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THE EFFECTS OF SPENT MUSHROOM COMPOST ON PLANT GROWTH PERFORMANCE AND SOIL PROPERTIES ON *Amaranthus tricolor*

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Abstract

Spent mushroom composts (SMC) are agricultural wastes from harvested mushroom farms. In Malaysia alone over 100 tonnes of fresh mushrooms are produced. Annually resulting in 438 tonnes of composted leftovers that require disposal. Currently, only 28% of the SMC is recycled for agricultural use, while 3% was burned, and over 69% is dumped in landfills or on the ground. However, it has been proven that SMC, which is rich in nutrients and organic materials, is an excellent option for agriculture as it is ideal for mulching soil and enhancing nutrient content. Thus, the objective of this study is to determine the effects of SMC on *Amaranthus tricolor* growth performance and to investigate its impact on soil properties. In this research, various concentrations of SMC 10%,20%,30% and 50% were applied to *A. tricolor* plants to evaluate their impact on plant height, leaf area, number of nodes and internodes, and stem diameter. Concurrently, soil samples were analyzed to determine the changes in soil analysis and proximate analysis. The results indicated that the applications of SMC significantly enhanced the growth performance of *A. tricolor*. From all of the treatments with SMC, the result obtained from the growth analysis of *A. tricolor* showed that the vegetable planted on 20% of SMC soil had the best growth. Overall, this study demonstrates that a certain amount of SMC on to soil is necessary to be an effective organic amendment for improving the growth of *A. tricolor* and enhancing soil health.

Keywords: Spent mushroom compost, *A. tricolor*, agriculture, organic materials

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Introduction

The leftover material from harvesting various mushroom flushes is called spent mushroom compost (SMC), sometimes referred to as spent mushroom substrate (Darajeh et al., 2021). It was observed that using agro-waste as a source of plant nutrients reduces farmers' need for mineral fertilizers and serves to cleanse the environment (Jonathan et al., 2011). Ranjbar and Nael (2023) stated that, spent mushroom compost is enhanced with micronutrients, nitrogen (N), phosphorus (P), and potassium (K). Therefore, reusing it as a soil amendment will enhance soil quality while simultaneously giving plants the nutrients they need. The use of SMC has been studied from various perspectives due to its potential benefits and applications in agriculture, horticulture, and environmental sustainability. Since SMC has all the necessary qualities of organic manure after recomposing by natural weathering or any other mechanism, it has been utilized extensively as fertilizer (Li et al., 2020). Many researchers have recently reported using SMC as a soil amendment to improve plant health and soil nutrients (Huang et al., 2023). For this research study, the SMC from mushroom *Volvariella volvacea* will be used.

The genus *Amaranthus*, commonly known as amaranth, comprises 60–70 species of herbs. The majority of the species are weedy annuals. This genus's species can produce ornamentals, vegetables, and pseudo-cereals. *Amaranthus* are grown as vegetables in Africa but are utilized as pseudo-cereals in Europe and America. The species of amaranth were divided into three categories: grain *Amaranthus (A. caudatus, A. cruentus* and *A. hypochondriacus*); vegetable *Amaranthus (A. tricolor L.*), weed *Amaranthus (A. viridis*, *A. dubius*, *A. hybridus*, *A.spinosus*, *A. graecizans* and *A. retroflexus* (Miguel, 2018). The *A. tricolor*, a plant species belonging to the *Amaranthus* family, that is grown as a leafy vegetable and is found throughout warm and tropical regions. Well-known traditional Chinese medicine, *A. tricolor*, is used to cure a wide range of ailments, such as colic, bronchitis, diarrhea, discomfort sore throats, fever eruptions, and anemia. It can absorb and handle biotic stressors because of its inherent antioxidant qualities (Chang et al., 2021). Japakumar et al. (2021) stated that like many other vegetables, *Amaranthus sp.* needs soil with a high organic content to provide the plant with the nutrients it needs for optimum performance. Therefore, this study is conducted to investigate the effects of SMC on plant growth performance and soil properties on *A.tricolor*. The effects of SMC on several quality and quantity parameters such as plant height, leaf area, length of internodes, number of leaves, stem diameter, number of nodes, soil pH, and soil organic matter were studied.

The agricultural waste from harvested mushroom farms is known as spent mushroom composts (SMC). Madzin et al. (2023) reported that, there are 5 kg of SMC leftovers produced for every 1 kg of mushroom produced. 80% of the world's fresh mushroom production comes from China, where over 20 million tonnes have been harvested. According to Phan & Sabaratnam (2012), Malaysia harvests about 100 tons of fresh mushrooms annually, leaving 438 tons of discarded mushroom composts that need to be disposed of (Madzin et al., 2023). That means unplanned disposal will cause land, air pollution and water together with the nuisance in the surroundings. In addition, the study by Umor et al. (2021) stated that in Malaysia, overall, over 69% of the SMC were disposed of in landfills or the ground, 28% were recycled for use in agriculture, and 3% were burned. However, it's been proven that spent mushroom have an effect on changing the soil properties resulting in better growth of plants. Muchena et al. (2021) stated that SMC, rich in nutrients and organic materials, is ideal for soil mulching and improving soil organic matter and nutrient content, making it a popular choice for agriculture. However, there is no research has been published on the use of compost from spent mushrooms to produce *A. tricolor,* that is why this research need to be done. Due to this reason, this study aims to provide information about the addition of SMC that will improve soil properties as a chemical property and increase the physiological performance of *A. tricolor*.

The research study on the effects of spent mushroom compost on the growth performance of *A. tricolor* holds immense significance in agricultural sustainability. By utilizing this compost as a soil amendment, farmers can reduce their reliance on chemical fertilizer, thus promoting environmentally friendly farming practices. Furthermore, from an economic perspective, utilizing spent mushroom compost can reduce production costs for farmers while potentially increasing crops yields and quality. *A. tricolor* is an important food source in many regions. Enhancing its growth performance through the application of mushroom compost can increase food production and contribute to food security.

Methods

Study Area

This study was conducted at UiTM Kampus Seri Melang, Kuala Pilah Negeri Sembilan.

Experimental Design

The field study was constructed using complete randomized design (CRD). Six treatments including the control (T1 soil only and T6 Commercial Fertilizer) were studied in this experiment and each treatment were replicated 5 times, resulted in a total number of 30 plants. The details of the treatment are given in the Table 1.

Table 1. Treatment description of SMC for *A. tricolor* plants

Treatment	Description	Soil (g)	SMC (g)
T1 (negative Control)	Soil only	1000	-
T2	10% SMC + Soil	900	100
T3	20% SMC + Soil	800	200
T4	30% SMC + Soil	700	300
T5	50% SMC + Soil	500	500
T6 (positive Control)	Soil + Commercial Fertilizer	1000	-

Preparation of Spent Mushroom Compost
The Spent Mushroom Compost used for this study was obtained from Unit Pengembangan Teknologi Cendawan Pusat Pengajian Biologi UiTM Kuala Pilah.

Preparation and Maintenance of Plant Sample
The seeds of *A. tricolor* were obtained from online market. The seeds were sown in seedling tray and after two weeks, five randomly selected seedlings were transplanted to a polybags 9cm x 10.6cm x 14.4cm that contain soil amendments as described in Table 1 (Oyewusi & Osunbitan, 2021). The plant was harvested at 30 days after planting. The *A. tricolor* plant was watered daily in the morning before 10 am and in the evening after 5 pm to ensure the normal growth and development of the plants (Gueco et al., 2016).

Parameters Measured for Growth performance of *A. tricolor*
The growth performance of *A. tricolor* was measured every 3 days or at the end of the experiments.

(a) Plant Height
The height of the plant was measured using a measuring tape, which was used to measure the plant from its stem at the soil's surface to the end of its tallest leaf (Mensah & Frimpong, 2018). The height of the plant was measured every three days after planting.

(b) Plant Stem
The stem diameter of *A. tricolor* leaves was measured at the base of the stem in cm every 3 days using vernier calliper.

(c) Number of leaves
The total number of *A. tricolor* leaves were counted manually every 3 days.

(d) Number of nodes and length of internodes
The number of nodes were monitored during the total plant growth period. The length of internodes was measured at the end of this experiment using measuring tape in cm.

(e) Leaf Area
The leaf area was measured by drawing the leaf on millimeter graph paper. Every plant's leaf was placed on graph paper, with a grid size of 1mm. On the graph paper, the leaf was outlined with a pencil precisely and carefully. The outline edge of the leaf was counted to determine how many grids in total it covers; if the outline occupies more than half of the grid, half of the grids will be classified as one, and if not, zero (Patil & Bodhe, 2011). This method was done after the plants are harvested.

Soil Chemical Properties

(a) Soil pH
Soil pH analysis adapted from Zhou et al. (2020) with some modifications. The soil samples were taken twice to determine the pH values, which represents the initial and final pH of the soil (Rusli et al., 2021).

The soil samples were taken from each polybag at 3 different spots into the lab for analysis. A pH meter was used to measure the pH of the soil. All the samples were air dried and after the soil samples were collected, the soil was mixed with distilled water into a 250ml beaker at a ratio of 1:1 respectively. The soil and water combination were stirred with a glass rod for 5–10 seconds until homogenized. The pH meter was immersed in the solution.

(b) Soil organic matter

The soil samples were analysed to determine soil organic matter (SOM) by the loss on ignition (LOI) method used by Rusli et al. (2021) with some modifications. The soil samples were taken twice to determine the SOM, which represents the initial and final SOM of the soil. The empty weight of crucible (W1) was weighed before adding any samples. A 3 g of air-dried soil was then placed into a porcelain crucible and weighed. Then, the samples were dried in a laboratory oven at 105 °C and allowed to cool in a desiccator. After cooling, the weight of the samples (W2) was recorded. Next, the crucible containing the soil was then placed in a muffle furnace at 360°C for 2 hours to combust the organic matter. After 2 hours, the crucible was placed back in the desiccator to cool for a minimum 30 minutes before being weighed again. (W3). The following formula was used to estimate the percentage of SOM using the LOI method:

Empty crucible weight (g)	= W1
Crucible + oven-dried soil weight	= W2
Crucible + burnt soil weight	= W3
Organic matter content (%)	$= \left(\frac{W2-W3}{W2-W1}\right) \times 100$

Statistical Analysis

Statistical Package for the Social Science (SPSS) software was used for statistical analysis of the obtained data. The analysis of the significant differences of all the treatments was conducted through one-way ANOVA. The post-hoc test that was used for this experiment was Tukey's test (Japakumar et al., 2021). Microsoft Excel version 2412 used to construct the graph.

Result and Discussion

Effects of SMC Treatments on Growth Performance of *A. tricolor*

Plant height

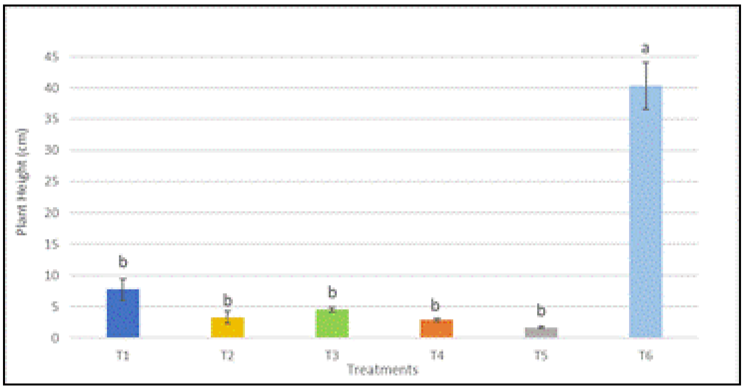

Figure 1. Plant height (cm) of *A. tricolor* on day 30. Each data item indicates the mean of the replicates. The error bar indicates the standard error. T1 (C) = soil only, T2 = 10% SMC, T3 = 20% SMC, T4 = 30% SMC, T5 = 50% SMC, T6 = Commercial fertilizer. Mean followed by the same letter are not significantly different ($p < 0.05$)

Figure 1 illustrates the plant height (cm) of *A. tricolor* on day 30 under different treatment conditions. The results demonstrate that treatments incorporating spent mushroom compost (SMC) had varied effects on plant growth, with higher concentrations negatively impacting plant height. When compared to the negative control (T1, soil only), the SMC treatments (T2–T5) did not significantly enhance plant height. The plant heights in T2 (10% SMC) and T3 (20% SMC) were comparable to T1, suggesting that these lower levels of SMC did not provide sufficient additional nutrients to promote growth. However, as the proportion of SMC increased, plant height declined, with the lowest height recorded in T5 (50% SMC) at 1.68 cm ± 0.299 [b]. This indicates that higher levels of SMC may lead to nutrient imbalances, excessive organic matter accumulation, or potential phytotoxic effects that inhibit plant growth (Rodríguez-Espinosa et al., 2023). The commercial fertilizer treatment (T6), serving as the positive control, resulted in the highest plant height (40.32 cm ± 8.27 [a]), significantly surpassing all other treatments ($p < 0.05$). This suggests that readily available nutrients in commercial fertilizer promote more robust plant growth compared to SMC amendments. The stark contrast between T6 and SMC treatments highlights the limitations of SMC in supplying sufficient or balanced nutrients for optimal plant growth (Alzain et al., 2023). Furthermore, the detrimental effects of higher SMC levels (30% and 50%) on plant height could be attributed to an excess of organic matter, leading to poor soil aeration and potential phytotoxicity (Hasan et al., 2023). These findings suggest that while lower levels of SMC (10–20%) may not hinder growth, they do not significantly enhance it either. In contrast, excessive SMC incorporation negatively affects plant development, emphasizing the need for appropriate composting or supplementation with additional nutrients to enhance its effectiveness.

Diameter of stem

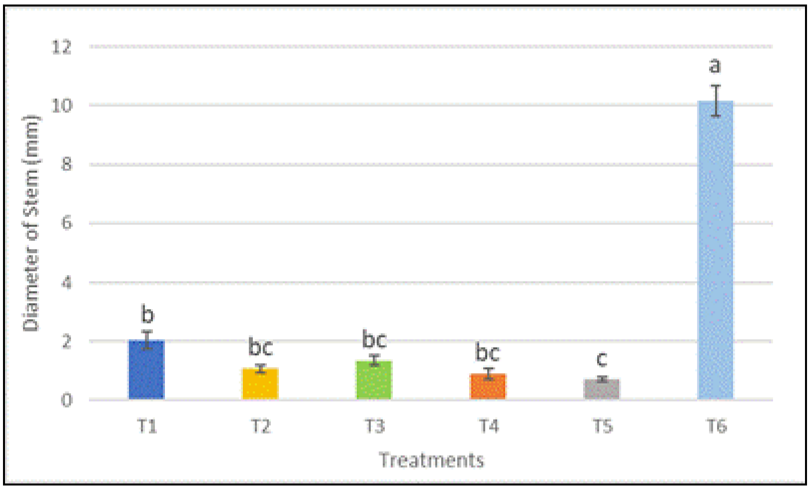

Figure 2. Diameter of stem (mm) of *A. tricolor* on day 30. Each data item indicates the mean of the replicates. The error bar indicates the standard error. T1 (C) = soil only, T2 = 10% SMC, T3 = 20% SMC, T4 = 30% SMC, T5 = 50% SMC, T6 = Commercial fertilizer. Mean followed by the same letter are not significantly different ($p < 0.05$)

Figure 2 illustrates the stem diameter of *A. tricolor* on day 30 under different treatment conditions. Among all treatments, the commercial fertilizer (T6) recorded the largest stem diameter (10.18 mm ± 1.15 [a]), significantly greater ($p < 0.05$) than the negative control (T1) and all SMC treatments (T2–T5). This result highlights the effectiveness of commercial fertilizer in enhancing stem growth, likely due to its balanced and readily available nutrient content, which supports vigorous plant development (Jemo et al., 2015). In contrast, the SMC treatments showed mixed results when compared with the controls. At lower concentrations (T2 and T3), stem diameter values were slightly lower than the negative control (T1), but not significantly different. This suggests that at these levels, SMC did not provide any clear advantage or disadvantage to stem development. However, as the concentration of SMC increased, stem diameter declined. Notably, T5 (50% SMC) recorded the smallest stem diameter (0.72 mm ± 0.19 [c]), significantly lower than both T1 and T6. This indicates that higher concentrations of SMC may negatively affect stem growth, possibly due to issues such as nutrient imbalances, excess organic matter, or phytotoxic compounds present in incompletely decomposed compost (Amarasinghe & Jayaweera, 2022). Interestingly, although T1 (soil only) did not outperform T6, it still produced a larger stem diameter than most of the SMC treatments. This suggests that while natural soil can support moderate stem growth, the addition of high levels of SMC might actually suppress development rather than enhance it. These findings echo those of Darjee et al. (2024), who noted that natural soil can support baseline growth, but without additional balanced nutrients, optimal development is limited. In summary, commercial fertilizer (T6) significantly improved stem diameter compared to both the negative control (T1) and all SMC treatments. The results also indicate that while low to moderate levels of SMC may be harmless, higher concentrations can hinder stem development.

Number of leaves

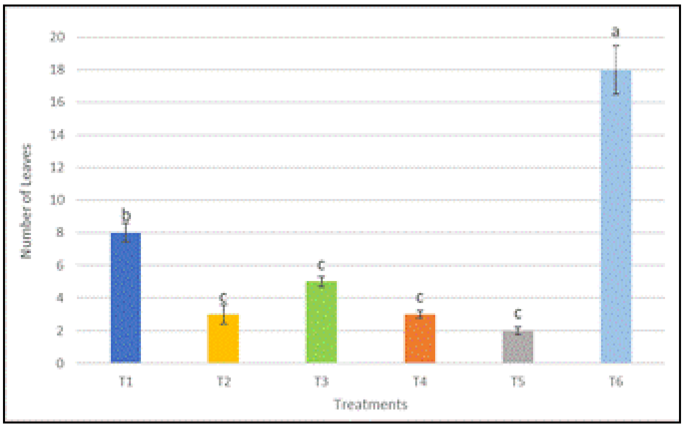

Figure 3. Leaves number of *A. tricolor* on day 30. Each data item indicates the mean of the replicates. The error bar indicates the standard error. T1 (C) = soil only, T2 = 10% SMC, T3 = 20% SMC, T4 = 30% SMC, T5 = 50% SMC, T6= Commercial fertilizer. Mean followed by the same letter are not significantly different ($p < 0.05$)

Next, the usage of commercial fertilizer has also positively affected the number of leaves of the *A. tricolor* (Figure 3). The least number of leaves was observed in the treatment T5 with value. 3.80 ± 0.45^{c}, while the highest number of leaves was obtained at T6 with value 18.00 ± 3.32^{a}. Comparing all the treatments carried out it was determined that the commercial fertilizer (T6) generated the highest number of leaves to show how effective it is as one of the treatments to promote high leaf production. This view is similar to the findings of other studies that suggest that commercial fertilizers that are marked with the availability of balanced nutrients increase the performance of plants by increasing the growth rate and number of leaves (Syamsiyah et al., 2024). Based on the results obtained from this study, it can be argued that the enhanced performance of T6 can be linked to the proper nutrient distribution for the development of better leaves and plant health. T5 had the smallest number of leaves, indicating that high concentrations of SMC might have negatively affect leaf growth. This could be due to the potential phytotoxicity associated with high levels of SMC (Amarasinghe & Jayaweera, 2022). High levels of SMC may contain phytotoxic compounds including phenols, ammonia and salt that are lethal to plants. Some of these compounds may be accumulated in the compost, especially when the compost is not properly decomposed before it is applied. The presence of these toxic substances can cause reduced root growth, nutrient absorption and generally inhibited plant growth and development which show up in a smaller number of leaves (Amarasinghe & Jayaweera, 2022). To further support these observations, additional investigation into the toxicity of SMC is recommended. Future studies should include chemical profiling of SMC to detect harmful compounds and conduct bioassays, like seed germination or root growth experiments, to see how much SMC is safe to use.

Number of nodes and length of internodes on day 30

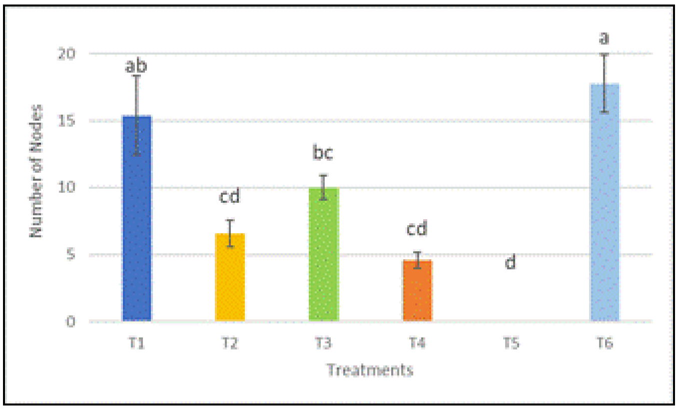

Figure 4. Number of nodes of *A. tricolor*. Each data item indicates the mean of the replicates. The error bar indicates the standard error. T1 (C) = soil only, T2 = 10% SMC, T3 = 20% SMC, T4 = 30% SMC, T5 = 50% SMC, T6 = Commercial fertilizer. Mean followed by the same letter are not significantly different ($p < 0.05$)

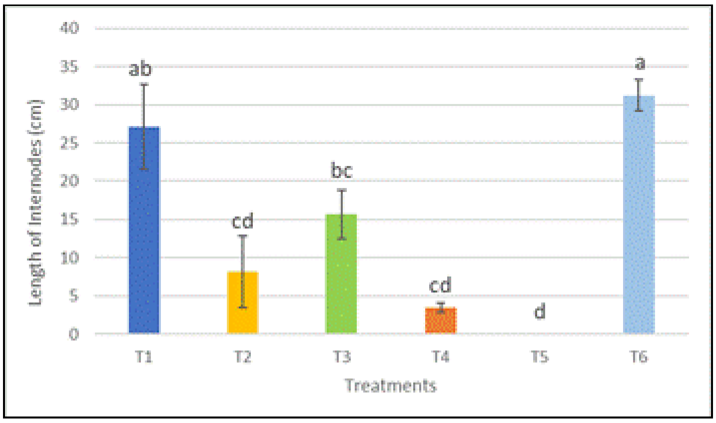

Figure 5. Length of internodes of *A. tricolor*. Each data item indicates the mean of the replicates. The error bar indicates the standard error. T1 (C) = soil only, T2 = 10% SMC, T3 = 20% SMC, T4 = 30% SMC, T5 = 50% SMC, T6 = Commercial fertilizer. Mean followed by the same letter are not significantly different ($p < 0.05$)

Figure 4 represents the number of nodes in *A. tricolor*. The use of commercial fertilizer (T6) produced highest number of nodes 17.80 ± 4.82^{a} more than the other treatments. The negative control T1 produced 15.40 ± 6.58^{ab} nodes, which was slightly lower than T6 but still higher than treatments with SMC amendments. Treatments having 10%, 20% and 30% of SMC had moderate nodal counts (6.60 ± 2.19^{cd}, 9.00 ± 2.00^{bc}, 4.60 ± 1.34^{cd}). While, we can see in Figure 4, T5 had the least number of nodes 0.00 ± 0.00^{d} indicating a significant inhibition of node information. Figure 5 represents the length of internodes in *A. tricolor*. The use of commercial fertilizer (T6) produced the highest length of internodes 91.90cm $\pm 8.92^{a}$ more than the other treatments. The negative control T1 had slightly more length of internodes with 27.10cm $\pm 12.50^{ab}$. Treatments having 10%, 20% and 30% of SMC had moderate length of nodal counts (8.16cm $\pm 10.63^{cd}$, 15.66cm $\pm 7.03^{bc}$, 3.48cm $\pm 1.45^{cd}$). While, we can see in Figure 5, T5 had the least length of internodes 0.00cm $\pm 0.00^{d}$ indicating a significant inhibition of node information. From the results, there is a positive indication of the number of nodes and length of internodes depending on the type of treatment in regard to various amendments done on the growth of *A.tricolor*. The highest node count in T6 proves the roles of the commercial fertilizer in the growth process of plants. These treatments provide nutrients that are essential to support a balance that is again supportive of plant development. It is noteworthy to reiterate that commercial fertilizers generally outcompete the organic ones where performance characteristics of the products is concerned and this based on several studies that have indicated the benefits to be obtained from the use of commercial fertilizers in improving growth and yield in plants (Khayoon & Reshag, 2024). However, the fact that the node count decreases at higher SMC application rates (T4 and T5) indicates that there could be an optimum level of SMC incorporation beyond which the effect is actually adverse. However, application of SMC in excess may increase the generation of organic acids and other microbial degradation products negatively effecting plant's rhizosphere and the number of nodes as well as internode length (Calleja-Cervantes et al., 2015).

Leave area of *A. tricolor* on day 30

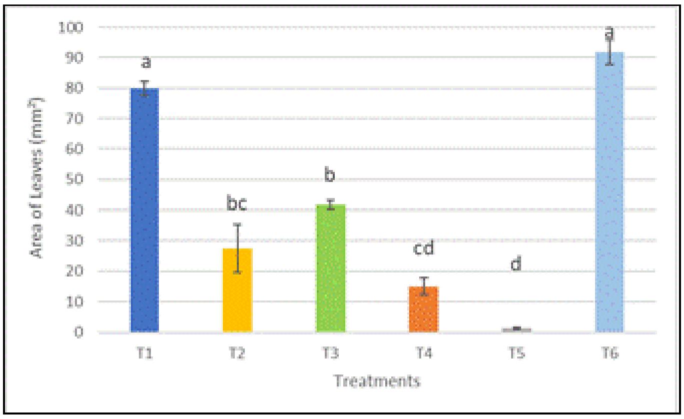

Figure 6. Leaves area of *A. tricolor*. Each data item indicates the mean of the replicates. The error bar indicates the standard error. T1 (C) = soil only, T2 = 10% SMC, T3 = 20% SMC, T4 = 30% SMC, T5 = 50% SMC, T6(CF) = Commercial fertilizer. Mean followed by the same letter are not significantly different ($p < 0.05$)

The results of this study indicate significant differences in the area of leaves among various treatments, highlighting the impact of different soil amendments on plant growth (Figure 6). From figure 6 the results show that T6 showed the greatest leaf area of 91.90 ± 8.92^{a}, while T5 resulted in the smallest leaf area at 1.40 ± 0.55^{d}. The other treatments, T1, T2, T3, T4 showed intermediate leaf areas, with T1 at 79.90 ± 5.46^{ab}, being statistically similar to T6, and T3 at 41.80 ± 3.17^{bc} being significantly greater than T2 and T4 ($p < 0.05$). In this case, the large leaf area observed in T6 could be due to a proper nutrition profile provided by the commercial fertilizer hence creating conducive environment for growth of the plants. This finding corresponds with previous research where nutrient availability was identified as a significant factor that enhances leaf growth as well as total plant biomass (Shan et al., 2021). The high leaf area in T1 also proves that only the soil can also contribute to a good result with regard to leaf area having approximately half that of the commercial fertilizer. Results regarding the effects SMC treatments showed a certain trend where greater increasing SMC concentration reduced leaf area in the following way: This high level of organic matter, especially SMC, could result in a shift in nutrient availability and an increase in microbial activities, these disparities may lead to a shrinkage of the leaf area since microorganisms can compete with plants for nutrients and in the process release possibly toxic compounds. (Michael et al., 2022).

Figure 7. Photograph of *A. tricolor* after harvest. T1 (C) = soil only, T2 = 10% SMC, T3 = 20% SMC, T4 = 30% SMC, T5 = 50% SMC, T6 = Commercial fertilizer

From Figure 7, it is evident that the morphology of *A. tricolor* varies significantly across treatments. The plant in T6 (commercial fertilizer) exhibits the most vigorous growth, with greater height, thicker stem, and more foliage. This indicates that commercial fertilizer supplies essential nutrients in readily available forms that promote rapid and healthy plant development (Jemo et al., 2015). Similarly, T3 (20% SMC) and T2 (10% SMC) show relatively healthy growth, indicating that lower concentrations of SMC can support plant development (Polat et al., 2009). However, growth performance began to decline at higher SMC levels. The plant in T4 (30% SMC) showed moderate growth, while T5 (50% SMC) resulted in the poorest growth, with stunted height and fewer leaves, possibly due to issues such as nutrient imbalances, excess organic matter, or phytotoxic compounds present in incompletely decomposed compost (Amarasinghe & Jayaweera, 2022). While T1 (soil only), produced plants with minimal yet better growth than T5.

Effects of Commercial Fertilizer and SMC on Soil Properties of *A. tricolor*

Soil pH

Table 2. Initial and Final pH

Treatments	Initial pH	Final pH
T1	8.09 ± 0.006^{c}	8.40 ± 0.04^{d}
T2	8.90 ± 0.12^{a}	8.56 ± 0.02^{c}
T3	8.39 ± 0.05^{b}	8.26 ± 0.01^{e}
T4	8.88 ± 0.02^{a}	9.14 ± 0.01^{a}
T5	8.32 ± 0.10^{b}	9.05 ± 0.01^{b}
T6	8.15 ± 0.006^{c}	7.04 ± 0.005^{f}

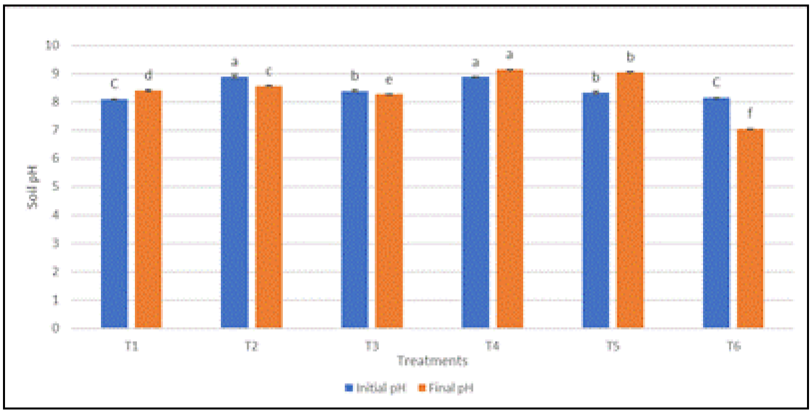

Figure 8. Initial and Final pH Each data item indicates the mean of the replicates. The error bar indicates the standard error. T1 (C) = soil only, T2 = 10% SMC, T3 = 20% SMC, T4 = 30% SMC, T5 = 50% SMC, T6(CF) = Commercial fertilizer. Mean followed by the same letter are not significantly different ($p < 0.05$)

Results in Figure 8 shows that there are significant differences in soil pH changes between the initial and final pH ($p < 0.05$). The initial pH of T1 was recorded at 8.09 ± 0.006 [c], which increased to 8.40 ± 0.04 [b] (Table 2) by the end of study, with an increase of 3.83%. This suggests that the natural buffering capacity of the soil helped maintain a stable pH. For treatment T2, the initial pH 8.90 ± 0.12 [a] decreased to 8.56 ± 0.02 [c] with a decrease of 3.82%. The decrease in pH observed in T2 suggests that the addition of SMC may increase soil pH due to its alkaline nature. This aligns with findings by (Zhang et al., 2023), indicating that organic amendments can influence soil acidity. Similar to T2, T3 also had a slight decrease in pH with 1.55%. T4 showed an increase in pH from 8.88 ± 0.02 [a] to 9.14 ± 0.01 [a]. The increase suggested that the high proportion of SMC can enhance soil alkalinity under certain conditions, hence, affecting the soil quality. The most increase in pH was observed in T5 with initial pH 8.32 ± 0.10 [b] to 9.05 ± 0.01 [b] (Table 2) and an increase of 8.77%. And the most striking result from figure 8 was observed in T6, where the initial pH of 8.15 ± 0.006 [c] decreased to 7.04 ± 0.005 [f], representing a 13.66% decrease. This considerable change in acidity indicated that the commercial fertilizer had acidifying elements that greatly reduced the pH of the soil (Guan et al., 2022). The results suggest that SMC can be effectively used to increase soil pH, thus can be recommended for use in soils with low alkalinity. However, the concentration of SMC must be controlled to ensure that it does not go high in order to avoid high alkalization. High concentration of SMC (T5) can increase the soil pH considerably, which may be disadvantages for taking up nutrients like iron, zinc which are more available at slightly acidic pH (Barrow & Hartemink, 2023). While commercial fertilizer can effectively reduce soil pH, making them useful for managing alkaline soils. High level of soil acidity is undesirable for the soil quality because they decrease the microbial functions and cause loss of essential nutrients which can diminish crop yields (Fageria & Baligar, 2008).

Soil Organic Matter

Table 3. Initial and Final SOM

Treatments	Initial SOM	Final SOM
T1	24.41 ± 0.10 [e]	29.34 ± 0.15 [d]
T2	18.10 ± 0.10 [f]	31.71 ± 0.10 [c]
T3	30.93 ± 0.08 [c]	42.20 ± 0.10 [a]
T4	36.68 ± 0.08 [b]	42.22 ± 0.08 [a]
T5	51.83 ± 0.08 [a]	36.17 ± 0.08 [b]
T6	25.35 ± 0.05 [d]	22.22 ± 0.008 [e]

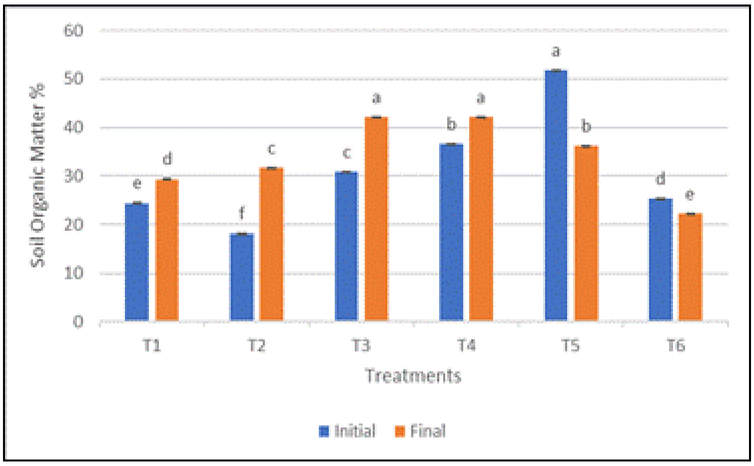

Figure 9. Initial and Final Soil Organic Matter Each data item indicates the mean of the replicates. The error bar indicates the standard error. T1 (C) = soil only, T2 = 10% SMC, T3 = 20% SMC, T4 = 30% SMC, T5 = 50%SMC, T6(CF) = Commercial fertilizer. Mean followed by the same letter are not significantly different ($p < 0.05$)

Result in Figure 9 shows that there is a significant difference of SOM changes between the initial and final SOM ($p < 0.05$). The initial SOM of T1 was recorded at 24.41 ± 0.10 ^{e}, which increased to 29.34 ± 0.15 ^{d} (Table 3) by the end of study, with an increase approximately 5% in SOM. For treatment T2, the initial SOM 18.10 ± 0.10 ^{f} increase to 31.71 ± 0.10 ^{c} with a significant increase of about 13% in SOM. The increase in SOM observed in T2 suggests that the effectiveness of SMC is 10% due to its rich organic material and nutrients. Similar to T2, T3 also showed a significant increase in SOM from 30.93 ± 0.08 ^{c} to 42.20 ± 0.10 ^{a} (Table 3). Other than that, SOM in T5 decreased from 51.83 ± 0.08 ^{a} to 36.17 ± 0.08 ^{b}. A decrease in SOM by approximately 16% was unexpected. This could be due to some issues such as excessive nutrient release. Lastly, SOM result in T6 decreased from 25.35 ± 0.05 ^{d} to 22.22 ± 0.008 ^{e}. The results indicate that the use of SMC raises the content of SOM. The most crucial favorable effect was obvious in T3 and T4, meanwhile, excessive SMC (T5) led to negative results. On the other hand, SOM decreased when commercial fertilizer was used (T6), which emphasized the necessity to apply organic supplements in order to support soil health. Nevertheless, T3 maintained high SOM levels stating that the amount of SMC was of positive effect on the soil. The main role of the compost in the experiment was to improve the soil there by the growth of the activity of microbes leading to the storage of more SOM (Durmuş & Kızılkaya, 2022) The unexpected decrease in SOM (T5) could be due to several factors. Excessive organic input may lead to nutrient imbalances therefore leading to increased microbial degradation of the organic materials than the rate of addition. Presence of high organic content may lead to the formation of anaerobic conditions which slow down the decomposition and results in formation of undecomposed material (Elumeeva et al., 2023).

Conclusion

In a nutshell, the results showed that commercial fertilizer (T6) led to the best plant growth, highlighting its quick effectiveness. Moderate level of SMC (20%) improved growth, suggesting that it can be a useful organic amendment. However, higher level of SMC (30% and 50%) didn't improve growth and may cause issues like nutrient imbalances and soil compaction. While the hypothesis that SMC could improve growth was supported at moderate levels, it's clear that too much can be harmful. Further research should explore the long-term effects of SMC on both soil health and plant growth to better understand its potential benefits and limitations.

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Author Contribution
Nabilah Jaludin – study design, data collection, analysis and interpretation of results and manuscript preparation
Dr Lili Syahani – supervision and review

Conflict of Interest
Authors declare no conflict of interest.

Declaration on the Use of Generative AI
Authors declare no generative AI used in the manuscript.

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