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Effect of differently matured compost produced from willow (*Salix viminalis L.)* on growth and development of lettuce (*Lactuca sativa* L.)†

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Abstract: Soil amendments from peats, brown coals and composts produced from segregated biodegradable waste or biomass from fallow land can increase soil fertility and improve soil productivity. The aim of the study was to determine the possibility of using willow *(Salix viminalis L)* biomass composts as a substrate component in horticulture. The objects of the research were composts produced from willow chips (A), willow mixed with hay (B) and willow mixed with hay and mineral nitrogen (Nmin) fertilizer (C). Composting was carried out in a pile under aerobic conditions. To determine the properties and fertilizing value of the composts, basic chemical parameters were analyzed (pH, total contents of C, N and P) and a pot experiment was established to analyze the germination and growth of lettuce *(Lactuca sativa L.)*. Changes in pH, total nitrogen content (TN), phosphorus (TP) and a decrease in TOC was observed in the investigated samples. Results of the experiment showed that the highest yield was obtained from the pots with the mixture of willow, hay and Nmin. Matured composts significantly stimulated the germination and growth of the test plants. It can be concluded that the addition of hay and Nmin significantly increased the fertilizing value of the investigated composts.

Keywords: composts; maturity; willow; fertilizing value

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1. Introduction

In recent decades, a significant decrease in humus resources in terrestrial environments (especially cultivated areas), due to increased mineralization of organic matter, has been observed [1]. The consequences of these adverse changes are a rapid reduction in soil fertility and productivity, and a catastrophic impact on crop production and the conservation values of terrestrial ecosystems [2]. This situation has given rise to concern among scientists. In order to reduce the negative effects of environmental changes, improve soil quality and increase soil organic matter (SOM) content, relevant guidelines, programmes and projects recommended by international organizations (FAO-WRB, IUSS, EGU-SSS, ISEB, etc.) have been developed [3,4]. The most likely solutions seem to be those suggesting the use of sustainable tillage and the introduction of organic or organic-mineral soil conditioners produced from exogenous organic matter (EOM). The use of alternative sources of EOM are also highly recommended: selected 'green waste', biodegradable municipal waste or biomass from the cultivation of various plant species, with a particular focus on the concept of using biomass from the cultivation of energy willow as a substrate for compost production [5].

The aim of this study was to analyze selected chemical properties of composts produced from energy willow (*Salix viminalis* L.) as well as to determine their influence on germination and growth of lettuce (*Lactuca sativa* L.).

2. Materials and Methods

The objects of the research were composts produced according to three variants: composts produced from willow chips, willow mixed with hay and willow mixed with hay and mineral (ammonium nitrate 34% N) nitrogen fertilizer (Variants A, B and C, respectively). Samples for analysis were taken from the piles at different maturity stage (after 1, 32, 71 and 167 days), t then air-dried and ground, then ground mechanically to a diameter of 2.0 mm. In collected materials the following determinations were performed: pH in 1 mol KCl · dm^{-3}, content of total organic carbon (TOC) and total nitrogen (TN) using Vario Macro Cube CN analyser (Elementar Analysensysteme GmbH, Germany), content of total phosphorus (TP) by MP-AES 4200 analyzer (Agilent, USA). To determine the fertilizer value and potential use of composts, two stages of pot experiment was established: the effect of composts at different maturity stages on germination (Stage 1) and initial growth (Stage 2) of lettuce *(Lactuca sativa L.)*. A randomized complete block method was used with the following parameters: 20 seeds per pot in 3 replicates (Stage1) and 3 seedlings per pot in 3 replicates (Stage 2) for each variant, respectively. During the experiment the influence of two factors were investigated: the type of composting variant and the compost maturity stage. The obtained results were statistically processed with Statistica 13 software. Differences among objects were checked according to Tukey's test at the significance level <0.05

3. Results and Discussion

The results presented in this paper are based on mean values obtained during chemical analyses and resulting from the vegetation experiment.

3.1. Changes in pH, TOC, TN and TP contents.

Changes in pH during composting indicate the intensity of biochemical processes. Values of pH in the range 5.5 to 8.0 are considered the most optimal, while the final product should be neutral or slightly acidic [6,7]. The analysis of the obtained results (Figure 1, Table 1) indicates too high acidification of the tested composts. Regardless of the variants used, the lowest value of this parameter was found in the initial materials: pH_{KCl} from 4.16 to 5.12 (variants A and B, respectively). Additionally, statistical analysis (Table 1) showed significant differences between the tested samples.

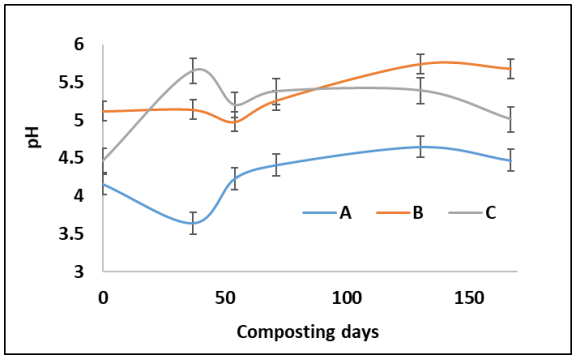


Figure 1. Changes in pH_{KCl} during composting of willow chips.

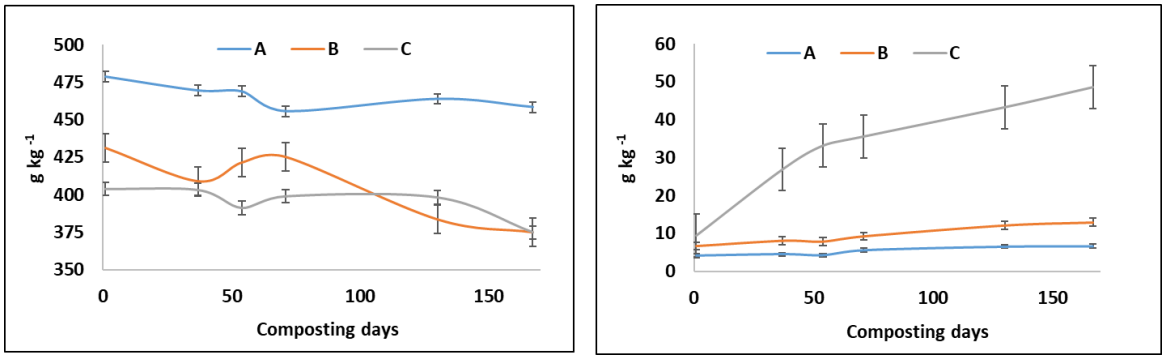
However, it should be noted that the dynamics of these changes differed between the composting variants. They result mainly from the composition of the composted biomass and the intensity and direction of the organic and mineral components transformations [8,9]. These phenomena are determined by the biodegradability of the substrates used and the conditions of the composting process [10].

Table 1. Changes in basic chemical parameters of differently matured composts produced from willow.

Variant	Composting days							
	1	St. Dev.	32	St. Dev.	71	St. Dev.	167	St. Dev.
				pH				
A	4,16[a]	0.07	3,64[a]	0.12	4,41[a]	0.13	4,47[a]	0.13
B	5,12[b]	0.09	5,14[a]	0.08	5,26[b]	0.16	5,68[b]	0.17
C	4,46[c]	0.16	5,65[ba]	0.17	5,38[b]	0.16	5,01[c]	0.15
				TOC g kg-1				
A	478,9[a]	14.37	469,6[a]	14.09	455,6[a]	13.67	458,4[a]	13.75
B	431,4[b]	12.94	409,1[ab]	12.27	425,4[b]	11.25	374,9[b]	11.25
C	404,1[c]	12.12	403,3[b]	12.10	399,1[b]	11.24	374,8[c]	11.24
				TN g kg-1				
A	4,30[a]	0.12	4,54[a]	0.14	5,59[a]	0.17	6,71[a]	0.20
B	6,90[b]	0.20	8,343[b]	0.24	9,57[b]	0.28	13,39[b]	0.39
C	9,78[c]	0.29	27,70[c]	0.81	36,66[c]	1.10	50,06[c]	1.46
				TP g kg-1				
A	1,36[a]	0.05	1,26[a]	0.04	1,33[a]	0.05	1,39[a]	0.05
B	1,12[b]	0.04	1,12[b]	0.04	1,55[b]	0.05	1,77[b]	0.06
C	0,92[c]	0.04	1,60[c]	0.06	1,36[a]	0.05	1,03[c]	0.04

Means followed by the same letter are not significantly different at $p < 0.05$ (ANOVA).

In all investigated samples a decreasing trend in TOC content (Figure 2a. Table 1) was observed. The dynamics of these changes showed statistically significant differences between the variants used in the experiment. In the initial phase of composting. TOC ranged from 478.9 to 404.1 g kg^{-1} (variants A and C. respectively). while in mature materials from 375.0 to 458.4 g kg^{-1} (variants B. C and A. respectively).



(a) (b)

Figure 2. Changes in: (a) TOC and (b) TN during composting of willow chips [g kg^{-1}].

The most intensive processes of TOC transformations were observed in variant B. enriched with hay. Analysis of TN contents (Figure 2b. Table 1) showed a significant increasing trend in all tested composts. especially in variants enriched with hay and nitrogen fertilizer. The highest quantitative changes of TN from 9.78 g kg^{-1} in the initial material to 50.06 g kg^{-1} in the final product. were observed for variant C. In the studied composts (Figure 3. Table 1). the TP contents ranged from 0.92 – 1.36 g kg^{-1} in the initial materials (variants C and A) and 1.03 – 1.77 g kg^{-1} in the final products (variants C and B. respectively).

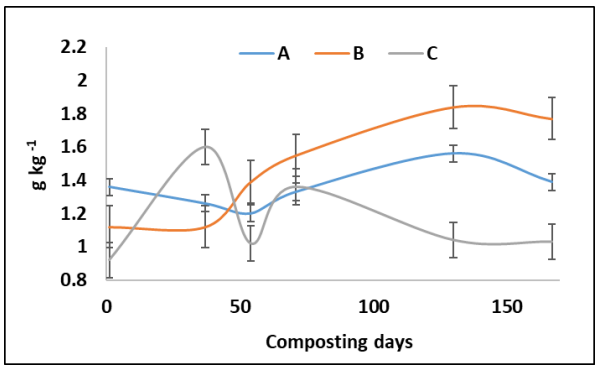


Figure 3. Changes in total phosphorus content [g kg^{-1}] during composting.

Moreover. the dynamics of TP content changes were significantly different depending on the maturity of the compost and the composition of the composted mass.

The results of the first stage of the pot experiment (Table 2) indicated differences in the influence of the investigated composts on the germination of lettuce.

Table 2. Number of lettuce seedlings (Lactuca sativa L.) after 20 days of incubation (number per pot, mean values).

Variant	Composting days			
	1	**32**	**71**	**167**
A	10	9	10	12
B	14	15	15	13
C	0	9	12	14
Control	8			

● – significant at $p<0.05$; LSD = 5.00 (ANOVA).

Although the number of germinated seeds in the control sample. 8. was lower than in all the tested composts. 9 – 15 (variants A. C and B respectively). the samples of variant B significantly stimulated germination regardless of composting time. Furthermore. the lack of statistical significance for variants A (all samples) and C (samples after 1. 32 and 71 days of composting) may indicate the effect of an inhibitory factor present in these composts [11].

Table 3. Lettuce yield obtained from seedlings after 20 days of experiment (grams per pot, mean values).

Variant	Composting days			
	1	**32**	**71**	**167**
A	1.22	1.83	1.13	1.35
B	0.86	1.98	2.09	2.15
C	4.78	1.97	10.37	5.55
Control	2.17			

● – significant at $p<0.05$; LSD = 2.52 (ANOVA).

The results obtained in the second stage of the pot experiment (Table 3) showed the lettuce yields obtained from the variant C samples after 1. 71 and 167 days of composting (4.70. 10.37 and 5.55 g pot^{-1}. respectively) were significantly higher than the yield of the control: 2.17 g pot^{-1}. Moreover. similarly to the germination experiment. samples of variant A did not significantly influence lettuce growth and yield.

The results obtained from the chemical analyses and vegetation experiments indicate the potential usefulness of willow composts as an alternative fertilizer product. Thus. further research should be conducted into optimizing the composition of willow compost through mineral and organic additives. It would also be useful to develop the most practical ways to stimulate the composting process using technical and microbiological methods [12].

4. Patents

Some of the results presented in this article were used in a patent filed on 28.06.2020 at the **Polish Patent Office No. P.435103.** A legal procedure is currently underway.

5. Conclusions

Based on the results of the study. the following conclusions can be drawn: 1) Willow chips can be a substrate for the production of alternative fertilizer substances; however. they require appropriate organic and mineral additives and optimized composting conditions; 2) Despite the applied organic and mineral additives. the tested composts were characterized by a relatively low fertilizer value; 3) The results of vegetation experiments showed that regardless of the maturity stage. composts made of willow chips without additives (variant A) had an inhibitory effect on germination. growth and yield of lettuce; 4) The addition of hay and Nmin to willow chips significantly increased the properties of the investigated products. especially in mature compost; 5) The study demonstrated the utility of using both chemical test results and vegetation experiments to verify compost quality.

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