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EFFECTS OF COMPOST ON PLANT AND SOIL: STUDY CASE IN SUCCESSIVE CROPS

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Abstract

Composting is a biotechnology that can turn waste into a product (compost). It can help to improve the condition of waste materials and thus increase the sustainability of the bioeconomy. Source separation is very important for the compost quality. This paper presents the results obtained in a study that involved three composts obtained from biodegradable waste. Two of these were obtained from the organic fraction of municipal solid waste (FODMS) collected together and separated within the integrated waste management center, and the third one resulted from biodegradable household waste, separated at source. Soil and compost mixtures were made of 25%, 50% and 75% compost. A 100% soil control was used for comparison. The study was conducted in a greenhouse, in pots. Three experiments were carried out: the first one involved ryegrass (Lolium perenne L.), the second one, lettuce (Lactuca sativa L.) and the third one, after lettuce, involved radish (Raphanus sativus L.). The effects of compost on plants growth and development, their production and chemical composition, as well as the effects on soil were analyzed.

Key words*: compost, circular economy, plant production, chemical composition, soil properties*

INTRODUCTION

Demographic growth also leads to an increase in the agricultural and food production. At the same time, both people and various industries and services produce large amounts of biodegradable wastes or bio-waste (Directive 2018/851/PE, CE) that can substantially contribute to the environment pollution and, therefore, they must be managed in a sustainable manner. Under the conditions generated by the energy crisis, the reduction of resources, the human impact on the environment and the climate, etc. it is necessary to identify sustainable alternative solutions and develop innovative and efficient technologies and processes to cover the deficits of conventional energy resources, materials necessary for agriculture, such as fertilizers and others.

Bio-wastes can be integrated as raw materials to obtain new products, such as biogas and compost, and the circular economy can contribute to minimizing their environmental impact and to maximizing their recovery (Velvizhi et al., 2020). In this context, the separate collection of bio-wastes is a *sine-qua-non* condition to make the processes more efficient. On the other hand, increasing the amount of bio-waste integrated into the circular economy through biogas production or composting can contribute to reaching the European Union (EU) target of recycling 65% of municipal waste by 2035 (EEA, 2020).

Composting is a bio-oxidative process of organic matter (OM) stabilization in the presence of air under the action of microorganisms (bacteria, fungi, actinomycetes). Considering the very diverse composition and characteristics of the raw materials (Siles-Castellano et al., 2020), the composting process must be conducted in such a way as to obtain a high quality product in order to eliminate the risks of phytotoxicity and to transfer some harmful compounds for plants, animals and humans in the food chain. In order to be used as a fertilizing material in agriculture, the compost must have a dry matter content (DM) ≥ 30%, a OM content ≥ 20% of the raw matter (RM), as well as a limited heavy metal content, such as arsenic (As), cadmium (Cd), chromium (Cr), mercury (Hg), nickel (Ni), lead (Pb), copper (Cu), zinc (Zn), etc.(NF U44-051, 2006).

This paper presents the results of a study that integrated three experiments with three composts obtained from biodegradable wastes. It aimed at highlighting the agronomic value of the composts and their quality so that they can be used as fertilizers for agricultural soils. To this end, test plants were cultivated that were able to absorb the heavy metals present in the compost, where applicable.

MATERIALS AND METHODS

Study establishment

The study was organized in the greenhouse of the University of Agronomic Sciences and Veterinary Medicine (USAMV) in Bucharest between October 1, 2021 and March 11, 2022 and included three experiments with compost and soil mixtures. The first two experiments (one in which ryegrass *Lolium perenne* L. was grown and another in which lettuce - *Lactuca sativa* L. was grown) were set up on October 1 (Photo 1), 2021, and the third one was set up on January 11 (Photo 2 and 3), 2022 after lettuce was harvested and radishes (*Raphanus sativus* L.) were cultivated instead.

The composts used for substrate mixtures were the following: 1) - *experimental compost* resulted from OFMSW after centralized separation - C1 (15-month old); small quantities were composted in specially constructed containers (almost 500 kg in a container); 2) - *experimental compost* resulted from OFMSW after centralized separation - C2 (18-month old); small quantities were composted in specially constructed containers (almost 500 kg in a container); 3) - *household compost* resulted from source separated bio-waste (biodegradable waste from garden and kitchen) - C3, produced on a household platform (12-month old).

Photo 1. Letuce and ryegrass experiment after six weeks from planting/seeding

Photo 2. Radish at seeding

Photo 3. Radish plant one month after seeding

The soil used in these experiments is of red preluvosoil type coming from Moara Domnească Teaching and Research Station of the USAMV of Bucharest and located in a sylvosteppe ecological area of the Romanian Plain. Both the composts and the soil were previously analyzed from a physico-chemical point of view, and their characteristics are presented in Table 1. The soil had a slightly acidic reaction, with pH value of 5.89, and the composts had a neutral - slightly alkaline reaction, with pH values between 8.26 and 8.49 (Blaga et al., 2008). The dry matter content was well over 50% in all composts. The $N\text{-}NH_4^+$

content of the composts ranged between 86 and 28 mg kg^{-1} d.m. According to Brinton (2000), taking $N\text{-}NH_4^+$ as the maturity index, they can be considered mature and even very mature. The degree of compost maturation is also revealed by the C: N ratio.

Table 1. Soil and compost physico-chemical characteristics

Soil and compost parameters	Soil	C1	C2	C3
pH	5.89	8.26	8.49	8.36
Moisture (%)	19.3	31.75	41.86	44.64
Dry matter (%)	80.7	68.25	58.14	55.36
C_org. (%)	2.02	15.46	15.8	9.71
C:N	9.35	10.24	9.88	9.23
Nt (%)	0.22	1.51	1.6	1.04
$N\text{-}NO_3^-$ (mg kg^{-1} d.m.)	28.67	195	197	910
$N\text{-}NH_4^+$ (mg kg^{-1} d.m.)	9.12	28	35	86
P (%)	0.16	0.82	0.9	0.46
K (%)	na*	2.32	2.53	1.48

*Not analized

The heavy metal content (Table 2) of the 3 composts was compared to the limits provided by the German standards for Class I and Class II (Biowaste ordinance). The following were revealed: i) the method used for the Cd analysis didn't detect Cd presence in any of the composts; ii) C1 and C2 exceed the limits provided by the German standards for Class II for Cu, Cr_tot and Zn content; iii) C3 falls into Class I, except for the Zn content, which recommends it for Class II; iv) all evaluated composts had Ni content below the limit imposed by the German standards for Class I.

In each of the three experiments from this study, the following substrate mixtures were used: Control - soil 100%; V1 - 75% soil + 25% C_1; V2 - 50% soil + 50% C_1; V3 - 25% soil + 75% C_1; V4 - 75% soil + 25% C_2; V5 - 50% soil + 50% C_2; V6 - 25% soil + 75% C_2; V7 - 75% soil + 25% C_3; V8 - 50% soil + 50% C_3; V9 - 25% soil + 75% C_3. All variants were made in four repetitions.

During the growing season, the necessary moisture for the plants was ensured by periodic sprinkling with water. The plants benefited from light conditions specific to the greenhouse during the winter.

Table 2. Heavy metals content of soil and compost used within experiments

Soil and compost parameters	Soil	C1	C2	C3	Biowaste ordinance (Germany)***	
					Compost class I	Compost class II
Cd (mg kg^{-1} d.m.)	nd**	nd	nd	nd	*1*	*1.5*
Cu (mg kg^{-1} d.m.)	26.8	119	121	34.5	*70*	*100*
Cr_tot (mg kg^{-1} d.m.)	32.5	311	341	34.7	*70*	*100*
Ni (mg kg^{-1} d.m.)	19.6	26.7	24.9	19.9	*35*	*50*
Pb (mg kg^{-1} d.m.)	12.3	12.6	19.7	10.5	*100*	*150*
Zn (mg kg^{-1} d.m.)	661	462	413	351	*300*	*400*

**Not detectat with the analysis methods used;
***Heavy metal limits for European compost standards. Final Report. ANNEX 2; JUNE 2004. Table A2-4. Heavy metal limits for European compost standards. Compost from source separated Biowaste.

RESULTS AND DISCUSSIONS

Lettuce and rye-grass experiments

Production. The lettuce and ryegrass plants had a good evolution during the growing season, no phytotoxicity phenomena were observed and no plant losses were recorded (Photos 4 and 5). Lettuce plants were harvested 10 weeks after planting and weighed as the resulting mass of lettuce plants in each variant, in all 4 repetitions of each variant. Lettuce production was analysed as an average for each variant (Figure 1). In almost all variants in which the composts were used in the mixture, the salad production was below the control variant (100% soil). Only in the variant with 25% C1, the lettuce production exceeded the control. Analysing separately the variants with compost, it can be observed that in general the highest lettuce productions were obtained in the variants with 25% and 50% compost in the substrate mixtures.

Photo 4. Lettuce - 9 weeks from planting

Photo 5. Ryegrass - 9 weeks from seeding

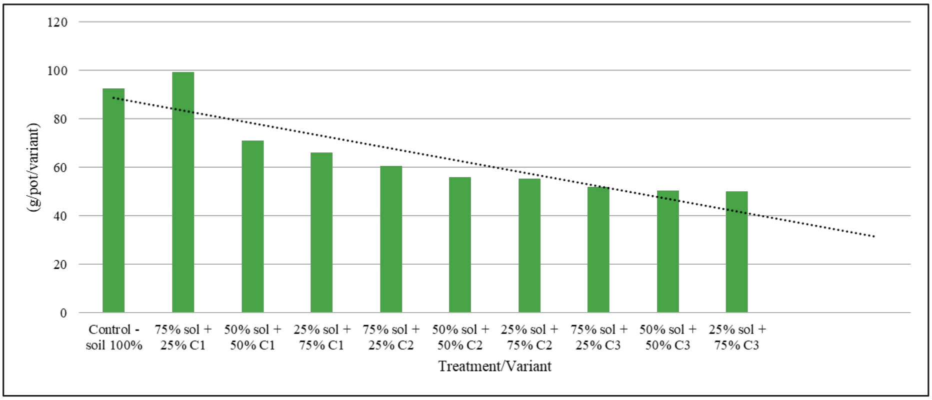

Figure 1. Average biomass of lettuce (g/pot/variant)

The production of ryegrass obtained in the variants in which the three types of compost were used in the substrate mixtures was above the one from the control variant (Figure 2). In the variants where C1 was used in the mixtures, the highest production of ryegrass was obtained at an intake of 50% compost followed by an intake of 75% compost. In the variants in which C2 was used in the mixtures, the highest production of ryegrass was obtained at an intake of 25% compost, followed by the variants with 75%, respectively with 50% compost. In the variants in which C3 was used in the substrate mixtures, the highest production of ryegrass was obtained at an intake of 25% compost followed by 50% and 75% compost respectively. Thus, as in the case of lettuce, it can be appreciated that, in general, an intake of more than 50% compost in the substrate mixture does not correlate with an increase in ryegrass biomass production.

Macronutrients and heavy metals content of lettuce plants (Table 3). The contents in N, P and K of lettuce plants obtained in all variants with compost exceeded the control variant (100% soil). In variants with C1, the N content exceeded the control variant by 18.46% (V1 - 25% C1), 12.81% (V2 - 50% C1) and 9% (V3 - 75% C1). In variants with C2, the N content exceeded the control variant by 9.2% (V4 - 25% C2), 7.7% (V5 - 50% C2) and 11.2% (V6 - 75% C2). In variants with C3, the N content of lettuce plants exceeded the control variant by 13.4% (V7 - 25% C3), 8.1% (V8 - 50% C3) and 4.5% (V9 - 75% C3). The highest P contents of lettuce plants, above the content reached in the control variant (100% soil) were recorded in V2 (50% C1) > V5 (50% C2) and > V8 (50% C3). The differences compared to the control variant were over 36.2% > 31.9% and > 10.1%. Compared to the control variant, the K content of the lettuce plants was much higher in all variants in which compost was integrated, regardless of the proportion, except for V2 (50% C1) in which it was below the level of the control variant. The highest K contents in lettuce plants were recorded in the C2 and C3 variants.

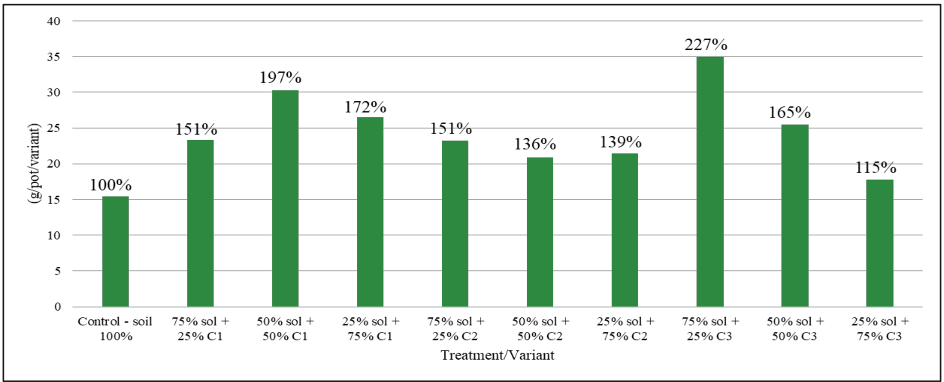

Figure 2. Average plant biomass of ryegrass at harvest

Regarding the heavy metals content, as it can be seen in Table 2, no Cd, Cr and Ni contents were determined in lettuce plants. In the variants with compost, the Cu content was between 5.3 mg/kg (V9 - 75% C3) and 9.5 mg/kg (V1 - 25% C1). The control, however, had a Cu content of 9.8 mg/kg. Normal average Cu contents in plants are between 5 and 20 mg/kg relative to dry matter (Jones, 1972). The Pb content in lettuce plants was below 5 mg/kg in all variants, and a normal Pb content would be ± 10 mg/kg relative to dry matter (Camerlynck and Velghe, 1979). The Zn and Fe contents of the lettuce plants were within the normal limits cited by the literature (Jones, 1972). Thus, Zn recorded contents between 62 and 93 mg/kg, the normal average contents being included between 25 and 150 mg/kg relative to dry matter. Fe recorded contents between 46 and 83 mg/kg, while the normal average contents are between 50 and 250 ppm relative to dry matter.

Table 3. Macronutrients and heavy metals content of lettuce plants

Treatment	N %	P %	K %	Cd mg/kg	Cu mg/kg	Fe mg/kg	Cr mg/kg	Ni mg/kg	Pb mg/kg	Zn mg/kg
Control - soil 100%	5.31	0.69	9.8	nd	9.8	83	nd	nd	2.4	67
75% sol + 25% C_1	6.29	0.82	10.0	nd	9.5	75	nd	nd	3.0	93
50% sol + 50% C_1	5.99	0.94	9.5	nd	8.7	58	nd	nd	2.9	74
25% sol + 75% C_1	5.79	0.80	13.5	nd	7.9	49	nd	nd	2.3	76
75% sol + 25% C_2	5.80	0.80	12.6	nd	8.9	54	nd	nd	1.8	69
50% sol + 50% C_2	5.72	0.91	13.6	nd	8.4	57	nd	nd	1.5	80
25% sol + 75% C_2	5.92	0.78	17.0	nd	7.4	56	nd	nd	1.7	80
75% sol + 25% C_3	6.02	0.75	14.3	nd	7.9	59	nd	nd	2.4	62
50% sol + 50% C_3	5.74	0.76	15.0	nd	7.2	55	nd	nd	2.3	68
25% sol + 75% C_3	5.55	0.72	12.5	nd	5.3	46	nd	nd	2.2	62

The results of chemical analyses regarding the content of ryegrass plants in macronutrients and heavy metals are presented in Table 4. The highest N contents (4.72%; 5.28%; 5.31%) of ryegrass plants were recorded in the variants with compost C3 where an increase somewhat correlated with the proportion of compost in the substrate mixture was also observed. In the other variants, the N contents of the plants were below 5% and not necessarily correlated with the proportion of compost in the substrate. Unlike the lettuce plants, the P and K contents of the ryegrass plants were much lower.

Regarding the Cd content, as in the case of lettuce, the presence of this element was not detected. The Cu, Ni, Pb and Zn contents of ryegrass plants were low, far below the limits proposed in the literature and mentioned above in the case of lettuce.

Table 4. Chemical composition of ryegrass plants after harvest

Treatment	N %	P %	K %	Cd mg/kg	Cu mg/kg	Ni mg/kg	Pb mg/kg	Zn mg/kg
Control - soil 100%	1.89	0.47	5.20	nd	3.29	1.55	1.28	5.04
75% soil + 25% C_1	2.73	0.68	6.10	nd	1.89	0.43	0.14	3.46
50% soil + 50% C_1	4.62	0.46	6.85	nd	1.25	0.39	0.31	5.22
25% soil + 75% C_1	4.85	0.51	7.93	nd	5.31	0.26	0.27	6.04
75% soil + 25% C_2	2.39	0.52	6.28	nd	0.90	0.26	0.15	3.82
50% soil + 50% C_2	3.28	0.41	5.85	nd	0.80	0.29	0.19	3.48
25% soil + 75% C_2	2.89	0.50	6.68	nd	1.53	1.38	1.26	5.36
75% soil + 25% C_3	4.72	0.40	6.10	nd	1.20	0.53	0.19	3.59
50% soil + 50% C_3	5.28	0.37	5.38	nd	0.80	0.42	0.17	3.63
25% soil + 75% C_3	5.31	0.51	7.28	nd	0.93	0.45	0.19	4.20

As presented in the "Materials and methods" chapter, after lettuce harvesting, a radish crop was established, knowing that this species, which is part of the *Cruciferae* family, like other species from this family, is a heavy metal accumulator. Radishes were harvested two months after seeding, and chemical analyses regarding the content of heavy metals were made on leaf and root samples (Table 5). Thus, no Cr, Fe and Pb contents were detected in the radish leaves, and the Cd, Cu, Fe and Zn contents were below 0.027 mg/kg f.m. for Cd, below 0.48 mg/kg f.m. for Cu, below 4.77 mg/kg f.m. for Zn and below 10.85 mg/kg f.m. for Fe.

Table 5. Heavy metals content of radish leaves

Treatment	Cd mg/kg f.m.*	Cu mg/kg f.m.	Cr mg/kg f.m.	Ni mg/kg f.m.	Fe mg/kg f.m.	Pb mg/kg f.m.	Zn mg/kg f.m.
Control - soil 100%	0.027	0.21	nd	nd	6.57	nd	3.18
75% soil + 25% C_1	0.011	0.35	nd	nd	7.97	nd	3.50
50% soil + 50% C_1	0.022	0.35	nd	nd	9.44	nd	3.85
25% soil + 75% C_1	0.018	0.32	nd	nd	4.96	nd	4.05
75% soil + 25% C_2	0.015	0.38	nd	nd	8.30	nd	4.02
50% soil + 50% C_2	0.013	0.42	nd	nd	10.85	nd	4.00
25% soil + 75% C_2	0.012	0.43	nd	nd	6.92	nd	4.77
75% soil + 25% C_3	0.023	0.48	nd	nd	8.09	nd	3.17
50% soil + 50% C_3	0.014	0.45	nd	nd	9.02	nd	3.92
25% soil + 75% C_3	0.013	0.41	nd	nd	9.97	nd	3.49

*fresh matter.

In radish roots, as in the case of leaves, no Cr, Ni and Pb contents were detected (Table 6). The Cd contents were much lower than those recorded in the leaves, with values between 0.019 mg/kg f.m. and 0.022 mg/kg f.m. According to Jackson and Allozay (1990), the Dutch regulations provide a maximum permissible concentration of Cd in fresh vegetable fruits (i.e. tomatoes) of 0.10 ppm. Also, the contents of radish roots in Cu, Fe and Zn were much lower than those recorded in their leaves.

Table 6. Heavy metals content of radish roots

Treatment	Cd mg/kg f.m.	Cu mg/kg f.m.	Cr mg/kg f.m.	Ni mg/kg f.m.	Fe mg/kg f.m.	Pb mg/kg f.m.	Zn mg/kg f.m.
Control - soil 100%	0.022	0.17	nd	nd	4.49	nd	2.44
75% soil + 25% C_1	0.019	0.11	nd	nd	4.41	nd	1.88
50% soil + 50% C_1	0.016	0.12	nd	nd	2.82	nd	1.75
25% soil + 75% C_1	0.004	0.11	nd	nd	2.10	nd	1.41
75% soil + 25% C_2	0.003	0.06	nd	nd	6.95	nd	2.06
50% soil + 50% C_2	0.006	0.08	nd	nd	3.23	nd	1.39
25% soil + 75% C_2	0.003	0.07	nd	nd	1.44	nd	1.85
75% soil + 25% C_3	0.026	0.12	nd	nd	6.81	nd	1.39
50% soil + 50% C_3	0.003	0.12	nd	nd	3.15	nd	1.47
25% soil + 75% C_3	0.004	0.11	nd	nd	2.75	nd	1.59

CONCLUSIONS

The study allowed the highlighting of important aspects for the recycling of bio-waste through composting and their use as fertilizers for agricultural soils. Thus, it is essential to collect bio-waste separately and avoid the risk of mixing it with materials that could affect the quality of the compost.

At the same time, composting must be conducted in such a way that the compost reaches a good state of maturity in order to be included in quality classes that allow agricultural use.

Establishing the doses of compost or the proportions that will be combined with the soil or with other materials to create mixtures for culture substrates must be done depending on the chemical composition of the compost, especially depending on the presence of some heavy metals (Cd, Cu, Ni, Cr, etc.).

REFERENCES

Camerlynck R. and Velghe G. (1979). Criteria for the evaluation of the influence of trace elements on plants. Essential and Non Essential Trace Elements in the System Soil – Water – Plant. In: Stan V. (1996). Teză de doctorat. *Contribuţii la valorificarea agricolă nepoluantă a unor reziduuri de gospodărie orăşenească.*

Davidescu D., Davidescu V., Calancea L., Handra M., Petrescu O. (1976*). Chimizarea agriculturii. Azotul în agricultură.* Ed. Academiei Române, pp. 107-132; 234-235.

Directive (UE) 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/CE on waste.

EEA (2020). Bio-waste in Europe - turning challenges into opportunities. European Environmental Agency. Report No 04/2020.

Jackson şi Allozay (1990). În: Stan V. (1996). Teză de doctorat. *Contribuţii la valorificarea agricolă nepoluantă a unor reziduuri de gospodărie orăşenească*.

Jones J.B. Jr (1972). Plant tissue analysis for micronutrients. In “Macronutrients in Agriculture”. Soil Sci Soc. Of America Madison. In: Loué A. (1993). *Oligoéléments en agriculture*. SCPA-NATHAN.

NF U 44-051 (2006). Norme Française. Amendements organiques. Dénominations, specifications et marquage. Boutique AFNOR. Accesat în mai 2017. http://www.vertcarbone.fr/wp-content/uploads/2021/03/Norme-NFU.44-051-copie.pdf

ORDIN nr. 344 din 16 august (2004) pentru aprobarea Normelor tehnice privind protecţia mediului şi în special a solurilor, când se utilizează nămolurile de epurare în agricultură. Publicat în Monitorul Oficial, Partea I nr. 959 din 19.10.2004.

Siles-Castellano A. B., López M. J., López-González J. A., Suárez-Estrella F., Jurado M. M., Estrella-González M. J., Moreno J. (2020). Comparative analysis of phytotoxicity and compost quality in industrial composting facilities processing different organic waste. *Journal of Cleaner Production*, 252, 119820. www.elsevier.com/locate/jclepro

Velvizhi G., Shanthakumar S., Das B., Pugazhendhi A., Shanmuga Priya T., Ashok B., Nanthagopal K., Vignesh R., Karthick C. (2020). Biodegradable and non-biodegradable fraction of municipal solid waste for multifaceted applications through a closed loop integrated refinery platform: Paving a path towards circular economy. *Science of the Total Environment*, 731, 138049.