy metal content is often so low that it does not pose a threat to cultivated plants or other living organisms, regardless of the origin of sewage deposits or the method of their stabilisation. The results of this research also showed that all deposits under analysis could be used to improve soil properties, owing to their high content of organic substances and the content of N, P and K.

The disposal and subsequent use of sewage deposits have been discussed for years and the interest in this subject has been growing in Europe. However, skilful management of this waste is as important as convincing the public opinion that it is possible to use it in agriculture or horticulture (Singh, Agrawal 2008).

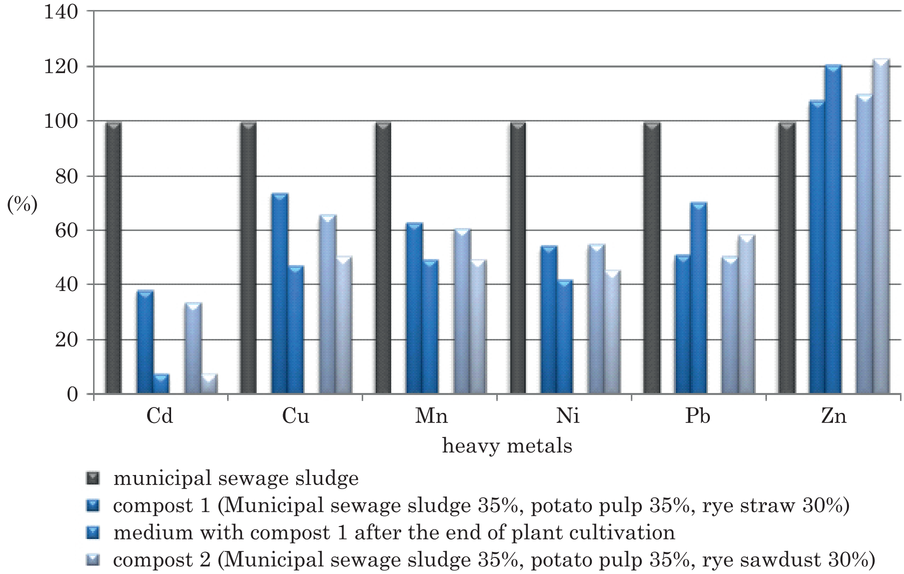

Fig. 1. Changesin the heavy metal content [%] in municipal sewage sludge, composts and media with addition of composts after the end of plant cultivation (2005-2007)

CONCLUSIONS

1. After a ten-month composting period, municipal waste deposits were a rich source of nitrogen, phosphorus and calcium; however, they required the supplementation of potassium in its mineral form.

2. Compost substrates made from municipal sewage deposits were rich in nutrients and provided plants with their appropriate levels.

3. After the completed plant growing season, peat substrates, even if previously supplemented with nutrients in the form of fertilisers, contained lower amounts of these elements, except K, than compost substrates.

4. Coconut fiber used as a substrate was characterised by the high content of K and microelements such as Pb and Mn.

5. Composts made from the municipal sewage waste contained considerable amounts of heavy metals; however, their values did not exceed the allowable concentrations for mineral soils intended for cultivations and lands.

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