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Assessment of the influence of composts on microbiological and biochemical parameters of substrates and the morphological traits of scarlet sage

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Abstract: The aim of the research was to assess the microbiological (number of heterotrophic bacteria, actinobacteria and moulds) and biochemical (urease and acid phosphatase activity) state of peat with the admixture of composts produced from sewage sludge. An additional aim of the research was to demonstrate the influence of those substrates on the morphological traits of scarlet sage (height, number and length of shoots, number of buds and inflorescences, greenness index (SPAD)). Composts produced from sewage sludge, wheat, maize and lupine straw were mixed with peat, where their percentage varied from 25% to 75%.

The substrate which included the composts applied in the experiment had a higher number of heterotrophic bacteria and a higher acid phosphatase activity level than the control substrate (peat). The multiplication of moulds and actinobacteria was more intensive than in the peat only in the combinations with K3 (sewage sludge 50%+sawdust 20%+ lupine straw 30%) and K4 (sewage sludge 50%+sawdust 20%+fresh maize straw 30%) composts, whereas the highest urease activity level was observed in the soils produced from K1 (sewage sludge 50%+sawdust 20%+white straw 30%) compost.

The most optimal development of plants was observed in the substrate with compost produced from wheat straw. Composts produced from municipal sewage sludge were found to be suitable for growing scarlet sage. However, their effect depends on the percentage of high peat in the substrate.

Introduction

At present high peat is a substrate used for growing ornamental plants. Its resources are continuously decreasing as a result of intensive exploitation. Therefore, there is search for new, alternative substrates, which may replace or minimise the consumption of peat in horticultural production. Composted sewage sludge and industrial waste, which is rich in organic and mineral compounds, may be a good source of components for the production of substrate (Krzywy et al. 2004, Ostos et al. 2008, Solecka at al. 2013, Starzyk et al. 2013, Wolna-Maruwka and Czekała 2007, Wolna-Maruwka and Dach 2009, Wolna-Maruwka and Pilarski 2011). According to Ingelmo et al. (1998), the admixture of sewage sludge may partially replace peat, whose deposits are exploited intensively. It is also economically justified, because according to the abovementioned authors, the cost of a soil with the admixture of sewage sludge is 20–40% lower.

Year by year the amount of sewage sludge is increasing. It is often deposited in landfills or areas around sewage treatment plants. As a result, it causes serious danger to the natural environment and contributes to its degradation. In spite of increasing social awareness and current legal standards, the problem of appropriate and rational handling of sludge remains topical and arouses numerous doubts (Czyżyk at al. 2001).

Due to the properties of sewage sludge, especially the content of organic matter, it is thought that it should be used in agriculture or horticulture. Due to its consistency and C:N ratio it is usually composted with the admixture of such structure-building materials as bark, woodchips, sawdust or various kinds of straw (Czekała 2004).

The use of composts in growing ornamental plants has broad perspectives. Their practical application may influence the general improvement of soil structure, its water absorption and fertility. Additionally, they enrich the substrate with useful microorganisms, whose metabolism is related to triggering biocontrol mechanisms responsible for reduction of phytopathogen-induced diseases (Schmidt at al. 2014, Stachowiak at al. 2006)

Microorganisms develop in close interdependence with plants from the moment of seed germination until the time when the plant becomes fully mature (Pietr 1990, Vessey 2003). The role of microorganisms in the soil, which consists in decomposition of organic debris, is very important because they liberate mineral forms of nutrients, which are an important source of nourishment for arable crops. Apart from that, as a result of the processes of microbiological transformation of organic matter, humus compounds are formed. Their content in the soil is one of the most important factors which are decisive for the capacity of soil to accumulate water and nutrients as well as to its physical structure (lumpiness, gas exchange). Microorganisms also contribute to the degradation and detoxification of various substances in the substrate (xenobiotics) and they have a direct or indirect effect on plant growth (Bashan 1998).

Moreover, plants affect microorganisms in the substrate by production of root secretions (Gracia at al. 1997, Wolna-Maruwka at al. 2010). According to Pietr (Pietr 1990), the composition of root secretions depends not only on the plant species or variety but also on their stage of development. According to Barabasz and Smyk (Barabasz and Smyk 1997), root secretions may have a stimulating or inhibiting effect on the cells of microorganisms.

Evaluation of the population of selected groups of microorganisms and the biochemical activity of substrate will allow us to assess which of the substrates applied to sage cultivation has the most significant contribution to the population and activity of microorganisms. Moreover, it will allow us to assess how the dynamics of variation in the metabolic activity of microorganisms is related to the growth and development of scarlet sage. Hence, the aim of the research was also to determine the influence of composts on the morphological traits of plants, chlorophyll content as well as the dynamics of their growth and florescence.

Material and methods

The experiment was carried out in 2013 using 'Red Alert' scarlet sage (*Salvia splendens*) in one of the glasshouses of Marcelin Experimental Station belonging to the Department of Ornamental Plants of Poznań University of Life Sciences.

The composted material comprised sewage sludge together with sawdust and maize, lupine and wheat straw (Table 1). The obtained mature composts were mixed with high moor peat in appropriate proportions (Table 2). Plants growing in deacidified high moor peat supplemented with 3 $g \cdot l^{-1}$ of slow-release fertilizer Osmocote 3–4 M were treated as a control group. Substrates prepared as described above were subjected to chemical analyses (Table 3).

Seedlings of garden scarlet sage were planted into pots of 9 cm in diameter and cultivated in a glasshouse. No top dressing was applied in the course of cultivation.

Table 1. Percentage composition of composts used in experiment

Kind of composts	Composition (%)
K1	Sewage sludge 50
	Wheat straw 30
	Sawdust 20
K2	Sewage sludge 50
	Maize straw 30
	Sawdust 20
K3	Sewage sludge 50
	Lupine straw 30
	Sawdust 20
K4	Sewage sludge 50
	Fresh maize straw 30
	Sawdust 20

Table 2. Percentage composition of substrates used under cultivation of scarlet sage

Combination	Composition (%)
K (control)	100% peat
K1I	100% compost
K1II	25% peat +75% compost
K1III	50% peat +50% compost
K1IV	75% peat+25% compost
K2I	100% compost
K2II	25% peat +75% compost
K2III	50% peat +50% compost
K2IV	75% peat+25% compost
K3I	100% compost
K3II	25% peat +75% compost
K3III	50% peat +50% compost
K3IV	75% peat+25% compost
K4I	100% compost
K4II	25% peat +75% compost
K4III	50% peat +50% compost
K4IV	75% peat+25% compost

Analysis of plant parameters

After three months of growth, the plants' height, number of shoots and leaves, length and number of inflorescences were measured during their florescence. The leaf greenness index was also determined by means of an N-Tester (Yara). The measurement is done to determine the intensity of greenness of leaves and it consists in calculating the light absorption ratio related to the presence of chlorophyll at the wavelength of

Table 3. Chemical properties of substrates

Combination	Volumetric weight (g·dm³)	pH	mg ·dm³ substrate						gNaCl·dm³
			N-NO_3	**P**	**K**	**Ca**	**Mg**	**Cl**	
K (control)	320	6.1	271	228	495	2431	212	113	3.35
K1I	340	7.1	9	866	4360	1583	508	1950	6.35
K1II	310	6.5	6	448	2260	2053	305	980	4.24
K1III	325	6.6	5	396	1785	2155	275	960	3.30
K1IV	325	6.4	6	232	1043	2058	209	520	2.30
K2I	570	6.6	78	762	1245	1369	421	362	2.70
K2II	425	6.8	9	418	700	1787	255	242	1.80
K2III	375	6.7	9	246	470	1808	191	169	1.30
K2IV	345	6.7	8	142	205	2094	180	98	1.10
K3I	325	6.7	6	836	3085	766	410	800	3.05
K3II	330	6.6	4	456	1760	1328	251	530	1.88
K3III	320	6.7	4	276	100	1706	213	300	1.45
K3IV	320	6.8	3.3	142	610	1992	179	208	1.13
K4I	300	7.2	3.3	688	3050	868	345	490	2.75
K4II	310	6.8	3.3	411	1650	1466	239	329	1.72
K4III	320	6.8	4	179	1095	3023	215	240	1.60
K4IV	305	6.8	3.3	161	665	1982	178	156	1.17

650 nm and absorption through the leaf tissue at the wavelength of 940 nm (Samborski and Rozbicki 2004). Additionally, at the end of the experiment chlorophyll content in dry matter was also analysed using the method described by Shoaf and Lium (Shoaf and Lium 1976). Samples for these measurements were taken during the phase of flowering. Chlorophyll *a*, *b* and *a*+*b* in fresh matter was first analysed and after evaluation of leaf dry matter content the total chlorophyll content in dry matter was calculated and presented in this paper. Moreover, to present the changes of the relation between chlorophyll *b* and *a*, the chlorophyll *b/a* ratio was calculated and presented here.

The main factor determining the moment of sample collection adopted in the methodology was the current developmental stage of scarlet sage: date I – seedling phase; date II – phase of vegetative development; and date III – phase of plant flowering.

Microbiological analysis

Microbiological analysis was performed on the basis of Koch's plate method and involved determining (using selective substrates) the numbers of colony forming units (cfu) of heterotrophic bacteria, moulds and actinobacteria. Estimation of cfu numbers of the above-mentioned microorganisms is a measure of the intensity of their current metabolic activity.

The number of heterotrophic bacteria was determined on Merck standard agar (3 g yeast extract; 5.0 g peptone from casein (free from fermentable carbohydrates); 5 g sodium chloride; 12 g agar, 1l H_2O), after 5–6 days of incubation at the temperature of 28°C (Merck 2004). Moulds were determined on Martin substrate (1 g KH_2PO_4, 0.5 g $MgSO_4$, 5 g peptone, 10 g glucose, 3.3 ml Bengal, 25 g agar, 0.1 g chlortetracycline, 1 l H_2O) for 5 days at the temperature of 24°C (Martin 1950) and numbers of actinobacteria were assessed on a selective Pochon substrate (0.05 g asparagine, 0.1 g nystatin, 2 g starch, 25 g agar, 5 g K_2HPO_4, 2.5 g $MgSO_4 \cdot 7H_2O$, 2.5 g NaCl, 0.05 g $MnSO_4 \cdot 5H_2O$, 0.05 g $Fe_2(SO_4)_2 \cdot 5H_2O$, 1l H_2O) (Kańska at al 2001) following plate incubation for 7 days at the temperature of 26°C.

Biochemical analysis

In addition, using a spectrophotometric method, the activity of acid phosphatase was determined using as substrate p-nitrophenylphosphate sodium, after one hour incubation at 37°C with wavelength 400 nm. Enzyme activity was expressed in µmol PNP·g^{-1}·h^{-1} (Tabatabei and Bremner 1969). Urease activity was determined using urea as substrate, after one hour incubation at 37°C with wavelength 410 nm. Enzyme activity was expressed in µg N-NH_4^+·g^{-1}·18 h^{-1} (Hoffmann and Teicher 1961).

Statistical analysis employed in the experiment was performed using the program STATISTICA 11.0 (Ott 1984).

Results and discussion

Microbiological analysis

The highest number of heterotrophic bacteria in the first period of the investigations (seedling planting stage) was observed in the combination K3II (Table 2), which consisted of 75% compost made from lupine straw and 25% peat, whereas the lowest number was observed in the control group, i.e. in the peat (Figure 1). Statistically significant differences in the number of bacteria between the combinations under analysis were observed during that period. Wolna-Maruwka et al. (2012) analysed the total bacterial population in composts under a verbena plantation and found that the most numerous population could be found in the substrate with compost produced from sewage sludge, sawdust and lupine straw.

At the stage of vegetative growth of sage (stage II) the number of bacteria in the control group remained at a low level. In the other combinations it varied depending on the compost applied and the percentage of peat in the substrate.

This situation may have been caused by different composition of chemical compounds produced as a result of the microbiological decomposition of organic matter from the composts applied in the experiment. Also, as shown in the studies by Wolna-Maruwka, Pilarski (2011) and Czekała (2004), composts produced from sewage sludge with different percentages of structure-building materials (sawdust, various types of straw) differ in the chemical composition, e.g. the C:N ratio.

At the stage of sage florescence (stage III) the number of the microorganisms under discussion decreased in most of the combinations under analysis, which was most likely caused by change in the qualitative and quantitative composition of sage root secretions. As Garcia et al. (Dobrowolska at al 2007) claimed, the composition of root secretions depends not only on the plant species or variety, but also on its stage of development.

Another group of microorganisms isolated from the substrates was actinobacteria. They play an important role in the mineralisation of the organic matter in substrate and thus they enable the plant to gain access to nutrients. Actinobacteria were found to produce such enzymes as cellulases and chitinases. Moreover, they produce enzymes which take part in the lysis of cellular walls of microorganisms (bacteria and fungi), e.g. lysozyme, peptidyl-peptide hydrolases, glucanases, mannanases and chitinases (Solecka at al 2013). The influence of actinobacteria on the biological activity of soil is additionally intensified by their phytosanitary properties, i.e. the ability to produce antibiotic (bactericidal and fungicidal) substances (Górska at al 2006).

The microbiological analysis (Figure 2) proved that at the first stage of analysis the highest number of actinobacteria was present in the control substrate, i.e. in the peat. According to Szember (Szember 2001), peat is an environment where actinobacteria are predominant.

At that stage the lowest number of microorganisms in question was observed in combinations K4I and K4IV, which were composed not only of peat but also compost produced from maize straw (especially combination K4IV).

At the second stage of investigations statistically significant differences in the number of actinobacteria were found between the combinations under analysis. In the substrates with compost produced from wheat straw (K1I–K1IV) the population of actinobacteria decreased. In most of the other experimental combinations an increase in

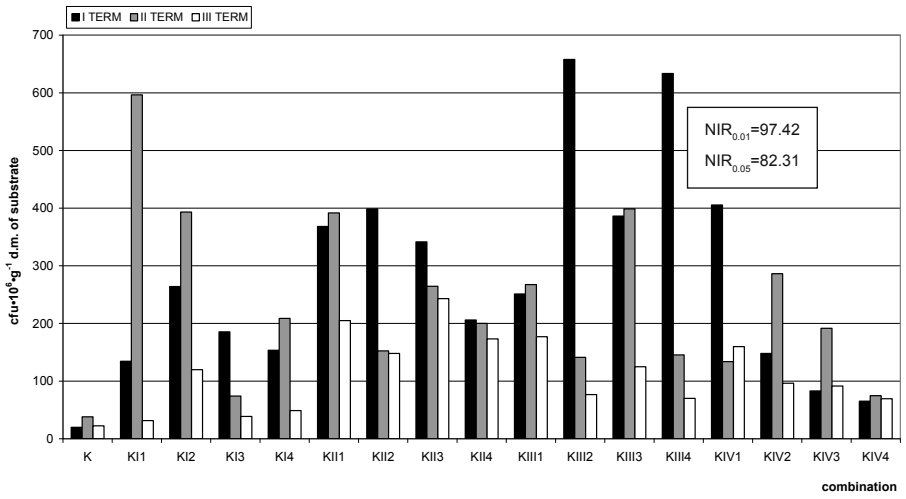

Fig. 1. Changes of the total bacteria number

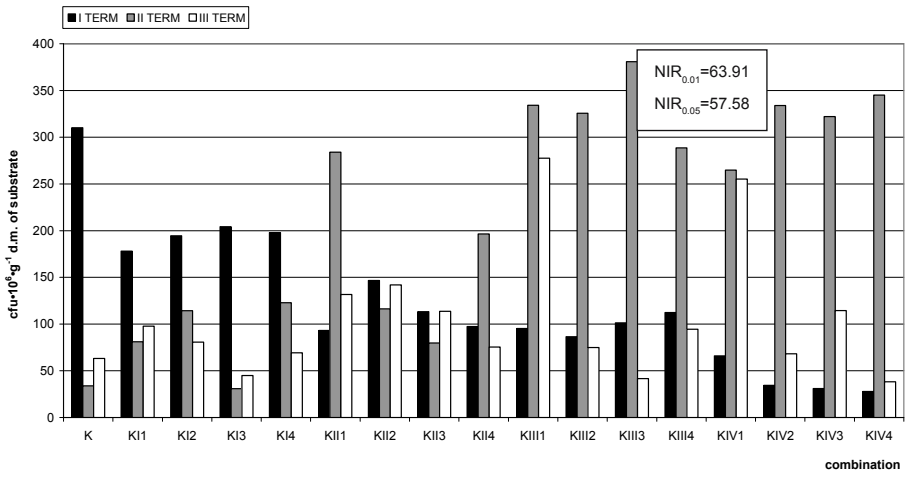

Fig. 2. Changes of the total actinobacteria number

the multiplication of the microorganisms in question could be observed at that time. It is most likely that this situation was caused by different composition of chemical compounds formed from the microbiological decomposition of organic matter from the composts applied in the experiment. In the second period of investigations the substrate pH fluctuated around neutral (Figure 3), so it had no influence on the multiplication of actinobacteria. According to Zakharov et al. (Zakharova at al 2003), the optimal pH substrate for the growth and development of most actinobacteria is close to neutral or slightly alkaline.

At the stage of sage florescence (stage III) variations in the population of microorganisms were incidental and they depended on the type of the experimental combination applied. The strongest multiplication of actinobacteria was observed in the substrates which were totally composed of a particular compost, except the compost made from stored maize straw (K2I).

The research findings revealed that the main factor affecting changes in the population of actinobacteria during the experiment was the type of combination applied. According to the results of the research by Wolna-Maruwka et al. (2012), the main factor affecting changes in the above-mentioned microorganisms was the development stage of verbena grown in substrates.

Besides bacteria and actinobacteria, moulds play a principal role in the circulation of nourishment in the substrate. There are numerous reasons why they are such powerful factors of geochemical transformations.

From the agricultural point of view, their physiological capacity to accumulate water, produce organic acids and liberate numerous nutrients from soil minerals makes them play an important function in the processes of plant nutrition. As saprophytes they carry out very intensive processes of organic matter mineralisation and thus contribute to higher fertility of the substrate (Bis 2002). Similarly to the total number of actinobacteria, at the first stage of analysis the largest population of moulds was noted in the control substrate, i.e. in the peat (Figure 4).

Also at the second stage of investigations there was a similar tendency in the dynamics of changes in the population of moulds, as was the case with the actinobacteria. In the substrates with compost produced from wheat straw (K1I–K1IV) the population of moulds fluctuated according to the percentage of compost in the soils. In the other experimental substrates an increase in the multiplication of the microorganisms in question was observed. At the stage of sage florescence (stage III) there were statistically insignificant variations noted in the number of moulds, which depended on the combination.

Similarly, as in the case with the actinobacteria, variations in the population of the group of microorganisms under study during the experiment indicated that their

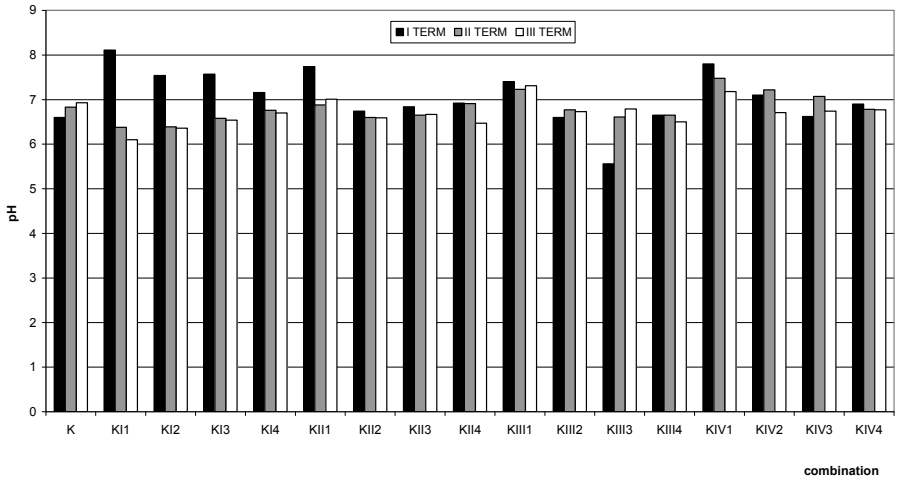

Fig. 3. Changes of pH combination

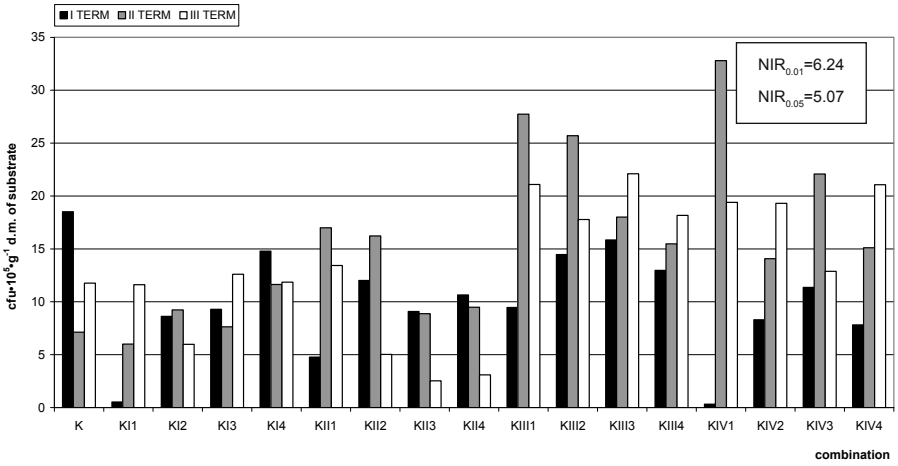

Fig. 4. Changes of the moulds number

proliferation is related to the quality and quantity of substrates in the soil and with the stage of sage development.

The above observations are confirmed by the findings of the research by Wolna-Maruwka et al. (2012), where the development stage of verbena was proved to have a statistically significant influence on the variations in the population of moulds in the substrate made from composts.

Biochemical analysis

According to Martyniuk et al. (2001), the enzymes which take part in the transformations of phosphorus compounds in soils are produced not only by microorganisms but also by plant roots. According to those authors, the high activity of these enzymes in the substrate indicates an intensive process of decomposition of organic matter and thus gives plants access to absorbable forms of nutrients. The analysis of variations in the level of phosphatase activity in the applied substrates (Figure 5) revealed that at the first two stages of the analysis the lowest activity of those enzymes was observed in the control substrate, i.e. in the peat, which probably resulted from the fact that phosphorus compounds are rarely found in peat (Ilnicki 2002).

At the first stage of the analysis the highest phosphatase activity was observed in the combination which was totally composed of compost produced from lupine straw (K3I). At the stage of sage vegetative growth a high level of these enzymes remained in substrate K3I. Additionally, strong phosphatase activity was observed in the combination which was totally composed of compost produced from fresh maize straw (K4I).

This phenomenon was probably related to the high content of organic phosphorus compounds in straw, especially maize straw, which is one of the components of compost.

At the plant florescence time (stage III) in all substrates except K3I and K4I the phosphatase activity level increased, which was most likely caused by changes in the qualitative and quantitative composition of sage root secretions or by increased secretion of enzymes from the roots of the plants at the stage of their generative growth.

Apart from determining the acid phosphatase activity level in the substrate samples under analysis, the urease activity was also estimated.

According to Bielińska and Żukowska (Bielińska and Żukowska 2002) the urease activity in the soil is correlated with the content of organic carbon and nitrogen. The authors also noted a significant correlation between the enzyme activity and the content of N-NH_4^+ in the substrate.

Presented research (Figure 6) revealed that at the first stage of the investigations the lowest urease activity level was noted in substrate K3IV, which consisted of 75% peat and 25%

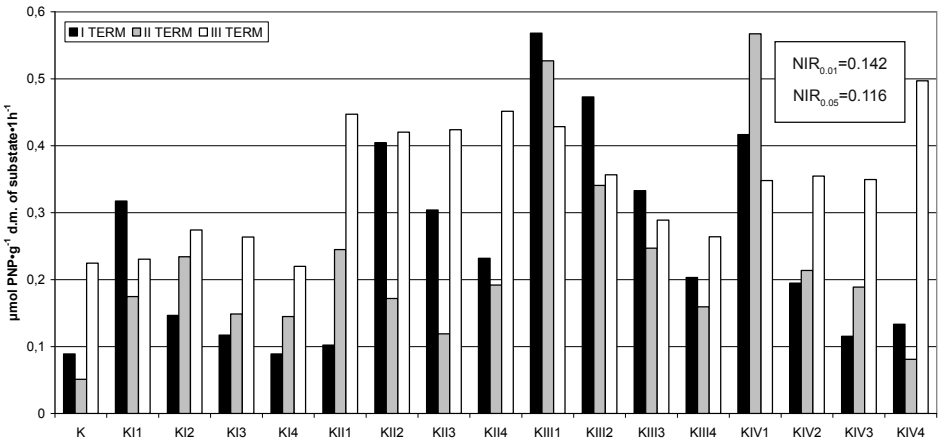

Fig. 5. Changes of the acid photophase activity

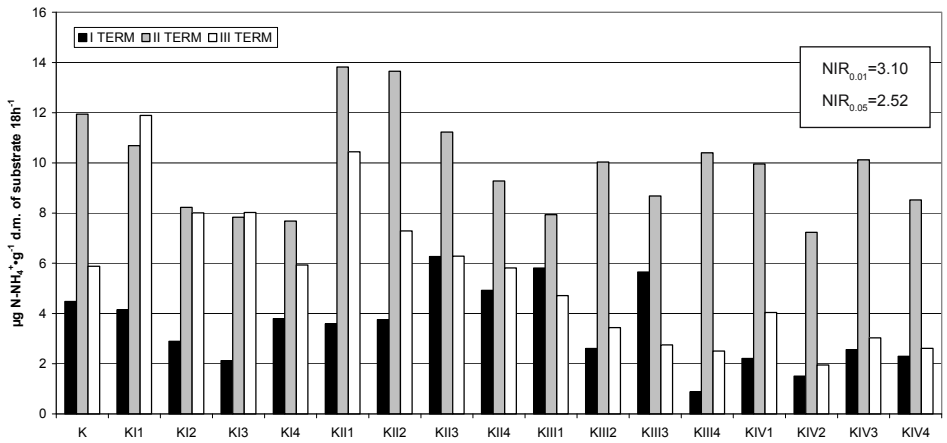

Fig. 6. Changes of the urease activity

compost made from lupine straw, whereas the highest level was noted in combination K2III (50% peat and 50% compost made from stored maize straw).

At the stage of vegetative growth of sage in most of the combinations under analysis there was a statistically significant increase in the enzyme activity observed, which was probably related to the change in the composition of sage root secretions at the time. According to Barabasz and Smyk (Barabasz and Smyk 1997), plant roots secrete amino acids, carbohydrates, organic acids, nucleotides, flavonoids, etc. into the soil. According to Wielgosz et al. (Wielgosz at al. 2004), root secretions change the physiochemical properties of the substrate and thus exert an influence on the metabolic activity of microorganisms.

Analysis of plant parameters

At the plant florescence time (stage III) in most of the experimental substrates under analysis there was a decreased urease activity level observed, which was also attributed to the change in the qualitative and quantitative composition of root secretions.

The assessment of morphological traits of sage revealed that the substrates used in the experiment exerted a heterogeneous influence on the growth and florescence of plants. The statistical analysis proved that the admixture of compost in peat stimulated the growth of sage. Only the plants grown on the soil which was totally composed of compost K1I, K3I and K4I were lower. Ostos et al. (Ostos at al 2008) reported the stimulating effect of compost made from sewage sludge on the growth of *Pistacia lentiscus*. Andre et al. (Andre at al 2002) observed stronger growth of pelargonium grown on a substrate composed of peat and sewage sludge, where the volume ratio was 1:1. According to Dobrowolska et al. (2013) the substrates produced from composts on the basis of sludge are suitable for the cultivation of the horned violet. Toumpelia et al. (Toumpelia at al. 2013) observed a stimulating effect of compost produced on the basis of plant mass and manure on the biomass and fruiting of tomato. Also, Zawadzińska and Kless (Zawadzińska and Klessa 2007) reported a positive impact of composts produced from sewage sludge on morphological traits of geranium. On the other hand, Dobrowolska et al. (Dobrowolska at al. 2007) obtained different results. They found that the admixture of composts from sewage sludge inhibited the growth of impatiens valerian and New Guinea impatiens.

The analysis of the obtained results did not show significant differences in the number of shoots depending on the composts used. Their number was smaller only in the soils 100% and 75% of which was totally composed of K4 compost. The applied compost had an unfavourable influence on the number of leaves developing on plants. The difference was particularly visible on the plants which grew on the substrate which was totally composed of K4 compost because they produced 66% fewer leaves. Janicka and Dobrowolska (2013) obtained similar results for horned violets.

Our research showed that regardless of the compost applied the greenness index value for leaves was lower than in the control plants grown on peat (Table 4). Only in the case of compost K1, except combinations where the compost constituted 25%, it was recorded at higher values compared to other combinations. However, they were lower than the control (Table 4). This may have been caused by very low content of $N\text{-}NO_3$ in those soils. Also, Dobrowolska et al. (2007) and Janicka and Dobrowolska (2013) observed lighter leaves in the horned violet and New Guinea impatiens grown on the soil with the admixture of sewage sludge. Similar results were obtained for chlorophyll content in dry matter. However, in the case of combination K1III (50% compost with wheat straw and 50% peat) higher levels of chlorophyll *a+b* and *a* were noted in relation to the rest of the combinations (Figures 7 and 8). Chlorophyll *b* is usually treated as more sensitive to changes in the environment; hence lower levels of this pigment were noted in all compost combinations in relation to the control (not always statistically significant) (Figure 9). The sensitivity of chlorophyll b in scarlet sage plants due to compost application was clearly observed in the case of the chlorophyll *b/a* ratio, where all combinations revealed statistically significant values compared to the control one (Figure 10).

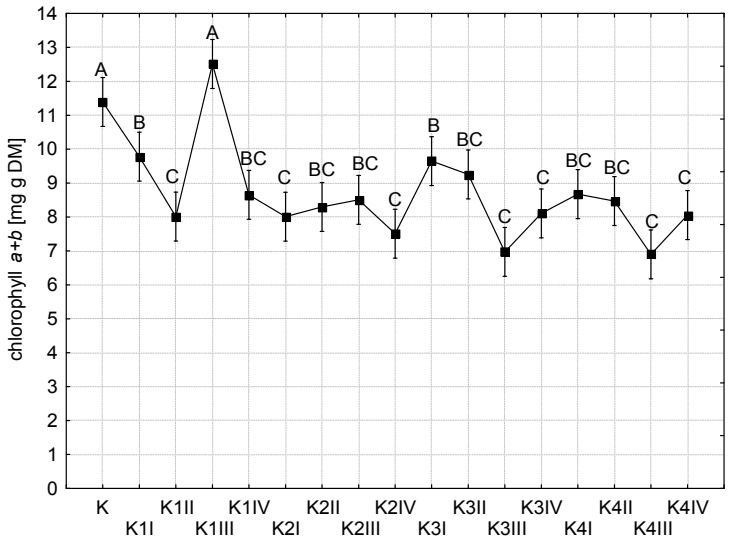

Fig. 7. Chlorophyll *a+b* content in dry matter (means ±SD; different letters denote statistical differences at level α=0.05)

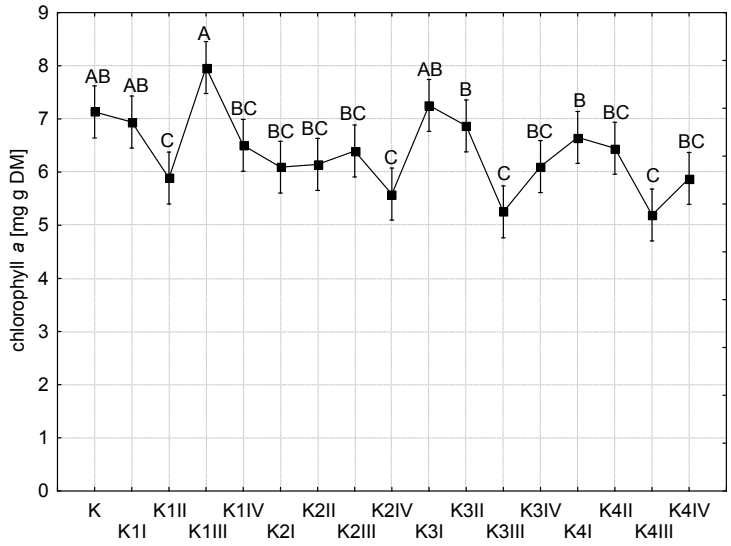

Fig. 8. Chlorophyll *a* content in dry matter (means ±SD; different letters denote statistical differences at level α=0.05)

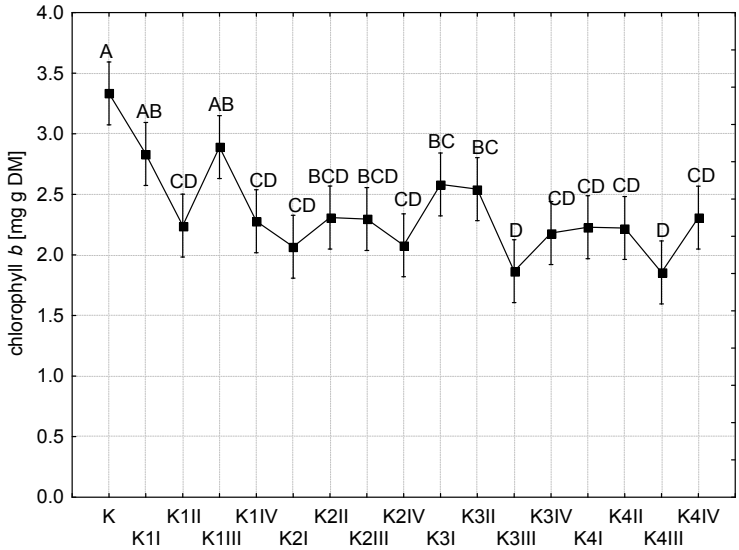

Fig. 9. Chlorophyll *b* content in dry matter (means ±SD; different letters denote statistical differences at level α=0.05)

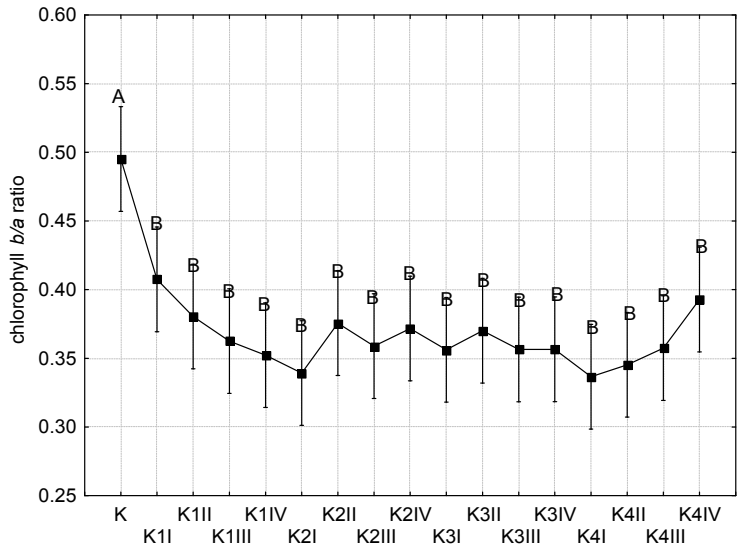

Fig. 10. Chlorophyll *b/a* ratio (means ±SD; different letters denote statistical differences at level α=0.05)

Table 4. The influence of compost media on morphological traits of scarlet sage

Traits	Combinations	K1	K2	K3	K4
Height of plants (cm)	control	13.6 c	13.6 c	13.6 c	13.6 c
	100% compost	11.6b	15.0 de	11.3b	9.0 a
	75% kompost + 25% peat	15.3 de	15.8 def	14.4 cd	17.1 fg
	50% kompost + 50% peat	16.1 def	16.3 ef	15.8 def	17.3 fg
	25% kompost + 75% peat	16.2 ef	15.8 def	16.4 ef	18.6g
Number of shoots	control	3.8 hi	3.8 hi	3.8 hi	3.8 hi
	100% compost	3.8 hi	3.2 defgh	3.4 efgh	1.8 a
	75% kompost + 25% peat	3.8 hi	3.6 fghi	3.0 cdef	2.4b
	50% kompost + 50% peat	4.1 i	3.6 ghi	3.0 cdef	3.2cdefg
	25% kompost + 75% peat	3.6 ghi	2.8 cde	2.6 c	2.6 cd
Number of leaves	control	44.8 i	44.8 i	44.8 i	44.8 i
	100% compost	39.8 h	24.3 cde	27.0 def	15.1 a
	75% kompost + 25% peat	42.4 hi	27.4 ef	25.4 cde	21.8 bc
	50% kompost + 50% peat	37.8 g	25.3 cde	24.8 cde	22.2 bc
	25% kompost + 75% peat	30.5 f	19.7 b	21.9 bc	23.0 bcd
Length of inflorescences (cm)	control	5.7 cd	5.7 cd	5.7 cd	5.7 cd
	100% compost	3.7 b	6.7 def	2.6 ab	2.3 a
	75% kompost + 25% peat	6.3 cde	6.4 cde	5.3c	7.3 ef
	50% compost + 50% peat	6.9 def	7.2 def	6.9 def	7.8 ef
	25% compost + 75% peat	7.1 def	8.0 f	7.4 ef	8.0 f
Number of inflorescences	control	3.7 c	3.7 c	3.7 c	3.7 c
	100% compost	5.2 d	2.2 abc	2.2 abc	1.6 a
	75% kompost + 25% peat	3.6 bc	2.5 abc	2.4 abc	2.4 abc
	50% kompost + 50% peat	3.5 bc	2.5 abc	2.6 abc	2.8 abc
	25% kompost + 75% peat	2.5 abc	2.0 ab	2.2 abc	2.6 abc
Greening index of leaves (SPAD)	control	49.3 g	49.3 g	49.3 g	49.3 g
	100% compost	38.9 f	31.5 bcd	31.3 bcd	29.2 abc
	75% kompost + 25% peat	36.4 ef	29.1 abc	31.1 bcd	34.4 de
	50% kompost + 50% peat	34.7 def	28.9 abc	31.7 bcd	31.7 bcd
	25% kompost + 75% peat	28.3 ab	26.0 a	29.3 abc	33.6 cde

a–i – Means followed by the same letter do not differ significantly at the p = 0.05

The composts applied in our own research also had an influence on the florescence of the plants. Inflorescence buds appeared soonest, i.e. after 50 days, on the plants grown on the substrates with 75%, 50% and 25% admixtures of K1 and K4 composts. On the other hand, they appeared latest, i.e. after 61 days, on the substrate which was totally composed of K3 and K4 composts. As Dobrowolska et al. (2007) reported, high doses of sewage sludge composts may inhibit and delay the florescence of impatiens valleriana and New Guinea impatiens.

The number of inflorescences did not change considerably because of the composts applied. Only the plantation with 100% K1 compost resulted in plants with a larger number of inflorescences than on the other plants. Wolna-Maruwka et al. (2012) obtained similar results for verbena grown on the same types of substrate. The authors obtained plants with more abundant inflorescences in the soils with a 25% admixture of compost composed of sewage sludge (50%), fresh maize straw (30%) and sawdust (20%).

K1, K3 and K4 composts without the admixture of peat had an unfavourable influence on the length of inflorescences. The plants had much shorter inflorescences than the control plants. Depending on the type of compost and its percentage in the substrate the inflorescences on the other plants were longer or they did not differ significantly from the control plants.

Conclusions

1. The stage of scarlet sage development was a more significant factor influencing variations in the population

of microorganisms under study and the level of enzyme activity than the type of compost applied.
2. There was a higher number of heterotrophic bacteria and a higher level of acid phosphatase activity in the substrate composed of peat and different admixtures of composts than in the peat only substrate.
3. Only the substrates produced from K3 (sewage sludge 50% + lupine straw 30% + sawdust 20%) and K4 (sewage sludge 50% + fresh maize straw 30% + sawdust 20%) composts contributed to a higher overall population of moulds and actinobacteria than in the control soil, i.e. in the peat.
4. Only in the combinations which included K1 (sewage sludge 50% + wheat straw 30% + sawdust 20%) compost was there higher urease activity than in the control substrate.
5. The increase in the population of microorganisms in the experimental substrates under analysis did not cause significantly lower quality of sage.
6. The substrates with the admixture of composts stimulated the elongation growth of scarlet sage shoots and inflorescences (except K1, K3 and K4 composts applied without the admixture of peat).
7. The applied composts had an unfavourable influence on the number of leaves and their greenness index. This was confirmed by the content of all chlorophyll forms, especially chlorophyll *b*. On the other hand, they had a favourable influence on the number of inflorescences (especially K1 compost applied without the admixture of high peat).
8. The composts applied in the experiment may be used for growing scarlet sage in combination with high peat.

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Ocena wpływu kompostów na parametry mikrobiologiczne i biochemiczne podłoży oraz cechy morfologiczne szałwii błyszczącej

Streszczenie: Celem badań była ocena stanu mikrobiologicznego (liczba bakterii heterotroficznych, promieniowców, pleśni) i biochemicznego (aktywność ureazy i fosfatazy kwaśnej) torfu z domieszką kompostów wytworzonych na bazie osadu ściekowego. Ponadto celem badań było wykazanie wpływu niniejszych podłoży na cechy morfologiczne szałwii błyszczącej (wysokość, liczba i długości pędów, liczba pąków i kwiatostanów, indeks zazielenienia (SPAD)). Komposty wyprodukowane z osadu ściekowego, słomy pszennej, kukurydzianej i łubinowej zmieszano z torfem w różnym udziale procentowym, od 25% do 75%.

Podłoża zawierające w swoim składzie komposty charakteryzowały się wyższą niż podłoże kontrolne (torf) liczbą bakterii heterotroficznych oraz wyższą aktywnością fosfatazy kwaśnej.

Silniejsze namnażanie grzybów pleśniowych oraz promieniowców w stosunku do kombinacji kontrolnej odnotowano jedynie w przypadku w kombinacji K3 (50% osadu ściekowego + 20% trociny + 30% słomy łubinowej) i K4 (50% osadu ściekowego + 20% trociny + 30% świeżej słomy kukurydzianej). Natomiast najwyższy poziom aktywności ureazy zaobserwowano w obiekcie K1 (50% osadu ściekowego + 20% trociny + 30% słomy pszennej). Najbardziej optymalny rozwój roślin zaobserwowano na podłożach wyprodukowanych na bazie kompostu z dodatkiem słomy pszennej.

Na podstawie uzyskanych wyników stwierdzono, że komposty wyprodukowane z komunalnych osadów ściekowych mogą być stosowane w uprawie szałwii błyszczącej. Ich działanie zależy od procentowego udziału kompostów w podłożu.