Vol. 11, No. 3, 2025

OPTIMIZATION OF SUBSTRATE COMPOSITION BASED ON FOOD AND ORGANIC WASTE COMPOST

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https://doi.org/10.23939/ep2025.03.245

Received: 09.07.2025

Abstract. The research investigated the influence of compost-based substrates on plant growth and development over 25 days. The study utilized compost from the Lviv municipal enterprise "Green City", which consisted of garden and park waste (leaves, branches, and mowed grass), as well as food waste from city residents and organic food waste from manufacturing enterprises. The composting process was conducted in a designated area under controlled conditions. A mixture of compost, peat, soil, sand, and clay, mixed in various ratios, was used to prepare the substrate. The bioindication method was used to evaluate how the substrates influenced the dynamics of plant growth. The experimental results were used to determine the average germination rate of ryegrass in the test samples, along with the average values of key plant parameters, including stem height, root length, and plant weight. It found that, after the experiment ended, the highest germination rate was in option 1 – 95.8 %, and the lowest in option 4 – 85.8 %. The highest average values of the main parameters of ryegrass were in options 1, 2, 3, and 4, and the lowest in the control sample and option 5.

Keywords: compost, substrate, bioindication, plant parameters, ryegrass.

1. Introduction

Modern agriculture and horticulture are actively seeking effective and environmentally safe methods to increase yields and improve product quality. A practical approach is to use sorbents (Ptashnyk et al., 2020; Soloviy et al., 2020; Malyovanyy et al., 2013) to enhance soil structure and encapsulated fertilizers (Vakal et al., 2020, Nahursky et al., 2022, Shkvirko et al., 2024, Grechanik et al., 2022) for the sustained release of plant nutrients. One of the key aspects in this context is the use of quality substrates that can influence plant growth and development. Recently,

For citation: Shkvirko, O., Malovanyy, M., Tymchuk, I., Zhuk, V., Bilokur, M., Tymchyshyn, L., Boyko, R., Korbut, M., Romanovych, B., Krusir, G. (2025). Optimization of substrate composition based on food and organic waste compost. *Journal Environmental Problems*, *10*(3), 245–251. DOI: https://doi.org/10.23939/ep2025.03.245

organic substrates based on compost have gained increasing popularity due to their environmental friendliness, high nutrient content, and ability to enhance the physicochemical properties of the soil (Shu et al., 2022).

Compost, when used as a substrate base, provides a rich supply of macro- and microelements, enhances soil structure, boosts its moisture retention ability, and supports the growth of beneficial microorganisms (Adugna, 2016; Cozzolino et al., 2016). However, different types of compost-based substrates can have different compositions and properties, which directly affects the effectiveness of their use in growing plants (Khater, 2015). Additionally, studies show that combining compost with other organic or inorganic components, such as peat, vermicompost, biochar, or mineral additives, can significantly alter its effects on plants (Bernal et al., 2017).

In the context of global climate change and increasing food needs, a crucial task is to enhance the resilience of agroecosystems and mitigate the anthropogenic pressure on soil cover. Therefore, the use of organic substrates, particularly compost-based ones, contributes not only to the conservation of natural resources but also to the reduction of synthetic fertilizer use, which in turn minimizes their negative environmental impact (Hargreaves et al., 2008). Additionally, composting organic waste helps alleviate the challenges of agricultural and household waste disposal, thereby contributing to a circular economy and sustainable agricultural development (Ayilara et al., 2020).

Studies have shown that the use of different compost-based substrates affects seed germination rates, plant biomass, root system development, and overall crop productivity (Hargreaves et al., 2008). However, the question of the optimal composition of substrates for specific plant species remains open, which necessitates a comparative analysis of different types of compost substrates. Furthermore, the effect of the substrate on plant development can depend largely on environmental conditions such as temperature, humidity, and soil type. Therefore, it is essential to determine which substrate characteristics—such as structure, organic matter content, water retention capacity, and microbiological activity—are most important for the growth of different plant species, as well as which combinations of components work best in various climate zones (Bedada et al., 2014).

Another key factor is the environmental advantages associated with the use of compost-based substrates. Because conventional fertilization methods frequently lead to negative effects like nitrate contamination of groundwater and soil degradation, using compost substrates offers a dual benefit: enhancing plant growth while also helping to preserve natural resources and reduce the environmental impact of agriculture (Ayilara et al., 2020, Grechanik et al., 2023).

The purpose of this study is to analyze and compare the effects of various compost-based substrates on plant growth and development.

This study will enable us to understand better the mechanisms by which different types of compost substrates influence plant growth and development. The findings can be used in industrial agriculture, organic farming, and horticulture to develop optimal crop cultivation technologies. Specifically, they can enhance the efficient use of organic waste, which is essential for promoting sustainable agricultural development and reducing environmental harm.

2. Materials and Methods

The studies were conducted using compost obtained from the Lviv Composting Station, along with dark gray podzolized soil, peat, sand, and clay.

The composting process was implemented at the composting site of the Lviv municipal enterprise "Green City" (Fig. 1).

Fig. 1. General view of the composting site of the Lviv municipal enterprise "Green City"

The technological scheme of composting provides for the presence of the following zones:

- composting zone (maturation in clamp), which is equipped with a hard improved coating and a sewage network for collecting surface rainwater and meltwater;

- branch crushing and screening area,
- input raw material storage areas,
- automotive parking lot;
- finished product storage area.

All organic and garden waste arriving at the composting station weighed on scales. Organic waste from the population is immediately loaded into containers for disinfection, where it remains for 48 hours. The branches are chopped in a woodchipper. After that, the organic waste is mixed with shredded wood, leaves, and grass. The resulting mixture is placed in clamps for maturation. The resulting mixture is placed in clamps for maturation. Every 3–5 days, the piles are mixed and aerated to prevent rotting. The composting process typically lasts between 3 a nd 5 months. This process occurs with the release of heat, so the temperature in the clamps can reach 70 °C. After 3 months, the mature, stabilized product is sieved through a sieve.

List of types of raw materials processed at the composting department:

- garden and park waste (leaves, branches, mowed grass);
- food organic waste from city residents;
- food organic waste from manufacturing enterprises.

All raw materials must meet the requirements specified in cooperation agreements.

During acceptance, company personnel verify compliance.

Requirements that raw materials must meet: the separately collected food waste must not contain plastic garbage bags, Tetra Pak, vinegar, oil, juice, milk, cheese, yogurt, butter, meat, fish products, or finished products that have been subjected to significant heat treatment as a result of frying.

To obtain substrates, the listed components were mixed in the following ratio:

- Control option: soil.
- Option 1: clay – 20 %, soil – 20 %, compost – 20 %, sand – 20 %, peat – 20 %.
- Option 2: clay – 20 %, soil – 20 %, compost – 30 %, sand – 20 %, peat – 10 %.
- Option 3: clay – 20 %, soil – 20 %, compost – 40 %, sand – 10 %, peat – 10 %.
- Option 4: clay – 0 %, soil – 30 %, compost – 40 %, sand – 30 %, peat – 0 %.
- Option 5: clay – 0 %, soil – 0 %, compost – 40 %, sand – 40 %, peat – 20 %.

To determine the effect of the substrate on plant growth and development, we used the bioindication method (DSTU, 2004; DSTU, 2002). To achieve this, 10 ryegrass seeds (*Lolium perenne*) were planted in 100 mL containers filled with the substrates mentioned above. During the experiment, observations were made of the time of sprout emergence, the number of sprouts per day, and overall germination. At the end of the experiment, root length and mass, as well as stem height and mass, were measured. To minimize statistical errors in data processing, experiments were conducted in six replicates.

3. Results and Discussion

To determine which substrate is best suited for growing plants using the bioindication method, the average germination rate of ryegrass was calculated, as shown in Table 1.

Table 1

Average ryegrass germination rate in the study samples, %

Variant	Days						
	4	*6*	*8*	*10*	*15*	*20*	*25*
Control	34.2	77.5	89.2	89.2	89.2	89.2	89.2
Option 1	80.8	95.8	95.8	95.8	95.8	95.8	95.8
Option 2	60.8	85.0	89.2	89.2	90.0	90.8	90.8
Option 3	72.5	82.5	84.2	87.5	90.8	90.8	90.8
Option 4	59.2	79.2	80.8	85.8	85.8	85.8	85.8
Option 5	58.3	75.8	80.8	86.7	86.7	86.7	86.7

As can be seen from this table, the first ryegrass sprouts appeared in all samples on the 4th day, with the best germination rate of 80.8 % observed in option 1 and the lowest in the control sample – 34.2 %. However, when examining the other samples, as in the case of option 1, the average germination rates on the fourth day also exceeded those of the control sample (soil). Thus, option 2 exceeded the control by 77.8 %, option 3 by 111.9 %, and options 4 and 5 by 73.1 % and 70.5 %, respectively. On the sixth day, the average germination rate continued to be higher in the compost-containing samples, with option 1 showing the highest rate at 95.8 %, compared to 77.5 % in the control sample. Beginning on the 10th day of the experiment, the average germination rate in the control sample, as well as in options 1, 3, and 5, stabilized and remained unchanged through the end of the study. As for options 2 and 3, here, the average indicator continued to change for another 10 days. At the end of the experiment (day 25), the average germination rate in options 1, 2, and 3 exceeded the control (soil) by 7.4 %

and 1.8 %, respectively, and in options 4 and 5 this rate was already lower than the control by 3.8 % and 2.8 %, respectively.

Fig. 2 shows the general appearance of plants in the study samples on t he 25th day of the experiment.

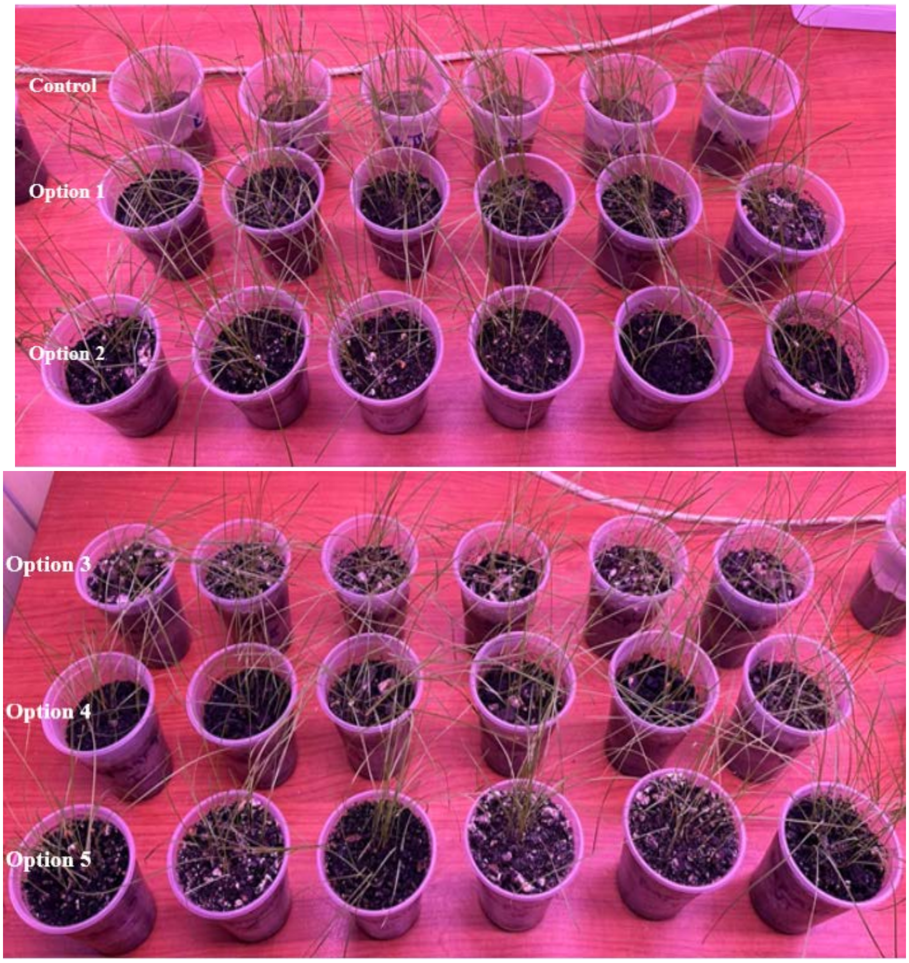

Fig. 2. General appearance of ryegrass plants in the study samples on the 25^{th} day

From this figure, it can be seen that, unlike the control sample, all samples containing compost had larger stems in the ryegrass plants, indicating an increased content of nutrients necessary for plant growth and development.

To determine the effect of compost-based substrates on the growth and development of ryegrass plants at the end of the experiment, Table 2 presents the main plant measurement parameters (stem height, root length, plant weight).

Table 2

Average measurements of the main parameters of ryegrass development in experimental samples

Variant	Average stem height, cm	Average root length, cm	Average stem weight, g	Average root weight, g	Average plant weight, g
Control	13.54	1.64	0.014	0.006	0.02
Option 1	14.89	4.11	0.016	0.008	0.024
Option 2	14.33	5.06	0.013	0.005	0.018
Option 3	14.34	2.35	0.018	0.007	0.025
Option 4	14.58	3.46	0.019	0.008	0.027
Option 5	13.48	3.54	0.012	0.005	0.017

Based on the data in Table 2, graphs were created to illustrate the changes in the average values of the main ryegrass parameters across the experimental samples (Fig. 3, 4). The parameters of ryegrass growth in the control sample (soil) were taken as 100 %.

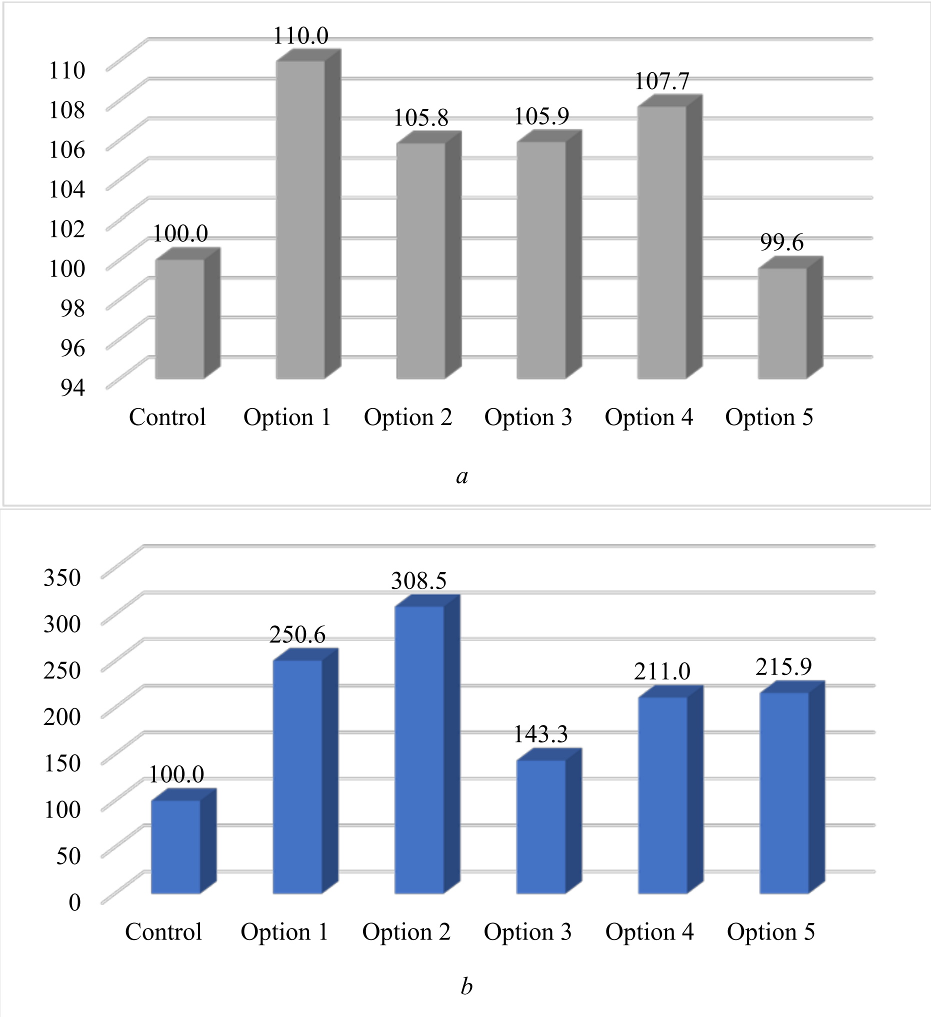

Fig. 3. Change in ryegrass growth indicators in experimental samples: *a* – stem; *b* – root

The results indicate that the highest average stem heights of ryegrass were observed in options 1, 2, 3, and 4, surpassing the control by 10 %, 5.8 %, 5.9 %, and 7.7 %, respectively. In contrast, option 5 showed an average stem height that was 0.44 % lower than the control.

Regarding the roots (Fig. 3, *b*), the average values show considerably greater variation compared to the control sample. The most substantial increase is seen in option 2, where the root index surpasses the control by 208.5 %. In options 1, 4, and 5, the increases are 150.6 %, 111 %, and 115.9 %, respectively. Even in option 3, although the increase is smaller, the value still exceeds the control by 43.3 %. As observed, in the four compost-containing substrates (options 1, 2, 4, and 5), the average root length was more than double that of the control, which can be attributed to the abundance of essential nutrients that support plant growth and development.

Fig. 4 displays the results of variation in the mass of key ryegrass parameters.

The average stem mass (Fig. 4, *a*) in options 1, 3, and 4 surpassed the control by 14.3 %, 28.6 %, and 18.8 %, respectively. In contrast, options 2 and 5 showed lower values, falling short of the control by 7.1 % and 14.3 %, respectively.

As in the previous case, the average root mass (Fig. 4, *b*) exceeded the control sample in options 1, 3, and 4. Meanwhile, the highest values were recorded in options 1 and 4, each showing a 33.3 % increase compared to the control, while option 3 demonstrated a 16.7 % improvement. As for options 2 and 5, here, the average root mass was already 16.7 % less than the control in both cases.

Analyzing the average mass of ryegrass plants (Fig. 4, *c*) reveals that, like the previous two parameters, the highest values were observed in options 1, 3, and 4 exceeding the control by 20 %, 25 %, and 35 %, respectively, while options 2 and 5 showed lower values, falling below the control by 10 % and 15 %, respectively.

Thus, in all three cases, the best impact on plant development was in options 1, 3, and 4.

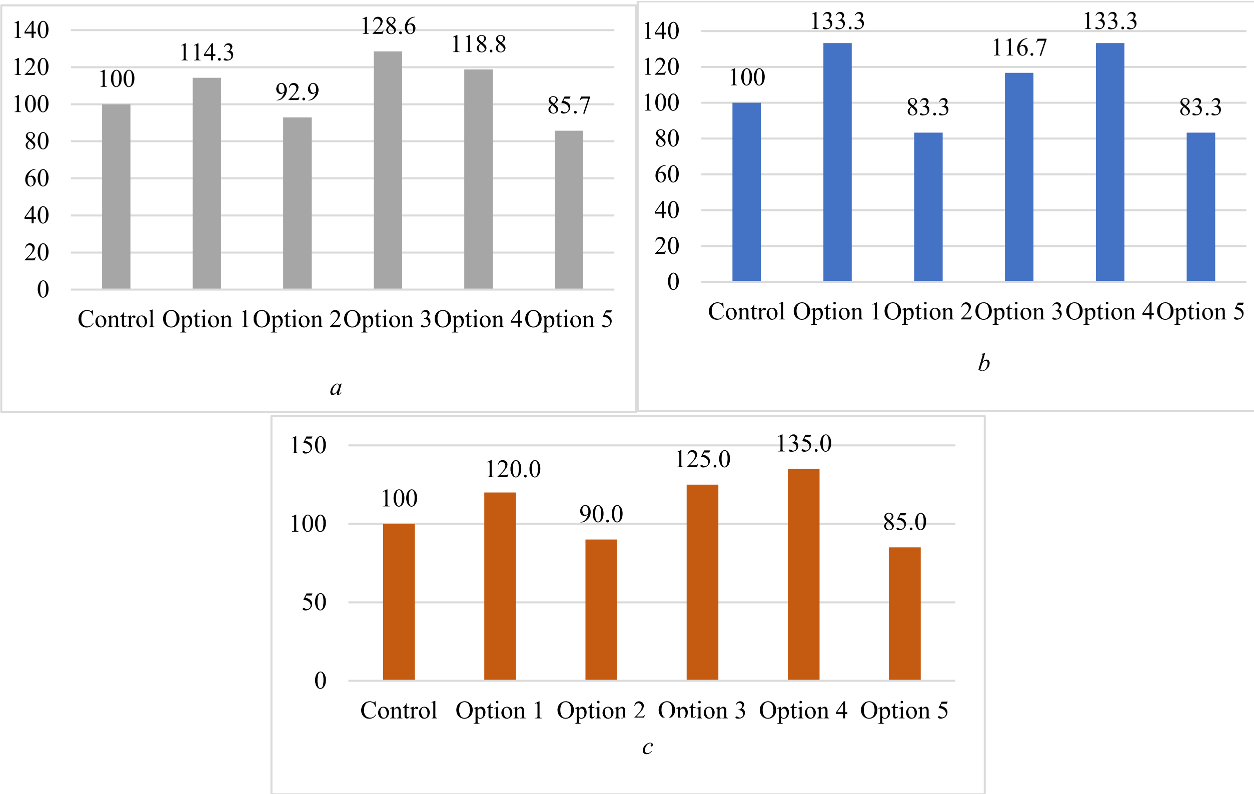

Fig. 4. Variation in the mass of key ryegrass parameters across the experimental samples:
a – average mass of the stem; *b* – average mass of the root;
c – average mass of the plant

4. Conclusions

Hence, the study's findings demonstrate that substrates composed of compost and additional components have a positive influence on plant growth and development. Thus, the highest average germination rate was in option 1 – 95.8 %, and the average indicators of the main plant parameters exceeded the control by 10 % when determining stem height, by 150.8 % – root length, by 14.3 % – stem mass, by 33.3 % – root mass, by 20 % – plant mass. In addition, high rates were also in option 3 and the lowest in option 5.

Therefore, compost-based substrates can serve as a full or partial substitute for peat, commonly used to support plant growth, without compromising crop yields. Compost substrates supply plants with essential macro- and microelements and also harbor beneficial microorganisms that support healthy root system development. Moreover, these findings can help optimize cultivation techniques for both agricultural and ornamental crops, contributing to the development of guidelines for the efficient application of organic fertilizers in crop production.

Acknowledgements

This research was supported by the Ministry of Education and Science of Ukraine (Agreement DB "A comprehensive technology for the restoration and rehabilitation of damaged land using substrates, encapsulated fertilizers and natural sorbents").

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