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Phytotoxicity Testing of Composts from Biodegradable Municipal Waste

Martina Sláviková[1], Anna Báreková[1], Lucia Tátošová[1], Ladislav Ducsay[2]

[1] Institute of Landscape Engineering, Faculty of Horticulture and Landscape Engineering, Slovak University of Agriculture in Nitra, Trieda Andreja Hlinku 2, 949 76 Nitra, Slovakia

[2] Institute of Agronomic Sciences, Faculty of Agrobiology and Food Resources, Slovak University of Agriculture in Nitra, Trieda Andreja Hlinku 2, 949 76 Nitra, Slovakia

* Corresponding author's e-mail: slavikova.matka@gmail.com

ABSTRACT

The production of compost from biodegradable municipal waste is important not only for reducing the amount of landfilled waste. The compost produced with the right technology can replenish the missing organic matter in the soil and improve its properties. This paper deals with the evaluation of the phytotoxicity of composts from garden and kitchen biodegradable wastes. Their effect on plant germination and overall plant condition under laboratory conditions was investigated. The samples of compost from the industrial composting plant of the city of Nitra and compost from the electric composter GG02 were used for this test. The tested composts were mixed with the reference substrate in different concentrations and applied to two plant species – Lettuce (Lactuca sativa) and Barley (Hordeum vulgare). After 21 days, the number of germinated plants (i.e. germination rate), the length of the aerial part of the plants, the weight of fresh biomass and also its weight after drying were evaluated. The highest lettuce germination rate was obtained with 25% of the compost from the industrial composting plant. Barley achieved the best germination rate at up to 50% concentration of this compost. However, the highest biomass weight was obtained for the barley in the reference sample, i.e. without the addition of compost. In contrast, the application of compost from the industrial composting plant on lettuce, regardless of its concentration, had a clear stimulating effect, in all the parameters studied. The compost from the electric composter at concentrations of 25 and 50% had an inhibitory effect on all tested parameters of both plants.

Keywords: composting plant, electric composter, phytotoxicity, germination, phytotron.

INTRODUCTION

To reduce greenhouse gas emissions, it is necessary to limit the amount of landfilled biodegradable municipal waste (BDMW) and to strengthen the use of alternative treatment methods [Kazimierowicz, 2014]. Also for this reason, according to the Waste Act [Act 79, 2015], every municipality in Slovakia is obliged to provide a sorted collection of BDMW for its citizens. The term BDMW includes not only bio-waste from the gardens of family houses, but also food waste (FW) from households. As a rule, garden BDMW is collected in brown bins and then processed in composting plants into compost. However, in the case of FW, it is necessary to ensure the so-called hygienisation of this waste. Efficient composting of FW in individual households as well as in restaurants, school canteens, etc., is possible in automatic electric composters [Kucbel et al., 2019]. This process, which takes place under thermoacidophilic conditions (also called „acidulocomposting"), is considered to be a generally efficient, relatively maintenance-free and convenient way of recycling FW [Nishino et al., 2003]. Eliminating the expense of transporting the FW to its processing location is also an advantage. On the other hand, the resulting compost from an electric composter is considered by some studies [Maxianova et al., 2021] [Cerda et al., 2018] to be unsuitable for land treatment and its further use is problematic [Maxianova et al., 2021]. High salt concentrations in the compost from FW can inhibit plant growth and negatively affect soil structure [Cerda et al., 2018]. However, the quality of the resulting compost depends not only on the quality of the input materials but also on the correct execution of the entire composting process. By applying high-quality, biologically complete compost to the soils with a lower degree of succession, it is possible to increase soil fertility dramatically. In a few months, the soil recovers as it would naturally for decades [Balak Lukanova, 2022]. The ability of compost to bind water is, in turn, relevant for the design of the water retention measures in the context of mitigating the impact of climate change on the urban environment [Pokryvkova et al., 2021]. From this perspective, composting needs to be considered as a process yielding a valuable product that is of strategic importance to society, and not just as an alternative way of disposing of biodegradable waste. Poorly executed composting processes result in poorly stabilised organic matter or immature compost, which can affect the soil environment and plant growth as well as be a source of disease and cause damage to crops through phytotoxicity [Cui et al., 2017]. One of the most widely used methods for assessing phytotoxicity is the determination of the germination index, which is widely used in composting to verify the final quality of the compost [Barral and Paradelo, 2011].

The aim of this experiment was to test the quality of compost from an industrial composting plant and compost from an electric composter as well as to verify their effect on the germination of selected plants and their general condition.

MATERIAL AND METHODS

The samples of compost from the industrial composting plant of the city of Nitra (KK) and compost from the electric composter GG 02 (KE) were used for this test. The municipal composting plant processes about 10 000 tonnes of BDMW from the gardens of family houses and public green areas of Nitra (south-western Slovakia) annually. The city has 76 028 inhabitants (as of 31.12. 2020) in an area of 100,48 km^2. Garden BDMW is collected in brown bins with a capacity of 120 litres, which are distributed in urban areas with family houses in about 8 000 households. The emptying interval is 14 days throughout the year. Composting takes place in semi-closed boxes with automatic aeration and irrigation of the treated substrate for about 12 weeks. The fresh compost then matures in an open covered area. The small electric composter GG 02 is designed for composting FW. The usable volume of the composter is 40–50 litres. The operating conditions are 65°C for the entire period of operation, except for one hour per day when the temperature is raised to 75°C for hygiene reasons. The internal agitator operates every hour for 20 minutes in alternating sequences of forwarding and reverse agitation. The substrate humidity shall be maintained at 21 ± 2%. The biodegradation process of the kitchen waste is carried out using the original ACIDULO® bacteria. The tested compost from the electric composter was provided by the Slovak University of Technology in Bratislava (Institute of Natural and Synthetic Polymers).

Selected physical and chemical properties of the tested composts as well as the content of some hazardous elements are presented in Table 1. Laboratory analysis of both compost samples (KK and KE) was carried out at the Institute of Agronomic Sciences, FAFR SUA in Nitra. The sample of compost from the electric composter (KE) did not meet the values required by the legislation [Decree 577, 2005] for pH, moisture content, calcium content and magnesium content in dry matter. The indicators of the compost sample from the municipal composting plant (KK) met almost all the required values, except for the cadmium content in the dry matter, where the permissible limit was exceeded. However, it should be taken into account that only one sample of approximately 250 g of each compost was analysed, which affected the accuracy of the results to some extent.

Phytotoxicity determination

To test the quality of the monitored composts, two plant species were used as phytotoxicity indicators: lettuce (lat. Lactuca sativa) – the samples labelled Š1 to Š6 and barley (lat. Hordeum vulgare) – the samples labelled J1 to J6. The sowing trays (12 pcs) measuring 290×390×55 mm were filled with the chosen mixtures of professional sowing medium (peat and silica sand-based) and the compost under study (KK or KE) in the proportions shown in Table 2. In each tray, 100 seeds of the test plant were sown using sowing strips. The experiment was conducted under laboratory conditions at the Phytotron at the Institute of Landscape Engineering, Faculty of Horticulture and Landscape Engineering, Slovak University of Agriculture, Nitra, Slovakia in April 2021.

Table 1. Comparison of the characteristics of the investigated composts with the limit values for compost

Indicator monitored	KK	KE	Limit values [Decree 577, 2005]
pH value [-]	7.39	3.55	6,5 – 8,5
Moisture content [%]	38.81	6.85	40 – 60
Combustible substances in dry matter [%]	50.96	93.87	min. 25
Nitrogen content as N in dry mater [%]	1.81	2.66	min. 1
Phosphorus as P_2O_5 in dry matter [%]	0.71	0.62	min. 0,5
Potassium as K_2O in dry matter [%]	2.30	2.04	min. 0,5
Calcium content as Ca in dry matter [%]	4.76	0.12	min. 1,2
Magnesium content as Mg in dry matter [%]	0.76	0.10	min. 0,5
Cadmium (Cd) content in dry mater [mg. kg^{-1}]	3.41	1.06	max. 2
Chromium (Cr) content in dry mater [mg. kg^{-1}]	14.90	14.80	max. 100
Nickel (Ni) content in dry mater [mg. kg^{-1}]	16.70	3.10	max. 50
Lead (Pb) content in dry mater [mg. kg^{-1}]	16.10	0.63	max. 100
Copper (Cu) content in dry mater [mg. kg^{-1}]	39.80	4.80	max. 200
Zinc (Zn) content in dry mater [mg. kg^{-1}]	288.00	30.40	max. 400

Table 2. Proportion of compost and sowing medium in lettuce and barley samples [%]

Marking of samples	Percentage of compost / substrate in given samples
Š1, J1	25 KK / 75
Š2, J2	50 KK / 50
Š3, J3	10 KE / 90
Š4, J4	25 KE / 75
Š5, J5	50 KE / 50
Š6, J6	0 / 100

The conduct of the experiment conformed to the OECD recommendations for testing terrestrial plants [OECD, 2006]. The experiment lasted 21 days, with germination taking place for the first 4 days in the dark at a temperature between 17 and 20°C. The light regime was then set to 16 h light and 8 h dark for the remaining days and the temperature increased to 20–25°C (± 3°C). The samples were visually inspected every 2–3 days. In some samples with KE (J4, J5, Š4 and Š5), mould was observed as early as day four after the start of the experiment.

RESULTS AND DISCUSSION

After 21 days, the following parameters were evaluated for each of the 12 samples:

- percentage of germinated plants (i.e. germination rate),
- length of the aerial part of the plants,
- fresh biomass weight,
- weight of biomass after drying.

Reference samples Š6 and J6 represent the plants germinated in 100% substrate. Figure 1 shows the distribution of all 12 samples and the status at the end of the germination test (after 21 days).

Germination rate

The graph in Figure 2 shows that the samples containing the KK compost (Š1, Š2, J1, J2) exceeded the 90% germination rate and also had a higher germination rate than the reference samples Š6 and J6. For lettuce, the best results were at a compost KK content of 25% and for barley at a KK content of 50%. Almost 90% germination was also achieved by lettuce sample Š3 at a KE proportion of 10%. The higher proportion of KE (25% and 50%) in the samples (Š4, Š5, J4, J5) inhibited germination in both plants, compared to the reference samples. The germination test in another study [Voberkova et al., 2020] showed even 100% inhibition of 25% proportion of the compost produced from FW in an electric composter. Low germination rate may also be due to insufficiently stabilised organic matter after the composting process in the electric composter [Kucbel et al., 2019].

Length of the aerial part of plants

The graph in Figure 3 shows the average length of the aerial part of each lettuce and barley sample. The compost KK with 25% (Š1 and J1) clearly had the most favourable effect on this parameter. For both plants, samples Š1 and J1 slightly exceeded the value achieved by reference

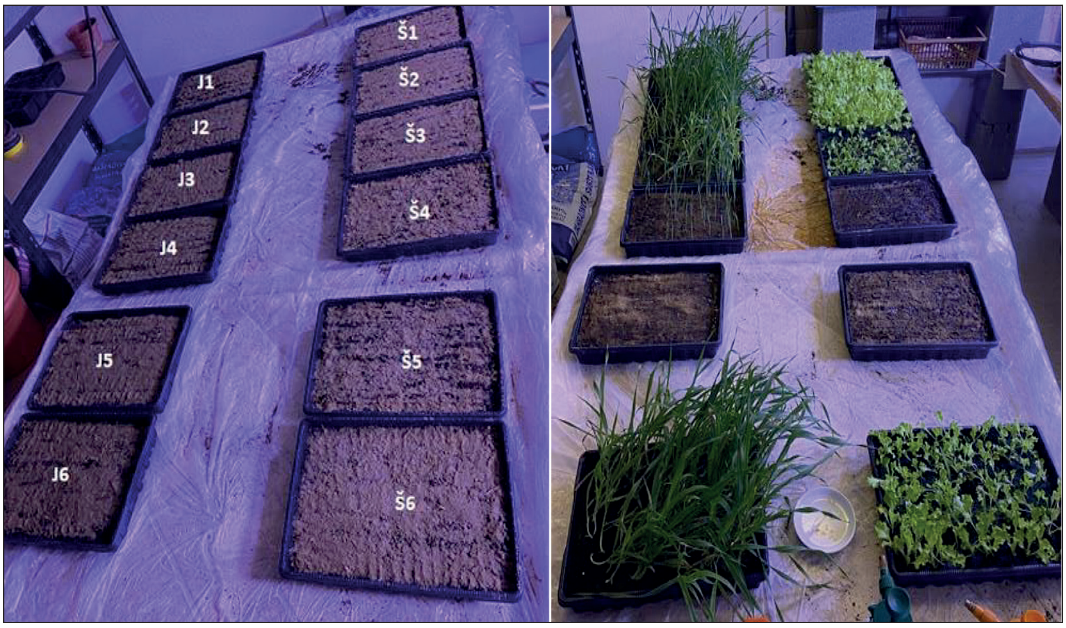

Figure 1. Status of the samples at the start of the experiment (left) and at the end of the experiment (right)

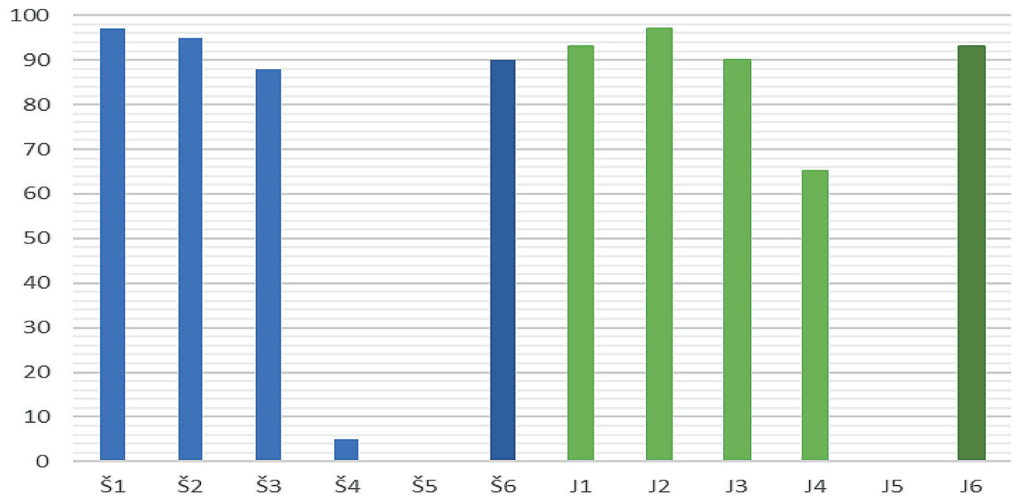

Figure 2. Germination rate in lettuce (Š1 to Š6) and barley (J1 to J6)

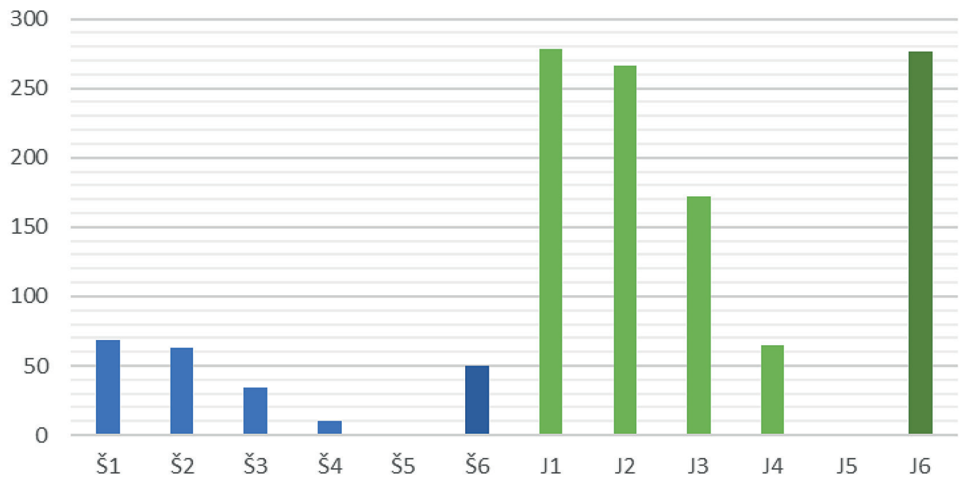

Figure 3. The average length of the aerial part of lettuce (Š1 to Š6) and barley (J1 to J6)

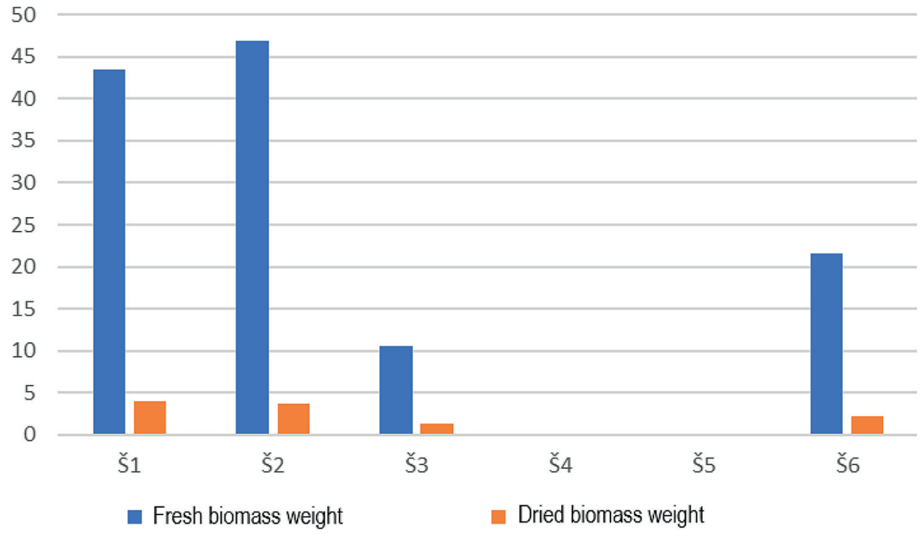

Figure 4. Lettuce biomass weight

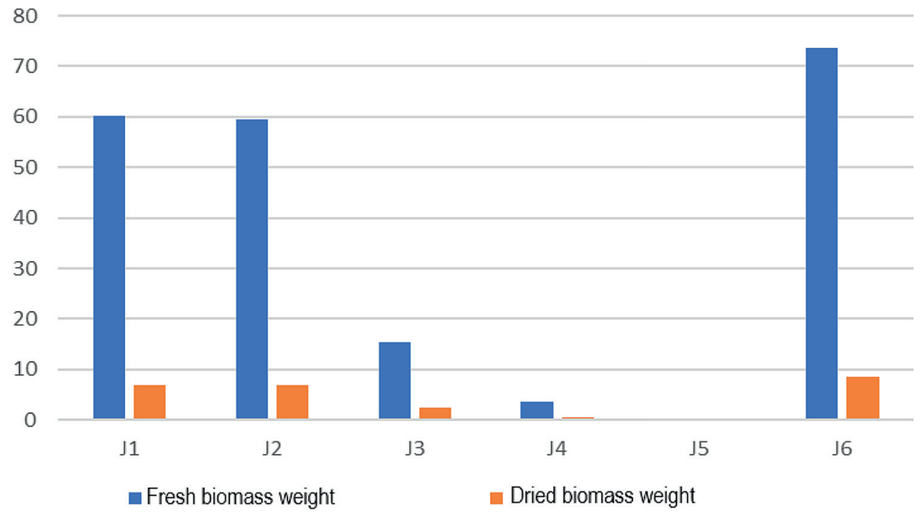

Figure 5. Barley biomass weight

samples Š6 and J6. For lettuce, a 50% proportion of KK still had a stimulating effect.

Biomass weight

Weighing of the fresh biomass of each lettuce sample (see blue bars in Figure 4) shows that the samples with KK compost (Š1 and Š2) exceeded the weight of the reference sample Š6 by more than 100%. The weight of the dried biomass (see orange bars in Figure 4) was 88% higher for Š1 and 70% higher for Š2. The sample Š3 with 10% KE compost weighed only about half of the weight of the reference sample Š6. The weights of samples Š4 and Š5 were negligible. Figure 5 shows that barley was not as favourably affected by the KE compost (J1 and J2) as lettuce. This time, the weight of both fresh and dried biomass was only 80% of the weight of the reference sample J6. The samples containing KE (J3, J4, J5) had a minimal biomass increase compared to the reference sample.

CONCLUSIONS

In this paper, the effect of different concentrations of composts from an industrial composting plant (KK) and from an electric composter (KE) on the germination and growth of two species of test plants (Lettuce and Barley) was investigated.Compared to the reference sample, KK had an inhibitory effect on the barley biomass growth at both concentrations (25 and 50%), while for lettuce it was shown to have a beneficial effect not only on fresh and dried biomass weight, but also on the length of the aerial part of the plants. In the samples with KE, neither parameter reached the values of the reference substrate. The samples with 10% KE (Š3 and J3) approached the control only in germination rate. In all samples with KE, mould appeared during the experiment, which was also observed in another study [Maxianova et al., 2021].

The conducted experiment demonstrated the predominantly beneficial effects of compost from an industrial composting plant made from garden BDMW. The compost from FW processed in an electric composter appears to be problematic, which is probably due to the high salinity and acidity of this compost. In the future, it would be advisable to increase its pH in advance and then repeat the phytotoxicity test. On the basis of the results of the experiment, it is recommended that further phytotoxicity studies should focus on the effect of lower concentrations of KE on different plant species. The effect of composts from FW should also be further tested at different stages of plant growth, as a beneficial effect of compost from an electric composter has already been observed, e.g. on the yield of potatoes and on the suppression of weed emergence and weed growth [Asagi et al., 2016]. It follows that the focus should not only be on the high efficiency of compost production from BDMW, but mainly on the high quality of the compost produced. Only then will the recycling of BDMW be truly meaningful.

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