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Morphological Variation in Fruit and Seed Size among Nine *Garcinia kola* Trees in A 13-Year-Old Plantation for Clonal Multiplication at the Swamp Forest Research Station, Onne, Nigeria

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ABSTRACT: There is a paucity of information on morphological differentiation in *Garcinia kola* to facilitate the domestication of the species. Hence, the objective of the study was to evaluate morphological variation in fruit and seed size among nine *Garcinia kola* trees in a 13-year-old plantation for clonal multiplication at the Swamp Forest Research Station, Onne, Nigeria using appropriate standard method. Results showed highly significant ($p < 0.001$) differences among trees for all traits, indicating strong intra-population variability. Tree 6 had the largest fruits and seeds (fruit length = 71.3 ± 5.6 mm; seed length = 38.6 ± 1.5 mm), followed by tree 4 (fruit length = 60.6 ± 3.5 mm; seed length = 31.2 ± 1.5 mm), while tree 2 had the smallest (fruit length = 52.5 ± 5.1 ; seed length = 30.1 ± 1.7). Correlation analysis revealed strong positive relationships between fruit length, fruit width ($r = 0.89$), and fruit weight ($r = 0.86$), as well as between fruit width and seed length ($r = 0.74$). Pulp thickness was negatively correlated with seed width ($r = -0.78$) and seed number ($r = -0.53$). The findings highlight the existence of substantial genetic variability and useful selection indices for fruit and seed improvement. Trees 4, 5, and 6 exhibited superior fruit and seed attributes and are recommended as candidate mother trees for vegetative propagation and domestication programs.

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Garcinia kola (Heckel) is a highly valued multipurpose tree species in West and Central Africa, particularly for its seeds, which contain numerous bioactive phytochemicals of medicinal importance (Ashiru *et al.*, 2018; Manourova *et al.*, 2023). The

recognized potency of the seed extract has made *G. kola* an important source of income for both rural and urban dwellers (Okonkwo *et al.*, 2020). Despite its socio-economic relevance, the *G. kola* seed trade remains largely informal and unregulated, forming

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part of the unreported yet economically significant non-timber forest product (NTFP) value chains (Kouakou *et al.*, 2016) in Nigeria. Although these markets operate outside formal recognition, *G. kola* remains an indispensable household product in both rural and urban communities (Okonkwo, 2023). However, the growing demand for *G. kola* seeds has not been matched by a corresponding increase in the cultivation and conservation of the species (Okonkwo, 2023). Natural populations are declining due to overexploitation and low regeneration, compounded by widespread deforestation, habitat degradation, and climate change (Cheek, 2004; Agwu *et al.*, 2020). Despite limited information on the distribution and population structure of *G. kola* in Nigeria, emerging studies have revealed substantial genetic diversity within and among populations (Olawuyi and Azeez, 2019). This high level of diversity provides a valuable genetic resource for the selection and development of improved cultivars with enhanced fruiting and seed traits. Vegetative propagation has long been a key strategy for reproducing desirable genotypes in tree crops. Individual trees exhibiting favorable characteristics such as early fruiting, high yield, large fruit or seed size, high phytochemical content, storability, and disease resistance (Asaah *et al.*, 2012; Rasool *et al.*, 2020) can be clonally propagated to ensure genetic uniformity and rapid multiplication. Moreover, vegetative propagation can significantly shorten the juvenile phase, thereby accelerating fruit production (Dao *et al.*, 2025).

Hence, the objective of the study was to evaluate morphological variation in fruit and seed size among nine *Garcinia kola* trees in a 13-year-old plantation for clonal multiplication at the Swamp Forest Research Station, Onne, Nigeria.

MATERIALS AND METHODS

Description of study area: The study was conducted in a *G. kola* mono-plantation established from seeds at the Swamp Forest Research Station of the Forestry Research Institute of Nigeria (FRIN), Onne, Rivers State, Nigeria. The plantation comprises approximately 13 trees aged 23 years and 80 trees aged 14 years, spaced at 5 m × 5 m intervals. Flowering and fruiting occur three to four times annually, often overlapping such that flowers and fruits are present throughout the year. Peak fruiting is typically observed between August and October (Okonkwo *et al.*, 2024).

The site lies between latitude 4°42'–10°32' N and longitude 7°10'–32°46' E. The area experiences a humid tropical climate with mean annual rainfall of

about 2,400 mm, mean monthly temperatures ranging from 25 °C (July) to 27 °C (February), and relative humidity of 78% in the dry season and 89% in the rainy season. The soils are ultisols derived from coastal sediments, strongly acidic (pH ≈ 4.4), low in fertility, and classified as siliceous, iso-hyperthermic, typic paleudults. They are typically deep, well-drained, and possess favorable physical properties for tree growth. The natural vegetation is a humid rainforest transitioning into mangrove forest zones (Okonkwo and Omokhua, 2022).

Sampling collection and treatment: Nine fruiting female *G. kola* trees were randomly selected from the plantation. From each tree, twenty-five (25) mature fruits were collected and allowed to undergo natural decay to facilitate seed extraction.

The following fruit and seed morphological traits were measured:

- Fruit length and width (mm) — measured using a vernier caliper.
- Pulp thickness (mm) — measured from the mesocarp layer.
- Fruit weight (g) — determined using an electronic weighing balance.
- Seed length and width (mm) — measured using a vernier caliper.
- Number of seeds per fruit — counted manually for each fruit.

Statistical data analysis and experimental design: The experimental design followed a completely randomized layout. Data were subjected to analysis of variance (ANOVA), and significant means were separated using Tukey's HSD test at $p < 0.05$. Pearson's correlation coefficients were computed to determine the relationships among fruit and seed morphological traits.

RESULTS AND DISCUSSION

Analysis of variance revealed significant ($p < 0.001$) variation among the nine *G. kola* trees for all fruit and seed traits. Fruit length ($F = 35.62$), fruit width ($F = 42.02$), pulp thickness ($F = 22.99$), fruit weight ($F = 17.33$), seed length ($F = 60.21$), seed width ($F = 48.82$), and seed per fruit ($F = 6.97$) all differed significantly, showing high morphological diversity within the population.

The significant variation in fruit and seed morphology observed among the nine *Garcinia kola* trees indicates a broad genetic base within the plantation population. This finding is consistent with the results of Olawuyi and Azeez (2019) and Manourova *et al.* (2023), who reported greater intra-

population than inter-population genetic diversity among *G. kola* accessions in Nigeria and Cameroon, respectively. Such variability presents valuable opportunities for selecting elite trees with desirable traits for domestication (Andrew *et al.*, 2021). This supports the findings of Okonkwo (2023), who reported low levels of self-fertilization in *G. kola*. Furthermore, the results corroborate the observations of Manourova *et al.*, (2023) that managed *G. kola* populations exhibit higher genetic diversity than wild

stands. Mean separation identified Tree 6 as having the largest fruits and seeds (fruit length = 71.3 ± 5.57 mm, fruit width = 62.7 ± 5.22 mm, seed length = 38.6 ± 1.49 mm), while Tree 2 produced the smallest fruits (52.5 ± 5.08 mm). Pulp thickness ranged from 3.2 ± 0.99 mm (Tree 9) to 6.8 ± 1.41 mm (Tree 4). The number of seeds per fruit varied from 1.83 ± 1.19 to 3.32 ± 0.79 , indicating no strict proportionality between fruit size and seed count (Table 1).

Table 1: Fruit length (FL), fruit width (FW), pulp thickness (Pth), fruit weight (FWt), seed length (SL), seed width (SW), and number of seeds per fruit (seed/fruit) differentiation among *G. kola* trees.

Trees/Traits	FL	FW	Pth	FWt	SL	SW	Seed/fruit
1	61.6±4.2 ^b	49.8±3.9 ^b	4.8±0.8 ^c	0.2±0.06 ^a	29.9±1.4 ^c	21.5±1.5 ^a	3.32±0.8 ^a
2	52.5±5.1 ^c	45.0±4.5 ^c	3.8±0.7 ^d	0.1±0.04 ^b	30.1±1.7 ^b	18.9±1.0 ^b	3.26±0.9 ^b
3	58.0±5.6 ^b	45.3±5.7 ^c	5.3±1.3 ^b	0.1±0.05	28.2±2.7 ^d	19.9±1.3 ^b	2.59±0.9 ^b
4	60.6±3.5 ^b	54.8±3.8 ^b	6.8±1.4 ^a	0.2±0.08 ^a	31.2±1.5 ^b	17.0±1.7 ^c	3.16±0.7 ^a
5	60.4±3.7 ^b	52.3±3.2 ^b	5.8±1.2 ^a	0.2±0.04 ^a	33.3±2.5 ^b	18.6±0.7 ^b	2.84±0.7 ^b
6	71.3±5.6 ^a	62.7±5.2 ^a	4.7±0.9 ^c	0.2±0.05 ^a	38.6±1.5 ^a	19.9±1.1 ^b	2.82±0.7 ^b
7	52.2±5.0 ^c	44.4±3.3 ^c	5.5±1.7 ^b	0.1±0.02 ^b	29.8±3.1 ^c	17.5±1.5 ^c	2.73±0.8 ^b
8	60.6±4.2 ^b	46.6±3.5 ^c	5.8±0.7 ^a	0.2±0.05 ^a	25.3±4.0 ^d	17.7±1.3 ^c	3.07±0.8 ^a
9	62.6±4.8 ^b	53.7±6.7 ^b	3.2±1.0 ^c	0.1±0.06 ^b	27.7±1.8 ^d	22.8±1.7 ^a	1.83±1.2 ^c

**Means with different alphabets are significantly different ($p \leq 0.05$).

Table 2: Correlation among fruit length (FL), fruit width (FW), pulp thickness (Pth), fruit weight (FWt), seed length (SL), seed width (SW), and number of seed per fruit in *G. kola*

Traits	FL	FW	Pth	FWt	SL	SW	Seed/fruit
FL	1.00						
FW	0.89	1.00					
Pth	-0.06	-0.04	1.00				
FW	0.86	0.84	0.32	1.00			
SL	0.55	0.74	0.04	0.71	1.00		
SW	0.38	0.24	-0.78	-0.02	-0.02	1.00	
Seed/fruit	-0.17	-0.17	0.47	0.20	0.14	-0.53	1.00

Tree 6, which exhibited the largest fruit and seed sizes, likely possesses favorable alleles influencing fruit growth and seed development. Similarly, Andrew *et al.*, (2021) reported that *Entandrophragma bussei* populations from high-rainfall agroecological zones in Tanzania produced larger fruits and seeds than those from drier zones. Large fruit and seed sizes are economically advantageous traits, as they enhance both market appeal and seedling vigor—attributes critical for successful plantation establishment (Leakey and Page, 2006). The observed morphological variability, despite uniform environmental conditions, underscores the underlying genetic potential within the plantation. This conclusion aligns with the findings of Manourova *et al.*, (2023), who demonstrated that morphological differentiation in *G. kola* is largely genetically determined rather than environmentally driven. Strong positive correlations were observed among fruit length, fruit width, and fruit weight, suggesting that trees with longer fruits also produced wider and heavier fruits (Table 2). The positive relationship between fruit width and seed length indicates that larger fruits tend to yield longer

seeds. Conversely, the strong negative correlation between pulp thickness and seed width suggests a trade-off between pulp and seed development.

The strong positive correlations among fruit dimensions and weight suggest that these traits can serve as reliable indicators of yield potential. Similar relationships have been documented in other tropical fruit trees (Sanchez *et al.*, 2011; Parkouda *et al.*, 2012; van den Bilcke *et al.*, 2014; Omondi *et al.*, 2019). The positive correlation between seed length and fruit width further suggests that selecting for larger fruit size indirectly enhances seed quality and potential germination vigor (Mkwesalamba *et al.*, 2015; Martinez-Gonzalez *et al.*, 2020). Negative correlations between pulp thickness, seed width, and seed number point to an internal resource allocation trade-off during fruit development. Increased pulp accumulation may limit resources for seed enlargement or formation. This trade-off pattern is consistent with fruit developmental dynamics observed in other *Garcinia* species and tropical fruit trees (Linkies *et al.*, 2010). From a domestication standpoint, the presence of phenotypically superior

trees within a single population offers a low-cost avenue for improvement through clonal propagation. Trees 4, 5, and 6, identified as superior performers, can serve as mother trees for grafting or cutting propagation to produce uniform, high-yielding planting stock. Such targeted selection and vegetative propagation could significantly reduce reliance on wild populations and promote sustainable cultivation (Leakey *et al.*, 2005a, b).

Conclusions: The study demonstrated significant variability in fruit and seed size among *G. kola* trees and showed strong interrelationships among key morphological traits. Positive correlations among fruit length, width, and weight identify them as effective selection indices for fruit size improvement, while the negative association between pulp and seed traits highlights potential developmental trade-offs. Some trees exhibited outstanding fruit and seed qualities and are recommended as mother trees for clonal propagation and domestication efforts. The pronounced intra-population variability indicates strong genetic potential for improvement through selection and breeding. These findings provide a scientific basis for developing improved *G. kola* cultivars, supporting sustainable production and conservation of the species.

DECLARATIONS

Ethical approval: This study did not involve human participants or animal experimentation and therefore did not require formal ethical approval. All procedures involving data handling and analysis were conducted responsibly and in accordance with standard academic and institutional guidelines.

Disclaimer (Artificial Intelligence): Author(s) hereby declare that generative AI technologies (ChatGPT version: 1.2025.328) have been used during the writing or editing of this manuscript. Sample prompts include:

1. “can you write a results section from data, and also write the discussion, conclusion, and conclusion”.
2. “correct the introduction and methods section for grammar and research tone”
3. “generate the keywords of the study”

Declaration of Data Availability: Data are available upon request from the first author.

Declaration of Conflict of Interest: The authors declare that no known conflict of interest or personal relationships that have influence on the work reported in this paper.

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