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Article

Effect of Container Type and Size on *Plukenetia conophora* Seedling Production

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Abstract: This study examined the effects of different container types and sizes on seedling emergence and growth of *Plukenetia conophora* Müll.Arg. (African walnut) to optimize nursery production practices. A 3 × 3 factorial experiment was conducted in a completely randomized design with three replications. The experiment was carried out at the greenhouse of the School of Agriculture and Agricultural Technology, Owerri. Seedling emergence, internode length, number of branches, number of leaves, and plant height were assessed at 9, 11, 13, 15, and 17 weeks after planting. The results revealed that container type, container size, and their interaction significantly ($p < 0.05$) affected seedling growth. Medium-sized plastic containers had the best growth performance, while polythene-based containers were less effective. These findings suggest that plastic containers of medium size can be used to achieve optimizing the nursery production of African walnut seedlings.

Keywords: African walnut, container attributes, seedlings emergence, seedling development.

Received for publication on Month 20.07.2024

Accepted for publication on Month 06.06.2025

1. Introduction

Seedling production in containers, baskets and seed trays is increasingly gaining prominence among farmers even at the subsistence level. The preferential choice of containers as against the convention and tradition of using raised seedbeds in open fields to grow seedlings is to ensure the production of high-quality seedlings. Unlike the open field, the container and its surroundings can be adjusted or manipulated to produce high quality seedlings. Improvement of seedling quality to the extent of altering the seedlings morphology and physiology has been achieved over the years (Tanaka and Timmis, 1974; Hunt, 1990; Mugnai et al., 2000; Ow and Ghosh, 2017). Modification of seedling morphology and physiology can be achieved by altering the container content (media) and or the physical property of the container. Earlier studies reported that one of the techniques employed in altering seedlings morphology is by modifying the physical properties of nursery containers, such as container type, colour, design, depth, diameter, volume, cavity, spacing (Segaw et al., 2016; Gallegos et al., 2020; Keyes and Brissette, 2017). Phenotypic seedling variation can be achieved in seedling production by altering the properties of the containers used to grow seedlings. In other words, the physical properties of containers used in seedlings production can be carefully engineered to raise choice seedlings for specific purposes.

Selection of container type for seedling production is essential for production of healthy and high-quality seedlings. Research works have shown that some attributes of the container such as size, type, and colour, had influence on seedling emergence, growth, and played a significant role in the out-planting field performance of the seedlings (Luna et al., 2009, Single and Single, 2010; Oagile et al., 2016; Negi and Shamet, 2020). Container

DOI: 10.7160/sab.2025.560418

volume is directly related to seedling size, and out-planting performance of seedlings is potentially determined by container size (Pinto et al., 2011). Several reports from workers have shown that large containers produce seedlings with better morphological and physiological attributes because they have adequate space for root growth and provide sufficient water and nutrients for seedling growth (Dominguez-Lerena et al., 2006, Islam et al., 2019; Keyes and Brissette, 2017; Salisu et al., 2018). Seedlings raised in small volume containers on the other hand showed a reduced rate of photosynthesis, and their growth rate was relatively hindered (Poorter et al., 2012). On container design, Single and Single (2010) reported that it strongly influenced seedling root system architecture and spiralling prevention. Reports on the effect of container type on seedling production include Dhavala et al (2004) on growth and quality of Indian sandalwood (*Santalum album* L.), Tian et al. (2017) on seedling growth and root morphology of *Cyclocarya paliurus* (Batalin) Iljinsk., South et al. (2005) on survival and early height growth of *Pinus palustris*, Oagile et al. (2016) on growth and development of Tomato seedlings, Yan et al. (2016) on *Pinus tabuliformis* Carrière , and Salisu et al. (2018) on growth and root morphology of Rubber (*Hevea brasiliensis* Mull. Arg). Unfortunately, none of these reports was on African walnut seedling production.

It is clear from the foregoing there is little or no report on the effect of container type and size on African walnut seedling production. *Plukenetia conophora* is a forest tree crop of African origin. It is popularly known as king of nuts because of the outstanding potentials of its highly nutritive edible seeds or nuts (Chijoke et al., 2017; Oke et al., 2020; Adetunji et al., 2021). Past reported studies (Onwualu et al., 2013; Oke et al., 2020) have shown that the production of African walnut is low, and till date hybrid of *P. conophora* has not been developed (Akinfernwa, 2022). Research attention on seedling production of this crop is poor. The few scholarly articles on seedling production of African walnut are Agbo et al (2014), and Onwubiko and Enwereji (2023). Therefore, this study was set up to assess the effect of two attributes of the container (type and size) on *P. conophora* seedling production.

2. Materials and Methods

2.1 Experimental Area and Environmental conditions

The study was conducted at the greenhouse of the School of Agriculture and Agricultural Technology, Federal University of Technology, Owerri (FUTO), Nigeria (5°20'N–5°25'N latitude and 7°00'E–7°05'E longitude) at an altitude of 90.91 m above sea level. The mean annual rainfall of this area was 2,990 mm and relative humidity 81.6%.

The materials used for this research study were African walnut seeds collected from the germplasm unit of the Department of Crop Science and Technology. Three container types: plastic, metal, and polyethene, and three container sizes: large, medium, and small were used for the study. Other materials were paper masking tape for tagging, markers, and meter ruler for data collection.

2.2 Planting Material and Pre-Treatment

Topsoil and poultry manure were used to prepare the planting media in the ratio v/v of 1:1. The media were contained in perforated plastic buckets of three sizes; large (25cm diameter x 21cm depth), medium (22 cm x 18 cm) and small (19 cm x 16cm), perforated metal containers of three sizes; large (24 cm x 19 cm), medium (20 cm x 16 cm), small (16 cm x 14 cm), and perforated polythene containers of three sizes; large (7 x 10 inches), medium (5.5 x 6 inches), small (4 x 6 inches).

African walnut seeds used for the study was 200 in number, and the weight of the seeds were between 10.23g – 10.31g. The seeds were soaked in water for 24 hours to break dormancy and planted in containers filled 2/3 in volume with topsoil mixed with poultry manure (v/v 1:1). Watering can was used to water the seedlings at intervals of four days and sanitary practices were regularly carried out to keep the experimental site free from weeds.

2.3 Data Collection and Statistical Analysis

Data were collected on the following parameters: number of days to emergence, internode length, plant height at 9, 11, 13, 15, 17 weeks after planting (WAP), number of leaves at 9, 11, 13, 15, 17 WAP, and number of branches at 9, 11, 13, 15, 17 WAP. All the collected data were subjected to analysis of variance (ANOVA), and means were separated using Fisher's least significant difference at 5% probability level.

3. Results

The result of the effect of container types and sizes on number of days to emergence of African walnut is presented in Table 1 below.

Table 1: Effect of container types and sizes on the number of days to emergence of African walnut

Container	Sizes			
Types	Large	Medium	Small	Mean
Metal	10.06	9.16	8.16	9.53
Plastic	9.66	8.16	8.00	8.61
Polythene	9.16	9.33	11.16	9.89
Mean	9.83	8.85	5.11	
LSD $_{0.05}$(types)	Ns			
LSD $_{0.05}$ (sizes)	Ns			
LSD $_{0.05}$(types and sizes)	Ns			

Ns = non-significant; LSD = Least significant difference

Analysis of variance (ANOVA) results showed no significant difference ($p > 0.05$) in number of days to emergence on container type, size, and their interaction. However, small size containers had the least mean number of days to emergence of 5.11 (approximately 5 days), while large sized containers had the highest mean value of 9.83 (approximately 10 days). Further, the container type that had the lowest mean value on emergence of 8.61 (approximately 9 days) was plastic containers while polythene bags recorded the highest mean value (9.89) of approximately 10 days.

Table 2 shows the result on the effect container types and sizes on number of leaves of African walnut at 9,11,13,15 and 17 WAP

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Table 2: Effect of container types and sizes on number of leaves of African walnut at 9,11,13,15 and 17 WAP

Container Type	9 WAP				11 WAP				13 WAP				15 WAP				17 WAP			
	Size				Size				Size				Size				Size			
	Large	Medium	Small	Mean	Large	Medium	Small	Mean	Large	Medium	Small	Mean	Large	Medium	Small	Mean	Large	Medium	Small	Mean
Metal	9.5	54.5	10.5	24.7	14.4	72.4	15.9	34.2	19.1	83.6	21.6	41.4	20.9	90.9	24.9	45.5	27.1	97.1	31.1	51.8
Plastic	10.0	54.0	54.3	39.6	18.4	61.9	61.3	44.2	24.1	72.6	68.0	34.9	29.4	81.9	75.3	62.2	34.1	93.1	85.3	70.9
Polythene	8.5	8.7	11.3	9.6	11.9	11.4	17.4	13.5	15.6	16.8	26.1	19.5	19.9	19.3	31.4	23.5	22.1	23.4	37.1	27.5
Mean	9.4	39.1	25.5		14.9	48.5	31.5		19.6	57.7	38.6		23.4	64.0	43.0		27.8	71.2	51.2	
LSD 0.05 (type)		16.08				14.98				16.27				16.25				18.05		
LSD 0.05 (size)		Ns				Ns				Ns				Ns				Ns		
LSD 0.05 (type and size)		27.86				25.94				28.18				28.15				31.27		

Ns = non-significant; LSD = Least significant difference

The result on the effect of container types on number of leaves showed significant differences ($p<0.05$). Seedlings raised in plastic containers recorded the highest mean values (of 39.6, 44.2, 62.2, and 70.9) in almost all the weeks (9, 11, 15, 17) except for 13 WAP that seedlings raised in metal container had the highest mean value (41.4) on number of leaves. The least mean values of 9.4, 13.5, 19.5, 23.5, and 27.5 were recorded for seedlings raised in polythene containers at 9, 11, 13, 15 and 17 WAP respectively. Unlike container type the result on container sizes did not show any significant difference. The interaction between container types and sizes at 9, 11, 13 ,15 and 17 WAP, recorded significant differences. The highest mean values on number of leaves of 54.5, 72.4, 83.6, 90.9, and 97.1 were recorded for seedlings raised in metal containers of medium size at 9, 11, 13 ,15 and 17 WAP. On the other hand, seedlings raised in polythene containers had the least mean values at 9, 13, and 17 WAP of 8.5, 15.6, and 22.1. Medium sized polythene containers had the least mean number of leaves of 11.4 and 19.3 at 11, and 15 WAP. The result on the effect of container types and sizes on number of branches of African walnut at 9,11,13,15 and 17 WAP is presented on Table 3 below.

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Table 3: Effect of container types and sizes on number of branches of African walnut at 9,11,13,15 and 17 WAP

Container Type	9 WAP				11 WAP				13 WAP				15 WAP				17 WAP			
	Size				Size				Size				Size				Size			
	large	Medium	small	mean	large	medium	small	mean	large	medium	small	Mean	large	medium	small	mean	large	medium	small	mean
Metal	0.73	5.23	2.23	2.73	0.82	7.32	2.32	3.49	1.99	8.99	2.99	4.66	2.45	9.45	3.95	5.29	2.88	11.38	3.88	6.05
Plastic	2.73	7.23	5.00	4.99	3.82	8.32	5.67	5.94	3.99	8.99	6.00	6.33	4.45	9.45	6.67	6.86	4.88	9.88	7.33	7.37
Polythene	0.73	1.08	0.73	0.85	1.82	2.07	1.82	1.90	2.49	3.00	2.49	2.60	2.95	3.54	2.95	3.15	3.38	4.16	3.88	3.81
Mean	1.40	4.52	2.66		2.15	5.90	3.27		2.83	7.00	3.83		3.29	7.48	4.52		3.72	8.47	5.08	
LSD 0.05 (type)		1.823				1.793				1.675				1.848				1.583		
LSD 0.05 (size)		1.823				1.793				1.675				1.848				1.583		
LSD 0.05 (type and size)		Ns				Ns				2.902				Ns				2.742		

Ns = non-significant; LSD= least significant difference

DOI: 10.7160/sab.2025.560418

On number of branches, significant differences ($p<0.05$) were observed for container types. Seedlings raised in plastic containers recorded the highest mean values of 4.99, 5.94, 6.33, 6.86, and 7.37 at 9, 11, 13, 15, and 17 WAP respectively. The least mean values of 0.85, 1.90, 2.60, 3.15 and 3.81 were obtained for seedlings raised in polythene containers at 9, 11, 13, 15 and 17 WAP. Similarly, the result on container sizes showed significant differences. Seedlings raised in medium containers had the highest mean values of 4.52, 5.90, 7.00, 7.48 and 8.47 at 9, 11, 13, 15, and 17 WAP respectively. On the contrary, seedlings raised in large container sizes recorded the least mean values of 1.40, 2.15, 2.83, 3.29, and 3.72 at 9, 11, 13, 15, and 17 WAP. The interaction effect between container types and sizes did not show any significant difference on number of branches.

Table 4 shows the result on the effect of container types and sizes on internode length of African walnut at 9,11,13,15 and 17 WAP.

Table 4: Effect of container types and sizes on internode length (cm) of African walnut at 9,11,13,15 and 17 WAP

Container type	9 WAP				11 WAP				13 WAP				15 WAP				17 WAP			
	Size				Size				Size				Size				Size			
	Large	Medium	Small	Mean	Large	Medium	Small	Mean	Large	Medium	Small	Mean	Large	Medium	Small	Mean	Large	Medium	Small	Mean
Metal	1.24	3.29	1.14	1.89	2.74	3.34	3.09	3.05	2.64	5.14	3.64	3.81	3.26	5.56	4.11	4.31	3.71	5.81	4.61	4.71
Plastic	1.79	5.84	5.23	4.52	3.44	7.64	7.50	6.19	4.09	7.34	8.20	6.54	4.06	8.16	8.77	7.00	5.66	9.06	9.63	8.12
Polythene	1.49	2.04	0.84	1.46	2.74	3.93	3.14	3.27	2.19	3.57	2.89	2.88	2.71	3.51	3.41	3.21	3.21	4.46	3.66	3.77
Mean	1.51	3.72	2.64		2.97	4.97	4.57		2.97	5.35	4.91		3.34	5.75	5.43		4.19	6.44	5.97	
LSD 0.05 (type)	2.196				2.347				2.386				2.409				2.205			
LSD 0.05 (size)	Ns				Ns				Ns				Ns				Ns			
LSD 0.05 (type and size)	Ns				Ns				Ns				Ns				Ns			

Ns = non-significant; LSD= least significant difference

The effect of container types on internode length at 9, 11, 13, 15, and 17 WAP showed significant differences ($p < 0.05$). Seedlings raised in plastic containers had the highest internode mean values of 4.52 cm, 6.19 cm, 6.54 cm, 7.00 cm, and 8.12 cm at 9, 11,13, 15, and 17 WAP respectively. On the contrary seedlings raised in polythene containers had the least mean values of 1.46 cm, 2.88 cm, 3.21 cm, and 3.77 cm for all the evaluation weeks except for 11 WAP that containers made of metal had the least mean value of 3.05 cm on internode length. No significant difference was observed on internode length for both container sizes, and the interaction between container types and sizes.

Presented in Table 5 is the result on the effect of container types and sizes on plant height of African walnut at 9,11,13,15 and 17 WAP.

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Table 5: Effect of container types and sizes on plant height (cm) of African walnut at 9,11,13,15 and 17 WAP.

Container type	9 WAP				11 WAP				13 WAP				15 WAP				17 WAP			
	Size				Size				Size				Size				Size			
	Large	Medium	Small	Mean	Large	Medium	Small	Mean	Large	Medium	Small	Mean	Large	Medium	Small	Mean	Large	Medium	Small	Mean
Metal	3.6	23.4	6.2	12.7	6.4	38.1	12.1	18.9	7.2	42.0	17.1	22.1	8.4	50.0	18.4	25.6	12.2	58.0	23.0	31.0
Plastic	11.7	28.2	35.6	25.2	16.5	35.3	42.0	31.2	21.8	42.0	52.2	38.7	25.1	48.2	60.2	44.5	32.2	58.4	67.7	52.8
Polythene	10.0	10.0	13.7	11.2	10.7	12.5	17.5	13.6	11.9	18.1	21.9	17.3	13.7	21.3	26.7	20.6	15.6	26.9	32.4	25.0
Mean	8.4	22.2	18.5		11.2	28.6	23.8		13.6	34.0	30.4		15.7	39.9	35.1		20.0	47.8	41.0	
LSD 0.05 (type)		7.35				7.46				8.84				9.46				9.37		
LSD 0.05 (size)		7.35				7.46				8.84				9.46				9.37		
LSD 0.05 (type and size)		12.74				12.93				15.32				16.39				16.23		

Ns = non-significant; LSD= least significant difference

Significant differences ($p < 0.05$) were observed on plant height for container types, and sizes. Further, the result showed significant differences ($p < 0.05$) on the interaction effect between container types and sizes. Seedlings raised in plastic containers had the highest mean values on plant height of 25.2 cm, 31.2 cm, 38.7 cm, 44.5 cm, and 52.8 cm at 9, 11, 13, 15 and 17 WAP respectively. Contrarily, the least mean values on plant height of 11.2 cm, 13.6 cm, 17.3 cm. 20.6 cm, and 25.0 cm were obtained for seedlings raised in polythene containers at 9, 11, 13, 15 and 17 WAP in that order. On container sizes, seedlings raised in medium sized containers had the highest mean plant height of 22.2 cm, 28.6 cm, 34.0 cm, 39.9 cm and 47.8 cm at 9, 11, 13, 15 and 17 WAP respectively. On the other hand, seedlings raised in large containers recorded the least mean plant height of 8.4 cm, 11.2 cm, 13.6 cm, 15.7 cm, and 20.0 cm at 9, 11, 13, 15 and 17 WAP respectively. Further, the interaction effect result showed that small plastic containers had the highest mean values on plant height of 35.6 cm, 42.0 cm, 52.2 cm, 60.2 cm, and 67.7 cm at 9, 11, 13, 15 and 17 WAP respectively, while the least mean plant height values of 3.6 cm, 6.4 cm, 7.2 cm, 8.4 cm, and 12.2 cm were obtained for large metal containers at 9, 11, 13, 15 and 17 WAP in that order.

4. Discussion

General external conditions necessary for seed germination include humidity (water), suitable temperature, oxygen, and light. Significant variations in the intensity and duration of these essential seed germination factors will either enhance or diminish seed germination. The impact container attributes like types and sizes may have on the essential seed germination factors is reasonable. In other words, container attributes can affect seed germination and the growth rate of seedlings. In this study, African walnut seedlings emergence and growth was influenced by container types and sizes. Further, it was observed that the interaction between the two attributes of the containers (types and sizes) also affected seedlings production of African walnut.

The number of days to emergence of African walnut in the study was observed to be between 5 - 14 days. Although the effect of container types and sizes did not significantly affect seed emergence, small containers had the best performance in seed emergence, approximately 5 days after planting (DAP). This result suggests that small containers provided the optimum seed germination conditions required to break dormancy and activate action of enzymes for seed germination. The bigger volume container sizes (medium and large) may have lowered the temperature in circulation in the containers, resulting in late seed emergence. Further, seed planted in plastic containers emerged earlier than other container types, approximately 9 DAP. This result has some implications on the properties of the containers. Plastic materials are not good conductors of heat and so they gain or lose heat gradually. They can retain heat for some time which may have provided uniform temperature that enhanced early seed emergence. Seeds planted in metal containers emerged late possibly because of frequent fluctuations in temperature associated with metal containers (being good conductors of heat). Suitable temperature for seed emergence was lacking. Similarly, the delay in emergence of seeds planted in polythene containers may be due to poor temperature regulatory properties of this type of container. The result of this study agrees with the report of other workers (Marotti et al, 2015; Shagufta et al., 2023; Kim et al, 2020).

Number of leaves obtained in seedlings grown in the different types of containers used for the study significantly differed. Containers made of plastic material recorded the highest mean values on number of leaves, except for 13^{th} WAP. The least mean value on number of leaves was consistently recorded for seedlings raised in polythene containers. This result suggests that thermal conductivity of the container types used for the study affected leaf growth of the seedlings. Among the three container types used to grow the seedlings, temperature regulatory pattern of plastic containers was more stable than others (metal and polyethene containers). Plastic containers enhanced the growth of leaves by providing adequate temperature conditions (stable heat supply) necessary for seedling development. The result of this study agrees with the reports of other workers (Sanchez-Aguilar et al. 2016; Singh et al, 2018; Markham et al, 2011). On the contrary, the poor heat regulatory properties of polythene containers may have been responsible for the least number of leaves consistently recorded for seedlings produced in it. Previous study on the effect of various types and sizes of container on the growth and root morphology of rubber (Salisu et al, 2018) had reported poor quality for polythene containers in seedling production. Further, although the result of this study showed that container sizes did not have any significant difference on number of leaves. However, a detailed analysis of the result showed that medium-sized containers consistently had the highest mean number of leaves. This result implies that small and large sizes of containers may have some deficiencies for seedling development (enhance the growth of leaves), unlike containers of considerable size (medium). While small sized containers may not be adequate to facilitate nutrient circulation, larger containers may result in availability of low concentration of nutrients, which may affect nutrient uptake that will support growth of leaves. Therefore, relatively large containers (medium-sized), as observed in this study, appear to be ideal to enhance leaf growth of seedlings of African walnut. The volume of medium-sized containers was adequate for nutrient circulation that enhanced nutrient uptake. Salisu et al (2018) reported higher leaf area index for seedlings planted in considerably large containers. In addition, combined effect of the container types and sizes showed significant differences in number of leaves, which implies that the interaction between both factors affected growth rate of leaves of African walnut seedlings.

The growth rate of the seedlings raised in the different container types and sizes were assessed with number of branches, internode length, and plant height. Container types showed significant differences in each of these parameters (number of branches, internode length, and plant height). The container sizes had significant differences on number of branches and plant height. There was no significant difference in internode length for both container types and sizes. Combined effect of the container types and sizes showed significant differences in all the parameters except for internode length. The obtained results showed that container types had more effect on the growth rate of the seedlings than container size, and the interaction effect. Consistently seedlings raised in plastic containers had the highest mean values for each of the three growth assessment parameters. Further, medium-sized containers had the highest mean values on number of branches, and plant height. The result obtained on rate of growth of the seedlings as appraised by number of branches, internode length, and plant height was similar to that on number of leaves. In the two results, seedlings raised in medium-sized plastic containers consistently recorded the highest mean values in all the parameters evaluated. Therefore, the result on growth rate gave credence to the result on number of leaves (which also is a growth assessment parameter). Apparently, medium-sized plastic containers provided the conditions adequate for optimum growth (early speedy growth and development) of the seedlings. This explains why seedling height increased vigorously, mostly in plastic containers of medium sizes than in other types and sizes of containers used in the study. There is consensus among workers (Aphalo and Rikala, 2003; Segaw et al., 2016; Dominguez-Lerena et al., 2006; Pinto et al., 2011; Raviteja et al., 2021) that containers of relatively large size can enhance growth rate of seedlings.

5. Conclusion

Container types and sizes significantly affected the emergence and growth rate of African walnut seedlings. However, container types had a more significant effect than container sizes in seedling production. The interaction effect between the container types and sizes also had a considerable significant effect on African walnut seedling production. Specifically, medium-sized plastic containers enhanced emergence and growth rate of the seedlings more than other types and sizes of containers used in the study. Therefore, medium-sized containers can be adequate for growing African walnut seedlings. On the other hand, all the polythene containers of all sizes used in the study did not enhance the production of African walnut seedlings.

Author Contributions: Author Contributions: Conceptualization, N.C.O. ; methodology, N.C.O., C.I.E.; validation, N.C.O., C.I.E; formal analysis, C.I.E.; investigation, N.C.O., C.I.E.; data curation, C.I.E.; writing — original draft preparation, N.C.O., C.I.E.; writing—review and editing, N.C.O., C.I.E.; supervision, N .C.O., R.E.K; project administration, N .C.O, R.E.K authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: We are grateful to the germplasm unit of the Department of Crop science for providing us with seeds of African walnut.

Conflicts of Interest: The authors declare no conflict of interest

Data availability statement: The data used in this study are available upon reasonable request from the author(s).

6. References

1. Adetunji JB, Adetunji CO, Olaniyan OT (2021): African Walnuts: A Natural Depository Nutritional and Bioactive Compounds Essential for Food and Nutritional Security in Africa. In: Babalola OO. (eds) Food Security and Safety. Springer, Cham. https://doi.org/10.1007/978-3-030-50672-8_19

2. Agbo EA, Ugese FU, Baiyeri PK (2014): Vegetative propagation of African walnut (*Plukenetia conophora*) using pre-treated stem cuttings of varied physiological ages. AgroScience 13, 37–43. 10.4314/as.v13i1.6

3. Akinfernwa G (2022): Walnuts Cultivation: Goldmine for huge revenue, employment opportunities, The Guardian Nigerian News, https://guardina.ng/features/walnuts-cultivation-goldmine-for-huge-revenue-employment-opportunities/ .

4. Aphalo P, Rikala R (2003): Field performance of silver-birch planting-stock grown at different spacing and in containers of different volume. New Forests 25, 93–108 (2003). https://doi.org/10.1023/A:1022618810937

5. Chijioke OC, Anosike CA, Ani CC (2015): Studies on the phytochemical and nutritional properties of *Tetracarpidium conophorum* (black walnut) seed. Journal of Global Bioscience 4, 1366-1372.

6. Dhavale D, Rathore TS, Joash G (2004): Effect of container types and sizes on the growth and quality of seedlings of Indian Sandalwood (*Santalum album* L.), Australian Forestry 67, 82-87. 10. 1080/00049158.2004.10676211

7. Dominguez-Lerena S, Herrero Sierra N, Carrasco Manzano I, Ocana Bueno L, Penuelas, Rubira JL, Mexal JG (2006): Container characteristics influence *Pinus pinea* seedling development in the nursery and field. Forest ecology and management 221, 63-71. https://doi.org/10.1016/j.foreco.2005.08.031

8. Gallegos J, Alvaro JE, Urrestarazu M (2020): Container design affects short and root growth of vegetable plant, HortScience 55, 787–794. https://doi.org/10.21273/HORTSCI14954-20

9. Hunt R (1990): Basic Growth Analysis- Plant growth analysis for beginners, Springer Dordirect.

10. Islam MDA, Rahman MDR, Hossain Mk (2019): Effect of container and potting media on raising quality seedlings of *Acacia auriculiformis* in the nursery, Asian Journal of Agriculture 3, 26-32. 10.13057/asianjagric/g03010505.

11. Keyes CR, Brissette CM (2017): Effect of Container Size and Design on Morphological Attributes of *Cercocarpus ledifolius* Nutt. (Curlleaf Mountain Mahogany) Seedlings, Volume 60, Number 1.

12. Kim JH, Kang B-Y, Ryu J, Nam I-H (2020): Effects on *Pinus densiflora* Seedlings as Affected by Different Container Growth Conditions. International Journal of Environmental Research and Public Health 10, 3565. https://doi.org/10.3390/ijerph17103565

13. Luna T, Landis TD, Dumroese RK (2009): Containers. In: Dumroese, R. Kasten; Luna, Tara; Landis, Thomas D., editors. Nursery manual for native plants: A guide for tribal nurseries - Volume 1: Nursery management. Agriculture Handbook 730. Washington, D.C.: U.S. Department of Agriculture, Forest Service. p. 99-111.

14. Mariotti B, Maltoni A, Jacobs DF, Tani A (2015): Container effects on growth and biomass allocation in *Quercus robur* and *Juglans regia* seedlings, Scandinavian Journal of Forest Research 5, 401-415. 10.1080/02827581,2015.1023352.

15. Markham JW III, Bremer DJ, Boyer CR, Schroeder KR (2011): Effect of Container Color on Substrate Temperatures and Growth of Red Maple and Redbud. HortScience 5, 721-726. https://doi.org/10.21273/HORTSCI.46.5.721

16. Mugnai S, Vernieri P, Tognoni F, Serra G (2000): Container volume effects on morphology and physiology of tomato seedlings. Acta Horticulturae. 516,49-56 https://doi.org/10.17660/ActaHortic.2000.516.5

17. Negi R, Shamet GS (2020): Standardization of best growing media and container type for quality stock production in *Embelica officinalis* Gaertn. Journal of Pharmacognosy and phytochemistry 6, 1535 -1538.

18. Oagile O, Gabolemogwe P, Matsuane C, Mathowa T (2016): Effect of container size on the growth and development of tomato seedlings. International Journal Current Microbiology and Applied Sciences 5, 890-896. http://dx.doi.org/10.20546/ijcmas.2016.504.100

19. Ojobor OC, Anosike CA, Ani CC (2015): Studies on the phytochemical and antinutritional properties of *Tetracarpidium conophorum* (Black walnut) seeds. Journal of Global Science 4, 1366 – 1372.

20. Oke OS, Oyaniyi T, Adewumi OT, Bamigboye OT, Lawah MO, Jatto KA, Adara CT, Marizu JT, Ogunbela AA (2020): Economic, Nutritional, and Medicinal Values of African walnut (*Tetracarpium cocnophorum*) in Nigeria

(hutch and Dalziel): A review, Journal of Research in Forestry. Wildlife and Environment 12, 80-89. http://www.ajol.info/index.php/jrfwe

21. Onwualu, A.P, Ogunwusi AA, Olife IC, Inyang A (2013). Raw Materials Development for the Transformation of the Manufacturing Sector in Nigeria. Published by Raw Materials Research and Development Council. ISBN: 978-978-52367-1-2

22. Onwubiko NC, Enwereji RO (2023): Effects of seed size and nursery media on the germination and seedling growth of *Plukenetia conophora*. Ilmu Pertanian (Agricultural Science) 8, 153–158. doi.org/10.22146/ipas.80771

23. Ow L, Ghosh S (2017): Comparing the morphology and physiology of trees planted in containers and in-ground sites, Arboricultural Journal 39, 198-207. https://doi.org/10.1080/03071375.2017.1392701

24. Oyekale KO, Odutayo OI, Esan EB, Ogunwemimo KO, Denton OA, Bolaji DT (2015): Comparative studies on phytochemical and proximate composition of four morphological distinct segment of the conophor seedlings (*Tetracarpidum conopphorum* Hutch and Dalziel), Brazilian Journal of Biological Sciences 3, 91–100.

25. Poorter H, Buhler J, Van Dusschoten D, Climent J, Postma JA (2012). Pot size matters: a meta-analysis of the effects of rooting volume on plant growth. Functional Plant Biology 39, 839-850. 10.1071/FP12049

26. Pinto JR, Marshall DB, Dumroesea RK, Davis AS, Cobos DR (2011): Establishment and growth of container seedlings for reforestation: A function of stocktype and edaphic conditions. Forest Ecology and Management 261, 1876-1884. 10.1016/j.foreco.2011.02.010

27. Raviteja MSV, Laxmon RH, Rashmi K, Kannan S, Namratha MR, Madhavi Reddy M (2021), Effect of container size and types on the root phenotypic characters of *Capsicum*. Journal of Horticultural Science 16, 261-270. https://doi.org/10.24154/jhs.v16i2.1606.

28. Salisu MA, Sulaiman Z, Samad MYA, Kolapo OK (2018): Effect of various types and sizes of containers on growth and root morphology of Rubber (*Hevea brasiliensis* Mull. Arg), International Journal of scientific and Technology Research 7, 2-18.

29. Sanchez-Aguilar H, Aldrete A, Vargas-Hernandez J, Ordaz-Chaparro V (2016): Influence of container type and colour on seedling growth of pine in nursery. Agrociencia, Vol. 50 No. 4.

30. Segwa HA, Tura FS, Gobella SK, Komicho DN, Gifawesen ST (2016): Evaluation of Effect of Pot of Different Sizes and Growing Media on the Seedling Growth Morphology of *Cajannus cajan* and *Sesbania sesban* in Dryland Areas, Sourthern Parts of Ethiopia, Journal of Biology, Agriculture and Healthcare 6, 62- 67.

31. Singh A, Husian M, Ali SR (2018). Effect of container type and growing media on germination and seedling growth parameters at nursery stage of *Allepo pine* in Kashmir valley, India, Flora and Fauna 24, 211 -217. 10.33451/florafauna.v24i2pp211-217

32. Shagufta; Noor-un-Nisa; Jamali NF, Ahmad W, Ul-Allah S, Wahocho NA, Jamali FA, Shah SA (2023): Comparative effect of varieties and types of containers on seed germination and seedling growth of Geranium (*Palergonium graveolens*). Seeds 2, 165-176. https://doi.org/10.3390/seeds2010013

33. Single J, Single S (2010): Good roots matter from day one. Sibbaldia. The Journal of Botanic Garden Horticulture 8, 179–187. https://doi.org/10.24823/sibbaldia.2010.145

34. South DB, Harris SW, Barnet JP, Hainds MJ, Cjerstad DH (2005): Effect of container type and seedling size on survival and early height growth of *Pinus palustris* seedlings in Alabama USA. Forest Ecology and Management 204, 385-389. https://doi.org/10.1016/j.foreco.2004.09.016

35. Tanaka Y, Timmis R (1974). Effects of container density on growth and cold hardiness of Douglas-fir seedlings. In: Tinus R.W., Stein W.I. and Balmer W.E. (eds), Proceedings of the North American Containerized

Forest Tree Seedling Symposium. Great Plains Agricultural Council, Denver, Colorado, August 27 – 29, pp. 181–186.

36. Tian N, Fang S, Yang W, Shang X, Fu X (2017): Influence of container type and growth medium on seedling growth and root morphology of *Cyclocarya paliurus* during nursery culture. Forests 8, 387. https://doi.org/10.3390/f8100387

37. Yan W, Yang L, Guolei L, Jiawei H, Junshan FW (2016): Effect of container types and sizes on water consumption and growth of containerized *Pinus tabulaeformis* seedlings under sub-irrigation. Scientia Silver Sinicae 6, 10-17. 10.11707/j.1001-7488.20160602