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GENETIC DIVERSITY OF *Garcinia kola* Heckel FROM SELECTED STATES IN NIGERIA

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ABSTRACT

The morphological variability of twenty five accessions of Garcinia kola from seven states in Nigeria (Abia, Anambra, Oyo, Osun, Ondo, Ogun and Ekiti) were evaluated in this study. The field experiment was laid out in a Complete Randomized Design (CRD) with three replicates. Accession OS4 (Ayekoka) had the best growth characters; plant height (24.08cm), leaf length (10.82cm) and stem girth (4.31cm), while OG3 from Ijebu ode had the best yield related characters for stem wet weight (2.56g), stem dry weight (2.22g), leaf wet weight (1.76g), leaf dry weight (1.23g), shoot wet weight (4.33g) and total wet weight (5.92g). Prin.1 accounted for the highest Eigen vector (9.64) and proportion (0.57) of the total variation. The leaf length and leaf width (r = 0.54) were positively associated, while strong positive correlations ranging between 0.88 and 0.99 were exhibited among the yield related characters. The highest genotypic variance (98.63) and phenotypic variance (394.37) were found in crown width. Stem girth (29.98%) and shoot wet weight (17.55%) had the highest heritability estimates. Therefore, accessions OS4 and OG3 could be further improved and Crown width, Stem girth, Plant height and Leaf length could be selected characters for Garcinia kola production.

Keywords: Variability, Accessions, *Garcinia kola*, Characterization and Heritability

INTRODUCTION

Garcinia kola Heckel is a dioecious medium-sized non-timber tree with unisexual flowers that usually grows to a height of 12m and 1.5m stem girth (Falconer, 1992; Abu *et al.*, 2013; Manourova *et al.*, 2017; Wikipedia, 2018). The plant is of high socio-economic and medicinal importance; widely utilized for ceremonial purposes and treatment of asthma, poisoning, vomiting, nervous alertness, induction of insomnia and improved bowel movement (Iwu, 1993; Uko *et al.*, 2001; Adebisi, 2004; Adedeji *et al.*, 2008; Abu *et al.*, 2013; Yakubu *et al.* 2014 b). However, indiscriminate exploitation of its fruits, wood and roots had contributed to its scarcity, thus currently threatened by extinction (Yakubu *et al.*, 2014 b; Koffi *et al*., 2015).

Garcinia kola has suffered tremendous neglect in terms of research and development (Adebisi 2004; Yakubu *et al.*, 2014 a). In order to develop strategies for its conservation and improvement, it is therefore essential to study the genetic diversity within *G.kola* and other Garcinia genetic resources. Unlike other species in the genus Garcinia, such as *Garcinia cambogia*, *G. gummi gatta* and *G. mangostana*, whose diversity assessment had received more attention, *G.kola* received relatively very little consideration and consequent upon this negligence, information on characterization and germplasm studies are currently lacking. Generally, diversity assessments so far in Garcinia are majorly from European and Asian countries such as Australia, China, India and Indonesia.

In Africa so far, previous studies on *Garcinia kola* diversity were the reports made by Kalousova *et al.* (2018) and Manourova *et al.* (2018). Presently, information on morphological variability in *Garcinia kola* is limited in Nigeria. The only available information is on molecular diversity of *G. kola* (Olawuyi and Azeez, 2019). Therefore, this study aimed at investigating the genetic

diversity of twenty-five accessions of *Garcinia kola* from selected states in Nigeria with a view to providing information on phylogenetic relationship using morphological features.

MATERIALS AND METHODS

Experimental Site and Sources of Accessions

The experiment was conducted at the nursery farm of the Department of Botany, University of Ibadan, Nigeria. The site lies between Latitude 7°02'49" and 7°43'21"N and Longitude 3°31'58" and 4°08'20"E with an altitude of 150m in the valley at 275m above sea level and the area receives moderate annual rainfall of 1,205mm (Amanambu and Egbinola, 2013). *Garcinia kola* fruits sourced from selected twenty-five local government areas within seven states in Nigeria (Plate 1) were identified at the Herbarium section of Forestry Research Institute of Nigeria, Jericho Ibadan.

Processing, Pre-planting, Experimental Design and Planting

The seeds were processed according to the procedure reported by Yakubu *et al.* (2014 b) and sown in a compartmentalized germinated pit constructed for this purpose. Four seedlings which served as replicates from each accession were transplanted in to 5kg soil in polythene bag, four weeks after germination. The experiment was laid out in a Complete Randomized Design (CRD) (Plate 2).

Morphological Characterization

The seeds of *Garcinia kola* were characterized based on qualitative traits; seed shape, seed coat colour and pattern,while quantitative growth characters (plant height, stem length, stem growth, number of leaves, leaf length, leaf width and crown width) of the seedlings were recorded every two weeks due to its exhibits slow growth. Yield related characters; Root wet and dry weights, Leaf wet and dry weights, Stem wet and dry weights, Shoot wet and dry weights and Total wet and dry weights were evaluated at the end of the14th week. After harvesting, the fresh weights were determined immediately, followed by oven drying at 48 hours in order to obtain the dry weights.

Statistical Analysis

The data collected on growth and yield related characters were subjected to Analysis of Variance (ANOVA) using SAS ver.9.3 software, while differences in means were separated using Duncan Multiple Range Test (DMRT) at 95% level of probability ($p<0.05$). Relationships among the traits were established using Pearson Correlation Coefficient and Principal Component Analysis (PCA). In addition, genotypic variance, phenotypic variance, heritability, Phenotypic Coefficient of Variation (PCV), Genotypic Coefficient of Variation (GCV) was determined using Kwon and Torrie (1964) formula below:

$$Genotypic\ variance = \frac{\text{Genotype MS} - \text{Error MS}}{\text{Replicates}}$$

$$Phenotypic\ variance = Genotypic\ variance + Error\ Ms$$

$$Genotypic\ Coefficient\ of\ Variation(GCV) = \frac{\sqrt{Genotypic\ variance}}{\text{Sample mean}}$$

$$Phenotypic\ Coefficient\ of\ Variation(PCV) = \frac{\sqrt{Phenotypic\ variance}}{\text{Sample mean}}$$

$$Heritability(\%) = \frac{Genotypic\ variance}{Phenotypic\ variance} X100\%$$

RESULTS

Qualitative traits in *Garcinia kola* accessions

The observation of qualitative traits among the accessions of *Garcinia kola* in Table 1 was graded in to three distinct categories. The seed shapes were; oval and elongated, oval but not elongated and oval *and* slightly elongated. The seed coat colours were light orange, deep orange and black, while the pattern on the seed coat was; not whorled, fairly whorled and heavily whorled. AB1, AB2, EK1, OG1, OG3, ON2, ON4, OS4, OS5, OS6 and OY2 were oval, slightly elongated light orange seeds except AB1 and OS6 which were deep orange with varied seed coat pattern. EK1, OG1 and OY2 were heavily whorled, ON2, ON4 and OS6 are fairly whorled, OS4 and OS5 were not whorled. AN1, OG2, ON1, ON3, OS2, OS7, OS8, OY3, OY4 and OY5 had oval but not elongated seeds with varied seed coat colour and pattern characteristics. AN1, OG2, OS7, OS8 and OY4 had light orange seeds with heavy whorled pattern. ON3 and OS2 had deep orange seeds with heavy whorled seed coat. ON1 and OY5 were fairly whorled with deep orange and light orange seeds respectively. OS1 and OS3 had oval, elongated deep orange seeds but the seed coats were not whorled. Only OS2 and OY1 had oval elongated seeds, while OY1 and OY3 had black seeds but with different seed coat patterns and shapes.

Mean square variance of growth and yield related characters of *Garcinia kola* seedlings

The result of mean square variance of the growth characters at different stages presented in Table 2 revealed that accessions and weeks highly significantly (P<0.01) increased the plant height, number of leaves, Leaf length, Leaf width, Stem girth and Stem lengthbut not significant for crown width for the weeks.

The mean square variance of yield related characters presented in Table 3 shows that the accessions and weeks had highly significant effect (P<0.01) on root wet weight, root dry weight, stem wet weight, stem dry weight, leaf wet weight, leaf dry weight, shoot wet weight, shoot dry weight, total wet weight and total dry weight.

Growth characters of *Garcinia kola* accessions at different stages.

There were variations among the accessions with respect to the mean values of the growth characters shown in Table 4. OS4 had significant higher mean values (p<0.05) for plant height (24.08cm), leaf length (10.82cm) and stem girth (4.31cm), while OG1 had significant lower mean for plant height (7.45cm), leaf length (3.16cm), leaf width (1.54cm), stem length (6.65cm) and crown width (6.14cm). However, OG4, AB2, OY4 and ON3 were significantly higher for number of leaves (6.22), leaf width (5.73cm), stem length (13.02cm) and crown width (30.51cm) respectively.

Yield related characters of *Garcinia kola* accessions

The yield related characters of *Garcinia kola* seedlings varied as shown in Table 5. OG3 was significantly higher (p<0.05) for stem wet weight (2.56g), stem dry weight (2.22g), leaf wet weight (1.76g), leaf dry weight (1.23g), shoot wet weight (4.33g) and total wet weight (5.92g),while ON2 had higher mean for root wet weight (1.61g), root dry weight (1.38g), shoot dry weight (3.03g) and total dry weight (4.42g) compared to other accessions, while OG1 had the least.

Phenotypic and Genotypic variance, Coefficients of Variation and Heritabilty estimates of Growth and Yield traits in *Garcinia kola* accessions.

The PVof both growth and yield related characters were higher than the GV in all the characters evaluated (Table 6). Crown width exhibited the highest phenotypic and genotypic variances of 98.63 and 394.37 respectively while root wet weight and leaf dry weight had the least values of 0.38g and 2.45g respectively for phenotypic and genotypic variances. Similarly, the PCV of both growth and yield related characters were higher than the GCV in all the characters. The highest value for GCV (0.59) and PCV (1.18) were observed in crown width while stem girth was the lowest for GCV (0.26) and PCV (0.48). Also in yield related characters, GCV (1.21) was higher in root dry weight and shoot dry weight while the root wet weight was the least (0.82). The highest (3.05) and lowest (2.27) for PCV were found in root dry weight and total wet weight respectively .Heritabilty estimates were higher for growth than yield related characters. Stem girth had the highest (29.98%) while plant height was the least (19.27%) for growth characters. The highest value of 17.55% was recorded for shoot wet weight while root wet weight had the least (12.27%).

Principal Component Analysis of growth and yield related characters of *Garcinia kola*

The result from Table 7 delineated the accessions in to twelve principal component axes; Prin.1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12. Prin.1 accounted for the highest proportion and eigen value of 0.96394 and 0.5670 respectively. Leaf length, leaf width and crown width are closely related, accounting for eigen values of 0.0608, 0.0588 and 0.0476 respectively. Similarly, root wet weight and root dry weight are closely related while stem wet weight, stem dry eight, leaf wet weight, leaf dry weight, shoot wet weight and shoot dry weight as well as total wet weight and total dry weight are closely related.

Correlation Coefficient among the growth characters of *Garcinia kola*

The correlation result in Table 8 shows that, leaf width is correlated (p< 0.05, r =0.54) with leaf length while the number of leaves is correlated with stem wet weight (r =0.54), stem dry weight (r = 0.54), leaf wet weight (r = 0.52), leaf dry weight (0.50), shoot wet weight (r=0.54), shoot dry weight (r= 0.53), total wet weight (r = 0.53) and total dry weight (r = 0.51). root wet weight is strongly associated with root dry weight (r = 0.99), stem wet weight (r = 0.92), stem dry weight (r = 0.91), leaf wet weight (r= 0.91), leaf dry weight (r = 0.89), shoot wet weight (r = 0.92), shoot dry weight (r = 0.91), total wet weight (r = 0.96) and total dry weight (r= 0.96). Root dry weight is strongly associated with stem wet

weight (r = 0.90), stem dry weight (r= 0.90), leaf wet weight (r = 0.90), leaf dry weight (r = 0.89), shoot wet weight (r = 0.90), shoot dry weight(r= 0.90), total wet weight (r= 0.94) and total dry weight (r= 0.95). Stem wet weight is strongly associated with stem dry weight (r= 0.99), leaf wet weight (r = 0.98), leaf dry weight (r = 0.96), shoot wet weight (r = 0.99), shoot dry weight (r = 0.99), total wet weight (r= 0.99) and total dry weight (r = 0.99). Stem dry weight is strongly associated with leaf wet weight (r = 0.97), leaf dry weight (r = 0.95), shoot wet weight (r = 0.99), shoot dry weight (r = 0.99), total wet weight (r = 0.99) and total dry weight (r= 0.99). leaf wet weight is strongly associated with leaf dry weight (r= 0.99), shoot wet weight (r = 0.99), shoot dry weight (r = 0.99), total wet weight (r = 0.98) and total dry weight (r = 0.98). Leaf dry weight is strongly associated with shoot wet weight(r = 0.97), shoot dry weight (r = 0.98), total wet weight (r = 0.97) and total dry weight (r = 0.97). Shoot wet weight is strongly associated with shoot dry weight (r = 0.99), total wet weight (r = 0.99) and total dry weight (r = 0.99). Shoot dry weight is strongly associated with total wet weight (r = 0.99) and total dry weight(r = 0.99). Total wet weight is strongly associated with total dry weight (r = 0.96).

Table 1: Qualitative traits in *Garcinia kola* accessions

Accessions	Seed Coat Colour	Seed Coat pattern	Seed Coat Shape
AB1	Deep Orange	Fairly whorled	Oval slightly elongated
AB2	Deep Orange	Not whorled	Oval slightly elongated
AN1	Light Orange	Heavy whorled	Oval not elongated
EK1	Light Orange	Heavy whorled	Oval slightly elongated
OG1	Light Orange	Heavy whorled	Oval slightly elongated
OG2	Light Orange	Heavy whorled	Oval not elongated
OG3	Deep Orange	Fairly whorled	Oval slightly elongated
OG4	Light Orange	Heavy whorled	Oval slightly elongated
ON1	Deep Orange	Fairly whorled	Oval not elongated
ON2	Light Orange	Fairly whorled	Oval slightly elongated
ON3	Deep Orange	Heavily whorled	Oval not elongated
ON4	Light Orange	Fairly whorled	Oval slightly elongated
OS1	Deep Orange	Not whorled	Oval not elongated
OS2	Deep Orange	Heavily whorled	Oval elongated
OS3	Deep Orange	Not whorled	Oval slightly elongated
OS4	Light Orange	Not whorled	Oval slightly elongated
OS5	Light Orange	Not whorled	Oval slightly elongated
OS6	Deep Orange	Fairly whorled	Oval slightly elongated
OS7	Light Orange	Heavily whorled	Oval not elongated
OS8	Light Orange	Heavily whorled	Oval not elongated
OY1	Black	Fairly whorled	Oval elongated
OY2	Light Orange	Fairly whorled	Oval slightly elongated
OY3	Black	Not whorled	Oval not elongated
OY4	Light Orange	Heavily whorled	Oval not elongated
OY5	Light Orange	Fairly whorled	Oval not elongated

Accessions from Abia state: **AB1** (Onitsha North) and **AB2** (Ikwuano), accession form Anambra state: **AN1** (Ihiala), accession from Ekiti state: **EK1** (Ado), accessions form Ogun state: **OG1** (Ijebu North), **OG2** (Ake 1), **OG3** (Ijebu ode) and **OG4** (Obafemi/ Owode), accessions from Ondo state: **ON1** (Odigbo), **ON2** (Okiti pupa), **ON3** (Ile oluji/ Oke igbo) and **ON4** (Akoko N/East**),** accessions from Osun state: **OS1** (Atakumosa East) **, OS2** (Ife South), **OS3** (Ilesha West), **OS4** (Ife central), **OS5** (Ife North), **OS6** (Atakumosa west), **OS7** (Ayedaade) and **OS8** (Irewole) and accessions form Oyostate: **OY1 (**Oluyole), **OY2 (**Ona- ara**), OY3** (Ibarapa East), **OY4** (Lagelu) and **OY5** (Akinyele).

Table 2: Mean square variance of growth characters in *Garcinia kola* seedlings.

Source of Variation	Df	Plant Height	No of Leaves	Leaf Length	Leaf Width	Stem Girth	Stem Length	Crown Width
Accessions	24	169.39**	19.46**	47.33**	11.67**	2.83**	39.31**	345.13**
Weeks	5	143.79**	199.03**	16.83**	8.76**	6.33**	59.62**	45.87^{ns}
Replicates	2	105.6^{ns}	2.14^{ns}	0.18^{ns}	1.12^{ns}	0.48^{ns}	25.80^{ns}	20.96^{ns}
Error	415	45.29	1.96	3.37	1.06	0.15	6.16	49.24
Corrected Total	446							

* = Significant at P<0.05, ** = highly significant at P<0.01 andDf = degree of freedom.

Table 3: **Mean square variance of yield related characters in *Garcinia kola***

Source of Variation	Df	Root Wet Weight	Root Dry Weight	Stem Wet Weight	Stem Dry Weight	Leaf Wet Weight	Leaf Dry Weight	Shoot Wet Weight	Shoot Dry Weight	Total Wet Weight	Total Dry Weight
Accessions	24	2.10**	2.41**	7.51**	6.12**	2.91**	1.82**	22.51**	15.39**	35.97**	26.55**
Weeks	5	278.79**	158.66**	862.79**	495.29**	338.50**	137.51**	2263.75**	1122.43**	4131.41**	2125.09**
Replicates	2	0.5^{ns}	0.42^{ns}	0.25^{ns}	0.16^{ns}	0.12^{ns}	0.06^{ns}	0.66^{ns}	0.32^{ns}	2.30^{ns}	1.46^{ns}
Error	418	0.97	0.87	2.38	1.97	1.00	0.63	6.98	4.82	11.41	8.50
Corrected Total	446										

* = Significant at P<0.05, ** = highly significant at P<0.01, ns=Non-significant, and Df = degree of freedom

Table 4: Growth characters of *Garcinia kola* accessions at different stages

Accessions	Plant Height(cm)	No of Leaves	Leaf Length(cm)	Leaf Width(cm)	Stem Girth(cm)	Stem Length(cm)	Crown Width(cm)
AB1	11.14^{bcd}	2.61^{i}	6.59^{gh}	3.23^{jk}	3.21^{i}	10.74^{bcdefg}	14.03^{fgh}
AB2	16.57^{b}	5.44^{abc}	10.03^{abc}	5.73^{a}	4.02^{bcd}	10.94^{bcdef}	23.47^{b}
AN1	11.20^{bcd}	3.72^{fgh}	7.88^{efg}	4.64^{bcde}	3.25^{hi}	9.04^{fghi}	16.07^{defgh}
EK1	11.98^{bcd}	4.67^{cdef}	8.53^{def}	4.42^{cdefg}	4.16^{ab}	8.84^{ghi}	16.31^{defgh}
OG1	7.45^{d}	3.33^{ghi}	3.16^{i}	1.54^{l}	3.45^{ghi}	6.65^{j}	6.14^{i}
OG2	12.17^{bcd}	4.61^{cdef}	5.89^{h}	3.59^{ghij}	3.64^{efg}	10.81^{bcdefg}	12.86^{gh}
OG3	13.56^{bc}	5.78^{ab}	8.67^{cdef}	4.33^{cdefg}	3.67^{efg}	11.03^{bcde}	15.84^{defgh}
OG4	11.29^{bcd}	6.22^{a}	7.40^{fg}	3.64^{ghij}	3.70^{efg}	7.42^{ij}	13.80^{fgh}
ON1	12.68^{bcd}	4.67^{cdef}	9.70^{abcd}	4.41^{cdefg}	3.46^{ghi}	10.73^{bcdefg}	19.89^{bcde}
ON2	12.22^{bcd}	3.83^{fgh}	10.28^{ab}	5.34^{ab}	3.53^{fgh}	10.61^{bcdefgh}	22.32^{bc}
ON3	14.74^{bc}	5.11^{bcde}	10.22^{ab}	4.69^{bcde}	3.91^{bcde}	11.30^{abcde}	30.51^{a}
ON4	13.59^{bc}	3.33^{ghi}	7.52^{fg}	4.17^{cdefghi}	3.25^{hi}	10.11^{cdefgh}	16.58^{defgh}
OS1	14.04^{bc}	4.56^{cdef}	7.78^{efg}	3.72^{fghij}	3.47^{ghi}	9.73^{efgh}	16.12^{defgh}
OS2	10.47^{cd}	2.94^{hi}	10.28^{ab}	2.56^{k}	2.93^{j}	9.87^{efgh}	11.98^{h}
OS3	16.29^{b}	4.67^{cdef}	9.18^{bcde}	4.79^{bcd}	4.00^{bcd}	12.00^{abc}	17.33^{cdefgh}
OS4	24.08^{a}	5.44^{abc}	10.82^{a}	4.95^{bc}	4.31^{a}	11.37^{abcde}	21.23^{bcd}
OS5	15.33^{bc}	4.50^{cdef}	7.91^{efg}	3.87^{efghij}	3.28^{hi}	12.38^{ab}	15.26^{efgh}
OS6	12.88^{bc}	3.39^{ghi}	7.52^{fg}	3. 89^{ij}	3.22^{i}	9.49^{efgh}	16.07^{defgh}
OS7	15.79^{bc}	4.56^{cdef}	8.42^{def}	4.16^{cdefghi}	4.11^{abc}	11.88^{abcd}	16.78^{defgh}
OS8	11.16^{bcd}	4.22^{efg}	6.07^{h}	4.54^{cdef}	2.74^{j}	8.70^{hi}	12.52^{gh}
OY1	16.14^{b}	4.28^{defg}	8.66^{cdef}	4.24^{cdefgh}	3.778^{def}	10.49^{bcdefgh}	17.52^{cdefgh}
OY2	15.42^{bc}	5.33^{abcd}	9.01^{bcde}	4.49^{cdef}	3.87^{cde}	10.00^{defgh}	18.93^{bcdef}
OY3	13.00^{bc}	5.89^{ab}	9.07^{bcde}	3.92^{efghij}	4.01^{bcd}	9.57^{efgh}	18.33^{bcdefg}
OY4	14.22^{bc}	2.00^{hi}	7.44^{fg}	3.49^{hij}	3.63^{efg}	13.02^{a}	15.28^{efgh}
OY5	14.96^{bc}	3.07^{hi}	8.72^{cdef}	4.08^{defghi}	3.33^{hi}	12.31^{ab}	16.00^{defgh}

Mean with the same letter in the same column are not significantly at $p \geq 0.05$ according to Duncan Multiple Range Test (DMRT).

Table 5: Yield related characters of *Garcinia kola* accessions.

Accessions	Root Wet Weight(g)	Root Dry Weight(g)	Stem Wet Weight(g)	Stem Dry Weight(g)	Leaf Wet Weight(g)	Leaf Dry Weight(g)	Shoot Wet Weight(g)	Shoot Dry Weight(g)	Total Wet Weight(g)	Total Dry Weight(g)
AB1	0.42 ^{def}	0.22^{cd}	0.25^{hi}	0.12^{f}	0.00^{g}	0.00^{g}	0.25^{h}	0.12^{gh}	0.67^{f}	0.34^{f}
AB2	1.33 ^{abc}	1.11^{ab}	1.93^{abcd}	1.68^{abc}	1.19^{abcde}	0.73^{abcde}	3.19^{abcde}	2.41^{abcd}	4.53^{abc}	3.52^{abc}
AN1	0.62 ^{cdef}	0.46^{bcd}	1.08^{bcdefghi}	0.81^{bcdef}	0.59^{defg}	0.34^{cdefg}	1.70^{cdefgh}	1.56^{cdefgh}	2.32^{cdef}	1.61^{cdef}
EK1	0.67 ^{cdef}	0.47^{bcd}	1.53^{abcdefg}	1.31^{abcde}	0.93^{bcdef}	0.56^{bcdefg}	2.50^{abcdefg}	1.86^{abcdefg}	3.17^{bcdef}	2.33^{bcdef}
AN1	0.62 ^{cdef}	0.46^{bcd}	1.08^{bcdefghi}	0.81^{bcdef}	0.59^{defg}	0.34^{cdefg}	1.70^{cdefgh}	1.56^{cdefgh}	2.32^{cdef}	1.61^{cdef}
OG1	0.23^{f}	0.12^{d}	0.23^{i}	0.10^{f}	0.00^{g}	0.00^{g}	0.23^{h}	0.10^{h}	0.46^{f}	0.22^{f}
OG2	0.71^{cdef}	0.54^{bcd}	1.31^{abcdefghi}	1.11^{abcdef}	0.77^{cg}	0.39^{efg}	2.16^{bcdefgh}	1.51^{bcdefgh}	2.86^{cdef}	2.04^{cdef}
OG3	1.58^{a}	1.37^{a}	2.56^{a}	2.22^{a}	1.76^{a}	1.23^{a}	4.33^{a}	2.44^{a}	5.92^{a}	4.28^{a}
OG4	0.50^{def}	0.33^{cd}	1.04^{cdefghi}	0.77^{bcdef}	0.59^{defg}	0.33^{cdefg}	1.65^{cdefgh}	1.10^{cdefgh}	2.15^{cdef}	1.43^{cdef}
ON1	0.91^{abcdef}	0.73^{abcd}	2.02^{abc}	1.72^{abc}	1.10^{abcde}	0.74^{abcd}	3.15^{abcde}	2.46^{abcd}	4.06^{abcde}	3.19^{abcd}
ON2	1.61^{a}	1.38^{a}	2.31^{ab}	1.83^{ab}	1.64^{ab}	1.20^{a}	3.98^{ab}	3.03^{ab}	5.58^{ab}	4.42^{ab}
ON3	1.11^{abcd}	0.89^{abc}	1.77^{abcdef}	1.43^{abcd}	1.11^{abcde}	0.68^{abcdef}	2.90^{abcde}	2.11^{abcdef}	4.01^{abcde}	2.99^{abcde}
ON4	0.38^{def}	0.21^{cd}	0.98^{cdefghi}	0.67^{cdef}	0.64^{defg}	0.37^{cdefg}	1.64^{cdefgh}	1.03^{cdefgh}	2.02^{cdef}	1.24^{cdef}
OS1	0.46^{def}	0.28^{cd}	1.24^{bcdefghi}	0.83^{bcdef}	0.79^{cdefg}	0.46^{cdefg}	2.04^{bcdefgh}	1.29^{bcdefgh}	2.51^{cdef}	1.57^{cdef}
OS2	0.7^{cdef}	0.51^{bcd}	0.53^{ghi}	0.24^{ef}	0.19^{fg}	0.09^{efg}	0.74^{gh}	0.33^{gh}	1.44^{ef}	0.84^{def}
OS3	0.94^{abcdef}	0.8^{abcd}	1.83^{abcdef}	1.37^{abcd}	1.06^{abcde}	0.73^{abcde}	2.91^{abcdef}	2.09^{abcdef}	3.86^{abcde}	2.89^{abcde}
OS4	0.76^{cdef}	0.54^{bcd}	1.89^{abcde}	1.48^{abcd}	1.04^{abcde}	0.73^{abcde}	2.96^{abcdef}	2.21^{abcde}	3.71^{abcde}	2.76^{abcde}
OS5	0.04^{abcde}	0.82^{abcd}	2.05^{abc}	1.47^{abcd}	1.50^{abc}	1.11^{ab}	3.59^{abc}	2.58^{abc}	4.63^{abc}	3.41^{abc}
OS6	0.77^{cdef}	0.56^{bcd}	1.11^{bcdefghi}	0.78^{bcdef}	0.62^{defg}	0.32^{cdefg}	1.76^{cdefgh}	1.10^{cdefgh}	2.52^{cdef}	1.66^{cdef}
OS7	0.71^{cdef}	0.53^{bcd}	1.47^{abcdefgh}	1.03^{bcdef}	0.72^{cdefg}	0.38^{cdefg}	2.24^{abcdefgh}	1.42^{bcdefgh}	2.94^{bcdef}	1.94^{cdef}
OS8	0.42^{def}	0.20^{cd}	0.72^{efghi}	0.36^{def}	0.41^{efg}	0.17^{defg}	1.17^{efgh}	0.53^{efgh}	1.59^{def}	0.73^{ef}
OY1	0.42^{def}	0.23^{cd}	1.45^{abcdefghi}	1.07^{bcdef}	0.81^{cdef}	0.49^{bcdefg}	2.28^{abcdefgh}	1.56^{bcdefgh}	2.70^{cdef}	1.79^{cdef}
OY2	0.92^{abcdef}	0.74^{abcd}	1.95^{abcdefg}	1.52^{abc}	1.19^{abcde}	0.88^{abc}	3.17^{abcde}	2.40^{abcd}	4.09^{abcde}	3.14^{abcd}
OY3	0.84^{bcdef}	0.59^{bcd}	1.99^{abc}	1.56^{abc}	1.33^{abcd}	0.90^{abc}	3.37^{abcd}	2.46^{abcd}	4.21^{abcd}	3.04^{abcde}
OY4	0.26^{ef}	0.12^{d}	0.64^{fghi}	0.38^{def}	0.56^{defg}	0.35^{cdefg}	1.25^{defgh}	0.73^{defgh}	1.51^{def}	0.85^{def}
OY5	1.38^{abc}	1.08^{ab}	0.67^{efghi}	0.37^{def}	0.21^{fg}	0.08^{fg}	0.91^{fgh}	0.45^{fgh}	2.29^{cdef}	1.53^{cdef}

Mean with the same letter in the same column are not significantly at $p \geq 0.05$ according to Duncan Multiple Range Test (DMRT).

Table 6: Phenotypic, Genotypic variances and Heritability estimates of growth and yield related Characters of *Garcinia kola* accessions.

Source of Variation	Genotypic Variance(O^2g)	Phenotypic Variance(O^2p)	Heritability (%)	Genetic Coefficient of Variation(GCV)	Phenotypic Coefficient of Variation(PCV)
Plant Height	41.37	214.68	19.27	0.47	1.07
No of Leaves	5.83	21.42	27.23	0.56	1.07
Leaf Length	14.65	50.7	28.90	0.46	0.86
Leaf Width	3.54	12.73	27.78	0.46	0.87
Stem Girth	0.89	2.98	29.98	0.26	0.48
Stem Length	11.05	45.47	24.30	0.32	0.65
Crown Width	98.63	394.37	25.01	0.59	1.18
Root Wet Weight	0.38	3.07	12.27	0.82	2.34
Root Dry Weight	0.51	3.28	15.65	1.21	3.05
Stem Wet Weight	1.71	9.89	17.29	0.95	2.28
Stem Dry Weight	1.38	8.09	17.10	1.12	2.71
Leaf Wet Weight	0.64	3.91	16.28	0.96	2.38
Leaf Dry Weight	0.40	2.45	16.19	1.19	2.95
Shoot Wet Weight	5.18	29.49	17.55	1.01	2.42
Shoot Dry Weight	3.52	20.21	17.43	1.21	2.89
Total Wet Weight	8.19	47.38	17.28	0.94	2.27
Total Dry Weight	6.02	35.05	17.17	1.14	2.75

Table 7: Principal Components Analysis (PCA) of Growth and Yield related characters of Accessions of *Garcinia kola*

Characters	Prin.1	Prin.2	Prin.3	Prin.4	Prin.5	Prin.6	Prin.7	Prin.8	Prin.9	Prin.10	Prin11	Prin.12
PH	0.0169	0.3573	-.0309	0.6819	0.1971	0.586	-.1324	-.0755	-.0047	-.0077	-.0016	-.0014
NL	0.0891	0.3186	0.7969	0.0007	0.093	0.0472	0.5537	-.1099	0.0866	0.0286	0.0073	0.0073
LL	0.0608	0.4609	-.0815	-.2999	-.2741	0.0391	-.0720	-.7387	-.2425	-.0259	0.0154	-.0077
LW	0.0588	0.4221	-.1336	-.3278	-.4497	0.3794	0.1996	0.5293	0.1621	0.0166	-.0183	0.0038
SL	0.0319	0.3916	-.3955	0.3100	0.1045	0.5336	0.5275	0.0829	-.1105	-.0055	0.0069	0.0058
CW	0.0476	0.3571	-.0278	-.4532	0.7854	0.0205	-.1700	0.1282	0.0365	-.0075	0.0017	0.0009
SG	0.0309	0.4105	0.3824	0.1873	-.2167	-.4702	0.5646	0.2037	0.1435	0.0137	0.0139	0.0034
RWW	0.2991	-.0334	-.1209	0.0135	0.0065	-.0262	0.0214	-.1653	0.5406	0.0171	0.3296	-.0283
RDW	0.2937	-.0298	-.1333	0.0155	0.0108	-.0379	0.0105	-.1991	0.5938	0.1336	-.3039	0.0146
SWW	0.3159	-.0424	0.0183	0.0072	-.0078	0.0112	0.0188	0.0583	-.1331	-.4225	0.2703	0.4966
SDW	0.3167	-.0340	0.0276	0.0121	-.0057	-.0044	0.0182	0.0599	-.1495	-.4562	-0.4216	-.3000
LWW	0.3153	-.0375	0.0165	0.0077	-.0009	0.0128	-.0251	0.0758	-.2267	0.3574	0.3056	-.6629
LDW	0.3100	-.0348	0.0077	0.0068	0.0008	0.0103	-.0401	0.0598	-.2647	0.6631	-.1600	0.4704
ShWW	0.3187	-.0407	0.0167	0.0076	-.0051	0.0119	-.0202	0.0667	-.1677	-.1214	0.3145	0.0358
ShDW	0.3186	-.0348	0.0208	0.0103	-.0035	0.0009	-.0264	0.0608	-.1934	-.0585	-.3334	-.0261
TWW	0.3208	-.0397	-.0202	0.0093	-.0021	0.0019	-.0094	0.0054	0.0203	-.0867	0.3258	0.0193
TDW	0.3209	-.0344	-.0238	0.0122	0.0006	-.0105	-.0163	-0.0137	0.0319	-.0039	-.3349	-.0149
Eigen value	9.6394	2.5731	1.0924	0.8981	0.7149	0.6106	0.5368	0.4614	0.3470	0.0949	0.0237	0.0047
Prorportion	0.567	0.1514	0.0643	0.0528	0.0421	0.0359	0.0316	0.0271	0.0204	0.0056	0.0014	0.0003

PH: Plant Height, **NL**: Number of leaves,**LL**: Leaf Length, **LW**: Leaf Width, **CW**: Crown width, **SG**: Stem girth, **RWW**: Root Wet Weight, **RDW**: Root Dry Weight**, SWW**: Stem Wet Weight, **SDW**: Stem Dry Weight, **LWW**: Leaf Wet Weight, **LDW**: Leaf Dry Weight, **ShWW**: Shoot Wet Weight, **ShDW**: Shoot Dry Weight, **TWW**: Total Wet Weight and **TDW**: Total Dry Weight.

Table 8: Correlation coefficient among the growth and yield related characters of *Garcinia kola* seedlings

	PH	NL	LL	LW	SL	CW	SG	RWW	RDW	SWW	SDW	LWW	LDW	SHWW	SHDW	TWW	TDW
PH																	
NL	0.15																
LL	0.28	0.20															
LW	0.25	0.20	0.54*														
SL	0.39	0.15	0.39	0.34													
CW	0.18	0.12	0.37	0.32	0.26												
SG	0.33	0.47	0.41	0.35	0.36	0.23											
RWW	0.09	0.47	0.21	0.21	0.24	0.09	0.24										
RDW	0.09	0.44	0.22	0.20	0.23	0.10	0.23	0.99**									
SWW	0.09	0.54*	0.19	0.22	0.20	0.09	0.23	0.92**	0.90**								
SDW	0.08	0.54*	0.20	0.22	0.20	0.10	0.28	0.91**	0.90**	0.99**							
LWW	0.09	0.52*	0.20	0.22	0.20	0.10	0.27	0.90**	0.89**	0.97**	0.97**						
LDW	0.09	0.50	0.20	0.21	0.19	0.10	0.26	0.89**	0.88**	0.96**	0.95**	0.99**					
ShWW	0.09	0.54*	0.20	0.22	0.20	0.09	0.28	0.92**	0.90**	0.99**	0.99**	0.99**	0.97**				
ShDW	0.09	0.53*	0.20	0.22	0.20	0.10	0.28	0.91**	0.90**	0.99**	0.99**	0.99**	0.98**	0.99**			
TWW	0.09	0.53*	0.20	0.22	0.21	0.09	0.27	0.96**	0.94**	0.99**	0.99**	0.98**	0.97**	0.99**	0.99**		
TDW	0.09	0.51*	0.21	0.22	0.21	0.10	0.27	0.96**	0.95**	0.99**	0.99**	0.98**	0.97**	0.99**	0.99**	0.99**	0.99**

PH: Plant Height, **NL**: Number of leaves, **LL:** Leaf Length, **LW**: Leaf Width, **SL**: Stem length, **CW**: Crown width**, SG:** Stem girth, **RWW:** Root Wet Weight, **RDW**: Root Dry Weight, **SWW**: Stem Wet Weight, **SDW**: Stem Dry Weight, **LWW:** Leaf Wet Weight, **LDW:** Leaf Dry Weight,**Shww**: Shoot Wet Weight, **ShDW**: Shoot Dry Weight, **TWW:** Total Wet Weight **TDW**: Total Dry Weight.

Plate1: *Garcinia kola* accessions from twenty-five Local Government areas

Plate 2: A cross section of the accessions on the field Within seven states in Nigeria

DISCUSSION

Findings from this study indicate that there were significant variations in the qualitative traits of seed collections comprising of the growth and yield related traits among the accessions of *Garcinia kola*. The variations exhibited at the morphological level is accordance with the reports made by Mansyah *et al.* (2015), that reported intra- and inter specific variations between seedlings and mother trees in *Garcinia* and Shameer *et al.* (2016) that reported variations in qualitative and quantitative characters of *Garcinia gummi gatta.*

The best performance exhibited by OS4, OG3 and ON4 could be due to genetic variation. Selections based on these characters could helpin solving the problem of slow growth and other related silvicultural challenges experienced by the plant under domestication, farmers and researchers. The phenotypic variance of both growth and yield related characters were higher than the genotypic variance in all the characters studied in accordance with the findings made by Wanderi *et al.* (2013) and Onuoha and Olawuyi (2017).

The Genotypic Coefficient of Variation (GCV) and Phenotypic Coefficient of Variation (PCV) were generally low, but occured in a wide range for both growth and yield related characters. This indicates significant variability among these characters for genetic improvement through selection. The values which were comparatively lower for growth characters shows that variations exist among the growth characters hence, breeders should source for high variability from these traits as recommended by Ahsan *et al.* (2015). This is similar to the report made by Wanderi *et al.* (2013) on *Glycine max* accessions.

The observed close range of values for GCV and PCV could be attributed to genetic factors which imply that, environmental factors played minimal role in the expression of these traits.

Therefore, such phenomenon according to Wanderi *et al.* (2013) will substantially favour selection at the early stage of improvement. The increased PCV and GCV values experienced by the yield related characters shows that these traits are more affected by environmental factors which did not influence the genetic factors in the expression of these traits compared to the oservation from the growth characters. Therefore, selection of such characters needs to be considered because environmental fluctuations are unpredictable and the results can be misleading (Kamwal and Singh, 2009). Although, coefficient of variation provides information on the extent of total variability existing in characters, which does not partition this variability into heritable and non-heritable components of variations as similarly observed by Govindaraj *et al.* (2011). In this study, heritable character provides information on the suitability and method of selecting suitable characters according to Selvaraj *et al.* (2011).

Heritability alone did not provide information on genetic progress for an effective selection of the best individual (Johnson, 1955). It is therefore important to combine high heritability, estimates with genetic gains and GCV values which are powerful indicators of additive gene action (Wanderi *et al.*, 2013). Generally, the broad sense heritability estimated for the characters was low but relatively increased values were found among the growth characters compared to the yield characters. The low values for heritability indicates that large portion of the phenotypic variance is due to environmental variance. This may be due to varied growth behaviour as a result of accessions and environment interaction. The highest value of heritability observed in stem girth which was closely followed by leaf length, leaf width and number of leaves indicates that growth characters are less affected by environmental pressure compared to the yield related characters. The least broad sense heritability value found in Root wet weight indicates this character is the most susceptible to environmental pressure.

Correlations among yield, yield related characters and other economic traits such as the growth characters is very vital because yield is a complex character whose expression is governed by a number of traits (Khayatnezhad *et al.*, 2011). Therefore it requires understanding of the magnitude and interrelationship of the characters among themselves and with the target yield and quality which helps in improving efficiency of selection by combining characters (Ahmad *et al.*, 2013). Further, the correlation analysis helps in determining the direction and number of characters to be considered in improving yield and quality (Simmonds, 1986). Traits may either be positively or negatively correlated due to the mutual association with other characters, and these correlations between pair of traits may be due to genetic, phenotypic and environmental factors in accordance with the findings of Solomon *et al.* (2014). Findings from the correlation coefficient shows that growth characters exhibit weak positive correlations with one another except Leaf width and Leaf length which exhibited positive correlations. The correlations between the yields related characters were strong and positive. Number of leaves had positive correlations with all the yield related characters. The implies that, selection based on any of the growth characters except leaf length may or may not favour the other but will favour the yield related characters to an extent.

The Principal Component Analysis (PCA) revealed than Prin.1 accounted for the highest variation based on the pattern of variation among the characters in accordance with the reports by Olawuyi *et al.* (2012) and Onuoha and Olawuyi, (2017).

Conclusion and Recommendations

Accessions from Aye koka (OS4) and Ijebu Ode (OG3) could be suggested for future breeding and improvement of *Garcinia kola*. There is a need to enlarge the scope and size of collection throughout the distribution areas during the fruiting season in order to discover other accessions of novel qualities at the morphological level which could be used for gene pool improvement. This report is the first attempt on genetic diversity of this fruit tree species in Nigeria and will serve as a preliminary and diversity exploration of genetic resources of naturally growing wild species which could be researched for conservation, domestication and improvement of *Garcinia kola.*

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