HSLU Hochschule Luzern

Practical 1:

Composting Parameters and Plant Tolerance Test

Environmental Chemistry and Biology HS2024

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1 Introduction

This experiment focuses on understanding how different types of compost affect plant growth. It aims to explore the chemical and physical interactions between compost and plant systems. Gaining a better understanding of these processes is essential for improving sustainable farming methods, making nutrients more available to plants, and managing resources effectively in agriculture.

2 Materials and methods

For this experiment, six gardening pots, three buckets containing different types of compost, a containment box, and a sieve were provided.

A scale and a measuring cylinder were used to determine the mass of the compost types (fresh, standard, and finished). The initial and final temperatures at the bottom of each pot were measured using a probe thermometer. Subsequently, pH measurements were conducted on each type of compost, with the samples dissolved in distilled water in a small beaker. Next, the composts were placed into different pots and divided into three distinct groups: 50% finished and 25% finished compost, 50% fresh and 25% fresh compost, and standard soil.

Finally, 15 seeds were carefully placed in each pot, and their growth and development were closely monitored.

2.1 Pictures of proceedings

Figure 1: Pot temperature

Figure 2: Compost dissolution

Figure 3: Compost pH results

Figure 4: Triplet of compost inside the pots

3 Results

3.1 Preliminary parameters

We collected three samples: Fresh, Finished, and Standard, and valuated them based on several characteristics, including pH, color, texture, odor, foreign objects, and moisture content. Each sample had distinct features, which helped us assess their condition and quality.

3.1.1 Preliminary parameters table

Table 1: Results of preliminary parameters

Sample	**pH**	**Color**	**Texture**	**Odor**	**Foreign objects**	**Moisture fist test**
Fresh	9	Light brown	Coarse	Smells ammonia	Large roots and plastics	30% humidity
Finished	8	Dark brown	Fine	Smells ammonia	Sticks and plastic particles	20% humidity
Standard	7	Darkest brown	Clumpy	Smells earthy	–	30% humidity

3.1.2 Compost temperature

The temperature of different composts was measured so that an assessment could be made of how favorable germination was within the compost. For the measurements, the probe thermometer was allowed to rest inside the compost for 5 minutes, and the initial and final temperatures were recorded.

Table 2: Compost temperature

Sample	**Initial** [°C]	**Final** [°C]	**Mean temp.** [°C]
Fresh	23.8	23.7	23.75
Finished	23.2	23.0	23.1
Standard	23.5		

3.2 Fresh, Finished and Standard compost

Three samples were collected, and their raw unit weight was evaluated. The mass of the empty cylinder was measured in grams, with a value of 168.24 g. The mass of the filled cylinder for each sample was then measured, obtaining values in liters. The volume of each sample was also measured in milliliters. Using these measurements, the density results were calculated in both [kg/L] and [kg/m^3] using the formulas:

$$\text{Density}\,[kg/L] = \frac{\text{Mass of filled cylinder }[g] - \text{Mass of empty cylinder }[g]}{\text{Volume of sample }[mL]}$$

Equation 1: Density formula in $[kg/L]$

$$\text{Density}\left[kg/m^3\right] = \text{Density}\,[kg/L] \cdot 1000\left[L/m^3\right]$$

Equation 2: Density formula in $[kg/m^3]$

The average values provided insight into the consistency of the raw unit weight across the different samples.

3.2.1 Fresh compost

Table 3: Results of raw unit weight in three different samples of fresh compost

Sample	**1**	**2**	**3**	**Average**
Mass of the empty cylinder in [g]	168.24			
Mass of the filled cylinder [g]	120.88	112.20	108.71	113.93
Volume of the sample in [mL]	340	330	390	353.33
Result in [kg/L]	0.356	0.34	0.279	0.325
Result in [kg/m^3]	356	340	279	325

3.2.2 Finished compost

Table 4: Results of raw unit weight in three different samples of finished compost

Sample	**1**	**2**	**3**	**Average**
Mass of the empty cylinder in [g]	168.24			
Mass of the filled cylinder [g]	214.54	202.91	202.68	206.71
Volume of the sample in [mL]	375	370	380	375
Result in [kg/L]	0.572	0.548	0.533	0.551
Result in [kg/m^3]	572	548	533	551

3.2.3 Standard compost

Table 5: Results of raw unit weight in three different samples of standard compost

Sample	**1**	**2**	**3**	**Average**
Mass of the empty cylinder in [g]	168.24			
Mass of the filled cylinder [g]	222.95	228.44	212.74	221.38
Volume of the sample in [mL]	355	370	360	361.67
Result in [kg/L]	0.628	0.617	0.591	0.612
Result in [kg/m^3]	628	617	591	612

3.3 Experiment results

Table 6: Experiment results

Group 4	**E0**	**E0**	**E25**	**E25**	**E50**	**E50**
mean compost density (kg/L)	0.325		0.382		0.438	
n° germinated seeds	12	13	11	12	11	10
plants weight (g)	1.672	1.882	0.997	1.294	1.058	1.105

Figure 5: Growth status 2 weeks after insemination

From the comparison of the different treatments, it is observed that compost E0 promoted both germination and plant growth in terms of biomass, with superior results compared to E25 and E50. The figure clearly shows that the plants treated with E0 are more developed compared to the other treatments. Treatments E25 and E50, with increasing percentages of finished compost, show limited growth.

3.4 Statistical formulas

For statistical analysis, the formulas mentioned below are used:

- **Arithmetic mean** ($\overline{x}$):

$$\overline{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

Equation 3: Arithmetic mean formula

Please note: since the class consists of two data points, the **median** corresponds to the arithmetic mean.

- **Variance** (σ^2):

$$\sigma^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \overline{x})^2$$

Equation 4: Variance formula

- **Standard deviation** (σ):

$$\sigma = \sqrt{\sigma^2}$$

Equation 5: Standard deviation formula

3.5 Statistical analysis for germinated seeds

3.5.1 Analysis for E0

Data set
The E0 group class consists of the data [12,13] for the number of sprouted seeds, respectively [1.672g, 1.882g] for their mass.

Arithmetic mean and median

$$\overline{x}_{E0} = \frac{12+13}{2} = 12.5$$

Equation 6: Arithmetic mean and median of germinated E0

$$\overline{m}_{E0} = \frac{1.672g + 1.882g}{2} = 1.78g$$

Equation 7: Arithmetic mean and median of E0 plants mass

Variance and standard deviation

$$\sigma_{x,E0} = \sqrt{\frac{(12-12.5)^2 + (13-12.5)^2}{2-1}} = \sqrt{0.5} \approx 0.707$$

Equation 8: Standard deviation of germinated E0

$$\sigma_{m,E0} = \sqrt{\frac{(1.672g - 1.777g)^2 + (1.882g - 1.777g)^2}{2-1}} \approx 0.148g$$

Equation 9: Standard deviation of E0 plants mass

3.5.2 Analysis for E25

Data set
The E25 group class consists of the data [11,12] for the number of sprouted seeds, respectively [0.997g, 1.294g] for their mass.

Arithmetic mean and median

$$\overline{x}_{E25} = \frac{11+12}{2} = 11.5$$

Equation 10: Arithmetic mean and median of E25

$$\overline{m}_{E25} = \frac{0.997g + 1.294g}{2} = 1.15g$$

Equation 11: Arithmetic mean and median of E25 plants mass

Variance and standard deviation

$$\sigma_{x,E25} = \sqrt{\frac{(11-11.5)^2 + (12-11.5)^2}{2-1}} = \sqrt{0.5} \approx 0.707$$

Equation 12: Standard deviation of E25

$$\sigma_{m,E25} = \sqrt{\frac{(0.997g - 1.146g)^2 + (1.294g - 1.146g)^2}{2-1}} \approx 0.210g$$

Equation 13: Standard deviation of E25 plants mass

3.5.3 Analysis for E50

Data set
The E50 group class consists of the data [10,11] for the number of sprouted seeds, respectively [1.058g, 1.105g] for their mass.

Arithmetic mean and median

$$\overline{x}_{E50} = \frac{10+11}{2} = 10.5$$

Equation 14: Arithmetic mean and median of E50

$$\overline{m}_{E50} = \frac{1.058g + 1.105g}{2} = 1.08g$$

Equation 15: Arithmetic mean and median of E50 plants mass

Variance and standard deviation

$$\sigma_{x,E50} = \sqrt{\frac{(10-10.5)^2 + (11-10.5)^2}{2-1}} = \sqrt{0.5} \approx 0.707$$

Equation 16: Standard deviation of E50

$$\sigma_{m,E50} = \sqrt{\frac{(1.058g-1.082g)^2 + (1.105g-1.082g)^2}{2-1}} \approx 0.0333g$$

Equation 17: Standard deviation of E50 plants mass

3.5.4 Summary table

Table 7: Statistical analysis by number of germinated seeds

	E0	E25	E50	Overall mean
mean and mediane	12.5	11.5	10.5	11.5
standard deviation	0.707			

Table 8: Statistical analysis for the weight of germinated seeds

	E0	E25	E50	Overall mean
mean and median [g]	1.78	1.15	1.08	1.34
standard deviation [g]	0.148	0.210	0.0333	0.131

3.6 Relative yield

To calculate the relative yield $FM(r)$ at 25% and 50% using the data from the table, we can use this formula:

$$FM(r)\% = \frac{FM\%}{E0\%} \cdot 100$$

Equation 18: Relative yield $FM(r)$

3.6.1 Average FM_{E0}

To calculate the average, the arithmetic mean formula was used [Equation 3]:

$$FM_{E0} = \frac{1.672g + 1.882g}{2} = \frac{3.554g}{2} = 1.777g$$

Equation 19: Average FM_{E0}

3.6.2 Calculation of the relative yields

1. **E25**:

$$FM(r)\ 25\% = \frac{0.997}{1.777} \cdot 100 = 56.1\%$$

Equation 20: Yield of the first E25% pot

$$FM(r)\ 25\% = \frac{1.294}{1.777} \cdot 100 = 72.8\%$$

Equation 21: Yield of the second E25% pot

2. **E50**:

$$FM_1(r)\ 50\% = \frac{1.058}{1.777} \cdot 100 = 59.5\%$$

Equation 22: Yield of the first E50% pot

$$FM_2(r)\ 50\% = \frac{1.105}{1.777} \cdot 100 = 62.2\%$$

Equation 23: Yield of the second E50% pot

3.6.3 Summary table

Table 9: Relative yields

	E25	E50	Overall mean
FM(r) 25%	56.1%	72.8%	64.5%
FM(r) 50%	59.5%	62.2%	60.9%

The FM (r) results indicate that E25 compost has a relative yield of 64.5 percent compared to E0 reference compost, while E50 compost has a relative yield of 60.9 percent. These values indicate that composts with higher percentages of finished compost have a lower yield than standard compost, showing what even a small fraction of an average finished compost causes to the plants.

3.7 Graphical results

Data visualized through boxplots allow observing the distribution of data obtained from the experiment and evaluating the performance of different composts. The medians, quartiles and extremes of the data allow visualizing the effectiveness of each type of compost with respect to plant development.

3.7.1 Boxplot of germinated seeds

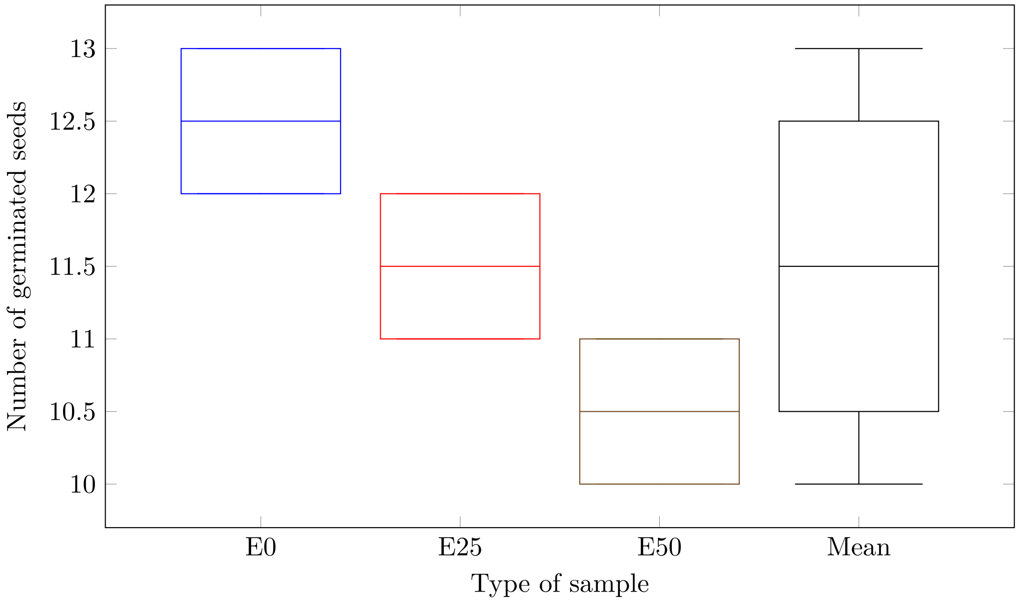

Figure 6: Boxplot of the germination of different composts

The boxplot shows the number of germinated seeds for the different compost treatments: E0, E25, E50, and the “mean” group. It can be observed that the E0 treatment has the highest median, and the E50 treatment has a lower median compared to the others, indicating a decrease in effectiveness for seed germination as compost maturity increases. The “mean” group displays the largest variability, highlighting significant differences between the compost treatments in terms of their ability to promote germination.

3.7.2 Boxplot of plant mass

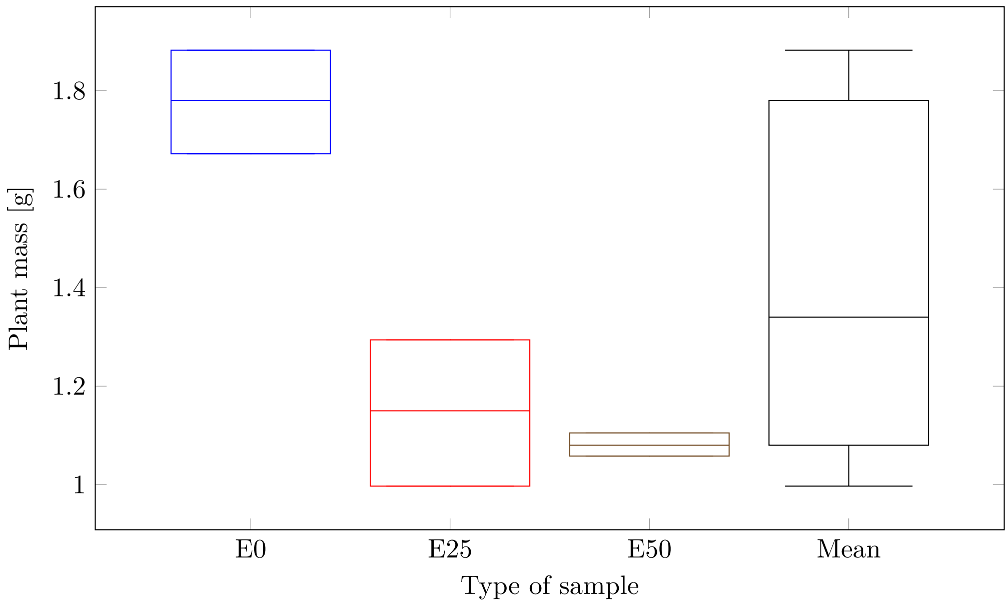

Figure 7: Boxplot of plant mass based on compost used

The boxplot shows the plant mass for different compost treatments: E0, E25, E50, and the overall group. It can be observed that the E0 treatment yields the highest median plant mass, suggesting that this compost type is the most effective in promoting plant growth. The E50 treatment has the lowest median, indicating reduced effectiveness in supporting plant growth with increasing compost maturity. The “mean” group displays the largest variability, highlighting significant differences between treatments.

4 Discussion

4.1 Results discussion

4.1.1 Compost

The different compost combinations (E0, E25, E50) significantly influenced plant germination. E0 provided the best conditions, likely due to an ideal nutrient balance and physical properties. E25 and E50 showed reduced germination, possibly due to greater chemical stability and less immediate nutrient availability.

4.1.2 Influence of pH and Nitrogen cycle

pH was an important factor in compost effectiveness. E0 had a balanced pH, favoring microbial growth and seed germination. In contrast, E25 and E50 may have had less suitable pH levels, affecting microbial activity and slowing nitrogen mineralization, reducing germination effectiveness.

Finished compost in E25 and E50 may have increased denitrification, reducing available nitrogen. Combined with reduced microbial activity, this limited nutrient availability in early growth stages. E0 showed better biomass growth, indicating the importance of immediate nutrient availability.

4.1.3 Plants mass

E0 was the most effective for plant growth by weight, providing readily available nutrients. E50 showed reduced growth, suggesting that a higher proportion of finished compost limited nutrient availability needed for early plant development.

4.2 Questions

1. What is the difference between raw unit weight and bulk density? Discuss your results based on the laboratory experiment.

   R:
   Raw unit weight is the density given by the division of the mass of the compost over the volume of the compost. The bulk unit is the density given by the division of the mass of the compost over the volume of the container.

2. How can the pH affect the compost?

   R:
   The more acidic the soil is, the more inactive the bacteria are, and this bring plants to not grow properly. Vice versa for the basicity.
   Compost microorganisms operate best under neutral to acidic conditions, with pH's in the range of 5.5 to 8. During the initial stages of decomposition, organic acids are formed. The acidic conditions are favourable for growth of fungi and breakdown of lignin and cellulose (Cornell University, n.d.).

3. What is the impact of immature compost on plant growth, and how can this be assessed in the lab?

   R:
   Plants will not grow properly if the nitrogen cycle is not working. Indeed, it is generally accepted that compost produced with substrates rich in nitrogen will have a better fertilizing effect, compared to other compost whose substrates are mainly woody. Likewise, immature compost will have a repressive effect on seed germination and plant growth (Aziable et al., 2021).
   In the lab, we can do the germination test and for immature compost you have standard growth.

4. How do you calculate the bulk density of compost, and why is this measurement important in the composting process?

   R:
   Divide the mass of the compost by the volume of the container. Bulk density provides an overall indication for the physical and aeration conditions of a composting mass (Paniwnyk, 2014).

5. What would be the environmental impact if fresh compost is added in the plantations/agriculture or when the recommended percentage of compost mixture is not followed?

   R:
   The addition of fresh compost may lead to suboptimal plant growth due to high biological activity and temperature, which could create unfavorable conditions for germination, compromising growth and plants

and reduced yields. Deviation from the recommended compost mixture could result in inconsistent results that would lead to reduced germination and growth compared to standard compost (Mladenov, 2018).

4.3 Conclusion

In this experiment, the effects of different types of compost (fresh, finished, and standard) on seed germination over a one-week period were investigated. The results indicated that fresh compost led to suboptimal seed growth due to its high biological activity and temperature, which created unfavorable conditions for germination. Finished compost produced moderate outcomes, showing some benefit to seed growth, but it was not as effective as standard compost. Indeed, standard compost demonstrated the best performance, supporting robust seed germination and growth, as it provided an optimal balance of nutrients and physical structure.

These findings highlight the significance of compost maturity in promoting plant growth, with standard compost proving to be the most suitable option for enhancing seed germination and early development. The results also indicate that a balanced pH and immediate nutrient availability are crucial factors for successful plant growth. The use of finished compost, particularly in E25 and E50, led to increased denitrification and reduced microbial activity, limiting nitrogen availability and affecting plant development negatively. Therefore, compost maturity and nutrient availability must be carefully managed to optimize germination and early plant growth.

List of Tables

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Declarations about AI tools

- "*ChatGPT-4 with canvas*" was used as a tool to enhance vocabulary.
  All original sentences come from our individual thoughts and were refined with the support of this tool.
  https://chatgpt.com/
- "DeepL" was used as a translator.
  https://www.deepl.com

References

Aziable, E., Koledzi, E. K., Krou, N. M., Tamakloe, M., & Tcha-Thom, M. (2021). Impact of composts maturity on growth and agronomic parameters of maize (*Zea mays*). *American Journal of Analytical Chemistry*, **12**, 29–45. https://doi.org/10.4236/ajac.2021.122003

Cornell University. (n.d.). Monitoring Compost pH - Cornell Composting. https://compost.css.cornell.edu/monitor/monitorph.html#

Mladenov, M. (2018). Chemical composition of different types of compost. *Journal of Chemical Technology and Metallurgy*, **53**, 712–716.

Paniwnyk, L. (2014). Application of ultrasound. *Emerging Technologies for Food Processing*, 271–291. https://doi.org/10.1016/B978-0-12-411479-1.00015-2