Original Research Article

Morphological diversity of 23 kola (*Cola nitida*) genotypes from Côte d'Ivoire and Nigeria

Abstract

Twenty-three kola clones from Côte d'Ivoire and Nigeria were assessed for their morphological characters. The objective of this study was to identify potentially promising genotypes for the improvement of kola productivity. The analyses showed that these two populations had contrasted morphological characters, with the exception of nut length. The Côte d'Ivoire genotypes produced large follicles with more nuts (7.21). Those from Nigeria have large leaves, a thick cortex and large but few nuts (5.08). A high correlation was noted among the foliar characters, as well as among the fruiting characters (nuts and follicles). These results provide opportunities for hybridization among these genotypes, both for plant breeding and for QTLs research for certain characters (nut and follicle size, cortex thickness and leaves dimensions).

Keys words: *Cola nitida*, Côte d'Ivoire, genotypes, morphological characters, Nigeria

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Comment [RN2]: The keyword "country" is too general and more commonly found in social science publications. It would be better to choose keywords that are more related to your research, especially focusing on unique aspects, such as the leaves or the nuts.

Alternatively, you could include an introduction lines, considering that the genotype you are using comes from abroad.

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1 Introduction

Kola, *Cola nitida* (Malvaceae), is a tree native to West Africa [1]. It is a diploecious plant (2n = 40) that can reach 25 m in adulthood [2]. The kola thrives in the humid tropical forest zones of Africa, where rainfall reaches 1,700 mm/year and temperatures range from 23°C to 28°C.

Kola is cultivated for its nuts, which are used in several sectors: in agri-food for the manufacture of energy drinks and wines [3,4], socially for ceremonies such as weddings, baptisms and funerals [5–7], and in the medical field for the manufacture of medicines and the treatment of several diseases [8,9]. Moreover, colaculture contributes significantly to the economic development of producing countries, and to household livelihoods [10–13].

In Côte d'Ivoire, kola is grown by many growers as a pure crop. In addition to these plantations, part of the production comes from spontaneous trees scattered in cocoa or coffee plots [14,15].

Côte d'Ivoire is the world's leading producer and exporter of kola nuts [16]. However, Ivorian colaculture faces major difficulties: aging orchards [14], lack of mastery of technical itineraries [17] and insufficient quality plant material. To guarantee its productivity, Côte d'Ivoire has set up collections of established trees collected in Côte d'Ivoire and Nigeria [18,19].

Analysis of molecular diversity of these genotypes revealed differentiation among the two origins [19]. Thus, morphological characterization of these genotypes, which is the subject of this article, is a step towards setting up a kola breeding program. It enables us to assess the level of variability of morphological characters between genotypes, with a view to extracting those that present characters of interest for genetic improvement.

2 Material and methods

2.1 Plant material

Morphological characters were assessed in 23 genotypes (13 from Côte d'Ivoire and 10 from Nigeria). For each genotype of the two origins, 3 to 15 trees were considered (Table 1).

Table 1. Origins and numbers of trees used for morphological characters measurements

Genotypes	Origin	Trees numbers
CIV-305	Côte d'Ivoire	5
CIV-306	Côte d'Ivoire	5
CIV-311	Côte d'Ivoire	5
CIV-313	Côte d'Ivoire	5
CIV-314	Côte d'Ivoire	7
CIV-315	Côte d'Ivoire	15
CIV-316	Côte d'Ivoire	5
CIV-318	Côte d'Ivoire	5
CIV-321	Côte d'Ivoire	8
CIV-322	Côte d'Ivoire	5
CIV-323	Côte d'Ivoire	5
CIV-A2	Côte d'Ivoire	5
CIV-A3	Côte d'Ivoire	5
NIG-329	Côte d'Ivoire	5
NIG-330	Nigeria	3
NIG-331	Nigeria	3
NIG-341	Nigeria	5
NIG-342	Nigeria	4
NIG-352	Nigeria	3
NIG-356	Nigeria	7
NIG-364	Nigeria	3
NIG-366	Nigeria	3
NIG-379	Nigeria	3
Total		80

2.2 Methods

2.2.1 Character measurement

Morphological variability of the genotypes was studied using 15 characters inspired by the work of [20] and [21]. Leaves characters measured were: length (LOF), width (LAF), leaf area (SURF = LOF x LAF) and petiole length (LOP). These measurements were recorded on 10 leaves taken at random from each tree.

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Follicle characters measured were: length (LOFR), circumference (CIRC), mass (POFR), cortex thickness (ECOR) and number of nuts (NOGR). These measurements were collected on 20 follicles. Follicle length and cortex thickness were measured with a caliper. The circumference, reflecting the size of the follicles, was measured with a tape measure in its median part. Mass was determined on a precision balance shortly after collection.

Regarding nuts, the characters measured were: length (LOGR), width (LAGR), thickness (EPGR), mass (POGR), size (VOGR = LOGR x LAGR x EPGR) and total nut mass (POGR/FR). These measurements were obtained on 30 nuts per genotype. Dimensions

were measured with a caliper. For mass, the nuts were first stripped of their husks and weighed.

2.2.1 Statistical analysis

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Means and standard deviations were calculated for each genotype. The two populations were compared with Student's t-test at the 5% level for each character. Genotypes were then compared by analysis of variance to one classification criterion, using the GLM procedure in SAS 9.4 software, with the Newman-Keuls test at the 5% level as the comparison test. Finally, links among pairs of characters were determined using Pearson's correlation test on STATISTICA 7.1 (2005) software.

3 Results

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3.1 General characters of the two populations

Genotypes from Côte d'Ivoire were significantly different from those from Nigeria for all characters except nut length (t = 0.49; p = 0.62). In Côte d'Ivoire origin, follicles were larger (23.47 cm), with the highest mass (346.43 g), the highest number of nuts per follicle (7.21), the thinnest cortices (6.75 mm) and the shortest follicles (13.17 cm). In contrast, the Nigerian population produced smaller follicles (22.89 cm) weighing 302.45 g, with thicker cortex (11.57 mm) and longer follicles (17.78 cm). The number of nuts per follicle was lower (5.08) than the value obtained in genotype native from Côte d'Ivoire.

Regarding nuts, the genotype population originating in Nigeria produced the largest (37.26 cm^3) with the highest mass (24.86 g); while those originating in Côte d'Ivoire produced smaller nuts (25.77 cm^3) with a lower mass than the former (22.81 g). The total nut mass per follicle was greater in genotypes from Côte d'Ivoire (157.72 g) than in genotypes from Nigeria (120.86 g) (Table 2).

Table 2. Mean values of morphological characters of kola trees from Côte d'Ivoire and Nigeria

Characters	Côte d'Ivoire	Nigeria	Means	p
LoF	19.29 ± 3.76	20.36 ± 4.71	19.65 ± 4.13	0.003
LaF	6.29 ± 1.49	6.79 ± 2.31	6.46 ± 1.82	0.002
Surf	125.67 ± 82	147.99 ± 65	133.24 ± 65.85	< 0.001
LoP	4.4 ± 1.67	5.01 ± 2.58	4.61 ± 2.04	< 0.001
Circ	23.47 ± 2.52	22.89 ± 3.47	23.28 ± 2.89	0.019
PoFr	346.43 ± 124.08	302.45 ± 137.21	331.52 ± 130.24	< 0.001
LoFr	13.17 ± 2.13	17.78 ± 3.39	14.74 ± 3.41	< 0.001
Ecor	6.75 ± 1.85	11.57 ± 2.53	8.39 ± 3.11	< 0.001
NoGr	7.21 ± 2.61	5.08 ± 2.5	6.49 ± 2.76	< 0.001
LoGr	4.02 ± 0.49	4 ± 0.72	4.02 ± 0.58	0.62
LaGr	2.99 ± 0.46	3.14 ± 0.71	3.04 ± 0.56	0.002
EpGr	2.05 ± 0.57	2.69 ± 0.72	2.27 ± 0.69	< 0.001
VoGr	25.77 ± 11.39	37.26 ± 21.59	29.67 ± 16.52	< 0.001
PoGr	22.81 ± 9.09	24.86 ± 13.39	23.51 ± 10.78	0.028
PoGr/Fr	157.72 ± 79.92	120.86 ± 84.97	145.22 ± 83.44	< 0.001

LoF: leaf length, LaF: leaf width, Surf: leaf area, LoP: petiole length PoFr: average follicle mass, LoFr: follicle length, Circ: follicle circumference, Ecor: cortex thickness, NoGr: number of nuts/follicle, LoGr: nut length, LaGr: nut width, EpGr: nut thickness, VoGr: nut volume, PoGr: average nut mass; PoGr/Fr: total nut mass/follicle

3.2 Morphological characteristics of genotypes

3.2.1 Leaf characteristics

Analysis of variance revealed a significant difference among genotypes for leaf characters ($p < 0.001$). Genotypes NIG-331 and NIG-352 had the largest leaves and longest petioles. In contrast, leaves and petioles were less developed in genotypes CIV-313 and NIG-329. All other genotypes showed intermediate values for the same characters (Table 3).

Table 3. Mean leaf characteristics of 23 kola genotypes from Côte d'Ivoire and Nigeria

Genotypes	LOF (cm)	LAF (cm)	SURF (cm²)	LOP (cm)
CIV-305	20.98 ± 1.53 cde	8.16 ± 0.82 b	172.06 ± 27.33 cd	5.29 ± 1.35 cde
CIV-306	17.24 ± 2.89 gh	5.57 ± 1.13 f	98.92 ± 36.81 g	4.81 ± 1.39 def
CIV-311	18.23 ± 2.37 g	5.75 ± 0.97 ef	106.84 ± 31.69 g	4.15 ± 1.15 efgh
CIV-313	14.39 ± 1.36 i	4.31 ± 0.52 g	62.45 ± 12.28 h	2.37 ± 0.84 j
CIV-314	16.82 ± 2.25 gh	5.74 ± 1.24 ef	98.89 ± 34.38 g	3.99 ± 1.49 fghi
CIV-315	18.75 ± 1.61 fg	7.42 ± 0.92 bc	139.59 ± 23.35 ef	3.6 ± 0.84 fghi
CIV-316	17.39 ± 2.08 gh	6.03 ± 0.91 ef	106.49 ± 28.21 g	3.37 ± 1.02 ghij
CIV-318	22.03 ± 2.71 bcd	7.09 ± 1.11 cd	158.42 ± 41.25 de	5.76 ± 2.11 cd
CIV-321	17.93 ± 2.52 g	5.52 ± 0.95 f	100.46 ± 29.21 g	3.48 ± 0.85 ghij
CIV-322	22.46 ± 2.19 bc	7.77 ± 1.17 bc	175.91 ± 39.76 cd	5.97 ± 1.36 cd
CIV-323	19.15 ± 2.64 efg	5.3 ± 0.96 f	103.35 ± 31.07 g	3.61 ± 1.05 fghi
CIV-A2	18.69 ± 2.69 fg	5.45 ± 0.92 f	103.43 ± 30.32 g	4.42 ± 0.77 efg
CIV-A3	26.68 ± 2.44 a	7.75 ± 0.71 bc	206.94 ± 26.04 b	6.39 ± 1.26 c
NIG-329	15.62 ± 1.6 hi	3.54 ± 0.49 h	55.88 ± 13.12 h	2.81 ± 0.81 ij
NIG-330	20.9 ± 2.33 cde	6.68 ± 0.61 de	140.86 ± 27.94 ef	5.65 ± 1.47 cd
NIG-331	26.59 ± 4.41 a	10.34 ± 2.09 a	282.84 ± 105.43 a	8.77 ± 2.87 a
NIG-341	23.68 ± 3.33 b	7.94 ± 1.35 b	189.91 ± 52.19 bc	5.31 ± 1.67 cde
NIG-342	17.05 ± 3.39 gh	6.12 ± 1.09 ef	107.55 ± 39.4 g	3.88 ± 1.48 fghi
NIG-352	26.31 ± 3.53 a	9.92 ± 1.81 a	266.1 ± 81.99 a	7.64 ± 2.51 b
NIG-356	20.37 ± 1.98 def	5.84 ± 0.74 ef	120.06 ± 25.43 fg	5.93 ± 1.53 cd
NIG-364	18.16 ± 1.98 g	5.78 ± 0.87 ef	106.04 ± 25.09 g	2.83 ± 1.14 ij
NIG-366	17.48 ± 2.86 gh	5.94 ± 1.29 ef	105.83 ± 34.84 g	4.32 ± 1.51 efg
NIG-379	17.46 ± 2.56 gh	5.86 ± 1.28 ef	104.89 ± 37.32 g	2.92 ± 1.14 hij
Means	19.65 ± 4.13	6.46 ± 1.82	133.24 ± 65.85	4.61 ± 2.04
p	< 0.001	< 0.001	< 0.001	< 0.001

Means with the same letter in a column are statistically equal at the 5% level.
LoF: leaf length, LaF: leaf width, Surf: leaf surface, LoP: petiole length

3.2.2 Follicle characteristics

All genotypes showed significant differences in follicle characteristics ($p < 0.001$). The largest follicles with the highest masses were observed in four genotypes: CIV-323 (25.52 cm, 508.23 g), CIV-322 (26.68 cm, 501.74 g), NIG-341 (26.41 cm, 433.07 g), NIG-352 (26.5 cm, 412.42 g). In contrast, the smallest follicles with the lowest masses were observed in genotypes NIG-342 (19.5 cm, 184.61 g), NIG-366 (20.49 cm, 217.99 g) and NIG-379 (20.5 cm, 213.81 g).

Five genotypes (NIG-330, NIG-341, NIG-356, NIG-364 and NIG-379), all of Nigerian origin, presented the longest follicles (18.34 to 19.49 cm). The Nigerian genotype NIG-352 had the thickest cortex (14.9 mm), on average three times that of genotypes CIV-313 and CIV-323. The number of nuts in the follicles was highest in genotype CIV-316 (10.68). On the other hand, 3.4 to 4.05 nuts were counted in genotypes NIG-342, NIG-330 and NIG-379. All other genotypes showed intermediate values for the same characters (Table 4).

Table 4. Mean values for follicle characters in 23 kola genotypes from Côte d'Ivoire and Nigeria.

Genotypes	CIRC (cm)	POFR (cm)	LOFR (cm)	ECOR (cm)	NOGR
CIV-305	24.1 ± 1.24 bcd	363.56 ± 74.08 bc	13.21 ± 1.19 gh	7.41 ± 1.11 fgh	7.32 ± 1.57 cdefg
CIV-306	23.83 ± 1.89 bcde	328.72 ± 72.02 cd	12.23 ± 1.08 hi	5.17 ± 1.03 jk	6.28 ± 1.74 fgh
CIV-311	21.49 ± 2.92 fg	332.7 ± 49.27 cd	14.53 ± 0.81 fg	8.17 ± 0.79 f	8.08 ± 1.87 bcd
CIV-313	25.1 ± 2.63 abc	436.75 ± 134.87 b	14.31 ± 1.65 fg	4.56 ± 1.15 k	7.64 ± 2.44 bcdef
CIV-314	23.19 ± 1.66 cdef	364.71 ± 79.72 bc	16.1 ± 1.27 def	7.02 ± 1.54 fgh	5.48 ± 2.26 ghi
CIV-315	22.64 ± 1.99 def	289.65 ± 89.87 cde	12.36 ± 1.85 hi	7.06 ± 1.67 fgh	6.24 ± 2.04 fgh
CIV-316	21.86 ± 1.42 efg	300.7 ± 45.03 cde	12.95 ± 0.84 gh	9.32 ± 0.82 e	10.68 ± 2.18 a
CIV-318	21.52 ± 1.88 fg	225.4 ± 71.48 ef	11.67 ± 1.64 hi	6.72 ± 1.83 ghi	5.72 ± 2.62 ghi
CIV-321	22.56 ± 2.81 def	220.7 ± 61.09 ef	10.15 ± 1.17 j	5.78 ± 1.30 ij	4.93 ± 2.45 hij
CIV-322	26.68 ± 2.03 a	501.74 ± 139.87 a	14.74 ± 1.68 efg	8.1 ± 1.68 f	8.93 ± 2.09 b
CIV-323	25.52 ± 1.87 ab	508.23 ± 119.55 a	15.03 ± 1.65 ef	4.54 ± 0.71 k	8.93 ± 1.46 b
CIV-A2	22.66 ± 1.7 def	268.49 ± 72.97 de	10.92 ± 1.29 ij	6.26 ± 0.65 hi	5.6 ± 1.52 ghi
CIV-A3	24.03 ± 1.66 bcd	362.7 ± 74.5 bc	13.11 ± 1.04 gh	7.68 ± 1.09 fg	8.24 ± 2.01 bc
NIG-329	22.45 ± 1.92 def	299.91 ± 71.14 cde	15.92 ± 2.59 def	11.45 ± 1.76 cd	6.5 ± 2.21 defg
NIG-330	24.3 ± 3.48 bcd	323.1 ± 135.93 cd	19.49 ± 3.56 a	11.50 ± 2.42 cd	3.55 ± 1.85 j
NIG-331	22.62 ± 2.67 def	298.67 ± 133.39 cde	17.08 ± 3.39 cd	11.35 ± 1.182 d	4.75 ± 2.02 hij
NIG-341	26.41 ± 3.66 a	433.07 ± 150.42 b	18.54 ± 3.47 abc	10.75 ± 3.32 d	5.45 ± 2.35 ghi
NIG-342	19.5 ± 2.53 h	184.61 ± 98.87 f	16.37 ± 2.86 de	13 ± 1.78 b	3.4 ± 1.81 j
NIG-352	26.5 ± 3.05 a	412.42 ± 137.57 b	17.62 ± 3.05 bcd	14.9 ± 1.39 a	6.35 ± 1.87 efgh
NIG-356	23.46 ± 1.28 cdef	379.02 ± 85.51 bc	18.96 ± 1.96 ab	11.6 ± 1.53 cd	7.95 ± 1.95 bcde
NIG-364	22.66 ± 2.88 def	261.87 ± 111.02 def	18.52 ± 4.55 abc	10.95 ± 2.19 cd	7.3 ± 2.71 cd
NIG-366	20.49 ± 1.39 gh	217.99 ± 35.32 ef	17 ± 2.17 cd	8.05 ± 0.51 f	5.1 ± 1.65 hij
NIG-379	20.5 ± 2.92 gh	213.81 ± 119.01 ef	18.34 ± 4.26 abc	12.15 ± 2.28 bc	4.05 ± 2.39 ij
Means	23.27 ± 2.89	331.52 ± 130.24	14.74 ± 3.41	8.38 ± 3.11	6.48 ± 2.76
p	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Means with the same letter in a column are statistically equal at the 5% level.
Circ: follicle circumference, PoFr: mean follicle mass, LoFr: follicle length, Ecor: cortex thickness, NoGr: number of nuts per follicle

3.2.3 Nut characteristics

Analysis of variance revealed a significant difference among genotypes for nut characteristics ($p < 0.001$). Nut volume (size) ranged from 13.11 to 71.99 cm3. The largest nuts were produced by NIG-330, followed by NIG-341 (63.15 cm3). However, CIV-316 produced the smallest nuts, followed by CIV-A3, CIV-318, CIV-311, NIG-352 and CIV-A2.

The biggest nuts are heavier: NIG-330 (45.32 g) and NIG-341 (40.88 g). In contrast, the smallest nuts are light: genotypes CIV-316 (10.63 g) and NIG-352 (12.09 g). Total nut mass per follicle was highest in CIV-323 (308.99 g), CIV-313 (232.96 g), CIV-322 (232.15 g), NIG-356 (224.8 g) and NIG-341 (215.93 g). On the other hand, NIG-342 (65.67 g), NIG-379 (70.08 g) and NIG-366 (72.7 g) were the lowest (Table 5).

Table 5. Mean follicle characteristics of 23 kola genotypes from Côte d'Ivoire and Nigeria

Genotypes	LOGR (cm)	LAGR (cm)	EPGR (cm²)	VOGR (cm)	POGR	POGR/FR
CIV-305	3.77 ± 0.32 defg	2.91 ± 0.27 fghijk	2.14 ± 0.42 efg	23.87 ± 7.13 fgh	22.56 ± 6.08 efghi	154.58 ± 38.65 cd
CIV-306	4.34 ± 0.23 c	3.11 ± 0.37 defghi	2.38 ± 0.39 cdef	32.16 ± 6.61 def	26.58 ± 7.49 def	154.21 ± 31.36 cd
CIV-311	3.78 ± 0.22 defg	2.77 ± 0.27 hijkl	1.73 ± 0.31 hij	18.21 ± 4.51 hi	17.66 ± 3.66 hijk	139.1 ± 31.27 cde
CIV-313	4.63 ± 0.31 b	3.20 ± 0.42 defg	2.08 ± 0.5 fgh	30.98 ± 9.82 def	31.99 ± 10.55 cd	232.96 ± 83.88 b
CIV-314	4.03 ± 0.47 cd	2.89 ± 0.49 fghijkl	2.05 ± 0.47 fgh	25.01 ± 11.55 fgh	24.68 ± 6.84 efg	129.16 ± 52.47 cdef
CIV-315	4.27 ± 0.38 c	3.22 ± 0.38 defg	2.26 ± 0.32 def	31.37 ± 7.69 def	17.63 ± 5.73 hijk	109.37 ± 47.71 defg
CIV-316	3.53 ± 0.14 fg	2.65 ± 0.24 ijkl	1.41 ± 0.37 j	13.11 ± 2.95 i	10.63 ± 1.41 l	112.59 ± 23.18 defg
CIV-318	3.52 ± 0.4 fg	2.65 ± 0.37 ijkl	1.82 ± 0.49 ghi	17.68 ± 8.51 hi	18.77 ± 10.33 ghij	93.58 ± 45.22 efg
CIV-321	4.06 ± 0.38 cd	3.02 ± 0.65 efghji	2.69 ± 0.51 bc	32.97 ± 10.48 def	21.17 ± 7.86 fghi	88.4 ± 30.11 efg
CIV-322	4.03 ± 0.41 cd	3.16 ± 0.35 defgh	2.46 ± 0.57 cdef	31.62 ± 9.52 def	26.36 ± 7.69 def	232.15 ± 80 b
CIV-323	4.63 ± 0.59 b	3.59 ± 0.5 bc	2.52 ± 0.35 cde	42.09 ± 10.58 c	34.97 ± 7.77 c	308.99 ± 76.48 a
CIV-A2	3.92 ± 0.23 de	2.88 ± 0.3 ghijkl	1.7 ± 0.39 hij	19.17 ± 4.68 hi	22.74 ± 2.7 efghi	127.08 ± 37.44 cdef
CIV-A3	3.85 ± 0.36 def	2.83 ± 0.35 ghijkl	1.53 ± 0.36 ij	16.79 ± 5.43 hi	20.82 ± 3.29 fghi	168.09 ± 41.18 c
NIG-329	3.84 ± 0.21 def	2.79 ± 0.34 hijkl	2.38 ± 0.45 cdef	25.46 ± 5.79 fgh	17.52 ± 2.94 hijk	114.52 ± 42.24 def
NIG-330	4.98 ± 0.37 a	4.17 ± 0.31 a	3.47 ± 0.65 a	71.99 ± 15.73 a	45.32 ± 5.57 a	158.04 ± 77.25 cd
NIG-331	3.78 ± 0.75 defg	3.25 ± 0.57 def	2.75 ± 0.65 bc	36.53 ± 19.44 cde	23.55 ± 12.51 efgh	112.34 ± 68.24 defg
NIG-341	4.83 ± 0.42 ab	3.79 ± 0.51 b	3.42 ± 0.52 a	63.15 ± 15.37 b	40.88 ± 9.54 b	215.93 ± 91.64 b
NIG-342	3.64 ± 0.72 efg	2.83 ± 0.64 ghijkl	2.61 ± 0.53 bcd	28.88 ± 14.31 efg	19.65 ± 9.57 ghij	65.67 ± 40.2 g
NIG-352	3.43 ± 0.44 g	2.49 ± 0.41 l	2.04 ± 0.7 fgh	18.29 ± 8.57 hi	12.09 ± 5.04 kl	78.47 ± 46.34 fg
NIG-356	4.3 ± 0.69 c	3.32 ± 0.59 cde	2.66 ± 0.67 bcd	39.32 ± 16.85 cd	28.2 ± 10.28 de	224.8 ± 100.82 b
NIG-364	4.14 ± 0.44 cd	3.44 ± 0.5 cd	2.94 ± 0.66 b	42.81 ± 14.3 c	30.64 ± 9.47 cd	96.07 ± 51.56 efg
NIG-366	3.46 ± 0.47 g	2.56 ± 0.47 kl	2.23 ± 0.45 def	21.12 ± 9.84 ghi	13.95 ± 6.4 jkl	72.7 ± 43.47 g
NIG-379	3.6 ± 0.33 efg	2.76 ± 0.51 ijkl	2.47 ± 0.48 cdef	25.01 ± 8.95 fgh	16.81 ± 5.29 ijk	70.08 ± 54.51 g
Means	4.02 ± 0.58	3.04 ± 0.57	2.27 ± 0.69	29.66 ± 16.52	23.51 ± 10.78	145.22 ± 83.44
p	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Means with the same letter in a column are statistically equal at the 5% level.
LoGr: nut length, LaGr: nut width, EpGr: nut thickness, VoGr: nut volume index, PoGr: average nut mass; PoGr/Fr: total nut mass per follicle.

3.3 Correlations among characteristics

Several pairs of characters are well correlated ($r > 0.8$), as is the case with leaf characters ($0.85 < r < 0.97$. Nut mass and size were positively correlated ($r = 0.89$), as were follicle circumference and mass ($r = 0.89$). These correlations indicate that the largest nuts are the heaviest. Follicle size and mass evolve in the same direction ($r = 0.89$). Furthermore, follicle mass and total nut mass per follicle were positively correlated ($r = 0.86$).

Other pairs of characters were strongly correlated ($0.5 < r < 0.8$). Nut mass was positively correlated with circumference ($r = 0.52$) and follicle mass ($r = 0.54$). This shows that nut mass evolves in the same direction as follicle size and mass. The same applies to the number and total mass of nuts per follicle ($r = 0.56$), and the average and total mass of nuts per follicle ($r = 0.65$). On the other hand, the number of nuts per follicle and nut thickness are inversely proportional ($r = -0.56$): the more nuts there are in the follicle, the thinner the nuts.

Follicle circumference was positively related to total nut mass ($r = 0.7$). This suggests that larger follicles contain more nuts. Correlation among follicle length and thickness ($r = 0.73$), indicates that longer follicles have a thicker cortex. Leaf length was moderately correlated with follicle circumference ($r = 0.44$). However, correlations among follicle circumference and other leaf characteristics were not significant ($p > 0.05$) (Table 6).

Table 6. Matrix correlations among the 23 kola genotypes characters.

	LOF	LAF	SURF	LOP	CIRC	POFR	LOFR	ECOR	NOGR	LOGR	LAGR	EPGR	VOGR	POGR
LAF	0.88*** p < 0.001													
SURF	0.95*** p < 0.001	0.97*** p<0.001												
LOP	0.89*** p < 0.001	0.85*** p<0.001	0.9*** p<0.001											
CIRC	0.44* p = 0.03	0.32* p = 0.14	0.39* p = 0.06	0.35* p = 0.1										
POFR	0.29* p = 0.18	0.17 p = 0.44	0.23* p = 0.28	0.23* p = 0.29	0.89*** p<0.001									
LOFR	0.15 p = 0.48	0.15 p = 0.49	0.17 p = 0.44	0.17 p = 0.43	0.09 p = 0.66	0.13 p= 0.55								
ECOR	0.32* p = 0.13	0.36* p = 0.09	0.37* p = 0.07	0.32* p = 0.13	-0.11 p = 0.61	-0.19 p= 0.37	0.73** p<0.001							
NOGR	0.05 p = 0.82	-0.06 p = 0.77	-0.01 p = 0.93	0.001 p = 0.99	0.37* p = 0.08	0.6** p=0.002	-0.34* p = 0.11	-0.36* p=0.09						
LOGR	-0.09 p = 0.68	-0.2 p = 0.35	-0.17 p = 0.43	-0.13 p = 0.54	0.54* p = 0.01	0.5* p = 0.02	0.2 p = 0.36	-0.25* p= 0.23	-0.03 p=0.88					
LAGR	0.1 p = 0.64	0.01 p = 0.95	0.03 p = 0.89	0.04 p = 0.83	0.45* p = 0.03	0.37* p = 0.07	0.38* p = 0.07	-0.02 p=0.93	-0.18 p=0.4	0.91*** p<0.001				
EPGR	0.08 p = 0.71	0.08 p = 0.69	0.08 p = 0.71	0.07 p = 0.72	0.22* p = 0.31	0.06 p = 0.78	0.61** p=0.002	0.35 p = 0.1	-0.56** p=0.005	0.61** p=0.002	0.78** p<0.001			
VOGR	0.11 p = 0.61	0.05 p = 0.81	0.06 p = 0.78	0.07 p = 0.72	0.38* p = 0.07	0.25* p = 0.24	0.53** p = 0.01	0.17 p=0.43	-0.36* p = 0.08	0.84*** p<0.001	0.95*** p<0.001	0.91*** p<0.001		
POGR	0.07 p = 0.75	-0.07 p = 0.75	-0.03 p = 0.89	0.03 p = 0.87	0.52** p = 0.01	0.54** p = 0.03	0.35* p = 0.09	-0.12 p= 0.59	-0.18 p= 0.39	0.91*** p<0.001	0.93*** p<0.001	0.71** p<0.001	0.89*** p<0.001	
POGR /FR	0.08 p = 0.69	-0.11 p = 0.61	-0.04 p = 0.86	0.37* p = 0.86	0.7** p<0.001	0.86*** p<0.001	0.05 p = 0.82	-0.4* p=0.06	0.56** p=0.006	0.7** p<0.001	0.57** p=0.006	0.17 p = 0.44	0.4* p=0.06	0.65** p = 0.001

LoF: leaf length, LaF: leaf width, Surf: leaf area, LoP: petiole length, PoFr: mean follicle mass, LoFr: follicle length, Circ: follicle circumference, Ecor : cortex thickness, NoGr: number of nuts per follicle, PoGr: mean nut mass, LoGr: nut length, LaGr: nut width, EpGr: nut thickness, VoGr: nut volume; PoGr/Fr: total nut mass per follicle.

*** very strong correlations at 5% level;

** strong correlations at 5% level;

* average correlations at 5% level;

no * weak correlations at 5% level.

4 Discussion

The aim of this study was to analyze the morphological diversity of *C. nitida* genotypes in CNRA's collection. At the end of the analyses, a significant effect of genotype origin on the characters measured was noted. Only nut length showed no significant effect. The superiority of genotypes from Nigeria over those from Côte d'Ivoire was thus demonstrated for leaf size, nut size and mass, and cortex thickness. But for follicle size and mass, genotypes from Côte d'Ivoire showed the highest values.

Genotypes evaluated had contrasting morphological characteristics. Analyses revealed significant differences between them for these characters. The variations observed suggest that these characters could serve as a genotype distinguishing index [22].

In terms of cortex thickness, genotypes from Nigeria all have a thick cortex. In contrast, genotypes of Ivorian origin have thin cortexes. These variations could be due to the appearance of the cortex. Indeed, [14] indicates that most genotypes of Ivorian origin in the collection have a smooth cortex, as opposed to Nigerian genotypes. The blisters formed on the follicle cortex help to increase its thickness [23]. In fact, for this reason, genotypes with rough follicles have a thicker cortex.

Regarding production parameters, analyses revealed that the largest follicles contain large nuts with high mass. These results concur with those reported by [24]. In this respect, genotypes CIV-313, CIV-322, CIV-323, NIG-330 and NIG-341 could be genotypes of interest. On the same genotypes, [25] obtained different results when the trees were younger. In addition, as mean nut mass is highly heritable in kola [25], the above-mentioned genotypes could be included in a varietal creation and selection program.

Some characters are positively correlated; this suggests that when one character varies, the character correlated with it may vary in the same direction, as these correlations are not genetic correlations. This is the case, for example, between follicle mass and nut mass, and between nut size and nut mass. These results concur with those of [26] on cocoa. Indeed, this author revealed the existence of a strong positive correlation between the mass of the pods and that of the fresh beans, and organs analogous to the follicles and nuts of the kola. Furthermore, in *C. nitida*, correlations between nut mass and follicle mass have been demonstrated by [25]. Moreover, follicle mass and average nut mass are characters associated with selection for yield. So, to improve plot yield, it is possible to select directly for the “follicle mass” or “nut mass” character. What's more, the fresh nut production of a plot can be directly estimated from measurements of follicle mass, rather than that of all the nuts harvested.

A negative correlation was observed between thickness and the number of nuts per follicle. This highlights the existence of a trade-off between the two linked characters. Thus, a reduction in nut thickness would favor an increase in the quantity of nuts produced, through resource allocation.

4 Conclusion

This study described and assessed the morphological diversity of kola genotypes in the existing collection in Côte d'Ivoire. The 23 genotypes analyzed showed contrasting characteristics. Genotypes originating in Nigeria are characterized by a thick cortex, large nuts and leaves. In the Côte d'Ivoire genotype, however, the cortex is thinner, and the leaves and nuts smaller. Several pairs of characters were correlated. Large nuts had the highest masses. Similarly, the biggest follicles were the heaviest. In view of these results,

these genotypes could serve as broodstock for the creation of large-nut varieties by introgression of other characters such as cortex thickness and number of nuts per follicle.

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