Quality of Spent Mushroom Compost Amended with Organic Material- Effect on Nutrient Content and Plant Growth

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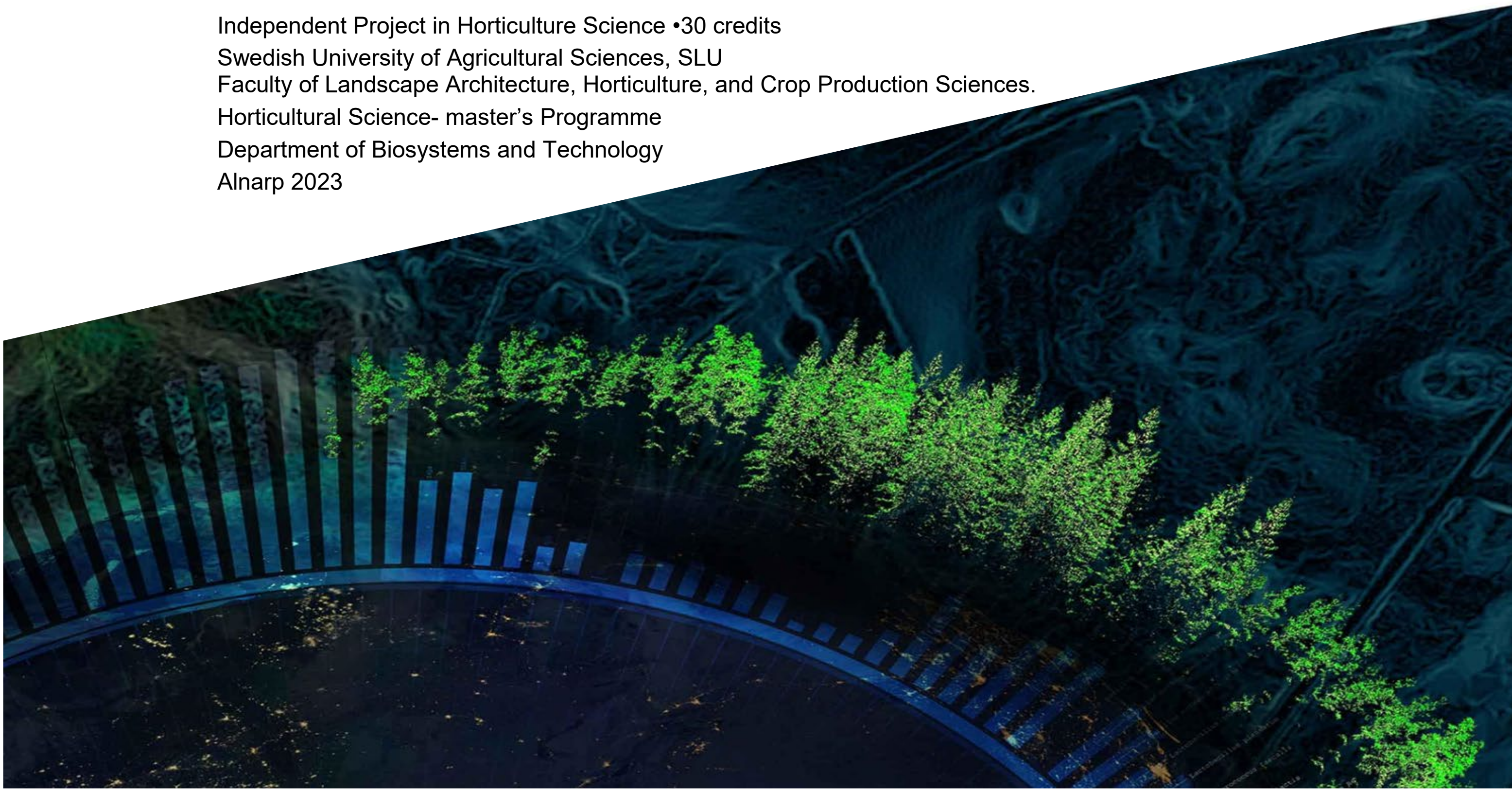

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Abstract

Peat, as a non-renewable growing media, poses environmental concerns due to extraction and decomposition processes, leading to increased greenhouse gas emissions. Alternatives growing media with potential to replace or reduce the use of peat are of great need. The current thesis aims to assess the quality and potential of the composted material generated from industrial waste streams as a peat substitute and evaluate its impact on plant growth and the physical, chemical, and microbial properties of the substrate. Three different compost proportions were prepared using apple wastes, spent mushroom compost (SMC), and wood chips. These compost mixtures were combined with peat in three different treatments (A, B, C), with treatment D serving as the control (100% peat). Treatment A consisted of 70% peat and 30% compost mixture consists of 40% apple wastes, 20% SMC, and 40% wood chips. Treatment B consisted of 70% peat and 30% compost mixture consists of 25% apple wastes, 50% SMC, and 25% wood chips. Treatment C consisted of 70% peat and 30% compost mixture consists of 33% apple wastes, 33% SMC, and 33% wood chips). The compost mixtures were evaluated in pot experiment under controlled conditions in a greenhouse chamber using basil plants (*Ocimum basilicum*) as a model crop. The physical parameters, including bulk density (BD), compact density (CD), water holding capacity (WHC), and porosity, were measured. Chemical parameters including pH, electrical conductivity (EC), and nutrient contents were also analyzed. Microbial analysis was performed to determine the bacterial and fungal flora present in the compost before and after plant cultivation´. Physical and chemical parameters were also evaluated before and after plant cultivation. Biomass measurements were taken after five weeks of growth. Statistical analysis was conducted using one-way analysis of variance (ANOVA) to assess significant differences among the treatments. Initial assessment of the composts prior to plant cultivation revealed alkaline pH values and low electrical conductivity (EC), which are unfavourable for plant growth. Addition of compost to the peat effectively lowered the pH values and improved the EC, bringing them closer to optimal ranges for plant growth. The addition of compost reduced also bulk density and increased soil porosity. Microbial assessments showed abundant microorganisms in the compost materials, with an increased abundance of bacterial and fungal flora observed in compost-amended substrates. The addition of compost, particularly treatment C, enhanced the abundance of bacterial flora. Treatments A and B incorporating compost exhibited better plant growth parameters, including fresh and dry weight of leaves and roots. Overall, the findings support the use of compost amendments in peat-based substrates to create a favourable environment for plant growth, improve nutrient availability, and enhance soil microbial communities.

Keywords: *Apple Waste, Wood Chips, Microbial Content, pH, Pseudomonas, General Bacterial Flora, General Fungal Flora, Electrical Conductivity, Nutrient Content, Bulk Density, Porosity, Water Holding Capacity.*

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Abbreviations

BD	Bulk Density
CD	Compact Density
P	Porosity
EC	Electrical Conductivity
KB	King's B Agar
MA	Malt extract Agar
SOM	Soil Organic Matter
SMC	Spent Mushroom Compost
TSA	Tryptic Soy Agar
VRBD	Violet Red Bile Dextrose
WHC	Water Holding Capacity
CFU	Colony Forming Unit

1. Introduction

Peat is an organic soft soil formed by the accumulation and incomplete decomposition of organic matter, including plant and tree residues and algae (Kazemian *et al*., 2011). It is widely utilised in agriculture globally. However, despite its organic origin, the use of peat poses several challenges and environmental concerns (Atzori *et al*., 2021). These concerns stem from the significant greenhouse gas emissions and environmental pollution associated with peat extraction, processing, transportation, and decomposition at excavation sites, which require substantial fuel consumption (Atzori *et al*., 2021). Moreover, classification of peat as a non-renewable resource contributes also to its negative environmental impact (Cleary *et al*., 2005). In southern Europe, the widespread use of peat as a substrate has resulted in a decrease in its availability, leading to escalating prices. As a non-renewable resource, the limited supply of peat has prompted growers to explore alternative options for the medium to long term (Ribeiro *et al*., 2007; Granberry *et al*., 2001).

To address these issues, it becomes crucial to explore environmentally friendly and sustainable alternatives that focusing on reusable and recyclable materials that are not sourced from non-renewable reservoirs like peat (Benito *et al*., 2005). Compost, derived from various recycled organic streams, such as pruning waste, spent mushroom substrates and green wastes emerges as a promising alternative that can serve as a growing medium and a nutrient source for plants after undergoing appropriate composting processes (Benito *et al.,* 2005).

Composting is an environmentally friendly and safe process involving partial aerobic and thermal decomposition of organic matter (Raviv, 2005). It is a sustainable practice with numerous benefits, particularly in reducing the reliance on chemical fertilisers and transforming organic waste into valuable compost for soil and plants (Mu *et al*., 2017). It serves as an integrated strategy to recycle organic waste into a useful product (Mengistu *et al*., 2017). Compost itself is a stable humus material created through the treatment of organic waste in specific proportions of temperature, oxygen, and humidity. Bulking agents like wood chips and softwood bark are added to provide adequate aeration, ensuring the compost's stability during the treatment period. During composting, microorganisms decompose the organic materials, converting them into stable humus as an energy source (Christian *et al*., 2023).

Different composting methods exist, varying in decomposition duration, stability, sanitation, and maturity (Mengistu *et al*., 2017). Compost has the ability to enhance soil structure by increasing the stability of soil aggregates, improves physical, chemical, and biological properties and enhances water retention especially in sandy soil (Cooperband *et al*., 2002). However, for compost to be beneficial for plant growth, it must be mature and possess favourable characteristics such as appropriate bulk density, water holding capacity, nutrient content, and organic matter content (Cooperband *et al*., 2002).

Targeting circular economy and resource efficiency in food production systems, different industrial side streams can be reused as composted material in plant cultivation. Spent mushroom compost is such an alternative (Medina *et al*., 2009). It has a high nutrient content and with potential to improve soil restructure, weed reduction and moisture retention (Umor et al., 2021). However, SMC remains one of the environmental challenges in mushroom producing countries. China, the leading producer of mushroom produces a significant amount of spent mushroom waste, approximately 5 kg per kg of mushroom produced. To address this issue sustainably, a strategy has been implemented to recycle this waste and produce spent mushroom compost (SMC), which enriches the soil with organic matter and nutrients. However, the direct application of SMC to the soil can have negative environmental consequences. It can lead to the deposition of nitrogen, phosphate, and organic matter through preferential flow, contaminating groundwater and causing nutrient loss from the soil. Moreover, SMC contains high levels of inorganic salts and dissolved organic carbon. To mitigate these environmental effects and maximise the benefits of SMC, it is advisable to combine it with other organic materials (Lou *et al*., 2017).

Furthermore, utilising plant residues and agricultural waste such as tree pruning waste, food industry waste and wood industry waste as agricultural materials is considered a viable solution to achieve agricultural environmental sustainability, (Atzori *et al*., 2020). Among these waste materials, wood chips are particularly useful as they are a renewable resource. However, due to their limited water-holding capacity, they cannot be used alone as a growth medium. Instead, wood chips are commonly incorporated as a component in growth media. This is because wood chips possess beneficial physical properties, including high total porosity, low bulk density, and high air content. These properties contribute to the improvement of soil structure and aeration, making wood chips an advantageous addition to growth media (Atzori *et al*., 2021).

Another promising organic waste for composting is apple waste from apple industry and refers to the residual material left over from the cultivation system or after apples are processed for various purposes and constitutes approximately 20-35% of the initial weight of fresh apples (Vendruscolo *et al.*, 2008). Apple waste is rich in organic material, uniform, and improves the physical and chemical properties of compost (Raviv, 2005).

Incorporating apple wastes and wood chips into SMC has thus the potential to mitigate enhance compost quality and thereby soil health after amendment as composted material. However, the specific impacts on nutrient content and plant growth remain unexplored. Understanding the effects of this amendment on nutrient availability, soil health, and plant performance is essential for optimising compost utilisation and developing sustainable agricultural practices.

This study investigated the quality of the composted material generated from SMC supplemented with wood chips and apple waste. The investigations target the biological, physical, and chemical content of the composted material before and after its use in plant cultivation and evaluate the impact of the composted material on plant growth and nutrient content.

1.1 Objective

The purpose of this study was to investigate the quality of the composted material originated based on spent mushroom compost (SMC) amended with apple waste, wood chips and its impact on plant growth and the substrate´s physical, chemical and microbial parameters.

1.2 Research questions

The research questions to be answered by this thesis are:

1. Do composted materials that consist of spent mushroom compost, apple waste and wood chips have a good quality including physical, microbial and chemical properties?
2. Can the composted material be used as a sustainable substitute in horticulture cultivation by improving soil health, plant growth and nutrient content?

2. Methods and Materials

The investigations were carried out in the laboratory and greenhouse at SLU Alnarp to evaluate the physical, chemical and microbiological properties of the composted material before and after plant cultivation and examine its ability to improve soil health, nutrient content and plant growth.

2.1Compost Materials

A six-month old composted material were used in this research in the following proportions:

- Proportion (1) consisted of 40% apple material: 20% SMC: 40% wood chips.
- Proportion (2) consisted of 25% apple material: 50% SMC: 25% wood chips.
- Proportion (3) consisted of 33% apple material: 33% SMC: 33% wood chips.

SMC samples contained aerobic fermented compost and comprised 80% Phase-3 compost (which itself was made up of 60% organic straw, 39.5% organic chicken manure, and 0.5% spawn), 18.5% casing soil, and 1.5% organic supplement. (Khalil et al. 2023 non published data

2.2 Experimental Set-Up and Growth conditions

For the pot experiment, the composted material (proportions 1-3) was mixed with peat as described in the following treatments:

a. Treatment (A) consisted of 70% of peat:30% of proportion 1.
b. Treatment (B) consisted of 70% of peat:30% of proportion 2.
c. Treatment (C) consisted of 70% of peat:30% of proportion 3.
d. The control treatment (Treatment D) consisted of 100% peat.

The proportions outlined above were derived from previous studies involving the use of SMC in strawberry cultivation (Elaamer et al.,2020) and indicating a positive impact of these proportions on plant growth.

Basil plants (*Ocimum basilicum*) were used as model crop and subjected to the treatments mentioned above. Each treatment had three replicates and the protions were placed in 1liter pots with ten basil seeds planted in each pot. The pots were placed in a greenhouse chamber with a temperature of 20 °C, 80% relative humidity and light intensity of 200 µmol/min. Temperature and humidity levels were regulated throughout the experiment. To ensure the plants received adequate moisture, the pots were watered twice a week. Daily monitoring was conducted to closely observe the progress of germination and track the growth of the basil plants over the five-week duration of the experiment.

2.3. Measurement of Physical Parameters

2.3.1 Bulky Density

Bulk density is a measure of how much space a certain mass of a substrate occupies, or alternatively, the weight of a specific volume (e.g., 1000 kg or 1000 L) of the substrate. In other words, bulk density quantifies the overall density of the substrate, considering both the solid particles and the void spaces within it. To determine bulk density, standard protocols (EN 13040:2007) were followed.

The assessment of bulk density (BD) was conducted for all composts before cultivation and at harvest. An iron cylinder with a known volume of 0.9 dm^3 was used for this purpose. The cylinder was filled with the substrate for all treatments and composts, ensuring that it overflowed slightly. The substrate was then compacted using weights for a duration of 3 minutes. Afterward, the excess substrate outside the cylinder was removed, and the remaining substrate within the cylinder was weighed. The bulk density was then calculated in units of grams per cubic decimeter (g/dm^3).

2.3.2 Compact Density

The compact density (CD) represents the density of the material itself, excluding the void spaces between the particles, essentially assuming a 100% compact state. The CD was measured in units of grams per cubic decimeter (g/dm^3). To determine the compact density (CD), a 50 mL volumetric flask was weighed and filled halfway with substrate samples from different treatments (at harvest) and compost samples (before cultivation). Subsequently, 25 mL of alcohol was added to each flask. The flasks were covered with parafilm and shaken for 30 minutes to ensure thorough mixing. After shaking, alcohol was added to reach the 50 mL mark on each flask, allowing the weight and volume of the pore-free substrates to be determined. The CD was then calculated based on this weight and volume, providing valuable information on the density of the substrate material without considering the presence of pores.

2.3.3 Water Holding Capacity

Water holding capacity (WHC), also known as pot capacity, refers to the maximum amount of water that a specific volume of substrate can retain after 24 hours of free drainage from a pot. In this study, a PVC cylinder with a volume of 0.9 L was utilised to measure the water holding capacity. The cylinder was filled with the substrate for each treatment (at harvest) and compost samples (before cultivation), respectively, above an additional ring. Water was added to the lower part of the extra ring, allowing it to saturate the substrate completely over a span of a few days. Subsequently, the cylinder was lifted out of the water to enable drainage for a period of 24 hours. After draining, any excess moisture was carefully removed, and the wet weight of the substrate was measured. Following this, all samples from each treatment were dried in a drying cabinet until they reached a completely dry state at a temperature of 107°C. The dried samples were then weighed again to determine their dry weight. The amount of water retained by the substrates was calculated by subtracting the wet weight from the dry weight.

2.3.4 Porosity

Porosity was calculated for all composts (before cultivation) and treatments (at harvest) after bulk density (BD) and compact density (CD) were measured by this equation:

$$(1 - (BD / CD)) * 100$$

2.4 Measurement of Chemical Parameters

2.4.1. pH and EC measurements

The analysis of pH and electrical conductivity (EC) were conducted for all composts before cultivation and at harvest . To perform the analysis, plastic bottles were used for the shaking process. In each bottle, a ratio of one part substrate to five parts water was added. Specifically, 25 g of substrate from each compost and treatment was mixed with 125 mL of water in each bottle. Subsequently, all bottles were shaken in a shaker for 1 hour. After shaking, the solution from each treatment and compost was poured into separate, empty, and clean bowls. pH and EC measurements were then taken, ensuring that the electrodes were rinsed with distilled water between each measurement to prevent cross-contamination and ensure accurate readings.

2.4.2 Nutrient content

To estimate the nutrient contents in the substrate both before planting and at harvest, samples were sent to a laboratory (LMI AB, Helsingborg, Sweden) for nutrient analysis. A sample of 500g was collected from each replicate in plastic bags and labelled with the name and number of the samples. The laboratory provided the nutrient analysis results.

2.5 Microbial Parameters

Microbial analysis was conducted to enumerate the general bacterial and fungal flora present in the compost before and in the treatments after plant cultivation. The analysis involved the preparation of four selective media for plating the samples on Petri dishes (Table 1). A detergent solution was prepared using 1.6 g of Na-hexametaphosphate, 0.8 g of peptone, and 800 ml of distilled water. Additionally, a NaCl solution was prepared using 6.8 g of NaCl and 800 ml of distilled water. For the dilution series, test tubes were marked for each replicate, and 9 ml of sterile NaCl solution was added to each tube. Serial dilutions were made from the initial suspension, ranging from 10^{-0} to 10^{-6}. The serial dilution process involved transferring 1 ml aliquots of the suspension into 9 ml of sterile saline solution, followed by thorough mixing.

For the analyses of the compost before plant cultivation, one sample of each compost material was used and enumerated on the selective media using two plates as replicates. The samples after cultivation on the other hand included three plant replicates in the analyses. In the enumeration analyses of the samples, 4 g of substrate was collected and mixed with 10 ml of the detergent solution. The mixture was shaken at 200 rpm for 20 minutes at room temperature. The microflora enumeration was performed on the selective media, targeting specific microorganisms as described in Table 1 below.

Table 1: The composition of selective media used in the experiments for microbial enumerations of different microbial groups and the required time for their growth.

Media	Media composition	Microorganism targeted	Incubation time
King B Agar (KB)	16.0 g proteose peptone, 1.5 g MgSo4·7H2O, 12 ml glycerol, 800 ml distilled water	*Pseudomonas spp.*	24- 48h
Tryptic Soy Agar (TSA)	3.2 g tryptone soy agar, 12.0 g Bacto agar, 800 ml distilled water	General bacterial flora	24- 48h
Malt Extract Agar (MA)	8.0 g malt extract, 16.0 g Bacto agar, 800 ml distilled water	General fungal flora	72 h
Violet Red Bile Dextrose (VRBD)	31.6 g VRBD, 800 ml distilled water	Enterobacteriaceae	24- 48h

The Colony Forming Units (CFU) of the samples were calculated using the following formula:

Log CFU/g substrate or compost= (no. of colonies x dilution factor) * no of ml of the dilution media/ volume on the culture plate/ gram root and substrate.

2.6 Biomass Measurements

The biomass assessment was conducted for all treatments after 5 weeks of growth. The plants were carefully removed from the pots, and the growing media was manually cleaned from the roots. The leaves and stems were separated from the roots for each treatment and the fresh and dry weights of both the roots and leaves were recorded. Subsequently, all leaf and root samples were dried in drying cabinets at 107°C for 72 hours, and their weights were measured accordingly. Plant growth were also observed visually as indicated in Fig. 8 where differences in the growth were observed

1. 2.7. Statistical analysis

The statistical software package Minitab®18 was used to perform the one-way analysis of variance (ANOVA). ANOVA helped to determine if there were statistically significant differences among treatment groups for the physical and chemical parameters measured. Significance levels, $p \leq 0.05$ were considered to determine if the observed differences were statistically significant among the treatments. Both Tukey and Fisher LSD pairwise comparisons were used to compare treatment means and determine which pairs are significantly different from each other, which helped in grouping the treatments based on their statistical similarities or differences.

3. Results

Physical, chemical, and microbiological properties of the compost before cultivation and the treatments at harvest were assessed to evaluate the compost's ability to improve soil health, nutrient content, and plant growth. Results on the measured parameters are presented in the subsequent sections.

3.1. Physical parameters before cultivation in the compost

The assessment of the physical parameters before cultivation showed that Proportion 2 had the highest bulk density (BD=854.44 g/cm3) while Proportion 3 had the lowest bulk density (BD=791.22 g/dm^3) among the three proportions (Table 2). Proportion 1 had the highest compact density (CD=24,490 g/dm^3) while Proportion 2 had the lowest compact density (CD=5,280 g/dm^3) among the three proportions. Proportion 1 had the highest water holding capacity (WHC=61.7g), while Proportion 2 had the lowest water holding capacity (WHC=58.7g) among the three proportions. Proportion 1 had the highest porosity (P=96.8%) while proportion 2 had the lowest porosity (P=83.9%) among the three proportions.

Table 2: Physical parameters regarding bulk density (BD), compact density (CD), water holding capacity (WHC), and porosity (%) for three different compost material proportioned as. Proportion 1: 40% apple material: 20% SMC: 40% wood chips; proportion 2: 25% apple material: 50% SMC: 25% wood chips and proportion 3: 33% apple material: 33% SMC: 33% wood chips) before cultivation.

Proportions	BD (g/dm^3)	CD (g/dm^3)	WHC (g)	Porosity (%)
1	795.44	24490	61.7	96,8
2	854.44	5280	58.7	83.9
3	791.22	10300	60.9	92.4

3.2. Physical parameters at harvest

At harvest, treatment A exhibited the lowest bulk density, with a value of 412.47 g/dm^3. Treatment B and C indicated similar bulk density with values of 433.69 and 480.6 g/dm^3 respectively. Comparatively, the control treatment (Treatment D) had the higher bulk density of 508.52 g/dm^3 compared to the compost material. Although, no significance differences in the bulk density could be indicated between the treatments ($p=0.339>0.05$).

Treatments A and B had a lower compact density of 1326.66 g/dm^3 and 1123.33 g/dm3 compared to the control (Treatment D, 1846.66 g/dm^3). Treatment C had the highest compact density (1955 g/dm^3) compared to the other treatments. However, no significance differences could be indicated between the treatments ($p = 0.074$).

Treatments (C, B, A) respectively had a lower water holding capacity compared to the control (Treatment D). However, the means of WHC between the treatments were not significantly different ($p = 0.072$).

Treatments A and B had lower porosity (69%) and (61.4%), respectively compared to the control (Treatment D), while Treatment C has a higher porosity (75.5%) compared to Treatment D (72.5%). However, the analysis of variance revealed no significance differences between the treatments ($p= 0.073$).

Table 3: Physical parameters including bulk density (BD), compact density (CD), water holding capacity (WHC), and porosity (%) for 4 treatments. Treatment A (70% peat: 30% of proportion 1), Treatment B (70% peat: 30% of proportion 2), Treatment C (70% peat: 30% of proportion 3) and the control treatment (D) (100% peat). Statistical analyses were performed using Minitab 18 statistical program with $P< 0.05$ as significant. Means that do not share the same letter are significantly different.

Treatments	BD (g/dm^3)	CD (g/dm^3)	WHC (g)	Porosity (%)
A	412.47^a	1326.66 ^{a}	57.47 ^{a}	69.0 ^{a}
B	433.69^a	1123.33 ^{a}	60.4 ^{a}	61.4 ^{a}
C	480.60^a	1955 ^{a}	64.29 ^{a}	75.5 ^{a}
D (Control)	508.52^a	1846.66^a	67.84 ^{a}	72.5 ^{a}

3.3. Chemical Parameters

3.3.1. pH and EC Before Cultivation in the Compost

Before cultivation, the pH and electrical conductivity (EC) of the compost proportions were measured The results indicated that Proportion 2 (25% apple material: 50% SMC: 25% wood chips) had the highest pH value of 7.80 (Table 4). Proportion 3 (33% apple material: 33% SMC: 33% wood chips), on the other hand, had the lowest pH value of it 7.44. In terms of EC, proportion 3 had the highest value of 0.50 ms/cm, indicating a relatively higher concentration of ions in the solution. Conversely, Proportion 1 had the lowest EC value of 0.41 ms/cm, suggesting a relatively lower concentration of ions in the solution.

Table 4: The pH and EC values in three different compost proportions: Proportion 1 (40% apple material: 20% SMC: 40% wood chips); Proportion 2 (25% apple material: 50% SMC: 25% wood chips); and Proportion 3 (33% apple material: 33% SMC: 33% wood chips) before cultivation.

Proportions	**pH**	**EC (ms/cm)**
1	7.46	0.41
2	7.80	0.46
3	7.44	0.50

3.3.2. Nutrient Contents in the Compost Before Cultivation

The total nitrogen content of the peat (the control) was higher compared to compost proportion 3, 2, and 1 respectively (Table 5). The phosphorus content of the peat was lower compared to compost propotion 3, 2, and 1 respectively. Also, the potassium content of the peat was higher compared to compost proportion 3, 2, and 1 respectively. The nutrient content of magnesium, sulphur, zinc, sodium and boron in the peat (control) was the lowest compared to compost proportion 3, 2, and 1. While the iron and manganese concentration was the highest in the peat (control compared to compost proportions 3, 2, and 1. proportion 3 had the highest concentration of aluminium compared to the peat (control) and proportion 1, and 2. The copper content in proportion 1 was the highest compared to the peat (control) and proportion 2, and 3. These differences suggest variations in nutrient availability and inputs among the treatments, requiring further investigation..

Table 5: The nutrient content in mg/l in the composts proportions before cultivation: Proportion (1); 40% apple material: 20% SMC: 40% wood chip; proportion (2): 25% apple material: 50% SMC:25% wood chips; proportion (3): 33% apple material: 33% SMC: 33% wood chips, and the control treatment (D) (100% peat).

Nutrient content in mg/l	Treatments			
	Compost proportion 1	Compost proportion 2	Compost proportion3	Control (peat)
N	319	363	526	1077
P	170	160	130	93
K	280	280	380	390
Mg	150	150	140	120
S	280	340	290	250
Ca	1600	1600	1400	1500
Mn	0.96	0.84	0.84	8.5
B	1.1	1.1	1	0.9
Cu	3.3	2.8	2.8	3.1
Fe	3.1	2.8	3.8	5.8
Zn	11	9.8	8.7	2.8
Mo	0.4	0.4	0.3	0.4
Na	44	48	47	39
Al	5.5	5	6.7	6.4

3.3.3. pH and EC at Harvest

At harvest, the highest pH values of treatment A,B and C were observed to be significantly higher ($p = 0.001$) compared to the control (treatment D) (Table 6). However, mean pH values in the treatments A, B, and C did not significantly differ from each other. With respect to EC values, there was a significant difference among the treatments ($p=0.009$). Treatment B exhibited the highest EC value of 1.603, and treatment C had the lowest value of 0.785, while treatment A had an EC value of 1.167 as compared to the control (D) with an EC value of 0.955.

Table 6: The values of pH and EC of compost: peat proportions used for five weeks in basil cultivation. Treatment A (70% peat: 30% of proportion 1), Treatment B (70% peat: 30% of proportion 2), Treatment C (70% peat: 30% of proportion 3) and the control treatment (D) (100% peat). Statistical analyses were performed using the Minitab 18 statistical program with P< 0.05 as significant. Means that do not share the same letter are significantly different.

Treatments	**Parameters**	
	pH	**EC (ms/cm)**
A	6.38^{a}	1.167^{b}
B	6.19^{a}	1.603^{a}
C	6.37^{a}	0.785^{ab}
D (Control)	5.66^{b}	0.955^{ab}

3.3.4 Nutrient Content at Harvest

The total nitrogen content of the treatment D (control) was higher compared to other treatments A, B, and C. The nitrogen content in treatment C was very low compared to control and treatments A and B. While the phosphorus content in treatment D was the lowest, compared to other treatments A, B, and C. the potassium content was the highest in treatment B compared to treatment D (control) and other treatments A and C. The control (treatment D) exhibit higher levels of manganese, and nitrogen content, and lower levels of copper compared to other treatments. Treatment C shows mixed results, with lower levels observed for some nutrients like nitrogin content, potassium, magnesium, calcium, sulphur, and sodium. And higher levels for iron and aluminium compared to the control (treatment D) and other treatments. These findings suggest variations in nutrient availability and supplementation among the treatments.

Table 7: Nutrient content in mg/l in compost's samples at harvest for all treatments: Treatment A (70% peat: 30% of proportion 1), Treatment B (70% peat: 30% of proportion 2), Treatment C (70% peat: 30% of proportion 3) and the control treatment (D) (100% peat).

Nutrient content in mg/l	Treatments			
	A	B	C	control D
N	107	513	6.2	904
P	160	150	160	76
K	220	410	160	330
Mg	120	160	90	110
S	260	340	120	230
Ca	1400	1600	1200	1300
Mn	0.9	0.84	1	5.4
B	1	1.1	0.9	0.9
Cu	2.8	2.7	2.7	2.6
Fe	8.5	5.3	15	8.2
Zn	9.8	9	9.8	3.6
Mo	0.3	0.3	0.3	0.3
Na	44	48	29	44
Al	15	9.4	28	11

3.4. Microbial assessment before cultivation

Enumeration of bacterial flora on the selective media TSA indicate that Compost 3 had the highest bacterial flora count among the three samples compared to compost 1 and 2 (Fig 1). On the other hand, Compost 2 showed relatively lower presence of *Pseudomonas spp*. compared to the other compost samples as enumerated on KB media. The results suggest that Compost 1 had the highest fungal flora count as enumerated on MA media. The counts for all three compost samples were relatively similar with no significant difference regarding presence of *Enterobacteriaceae* enumerated on VBRD media.

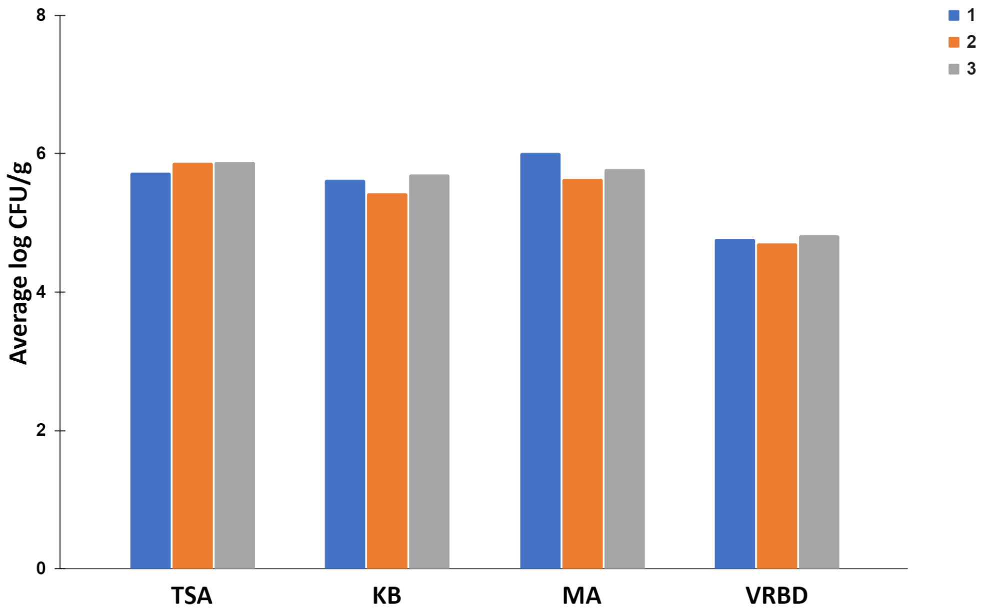

Figure 1: Log CFU/g substrate of bacteria enumerated on selective media Tryptic Soy Agar (TSA), Pseudomonas ssp. enumerated on King's B Agar (KB), fungi enumerated on Malt Extract Agar (MA), and of Enterobacteriaceae spp. enumerated on Violet Red Bile Dextrose (VRBD) in the compost's samples; compost 1: 40% apple material: 20% SMC: 40% wood chips; compost 2: 25% apple material: 50% SMC: 25% wood chips and compost 3: 33% apple material: 33% SMC: 33% wood chips.

3.5. Microbial Assessments at Harvest

3.5.1. Enumeration of General Bacterial Flora in Different Treatments

Enumeration of bacterial flora on the selective media TSA indicates that higher in treatment C compared to the other treatments (Fig 2). However, the results showed no significant differences between the treatments (p=0.517). Treatment C exhibited the highest bacterial growth. On the other hand, Treatment B showed the lowest mean bacterial growth, indicating that it may have had an inhibitory effect on bacterial populations.

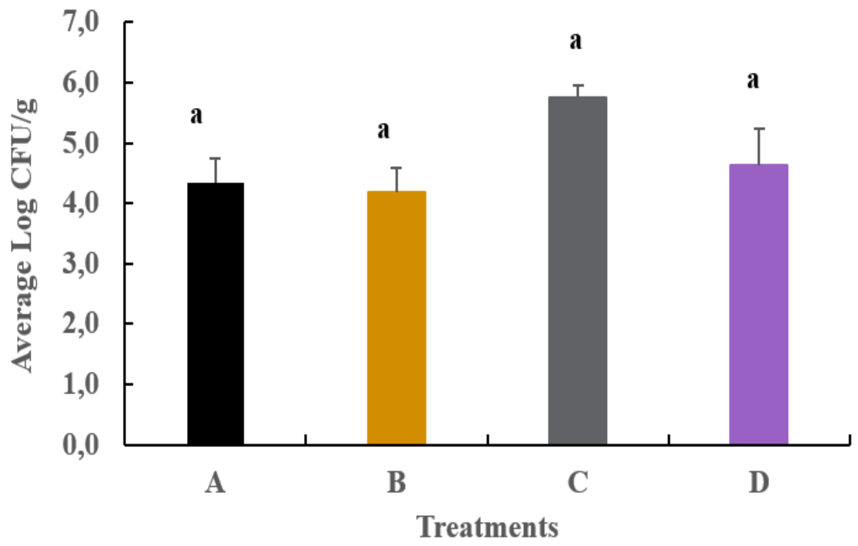

Figure 2: Log CFU/g substrate of general bacterial flora enumerated on selective media Tryptic Soy Agar (TSA) in four different treatments: A = 70% peat: 30% of proportion 1; B = 70% peat: 30% of proportion 2; C = 70% peat: 30% of proportion 3; and D = 100% peat. Statistical analyses were performed using Minitab 18. Letters above the bars indicate significant differences between the compost samples with $p < 0.05$. Mean + standard deviation are shown, n= 3.

3.5.2 Enumeration of General Fungal Flora

The enumeration of general fungal flora on Malt Extract media (MA) indicate the higher in the Treatment C and A respectively compared to the control D (Fig 3). The results showed treatment C had the highest mean fungal flora count , followed by Treatment A. Treatment D displayed , while Treatment B had the lowest. There was no statistically significant difference among the treatments (p-value= 0.424).

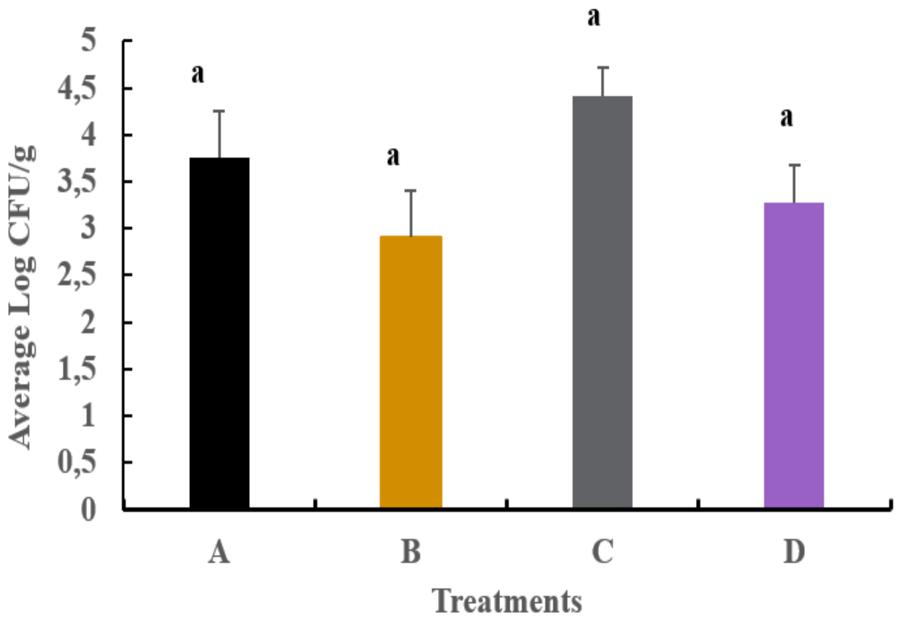

Figure 3: Log CFU/g substrate of general fungal flora enumerated on Malt Extract Agar (MA), in the compost's treatments; treatment A = 70% peat: 30% of proportion 1; treatment B = 70% peat: 30% of proportion 2; treatment C = 70% peat: 30% of proportion 3; and control treatment D = 100% peat. Statistical analyses were performed using the Minitab 18. Letters above the bars indicate significant differences between the compost samples with p < 0.05. Mean + standard deviation are shown, n= 3.

3.5.3 Enumeration of the *Pseudomonas spp*.

The enumeration of *Pseudomonas* spp. on King's B Agar (KB) media indicate the higher in treatment C, treatment B, and treatment A respectively compared to the control treatment D (Fig. 4). However, the observed differences were not statistically different among the treatments ($p = 0.404$).

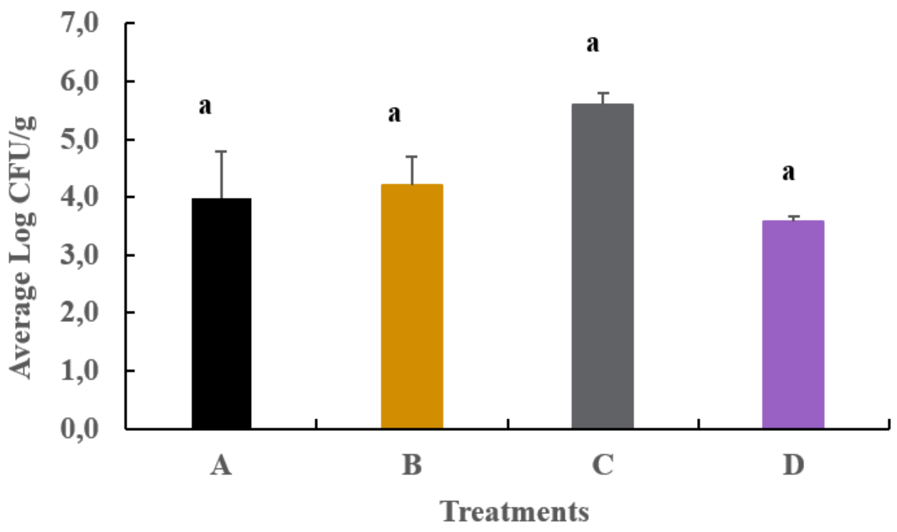

Figure 4: Log CFU/g substrate of Pseudomonas spp. enumerated on King's B Agar (KB) in in the compost's treatments; treatment A = 70% peat: 30% of proportion 1;treatment B = 70% peat: 30% of proportion 2;treatment C = 70% peat: 30% of proportion 3; and control treatment D = 100% peat on plates of King's Agar (KB). Statistical analyses were performed using the Minitab 18. Letters above the bars indicate significant differences between the compost samples with p < 0.05. Mean + standard deviation are shown, n= 3.

3.5.4. Enumeration of the *enterobacteriaceae*

The enumeration of *enterobacteriaceae* on Violet Red bile dextrose media (VRBD) indicates the highest in treatment C , B respectively and the lowest in treatment A compared to treatment (control) (Fig.5). However, the observed differences were not statistically significant among the treatments ($p = 0.037$).

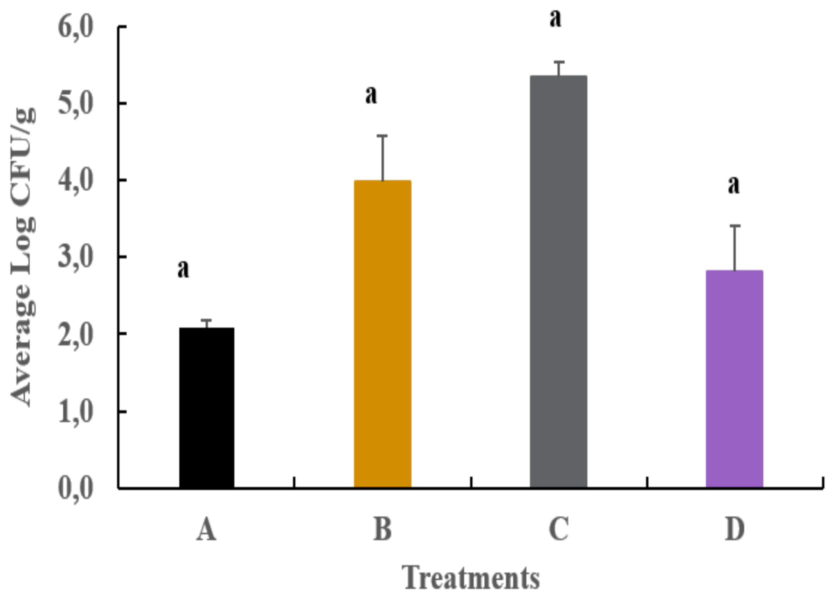

Figure 5: Log CFU/g substrate of enterobacteriaceae enumerated on Violet Red bile dextrose media (VRBD) in the compost's treatments; treatment A = 70% peat: 30% of proportion 1; treatment B = 70% peat: 30% of proportion 2; treatment C = 70% peat: 30% of proportion 3; and control treatment D = 100% peat. Statistical analyses were performed using the Minitab 18. Letters above the bars indicate significant differences between the compost samples with p > 0.05. Mean + standard deviation are shown, n=3.

3.6. Plant Growth Parameters

Treatments A, B, and D exhibited variations in fresh weights for both leaves and roots (Fig. 6). The highest fresh weight of leaves was observed in treatment A, followed by Treatment B and the lowest in the control treatment D. Treatment C showed no observable growth or presence of leaves and roots. The plants in treatment C germinated at the first three weeks after cultivation, then all the plants died. However, the observed differences in the fresh leaves weight are not statistically different between the treatments (p=0,263). The highest fresh of roots weight was observed in treatment A followed by Treatment B, while the lowest was observed in the control. However, there was no significant difference in the fresh weight of roots between the treatment (p= 0,426).

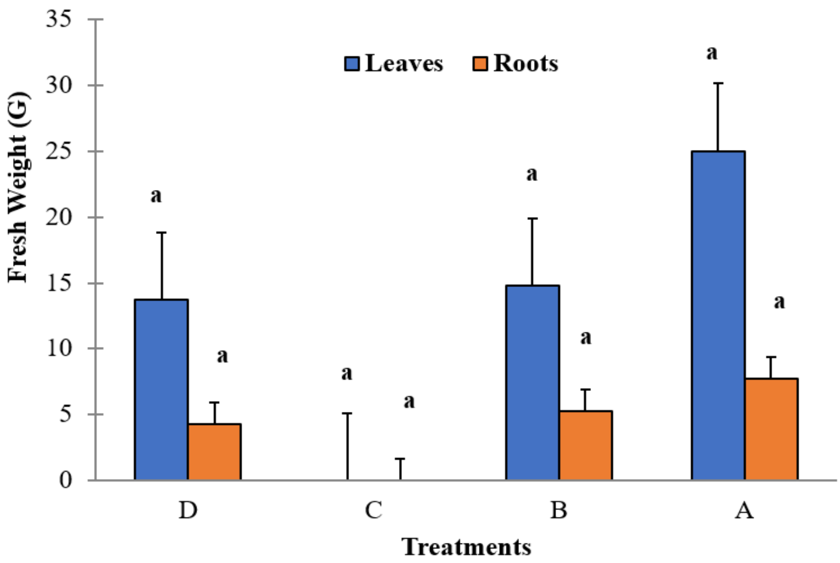

Figure 6: The average fresh weight (g) of leaves and roots in four different treatments: treatment A = 70% peat: 30% of proportion 1; treatment B = 70% peat: 30% of proportion 2; treatment C = 70% peat: 30% of proportion 3; and treatment D = 100% peat. Statistical analyses were performed using the Minitab 18. Letters above the bars indicate no significant differences between the compost samples with $p < 0.05$. Mean + standard deviation are shown, n=3.

Treatments A and B and D (control) exhibited variations in dry weights for leaves and roots (Fig. 7). Dry weight of leaves was higher in Treatment A, followed by Treatment B and Treatment D. However, the observed differences in means between the treatments were not statistically significant (p = 0,330). Treatment B had the highest dry weight of root , followed by Treatment A and the control D. Treatment C showed no biomass accumulation both in terms of roots and leaves. However, the differences in means were not statistically significant across the treatments (p = 0.444). There is no significant difference between the treatments and the control group in terms of dry weight of roots and leaves.

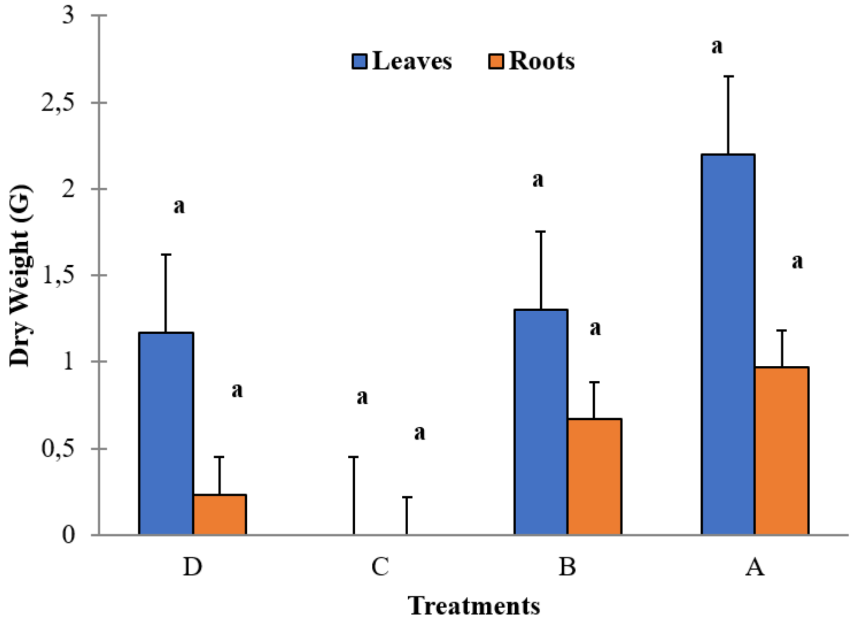

Figure 7: The average dry weight (g) of leaves and roots in four different treatments: treatment A = 70% peat: 30% of proportion 1; treatment B = 70% peat: 30% of proportion 2; treatment C = 70% peat: 30% of proportion 3; and control treatmentD = 100% peat. Statistical analyses were performed using the Minitab 18. Letters above the bars indicate no significant differences between the compost samples with $p < 0.05$. Mean + standard deviation are shown, n=3.

Plant growth was also observed visually as indicated in (Fig. 8) where differences in the growth were observed.

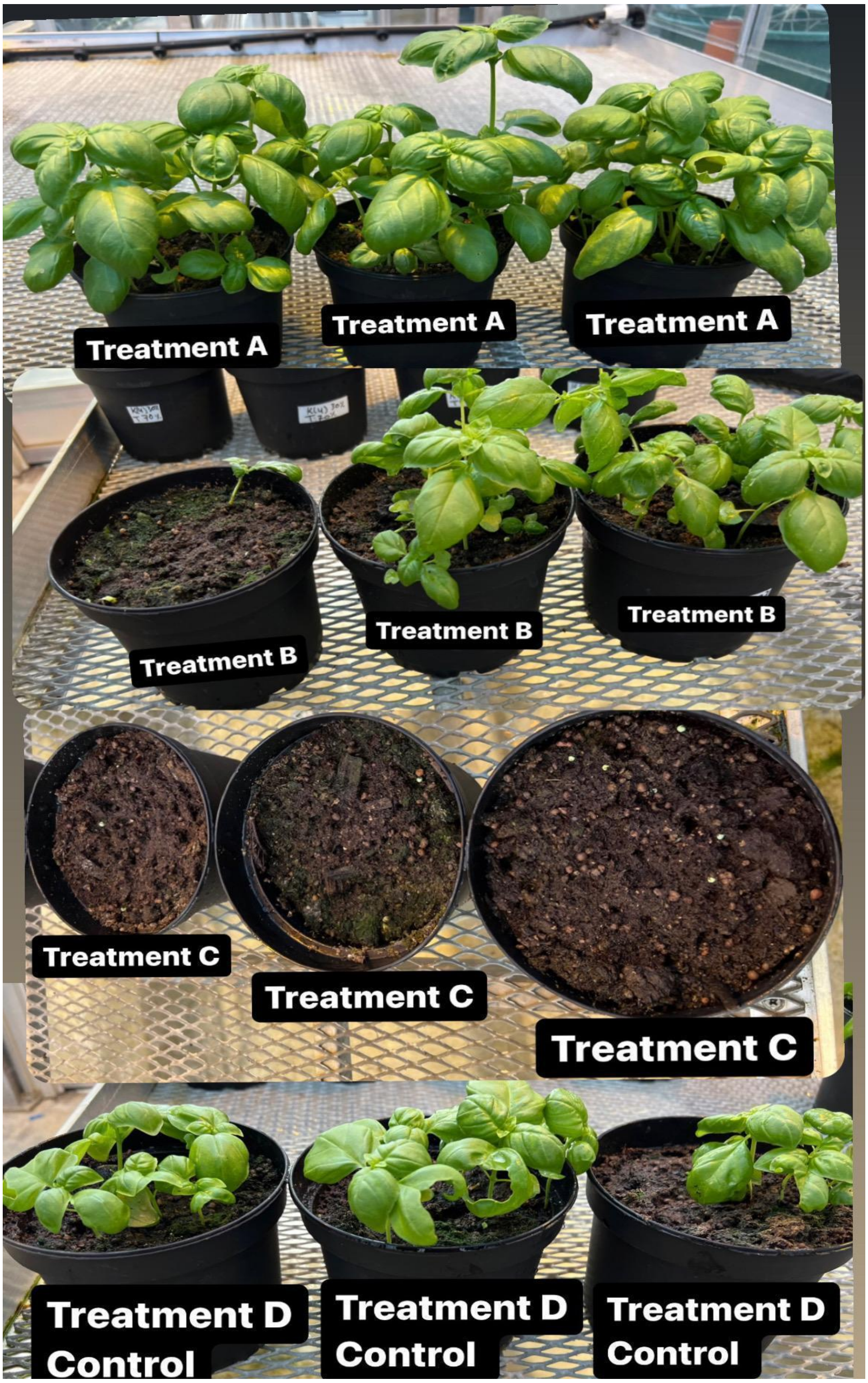

Figure 8: Visual assessment of plant growth and leaves in four different treatments: treatment A = 70% peat: 30% of proportion 1; treatment B = 70% peat: 30% of proportion 2;treatment C = 70% peat: 30% of proportion 3; and control treatment D = 100% peat. Authorship: Rasha Kamel.

4. Discussion

The assessment of chemical parameters for composts 1, 2, and 3 revealed alkaline pH values (7.46, 7.80 and 7.44) and low electrical conductivity (EC). Compost 2 made of 25% apple material: 50% SMC: 25% wood chips showed a slightly more alkaline environment (pH=7.80) while proportion 3 made of: 33% apple material: 33% SMC: 33% wood chips showed a slightly less alkaline environment (pH=7.44) as compared to the other proportions. These pH and EC values are not ideal for promoting optimal plant growth. Alkaline soil pH can prevent nutrient availability and uptake by the (Msimbira & Smith, 2020).

To address this issue of alkaline pH values, a potential solution was to mix 30% of each compost's substrates in all treatments with 70% peat in order to improve the pH and EC values. Previous research also showed that the addition of peat to composts can effectively reduce pH levels and bring it closer to the optimal ranges (Oviedo-Ocaña *et al*., 2015). Chen *et al*. (2012) also demonstrated that the combination of compost and peat resulted in improved EC of the substrate, which positively influenced proper nutrient uptake and plant growth parameters.

Results indicate that at harvest, the pH values decreased in all treatment (A, B, and C) substrates compared to the pre-cultivation samples. Treatment A, which consisted of 30% compost 1 and 70% peat, had the highest pH value of 6.38, while the pH values of treatments B and C were 6.19 and 6.37, respectively. On the other hand, the control treatment D, consisting of 100% peat, had the lowest pH value of 5.66, an indication that peat alone leads to a relatively acidic growing medium. The favourable pH range for plant growth and nutrient availability is typically between 5.5 and 6.5 (Msimbira & Smith, 2020), and all treatments in this study fall within this range. The results suggest that the addition of compost 1, compost 2 or compost 3 can help adjust the pH of the growing medium to the optimal range for plant growth and nutrient uptake. Compost has been recognised as a beneficial organic amendment for improving soil properties and promoting plant growth (Nardi *et al*., 2017). Therefore, the findings of this study support the use of compost amendments to improve the pH of the growing medium and create a favourable environment for plant growth and nutrient uptake.

The EC values measured for different treatments showed significant differences among them ($p = 0.009 < 0.05$). Treatment B had the highest EC value of 1.603, followed by treatment A with an EC value of 1.167. The control treatment D had an EC value of 0.955, while treatment C exhibited the lowest EC value of 0.785. A low EC value in treatment C suggests a lack of nutrients, which may explain the plant death observed in that treatment. On the other hand, treatments A and B, which incorporated compost, showed improved EC values compared to the control treatment. Therefore, the addition of compost in treatments A and B contributed to higher EC values, suggesting improved nutrient availability and potentially explaining the better growth rates observed in these treatments. These findings are in line with previous studies indicating that basil plants prefer higher EC levels above 1.2 ms/cm for optimal growth and productivity. Lower EC values in the range of 0.5–1 ms/cm are associated with reduced productivity (Hosseini *et al*., 2021).

Furthermore, the addition of compost substrates at a 30:70 ratio to peat significantly decreased the bulk density for all treatments (A=412.47 g/dm^3 B=433.69 g/dm^3 and C=480.60 g//dm^3) compared to the control treatment (D=508.52 g/dm^3)(Table 3). This suggests that incorporating compost can improve the bulk density of the growing medium. Lower bulk density is favourable as it allows better root penetration, water movement, and air circulation, thus promoting plant growth and nutrient uptake. This is consistent with Chaudhari *et al*. (2021) and Xuan *et al*. (2022) who also highlighted the positive impact of compost amendments on reducing bulk density of the substrates.

Furthermore,the addition of compost substrates improved the soil porosity of the substrates. Porosity was 61.4% in treatment B, which is closer to the optimal range for soil porosity, which is between 30 and 60% (Annan *et al*., 1998), and 69% in treatment A compared to the control (Porosity = 72.5%). Treatment C exhibited the highest porosity at 75.5%. Improved soil porosity is indeed beneficial for various aspects of plant growth and soil health. Higher porosity promotes better circulation and availability of nutrients in the soil, allowing for efficient nutrient transport and distribution (Doran *et al*., 2015). This, in turn, enhances nutrient uptake by plant roots, contributing to improved plant growth and productivity. However, excessively high porosity, as observed in treatment C, can be detrimental to plant growth. Inadequate soil particle bonding and excessive pore spaces may result in poor root anchorage, limited water retention, and nutrient leaching (Bengough *et al*., 2011). These conditions can lead to plant stress and even plant death.

Microbial assessment is crucial in understanding the impact of compost addition on the bacterial flora in peat-based substrates. All compost proportions (1, 2, and 3) exhibited high levels of log CFU/g substrate of bacterial, fungal, *enterobacteriaceae*, *pseudomonas* compared with peat (control) on all selective media plates, indicating the presence of abundant microorganisms. This observation suggests that the composts were effective in supporting microbial growth, which is consistent with previous studies highlighting the richness of microorganisms in compost materials (Mohd-Zainudin *et al*., 2022).

The content of general bacteria flora on tryptic soy agar, treatment C (30% compost 3, 70% peat) displayed higher CFU/g levels compared to treatment D (control) and other treatments. This finding suggests that the addition of compost to peat resulted in an increased amount of bacterial flora. Another suggesting that treatment C may have provided more favourable conditions for bacterial proliferation compared to the other treatments. On the other hand, Treatment B showed the lowest mean bacterial growth, indicating that it may have had an inhibitory effect on bacterial populations. These results are in line with previous studies that have demonstrated the stimulatory effect of compost on microbial growth (Mazzarino *et al*., 2017). Interestingly, treatment D (100% peat) exhibited higher CFU/g levels than treatments A and B. This observation implies that the bacterial flora decreased when compost of proportion 1 and 2 was added to peat, in comparison to the control treatment without compost addition. The decrease in bacterial flora in treatments A and B could be attributed to several factors. One possible explanation is the altered pH levels resulting from the addition of compost. Bacteria generally thrive best in neutral pH values (6.6-7.3) (Msimbira & Smith, 2020). It is possible that the compost addition to the peat in treatments A and B caused a shift in the pH towards more acidic conditions, inhibiting the growth of bacteria.

The addition of compost, i.e. compost of proportion 3, to peat-based substrates can enhance the abundance of bacterial flora, which can have beneficial effects on plant growth and nutrient cycling. Bacteria play a crucial role in nutrient mineralization, disease suppression, and organic matter decomposition (Corato *et al*., 2020). The increased abundance of bacterial flora in treatment C suggests that this combination could potentially improve soil health and plant performance. However, it is important to note that the addition of compost to peat-based substrates may not always result in positive outcomes. The decrease in bacterial flora observed in treatments A and B indicates that the proportions and types of compost used must be carefully considered.

The assessment of fungal flora using malt extract agar revealed higher levels in treatments A and C compared to the control treatment D (Fig 3). These fungi are likely to have beneficial effects on plants in treatment A a since they did not negatively impact the fresh and dry weight of leaves and roots. But it is possible that these fungi are harmful and negatively affected the plants in treatment C and led to their death. Furthermore, the evaluation using King's B agar for *Pseudomonas* spp. indicated higher colony-forming unit (CFU/g) levels in treatment C than in treatment D. These findings suggest that compost materials containing organic waste, when added to peat, can improve the biological properties of the soil. Moreover, the absence of plants in the pots allowed for the continued decomposition of organic matter, providing abundant nutrients for microorganisms.

Better plant growth parameters were observed in treatments A and B . Fresh weight was higher in treatment A for both leaves and roots (Fig 6). Dry weight of leaves was higher in treatment A while higher dry weight of roots was observed in treatment B (Fig 7). Therefore, treatments A and B, which incorporated compost materials, exhibited better plant growth in terms of fresh weight and dry weight of roots and leaves. This aligns with the results of (Hassan & Abo-Elyousr (2013) and Ndzingane *et al*. (2022) who also showed that organic fertilisation increased the dry and fresh weight of leaves and roots in basil plants. Compost improves physical and biological properties and provides the necessary resources for optimal plant growth and biomass accumulation (Visconti *et al*., 2023).

5. Conclusions

The results of this study indicate that composted materials consisting of spent mushroom compost, apple wastes, and wood chips have good quality including physical, microbial, and chemical properties. The addition of compost to peat-based substrates improved pH values, bringing them closer to the optimal range for plant growth and nutrient availability. Furthermore, incorporating compost resulted in improved electrical conductivity (EC) values, indicating enhanced nutrient availability. The addition of compost also reduced bulk density,

allowing for better root penetration, water movement, and air circulation, which positively influenced plant growth and nutrient uptake. Moreover, the inclusion of compost improved soil porosity within the optimal range, facilitating nutrient transport and distribution. The microbial assessment revealed increased abundance of bacterial flora in the compost-amended treatments, which can contribute to nutrient cycling and disease suppression. Additionally, higher levels of beneficial fungi were observed in the compost-amended treatments, indicating potential positive effects on plant growth.

Therefore, composted materials in treatments A and B can be used as sustainable substitutes in horticulture cultivation to improve soil health, plant growth, and nutrient content. But plants in treatments C died because of low EC and high porosity. Also a higher CD. Treatment C also had a very low N content (table 7). Treatment C had the highest microbial flora growth. The addition of compost amendments enhances physical, chemical, and microbial properties of the growing medium, creating a favourable environment for plant growth and nutrient uptake. This aligns with previous research indicating the positive impact of compost amendments on plant growth and biomass accumulation. Therefore, incorporating composted materials in horticulture cultivation can contribute to sustainable agricultural practices by promoting soil fertility, plant health, and overall productivity in agriculture.

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