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SCHOLARLY, PEER REVIEWED
Volume 26 No. 9
October 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Afr. J. Food Agric. Nutr. Dev. 2026; 26(9): 30842-30860 https://doi.org/10.18697/ajfand.156.26700

Date	Submitted	Accepted	Published
	7th December 2025	14th September 2026	19th November 2026

EVALUATION OF SAWDUST AMENDED WITH PIG AND GOAT MANURE ON CABBAGE SEEDLING GROWTH

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Volume 26 No. 9
October 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

ABSTRACT

High media costs, coupled with poor germination and seedling performance, render cabbage nursery and field production enterprises unsustainable for numerous disadvantaged small-holder farmers. There is limited knowledge on the use of readily available organic materials, such as sawdust and sawdust amended with animal manure for raising cabbage seedlings. The aim of this study was to investigate the effect of sawdust amended with pig and goat manure on cabbage seedling growth as an alternative growing medium for resource-poor smallholder farmers. The study was conducted in a controlled environment using a randomized complete block design (RCBD) with four replicates and nine treatments. Treatments consist of 100 % sawdust (SD), 100 % pig manure (PM0), 25 % sawdust plus 75 % pig manure (PM1), 50 % sawdust plus 50 % pig manure (PM2), 75 % sawdust plus 25% pig manure (PM3), 100 % goat manure (GM0), 25 % sawdust plus 75 % goat manure (GM1), 50 % sawdust plus 50 % goat manure (GM2), and 75 % sawdust plus 25 % goat manure (GM3 [MO1.1]). The following seedling growth parameters were measured: seed germination, shoot height (cm), number of leaves, stem diameter (mm), leaf length (cm), chlorophyll content, seedling height (cm), root-to-shoot ratio, and fresh and dry biomass (g). The results showed that treatments 25 % sawdust plus 75 % pig manure and 50 % sawdust plus 50 % pig manure produced cabbage seedlings with good growth characteristics. Results also revealed that the application of pig manure significantly increased these growth parameters compared to sawdust alone and the mixture with goat manure. The maximum and significantly higher increment in growth parameters was observed with the application of 50% sawdust plus 50% pig manure, followed by 75% sawdust plus 25% pig manure, and then 25% sawdust plus 75% pig manure. In conclusion, treatment with 50 % sawdust plus 50 % pig manure is recommended as the most desirable growing medium for raising cabbage seedlings for the disadvantaged small-scale farmers.

Key words: pig and goat manure, germination, sawdust growth media, seedling quality, cabbage

Citation: Manyaku A and SM Ngwenya Evaluation of Sawdust Amended with Pig and Goat Manure on Cabbage Seedling Growth. *Afr. J. Food Agric. Nutr. Dev*. 2026; **26(9):** 30842-30860.
https://doi.org/10.18697/ajfand.156.26700

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INTRODUCTION

Modern nurseries are used to produce high-quality, disease-free seedlings in the horticulture industry. However, the quality of the seedlings is mainly determined by the attributes and nutritional content of the growing media. There is growing interest in using organic waste as a growing medium. Organic growing media have been shown to improve plant growth by increasing the porosity and water retention of the growing medium [1]. Organic materials such as peat, compost, vermiculite, and sawdust have attracted researchers for their effects on seedling quality [2-5]. Sawdust material is a waste product from the processing of wood [6]. It is less expensive than imported growing media such as peat and perlite; sawdust can be used as a growing medium [7]. The use of sawdust as a plant growth medium in industrial areas has increased due to its favourable physical properties, including acceptable biodegradability, low surface-specific gravity, high porosity and high-water retention, moderate drainage, and high bacterial tolerance [1,8]

Furthermore, a good growing medium should be a proper mix of ingredients that provides seedlings with anchorage, acts as a reservoir for water and nutrients, and allows sufficient aeration to ensure that oxygen is diffused to the roots. It is said that sawdust is low in nutrient content [9]. Its availability is always a concern due to the prohibition on using virgin wood to preserve forests [10], virgin wood is used because it is untreated and free from paints, preservatives, glues, and other contaminants. These limit its role in nursery media and necessitate amending sawdust with other nutrient-rich organic materials to make a good growing medium. Sawdust mixed with vermicast extracts increases nitrogen uptake in Syngonium spp. and this mixture can significantly enhance the biological, physical, and chemical qualities of the growing medium [11].

Animal manures, such as pig and goat manure, have the potential to be effective sawdust amendments because they are rich in nutrients and readily available to small-holder farmers. Pig manure is rich in organic carbon and nutrients [12,13]. Pig manure biochar has high organic matter ranging from 40.1 to 56.5%, and the concentrations of total nitrogen, phosphorus pentoxide, and potassium oxide ranged from 2.52 to 3.18%, 4.92 to 7.01%, and 0.41 to 1.51%, respectively [13]. It was concluded that these results met the requirements of the National Standard (NY525-2012) (China) for Organic Fertilizers (OM content ≥ 45 %, N + P_2O_5 + K_2O content ≥ 5 %). Pig manure also has a pH value of 6,8, which makes pig manure a good organic amendment [14]. Pig manure anaerobic digester and compost from the biogas digestate make a good seedling substrate for tomatoes and lettuce [15].

Goat manure (GM) has high nutrient content, and it also has the potential to meet the NPK (nitrogen, phosphorus and potassium) nutrients needed by most crops [16,17]. Goat manure is rich in essential nutrients, particularly potassium (2.79 %),

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calcium (1.56 %), nitrogen (1.15 %) and sulphur (2050 ppm) among macronutrients, and contains notable amounts of micronutrients like iron (7214 ppm), and zinc (924 ppm), indicating its potential value as a balanced organic amendment [16]. It significantly increased the levels of macro- and micronutrients in Sesamum alatum leafy vegetables [18]. Goat manure from different regions in South Korea (Namwon, Jangsu, Sancheong, Goesan, Hoengseong, and Chupungnyeong) before composting had pH values ranging from 7.42 to 9.24 and electrical conductivity ranging from 336.5 to 953 µS/cm [19]. It has a naturally low odour; a naturally dry, pelletized state makes it easier to collect, store, and apply; it can be applied straight onto crops without burning; and it does not attract insects. Furthermore, GM improves soil fertility, microbiological activity, and water-holding capacity and can be used to replace part of an NPK fertilizer application [19].

However, small-holder farmers often neglect using sawdust and animal manure as growing media because they lack the knowledge to utilize them effectively. They rely on buying synthetic growing media, which is costly, while they have limited financial support to produce enough cabbage seedlings. This results in fewer cabbage seedlings and poorer production among small-holder farmers. Therefore, information on the utilization of readily available materials, such as sawdust and animal manure, may reduce the cost of growing media and improve seedling production. The aim of the present study was to investigate the effect of sawdust amended with pig and goat manure on cabbage seedling growth, as an alternative for disadvantaged farmers.

MATERIALS AND METHODS

Study site

This study was conducted in the glasshouses of the University of Fort Hare (Alice Campus), Alice, Eastern Cape Province, Republic of South Africa. The glasshouse conditions were fully managed and carefully controlled throughout the experimental period. The research site is located at 32.7853°S, 26.83582°E, and 542 meters above sea level. It has a Mid-latitude steppe climate (Classification: BSk). The district's average annual temperature is 18.0 ºC, which is 3.22 % lower than South Africa's average. Alice typically receives about 89.4 mm of precipitation and has 132.76 rainy days (36.37% of the time) annually.

Preparation of goat and pig manure

The goat and pig manure were obtained from local farmers in Alice, Eastern Cape, South Africa. These two manures are readily available in most rural homes in the province, compared to other manures such as chicken and cattle manure. A total of 5 kg of each manure (fresh) was dried in the sun for 2 days at 30 ^{o}C at night; it was then kept in a storeroom at room temperature, and the manure was ground using a mechanical grinder to obtain a 2 mm powder. Sun drying was utilized to dry these

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PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
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manures because it reduces moisture content faster, which decreases nutrient loss and pathogens [20]. The nutrient compositions of goat, pig manure, and sawdust are presented in Table 1(a), 1(b), and 1(c). The nutrient analysis of goat and pig manure was conducted at the Dohne Agricultural Research Institute in Stutterheim, South Africa.

Determination of the chemical composition of sawdust and animal manures

The pH of sawdust and animal manures was determined using a digital bench-top pH meter; 5 g of soil sample and 20 ml of distilled water were mixed and shaken for one minute and placed at room temperature overnight [21]. Concentrations of Zn, Cu, Mg, K, Ca, Mn, Na (mg kg^{-1}), Fe and Al (g kg^{-1}) were measured using ICP-MS-7500 after extracting with 2 ml of 30 % hydrogen peroxide and 8 ml of 55 % nitric acid in 5 g, subjected to a microwave instrument (Milestone Ethos 1) in three steps. In the first step, the temperature was increased to 50 °C for 10 minutes; in the second step, the temperature was increased to 150 °C for 15 minutes; and in the third step, the temperature was increased to 200 °C for 15 minutes, operating at 1000 W in all steps as described by Alsehli [22]. In between the steps the temperatures kept changing according to the steps while the samples were inside the microwave, without cooling them. The NO_3^-, and $PO4_3^-$ concentrations (mg L^{-1}) were measured using IC 004-C104 after extracting with 12 ml deionized water in a 6.0 g soil sample, shaken for 15 minutes and placed in a centrifuge for 30 minutes at 5500 rpm and filtered three times.

Experimental design

The experiment was laid out in a randomized complete block design (RCBD) with four replications, 40 seeds per treatment in each replicate. Nine treatments were tested on Gloria cabbage cultivar seeds (a robust and highly adaptive cultivar) which and were; SD (100% sawdust), PM0 (100 % pig manure), PM1 (25% sawdust plus 75 % pig manure), PM2 (50 % sawdust plus 50 % pig manure), PM3 (75 % sawdust plus 25 % pig manure) and GM0 (100 % goat manure), GM1 (25% sawdust plus 75% goat manure), GM2 (50 % sawdust plus 50 % goat manure), GM3 (75 % sawdust plus 25 % goat manure). The seeds obtained from Umthiza Co-op were sown at a depth of 0.5- 1 cm in a 200-cavity seedling tray. Twelve seedling trays were used, divided into four replicates, and labelled A, B, C, and D.

Experimental procedures

The seedling trays were disinfected with Chlorox. Treatments were mixed thoroughly according to their ratios/volume, and the mixed growing media were applied to the seedling trays in accordance with their assigned plots. Each plot contained 40 seeds planted at 0,5 to 1 cm depth and watered. Seedling trays were then placed in a germination room until emergence was noticed on day three. After three days, the seedling trays were transferred to the glasshouse, placed according to the

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experimental design, and kept moist throughout the experiment. Qula water-soluble fertilizer was applied through fertigation at a rate of 3 g/L. Fertigation water was used to irrigate five days per week; on weekends, only water was used to wash off/leach excess fertilizer.

Data collection

The number of seeds that emerged in each plot per treatment across all blocks was recorded for up to 14 days after sowing. Germination rate was then calculated using the following formulae:

$$\text{Germination Percentage} = \frac{\text{seeds germinated}}{\text{total seeds}} \times 100 \quad [23]$$

The following data were collected randomly in the 16 seedlings in the middle of each treatment, leaving the 24 seedlings from the border lines. The number of leaves was counted; the stem diameter was measured using a vernier calliper, and the shoot height was measured using a ruler. Leaf length was measured with a ruler. Chlorophyll content was measured using a spadmeter. The seedling length was measured at harvest from the root tip to the shoot tip using a 300 mm ruler and similarly the root length.

Statistical Analysis

The data were analyzed using JMP version 18 statistical software to obtain descriptive statistics, and hypothesis testing was subjected to analysis of variance (ANOVA). Where a significant difference was detected using Tukey Kramer's test procedure, a significance level α (0.05) was used to separate treatment means.

RESULTS AND DISCUSSION

The results of this study showed significant differences among treatments in germination, seedling growth, and the physiological attributes of cabbage seedlings. The results demonstrate that both the type of manure and the sawdust amendment ratio substantially affected seedling growth. The two-way analysis of variance (ANOVA) revealed that the interaction among application rates (treatments) and experimental period (weeks) was not statistically significant for any of the seedling growth parameters ($p > 0.05$), indicating that their combined effect did not influence the cabbage seedling growth (Tables 2 and 3). However, the main effect of treatments and growth period were highly significant ($p < 0.01$) across most parameters. Overall, these results indicate that treatments and experimental period were the dominant factors on the cabbage seedling growth, with limited interaction effects among the experimental factors.

Effect on seed germination

Seed germination varied significantly across the treatments (Fig. 1A). The highest germination rate (51.21%) was recorded in the treatment 25 % sawdust + 75 % pig

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manure, while the lowest among germinating treatments occurred in the 50 % sawdust + 50 % goat manure (36.89 %). No germination occurred in 100 % goat manure and 25 % sawdust + 75 % goat manure. These results suggest that high proportions of goat manure inhibited germination, likely due to underlying physicochemical factors, some of which may not have been established in this study, such as high electrical conductivity (EC), which has been reported to reduce seed emergence [19]. By contrast, the improvement in cabbage seedling germination as influenced by pig manure has been reported in the literature [24].

Effect on seedling growth attributes

The results of the study show that there was a significant difference in growth attributes of cabbage seedlings observed among the treatments (Fig. 2A–D). The tallest seedlings were recorded in 50 % sawdust + 50 % pig manure (242 mm), while the shortest (168.83 mm) occurred in 75 % sawdust + 25 % goat manure. Shoot height followed a similar pattern, with PM1 producing the highest value (142.7 mm) and GM2 the lowest (76.58 mm). All pig manure treatments (PM0–PM3) produced higher shoot heights compared to goat manure treatments, indicating superior nutrient balance and media structure. Stem diameter was also highest in PM2 (4.07 mm) and lowest in GM2 (0.91 mm) (Fig. 2B). The generally poor performance of GM0–GM2 is attributed to nutrient imbalances and high EC in goat manure, which likely restricted early growth [19]. Moreover, land management and livestock management, such as goat feeding, play a big role in the nutrient composition of manure. Improper management of goat feeding and the storage systems may lead to the goat manure releasing phytotoxic compounds that limit seedling growth [19].

Root development of cabbage seedlings was also affected by the treatments (Fig. 2C–E). The longest roots (95.05 mm) occurred in PM2, whereas GM3 produced the shortest (52.95 mm). Root-to-shoot ratios were highest in GM2 and PM3, although the absolute root lengths were lower in goat-based substrates. The strong root development observed in PM2 indicates that pig manure mixed with sawdust provided a more aerated and nutrient-rich substrate conducive to root elongation. The sawdust and organic manure mixtures enhanced root development in tree seedlings [25].

Pig manure treatments consistently produced more leaves and longer leaves than with goat manure treatments (Fig. 2C; Table 4). The highest number of leaves (6) was recorded in PM1, and the lowest (4.75) in GM2. Leaf length at week 6 was also greatest in PM1 (74.50 mm), followed by PM0 and PM3. The poorest leaf development occurred in GM2. These trends further support the superior nutrient availability and water-holding capacity of pig manure–sawdust mixes compared with goat manure–sawdust substrates.

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The results further show variation in fresh and dry biomass across treatments (Fig. 1E–F). Treatment PM2 produced the highest fresh (3.99 g) and dry biomass (2.04 g), indicating strong overall plant vigour. The lowest biomass values were from GM2 (0.81 g fresh and 0.62 g dry). While GM3 performed better than GM2, both goat manure treatments produced substantially weaker seedlings than the equivalent pig manure treatments. This may be due to improved binding of humic substances and slight dilution of adverse properties by sawdust at higher proportions (25 % goat manure in GM3) [26].

Chlorophyll content remained relatively high across all treatments (Table 4). PM1 had the highest value (51.21), followed closely by 100 % sawdust (49.09). This contrasts with its weak structural growth performance and suggests that sawdust's excellent aeration and water-holding capacity can enhance chlorophyll production despite nutrient deficiencies. Sawdust-based substrates increased water content in garlic [27].

Overview of media effects on cabbage seedlings

Growth in 100 % sawdust was generally poor, with delayed seedling height, stem diameter, and leaf length extension. The lack of microorganisms and slow nutrient mineralization in sawdust likely restricted early growth; it has been reported that sawdust restricted tomato seedling growth by Agboola et al. [1]. Despite poor structural growth, the high chlorophyll content indicates that sawdust improves water retention and aeration but lacks sufficient nutrients for normal seedling development.

Pure goat manure (GM0) and high-proportion goat manure (GM1) severely inhibited germination and growth. However, moderate dilution with sawdust (GM2 and GM3) improved growth, with GM3 outperforming GM2 in chlorophyll content and leaf length. This indicates that low levels of goat manure (25 %) may enhance the water-holding capacity of sawdust while reducing nutrient stress.

Pig manure treatments consistently produced the best seedling growth. Treatment PM1 had the highest germination rate, while PM2 produced the most significant biomass, longest roots, thickest stems, and tallest seedlings. The positive effects of pig manure are attributed to its rich macro- and micronutrient content (Table 1(b)) and organic matter, which enhance aeration, nutrient supply, and water retention. Similar benefits of pig manure on plant growth have been reported in tomatoes and other crops [12, 28]. Sawdust amended with pig manure proved to be a good growing medium for cabbage seedlings.

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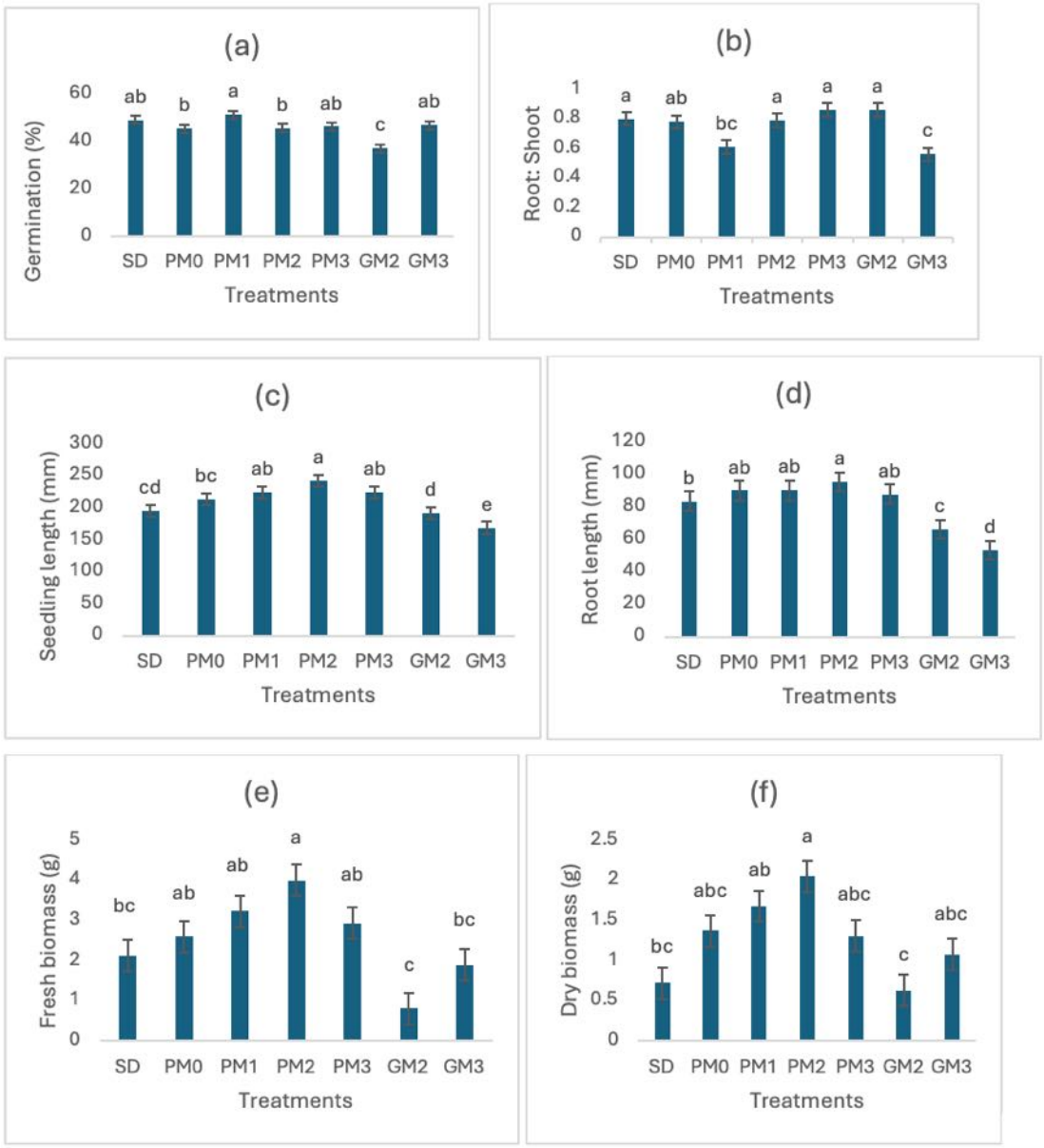


Figure 1: Showing the effect of different growth media on germination percentage (a), root: shoot ratio (b), seedling height (c), root height (d), fresh biomass (e) and dry biomass (f) of cabbage seedlings after six weeks of sowing. Means with different letters are significantly different to each other (means were separated using Tukey's test, P< 0,05). The error bars show the standard errors. Bars followed by the same letter for each treatment are not significantly different according to Tukey's (HSD) (0.05)

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PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
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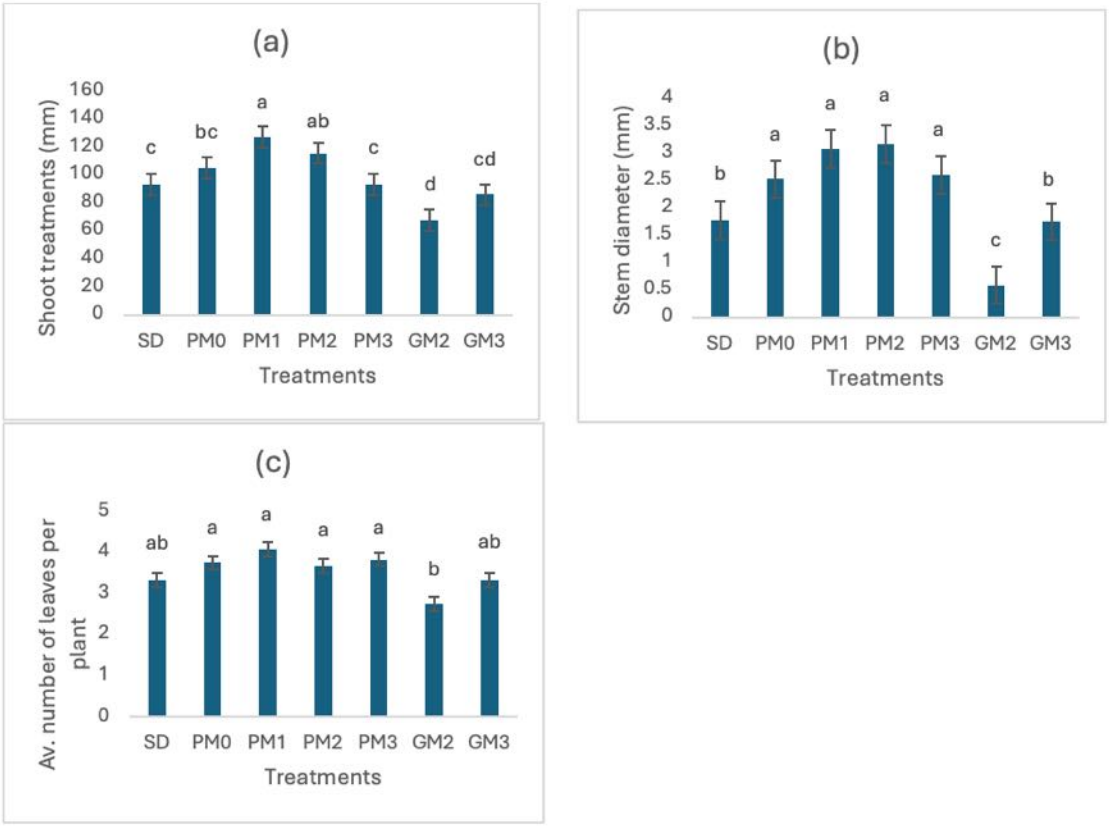


Figure 2: Showing the effect of sawdust and animal manure on the vegetative growth of cabbage seedlings. [Figure 2a) Shoot height (cm), Figure 2b) Stem diameter (mm) and Figure 2c) number of leaves]. The error bars show the standard errors. Bars followed by the same letter for each treatment are not significantly different according to Tukey's (HSD) (0.05)

CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

In conclusion, this study demonstrates that a growing medium composed of 50 % sawdust amended with 50 % pig manure is a viable option for cabbage seedling production, particularly for resource-poor smallholder farmers. The importance of selecting appropriate growing media is illustrated by the week 6 growth peak, which is consistent with the critical period for microbial mineralization and nutrient availability from manure. This study also provides new insight into the temporal dynamics of cabbage seedling production, suggesting that growth can be synchronized with crop nutrient demand to increase the efficiency of organic growing media. The mixture of sawdust and pig manure offers the potential for more cost-effective cabbage seedling production for resource-poor small-smallholder farmers. However, further trials with other crop types, such as pepper, cucumber, onion, and

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Volume 26 No. 9
October 2026
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ISSN 1684 5374

tomato, are needed to assess broader applicability. Moreover, alternative combinations such as 50 % sawdust plus 50 % goat manure and 75 % sawdust plus 25 % goat manure warrant additional investigation as these substrates could benefit farmers who keep goats as their primary livestock. Moreover, composting the goat manure before use to enhance the physical properties of the growing medium, improve nutrient availability and reduce phytotoxic compounds.

ACKNOWLEDGEMENTS

No acknowledgements

Declaration

The authors would like to declare the following:

Funding: Not applicable

Conflicts of Interest: The authors declare no conflicts of interest.

Author Contributions: Conceptualization, methodology, S.M.N. and A.M.; formal analysis, writing—original draft preparation, A.M.; writing—review and editing, S.M.N; visualization, A.M.; supervision, S.M.N.

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Volume 26 No. 9
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PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
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Table 1: The goat and pig manure reaction (pH) macro and micronutrient composition

Nutrient Composition	Content (Goat)	Pig
pH	6.72	6.5
Total N	77.0 %	2200mg/kg
P	0.05 %	14 mg/kg
Ca	3.57 %	23 mg/kg
Mg	0.33 %	2 mg/kg
K	0.66 %	270 mg/kg
Na	1448 mg/kg	76 mg/kg
Fe	2312mg/kg	9.7 mg/kg
Mn	434mg/kg	2.2 mg/kg
Zn	46mg/kg	15.20mg/kg

Table 1b: Sawdust pH, macro and micronutrient content

Nutrient composition	Content
pH	11.1
N	0.27%
P	0.01 mg/kg
K	2.26 mg/kg
Ca	300.59 mg/kg
Mg	492 mg/kg

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Table 2: ANOVA results (probability values) for the effects of sawdust and different animal manures application rate (treatments) and experiment period (weeks) on cabbage seedling growth parameters (Shoot length, stem diameter and average number of leaves). DF – degree of freedom

Source of Variation	Df	Shoot height (cm)	Stem diameter (mm)	Number of leaves
Treatments	6	<.0001	<.0001	0.0018
Weeks	2	0.0010	<.0001	<.0001
Replicates	3	0.5365	0.9081	0.1946
Treatments x Weeks	12	0.9532	0.6021	0.4880

Table 3: ANOVA results (probability values) for the effects of sawdust and different animal manures application rate (treatments) and experiment period (weeks) on cabbage seedling growth parameters (leaf length and chlorophyll content). DF – degree of freedom

Source of Variation	Df	Leaf length	Chlorophyll content
Treatments	6	<.0001	<.0001
Weeks	1	<.0001	<.0001
Replicates	3	0.0637	0.0829
Treatments x Weeks	6	0.0003	0.9014

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Volume 26 No. 9
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Table 4: Effect of sawdust, pig manure and goat manure amendments on chlorophyll content and leaf length of cabbage seedlings. Results followed by the same letter for each treatment are not significantly different according to Tukey's (HSD) (0.05)

Treatments	Chlorophyll content		Leaf length (mm)	
	5 weeks	6 weeks	5 weeks	6 weeks
SD	38,93de	49,08ab	44,35g	59,40de
PM0	37,09e	45,29bc	60,52cd	70,55b
PM1	43,01cd	51,21a	63,75c	74,50a
PM2	37,51de	45,46bc	56,45ef	67,70b
PM3	38,70de	46,15abc	58,75de	70,25b
GM2	27,69f	36,89e	10,25i	16,75h
GM3	37,62de	46,82abc	41,42g	53,92f

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