

Characterization of some Nigerian monkey kola (*Cola pachycarpa* K. Schum.) accessions using pomological and seed traits

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Abstract

This study was conducted in where? to evaluate and characterize selected Nigerian accessions of monkey kola (*Cola pachycarpa* K. Schum) using pomological, seed, and seedling traits, with the aim of identifying genetically diverse and agronomically superior materials for future breeding and domestication efforts. The experiment employed a completely randomized design (CRD) with three replicates for fruit and seed traits, and four replicates for seedling growth traits. Substantial genotypic variability was observed among the accessions for all measured traits. Fruit weight ranged from 18.13 ± 2.41 g to 28.55 ± 3.91 g, while seed weight varied between 2.58 ± 0.26 g and 3.86 ± 0.42 g, highlighting the existence of variability exploitable through selection. Significant differences ($p < 0.05$) were also recorded for fruit length, circumference, pericarp thickness, and seed dimensions). Heritability estimates were high for key traits such as pulp length (95.35%), seed length (87.85%), and pulp circumference (84.27%), suggesting strong genetic control and good prospects for selection. The results highlighted the presence of substantial genetic variation in *C. pachycarpa*, particularly in traits associated with fruit yield and seed vigor. These findings provided a foundation for selection, breeding, and conservation of superior genotypes, and supported the integration of this species into fruit crop development programs

Keywords: *Cola pachycarpa*, fruit traits, genetic variability, monkey kola, seed traits.

Introduction

Sub-Saharan Africa harbors a rich diversity of underutilized fruit crops, many of which are poorly characterized yet hold substantial promise for nutritional, medicinal, and economic applications. One such indigenous fruit tree is monkey kola (*Cola pachycarpa* K. Schum) belonging to the Malvaceae family, produces edible fruits that are consumed locally and by wild primates (Keay, 1989; Ogbu & Umeokechukwu, 2014). It is native to southern Nigeria and parts of Central Africa, Despite its cultural and nutritional importance, *C. pachycarpa* remains largely neglected in mainstream agricultural research and breeding initiatives. It is often harvested from wild or semi-domesticated stands, with little attention paid to the improvement of its fruiting potential. Yet, the species exhibits considerable variability in fruit and seed traits, offering a genetic resource base that could be harnessed for crop improvement and domestication efforts (FAO, 2010; Akinmoladun *et al.*, 2019).

Pomological traits such as fruit weight, length, pulp thickness, and pericarp dimensions play a critical role in consumer preference, yield assessment, and market value. Likewise, seed traits including seed size, weight, and germination capacity are central to propagation, nursery performance, and early seedling vigor (Agboola *et al.*, 2021). Understanding the extent of phenotypic and genotypic variability among these traits is essential for selecting superior genotypes and implementing effective breeding strategies. Previous reports have identified morphological distinctions between *C. pachycarpa* and its close relatives like *C. lepidota* and *C. laterita*. *C. pachycarpa* generally exhibited larger fruits and sweeter

pulp (Ogbu and Umeokechukwu, 2014). However, detailed quantitative evaluations of fruit and seed parameters across multiple accessions remain limited. Furthermore, data on trait heritability and genotype-by-environment interactions for these characters are largely unavailable.

Characterization of pomological and seed traits serves as a foundational step toward the genetic improvement of underutilized crops. By identifying traits with high heritability and significant genetic variation, breeders can target desirable attributes more efficiently, thereby enhancing selection gains (Burton, 1952; Johnson *et al.*, 1955). Such characterization will also support in-situ and ex-situ conservation efforts, ensuring sustainable utilization of plant genetic resources (FAO, 2010). This study therefore aims to evaluate the variability in fruit and seed traits of thirteen *Cola pachycarpa* accessions collected from southeastern Nigeria.

Materials and Methods

Germplasm Source and experimental design

A total of thirteen (13) accessions of *C. pachycarpa* were collected from diverse ecological locations across southeastern Nigeria, representing significant genetic and environmental variation. These accessions were sourced from seven local government areas in Abia State and one in Imo State. The detailed information on the accession codes, collection sites, and geo-coordinates are presented in Table 1. The selection of these sites aimed to capture natural population variability for meaningful trait comparisons and breeding utility. The experimental design was the Completely Randomized Design (CRD) five replications

Fruit and seed characteristics determinations

To assess fruit and seed characteristics, the following fruit characteristics were measured:

Fruit weight (g): The weight of each individual fruit was determined using a sensitive weighing scale (electronic kitchen scale SF-400). Ten fruits were selected at random and weighed and their mean weight calculated and recorded.

Fruit length (cm): The length of each fruit was measured using a meter rule and a sewing thread, the thread was placed on the length of the fruit from tip to tip before being placed on the ruler to ascertain its fruit length. Ten randomly selected fruits were measured and their mean length computed.

Fruit circumference (cm): The circumference of each fruit was measured using a meter rule and a sewing thread, the thread was placed round the circumference of the individual sample fruit before being placed on the ruler to ascertain its circumference. The circumference of ten randomly selected fruits was measured and the mean recorded

Pericarp length (cm): The length of the pericarp (the outer fleshy layer of the fruit) was measured using a meter rule and a sewing thread, the thread was placed on the length of the fruit pericarp from tip to tip before being placed on the ruler to ascertain its fruit pericarp length. The pericarp length of ten fruits randomly selected were measured and the mean recorded

Fruit pericarp weight (g): The weight of the pericarp was determined using a sensitive weighing scale (electronic kitchen scale SF-400) by weight the individual sample fruit pericarp. The fruit pericarp weight of ten fruits selected at random was measured and the mean recorded.

Seed weight (g): The weight of each individual seed was determined using a sensitive weighing scale (electronic kitchen scale SF-400) by weight the individual sample fruit seeds. Ten seeds which were selected at random were weighed and their mean weight recorded

Seed circumference (cm): The circumference of each seed was measured using a meter rule and a sewing thread, the thread was placed round the circumference of the individual sample fruit seeds before being placed on the ruler to ascertain its circumference. The seed circumference of ten randomly selected seeds was measured and the mean recorded.

Seed length (cm): The length of each seed was measured using a meter rule and a sewing thread, the thread was placed on the length of the fruit seeds from tip to tip before being placed on the ruler to ascertain its seed length. The seed length of ten seeds randomly selected was measured and the mean recorded.

Data analyses

All collected data were subjected to Analysis of Variance (ANOVA) using Genstat Discovery Edition 12.1 (Genstat, 2009). Least Significant Difference (LSD) Test was done at 5% probability level to separate means where significant differences were observed. Genetic variability among the genotypes for the traits was assessed using the method of Wricke and Weber (1986):

$$VG = \frac{MSG - MSE}{r}$$

$$VP = \frac{MSG}{r}$$

$$VE = \frac{MSE}{r}$$

Where MSG, MSE and r are the mean squares genotypes, mean squares error and number of replications respectively.

Heritability in broad sense ($h^2B\%$), Phenotypic (PCV) and Genotypic (GCV) coefficients of variations were estimated by the methods of Burton (1952) and Johnson *et al.* (1955) and Kumar *et al.* (1985) as follows:

$$PCV = \frac{\sqrt{VP}}{\bar{X}} \times 100$$

$$GCV = \frac{\sqrt{VG}}{\bar{X}} \times 100$$

$$ECV = \frac{\sqrt{VE}}{\bar{X}} \times 100$$

Where VP, VG and \bar{X} are phenotypic and genotypic variances and grand mean respectively for each attribute under consideration.

$$h^2B(\%) = \frac{VG}{VP} \times 100$$

Broad sense heritability (h^2B) expressed as the ratio of VG to the VP was estimated on genotypic mean basis as described by Allard (1991).

Results

Fruit traits of 13 *C. parhycarpa* accessions in 2021 and 2022 are presented in Table 2. In 2021, the measurements for the 13 accessions show variability across the fruit traits: The fruit weight ranged from 130.40 g (OL) to 257.00 g (OR); the fruit length ranged from 11.81 cm (OH) to 19.01 cm (ND); the fruit circumference ranged from 12.22 cm (AM) to 16.00 cm (OR); the fruit back weight ranged from 22.07 g (OL) to 55.33 g (OR); the number of seeds ranged from 3.20 (UM) to 4.90 (ND); the pulp weight ranged from 17.84 g (OH) to 32.44 g (OR); the pulp length ranged from 2.93 cm (UH) to 18.02 cm (UM); and the pulp circumference ranged from 3.22 cm (UB) to 16.47 cm (AM). The mean values for 2021 were: Fruit Weight: 170.99 g; Fruit Length: 14.13 cm; Fruit Circumference: 13.68 cm; Fruit Back Weight: 33.93 g; Number of Seeds: 4.15; Pulp Weight: 23.29 g; Pulp Length: 8.07 cm; Pulp Circumference: 9.06 cm.

In 2022, the measurements for the 13 accessions shows different trends with generally higher values compared to 2021: The fruit weight ranged from 157.70 g (UO) to 318.30 g (UH); the fruit length ranged from 17.34 cm (OL) to 22.50 cm (UB); the fruit circumference ranged from 15.08 cm (UO) to 34.20 cm (OH); the fruit back weight ranged from 43.30 g (UO) to 89.10 g (UH); the number of seeds ranged from 3.20 (AE) to 21.47 (OL); the pulp weight ranged from 12.48 g (OL) to 33.04 g (UB); the pulp length ranged from 3.96 cm (OL) to 16.15 cm (UB); the pulp circumference ranged from 10.61 cm (OL) to 20.14 cm (OH). The mean values for 2022 were: Fruit Weight: 234.22 g; Fruit Length: 19.35 cm; Fruit Circumference: 18.51 cm; Fruit Back Weight: 65.58 g; Number of Seeds: 5.14; Pulp Weight: 27.26 g; Pulp Length: 5.54 cm; Pulp Circumference: 13.87 cm. The

significance levels indicate that the differences between years are highly significant ($P < 0.01$) for most traits, suggesting a strong influence of the year on these traits. The differences between accessions are also highly significant ($P < 0.01$) for most traits, indicating significant differences among the accessions. The interaction between accession and year is significant ($P < 0.01$) for most traits..

The seed traits of 13 *C. pachycarpa* accessions in 2021 and 2022 is presented in Table 3. In 2021, the measurements for the 13 accessions show variability across the seed traits: the seed weight ranged from 4.52 g (UH) to 23.79 g (NT); the seed length ranged from 4.27 cm (OL) to 11.72 cm (AM); and the seed circumference ranged from 7.91 cm (UB) to 15.52 cm (UH). The mean values for 2021 were: Seed Weight: 14.28 g; Seed Length: 5.82 cm; and Seed Circumference: 9.86 cm. In 2022, the measurements for the 13 accessions show different trends with generally similar values compared with 2021: the seed weight ranged from 10.67 g (UO) to 16.27 g (UH); the seed length ranged from 3.94 cm (OB) to 6.43 cm (UH); and the seed circumference ranged from 6.92 cm (OB) to 9.79 cm (UM). The mean values for 2022 were: Seed Weight: 14.11 g; Seed Length: 5.20 cm; and Seed Circumference: 8.71 cm.

The significance levels indicate that the differences between years are significant ($P < 0.01$) for seed circumference. The differences between accessions are highly significant ($P < 0.01$) for all traits, indicating significant differences among the accessions. The interaction between accession and year is also significant ($P < 0.01$) for all traits. The data from Table 3 shows that the seed traits of *Cola pachycarpa* accessions varied significantly between 2021 and 2022,. 2021 exhibited higher values for seed weight and seed length.

Genetic component analyses of 13 accessions of *Cola pachycarpa*. The values of phenotypic variance (VP), genotypic variance (VG), and error variance (VE), as well as the heritability in the broad sense (h^2_B) are presented in Table 4. Fruit weight has a grand mean of 202.60 g with a heritability (h^2) of 61.10 %, while fruit length has a mean of 16.76 cm and a heritability of 63.23 %. Pulp length had a mean of 6.75 cm and a heritability of 95.35 %, while pulp circumference had a mean of 11.24 cm and a heritability of 84.27 %. Seed weight has a mean of 14.17 g and a heritability of 80.12 %, while seed length had a mean of 5.49 cm and a heritability of 87.85 %. Seed circumference, with a mean of 9.29 cm and a heritability of 70.37 %.

Discussion

This study demonstrated substantial phenotypic and genotypic variation in pomological and seed traits among *C. pachycarpa* accessions collected from southeastern Nigeria, highlighting the species' potential for genetic improvement and domestication. Such variability is a prerequisite for effective selection in any crop improvement program (Johnson *et al.*, 1955; Burton, 1952). Substantial differences among accessions

in fruit weight, length, pulp characteristics, and pericarp thickness is an indication of the presence of diverse genotypes with distinct yield and market qualities. This level of variation is a promising indication that meaningful genetic gains can be achieved through selection. Particularly, accessions such as OR, UB, and UH showed consistent superiority in multiple fruit traits across years, highlighting their potential as candidate genotypes for improvement programs. These accessions represent promising genetic materials for the development of improved varieties. The fruit traits of *Cola pachycarpa* accessions varied significantly between 2021 and 2022, with 2022 exhibiting higher mean values for most traits. The significant differences among accessions and the interaction between accession and year indicate that both genetic and environmental factors influence the fruit traits

The moderate to high heritability estimates recorded for fruit weight, fruit length, pulp length, and pulp circumference is a reflection of strong genetic influences on these traits. These values implied that additive gene effects are predominant in their expression. In breeding terms, these values is an indication that direct selection based on phenotype would be effective for trait improvement (Allard, 1991) especially for pulp-related parameters that directly influence consumer preference and processing quality. Such traits can form the core of selection criteria in early domestication efforts and trait-based breeding. These observations are consistent with previous findings on other tropical fruit trees where high heritability has been reported for yield-contributing traits (Akinmoladun *et al.*, 2019).

Seed characteristics such as seed weight, length, and circumference also exhibited variability among accessions, with high heritability. These are indicative of strong genetic control, and selection for seed traits which could facilitate the development of vigorous, high-performing seedlings for propagation. The trait stability observed across two years further validated the potential for consistent seedling performance under varying environmental conditions. Agboola *et al.* (2021) had earlier reported that seed size often correlated with germination rate and seedling vigor in perennial crops. This implied that accessions with larger seeds could serve as superior planting stock.

Seasonal variation on pomological and seed traits of *C. pachycarpa* could have resulted from variations in temperature, rainfall, and soil fertility leading to differential leaf size, stem robustness, and fruit development. Studies have shown that members of Malvaceae exhibited considerable phenotypic plasticity, adapting its morphological traits to different environmental conditions (Johnny and Basse, 2020; Ogbu and Umeokechukwu, 2014; . In the present study, genotypic variance contributed immensely to trait expression and notable effects from environmental variation and year-to-year differences. Accession \times year interactions in fruit and seed traits indicated that certain

Table 1: *Cola parchycarpa* accessions and area of collection

S/N	Accession No	Town	LGA	State	Latitude	Longitude
1	NT	Ntiga	Isiala Ngwa north	Abia	5°24'11.0"N	7°25'11.5"E
2	OR	Orie Ugba	Umuahia North	Abia	5° 31' 33" N	7° 30' 10" E
3	ND	Ndoru	Ikwuano	Abia	5° 26' 13" N	7° 33' 56" E
4	OB	Obegu	Ugwunagbo	Abia	4° 59' 4.1" N	7° 19' 32.82" E
5	OH	Ohuhu	Umuahia North	Abia	5° 35' 59.99" N	7° 31' 59.99" E
6	UO	Umuosu	Isiala-Ngwa South	Abia	5° 23' 45" N	7° 28' 45" E
7	UB	Ubani	Umuahia North	Abia	5° 35' 57" N	7° 30' 6" E
8	UM	Umuikca	Isiala ngwa south	Abia	5°21'44.7"N	7°23'59.9"E
9	OL	Olokoro	Umuahia South	Abia	5° 28' 7.83"N	7° 29' 46.43"E
10	AM	Ahiazu mbaise	Ahiazu mbaise	Imo	5°32'49"N	7°16'13"E
11	OD	Obuda	Aba South	Abia	5° 5' 27" N	7° 20' 52" E
12	AE	Ahiaeke	Umuahia North	Abia	5° 30' 37" N	7° 31' 44" E
13	UH	Umuahia	Umuahia North	Abia	5° 31' 60" N	7° 28' 60" E

Table 2a: Fuit traits of 13 *Cola parchycarpa* accessions (2021)

Accession	2021							
	Fruit Weight (g)	Fruit Length (cm)	Fruit Circumference (cm)	Fruit Back Weight (g)	Number of Seed	Pulp Weight (g)	Pulp Length (cm)	Pulp Circumference (cm)
NT	162.40	12.91	14.20	33.73	4.30	23.57	2.94	6.29
OR	257.00	16.61	16.00	55.33	4.10	32.44	5.15	10.12
ND	226.90	19.01	14.95	37.35	4.90	22.01	3.80	12.41
OB	174.30	12.84	13.44	32.56	4.50	20.44	4.18	11.44
OH	132.70	11.81	13.56	30.22	3.50	17.84	15.25	4.23
UO	167.00	13.26	12.75	32.78	4.40	18.99	3.10	9.20
UB	145.40	13.65	13.26	32.30	4.60	19.02	15.23	3.22
UM	131.00	13.22	12.81	26.64	3.20	19.56	18.02	4.58
OL	130.40	12.38	12.87	22.07	3.90	30.93	6.17	13.20
AM	132.50	14.99	12.22	28.60	3.30	30.51	5.67	16.47
OD	192.00	14.06	14.19	35.81	4.60	23.96	17.95	3.41
AE	186.30	16.40	14.68	37.16	4.30	18.65	4.51	13.47
UH	185.00	12.61	12.91	36.52	4.30	24.83	2.93	9.71
MEAN	170.99	14.13	13.68	33.93	4.15	23.29	8.07	9.06
LSD ACCESSION	46.80***	1.96***	ns	9.91***	ns	Ns	1.91***	2.23***
LSD YEAR	18.36***	0.77***	2.63***	3.89***	ns	2.30***	0.75***	0.87***
LSD ACCESSION & YEAR	66.19***	2.76***	ns	14.01***	ns	8.49***	2.70***	3.15***

Table 2b: Fruit traits of 13 *Cola parchycarpa* accessions (2022)

Accession	2022							
	Fruit Weight (g)	Fruit Length (cm)	Fruit Circumference (cm)	Fruit Back Weight (g)	Number of Seed	Pulp Weight (g)	Pulp Length (cm)	Pulp Circumference (cm)
NT	212.70	20.21	16.20	54.70	3.60	30.60	4.99	13.99
OR	214.50	19.02	16.52	66.90	3.60	26.32	4.68	13.09
ND	235.40	19.25	17.25	68.70	3.90	28.12	4.66	14.51
OB	243.40	20.38	16.43	68.80	3.50	27.01	4.90	14.56
OH	231.00	18.96	34.20	57.30	3.70	31.65	4.65	20.14
UO	157.70	18.14	15.08	43.30	3.80	20.30	4.45	11.18
UB	257.60	22.50	17.35	64.10	4.10	33.04	16.15	14.97
UM	257.20	21.14	17.26	68.40	3.70	32.90	4.75	14.59
OL	249.80	17.34	19.67	68.20	21.47	12.48	3.96	10.61
AM	200.10	18.10	16.22	65.80	4.10	22.12	4.25	12.45
OD	257.80	19.61	17.82	73.90	4.00	28.03	4.70	13.45
AE	209.30	17.45	16.97	63.40	3.20	29.25	5.22	12.96
UH	318.30	19.50	19.61	89.10	4.10	32.58	4.69	14.53
MEAN	234.22	19.35	18.51	65.58	5.14	27.26	5.54	13.87
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Table 3: Seed Traits of 13 *Cola parchycarpa* accessions (2021 and 2022)

Accession	2021			2022		
	Seed weight (g)	Seed length (cm)	seed circumference (cm)	Seed weight (g)	Seed length (cm)	seed circumference (cm)
NT	23.79	5.35	8.50	15.57	5.15	9.10
OR	21.65	4.46	8.62	13.22	4.98	8.67
ND	18.65	5.42	9.00	13.29	6.03	8.72
OB	14.68	4.70	8.33	10.76	3.94	6.92
OH	11.37	5.77	9.62	15.24	4.75	8.85
UO	15.62	4.49	8.17	10.67	4.61	7.45
UB	8.86	5.34	7.91	16.04	5.42	8.89
UM	10.31	5.58	10.78	16.18	5.62	9.79
OL	10.61	4.27	8.07	15.96	5.51	9.64
AM	16.50	11.72	11.64	11.72	4.54	8.22
OD	11.84	5.18	13.76	14.82	5.69	8.68
AE	17.25	5.22	8.30	13.67	4.98	8.89
UH	4.52	8.13	15.52	16.27	6.43	9.42
MEAN	14.28	5.82	9.86	14.11	5.20	8.71
LSD ACCESSION	3.00***	0.98***	2.08***			
LSD YEAR	Ns	ns	0.82**			
LSD ACCESSION & YEAR	4.25***	1.38***	2.08**			

Note: cm = centimetre, ns = not significant, * =significant at 5%, ** = significant at 1% and *** = significant at 0.01%, Gm = grand mean.

Table 4: Genetic component parameters for fruit and Seed traits of 13 accessions of *Cola pachycarpa*.

Attributes	Grand Mean (X)	VP	VG	Ve	h ² B (%)	PCV	GCV	PCV-GCV	ECV
Fruit Weight	202.60	4834.000	2953.667	1880.333	61.10192	34.317	26.8251	7.492264	21.403
Fruit Length	16.76	8.920	5.640	3.280	63.2287	17.820	14.16986	3.65017	10.806
Pulp Length	6.75	67.423	64.287	3.137	95.3478	121.647	118.7837	2.863327	26.238
Pulp Circumference	11.24	27.063	22.807	4.257	84.27146	46.283	42.48783	3.795467	18.356
Seed weight (g)	14.17	38.907	31.173	7.733	80.12337	44.019	39.40232	4.616884	19.625
Seed length (cm)	5.49	6.747	5.927	0.820	87.84585	47.303	44.33572	2.967766	16.491
seed circumference (cm)	9.29	12.497	8.793	3.703	70.36543	38.052	31.91987	6.132475	20.715

Note: VP = Phenotypic variance, VG = genotypic variance, Ve = environmental variance, h²B (%) = heritability in a broad sense, PCV = Correlation of phenotypic variance, GCV = Correlation of genotypic variance, ECV = Environmental correlation of variance, mg = milligrams, g = grams, W = Week

genotypes may perform differently under varying environmental conditions, which has important implications for the stability and adaptability of selected lines (Abua *et al.*, 2020). This interaction suggests that breeding programs must account for environmental variability to ensure stability and adaptability of selected genotypes (Edugbo *et al.*, 2015). The consistently higher phenotypic coefficient of variation (PCV) compared to genotypic coefficient of variation (GCV) also implied that some level of environmental influence, particularly for traits like seed circumference and fruit length. Despite this, the narrow PCV-GCV gap for most traits points to the predominance of genetic factors, confirming that selection based on phenotypic performance remains a reliable strategy in *C. pachycarpa* (Nwofia and Ojmelukwe, 2012). The disparity in errors was minuscule compared to the hereditary disparities for the remarkable traits. The phenotypic disparity surpassed the corresponding genotypic disparities, signalling that most of the characteristics are governed by hereditary traits. The phenotypic coefficient of variation (PCV) overshadowed the genotypic coefficient of variation (GCV) for all the traits, suggesting that there was some level of interaction with the environment among these traits. High levels of PCV and GCV were noted when examining the fruit, seed and pulp characteristics. However, it is quite interesting to observe that the heritability in the broad sense was found to be relatively moderate for these particular attributes.

Conclusion

This study has demonstrated that *C. pachycarpa* exhibited phenotypic diversity in fruit and seed traits across accessions collected from southeastern Nigeria. The observed variation in fruit weight, length, pulp content, seed size, and other pomological attributes offered valuable opportunities for selecting genotypes with superior agronomic and consumer-preferred characteristics. The high heritability values for several traits, particularly pulp and seed dimensions, indicated that these characters are largely under genetic control and

can be effectively targeted in early-generation selection. The moderate heritability of traits like fruit weight and length further suggested that both genetic and environmental factors influenced their expression, highlighting the need for multi-location testing to identify stable performers. Accessions such as OR, UB, and UH demonstrated superior performance across multiple traits and are recommended for further breeding, domestication, and conservation efforts. These findings had provided a scientific foundation for initiating structured crop improvement programs in *C. pachycarpa*, focusing on fruit quality, propagation efficiency, and genetic resource sustainability. Future work should integrate molecular characterization, explore genotype-environment interactions in greater detail, and assess the nutritional and phytochemical profiles of elite genotypes to support broader utilization and commercialization of this underexploited indigenous fruit species.

References

- Abua, M. N., Iwo, G. A., Ittah, M. A., Obok, E. E. and Edugbo, R. E. (2020). GGE biplot analysis of multi-location yield trial of ginger (*Zingiber Officinale* Rosc.) genotypes in South-Eastern, Nigeria. *Asian Journal of Agriculture and Rural Development*, 10(1), 485-503.
- Agboola, D. A., Akinlosotu, T. A. and Agboola, A. A. (2021). Seed germination and early seedling growth responses of Monkey kola (*Cola spp.*) under different conditions. *African Journal of Agricultural Research*, 16(2): 197–204.
- Akinmoladun, F. O., Akinrinlola, B. L. and Olaleye, T. M. (2019). Phytochemical and antioxidant properties of Monkey kola (*Cola pachycarpa*) fruits. *African Journal of Food Science*, 13(2):25–32.
- Allard, R. W. (1991). *Principles of Plant Breeding* (2nd ed.). John Wiley & Sons.
- Burton, G. W. (1952). Quantitative inheritance in grasses. *Proceedings of the 6th International Grassland Congress*, 1: 227–283.
- Edugbo, R. E., Nwofia, G. E., & Fayeun, L. S. (2015). An assessment of soybean (*Glycine max* L. Merrill) yield in different environments using AMMI and GGE biplot models in humid

rainforest fringes of Nigeria. *Agricultura Tropica et Subtropica*, 48(3), 82-90.

FAO. (2010). The second report on the state of the world's plant genetic resources for food and agriculture. Food and Agriculture Organization of the United Nations.

Johnny, I. I. and Bassey, M. E. (2020). Pharmacognostic and taxonomic studies of *Cola pachycarpa* K. Schum (Malvaceae). *Asian Plant Research Journal*, 6(3), 33-45

Johnson, H. W., Robinson, H. F. and Comstock, R. E. (1955). Estimates of genetic and environmental variability in soybeans. *Agronomy Journal*, 47(7): 314–318.

Kumar, J., Krishna, G. S., & Sharma, D. (1985). Genetic variability and heritability in groundnut (*Arachis hypogaea* L.). *Indian Journal of Agricultural Sciences*, 55(8), 560–562.

Keay, R. W. J. (1989). *Trees of Nigeria: A revised version of Nigerian trees* (Vol. 1). Clarendon Press.

Nwofia, G. E. and Ojimekwe, P (2012). Variability in proximate, mineral and vitamin contents of *Carica papaya* (L.) leaves, fruit pulp and seeds. *International Journal of Medicinal and Aromatic Plants*, 2(1): 90-96

Ogbu, J. U. and Umeokechukwu, E. A. (2014). Comparative study of pomological traits in Monkey kola (*Cola pachycarpa*, *C. lepidota*, and *C. lateritia*). *Journal of Agricultural and Biological Science*, 9(6): 243–247

Prasad, B., Kumar, D., Jaiswal, H. K., & Prakash, V. (2010). Genetic variability, heritability, and genetic advance in rice (*Oryza sativa* L.). *Research Journal of Agricultural Sciences*, 1(4), 276–278

Wricke, G., & Weber, W. E. (1986). Quantitative genetics and selection in plant breeding. Walter de Gruyter.