https://doi.org/10.17221/116/2025-RAE

Biodegradable seedling pots from sawdust and spent mushroom compost

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Citation: Conduah J.K., Kumi F., Murangaza H.F., Osei S. (2025): Biodegradable seedling pots from sawdust and spent mushroom compost. Res. Agr. Eng., 71: 247–258.

Abstract: Circular bioeconomy is rapidly gaining ground in the agricultural sector with priority given to the utilisation of more environmentally friendly materials for production and processing. Thus, in this study, biodegradable seedling pots were developed using sawdust (SD) and spent mushroom compost (SMC) as a sustainable alternative to plastic containers. Four pots composed of SMC : SD ratios of 100 : 0, 70 : 30, 60 : 40, and 50 : 50 were developed and evaluated. The mechanical properties, structural characteristics, and water absorption capacity of the pots were assessed and seedlings were made to grow in them to monitor the growth support potential. A universal tensile test machine was used to assess the indirect tensile strength (mechanical properties), while a scanning electron microscope was used to examine the morphology of the samples. Also, images of the seedling roots were segmented and analysed in ImageJ and WinRHIZO software to determine the root system architecture. The results demonstrated that the 60 : 40 ratio exhibited superior performance including having optimal water absorption capacity, indirect tensile strength, and structural properties. The 70 : 30 ratio also showed comparable tensile strength values. However, increasing the SMC content in the pot improved the root developments. This research presents a viable solution for converting agricultural waste into environmentally friendly seedling containers and suggests a potential option for reducing the dependency on plastic pots in agriculture.

Keywords: circular economy; growth; ratios; structure; tensile properties; water absorption

Globally, there has been an increased production of plastics with majority of them ending up as litter or in landfills after use (Kehinde et al. 2020). In agriculture, plastics are used as films for soil mulching, packaging materials, sacks, threads and ropes, pots, protective nets and shading. However, plastic waste alters the soil's porosity, limiting the aeration (Chen et al. 2024), negatively affecting the microbial growth, reducing the soil fertility as well as having the risk of being built up into crops, exposing consumers to cancer risks (Wang et al. 2021).

Funded from the Sam and Emelia Brew Butler School of Graduate Studies/Graduate Student Association of Ghana Research Grant. It was also financially supported by the Revenue Diversification pathways through biobased and circular agricultural innovations in Africa (DIVAGRI) funded by the European Commission Horizon 2020 under Grant Agreement No.101000348.

https://doi.org/10.17221/116/2025-RAE

It is therefore important to monitor and address the challenges posed by the overuse of plastic containers and materials for major agricultural operations. One of the key activities on the farm which makes use of plastics is the transplanting of seedlings. Growing seedlings for transplanting in pots or trays has long been a common practice in plant nurseries and greenhouses in many temperate and sub-tropical areas of the world. Usually, transplanting pots or trays are made of non-renewable materials including polystyrene, polyethylene, and propylene. These materials are expensive and non-degradable (Rosenboom et al. 2022) and could release harmful chemicals and microplastics into the soil and, over time, affect the soil fertility and health (Mészáros et al. 2023).

The recent advocation of an agricultural circular bioeconomy has led to many resorting to using other materials other than plastics including paper, straw, manure, coconut fibres, peat, wood fibres, and mixes of polyester and plant fibres as well as a combination of hemp fibres and chicken feathers for making pots for the purpose of raising seedlings (Evans et al. 2010). In Ghana and other countries in Sub-Sahara Africa, forest resources like timber which contribute significantly to the economy could be more beneficial if other waste emanating from the products during processing such as sawdust are exploited and utilised (Ampadu and Yang 2024). Additionally, mushroom farming is a booming business and through innovative biotechnology practices, farmers and actors in the value chain have been introduced to various appropriate technologies to help increase productivity. However, the aftermath of mushroom production has left producers to deal with large chunks of spent compost materials which, if not well managed, could pose serious environmental risks to people. Hence, finding a better use for the sawdust and spent mushroom compost pots could promote resource use efficiency and environmental sustainability.

Consequently, there is little information on the development of such pots using the aforementioned materials and the characterisation of their properties. Even for a few cases found in the literature; the key properties have rarely been investigated. According to a study by Beeks and Evans (2013), biodegradable pots lose more water and contain more algal and fungal development than plastic ones. Also, their tensile and structural properties have not received much attention. This work aimed at developing and evaluating the performance of biodegradable seedling pots composed mainly of sawdust and spent mushroom compost. The pots were assessed in relation to their mechanical and structural properties as well as the water absorption nature. The potential of the pots to support seedling development was also assessed using pepper as a test crop.

MATERIAL AND METHODS

Study areas. The moulding of the pots was conducted at the Cape Coast Technical Institute while the pepper seedling pot performance test was conducted in a greenhouse at the Alexander G. Technology Centre of the School of Agriculture, University of Cape Coast, both located in Cape Coast in the Central Region of Ghana. The morphological and mechanical properties of the biodegradable seedling pots were assessed at the Regional Water and Environmental Sanitation Centre Kumasi (RWESCK) Laboratories at Kwame Nkrumah University of Science and Technology in Kumasi and the Aviation Industry Corporation of China (AVIC) Centre at the Cape Coast Technical University, respectively.

Materials. Sweet pepper (*Capsicum annuum* L.) – which is commonly cultivated and consumed in Ghana – seeds ('Yolo Wonder' variety) were used in this study. Also, a white glue (Simater Company Limited, P.R. China) – made up of 50% polyvinyl acetate (PVA), 45% polymer water and 5% additives like plasticisers, stabilisers, and preservatives – was used as a binding material in producing the pots. The PVA composites have the potential of being biodegradable when mixed with other natural fibres (Saini et al. 2025). Additionally, such composites maintain their essential binding properties while significantly reducing the environmental impact, which is a critical sustainability factor (Iqbal et al. 2024).

Plywood was used for moulding the pots with the dimensions (shown in Figure 1) taken using a ruler before cutting, and joining them. The different proportions of the spent mushroom compost (SMC) and sawdust (SD) were then prepared to be used for the development of the pots.

An AEVO MA 15 (Zeiss, Germany) scanning electron microscope was used to examine the mor-

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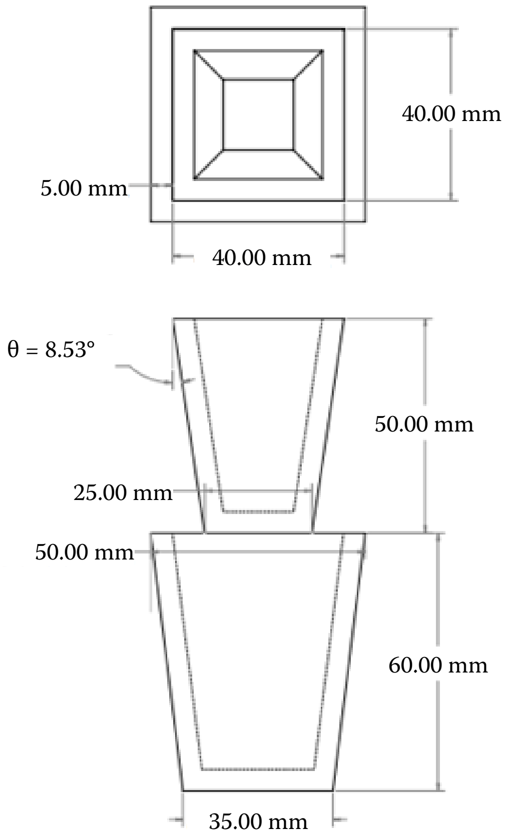
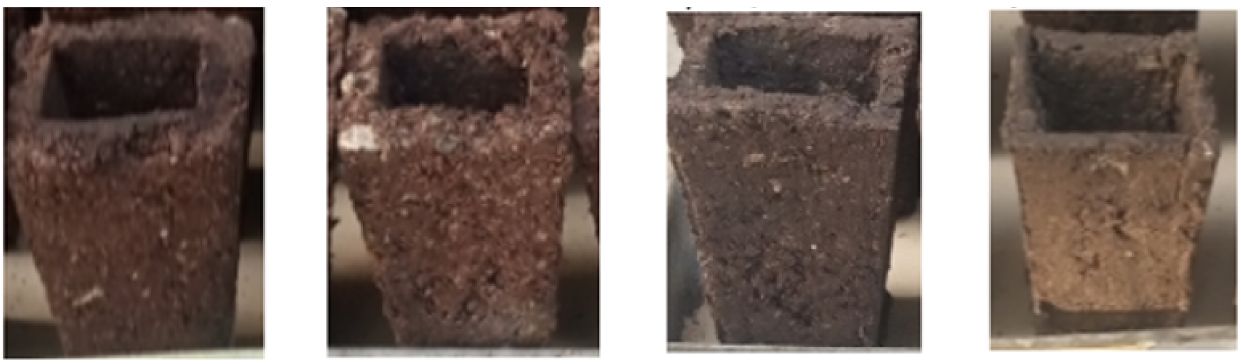


Figure 1. Schematic drawing of the pot mould

phology of the samples while a Universal tensile test machine was used to assess the indirect tensile strength of the samples (Figures 3, 4, and 5).

Methods. Upon several considerations and assessment criteria, using key criteria, such as the ease of moulding and removal of seedlings from the pots and the shape of commonly used trays, the trapezoidal design concept was chosen for moulding the pots as shown in Figure 1. The moulded pots are also shown in Figure 2.

The raw SMC and SD were sun-dried for five days to an average moisture content of 10%. The raw SD was characterised by a mean pH of 5.41 and cation exchange capacity (CEC) of 3.71 $cmol.kg^{-1}$ with the particle size distribution showing approximately 70.8% of particles passing through a 2 mm mesh sieve. The characteristics of the raw SMC included a mean pH of 9.96 and a CEC of 2.15 $cmol.kg^{-1}$. In the case of the particle size analysis for the SMC, approximately 76.9% of the particles passed through a 2 mm mesh sieve. Generally, the raw inputs of the latter were finer than the former since no particle passed through the sieve with a mesh size of 0.1 mm for the SD while that of the SMC recorded 13.8% particles successfully passing through the same sieve. Prior to using them for moulding pots, both materials were further ground to allow all the particles to pass through a 2 mm mesh sieve. In preparing the materials for forming the pots, a constant mass of white glue (25 g) was manually mixed with different proportional compositions with 75 g of SMC used for the 100% SMC100 : SD0 pots, 52.5 g of SMC and 22.5 g of SD for the SMC70 : SD30 pots, 45 g of SMC and 30 g of SD used for the SMC60 : SD40 pots while 37.5 g of SMC and 37.5 g of SD were utilised as components for the SMC50 : SD50 containers. Each mixture was then manually pressed into the pot mould. The pots were then removed from the mould and stored in a dry container at room temperature. In the end, twenty (20) pots per formulation were produced making a total of eighty (80) pots available for the work.



(A) (B) (C) (D)

Figure 2. Moulded pots with different pot compositions – (A) SMC50 : SD50, (B) SMC60 : SD40, (C) SMC70 : SD30 and (D) SMC100 : SD0

SD – sawdust; SMC – spent mushroom compost

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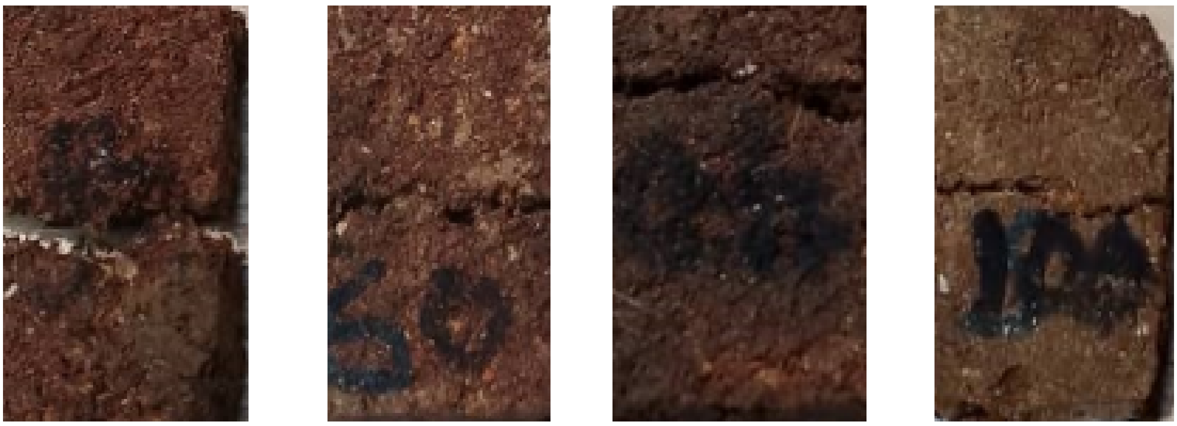
(A) Tensile machine without load (B) Tensile machine with load

Figure 3. Universal tensile testing machine for the tensile testing of the samples

(A) 50 : 50 (B) 60 : 40 (C) 70 : 30 (D) 100 : 0

Figure 4. Samples before the tensile test



(A) 50 : 50 (B) 60 : 40 (C) 70 : 30 (D) 100 : 0

Figure 5. Samples after the tensile test

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In determining the moisture content, an empty cup was dried at 105 °C for 15 min, then cooled in a desiccator and weighed (W_1). The mass of each pot sample (W) was measured before placing it in the cup. It was then heated at 105 °C until its mass remained constant. Afterwards, the cup with the sample was cooled using a desiccator and weighed (W_2). The moisture content was determined using the given formula.

$$\text{Moisture content} = \frac{[W - (W_2 - W_1)]}{W} \times 100\% \qquad (1)$$

where: W – the initial mass of the sample (g); W_2 – the mass of the dry sample and the cup (g); W_1 – the mass of the empty cup (g).

In terms of the water absorption of the dry pots, each was measured by initially weighing them and recording this as W_0. After submerging the samples in distilled water for ten minutes at room temperature, they were weighed again. Any excess water on the specimen's surface was gently removed with a moist towel before taking this measurement. This mass was recorded as W_f. The water absorption rate (Q) was then calculated using the average results from three repetitions of this procedure and applying the following equation:

$$Q = \frac{W_f - W_0}{W_f} \times 100\% \qquad (2)$$

where: Q – the water absorption rate (%); W_0 – the mass of pot before immersion (dry pot) (g); W_f – the mass of pot after immersion (wet pot) (g).

One crucial factor that shows how well the biodegradable seedling pots can be handled is their tensile strength. During plant growth and physical developments, the pots are usually subjected to tensile loads especially on the pots walls and therefore it was important to assess their tensile strengths in this work. The tensile strength, elongation at break, and other tensile properties significantly influence the performance and quality of the pots. The tests were performed on biodegradable pot specimen measuring 20 mm by 60 mm, with an extension rate of 2 mm.min^{-1}. Each sample was replicated three times.

Every sample was subjected to a load of 10 kN, to ascertain the extent to which each pot could withstand deformation. The test was conducted in accordance with the American Society for Testing and Materials (ASTM) Standards.

Also, the structural characteristics of the samples were determined by finely cutting portions into pieces and a sub-sample was placed into a steel sample holder. The diffractometer operated at 30.0 kV and 10.0 mA, with a diffraction angle range of 4.998° to 79.996°, at intervals of 0.01°, and a count time of 64 s per step. Scanning Electron Microscopy with Energy Dispersive X-ray (SEM-EDX) was then utilised to scan and assess the morphology of the samples. All the samples were assessed in triplicates.

The next stage was to carry out the greenhouse experiment to determine how pepper seedlings develop in the pots over time. The experimental design employed in this aspect of the study was a completely randomised design (CRD). The greenhouse experiment for testing the performance was conducted using four (4) pots for each pot composition and replicating three (3) times. The developed biodegradable seedling pots were then tested to evaluate their suitability for growing seedlings by taking data on the plant height, number of leaves, and stem diameter.

The process of seed propagation began by filling individual pots with a growing medium (a mix of coconut coir and peatmoss) and the seeds were nursed on May 11th 2024 in a greenhouse at the Alexander G. Carson Technology Centre of the University of Cape Coast, Cape Coast, Ghana. The seeds were sown in each pot. The pots were placed in the greenhouse, where the seedlings were nursed for a period of twenty-eight (28) days. In the end, the parameters, such as the plant height, number of leaves per plant and stem diameter, were documented for each individual plant within the designated pots.

Also, the characteristics of the pepper root architecture were assessed by excavating the whole plant out of the growing media, carefully cleaning the roots, and then imaging the root systems using a professional camera. The root system was then segmented from the background using Otsu thresholding techniques (Otsu 1979). The segmented images were then converted into a binary format, where the roots appeared as white pixels against a black background. The roots were analysed using ImageJ and WinRHIZO to quantify the traits like the total root length, surface area, volume, diameter distribution, and branching pattern. Figure 6 shows an example of an excavated root which was binarised and analysed.

Figure 6. Excavated and washed (left), binarised (middle) and analysed (right) roots

The data collected on the plant height, number of leaves, stem diameter, root parameters and tensile strength were analysed using the 2021 version of Minitab. An analysis of variance (ANOVA) was performed, with the means separated at 5% significance level using the Tukey and Fisher least significant difference (LSD) tests.

RESULTS AND DISCUSSION

Evaluation of the physical and mechanical properties. The water absorption rates results were investigated using different ratios of SMC and SD treatments for 10 min (Figure 7) with the 60 : 40 (SMC : SD) ratio showing an optimal absorption of 22%. The pure SMC composition (100 : 0) consistently showed lower absorption rates compared to the mixed ratios. The superior performance of the mixed ratios can be attributed to the complementary properties of the used materials. SMC usually contributes a high organic matter content, enhancing the nutrient availability and moisture retention while sawdust's porous structure facilitates improved aeration and water retention and drainage capabilities (Del Sole et al. 2023). This synergistic relationship creates an optimal environment for water absorption and retention, supporting the findings from previous studies on organic material combinations. Thus, the increase in the observed water absorption is a characteristic of lignocellulosic materials in agricultural waste composites like sawdust. Liang et al. (2021) demonstrated enhanced performance in the enzymatic saccharification of mixed sawdust waste, an indication of the structural integrity provided by sawdust for improved mechanical strength and stability while simultaneously promoting better air circulation within the composite material. These findings suggest that the 60 : 40 ratio represents an optimal balance between SMC's nutrient-rich composition and sawdust's structural properties, with practical implications for agricultural and horticultural applications.

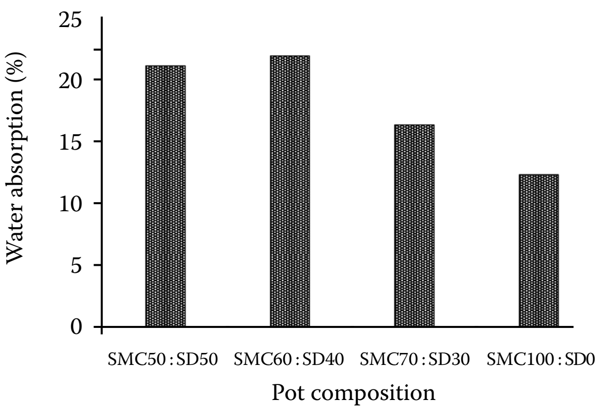

Figure 7. Rate of water absorption

SD – sawdust; SMC – spent mushroom compost

The mechanical test produced a load-displacement curve with the aim of assessing the mechanical behaviour of the composition ratio of the spent mushroom compost (SMC) and sawdust (SD), and it showed differences in their properties. The areas under the load-displacement curves of 70 : 30 and 60 : 40 were the highest followed by 50 : 50 mixture with the 100 : 0 recording the lowest. This shows that the two ratios (70 : 30 and 60 : 40) can potentially store more energy and resist deformation more than the others. With respect to the tensile load capacity, the pure SMC was notably low, likely due to the material's structural characteristics and failure mechanisms (Ogi and Yamanouchi 2011) which may not be able to withstand excessive loads.

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With a noticeable increase in the load and peak displacement of about 7 mm, the 60 : 40 and 70 : 30 mixtures exhibited a greater tensile load capacity as compared to the 100 : 0 mixture. The structural properties of the material could be responsible for this improved performance. An increased tensile load capacity is demonstrated by the 60% SMC and 40% SD mixture, which showed a sharp rise in load with a peak load occurring at approximately 7.5 mm displacement. The special qualities of SMC and the combined impacts of the SD composition could potentially be responsible for this improvement (Kabelka et al. 1996). Overall, 70 : 30 followed by 60 : 40 seem to have had the highest tensile strength at its peak load of more than 9.5 kN. Figure 8 shows the yield point at which material failure occurred, indicating the limit of elastic behaviour and the onset of plastic deformation in the material. The observation on the mechanical properties of the bio-pot shows the pots composition of 70 : 30 had the maximum resistance load of 7 kN at the yield point with an ultimate point of 9 kN and 10 kN failure point, followed by 60 : 40 and the remaining pots demonstrating slight variations. All the pots exhibited similar elastic behaviour up to 3–4 kN, indicating consistent compressive properties. Nevertheless, a notable transition occurred at the 0.5–1 mm displacement, where the load resistance sharply increased, followed by stabilisation. This behaviour could be due to the weak strength of the organic waste composite materials when subjected to mechanical load. The ultimate load capacity convergence at 9–10 kN across the variants demonstrates the material's consistent strength characteristics. Particularly interesting is the uniform

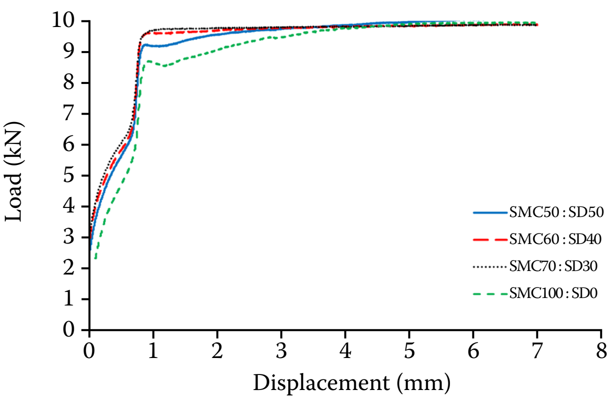

Figure 8. Load-displacement curve from tensile test on the bio-pots

SD – sawdust; SMC – spent mushroom compost

plateau behaviour observed in SMC50, SMC60, and SMC70 compared to SMC100, which can be attributed to variations in the composition ratio and particle size distribution within the spent mushroom substrate and sawdust. As noted by Brunetti et al. (2009), these properties make SMC and SD suitable for applications requiring specific load-bearing capabilities, such as landfill covers or soil amendments. Higher composition levels may have enhanced their mechanical properties, contributing to their load-bearing capabilities. Additionally, Martín et al. (2023) suggested that a more uniform particle size in SMC and SD variants can lead to better compaction and strength, enhancing the load-bearing performance.

The morphology and structure of the biodegradable pots was examined using scanning electron microscopy (SEM) to analyse the particles binding various composition of the pots developed. The plates below in Figure 9 show an SEM sample for each pot composition. The presented images illustrate the particle-binding properties of biodegradable pots created using SD and SMC in various composition ratios. When evaluating the pots' structure, the SEM approach works well (Yang et al. 2016) and, as a result, the morphological and structural characteristics of the pot's composition are exhibited by scanning electron microscopy (SEM) images. Usually, physical qualities of the material combinations characterise different pots (Díaz-Pérez and Camacho-Ferre 2010). Hence, while a combination of 50% SMC and 50% SD shown in Figure 9A created a porous structure that facilitates moderate particle binding and adhesion, making it suitable for various applications, it is quite different from the others. The composition ratio of 60% SMC to 40% SD results in a more cohesive and compact structure resulting in an enhanced particle binding effect.

Also, a dense and well-bound structure was produced by the composition of 70% SMC and 30% SD, which increases the material's durability and potentially decreases its porosity. This combination makes use of compounds, making up the nutrient profile that contributes to the structure which include mycelium and vital organic materials, while the sawdust could potentially help maintain the composite's structural integrity.

The use of 100% SMC without sawdust results in a highly cohesive and compact structure, demonstrating more particle binding and adhesion ef-

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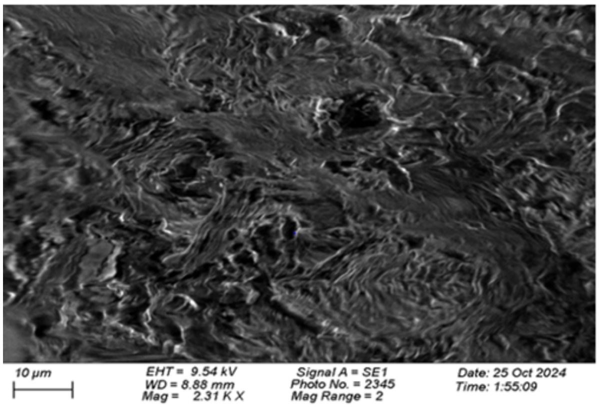
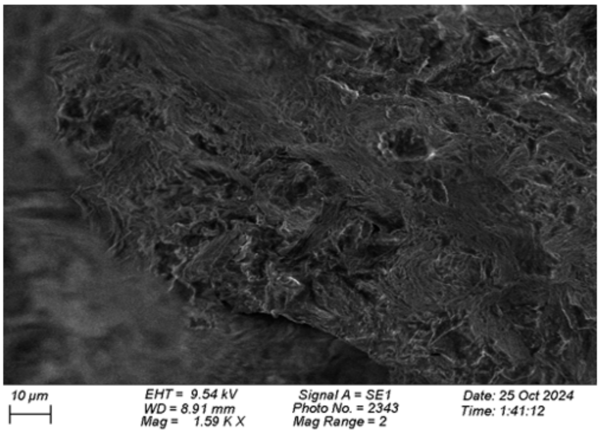
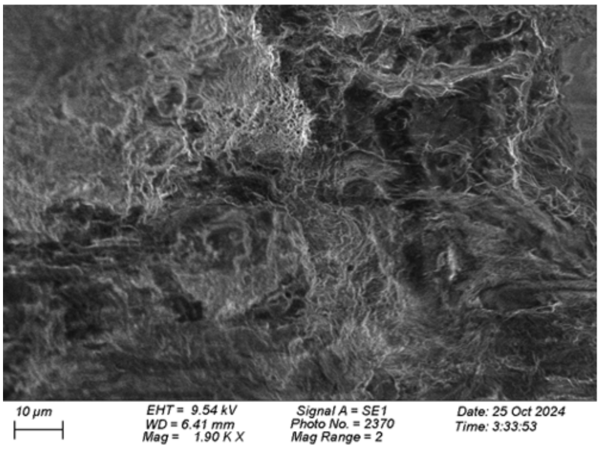


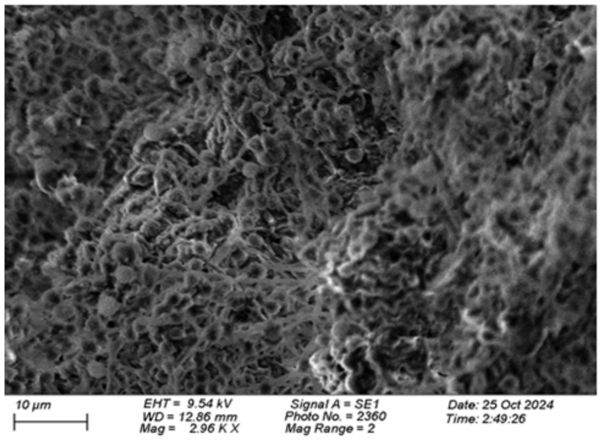
(A) SMC50 : SD50



(B) SMC60 : SD40



(C) SMC70 : SD30



(D) SMC100 : SD0

Figure 9. SEM images of the profile for the (A) SMC50 : SD50, (B) SMC60 : SD40, (C) SMC70 : D30, (D) SMC100 : SD0 pots

SD – sawdust; SMC – spent mushroom compost

fects likely culminating in poor particle spaces and potentially a low rate of water absorption and aeration. This characteristic, though undesirable, could be attributed to the high organic matter content and active ingredients present in the SMC, which enhance the binding properties of the compost particles (Mwangi et al. 2024). The observations imply that the particle binding and adhesion improve with increasing SMC content in the mixture. A larger SMC concentration seems to improve the material's cohesive qualities, resulting in a less porous and more consolidated structure. All of the composition ratios showed the 60 : 40 and 70 : 30 samples depicting more structural prominence to support plant growth.

Pepper seedlings above-ground growth performance on the various pot compositions. The material composition of biodegradable pots significantly influences their degradation patterns under various environmental conditions. Moisture plays a crucial role in the degradation rates and thus pots manufactured from peat and coconut fibre break down more rapidly in consistently moist environments, while fluctuating moisture levels, on the other hand, delay the degradation process (Hubbe et al. 2025). The water-retention properties of biodegradable materials are particularly beneficial for vegetables, which require consistent moisture. Hence, the experiment on the development of the seedlings in the biodegradable pots was assessed by monitoring the plant height, number of leaves and stem diameter.

The experimental results (Figure 10) indicate that the plant heights vary across different SMC : SD ratios, with the maximum plant height (10 cm) achieved at a composition ratio of SMC60, SD40.

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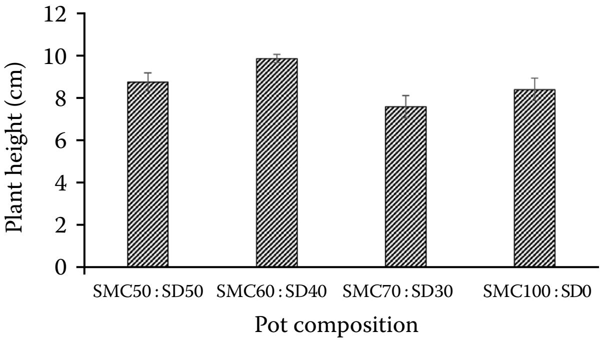

Figure 10. Effects of various pot compositions on the pepper plant height

SD – sawdust; SMC – spent mushroom compost

This was followed by a height of 8.8 cm with the composition ratio of SMC70, 8.5 cm with SMC50, and 7.5 cm with SMC100. The observed variations in plant height can be attributed to the balanced nutrient profile and improved aeration provided by the 60 SMC pot. There was significant difference (P < 0.05) among the various composition ratios related to the plant height implying that the composition had an effect on the plant height.

According to Jasińska (2018), SMC is rich in essential nutrients such as nitrogen (N), phosphorus (P), and potassium (K), which are vital for plant growth. Also, it can significantly enhance the soil fertility and microbial diversity, thereby promoting healthier plant development. The combination of SMC and SD creates an optimal environment for seed germination and plant growth. This could support the superior performance of the SMC60 : SD40 composition ratio. The utilisation of SMC and SD aligns with the principles of a circular economy, as it reduces waste and promotes sustainable agricultural practices.

Figure 11 demonstrates a slight variation in the number of leaves on the pepper plants across different ratios of the spent mushroom compost (SMC) and sawdust (SD).

The SMC60 : SD40 ratio, again, exhibited the highest number of leaves of the seedlings compared to those growing in other pots with different ratios. According to Logendra et al. (2001), an increase in the number of leaves of plants tends to enhance its photosynthetic activities and underscores the potential for increased photosynthate and, consequently, higher productivity. The role of SMC in enhancing the growth of pepper plants is attributed to its ability to improve the nutrient availability, particularly phosphorus, which is essential for root and leaf development (Roy et al. 2015).

Another key growth parameter that could point to a healthy seedling development is the stem diameter, which, if developed well, tend to help move the absorbed water and minerals from the roots to various parts of the plant and store nourishment and the movement of the sugar produced by photosynthesis from the leaves to the other parts of the plant. In this instance (Figure 12), SMC60 and SMC100 supported the best seedling stem performance.

There was a significant difference among the treatment means for the stem diameter data (P < 0.05), with the 100% spent mushroom compost (SMC) pot having improved the seedling growth, especially in terms of stem diameter followed by 60% SMC and 40% SD. In comparison to a balanced composition of 50% SMC and 50% SD, higher quantities of SMC, such as 100% SMC, showed better effects. Generally, seedlings cultivated at greater SMC concentrations lead to larger stems (Zeljković et al. 2021). Furthermore, optimum height and stem

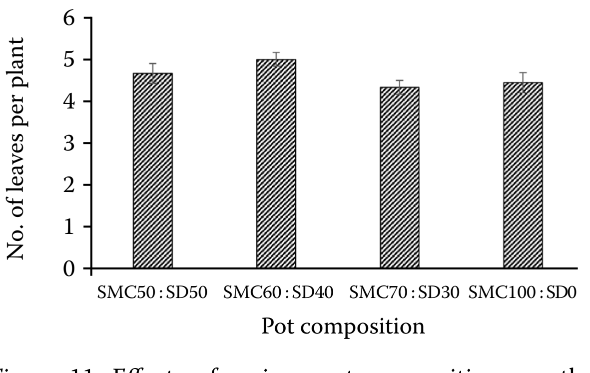

Figure 11. Effects of various pot compositions on the number of leaves per plant

SD – sawdust; SMC – spent mushroom compost

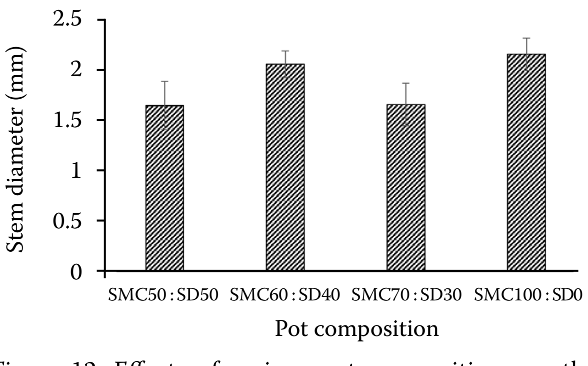

Figure 12. Effects of various pot compositions on the pepper stem diameter

SD – sawdust; SMC – spent mushroom compost

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Table 1. Root system architecture

Treatment	Convex area (mm^2)	Depth (mm)	Lower root area (mm^2)	Maximum diameter (mm)	Maximum number of roots	Network area (mm^2)	Number of root tips	Perimeter (mm)	Surface area (mm^2)	Total root length (mm)	Volume (mm^3)
SMC50	8 613^{a}	15.2^{a}	2 273 ^{a}	1.5^{a}	11.8^{a}	2 081^{a}	275^{a}	444.3^{a}	10 752^{a}	335.4^{a}	54 823^{a}
SMC60	11 500^{b}	21.3^{a}	3 163^{ab}	2.4^{b}	16.3^{b}	3 368^{b}	410.3^{b}	531.3^{a}	23 402^{b}	449.8^{b}	94 835^{a}
SMC70	17 413^{c}	34.9^{b}	4 214 ^{b}	3.1^{c}	21.3^{c}	4 896^{c}	521.7^{c}	666^{ab}	29 333^{b}	499.4^{b}	264 812^{b}
SMC100	25 325^{d}	45.4^{c}	6 326^{c}	3.6^{d}	26^{d}	7 013^{d}	640.3^{d}	761.8^{b}	45 784^{c}	690.2^{c}	333 660^{c}
P-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
LSD	1 619.8	6.3	1 072	0.38	2.81	771.4	38.2	160.4	7 000.2	72.2	31 135.7
CoV (%)	5.2	10.8	13.4	7.1	7.5	8.9	4.1	13.4	12.8	7.3	8.3

$^{a–d}$Means followed by the same superscript letters are not significantly different at a 95% confidence interval; CoV – coefficient of variation; LSD – least significant difference; SD – sawdust; SMC – spent mushroom compost

diameters were observed in 60 : 40 ratios giving a good stem : height ratio which is key to assess its suitability of producing quality seedlings.

Effects of various pot compositions on the pepper root system architecture. At the maturity stage (28 days) of the pepper seedlings, all the plants were excavated out of the growing media, followed by an analysis of the root system architecture. The root system architecture of pepper plants results have been presented in Table 1 [the measured traits showed highly significant differences among treatments ($P < 0.001$)]. The 100% SMC consistently demonstrated superior performance across nearly all the traits. It recorded the highest values for convex area (25 325 mm^2), depth (45.4 mm), lower root area (6 326 mm^2), maximum diameter (3.6 mm), number of roots (26), network area (7 013 mm^2), number of root tips (640.3), perimeter (761.8 mm), surface area (45 784 mm^2), total root length (690.2 mm), and root volume (333 660 mm^3). In contrast, the 50% SMC generally recorded the lowest values in most traits, indicating that, under the application of SMC, it may limit root development. Notably, the 60% and 70% SMC produced intermediate values, with significantly higher root tips and root volume compared to SMC50. The coefficients of variation (CoV) ranged from 4.1% (number of root tips) to 13.4% (lower root area), indicating acceptable experimental precision. The results demonstrate that more compost provides the optimal conditions for enhancing the root system development in peppers, likely due to the supply of the offered organic matter properties.

The enhanced network area (7 013 mm^2) and surface area (45 784 mm^2) in SMC100 suggest that this pot potentially achieves optimal physical characteristics and that the spent mushroom substrate contains beneficial microorganisms and plant growth-promoting compounds that can enhance the root development as indicated by Raviv et al. (2002).

CONCLUSION

Biodegradable seedling pots composed of SD and SMC were developed with different SMC : SD ratios (50 : 50, 60 : 40, 70 : 30 and 100 : 0) exhibiting promise as eco-friendly substitutes to traditional plastic containers used for growing seedlings. The material's mechanical, structural and physical qualities are among the attributes that define the quality of the biodegradable pots. Developing and using biodegradable containers is meant to accomplish the sustainable agricultural goal of striking a balance between environmental concerns and productivity.

According to the findings of this study, a composition of an SMC : SD ratio of 60 : 40 results in greater water absorption, with the lowest recorded with the 100 : 0 ratio. The load-displacement curve recorded from the indirect tensile strength test also showed highest strength recorded closely in the 60 : 40 and 70 : 30 ratios with the 100 : 0 ratio having the least strength. In the 60 : 40 formulations, the highest results for water absorption and tensile strength, were at 22% and 10 kN, respectively. Also, according to the seedling tests, pepper plants grew better in the

https://doi.org/10.17221/116/2025-RAE

biological pots with a 60% SMC and 40% SD for the above ground seedling growth followed by 70% SMC and 30% SD. However, the roots developed better in pots with higher compositions of SMCs.

In summary, the study provides relevant information on the development of biodegradable seedling pots made from sawdust and spent mushroom compost as a sustainable alternative to plastics. The biodegradable options not only support plant health, but also contribute to reducing plastic waste while offering a promising solution for sustainable agriculture. Using biodegradable pots instead of plastic offers a welcome solution to reducing waste and supporting healthier plant development due to the fact that the pots can decompose when placed in the soil, add nutrients and relieve seedlings of transplanting shock. Also, transitioning to biodegradable pots will help reduce the overreliance on fossil fuels used for producing plastics, minimise the environmental plastic disposal nuisance and improve the soil health. On the small-scale farming levels, biodegradable pots could be implemented as part of sustainable gardening practices. They could promote the concept of an agricultural circular economy and environmental sustainability while creating job opportunities for people.

Further studies could be conducted to utilise other types of composts and agricultural wastes with or without SD and SMC and subsequently assess the long-term resilience of plant pots composed of biodegradable materials, their level of biodegradability and their ability to withstand different climatic conditions. Additionally, more work could be done to standardise biodegradable pots and assess customer acceptability as well as their environmental effects at every stage of their life cycle. In order to increase the sustainability and feasibility of plant pots made from biodegradable materials and encourage their market adoption, these research gaps need to be filled.

Acknowledgement: We thank Mr. Aidoo from Cape Coast Technical Institute, Cape Coast for his great assistance in developing the pot mould.

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Received: July 19, 2025
Accepted: October 15, 2025
Published online: December 9, 2025