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Formulation and Evaluation of Soilless Media for Producing Tomato (*Solanum lycopersicum*) Seedlings

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ABSTRACT
The high cost and limited availability of good quality growing media for tomato seedling production has created the need for sustainable and locally available alternatives. Basal soilless media was formulated using coco peat (CP), sawdust (SD) and sand as basal ingredients. Growmax (GM) and Urea Supersaturated biochar effect on Tomato seedlings was investigated. Dilution effect of GM on optimum inclusion level of biochar for profound seedlings growth was studied. 30%v/vCP+30%v/vSD+40%v/vSand showed 90% germination index (GI), pH (7.1 to 7.6), Electrical conductivity (EC) of 100 µS/cm and total dissolved solids (TDS) of 52.3 ppm. GM supersaturated biochar (GMCBH) containing 2%GMCBH gave highest (98.75%) GI compared to Urea saturated biochar (UCBH) of 93.75%. GMCBH influenced highest root development (6.4 cm) at 2% compared with UCBH (5.0 cm). Seedlings on GMCBH achieved significantly (p<0.05) high plant height with 2% concentration. Further dilution of GM increased plant height and number of leaves significantly (p<0.05) under 1:750 dilution on 2%GMBC between week 1 and week 4.

Keywords: Soilless, Cocopeat, Sawdust, Supersaturated, Biochar

INTRODUCTION

Tomato (*Solanum lycopersicum*) is among the most widely cultivated and economically important vegetable crops in the world, valued both for its direct culinary use and as a raw material for the processed food industry (FAO, 2023). In Nigeria, *Solanum Lycopersicum* (*S. lycopersicum*) occupies a central place in household diets and represents a significant source of income for smallholder and commercial growers. Despite growing interest, production continues to dwindle and short of demand, resulting in seasonal price volatility. A substantial share of this shortfall has been attributed to production constraints associated with conventional open-field, soil-based cultivation which is prone to declining soil fertility under continuous cropping and soil-borne pests and diseases (Amurtiya and Adewuyi, 2020), as well as erratic rainfall and limited land availability in peri-urban areas where demand for fresh produce is concentrated (Liverpool-Tasie *et al*., 2024).

Soilless culture has emerged internationally as a response to constraints of soil based farming by offering a production system in which the crop is grown in an artificial rooting medium or nutrient solution rather than in natural soil. The theoretical rationale for this shift rests on the recognition that soil-based production, while historically dominant, imposes limitations such as salinity build-up, compaction, and the accumulation of soil-borne pathogens that soilless systems are specifically designed to circumvent (Fussy and Papenbrock, 2022). The adoption of soilless cultivation techniques in Nigeria has been driven by declining arable land, increasing urbanization and increased population.

Most investigators on soilless farming focused on identifying and optimizing the growing media used in soilless tomato seedling production. Comparative studies of organic and inorganic substrates have shown that materials such as peat moss, cocopeat, vermicompost, perlite, and leonardite differ considerably in their effect on tomato growth with performance depending on the physical and chemical properties of the specific material and how it is blended with complementary substrates (Subramani *et al.,* 2020; Aliyu *et al.*, 2024 and Erdal and Aktaş, 2025). Studies consistently demonstrate that no single substrate uniformly satisfies the physical and nutritional requirements of the tomato root system, and that substrate performance is highly sensitive to blend ratio, underlying physicochemical properties, and the local production environment in which the trial is conducted (Khatri *et al.*, 2025).

The cost and environmental footprint associated with commercial substrates such as imported cocopeat and peat moss have motivated a distinct and growing strand of research into local agro-industrial by-products as alternative or complementary growing media (Fussy and Papenbrock, 2022). Materials such as rice husk, rice husk ash, and various forms of composted agricultural and agro-processing waste have been investigated as substrate components, with several studies reporting that such materials can match or, under appropriate formulation, exceed the performance of conventional substrates while simultaneously offering a route to reducing agricultural waste disposal burdens (Zawadzińska *et al.,* 2022). This circular-economy positioning of soilless substrate development advocates agricultural waste as resources awaiting conversion to productive input to solve waste disposal problem. This notion has been advanced a sustainability imperative to further deepen research in growing media (Taparia et al., 2021).

The continued reliance on soil-based nursery systems for tomato seedling production is becoming increasingly unsustainable given the rising incidence of soil-borne pests and diseases, the physical inconsistency of topsoil, and the progressive depletion of arable land through erosion and urban encroachment (Kumari *et al.,* 2024). These challenges often translate into poor seedling vigor, non-uniform stands, and diminished transplant success, ultimately affecting

overall crop yield and profitability (Gulzar *et al.,* 2024). Soilless growing media present a viable alternative by offering a controlled, pathogen-free rooting environment with the potential for optimized physical and chemical properties.
Peat, which is commonly used as an alternative growing medium elsewhere, is not readily available locally and its extraction raises environmental concerns, making it an impractical option for many growers. This creates a need to explore other materials that are cheap, locally available, and capable of supporting good seedling growth (Samuel *et al.,* 2025).
Coco peat, sawdust, sand, and biochar are materials that can potentially fill this gap, but there is limited information on how best to combine them to produce a medium that supports strong germination and vigorous seedling growth. In addition, while biochar is known to improve the physical and chemical properties of growing media, its benefits depend on how it is enriched or "super saturation" with nutrients before use, and there is not enough clarity on which method of enrichment works best or at what inclusion rate it should be used to achieve optimal germination and seedling performance.
This study is therefore seeking to generate practical, locally relevant knowledge on how cocopeat, sawdust, biochar and sand that are readily available materials can be combined to produce an effective soilless medium for tomato seedling production. By systematically evaluating the physical and chemical suitability of these substrates, the study contributes to reducing production costs for nursery operators, promoting the recycling of agricultural residues into valuable growing media, and supporting more sustainable, resource-efficient approaches to seedling raising. The main objective of this study is to develop and evaluate suitable soilless media for effective growth and production of tomato seedlings.

MATERIALS AND METHODS

Experimental Location

The study was carried out between March and July, 2025 at the teaching and research farm of Faculty of Agriculture, Al-Hikmah University, Igbaja Campus (8.23°N, 4.88°E), Kwara State, Nigeria.

Procurement and Preparation of Soilless Media Ingredients

The soilless media ingredients, Sawdust (SD), Sand, and Cocopeat (CP) were procured from Igbaja and its environs. Sawdust was collected from a local sawmill and sieved with basket (≤0.5mm) to remove large wood particles and physical contaminants. Sawdust was air-dried for 5 days before use. Sand was collected from runoff paths within the campus and sterilized at 100ºC for 2hr to kill weed seeds, contaminants and microorganisms. Treated and bailed Cocopeat was procured from suppliers in Ibadan Oyo, State. It was pulverized, sun-dried and sieved with basket (≤0.5mm) to remove large fibrous materials. Tomato seeds used were extracted from fresh, healthy tomato fruits using the fermentation method. Fresh tomatoes fruits were cut into halves, and the pulp containing the seeds was carefully removed and allowed to ferment for 2 days. The seeds were washed with clean water to remove pulp, air dried under ambient conditions and stored in airtight container till further use. Formulation of base ingredients of the soilless media was carried out by mixing in into five (5) treatments as 10%v/vCP+50%v/vSD, 20%v/vCP+40%v/vSD, 30%v/v+40%v/vSD, 40%v/v+20%v/v, 50%v/v+10%v/v and 100%v/v sand. The best combination in displaying optimum outcomes was tagged “Combo” in the subsequent investigation.

Production of Biochar and Nutrient Saturation

The biochar was produced using discarded Neem tree branches gathered from Igbaja campus forest. The wastes were cut into approximately 46 cm long using axe and cutlass. The size reduced forest waste was pyrolyzed at 500-700ºC in an oxygen depleted Kontiki kiln with dimension 30cm × 20cm × 30cm. The biochar was quenched with tap water and allowed to cool before removal from the kiln. The raw wet biochar was sun-dried. Dried biochar was pulverized using mortar and pestle and stored in airtight container until further use (Baidoo et al., 2016). Sieved biochar was supersaturated with 1:50 diluted stock solution of Urea and Growmax (GM) fertilizer for 2 days under ambient temperature. Inclusion level of supersaturated biochar (SSB) was varied according to yield five (5) treatments as 1%v/v SSB+99%v/vCombo, 2%v/v SSB+98%v/vCombo, 3%v/v SSB+97%v/vCombo, 4%v/v SSB+96%v/vCombo and 5%v/v SSB+95%v/vCombo.

Determination of Concentration Effects of Selected Fertilizer on Formulated Soilless Media

A concentration effect of best fertilizer for super saturation was assessed by varying the concentration prior to super saturation at 1:500, 1:750, 1:1000, 1:1250 and 1:1500. About 750 ml of diluted fertilizer was applied to each the grow bag before seeding.

Determination of pH, Electrical Conductivity (EC) and Total Dissolved Solids (TDS)

The Electrical Conductivity (EC), Total Dissolved Solids (TDS) and pH of formulated soilless media at all development levels was determined using table top pH meter, EC and TDS meter respectively. Prior to determination, 1 g of formulated soilless media was weighed and diluted with 10 ml of distilled water before pH, EC and TDS were determined

Determination of Germination Index

Tomato seeds was planted in each seedling tray already filled with media. Two (2) seeds were planted per each seedling tray cell and the experiment was repeated thrice and germination index was calculated according to the relationship below:

$$\textbf{Germination index} = \frac{\text{Number of Germinated Seeds}}{\textit{Total number of seeds planted}} \times 100$$

Statistical Analysis

All experiments were laid out in a under randomized complete block design (RCBD) and data obtained were subjected to analysis using excel in Microsoft office 2016. Significant difference among means was measured at $p<0.05$ and separated using Duncan Multiple Rate Test (DMRT) analysis.

RESULTS AND DISCUSSION

Germination Index of Formulated Base Ingredients of Soilless Media

To identify the effect of organic amendment ratios on seed germination index (GI), different proportions of cocopeat (CP), sawdust (SD), and Sand were investigated as soilless growing media. Treatment containing 30%v/vCP+30%v/vSD+40%v/vSand showed the highest but not significantly different ($p<0.05$) GI of 100% (Figure 1a). The ability of the treatment to support perfect germination index could be due to average inclusion levels of all ingredients. This result is consistent with other reports where varied ratios of organic amendments that included treated cocopeat produce more favorable germination. GI has been

reported to respond to proportion of base materials in soilless media (Kafle *et al.*, 2024). The negative control recorded no GI. Reduced germination in sand-only treatment could be attributed to poor moisture retention. Poor moisture retention could hamper seed germination (Gowthami *et al.*, 2024). The pH of the growing media ranges from 7.1 to 7.6 and it was not significantly different ($p<0.05$) in all treatments (Figure 1b). This indicates that all the formulated media maintained conditions suitable for nutrient availability. However, EC and TDS showed considerable variation among treatments. Treatment 10%CP+50%SD+40%Sand exhibited elevated EC and TDS values of 482µs/cm and 203ppm which might impact GI negatively while treatment 10%CP+50%SD+40%Sand that demonstrated lower EC (100 µS/cm) and TDS (52.3 ppm) could trigger higher GI (Figure 1b). The results suggest that higher SD proportions increased EC and TDS. Excessive EC and TDS concentrations can create osmotic.

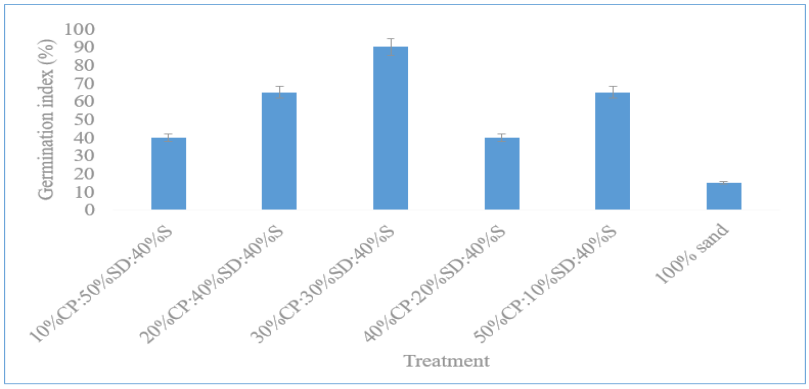


Figure 1: Effect of Formulated Base Ingredients of Soilless Media on (a) GI (b) EC, pH and TDS

Effect of Biochar Treatment Condition on GI and Root Elongation

In order to assess the effect of biochar-based nutrient amendments on seed GI, treatment combinations were supplemented with biochar charged with a commercial liquid organic fertilizer (Growmax) and Urea at varying concentrations (1–5%). The Growmax (GM) supersaturated biochar (GMCBH) treatment containing 2%GMCBH showed highest (98.75%) GI compared to Urea charged biochar (UCBH) that achieved same GI on 5%UCBH (Figure 2a). The results demonstrate that biochar nutrient amendment strategy significantly influences germination outcomes. The outcome of present work is consistent with reports that enriched biochar often improves performance of most organic soil amendments and fertilizers performs at a moderate rate amendment rather than a high rate substitute (Lamichhane *et al.*, 2025). The root elongation of germinating seed was measured to identify the effect of charged biochar on growth; GMCBH influenced highest root development at 2% compared with UCBH (Figure 2b). The lower root elongation by UCBH could be due to increased toxicity compared with GMCBH –an organic fertilizer. The stable GMCBH performance across concentrations suggested consistent nutrient bioavailability. The inhibition of Urea at 2% is consistent with report that UCBH produces concentration-dependent effects on tomato vegetative growth generating elevated salt concentrations that constrain root development before nitrogen is made available (Fornes *et al.*, 2025).

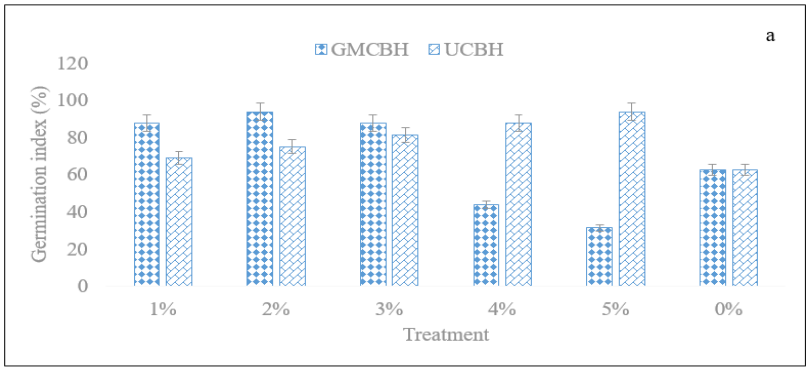


Figure 2: Effect of Biochar Treatment on (a) GI (b) Root Length of Germinating Seed

Effect of GMCBH and UCBH on Plant Height

Plant heights differed significantly between GMCBH and UCBH treatments across the three-week period. In Week 1, GM treatments showed concentration-dependent responses ranging from 0.5 cm at 3% and 4% to 1.8 cm at 1% and 2%, while Urea treatments remained uniform across all concentrations (Table 1). By Week 3, seedlings on GMCBH had increased heights significantly with 2% concentration achieving maximum height. The outcome of this investigation is consistent with other works where tomato seedlings responded to low concentration of fertilizer for proper growth and development (Erdal and Aktaş, 2025).

Table 1: Effect of GM and Urea Charged Biochar on Plant Height

Treatment	Week 1 (cm)		Week 2 (cm)		Week 3 (cm)	
	GMCBH	UCBH	GMCBH	UCBH	GMCBH	UCBH
1%	1.8^{c}	1.2^{b}	6.6^{b}	5.0^{a}	7.0^{c}	5.3^{a}
2%	1.8^{c}	0.5^{a}	7.0^{c}	6.1^{b}	8.0^{d}	6.6^{b}
3%	0.5^{a}	1.0^{a}	6.2^{b}	6.3^{b}	6.9^{bc}	7.1^{c}
4%	0.5^{a}	1.3^{b}	4.4^{a}	6.8^{bc}	5.8^{a}	6.7^{b}
5%	1.4^{b}	1.5^{b}	4.8^{a}	5.9^{b}	5.1^{a}	5.6^{a}
0%	1.1^{a}	1.1^{a}	5.8^{b}	5.8^{b}	6.6^{b}	6.6^{b}
Sig.	*	*	*	*	*	*

*Sig. Denotes significant level at p<0.05, GMCBH: Growmax-charged biochar; UCBH: Urea-charged biochar
$^{a,b,c;}$ Superscript for significant difference

EC, pH and TDS of GMCBH and UCBH

The incorporation of different percentages of nutrient embedded biochar influenced the chemical properties of the substrate. In the first week, the pH of the biochar-amended substrates was slightly lower than the control but increased and stabilized near neutral by Weeks 2 and 3, indicating that biochar gradually buffered the substrate and created conditions suitable for nutrient availability for tomato seedling growth (Table 2). EC and TDS also varied with biochar application, with higher values generally observed during the early stages, followed by stabilization as the experiment progressed. The result agrees with recent studies showing that biochar enhances substrate buffering capacity, improves nutrient retention, and promotes gradual nutrient release in soilless growing media (Joseph *et al.*, 2021).

Table 2: EC, pH and TDS of Growing Media Amended with GMCBH and UCBH

	Treatment	Week 1		Week 2		Week 3	
		GMCBH	UCBH	GMCBH	UCBH	GMCBH	UCBH
pH	1%	5.9^{a}	6.3^{a}	7.4^{b}	7.3^{b}	7.3^{a}	7.4^{b}
	2%	6.0^{a}	6.2^{a}	7.5^{c}	7.2^{b}	7.2^{a}	7.4^{b}
	3%	6.1^{b}	6.3^{a}	7.4^{b}	7.4^{b}	7.4^{b}	7.3^{a}
	4%	6.2^{b}	6.3^{a}	7.4^{b}	7.3^{b}	7.4^{c}	7.3^{a}
	5%	6.0^{a}	6.5^{c}	7.1^{a}	7.3^{b}	7.5^{b}	7.4^{b}
	0%	6.3^{b}	6.3^{b}	7.0^{a}	7.0^{a}	7.8^{c}	7.8^{c}
EC (µS/cm)	1%	538^{a}	516^{a}	478^{a}	497^{a}	542^{a}	540^{a}
	2%	515^{a}	505^{a}	484^{a}	494^{a}	510^{a}	533^{a}
	3%	551^{a}	507^{a}	489^{a}	498^{a}	550^{a}	543^{a}
	4%	537^{a}	470^{a}	505^{a}	487^{a}	525^{a}	623^{a}
	5%	400^{a}	532^{a}	518^{a}	525^{a}	524^{a}	629^{a}
	0%	568^{a}	568^{a}	459^{a}	459^{a}	506^{a}	506^{a}
TDS (ppm)	1%	260^{a}	275^{a}	238^{a}	253^{a}	268^{a}	270^{a}
	2%	274^{a}	266^{a}	241^{a}	241^{a}	257^{a}	263^{a}
	3%	302^{a}	239^{a}	251^{a}	237^{a}	270^{a}	266^{a}
	4%	291^{a}	265^{a}	256^{a}	257^{a}	267^{a}	315^{a}
	5%	207^{a}	294^{a}	272^{a}	266^{a}	262^{a}	318^{a}
	0%	242^{a}	242^{a}	250^{a}	250^{a}	260^{a}	260^{a}

GMCBH: Growmax-charged biochar; UCBH: Urea-charged biochar
Legend: Superscript with the same alphabet within the same column are not significantly different (p< 0.05)

Effect of Different Dilutions of GM Applied On The 2% GMCBH On Seedlings Growth

The plant height increased significantly (p>0.05) from 1.9 cm in week 1 to week 4 16.3 cm in Week 4 (Table 3). The 1:750 treatment produced the tallest seedlings followed closely by 1:1000 and 1:500 indicating that these nutrient concentrations provided an optimum nutrient supply for vegetative growth. Similar findings have been reported in soilless culture (Savvas *et al.*, 2018; Zhang *et al.*, 2022).

Table 3: Effect of Different GM Concentrations on Plant Height

Treatments	Week 1 (cm)	Week 2 (cm)	Week 3 (cm)	Week 4 (cm)
1:500	2.0^{b}	7.8^{c}	9.6^{c}	13.3^{c}
1:750	2.5^{c}	8.8^{c}	11.2^{d}	16.3^{d}
1:1000	2.2^{c}	8.6^{c}	10.7^{c}	14.8^{c}
1:1250	2.4^{c}	6.0^{b}	6.7^{b}	7.4^{b}
1:1500	1.9^{b}	6.9^{b}	7.7^{b}	8.3^{b}
Control	0^{a}	0^{a}	0^{a}	0^{a}

^{a,b,c}; Superscript for significant difference ($p<0.05$).

Effect of Different Dilutions of GM Applied on 2% GMCBH on Number of Leaves

The number of leaves increased; albeit not significantly different ($p<0.05$) between week 1 and week 4 in all treatments (Table 4). Dilution of 1:750 recorded the highest number of leaves followed by 1:1000 and 1:500. This suggests that the 1:750 ratio provided the optimum nutrient for leaf development in tomato seedlings. Balanced supply of nutrients by fertilizers have been reported to support overall vegetative growth in soilless tomato seedlings production (Savvas *et al.*, 2018).

Table 4: Effect of Different Growmax Concentrations on Number of Leaves

Treatments	Week 1	Week 2	Week 3	Week 4
1:500	2^{a}	3^{a}	4^{a}	8^{ab}
1:750	2^{a}	4^{a}	6^{b}	10^{c}
1:1000	2^{a}	4^{a}	5^{a}	9^{b}
1:1250	2^{a}	3^{a}	4^{a}	6^{a}
1:1500	2^{a}	3^{a}	5^{a}	7^{a}
Control	2^{a}	3^{a}	4^{a}	6^{a}

^{a,b,c}; Superscript for significant difference ($p<0.05$).

CONCLUSION

Formulated soilless growing media formulated from cocopeat, Sawdust and Sand supported profound germination of seeds, optimum pH, EC and TDS. Inclusion of 2% supersaturated GMBCH supported all growth characteristics of tomato seedlings. Dillution of GM at 1:750 prior to supersaturation supported plant height, number of leaves and electrochemical properties of the soilless growing media. The combination of 30% coco peat, 30%SD and 40% Sand, amended with supersaturated charged biochar at a moderate inclusion level of approximately 2%, represents the best-performing growing medium identified in this study, offering the strongest balance of germination index, root length, plant height, and stable media chemical properties. Nursery operators and growers producing tomato seedlings in soilless media should adopt a base medium of 30% cocopeat, 30%SD, and 40% sand. Supersaturated biochar with Growmax should be incorporated into the medium at a concentration of 2% and diluted at 1:750 to produce best overall germination and growth outcomes. Additional investigation is recommended to explore other locally available biochar feed stocks and alternative nutrient sources.

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