



## OPEN ACCESS

## EDITED BY

Sunny Sharma,  
Lovely Professional University, India

## REVIEWED BY

Mahesh Kumar Mahatma,  
National Research Centre on Seed Spices  
(ICAR), India  
Jhon Hardy Purba,  
Universitas Panji Sakti, Indonesia

## \*CORRESPONDENCE

Stanlake Mangezi,  
✉ stanlake.mangezi@staff.msuas.ac.zw

RECEIVED 28 October 2025

REVISED 08 December 2025

ACCEPTED 29 December 2025

PUBLISHED 20 January 2026

## CITATION

Mangezi S, Manjeru P, Makuvaro V, Chaibva P,  
Mutetwa M and Muziri T (2026) Cattle manure  
amended soil influences germination and early  
seedling development of marula (*Sclerocarya  
birrea* (A. Rich) Hochst.).  
*Front. Food Sci. Technol.* 5:1734009.  
doi: 10.3389/frfst.2025.1734009

## COPYRIGHT

© 2026 Mangezi, Manjeru, Makuvaro, Chaibva,  
Mutetwa and Muziri. This is an open-access  
article distributed under the terms of the  
[Creative Commons Attribution License \(CC BY\)](https://creativecommons.org/licenses/by/4.0/).  
The use, distribution or reproduction in other  
forums is permitted, provided the original  
author(s) and the copyright owner(s) are  
credited and that the original publication in this  
journal is cited, in accordance with accepted  
academic practice. No use, distribution or  
reproduction is permitted which does not  
comply with these terms.

# Cattle manure amended soil influences germination and early seedling development of marula (*Sclerocarya birrea* (A. Rich) Hochst.)

Stanlake Mangezi<sup>1,2\*</sup>, Pepukai Manjeru<sup>2</sup>, Veronica Makuvaro<sup>2</sup>,  
Paul Chaibva<sup>2</sup>, Moses Mutetwa<sup>2</sup> and Tavagwisa Muziri<sup>2</sup>

<sup>1</sup>Department of Agronomy, Manicaland State University of Applied Sciences, Mutare, Zimbabwe,  
<sup>2</sup>Department of Agronomy and Horticulture, Midlands State University, Gweru, Zimbabwe

**Introduction:** The choice of growth media is an important aspect of nurseries, as it affects the success and quality of the seedling establishment. A greenhouse experiment was conducted to investigate the effects of soil amendment on germination and growth of marula.

**Methods:** The soil was amended with cattle manure at the following ratios: T1 (5 parts topsoil: 1-part sand: 4 parts cattle manure), T2 (6 parts topsoil: 1 part sand: 3 parts cattle manure), T3 (4 parts topsoil: 2 parts sand: 4 parts cattle manure), T4 (5 parts topsoil: 2 parts sand: 3 parts cattle manure), T5 (4 parts topsoil: 4 parts sand: 2 parts cattle manure), T6 (topsoil only), T7 (Cattle manure only), and T8 (sand only). A randomized complete block design (RCBD) was used and replicated four times.

**Results:** The effects of soil amendment on germination were highly significant ( $p < 0.001$ ) at two weeks, three weeks, and four weeks after planting. Marula seeds that were grown in a medium of cattle manure only showed the highest final germination percentage (92.25%) after six weeks. Plant height was also significantly influenced by growth media at eight ( $p < 0.001$ ) and 12 ( $p < 0.05$ ) weeks after planting. The effects of growth media were also highly significant ( $p < 0.001$ ) on the germination index, germination rate, and vigor index. Significant differences ( $p < 0.05$ ) in root lengths were recorded 90 days after planting.

**Discussion:** From these results, it can be concluded that soil amendment with cattle manure enhances germination and early seedling growth and development of marula.

## KEYWORDS

cattle manure, germination, growth, sand, topsoil

## 1 Introduction

The harvesting, use, value addition, and commerce of wild fruit and nut tree products have always been an integral part of the socio-economic fabric of many rural communities across the African continent (Leakey et al., 2005; Akinnifesi et al., 2007). The consumption of these wild fruits has helped many communities during periods of drought and famine. Commerce in indigenous fruits has generated incomes and created job opportunities in the trade, processing, and value addition (Ruiz-Perez et al., 2004; Saka et al., 2004; Leakey et al., 2005). Marula is one of the ten most used indigenous fruit species and is also ranked among

the top species whose trade generates income for inhabitants of Sub-Saharan Africa (Muok et al., 2011). Most parts of the tree can be consumed in a raw form or cooked as a source of food or medicine. The pulp of marula fruits contains several micronutrients and minerals (Dlamini, 2011; Muok et al., 2011). The fruits can be fermented to make beer, while the kernels are eaten raw or processed into either butter or oil. Animals browse the leaves of marula, and the bark has many medicinal uses.

Over 90% of all indigenous fruits marketed in the miombo eco-region still come from wild stands (Akinnifesi et al., 2008). Until recently, farmers in Zimbabwe and other countries have not practiced the deliberate cultivation of indigenous fruit trees on the African continent because of a lack of knowledge on propagation techniques and management (Schreckenberget al., 2006). Growth in the trade of indigenous fruits has led to over-extraction of the resources and shortages most times (Simons and Leakey, 2004). This has led commercial cultivation to emerge as an important agroforestry initiative in tropical countries over the past 2 decades, continuing from work started in the mid-1990s (Tchoundjeu et al., 2006; Akinnifesi et al., 2008). During this time, the World Agroforestry Centre (ICRAF) was at the forefront of research efforts to commercialize IFTs for economic empowerment and biodiversity conservation. The main aim has been to establish production manuals for these indigenous fruit trees, from propagation, and management to harvesting and conservation.

Marula (*Sclerocarya birrea* (A.Rich.) Hochst) belongs to the Anacardiaceae family (Mng'omba et al., 2012). It is a common fruit species in the drier parts of Africa and occurs in areas which receive an annual rainfall within the range of 200–1,500 mm and in a wide range of soil conditions mostly well-drained soils. Its leaves, fruits, stem bark and roots are utilised by many inhabitants in these regions for food, medicine and timber. The fruit is also processed at a small scale to produce wines, drinks and oil among other products. In Tanzania, an estimated 1,000 tonnes of the fruit is harvested in the wild, while in South Africa 2,000 tonnes are processed annually (Akinnifesi et al., 2008; Ham and Chirwa, 2011). In Zimbabwe, although the marula tree is abundant, it remains underutilised because of a lack of research on the tree (Maroyi, 2013).

Using soil amendments is a vital component in the propagation of many species of fruit trees and vegetables around the world today. The growth media is used as a source of nutrients and water for plant growth, provides anchorage, and facilitates gaseous exchange between the roots and the atmosphere (Abad et al., 2002). Therefore, the composition of the media directly affects the quality of the seedlings produced. The quality of seedlings affects re-establishment in the field and, subsequently, orchard productivity (Wilson et al., 2001; Baiyeri and Mbah, 2006). When the soil medium provides adequate aeration, water, and nutrients to the plant, it develops a root system that can support its luxurious growth (Neelam and Ishtiaq, 2001). Growth media for fruit seedling production are usually composed of soil, organic matter, and sand. The major function of sand is to make the medium more porous and facilitate root growth, while the organic matter acts as a nutrient reservoir. Growth media composition has been reported to influence growth and survival in indigenous fruit tree species, such as *Uapaca kirkiana* (Mhango et al., 2008).

However, literature on the effects of soil media on the germination, growth, and development of IFTs for growth models and production protocols remains scarce (Omokhua et al., 2015). Moreover, there is scarce information on the uses, benefits, nutritional value and cultivation of marula in Zimbabwe. In contrast, the cultivation of exotic fruit tree species like mango and citrus fruits is relatively well supported by research and extension stretching for decades, ensuring that a range of high-yielding varieties is today available for diverse climatic and soil conditions. This study aims to formulate a suitable media for marula germination and early growth from different soil types and organic manure.

## 2 Materials and methods

### 2.1 Seed collection and processing

Freshly ripened fruits were collected from beneath a tree domesticated in a farmer's agricultural field in the Chivi district of Zimbabwe at 20° 24'S, and 30° 13'E in May 2020. The tree had been retained on the farm for its big fruits with high juice content. The fruits were brought to the laboratory at the Midlands State University where they were peeled and pulp was removed from the seeds. The seeds were washed, dried, and then stored at room temperature until setting up the trials. Before germination, the viability of the seeds was determined using the dens metric test with tap water to remove the nonviable seed.

### 2.2 Site description

A greenhouse experiment was conducted at Midlands State University Kwekwe farm. The area falls under Natural Region III of Zimbabwe's Agro-ecological zones (Manatsa et al., 2020) and is located 18° 55' 04.5" S, 29° 45' 03.2" E with an altitude of 1355 m above sea level. The average annual rainfall is 883mm, and the mean temperature is around 23 °C–30 °C.

### 2.3 Experimental soil and manure description

To perform initial soil characterization, twenty soil samples were collected from randomly selected points of the greenhouse using a soil auger at a depth of 20 cm. The twenty soil samples were then mixed thoroughly in a clean plastic bucket to obtain a composite sample. The composite sample was air-dried (<2 mm) and characterized (Table 1). The content of soil organic carbon (Table 2) in the soil sample was measured using the Walkely and Black method (Nelson and Sommers, 1996). The texture class of the soil sample was measured using the Bouyocous hydrometer method (Bouzoukis, 1962). The pH of the composite soil sample was measured by weighing a 15 g soil sample in a 200 mL honey jar and adding 75 mL 0.1M CaCl<sub>2</sub> to the sample. The mixture was shaken for 30 min and pH was determined using a digital pH meter (Model: Orion 701, Orion Manufacturing, MI, USA). The total nitrogen content was calculated through the Kjeldahl method using concentrated H<sub>2</sub>SO<sub>4</sub>, K<sub>2</sub>SO<sub>4</sub> and HgO to digest the sample (Bremner, 1996).

TABLE 1 Chemical and physical properties of the experimental soil.

% Sand	% Clay	% Silt	pH	Total soluble salts (ppm)	Nitrate nitrogen (ppm)	Organic carbon %	C: N ratio	Bulk density
72	14	12	5.9	74	6.23	1.54	0.25	1.26

TABLE 2 Selected chemical properties of experimental cattle manure.

Nitrogen %	Organic carbon %	Moisture content	Ash content	C: N ratio
1.05%	6.91%	5.15%	38.12%	0.29

The bulk density of the experimental soil sample was measured using the core method (Blake and Hartge, 1986). Twenty soil cores were randomly collected from the experimental greenhouse for bulk density determination. Bulk density ( $Db$ ) was calculated using the following formula:

$$Db = MsVt$$

Where  $Ms$  is the mass of oven-dry solids and  $Vt$  is total soil volume. The soil cores were oven-dried at 105 °C (to constant weight) to ascertain the mean gravimetric water content.

Taking particle density ( $Pd$ ) of soil to be 2.65 g cm<sup>-3</sup> total porosity was calculated as:

$$1 - DbPd$$

## 2.4 Experimental procedure and design

The different combinations of topsoil, sand, and cattle manure were the treatments. Treatment 1 comprised 5 parts topsoil, 1 part sand and 4 parts cattle manure (5 TS:1 S:4 CM), T2- 6 parts topsoil, 1 part sand and 3 parts cattle manure (6 TS:1 S:3 CM), T3- 4 parts topsoil, 2 parts sand and 4 parts cattle manure (4 TS:2 S:3CM), T4- 5 parts topsoil, 2 parts sand and 3 parts cattle manure (5 TS:2 S:3 CM), T5- 4 parts topsoil, 4 parts sand and 2 parts cattle manure (4 TS:4 S:2 CM). T6 was topsoil only (TS), T7-cattle manure only (CM), and T8 – only sand (S). Trenches with dimensions 30 cm length x 10 cm width x 10 cm depth were dug and filled with the different cattle manure amended soil. The trenches were dug along drip lines to ensure that each plant got uniform and adequate moisture. Irrigation was done for 1 hour twice everyday. Each trench represented an experimental plot. The treatments were arranged in an RCBD and replicated four times. Twelve marula seeds were sowed into each experimental plot 5 cm apart, at a depth of 5cm, and then covered with the respective media.

## 2.5 Data collection

Germination parameters were observed at weekly intervals until no further germination was observed. A seed was considered to have germinated where there was a visible protrusion of split seed coat with the cotyledons, hypocotyls, and epicotyl above the soil's surface. Weekly germination percentages were calculated and summed up to get cumulative germination for each treatment using the formula:

$$\text{Germination Percentage} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds sown}} \times 100$$

At the end of the germination experiment, we calculated the germination index (GI) as described by the Association of Official Seed Analysis (1983):

$$\text{Germination Index} = \frac{\text{Number of germinated seeds}}{\text{Days to the first count}} + \frac{\text{Number of germinated seeds}}{\text{Days to the last count}}$$

The rate of germination was calculated using a modified formula from Islam et al. (2009):

$$\text{Rate of germination} = \frac{\text{Number of seeds emerged 14 days after planting}}{\text{Number of seeds emerged 21 days after planting}} \times 100$$

The collection of germination data was stopped when no further germination was observed for a sustained period of 21 days. Seedling growth performance was monitored from 4 weeks after emergence up to 12 weeks after emergence to assess the effect of soil media composition on plant growth. Five seedlings were randomly selected in each plot and seedling height and the number of leaves was measured and counted after every 4 weeks. Seedling height was measured using a string and ruler to the nearest cm from below the cotyledons. At the end of the experiment (12 weeks after planting), three plants were uprooted in each experimental unit and the length of the roots was measured. The vigor index was calculated as final germination × total plant length.

## 2.6 Data analysis

Analysis of Variance (ANOVA) was done on data of all germination and growth parameters using GenStat 18th Edition, and differences between treatments means were separated using the Least Significant Difference (LSD) test at the 5% significance level.

## 3 Results

### 3.1 Effects of cattle manure soil amendments on germination percentage of marula seeds

There was a significant difference among the different soil media compositions in germination percentage ( $p < 0.001$ ) 2 weeks after

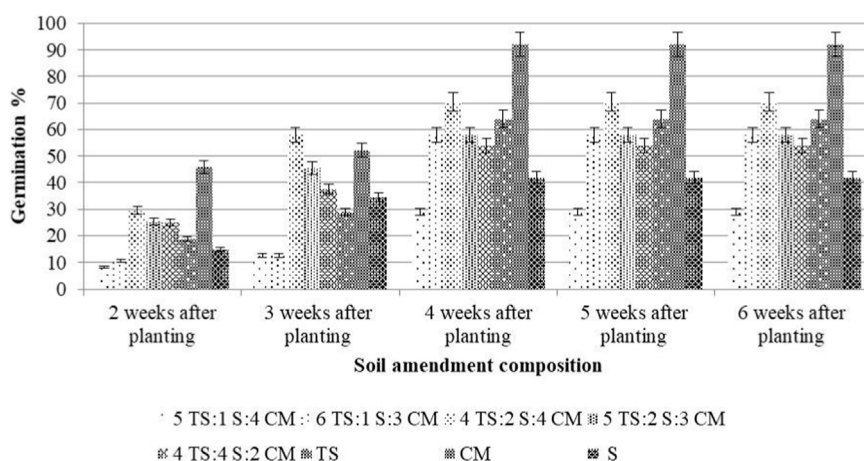


FIGURE 1 Effects of cattle manure soil amendments on marula seed germination.

TABLE 3 Effects of cattle manure soil amendments on germination index, rate of germination and vigor index.

Soil amendment composition	Germination index	Rate of germination (%)	Vigor index
5 TS:1 S:4 CM	0.19 <sup>a</sup>	29.15 <sup>ab</sup>	16.20 <sup>a</sup>
6 TS:1 S:3 CM	0.30 <sup>abc</sup>	17.67 <sup>b</sup>	36.00 <sup>c</sup>
4 TS:2 S:4 CM	0.5 <sup>e</sup>	40.25 <sup>bc</sup>	45.67 <sup>d</sup>
5 TS:2 S:3 CM	0.43 <sup>bcd</sup>	35.71 <sup>b</sup>	39.75 <sup>c</sup>
4 TS:4 S:2 CM	0.49 <sup>de</sup>	49.39 <sup>c</sup>	34.35 <sup>c</sup>
Topsoil (TS) only	0.39 <sup>bcd</sup>	29.02 <sup>ab</sup>	39.45 <sup>c</sup>
Cattle manure (CM) only	0.83 <sup>f</sup>	50 <sup>c</sup>	59.38 <sup>e</sup>
Sand (S) only	0.30 <sup>ab</sup>	35 <sup>b</sup>	28.32 <sup>b</sup>
P-value	<0.001	<0.001	<0.001
CV	20.50%	23.6%	9.5%
LSD	0.1170	12.44	5.225

TS, topsoil; S, sand; CM, cattle manure.

Means with different subscript within a column significantly differ ( $p < 0.05$ ).

planting. The highest germination percentage was observed in T7 (cattle manure only) (45.75%), while the lowest (%) was in T1 (5 parts topsoil: 1 part sand: 4 parts manure) (Figure 1). Again, there was a significant difference in germination percentage ( $p < 0.001$ ) 3 weeks after planting. The highest germination percentage at 3 weeks was T3 (4 parts topsoil: 2 parts sand: 4 parts cattle manure) with 58%, and the lowest was T1 (5 parts topsoil: 1 part sand: 4 parts manure) with 12.66% (Figure 1). Finally, there were significant differences ( $p < 0.001$ ) in germination percentages 4 weeks after planting among different soil media compositions. The highest germination percentage was 92.25%, recorded in T7 (cattle manure only). The lowest germination percentage was 29% recorded in T1 (5 parts topsoil: 1 part sand: 4 parts manure) (Figure 1). Thereafter, there was no further germination for the next 3 weeks.

### 3.2 Effects of cattle manure soil amendments on germination index, rate of germination, and vigour index of marula seedlings

The effects of media composition on the germination index were significant ( $p < 0.001$ ). The highest germination index (0.825) was recorded in seeds sown in T7 (cattle manure only) and the lowest (0.1875) in T1 (5 parts topsoil: 1 part sand: 4 parts manure) (Table 3). In addition, there was a significant difference ( $p < 0.001$ ) in seedling germination rate on different media compositions. Seeds that were sown in T7 (cattle manure only) emerged fastest (50%), while those sown in T2 (6 parts topsoil: 1 part sand: 3 parts cattle manure) had the lowest (17.67%) rate of emergence (Table 3). The effects of media composition on the

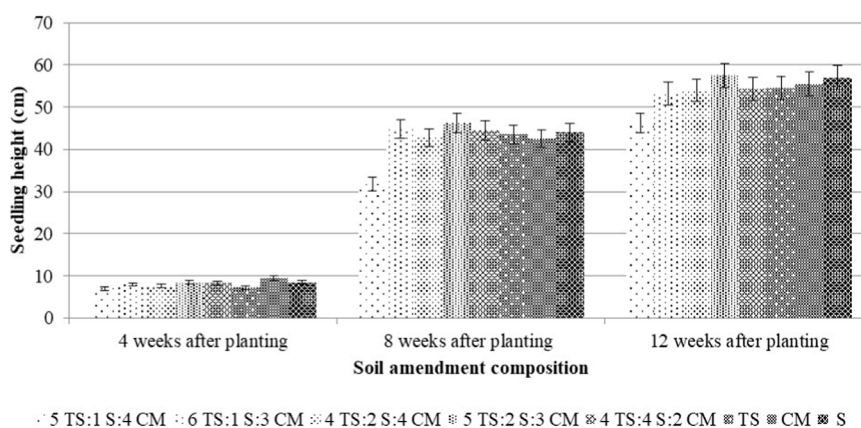


FIGURE 2

Effects of cattle manure soil amendments on marula seedling height at different time intervals.

vigor index were significant ( $p < 0.001$ ). The highest vigor index (59.38) was recorded in seeds sown in T7 (cattle manure only) and the lowest (16.2) in seeds sown in T1 (5 parts topsoil: 1 part sand: 4 parts manure) (Table 3).

### 3.3 Effects of cattle manure soil amendments on marula seedling height

At 4 weeks after planting, the effects of growth media composition on plant height were not significant ( $p = 0.062$ ). However, at 8 weeks after planting, the effects of soil media compositions on plant height were significant ( $p < 0.001$ ). Seedlings growing in T4 (5 parts topsoil: 2 parts sand: 3 parts cattle manure) recorded the highest plant height (46.25 cm), and T1 (5 parts topsoil: 1 part sand: 4 parts manure) recorded the lowest plant height (31.75 cm) (Figure 2). At 12 weeks after planting, the effect of soil media composition on plant height (final height) was significant ( $p < 0.05$ ). Seedlings growing in T4 (5 parts topsoil: 2 parts sand: 3 parts cattle manure) had the highest final plant height (57.5 cm), while the lowest plant height (46.75 cm) was recorded in T1 (5 parts topsoil: 1 part sand: 4 parts manure) (Figure 2).

### 3.4 Effects of cattle manure soil amendments on the number of leaves of marula seedlings

There were no significant differences in the number of leaves from different growth media compositions at four, eight ( $p = 0.117$ ), and twelve ( $p = 0.473$ ) weeks after emergence.

### 3.5 Effects of cattle manure soil amendments on the root length of marula seedlings

The effect of growth media composition on root length was significant ( $p < 0.001$ ). The longest root length (11.05 cm) was

of seedlings grown in T4 (5 parts topsoil: 2 parts sand: 3 parts cattle manure), and the shortest (8.60 cm) was recorded in T2 (6 parts topsoil: 1 part sand: 3 parts cattle manure) (Figure 3).

## 4 Discussion

### 4.1 Effects of cattle manure soil amendments on germination parameters

This study shows that growth media compositions influence seed germination percentage and the rate of germination. The early and better germination percentage, index, and rate of germination in the cow dung slurry treatment might be because of growth promoters present in cattle manure such as bacteria, yeast, actinomycetes, and certain fungi have been reported in cow dung which help in softening the seed coat hence increasing the permeability of the seed to water (Basavaraj et al., 2002; Lokesh, 2007; Swain and Ray, 2009). The cattle manure also improves physical conditions such as porosity and water holding capacity and helps maintain soil temperatures, enhancing higher germination percentages and emergence rates (Srivastava, 1998). This also explains the high germination percentages and rate of emergence found in seeds grown in the medium composed of 4 parts topsoil: 2 parts sand: 4 parts cattle manure. The presence of growth-promoting substances (auxins) and nutrients in the cattle manure gives seedlings emerging in this treatment a competitive advantage in early growth, survival, and development (Sankaranarayanan et al., 1994; Swamy et al., 1999). Seeds that were grown in a medium of sand only had a relatively low final germination percentage (42%). This might be due to the poor water holding capacity of sand. These results do not agree with the findings of Dolor, (2011), who observed high germination percentages in *Irvingia wimbolu* seeds grown in river sand. Anber, (2010) also reiterated the high germination percentage observed in sand media in a study on *Bauhinia variegata* and *Delonix regia*. In a growth medium composed of sand and cattle manure, the properties of

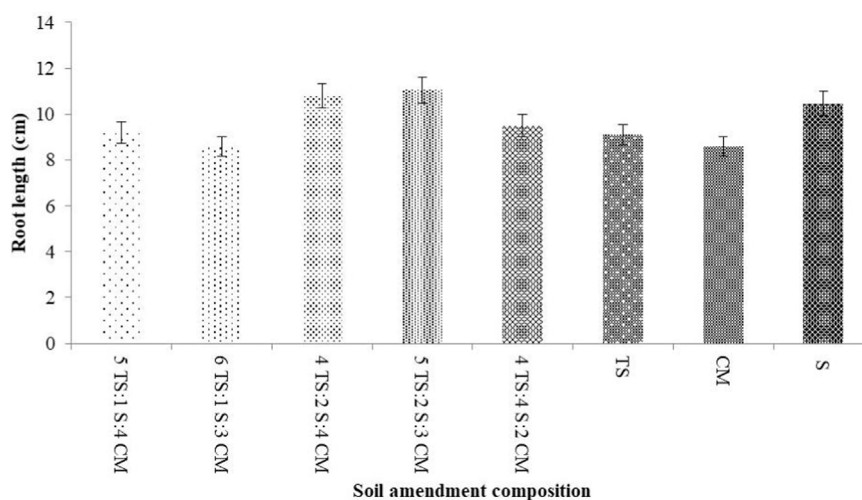


FIGURE 3  
Effects of cattle manure soil amendments on root length.

the soil's biology, physics and chemistry are improved, leading to increased germination and growth, as the organic matter acts as a glue leading to soil aggregation and also increases the fertility of the soil (Das et al., 2017). This can help explain the high final germination in the medium with 4 parts topsoil, 2 parts sand and 4 parts cattle manure where the sand component helps make the medium more penetrable by the radicle and roots of the plant. In contrast, the cattle manure component provides the needed nutrients to support plant growth.

## 4.2 Effects of cattle manure soil amendments on seedling height and number of leaves

Seedling height in *Sclerocarya birrea* seedlings is influenced by the volume of soil organic matter, as Okunomo et al., 2000 stated, who recorded higher plant heights in plants grown in a medium of poultry droppings than in topsoil, sawdust, and clay soil with *Pittosporum bicolor*. Yadav and Sidhu, 2016 also supported this when they reported that the addition of organic matter to the soil medium increased the availability of nutrients that facilitate plant growth. This results from the increased photosynthetic activity, partitioning of photosynthates, and improved permeability of the cell membrane in the plants (Shukla et al., 1997). The high plant heights observed in sand media confirm the findings of Anber (2010), who also got the highest seedling heights of *Bauhinia variegata* and *Drosera regia* in the sand. Leaf production and growth are important indicators of the plant's efficiency in trapping sunlight for photosynthesis (Detpiratmongkol et al., 2014). The cattle manure component of the soil media increases the carbon, nitrogen, pH, Cation exchange capacity, and exchangeable Ca, Mg and K in the soil, consequently enhancing vegetative growth (Ayoola and Makinde, 2008).

## 4.3 Effects of cattle manure soil amendments on root growth

The longer root lengths of seedlings grown in the media with 4 parts topsoil, 2 parts sand and 4 parts cattle manure and 5 parts topsoil, 2 parts sand and 3 parts cattle manure are because of the efficient assimilation and partitioning of assimilates within the marula seedlings, which promotes luxurious growth of above and below-ground parts of the tree (Pandiyan et al., 2011). Water retention capacity and nutrition retention in the topsoil and cattle manure components in 4 parts topsoil, 2 parts sand and 4 parts cattle manure and 5 parts topsoil, 2 parts sand and 3 parts cattle manure could be the reason for the higher root lengths of these treatments (Malamy and Ryan, 2001). A closer observation of the results shows that plants that are grown in the sand-only medium (T8) and media with a higher proportion of sand 4 parts topsoil, 4 parts sand and 2 parts cattle manure also recorded longer root length, and this can be because of the porosity of the sand and the media with a high percentage of sand. The higher percentage of topsoil in the medium with 6 parts topsoil, 1 part sand and 3 parts cattle manure and topsoil only medium give the media higher water holding capacities. This unfavorable characteristic leads to reduced oxygen diffusion to the root and consequently reduced water availability if the matric potential is too low and mechanical impedance if the soil is too compacted or dry. Hence, the slower root growth compared with other treatments (Chen et al., 2010).

## 5 Conclusions and recommendations

From the results, it can be concluded that growth medium composition influences germination percentage, germination index, and emergence rate of marula seeds. This study revealed that germination and initial growth stages have different requirements, so different growth media compositions should be used. The researcher recommends using cattle manure as a medium in the germination stage and then adding on the sand and topsoil once the seedlings are at early

growth stages to promote good growth of above and below-ground parts. The root lengths of marula seedlings in this study might have been greatly limited by the depth of the experimental trenches. The researchers therefore recommend the use of pots or trenches with a greater depth so as to allow unlimited, luxurious root growth.

## Data availability statement

The original contributions presented in the study are included in the article/[Supplementary Material](#), further inquiries can be directed to the corresponding author.

## Author contributions

SM: Software, Visualization, Formal Analysis, Data curation, Writing – original draft, Conceptualization, Investigation, Methodology, Writing – review and editing. PM: Writing – review and editing, Conceptualization, Supervision, Methodology, Writing – original draft, Project administration, Funding acquisition. VM: Methodology, Writing – review and editing, Project administration, Funding acquisition, Supervision. PC: Writing – review and editing, Investigation, Data curation, Methodology. MM: Data curation, Investigation, Methodology, Software, Writing – review and editing, Formal Analysis. TM: Data curation, Supervision, Methodology, Conceptualization, Writing – original draft, Writing – review and editing, Funding acquisition, Project administration.

## Funding

The author(s) declared that financial support was received for this work and/or its publication. This research project was funded by the Ministry of Higher and Tertiary Education, Innovation, Science, and Technology Development, under the Beneficiation and Commercialization of Indigenous Fruits and Herbs Program (2020–2023). The work was funded internally by the responsible ministry through the Midlands State University's Research and Innovations office.

## References

- Abad, M., Noguera, P., Puchades, R., Maquieira, A., and Noguera, V. (2002). Physico-chemical and chemical properties of some coconut coir dusts for use as a peat substitute for containerised ornamental plants. *Bioresour. Technology* 82 (3), 241–245. doi:10.1016/S0960-8524(01)00189-4
- Akinnifesi, F. K., Mhango, J., Sileshi, G., and Chilanga, T. (2007). Early growth and survival of three miombo Indigenous fruit tree species under fertilizer, manure and dry-season irrigation in southern Malawi. *For. Ecol. Manag.* 255 (34), 546–557.
- Akinnifesi, F. K., Sileshi, G., Ajayi, O. C., Chirwa, P. W., Mng'omba, S., Chakeredza, S., et al. (2008). Domestication and conservation of Indigenous miombo fruit trees for improving rural livelihoods in Southern Africa. *Biodiversity* 9, 1–2. doi:10.1080/14888386.2008.9712888
- Anber, M. A. (2010). Improving seed germination and seedling growth of some economically important trees by seed. *For. Sci.* 7 (3), 371–382.
- Ayoola, O. T., and Makinde, E. A. (2008). Performance of green maize and soil nutrient change with fortified cow dung. *Afr. J. Plant Sci.* 2 (3), 19–22.
- Baiyeri, K. P., and Mbah, B. N. (2006). Effects of soilless and soil-based nursery media on seedling emergence, growth and response to water stress of African breadfruit (*Treulia africana* decne). *Afr. J. Biotechnol.* 5 (15).
- Basavaraj, L. T., Srinivas, V., and Devakumar, A. S. (2002). Effect of seed treatments on seed germination and seedling growth in *Elaeocarpus munronii*. *My For.* 119 (5), 360–366.
- Blake, G. R., and Hartge, K. H. (1986). Bulk density. *Methods of Soil Anal. Part 1. Physical and Mineralogical Methods* 5, 363–375.
- Bremner, J. M. (1996). "Nitrogen total," in *Methods of soil analysis part 3: chemical methods*, SSSA book series 5. Editor D. L. Sparks (Madison, Wisconsin: Soil Society of America), 1085–1122.
- Bouzoukis, G. J. (1962). Hydrometer method improved for making particle size analysis of soils. *Agron. J.* 54, 464–465. doi:10.2134/agronj1962.00021962005400050028x
- Chen, X., Dhungel, J., Bhattarai, S. P., Totabi, M., Pendergast, L., and Midmore, D. J. (2010). Impact of oxygenation on soil respiration, yield and water use efficiency of three crop species. *J. Plant Ecol.* 4 (4), 236–248. doi:10.1093/jpe/rtq030
- Das, S., Jeong, S. T., Das, S., and Kim, P. J. (2017). Composted cattle manure Increases Microbial activity and soil fertility more than composted swine manure in a submerged rice paddy. *Front. Microbiol.* 8, 1702. doi:10.3389/fmicb.2017.01702

## Acknowledgements

The authors thank the staff at the Midlands State University Kwekwe farm for their assistance in setting up and managing the experimental plots.

## Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Generative AI statement

The author(s) declared that generative AI was not used in the creation of this manuscript.

Any alternative text (alt text) provided alongside figures in this article has been generated by Frontiers with the support of artificial intelligence and reasonable efforts have been made to ensure accuracy, including review by the authors wherever possible. If you identify any issues, please contact us.

## Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

## Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/frfst.2025.1734009/full#supplementary-material>

- Detpiratmongkol, S., Ubolkerd, T., and Yoosukyingstaporn, S. (2014). Effects of chicken, pig and cow manures on growth and yield of kalmegh (*Andrographis paniculata* nees). *J. Agric. Technol.* 10 (2), 475–482.
- Dlamini, C. S. (2011). Provenance and family variation in seed mass and fruit composition in *Sclerocarya birrea* sub-species *caffra*. *J. Hort. For.* 3 (9), 286–293.
- Dolor, D. (2011). Effect of propagation media on the germination and seedling performance of *irvingia Wombolu* (vermoesen). *Am. J. Biotechnol. Mol. Sci.* 1 (2), 51–56. doi:10.5251/ajbms.2011.1.2.51.56
- Ham, C., and Chirwa, P. W. (2011). Forest resource use in southern Africa. Natural Resources Governance in Southern Africa. *Africa Institute of South Africa*, 67–91.
- Islam, A. K., Anuar, N., and Yaakob, Z. (2009). Effect of genotypes and pre-sowing treatment on seed germination behavior of *jathropha*. *Asian J. Plant Sci.* 8, 433–439. doi:10.3923/ajps.2009.433.439
- Leakey, R. R. B., Tchoundjeu, Z., Schreckenber, K., Shackleton, S. E., and Shackleton, C. M. (2005). Agroforestry tree products (AFTPs): targeting poverty reduction and enhanced livelihoods. *Int. J. Agric. Sustain.* 3 (1), 1–23. doi:10.1080/14735903.2005.9684741
- Lokesh, S. L. (2007). *Standardization of nursery techniques in Terminalia chebula retz: an important medicinal tree*. M. Sc. (For.) Thesis, University of Agricultural Science, Dharwad (India).
- Malamy, J. E., and Ryan, K. S. (2001). Environmental regulation of lateral root initiation in *arabidopsis*. *Plant Physiol.* 127, 899–909. doi:10.1104/pp.010406
- Manatsa, D., Mushore, T. D., Gwitira, I., Wuta, M., Chemura, A., Shekede, M. D., et al. (2020). Revision of Zimbabwe's agro-ecological zones. A technical report submitted to the zimbabwe national geospatial and space agency (ZINGSA) for the ministry of higher and tertiary education. *Innovation, Sci. Technol. Dev.*
- Maroyi, A. (2013). Traditional use of medicinal plants in south-central Zimbabwe: review and perspectives. *J. Ethnobiol. Ethnomed.* 9 (1), 31.
- Mhango, J., Akinnifesi, F. K., Mng'omba, S. A., and Sileshi, G. (2008). Effect of growing medium on early growth and survival of *Uapaca kirkiana* muell arg. Seedlings in Malawi. *Afr. J. Biotechnol.* 7 (13).
- Mng'omba, S. A., Sileshi, G. W., Jamnadass, R., Akinnifesi, F. K., and Mhango, J. (2012). Scion and stock diameter size effect on growth and fruit production of *Sclerocarya birrea* (Marula) trees. *J. Hort. For.* 4 (9), 153–160.
- Muok, B. O., Khumalo, S. G., Tadesse, W., and Alem, S. (2011). *Sclerocarya birrea, marula. Conservation and sustainable use of genetic resources of priority food tree species in Sub-Saharan Africa*. Rome, Italy: Biodiversity International.
- Neelam, A., and Ishtiaq, M. (2001). Response of *Eucalyptus camaldulensis* seedlings to different soil media. *Sarhad J. Agric.* 17 (1), 75–79.
- Nelson, D. W., and Sommers, L. E. (1996). "Total carbon, organic carbon, and organic matter," in *Methods of soil analysis. Part 3: chemical methods, SSSA book series 5*. Editor D. L. Sparks (Madison, Wisconsin: Soil Society of America), 961–1010.
- Okunomo, K., Ureigho, U. N., and Opute, H. O. (2000). The effect of soil amendment on the performance of gambayaalbida (linn) seedlings. *Eur. J. Sci. Res.* 13, 244–250.
- Omokhua, G. E., Ogu, A., and Oyeade, B. A. (2015). Effects of different sowing media on germination and early seedling growth of *Terminalia ivorensis* (A. chev.). *Int. Journal Scientific Technology Research* 4 (3), 119–122.
- Pandiyan, R., Manivannan, K., and Ashok Kumar, R. (2011). Effect of growth regulators and age of root stocks on the propagation of Jack through grafting. *Res. J. Agric. Sci.* 2 (2), 214–243.
- Ruiz-Perez, M., Belcher, B., Achdiawan, R., Alexiades, M., Aubertin, C., Caballero, J., et al. (2004). Markets drive the specialization strategies of forest peoples. *Ecol. Soc.* 9 (2), 4. doi:10.5751/es-00655-090204
- Saka, J. D. K., Swai, R., Mkonda, A., Schomburg, A., Kwasiga, F., and Akinnifesi, F. K. (2004). "Processing and utilization of Indigenous fruits of the miombo in Southern Africa," in *Proceedings of regional agroforestry conference on agroforestry impacts on livelihoods in Southern Africa: putting research into practice*, 343–352.
- Sankaranarayanan, R., Vijayakumar, M., and Rangasamy, P. (1994). Cow urine for ideal seed germination in tamarind. *Indian Hort.* 38 (4), 15.
- Schreckenber, K., Awono, A., Degrande, A., Mbosso, C., Ndoye, O., and Tchoundjeu, Z. (2006). Domesticating Indigenous fruit trees as a contribution to poverty reduction. *For. Trees Livelihoods* 16, 35–52. doi:10.1080/14728028.2006.9752544
- Shukla, K. C., Singh, O. P., and Samaiya, P. K. (1997). Effect of foliar spray of plant growth regulator and nutrient complex on productivity of soybean Var. Js 79. *Crop Res.* 19, 213–215.
- Simons, A. J., and Leakey, R. R. B. (2004). Tree domestication in tropical agroforestry. *Agrofor. Syst.* 61, 167–181. doi:10.1023/b:agfo.0000028997.74147.f9
- Srivastava, O. P. (1998). Integrated nutrient management for sustainable fertility of soil. *Indian J. Agric. Chem.* 31 (1), 1–12.
- Swain, M. R., and Ray, R. C. (2009). Biocontrol and other beneficial activities of *Bacillus subtilis* isolated from cowdung microflora. *Microbiol. Research* 164 (2), 121–130. doi:10.1016/j.micres.2006.10.009
- Swamy, G. S. K., Patil, P. B., Athani, S. I., and Prabhushankar, D. S. (1999). Effect of organic and inorganic substances on germination of jamun (*Syzygium cumini*) seeds. *Adv. Agric. Res. India* 11, 89–91.
- Tchoundjeu, Z., Asaah, E. K., Aneghbeh, P., Degrande, A., Mbile, P., Facheux, C., et al. (2006). Putting participatory domestication into practice in west and Central Africa. *For. Trees Livelihoods* 16, 53–70. doi:10.1080/14728028.2006.9752545
- Wilson, S. B., Stoffella, P. J., and Graetz, D. A. (2001). Use of compost as a media amendment for containerized production of two subtropical perennials. *J. Environ. Hort.* 19, 37–42. doi:10.24266/0738-2898-19.1.37
- Yadav, B. K., and Sidhu, A. S. (2016). Dynamics of potassium and their bioavailability for plant nutrition. in *Potassium solubilizing microorganisms for sustainable agriculture (187–201)*. New Delhi: Springer India.