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QUANTITATIVE VARIATIONS IN FRUITS/SEEDS OF *Garcinia kola* HECKEL FROM LOWLAND RAINFOREST ZONES OF NIGERIA: PROSPECTS FOR DOMESTICATION

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ABSTRACT

Garcinia kola Heckel is a valuable fruit tree species that plays a significant role in contributing to household economies in West and Central Africa where the species is endemic. This study assessed the variations in six sources of *G. kola* in Southern Nigeria. Fruit and seed characteristics (fruit length (FL), fruit diameter (FD), number of seeds per fruit (NS), fruit weight (FW), seed weight (SW), seed length (SL), and seed diameter (SD)) were evaluated. Data collected were analyzed using combinations of analysis of variance, Pearson's correlation coefficient, principal component analysis (PCA) and dendrogram analysis. Significant variations ($P<0.05$) were found in all the characters evaluated. Significant and strong positive correlations were found between SL and NS (0.87), FW and FL (0.76), FW and FD (0.94), FL and FD (0.67). The PCA revealed FW, FD, SW and NS as the most discriminating traits upon which three clusters were identified. Results of this study could serve as a guide for selection and improvement of *G. kola* for domestication purposes.

Keywords: *Garcinia kola*; species diversity; fruit characters; seed morphology

INTRODUCTION

Garcinia kola (bitter kola) of Clusiaceae family is a valuable tree species of the tropical rainforest of West and Central Africa. Bitter kola is valued for its edible fruits and medicinal properties in Nigeria (Anegbeh *et al.*, 2006). *Garcinia kola* is widely distributed throughout Southern Nigeria, from Sierra Leone, Cameroon, Ivory Coast, Liberia, Niger and Congo to Angola (Burkill, 1985). The species grows to a height of 12 to 30 m with an average girth of 1.8 m (Burkill, 1985). The tree produces yellowish-, reddish- or orange-coloured fruits and fruiting events occur between July and September. In traditional African medicine, all parts of the plant (seeds, stem, and leaves) have medicinal values. The seeds of *G. Kola* are recalcitrant, edible and have been widely consumed for treatment of throat infections, cough and bronchitis, liver disorders and hepatitis (Ebemoji and Okojie, 2012).

In Nigeria and other African countries, sales of bitter kola fruits and/or seeds contribute to the socio-economic income of rural and urban households (Anegbeh *et al.*, 2006). Unfortunately, *G. kola* populations have become extremely small and threatened with disappearance in its natural habitat due to unsustainable exploitation, increasing urbanization and deforestation in Nigeria. The tree is listed as vulnerable by the UCN classification as a result of over-exploitation of wood for chew-sticks and fruits for medicinal and economic use. Hence, specific actions are required to protect the species in order to avoid erosion of *G. kola* stock and ensure its continuous availability. Species domestication has been proposed as a strategy that will not only enhance food security through the provision of high-quality fruits on adequate basis but also improve household revenue while reducing deforestation and environmental degradation (Leakey, 2001). Tree domestication is the process of selecting, managing and propagating trees (Simons and Leakey, 2004). This process entails identification of product traits which should be improved through germplasm selection (Egbe *et al.*, 2013). However, selection of germplasm depends largely on phenotypic variations that occur among the populations of an organism. Understanding the quantitative variations in fruit morphology of *G. kola* is vital towards initiating its domestication plan. Morphological diversity of *G. kola* phenotypes has been reported to exist in Cote d'Ivoire (Komenan *et al.*, 2019) and Southern Benin (Dah-Nouvlessounon *et al.*, 2016). Recently, phenotypic variation studies have revealed high level of morphological variability in *G. kola* trees in Nigeria which is attributed to the out-crossing nature of the species (Ashiru *et al.*, 2018). However, there is inadequate information on the morphological variability that exists in fruits and seeds of *G. kola* in Nigeria. Morphological traits have been used to evaluate different crops (Kaemer *et al.*, 1995). Availability of such information will be useful to identify and select genetically and phenotypically superior seeds for mass afforestation. The morphometric analysis of fruits and seeds also reveals valuable information for taxonomic application, mechanism of fruit dispersal and germination viability (Pereira *et al.*, 2017). This will also facilitate tree breeding programs for wider geographic adaptability in relation to biotic and abiotic stresses (Onomo *et al.*, 2006). In addition, extent and pattern of intra/inter specific variation is vital for improvement and conservation of genetic resources. Maximum productivity in plantation forestry can be achieved by planting seedlings produced from outstanding seed source (Takuathung *et al.*, 2012). Variations in seed traits have been reported for a number of tropical trees including *Cordia africana* (Loha *et al.*, 2006), *Faidherbia albida* (Fredrick *et al.*, 2015) and *Hymenaea stigonocarpa* (de Castro *et al.*, 2021). In view of this, the aim of this study was to assess the morphological variation in fruits and seed traits of *G. kola* among the selected zones in Southern Nigeria for plant improvement and sustainable management.

MATERIALS AND METHODS

Study Area

The study was carried out in six locations within the natural distribution range of *G. kola* in lowland rainforest zones of Nigeria in August 2019. Two adult trees distant by at least 50 m were purposively sampled in each location to avoid sampling related trees. The location of each site was determined using the geographical positioning system (GPS) (Table 1). The study sites have a bimodal rainfall pattern characterized by two distinct seasons (dry and rainy). The dry season occurs between November to March while the rainy season occurs between April and October. A total of 12 trees were sampled in all the locations and at least thirty (30) fruits were randomly sampled per tree. The sampled fruits were collected in mesh bags labeled with the location and the corresponding mother tree. Data were collected based on some descriptors of Bioversity International (IPGRI, 2004).

Table 1: Location and geographical description of selected *Garcinia kola* in Nigeria

Location	State	Latitude (ºN)	Longitude (ºE)	Altitude (m)	MMT (ºC)	MMR (mm)
Idi-ogungun	Osun	7.79	4.60	363	25.6	127.8
Kelebe	Osun	7.81	4.65	366	25.5	127.8
Uromi	Edo	6.71	6.34	372	28.8	183.5
Awo	Edo	6.73	6.39	376	25.7	189.6
Moniya	Oyo	7.49	3.85	255	27.8	120.1
Ajibode	Oyo	7.42	3.89	256	28.9	120.1

*MMT- Mean Monthly Temperature; MMR-Mean Monthly Rainfall

Determination of Fruit/Seed Morphological Character

Thirty (30) fruits and 60 seeds were randomly selected on each *G. kola* tree respectively. Seeds were extracted from the fruits by manual de-pulping on each fruit/seed; length and width were determined using a digital caliper while weight was determined using semi-analytical digital weighing balance (accuracy of 0.1 g). Length was measured over the seed coat along the longest axis of the seed while width was measured on the smallest axis at the middle of the seed. The number of seeds per fruit was evaluated by extracting them from fruit pulp and counting.

Statistical Analysis

Data collected were subjected to one-way ANOVA and similarity matrix (Dendrogram) was generated using SPSS version 16. Significant means were compared using Tukey's Honesty Significant Difference Test at $P < 0.05$. Relationship among morphological traits was examined using Pearson's correlation. Principal component analysis (PCA) was performed to determine the pattern of variation among genotypes. Groups of individuals with similar morphological traits were defined using hierarchical cluster analysis on Minitab v.17s.

RESULTS

Seed and Fruit Morphology

Significant differences ($P < 0.05$) existed among sources for all seed morphometric characters (Tab. 2). The seed weight was significantly highest in Uromi and lowest in Ajibode (Table 3). Seed length ranged from 30.0 ± 2.8 mm (Idi-Ogungun) to 39.6 ± 2.9 mm (Uromi) while seed width varied between 15.8 ± 1.1 mm (Awor) and 21.2 ± 1.5 mm for Idi-ogungun (Table 3).

There were significant differences ($P < 0.001$) in all the fruit morphometric characters (Table 2). The highest number of seeds per fruit (3.6) was found in Ajibode while the lowest (2.3) was Idi-ogungun (Table 3). Fruit weight was signicantly highest in Idi-ogungun source (209.3 g) and lowest (91.2g) in Moniya (Table 3). Idi-ogungun had the highest fruit length (68.5 mm) while Kelebe had the least (56.1mm). Similarly, the largest fruit width (75.8 mm) was found in Idi-ogungun source while the lowest (54.3mm) was Moniya source.

Table 2: Summary of analysis of variance for fruit and seed traits of *Garcinia* kola from 6 natural populations in Southern Nigeria

Source of variation	Mean square							
	DF	FL	FD	FW	NS	SL	SD	SW
Source	5	647.30**	1807.05**	48191.00**	7.27**	716.84**	227.22**	25.87**
Error	174	50.55	38.38	1450.00	0. 82	11.50	2.34	2.91
Total	179							

FL; Fruit length, Fruit diameter, FW; Fruit weight, NS; Number of seeds, SL; Seed length, SW; Seed weight. ** Significant at $P < 0.01$

Table 3: Mean values of fruits and seed traits of *Garcinia kola* from different sources

Character	Seed source					
	ID	KL	UR	AW	MY	AJ
SW (g)	7.85 ± 1.3^{a}	6.76 ± 1.8^{b}	8.47 ± 1.5^{a}	7.07 ± 1.4^{b}	7.47 ± 2.3^{ab}	6.71 ± 1.7^{b}
SL (mm)	30.1 ± 2.8^{a}	30.8 ± 2.7^{a}	39.6 ± 2.9^{c}	35.3 ± 3.0^{b}	31.7 ± 4.2^{a}	35.3 ± 4.3^{b}
SD (mm)	21.2 ± 1.5^{e}	19.4 ± 1.8^{b}	17.8 ± 1.2^{bc}	16.1 ± 1.1^{bcd}	17.6 ± 1.7^{abc}	15.8 ± 1.65^{bcd}
FW (g)	209.3 ± 55.5^{a}	116.5 ± 51.1^{b}	130.4 ± 28.7^{b}	120.5 ± 29.2^{b}	91.2 ± 28.9^{c}	139.3 ± 22.2^{bc}
FL (mm)	68.5 ± 12.7^{a}	56.4 ± 5.8^{c}	61.8 ± 5.7^{b}	$60.5 \pm 6.3b^{c}$	56.1 ± 4.0^{c}	63.2 ± 4.4^{b}
FD (mm)	75.8 ± 7.7^{a}	61.4 ± 8.2^{b}	58.3 ± 4.6^{bcd}	55.6 ± 5.5^{cd}	54.3 ± 5.9^{d}	59.9 ± 4.1^{bc}
NS	2.0 ± 1.0^{a}	3.0 ± 0.9^{ac}	4.0 ± 0.6^{b}	3.0 ± 1.4^{bc}	3.0 ± 0.7^{ac}	4.0 ± 0.6^{b}

Note: Mean values are followed by standard deviation. Means with different superscript within a row are significantly different ($P < 0.05$). ID- Idi-ogungun, KL- Kelebe, UR- Uromi, AW- Awo, MY- Moniya, AJ- Ajibode

Correlations of Seed/Fruit Morphological Traits

The seed weight was positive and moderately correlated with seed diameter (0.45) and seed length (0.5) (Table 4). There was a significant and strong negative correlation (-0.84) between seed diameter and number of seeds per fruit. On the other hand, a significant and strong positive correlation was found between seed length and number of seeds (0.87). A positive and significant correlation was found between fruit length and fruit width (0.67). Fruit weight was significantly and positively correlated with fruit length (0.76) and fruit diameter (0.94). No correlation was found between number of seeds and fruit weight (0.0), fruit length (0.0) and fruit width (0.0).

Table 4: Correlations of seed/fruit morphological traits of *Garcinia kola*

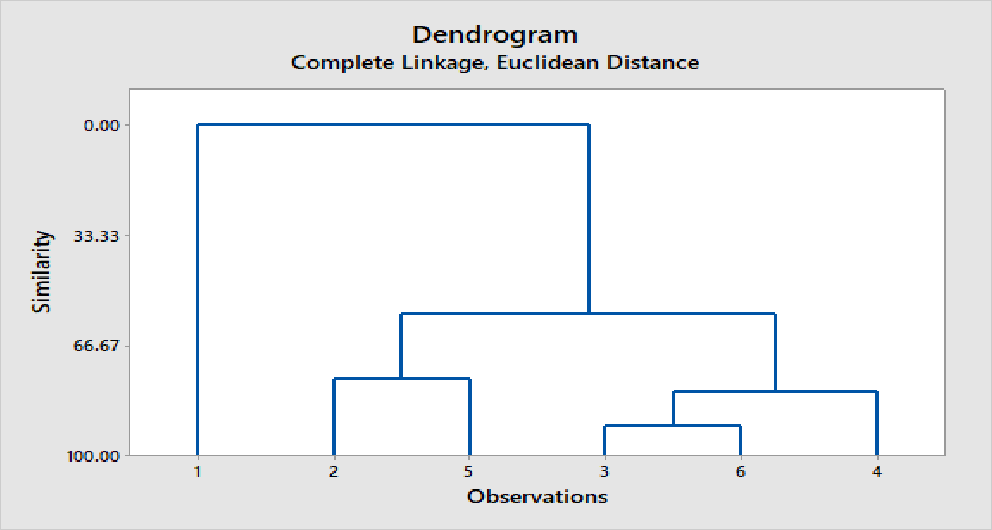
Variable	Seed weight	Seed diameter	Seed length	Fruit weight	Fruit length	Fruit diameter
Seed diameter	0.45**					
Seed length	0.51**	-0.14*				
Fruit weight	0.29	0.61	-0.23			
Fruit length	0.35	0.33	0.04	0.76**		
Fruit diameter	0.22	0.81*	-0.48	0.94**	0.67**	
Seeds per fruit	-0.09	-0.84*	0.87*	0.03	0.15	-0.63

** Highly significant (P<0.01) *significant (P<0.05)

The principal component analysis (PCA) revealed that the first three components have eigenvalues > 1 and this explained 82.7 % of the total variation (Table 5). The principal component PC1 (40.2 % of the total variation) is largely comprised of fruit weight (0.59), fruit diameter (0.56) and fruit length (0.51). These characters are positively correlated with PC1, and this can be defined as the growth axis of the fruit. This axis also distinguishes the sources that produce large fruits. On the other hand, the PC2 (23 % of the total variation) is comprised of number of seeds per fruit (0.85), seed weight (-0.745), seed length (-0.525), and seed diameter (-0.372). These characters are negatively correlated with PC2 and this can be defined as the growth axis of the seeds. The variable that contributes largely to PC3 (19.6 %) is the number of seeds per fruit. The dendrogram analysis revealed three major clusters (Figure 1). Idi-ogungun formed a distinct cluster, cluster 2 comprised of kelebe and Moniya while Uromi and Ajibode are grouped together as a sub cluster with Awor in cluster 3.

Table 5: Eigenvalue and percentage variance of morphological characteristics of *Garcinia kola* from southern Nigeria

Variables	PC Axis 1	PC Axis 2	PC Axis 3
Seed weight	0.079	-0.745	0.004
Seed length	-0.154	-0.525	0.497
Seed diameter	0.353	-0.372	-0.405
Fruit weight	0.587	0.181	0.203
Fruit length	0.505	0.475	0.334
Fruit diameter	0.563	-0.111	0.031
Number of seed	-0.327	0.854	0.660
Eigenvalue	2.812	1.610	1.369
% expressed variance	40.2	23.0	19.6
% cumulative variance	40.2	63.2	82.7



1: Idi-ogungun; 2: Kelebe; 3: Uromi; 4: Awor; 5: Moniya and 6: Ajibode

Figure 3: Dendrogram of different clusters of *Garcinia kola* based on quantitative characters

DISCUSSION

This study reveals the existence of morphological diversity in *G. kola* for fruits and seed traits in the Southern Nigeria. This study also confirms significant intra and interspecific variations in all the studied traits. The result of this study on inter-population variation is similar to those obtained on *Pentaclethra macrophylla* (Tsobeng *et al*., 2022). A comparable result was also obtained in Cote d'Ivoire for *G. kola* in all the studied traits except for the number of seeds per fruit (Komenan *et al*., 2019). The result of this study recorded significant differences for the number of seeds per fruit, unlike what was reported in Cote d'Ivoire for the number of seeds (Komenan *et al*., 2019). This is noteworthy that there is valuable variability of these traits within the distribution range of *G. kola* in Africa. The occurrence of significant differences in the evaluated traits of *G. kola* might be attributed to differences in the environmental or ecological factors. However, genetic differences may also explain the observed variation, but there is paucity of data in this regard.

The results of PCA in this study indicated that the highest variability in PC1 is recorded in fruit weight and fruit dimensions, thus, this axis distinguishes the sources that produced large fruits. From this study, Idi-ogungun source have been identified as population with highest fruit weight, length and diameter. Similarly, PC2 distinguishes Uromi, Awo and Ajibode as the sources with the highest number of seeds per fruit. This finding is supported by cluster analysis which grouped the sources into three distinct groups. For instance, Uromi, Ajibode and Awo source are grouped together based on the most discriminating traits according to the result of dendrogram analysis and these sources are characterized with trees that have higher seed weight and number of seeds per pod. The observed intra-specific variations in this study present an opportunity to select elite trees from these sources for cultivar development. It is noteworthy that *G. kola* seeds are the most economically valuable resource in most regions where they exist, hence selection for this trait will be justified.

Source could be selected for cultivar development based on highest number of seeds per pod and seed weight (Leakey and Page, 2006). The significant positive correlation between seed weight and seed dimensions (length and diameter) indicates that improvement in one trait would correspond to the improvement of others. This study also found a strong positive correlation between seed length and number of seeds per fruit. Furthermore, a strong negative correlation between seed diameter and number of seeds per fruit in this study would imply that the higher the number of seeds per fruit, the lower the corresponding seed diameter and vice-versa. The lack of significant correlation between number of seeds and fruit weight would indicate that the collection of larger and heavier fruit does not correspond to greater number of seeds.

CONCLUSION

This study revealed the existence of considerable variation among the sources in terms of fruit/seed morphological character of *Garcinia kola*. Based on most discriminating fruit traits, the largest variations were observed for fruit weight, while that in seed traits were observed for seed weight and number of seeds per fruit. Fruits of *G. kola* could be sourced from Uromi (Edo state) or Ajibode (Oyo state) for improved yield. Results of this study can serve as a basis on which further improvement work on this species can be based.

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