Drewno 2014, Vol. 57, No. 191
DOI: 10.12841/wood.1644-3985.074.01

PRACE NAUKOWE – RESEARCH PAPERS

Hanna Wróblewska, Anita Schroeter-Zakrzewska, Katarzyna Głuchowska, Agnieszka Wolna-Maruwka, Tomasz Kleiber

APPLICATION OF POST-CONSUMER WOOD COMPOSTS IN CANNA LILY (*CANNA* X *GENERALIS* L.H. BAILEY) CULTIVATION

*The purpose of the conducted experiment was to learn about the influence of composts obtained from post-consumer wood on the growth, flowering and nutrition of the canna lily (*Canna *x* generalis *L.H. Bailey)'Tropical Yellow'. The number of microorganisms and the level of their enzymatic activity in the media in which the plants were cultivated were also examined. Two variants of composts made from post-consumer wood, marked OPA and OPB were used in the experiment. Plants were cultivated in the media consisting of compost and high peat in different volumetric combinations. The content of macro- and microelements, the pH and salinity of particular media were the derivatives of compost and peat percentage in the medium. It was found that the medium type had a significant influence on the growth and flowering of the canna lily. The type of the compost used proved to be a determining factor in changes in the number and activity of the microorganisms in the examined media, as well as the nutritional status of the plants.*

Keywords: post-consumer wood, nutrition, enzymatic activity, canna lily

Hanna Wróblewska, Wood Technology Institute, Poznan, Poland
e-mail: h_wroblewska@itd.poznan.pl
Anita Schroeter-Zakrzewska, Poznań University of Life Sciences, Poznan, Poland
e-mail: anitazak@up.poznan.pl
Katarzyna Głuchowska, Poznań University of Life Sciences, Poznan, Poland
e-mail: kasiaglu@up.poznan.pl
Agnieszka Wolna-Maruwka, Poznań University of Life Sciences, Poznan, Poland
e-mail: amaruwka@up.poznan.pl
Tomasz Kleiber, Poznań University of Life Sciences, Poznan, Poland
e-mail: tkleiber@up.poznan.pl

Introduction

Canna lily is a species which is widely used in green spaces in cities. It is also used in the process of phytoremediation. It is usually propagated vegetatively, for example by means of rhizome division. The novelty on the market is the Tropical group which is propagated from seeds. Regardless of the propagation manner, the indispensable stage of production is preparing the seedlings under cover. The basic medium used in cultivation under covers is high peat. Due to excessive and long-term exploitation, the deposits of high peat are shrinking [Ilnicki 2002]. Thus, alternative materials which could totally or even partially replace this hardly-renewable natural resource are being sought. In gardening production, peat might be replaced with such components as: straw, composts of various origins, wood waste, coconut fibres and shells [Dobrowolska et al. 2007; Krzywy et al. 2007; Dobrowolska, Janicka 2008; Wraga 2008; Larcher et al. 2011].

Composts prepared from different kinds of wood waste can be used in order to enrich a soil in terms of its nutrients and also hummus substances. Composts made from post-consumer wood (old furniture, windows and doors, building structures, wooden packaging) might, in certain cases, contain some harmful substances (e.g. heavy metals, preservatives) coming from finishing materials, resins and adhesives. For this reason they should not be used in the production of plants designed for consumption, although they may be used in ornamental plant cultivation.

Different plants exhibit various soil requirements in terms of nutrient content and also as far as microbiological medium activity is concerned. The basic role of microorganisms in the soil is the constant transformation of organic and mineral compounds, making nutrients available to plants [Blum 1998]. Microorganisms are closely related to plants and their root system, and with their root excretions too. They also take part in decomposition of toxic substances. Moreover, they are responsible for secondary metabolite synthesis. Secondary metabolites (plant growth hormones, phytochelatins, organic acids, B vitamins) have a favourable effect on plant growth. Microorganisms can also release substances (antibiotics, H_2S) which are toxic towards phytopathogens or animal organisms, in this way improving plant condition and health [Marschner 2007].

The usefulness of the media made with post-consumer wood composts in ornamental plant cultivation needs to be tested experimentally. The purpose of the experiment discussed in the following paper was the assessment of the growth, flowering and nutritional state of the canna lily cultivated in media consisting of high peat and composts prepared from post-consumer wood.

Materials and methods

Vegetation test

The experiment, whose major purpose was to assess composts made from post--consumer wood in the cultivation media, was conducted in the greenhouse of the Department of Ornamental Plants at Poznań University of Life Sciences. Two variants of composts (OPA and OPB) prepared in two piles of a dimension 5 m^3 at the Wood Technology Institute in Poznań were used in the experiment. The compost variant marked as OPA consisted of post-consumer wood waste (OP) (weighing 70%) mixed with powdery waste from processed MDF boards (6%), mature compost made from fibre board waste (19%), high peat (4%), water, a biological inoculum "Activit Las" and 30 kg urea. The OPB compost was different from the OPA variant as it did not contain urea, but the following substances were added: ammonium nitrate (1.5 kg), magnesium sulphate (0.4 kg), potassium phosphate (0.8 kg) and calcium phosphate (0.9 kg).

The object of study was the canna lily (*Canna* x *generalis* L.H. Bailey) 'Tropical Yellow' propagated generatively, characterized by green leaves and yellow flowers. The seedlings with 2–3 leaves were planted on 3 April 2012 into pots of 17 cm in diameter and a volume of 2100 cm^3. The plants were cultivated in substrates consisting of peat with the addition of the OPA or OPB composts in different volume ratios. The control group consisted of plants grown in high peat limed to pH 6.3.

The markings of the particular combinations are presented below:

1. I OPA – 100% of OPA compost
2. II OPA – 75% of OPA compost + 25% of peat
3. III OPA – 50% of OPA compost + 50% of peat
4. IV OPA – 25% of OPA compost + 75% of peat
5. I OPB – 100% of OPB compost
6. II OPB – 75% of OPB compost + 25% of peat
7. III OPB – 50% of OPB compost + 50% of peat
8. IV OPB – 25% of OPB compost + 75% of peat
9. control group – 100% of peat

The experiment consisted of 9 combinations, each with 11 replications, where one plant was a single replication.

Plant analyses

Measurements of the following characteristics of the canna lily plants were taken on the last day of the experiment: the plant height, the number of leaves, the length of the inflorescence and the shoots with inflorescences, the number of flowers in the inflorescences and the diameter of the flowers. The leaf fresh and dry matter, as well as the rhizome fresh matter and the number of rhizome branches were determined. The size of the leaf assimilation area was measured by means of a CL-202 Portable Leaf Area Meter. The index of leaf greenness (SPAD) was also determined by means of a Yara N-Tester apparatus. This measurement is used to determine the intensity of the green colour of the leaves and is calculated as a quotient of light absorption connected with the presence of chlorophyll at the wavelength of 650 nm and the absorption by the leaf tissue at a wavelength of 940 nm [Samborski, Rozbicki 2004]. The results were statistically calculated by means of the analysis of variance. The means were grouped with the use of the Duncan test with inference at the significance level of $\alpha = 0.05$.

On completion of the experiment, the plant material was taken for chemical analyses of their macro- and microelement content. The aboveground parts of the plants were collected and then dried at 45–50ºC and then ground. For the assays of total nitrogen, phosphorus, potassium, calcium and magnesium, the plant material was mineralized in concentrated sulphuric acid [IUNG 1983]. After mineralization of the plant samples, chemical analyses were performed using the following methods: N – total according to Kjeldahl in a Parnas-Wagner distillation apparatus, P by colorimetry with ammonium molybdate, and K, Ca, Mg by atomic absorption spectrometry (in a Carl Zeiss Jena apparatus). To determine the total iron, manganese, zinc and copper, the plant material was mineralized in a mixture of dioxonitric and tetraoxochloric acids (3:1 v/v) [IUNG 1983]. After mineralization, Fe, Mn, Zn and Cu were determined according to the ASA method. The results of the chemical analyses of the plants for their macro- and microelement content were analyzed statistically using the Duncan test, with inference at the significance level $\alpha = 0.05$.

Substrates analyses

Before commencing the cultivation (term I) and on its completion (term II) the substrate samples were collected for microbiological analyses.

The microbiological analyses were performed on the basis of Koch's plate method and consisted in the determination, with the use of selective media, of the counts of heterotrophic bacteria, moulds and actinomycetes. The assessment of colony forming units (cfu) of the above-mentioned microorganisms by means of culturing methods was a measure of the intensification of microorganisms characterised by current high metabolic activity.

The counts of heterotrophic bacteria were determined on the agar medium (Merck 101621 Standard count agar for microbiology) following 5 to 6-day incubation at a temperature of 28°C. Mould fungi were determined on the Martin medium within a period of 5 days at a temperature of 24°C [Martin 1950]. The number of actinomycetes were determined on the Pochon selective medium [Kańska et al. 2001], incubating plates for 7 days at a temperature of 26°C.

In addition, using the spectrophotometric method, enzymatic activity was determined within the collected samples of the composted material. Dehydrogenase activity was determined using 1% TTC (triphenyltetrazolium chloride) as a substrate, after a 24-hour incubation period at a temperature of 30°C, and at a wavelength of 485 nm. The activity of this enzyme was expressed in μmol TPF·g^{-1} d.m. of substrate·$24h^{-1}$ [Thalmann 1968]. The activity of acid phosphatase was determined using p-nitrophenylophosphate sodium as a substrate, after one hour incubation at 37°C, at 400 nm wavelength and expressed in μmol PNP·g^{-1} d.m. of substrate·$1h^{-1}$. Urease activity was determined using urea as a substrate, after 18-hour incubation at 37°C. Enzyme activity was expressed in μg $N\text{-}NH_4^+$·g^{-1} d.m. of substrate·$18h^{-1}$.

Table 1. The chemical composition of the medium used, beginning and after the end of the experiment

Medium		$N\text{-}NO_3$	P	K	Ca	Mg	Fe	Mn	Zn	Cu	Cl	Salinity g NaCl	pH
		[mg·dm^{-3}]											
Beginning of experiment													
Peat – Control		8	57	35	2581	139	43.5	5.78	3.7	0.38	72	1.33	6.3
End of experiment													
Peat – Control		12	23	20	2423	130	15.5	1.56	6.2	1.24	203	1.28	7.5
Beginning of experiment													
OPA	I	546	29	55	570	47	45.0	17.68	720.0	1.58	37	2.97	3.6
	II	357	29	45	974	67	56.5	14.70	539.5	0.94	46	2.05	5.0
	III	320	25	40	1296	87	51.2	13.26	411.5	0.78	55	2.07	5.4
	IV	167	29	40	1887	117	46.0	9.94	203.6	0.42	67	1.85	6.2
End of experiment													
OPA	I	422	33	55	808	105	41.2	12.32	616.0	1.92	229	2.96	4.0
	II	336	20	20	1080	102	41.0	9.16	444.0	2.96	230	2.30	5.1
	III	253	33	10	1464	106	34.9	3.24	346.0	2.68	224	2.24	5.7
	IV	72	23	5	1645	94	28.5	0.96	194.0	2.98	184	1.36	6.3
Beginning of experiment													
OPB	I	733	50	70	591	53	57.4	19.40	786.0	0.90	39	4.30	3.7
	II	460	36	55	974	70	54.5	15.26	594.5	0.48	49	2.46	5.2
	III	408	36	50	1183	104	44.8	12.80	379.5	0.44	66	2.76	5.8
	IV	251	36	45	1845	119	41.9	10.80	244.0	0.42	69	2.28	6.2
End of experiment													
OPB	I	251	30	35	535	66	55.4	10.28	584.0	2.24	184	1.88	4.0
	II	286	27	30	1211	94	44.3	6.00	458.0	1.94	181	2.06	5.1
	III	283	30	20	1585	112	32.5	2.16	359.0	2.32	221	2.39	5.9
	IV	111	20	20	2089	117	23.0	1.30	180.0	2.48	253	1.83	6.9

Enzymatic activity investigations are believed to reflect substrate microbiological activity set against the background of the traditional method of determining the total count of microorganisms using Koch's plate method.

Changes in the total count of microorganisms and their metabolic activity levels were statistically calculated with the use of Statistica 10.0 software.

The content of macroelements (N-NO_3, P, K, Ca, Mg, Cl) and microelements (Zn, Cu, Mn, Fe) in the tested substrates as well as their bulk density, salinity and pH were analysed prior to and after the vegetation test (table 1). The macroelements and microelements in the substrates were analysed with the method modified by Nowosielski [Breś et al. 1991]: the macroelements in a universal extract (CH_3COOH at a concentration of 0.03 mol·dm^{-3}) and the microelements in Lindsay's extract. Nitrate nitrogen was determined potentiometrically, phosphorus spectrophotometrically, potassium and calcium by flame photometry, magnesium, copper, zinc, iron and manganese by the atomic absorption spectroscopy method (AAS) with atomization in the flame, chlorides were determined potentiometrically, salinity conductometrically, pH potentiometrically, and density by weight method.

Results and discussion

On the basis of the conducted experiment it can be concluded that plant development (growth and flowering) are significantly dependent on the compost variant used, and especially on its percentage in the medium (table 2 and 3). Regardless of the compost type, the plants cultivated with its higher percentage in the medium (100% and 75%) were, on average, 31–55% lower when compared with the plants from the control group (table 2). According to Wilson et al. [2001, 2002], the addition of 50%, 75% and 100% compost retards the gloxinia and angelonia growth. A similar tendency was observed while analyzing the remaining features under examination, such as the number of leaves, their colour and their fresh and dry matter (table 2). This is confirmed by the study conducted by Larcher et al. [2011], who, as a result of camellia cultivation in a peat medium with 30% compost, obtained plants which were lower, had fewer leaves of a brighter colour and lower dry matter in shoot.

The leaf blade is a plant organ which is extremely significant in the photosynthesis process. Limiting the leaf assimilation area retards the process significantly, which, in turn results in the plants' lower quality. In the conducted experiment, regardless of the compost variant, the leaf assimilation area of the plants cultivated in 100% compost and in the medium with either 75% or 50% compost was significantly smaller when compared with that of the plants from the control group. The plants cultivated in the medium with 25% compost, on the other hand, did not differ significantly from those cultivated in the peat (table 2). Lower fresh and dry matter of the aboveground parts of the plants and the fresh matter of the rhizomes in the plants cultivated in the media with a higher content of compost (100% and 75%) also proved that the photosynthesis process was inefficient. The addition of 50% and 25% compost to the media, regardless of its composition, resulted in an increase in the fresh and dry matter of the aboveground parts of the plants, SPAD and the number of leaves when compared with the control group (table 2).

Table 2. The influence of OPA and OPB compost on morphological features of canna lily

Medium		Height of plants [cm]	Number of leaves	Leaf area [cm^2]	Greening index of leaves [SPAD]	Fresh weight of leaves [g]	Dry weight of leaves [g]
OPA	control-peat	32.7 d*	6.1 b	129.6 d	46.5 d	21.4 c	3.8 b
	100% compost	14.4 a	5.2 a	63.9 ab	15.4 ab	6.1 a	1.1 a
	75% compost + 25% peat	22.4 b	6.5 bc	73.5 b	31.0 c	13.5 b	3.5 b
	50% compost + 50% peat	28.3 c	6.9 bc	97.7 c	56.6 e	24.4 d	4.9 c
	25% compost + 75% peat	32.0 d	7.3 cde	128.7 d	55.7 e	24.0 d	5.1 c
OPB	control-peat	32.7 d	6.1 b	129.6 d	46.5 d	21.4 c	3.8 b
	100% compost	15.5 a	4.7 a	53.7 a	11.4 a	2.8 a	0.7 a
	75% compost + 25% peat	20.8 b	6.5 bc	76.6 b	21.6 b	12.4 b	2.2 ab
	50% compost + 50% peat	28.7 c	8.0 e	98.6 c	59.9 e	27.5 de	5.3 c
	25% compost + 75% peat	32.7 d	7.7 de	117.9 d	54.9 e	30.0 e	5.9 cd

** Means followed by the same letter are not significantly different at α = 0.05*

The compost variant and its percentage in the medium had a significant effect on plant flowering. The application of the OPB compost at a dosage of 50% and 25% proved to be more favourable. In this case, 81% and 90% of the plants, respectively, flowered. The plants in the control group did not flower, which could be due to the low content of nutrients in the peat (fig. 1, table 3).

In the canna lily it is the rhizome which is the spore organ. Moreover it is used as reproductive material. For this reason it is essential to obtain rhizomes which have many branches as it is then much easier to obtain, after division, a higher number of daughter plants. In the experiment the canna lily seedlings formed rhizomes of different mass and branching during the vegetation process. This was significantly dependent upon the percentage content of the compost in the medium. The lower the compost content, the higher the number of branches (table 3).

Microorganism colonization of the substrates is highly dependent on their wealth of nutrients, such as sugars, proteins and fats. The quantitative and qualitative composition of the soil microorganisms is highly conditioned by the presence of allopathic compounds released by plant roots, and also by the reciprocal interactions between the microorganisms [Badura 2006; Niewiadomska et al. 2010a].

Table 3. The influence of OPA and OPB compost on vegetative and generative features of canna lily

	Medium	Length of inflorescences shoot [cm]	Length of inflorescences [cm]	Number of flowers of inflorescences	Diameter of flower [cm]	Fresh weight of rhizome [g]	Number of branch rhizome
OPA	control-peat	-	-	-	-	40.6 e	6.0 d
	100% compost	-	-	-	-	3.5 a	2.5 a
	75% compost + 25% peat	32.2 b	14.0 a	4.0 a	5.5 a	10.0 b	3.1 a
	50% compost + 50% peat	33.0 b	12.6 a	6.3 b	6.0 a	17.8 c	4.0 b
	25% compost + 75% peat	29.0 a	13.5 a	6.0 b	6.0 a	31.2 d	5.3 cd
OPB	control-peat	-	-	-	-	40.6 e	6.0 d
	100% compost	-	-	-	-	3.2 a	2.7 a
	75% compost + 25% peat	16.5 a	8.0 a	3.0 a	6.0 a	6.9 ab	3.0 a
	50% compost + 50% peat	29.8 b	11.0 b	4.7 b	6.4 a	25.2 d	4.1 b
	25% compost + 75% peat	32.8 c	11.3 b	5.3 b	7.5 ab	26.7 d	5.1 cd

* Means followed by the same letter are not significantly different at α = 0.05

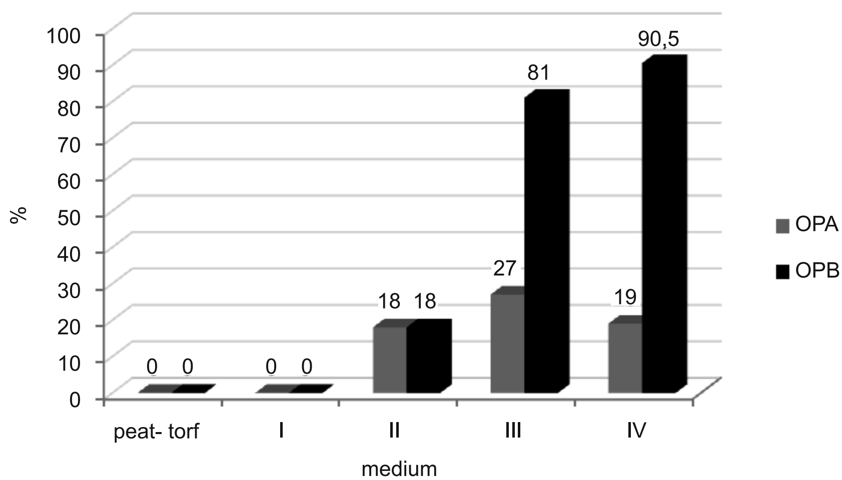
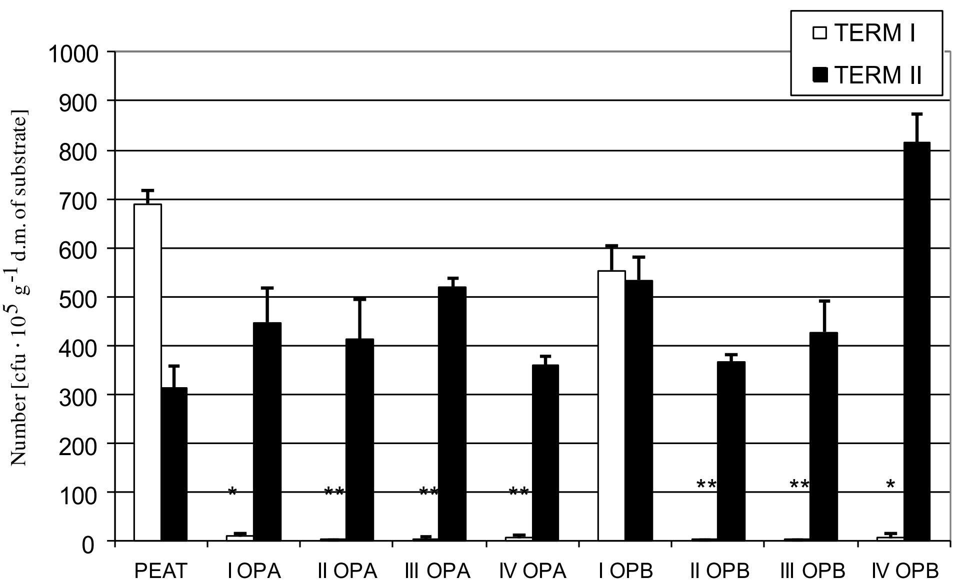


Fig. 1. Percentage of flowering plants, depending on the medium

Bacteria, actinomycetes and fungi are reported to play an essential role in organic matter mineralization in soil.

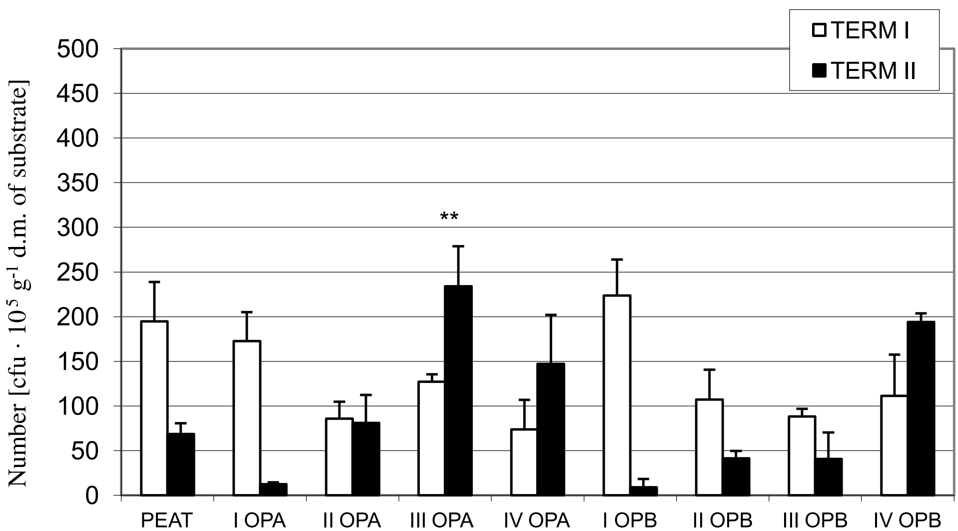
While analyzing the microbiological research results presented in fig. 2, it was found that the general counts of heterotrophic bacteria only diminished in the variants with the pure OPB compost or pure peat (the control group) when compared with the state at term I of the analyses, that is before commencing the cultivation of the canna lily. In the remaining combinations, a statistically significant increase in the bacteria counts was observed when compared with their counts at the beginning of the experiment (term I). On both dates (before the experiment and on its completion), the OPB compost was characterized by higher heterotrophic bacteria counts when compared with the OPA compost. While analyzing the experimental variants with the OPA compost, the highest counts of the abovementioned microorganisms were observed after the end of the experiment, in the combination in which this compost was mixed with peat in a 1:1 ratio. As far as the OPB variants are concerned, on the other hand, the highest counts of bacteria were observed in the combination consisting of 25% OPB + 75% peat. The reason for the abovementioned phenomenon could be the different chemical composition of the media used and also the presence of canna lily root excretions, whose quantitative and qualitative composition is dependent on the plant's development stage. According to Różycki and Strzelczyk [1985] as well as Barabasz and Smyk [1997] root excretions can have both a stimulating and retarding effect on microbiological development and activity in the medium.



* significantly differ at α = 0.05
** significantly differ at α = 0.01

Fig. 2. Changes of total bacteria number

Actinomycetes are also very important microorganisms colonizing all ecosystems: both natural and artificial. They have the ability to mineralize both simple and complex organic compounds and their metabolites have either a retarding or stimulating effect on the remaining micro flora present in the environment [De Boer et al. 2005]. Taking into consideration changes in the actinomycete counts at subsequent times of the analyses, it was observed that on commencing the experiment (term I) the highest count of actinomycetes (fig. 3) was found in the OPB combination which consisted of 100% compost. The addition of different amounts of peat resulted in a decrease in the actinomycete counts. After finishing cultivation, an increase in the number of the abovementioned microorganisms was observed only in the variant consisting of only 25% OPB compost. At this time the highest actinomycete counts were observed in the variant in which the OPA compost was mixed with peat at a ratio of 1:1. However, the increase in these counts, when compared with the pure OPA compost, was observed in all its combinations with peat.



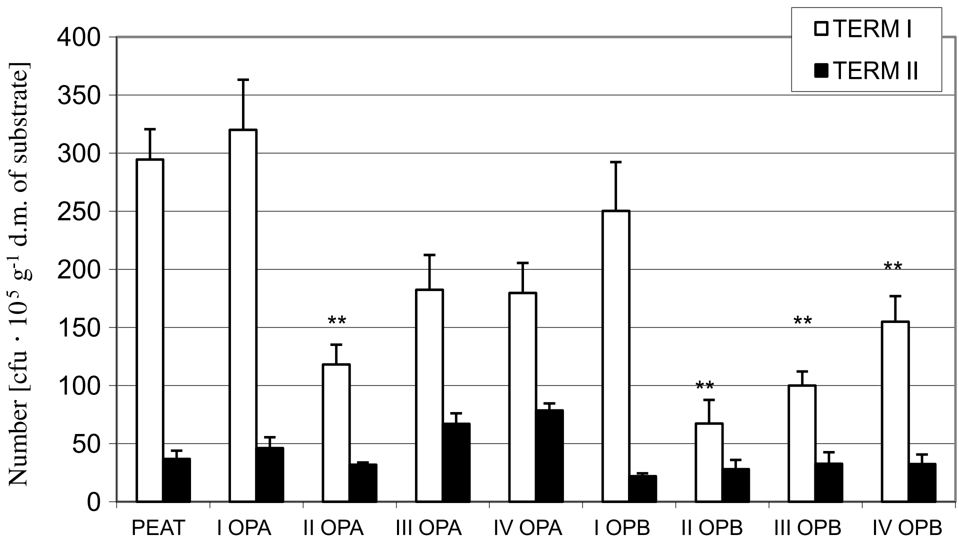
** significantly differ at α = 0.01

Fig. 3. Changes in the total number of actinomycetes

The fluctuations in the actinomycete counts in the analysed experimental combinations could be related to the quantitative and qualitative composition of the root excretions which influence the physicochemical properties of the substrate and microorganism multiplication [Wolna-Maruwka et al. 2012]. It can also be related to the chemical composition of the media used (compost or peat).

Apart from bacteria and actinomycetes, fungi also play an essential role in nutrient circulation in the soil. According to Howell [2003], the important role of fungi in the environment is connected with the fact that they produce enzymes which can inhibit plant pathogen development.

In all the variants of the experiment, the total count of moulds (fig. 4) was higher at the beginning of the experiment (term I) than at the end of the experiment (term II). The highest counts of the abovementioned microorganisms were observed at the beginning of the experiment, at term I, in the combination where the OPA compost constituted 100% of the medium and in the control group. Moreover, stronger mould multiplication was observed in the combination consisting of the OPA compost when compared with the OPB compost. These differences in fungi counts were probably due to the different chemical composition of the composts used in the experiment. What is more, it was observed that a statistically significant decrease in the fungi counts was related to the quantitative and qualitative changes of the root excretions at term II of the analysis [Wolna-Maruwka et al. 2012], or to the emergence of the metabolites of microbiological reactions with inhibitive properties.



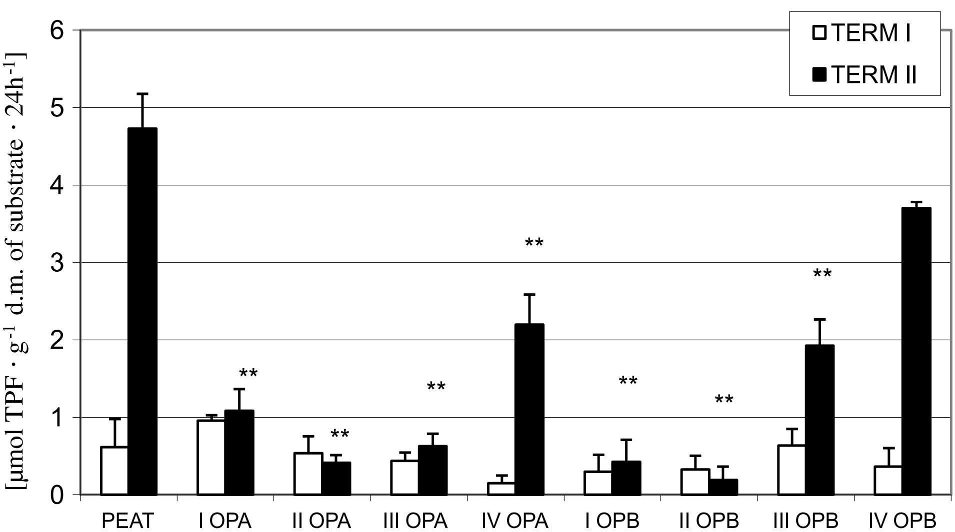
** significantly differ at α = 0.01

Fig. 4. Changes in the number of moulds

The metabolic activity of microorganisms, which is characterized by all compounds and energy transformations, might be manifested by their enzyme activity [Calderon et al. 2000]. According to numerous authors, the recognition of the enzymatic activity of the substrate gives an objective image of the undergoing processes [Drijber et al. 2000; Waldrop et al. 2000; Koper, Siwik-Ziomek 2003]. Nowadays, it is assumed that enzymatic activity of the soil is a better measure of its fertility and productivity than other biological indicators, such as microorganism counts or their biomass [Kobus 1995; Ścigalska, Klima1997; Niewiadomska et al. 2010b]. Determining dehydrogenase activity is an indicator of the intensity of the respiratory metabolism of soil microorganisms, mainly bacteria and actinomycetes. The significance of dehydrogenases to the functioning of microorganisms makes it a very common indicator for determining microbiological activity of the given substrate. According to Brzezińska and Włodarczyk [2005], on the basis of the enzymatic activity level, one can determine the physiological condition of the microorganisms.

Pędziwilk and Gołębiowska [1984], as well as Lynch and Panting [1980] proved that microorganism counts are not always positively correlated with the microorganisms' metabolic activity level. According to these researchers, higher microorganism counts might indicate low metabolic activity.

The highest level of dehydrogenase activity (fig. 5) was observed on completion of the cultivation in the variant consisting of 100% peat. The activity level of the microorganisms in question in the abovementioned combinations was highly significant statistically when compared to the other objects of study. A high level of dehydrogenase activity was also observed in the objects with both the OPA and OPB composts containing 75% peat. The lower activity of these enzymes in the majority of the compost media could result from the content of the compost additives such as adhesives, resins, paints, etc., which can inhibit the activity of these enzymes.



** significantly differ at α = 0.01

Fig. 5. Changes in dehydrogenase activity

Another class of enzymes that play a significant role in soil are phosphatases which stimulate the chemical changes of phosphorus compounds into inorganic phosphates (HPO_4^{-2} and $H_2PO_4^{-2}$) directly accessible to plants. The phosphatase activity in the soil environment reflects enzymatic activity related to soil colloids and humus substances, free phosphatases in the soil solution and phosphatases linked to the live and dead cells of plants and microorganisms [Nannipierl et al. 1990; Januszek 1999; Mocek-Płóciniak 2010].

In all the analysed combinations (fig. 6), the level of acid phosphatase was higher at the beginning of the experiment (term I) than on its completion, which was probably related to the decrease in the contents of the decomposing organic phosphorus compounds. Moreover, on the second analysis date the activity level of these enzymes grew together with the peat percentage in a given combination.

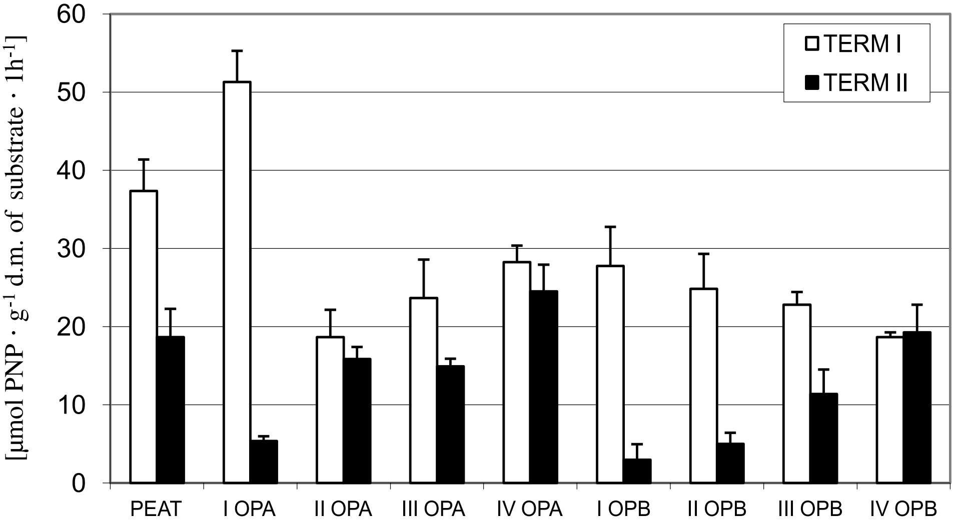
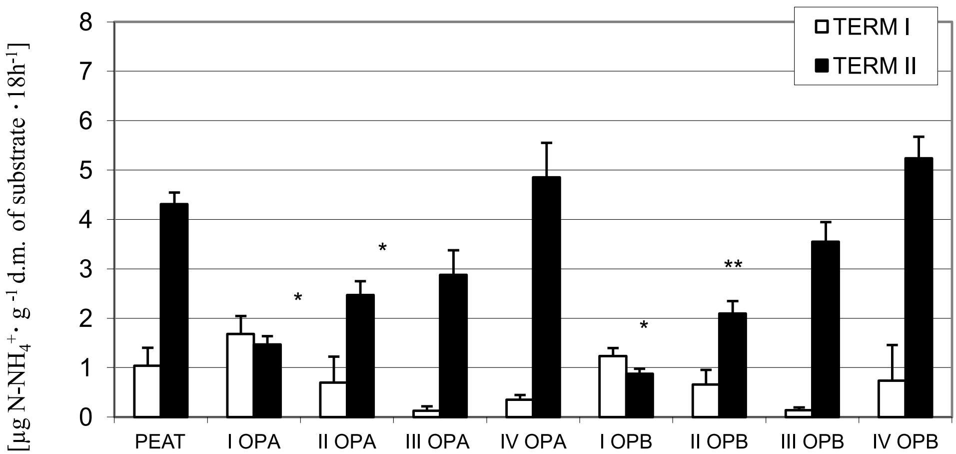


Fig. 6. Changes in acid phosphatase activity

The activity of the enzymes taking part in nitrogen changes in the soil environment can also be an indicator of the soil environment biological activity, the intensity of the changes in these compounds and nitrogen accessibility to plants. Urea and organic nitrogen compounds in the soil and in other environments undergo the process of hydrolysis under the influence of urease produced microbiologically.

The changes in the urease activity presented as a chart (fig. 7) show that at the beginning of the experiment the highest activity of the enzymes in question was found in the following combinations: OPA 100% and OPB 100%, which consisted of composts only. However, after cultivation, the highest urease activity level was observed in the variants in which both the OPB and OPA composts accounted for only 25% of the media. Moreover, it was also observed that together with an increase in the peat percentage in the medium, the urease activity level also increased after cultivation. The increase in urease activity in the analysed objects at the end of the experiment could result from the presence of root excretions of nitric character. According to Bais et al. [2006] and Dąbek-Szreniawska et al. [2006], the excretion composition can result in microorganisms producing ureases due to higher plant demand for nitrogen.



* significantly differ at α = 0.05

** significantly differ at α = 0.01

Fig. 7. Changes in urease activity

The content of macro- and microelements in the examined media was dependent on the type of wood waste used to produce a given compost variant and on the quantitative relation of the compost with the peat. This thesis is confirmed by Wróblewska et al. [2008], according to whom the chemical parameters of the composts depend heavily on the type of wood waste used in compost production. In general, in the research presented, before commencing cultivation, the analyzed media contained high quantities of nitrogen and zinc, low quantities of phosphorus, potassium and magnesium, and appropriate quantities of calcium, iron, manganese and copper (table 1). Kozik et al. [2010] in their research also observed high quantities of nitric nitrogen and low quantities of phosphorus, potassium, and magnesium, together with low pH levels in composts used for plant cultivation. During the vegetation process the tendency was for nitric nitrogen, potassium, magnesium, manganese and zinc to diminish their contents, and higher amounts of copper and the pH levels were observed in most of the examined combinations. On completion of the experiment, an excess content of nitrogen, low content of phosphorus, potassium and magnesium, and a standard content of calcium, iron, manganese and copper were observed (table 1). Contrary to the research presented, Wróblewska et al. [2008] found, after finishing *Salix alba* cultivation, only trace contents of nitrogen and almost no potassium, but an increase in the contents of calcium, chlorine and soil reaction. Wróblewska et al. [2007] state that releasing nitrogen from composts produced from wood waste can last for a long time, even for several years.

In the experiment conducted, regardless of the compost type, no significant differences between the average plant nutrition state, as far as both macro- and microelements are concerned, were observed. Wróblewska et al. [2008], on the other hand, observed the highest amounts of zinc in the plants cultivated in the medium with OPB compost, and of boron in the leaves of willow cultivated in OPA compost.

Significantly the highest contents of nitrogen and phosphorus were marked in the case of the plants grown in the OPB compost (100%) (table 4). The lower contents of the abovementioned elements, on the other hand, were marked in the control group combination, where the plants were cultivated in peat only; and in the case of phosphorus, also in the medium consisting of peat with the addition of 50% or 25% OPA compost, and also in the medium with the addition of 25% OPB compost. The addition of peat to the medium significantly worsened plant nutrition with these elements. Similarly, as in the case of nitrogen and phosphorus, the highest content of potassium in the plants was found in the case of cultivation in the medium consisting of 100% OPA compost, and, significantly, the lowest content in the control combination and with a 75% and 50% addition of either of the two examined compost types to the medium. The highest calcium content was found in the plants cultivated in the medium with the addition of 75% and 50% OPA compost and also in 100% OPB compost. The highest amounts of magnesium in the plants were found in the case of the control combination and with 25% of either compost type in the medium. Regardless of the compost type, in all the examined combinations in the case of N, P, K and Ca – higher contents of these elements were found in the terrestrial parts of the plants when compared with the control combination.

Table 4. The influence of medium on the content of macroelements in leaves

Medium	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu
	% oven dry mass					$mg \cdot kg^{-1}$ oven dry mass			
Control-peat	1.35 a	0.37 a	1.15 a	1.79 a	1.21 c	40.7 b	100.9 a	27.9 a	4.40 a
OPA									
I	2.45 cd*	0.50 ab	2.58 c	2.84 b	0.29 a	77.5 c	262.2 d	430.7 e	8.70 b
II	2.14 b	0.46 ab	2.21 b	3.74 c	0.34 a	44.2 b	244.7 d	278.6 d	9.10 b
III	1.93 b	0.39 a	1.18 a	3.48 c	0.61 b	49.2 b	207.3 c	210.5 cd	9.10 b
IV	1.54 a	0.34 a	1.19 a	2.78 b	1.39 c	41.5 b	133.5 b	135.3 b	6.40 ab
Mean	2.01 a**	0.42 a	1.79 a	3.21 a	0.66 a	53.1 a	211.9 a	263.8 a	8.33 a
OPB									
I	2.80 d*	0.80 c	2.31 b	3.70 c	0.53 ab	29.9 a	137.7 b	413.5 e	5.50 ab
II	2.45 cd	0.60 ab	2.05 b	3.14 bc	0.24 a	26.5 a	194.7 c	266.0 d	8.30 ab
III	1.70 ab	0.43 ab	1.34 a	3.08 bc	0.93 ab	45.5 b	174.4 c	251.1 d	7.20 ab
IV	1.58 ab	0.38 a	1.30 a	2.77 b	1.78 d	49.0 b	155.9 bc	197.3 c	6,40 ab
Mean	2.13 a**	0.50 a	1.72 a	3.43 a	0.72 a	41.2 a	180.8 a	259.5 a	7.53 a

* Values in columns followed by the same letter are not significantly different at $\alpha = 0.05$

** Means followed by the same letter are not significantly different at $\alpha = 0.05$

As far as iron is concerned the lowest contents of this element in the plants were found in the combination in which the plants were cultivated in the medium consisting of 100% and 75% OPB compost, while the highest contents were found in the case of the 100% OPA compost. Plant nutrition with this element was similar to the control group. In the case of the OPA compost, the addition of peat significantly lowered the content of iron, while in the media with the addition of OPB, it had a favourable effect on the iron content in the terrestrial parts of the plants. In all the examined combinations higher contents of manganese in the terrestrial parts of the plants, when compared with the control, were found. In the case of the OPA, these contents were of the highest values in the combination in which this compost variation accounted for 100% and 75% of the medium, and in the case of the OPB – in the combination with 75% and 50%. Similarly, as in the case of manganese, significantly higher contents of zinc were found in the plants when compared with the control. They had the highest values for OPA and OPB (100%). Similarly, as in the case of manganese and zinc discussed above, plants cultivated in peat were characterised by the lowest content of copper. In general, plants cultivated in the OPA compost exhibited a higher content of this element than those cultivated in the OPB.

Changes in the content of elements in the aboveground parts (leaves) of the plants can be accounted for on the basis of the chemical composition of the media used for cultivation. As far as the examined composts are concerned, it may be concluded in general that the plants cultivated in 100% OPA compost contained the highest quantities of nitrogen, phosphorus, potassium, iron, manganese and zinc; those cultivated in the medium containing 75% OPA compost contained the highest quantities of calcium; and those with 25% OPA compost had the highest amounts of magnesium. As far as the OPB compost is concerned, the plants cultivated in the medium consisting of 100% OPB contained the highest quantities of nitrogen, phosphorus, potassium, and calcium; those cultivated in the medium containing 75% OPB had the highest amounts of manganese and zinc, and those cultivated in the medium consisting of 25% OPB – had the highest amounts of magnesium and iron.

Research into the application of OPA and OPB composts was conducted previously by Wróblewska et al. [2009]. The authors observed a particularly favourable effect of the addition of OPA compost onto the growth and development of willow leaves and shoots when compared with the plants cultivated in mineral soil only. They also proved the much lower influence of the addition of compost to the substrate on the macro element content in willows than in the case of the canna lily in the research presented here. Similarly to the research presented, Kozik et al. [2010] observed a differentiation in plant nutrition under the influence of different compost types.

There is very little data concerning nutrient content in canna lily in literature. Nitrogen content, between 1.54% and 2.80% N, depending on the examined combination, considerably exceeded the contents reported by Yeh et al. [2004] in their experiment. These authors in their research on the influence of nitrogen nutrition in canna lily observed the nutrient content in leaves between 0.6 and 1.4% N, which was connected with an increase in the dry matter. Broschat et al. [2008] report that it is the fertilization applied which significantly influences the contents of nitrogen, phosphorus, magnesium and manganese in the canna lily leaves. Depending on the combination examined, they marked similar contents of nitrogen (2.26–2.80%) and phosphorus (0.42–0.51%), a much lower content of manganese (43.6–152.5 $mg \cdot kg^{-1}$), and a higher content of potassium (2.49–2.86%).

Taking into consideration the growth and development of the plants in the research presented, the following element contents (in the combination in which 25% of either the OPA or OPB compost was used) should be considered as optimal: N – 1.54–1.58%, P – 0.34–0.38%, K – 1.19–1.30%, Ca – 2.77–2.78%, Mg – 1.39–1.78% of dry matter, and Fe – 41.5–49.0 $mg \cdot kg^{-1}$, Mn – 133.5–155.9 $mg \cdot kg^{-1}$, Zn – 135.3–197.3 $mg \cdot kg^{-1}$, Cu – 6.40 $mg \cdot kg^{-1}$ of dry matter.

Conclusions

The medium containing a higher percentage of post-consumer wood compost (100%, 75%) had an unfavourable effect on the plants. Composts prepared from post-consumer wood can constitute a 25% addition to peat in canna lily cultivation. The type of compost used was found to be a factor determining the microbiological quantity and activity. Actinomycetes and moulds multiplied most intensively on the first date of analysis, while this happened to the bacteria on the second date of analysis. The highest level of dehydrogenase and urease activity was observed on completion of the experiment, while the highest level of acid phosphatase was observed before the beginning of cultivation. The OPA compost had the most stimulating effect on the multiplication of moulds, actinomycetes and the phosphatase activity. The OPB compost had a stimulating effect on the bacteria count and an increase in the urease and dehydrogenase activity level.

References

Badura L. [2006]: Czy mikroorganizmy są niezbędne dla życia roślin (Whether microorganisms are essential for the life of plants), W. Barabasz (ed.). Materiały Ogólnopolskiego Sympozjum Mikrobiologicznego, Wyd. AR Kraków

Bais H.P., Weir T.L., Perry L.G., Gilroy S., Vivanco J.M. [2006]: The role of root exudates in rhizosphere interactions with plants and other organisms. Annual Review of Plant Biology 57: 233–266

Barabasz W., Smyk B. [1997]: Mikroflora gleb zmęczonych (Microflora of tired soils). Zeszyty Problemowe Postępów Nauk Rolniczych 452: 37–50

Blum U. [1998]: Effects of microbial utilization of phenolic acids and their phenolic acid breakdown products on allelopathic interaction. Journal of Chemical Ecology 24: 685–708

Breś W., Golcz A., Komosa A., Kozik E., Tyksiński W. [1991]: Nawożenie roślin ogrodniczych. Cz. I. Diagnostyka potrzeb nawozowych (Fertilization of horticultural plants. Part 1. Diagnostics of fertilizer needs). Wyd. Akademii Rolniczej w Poznaniu

Broschat T.K., Sandrock D.R., Elliott M.L., Gilman E.F. [2008]: Effects of Fertilizer Type on Quality and Nutrient Content of Established Landscape Plants in Florida. Hort Technology 18 [2]: 278–285

Brzezińska M., Włodarczyk T. [2005]: Enzymy wewnątrzkomórkowych przemian redoks (oksydoreduktazy) (Enzymes of intracellular redox transformation (oxidoreductases)). Acta Agrophysica, Rozprawy i Monografie [3]: 11–26

Calderon J.F., Jackson L.E., Scow K.M., Rolston D.E. [2000]: Microbial responses to stimulated tillage in cultivated and uncultivated soils. Soil Biology and Biochemistry 32: 1547–1599

Dąbek-Szreniawska M., Zimoń A., Wyczółkowski A. [2006]: Aktywność enzymów w procesie amonifikacji w glebie z dodatkiem azotowych substancji organicznych (Soil enzymes activity of amonification process in the soil with the addition of organic nitrogen). Acta Agrophysica 8 [1]: 23–33

De Boer W., Folman L.B., Summerbell R.C., Boddy L. [2005]: Living in a fungal world: impact of fungi on soil bacterial niche development. FEMS Microbiology Reviews 29: 795–811

Dijber R.A., Doran J.W., Parkhurst A.M., Lyon D.J. [2000]: Changes in soil microbial community structure with tillage under long-term wheat-fallow management. Soil Biology and Biochemistry 22: 1419–1430

Dobrowolska A., Klessa M., Placek M. [2007]: Evaluation of use of media with addition of municipal sewage sludge compost in cultivation of *Impatiens waleriana* and *Impatiens Hawkerii*. Part I. Vegetative traits. Folia Universitatis Agriculturae Stetinensis 259 [4]: 35–40

Dobrowolska A., Janicka D. [2008]: Wpływ podłoży z dodatkiem kompostów na wzrosti kwitnienie bratka ogrodowego z grupy Patiola (Influence of media with addition of composts on the growth and flowering of Patiola Pansy). Zeszyty Problemowe Postępów Nauk Rolniczych 525: 89–96

Howeel C.R. [2003]: Mechanisms employed by *Trichoderma* species in the biological control of plant diseases: The history and evolution of current concepts. Plant Disease 87 [1]: 4–10

Ilnicki P. [2002]: Torfowiska i torf (Peat bogs and peat). Wyd. AR, Poznań

IUNG [1983]: Metody badań laboratoryjnych w stacjach chemiczno-rolniczych. Cz. III. Badanie gleb, ziemi podłoży spod warzyw i kwiatów oraz części wskaźnikowych roślinw celach diagnostycznych (Methods of laboratory analyses for chemical and agricultural stations. Part III. The study of soils, substrates from cultivation of vegetables and flowers and index parts of plants for diagnostic purposes). Instytut Uprawy Nawożenia i Gleboznawstwa, Puławy: 28–81

Januszek K. [1999]: Aktywność enzymatyczna wybranych gleb leśnych Polski południowejw świetle badań polowych i laboratoryjnych (The enzymatic activity of selected forest soils in the South of Poland in the light of field and laboratory research). Zeszyty Naukowe AR Kraków, Rozprawa 250

Kańska Z., Grabińska-Łoniewska A., Łebkowska M., Żechowska E. [2001]: Laboratory exercises in sanitary biology. Warsaw Polytechnic

Kobus J. [1995]: Biologiczne procesy a kształtowanie żyzności gleb (Biological processes and the formation of soil fertility). Zeszyty Problemowe Postępów Nauk Rolniczych 421: 209–219

Koper J., Siwik-Ziomek A. [2003]: Następcze oddziaływanie monokultury i zmianowania tradycyjnego na aktywność amylaz i dehydrogenaz glebowych na tle właściwości fizyko-chemicznych gleby (Subsequent impact of monoculture and traditional crop rotation on the activity of soil amylase and dehydrogenase against the background of physico-chemical properties of the soil). Zeszyty Problemowe Postępów Nauk Rolniczych 493: 637–643

Kozik E., Wróblewska H., Bosiacki M., Wojciechowska E. [2010]: Wykorzystanie kompostów z odpadów drzewnych w uprawie wybranych gatunków roślin ozdobnych (The use of wood waste compost in the cultivation of selected species of ornamental plants). Aparatura Badawcza i Dydaktyczna 4: 75–81

Krzywy E., Wraga K., Zawadzińska A. [2007]: Effects of applied substrate from municipal sewage sludge on the growth and development of *Chrysanthemum* x *grandiflorum* Ramat./Kitam. Advances of Agricultural Science Problem 518: 93–100

Larcher F., Berruti A., Gullino P., Scariot V. [2011]: Reducing peat and growth regulator input in camellia pot cultivation. Horticultural Science (Prague) 38 [1]: 35–42

Lynch I.M., Panting L.M. [1980]: Cultivation and the soil biomass. Soil Biology and Biochemistry 12: 29–35

Marschner P. [2007]: Plant-microbe interactions in the rhizosphere and nutrient cycling. Soil Biology. Springer-Verlag Berlin Heidelberg. 10: 159–1182

Martin J.P. [1950]: Use of acid, rose bengal and streptomycin in the plate method for estimating soil fungi. Soil Science 69: 215

Mocek-Płóciniak A. [2010]: Wykorzystanie aktywności enzymatycznej do oceniania wpływu antropogenicznych zmian wywoływanych przez metale ciężkie w środowisku glebowym (Utilisation of enzymatic activity for the evaluation of the impact of anthropogenic changes caused by heavy metals in soil environment). Nauka Przyroda Technologie 4 [6]: 1–10

Nannipierl P., Grego S., Ceccanti B. [1990]: Ecological significance of the biological activity in soil. In: Soil biochemistry, 6. Red. I.M. Bollag, G. Stotzky. Dekker, New York: 293–355

Niewiadomska A., Kleiber T., Komosa A. [2010a]: Optimization of lawn fertilization with Nitrogen. Part III. Dynamics of soil microbiological composition and enzymatic activity of dehydrogenases. Ecological Chemistry and Engineering A. 17 [12]: 1597–1606

Niewiadomska A., Sulewska H., Wolna-Maruwka A., Klama J. [2010b]: Effect of organic fertilization on development of proteolytic bacteria and activity of proteases in the soil for cultivation of maize (*Zea Mays* L.). Archives of Environmental Protect 36 [2]: 36–47

Pędziwilk Z., Gołębiowska J. [1984]: CO_2 release as index of biological activity of cultivated soil. Acta Microbiologica Polonica 33: 249–255

Różycki H., Strzelczyk E. [1985]: Połączenia organiczne wydzielane przez drobnoustroje glebowe i korzenie roślin (Organic compounds released by soil microorganisms and plant roots). Postępy Mikrobiologii 24 [4]: 285–303

Samborski S., Rozbicki J. [2004]: Kalibracja chlorofilometru do oceny odżywienia zbóż azotem (Calibration of chlorophyll meter in the assessment of cereal nitrogen nutrition status). Postępy Nauk Rolniczych 5: 27–37

Ścigalska B., Klima K. [1997]: Zależność między aktywnością celulolityczną gleby górskiej i plonowaniem uprawianych roślin (The dependence between the cellulolitic activity of the mountain soil and yielding of cultivated plants). Roczniki Gleboznawcze XLVIII [1/2]: 39–48

Thalmann A. [1968]: Zur Methodik der Bestimmung der Dehydrogenase Aktivität in Boden Mittels Triphenyltetrazoliumchlorid (TTC). Landwirtschaftliche Forschung 21: 249

Waldrop M.P., Balser T.C., Firestone M.K. [2000]: Linking microbial community composition to function in tropical soil. Soil Biology and Biochemistry 32: 1837–1846

Wilson S.B., Stoffella P.J., Graetz D.A. [2001]: Use of compost as a media amendment for containerized production of two subtropical perennials. Journal of Environmental Horticulture 19: 37–42

Wilson S.B., Stoffella P.J., Graetz D.A. [2002]: Development of compost-based media for containerized perennials. Scientia Horticulturae 93: 311–320

Wolna-Maruwka A., Schroeter-Zakrzewska A., Dach J. [2012]: Analysis of the growth and metabolic activity of microorganisms in substratum prepared on the base of sewage sludges and their impact on growth and flowering of garden verbena. Fresenius Enviromental Bulletin 21 [2]: 325–336

Wraga K. [2008]: Wpływ podłoża z udziałem kompostu na cechy wegetatywne i dekoracyjność piątaka lancetowatego (*Pentas lanceolata* (Forssk.) Deflers) (Effects of media supplemented with compost on vegetative traits and ornamental value of (*Pentas lanceolata* (Forssk.) Deflers)). Zeszyty Problemowe Postępów Nauk Rolniczych 525: 477–484

Wróblewska H., Czajka M., Tymek A. [2007]: Charakterystyka kompostów otrzymanych z poużytkowych odpadów tworzyw drzewnych (Characteristics of composts obtained from post-used wood-based materials waste). W: Efektywne zarządzanie gospodarką odpadami. Wyd. Futura i PZITS, Poznań: 875–886

Wróblewska H., Kozik E., Czajka M. [2008]: Wpływ kompostów z opadów drzewnych na wzrost i stan odżywienia wierzby *Salix alba* L. (Effect of composts from wood waste material on the growth and nutritional status of willow *Salix alba* L.). Journal of Research and Applications in Agricultural Engineering 53 [4]: 143–147

Wróblewska H., Kozik E., Czajka M. [2009]: Content of macro- and microcomponents in willow (*Salix purpurea* L.) grown in substrates with composts of post-use wood waste. Folia Forestalia Polonica Series B 40: 23–30

Yeh D.M., Hsu P.H., Atherton J.G. [2004]: Growth and flowering responses of *Canna* × *generalis* to nitrogen supplied to the growing medium via top- or sub-irrigation. Journal of Horticultural Science and Biotechnology A 79 [4]: 511–514

ZASTOSOWANIE KOMPOSTÓW Z DREWNA POUŻYTKOWEGO W UPRAWIE PACIORECZNIKA OGRODOWEGO (*CANNA* X *GENERALIS* L.H. BAILEY)

Streszczenie

Celem przeprowadzonych badań było poznanie wpływu kompostów uzyskanych z drewna poużytkowego na wzrost, kwitnienie i stan odżywienia paciorecznika ogrodowego (*Canna* x *generalis* L.H. Bailey) „Tropical Yellow”. W doświadczeniu analizowano także liczebność mikroorganizmów oraz poziom ich aktywności enzymatycznej w podłożach, w których uprawiane były rośliny. W badaniach zastosowano dwa warianty kompostów z drewna poużytkowego oznaczonych symbolami OPA i OPB. Rośliny uprawiano w podłożach składających się z kompostów i torfu wysokiego w następujących kombinacjach objętościowych: kompost 100%, kompost 75% + torf 25%, kompost 50% + torf 50%, kompost 25% + torf 75% i torf 100% (kontrola). Zawartość makro- i mikroskładników, pH i zasolenie poszczególnych podłoży były pochodną procentowego udziału kompostu i torfu w podłożu. Analizując uzyskane wyniki, stwierdzono, że rodzaj podłoża wywarł istotny wpływ na wzrost i kwitnienie paciorecznika ogrodowego. Podłoża zawierające 25% i 50% kompostu miały korzystny lub obojętny wpływ na wzrost i kwitnienie roślin paciorecznika. Większy udział kompostu (100% i 75%) w podłożu niekorzystnie wpływał na wzrost i kwitnienie roślin. Rodzaj zastosowanego kompostu okazał się czynnikiem determinującym zmiany liczebności i aktywności mikroorganizmów w badanych podłożach, a także stanu odżywienia roślin.

Słowa kluczowe: poużytkowe drewno, odżywienie, aktywność enzymatyczna, paciorecznik ogrodowy

Acknowledgements

The scientific work was financed by Funds for Science in the years 2010–2013 as a part of research project no. NN309281637.