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NOTES ON NEGLECTED AND UNDERUTILIZED CROPS

Morpho-agronomic variability of three kola trees accessions [*Cola nitida* (Vent.) Schott et Endl., *Cola acuminata* (P. Beauv.) Schott et Endl., and *Garcinia kola* Heckel] from Southern Benin

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Abstract *Cola nitida*, *Cola acuminata* and *Garcinia kola* are part of underutilized forest resources in Benin. The lack of information on these trees limits seriously the exploitation, regeneration and use of their genetic resources. This study aimed to evaluate the morphological diversity of these kola trees for a better management and rationale utilization of their genetic resources. For this purpose, 90 trees samples were characterized through 19 descriptors for *G. kola*, and 38 for both *C. nitida* and *C. acuminata*. An analysis of variance and a numerical classification followed by principal component analysis of quantitative data in addition to the descriptive analysis of the qualitative data were used to describe the inter and intra-specific diversity in these kola trees. The study revealed strong correlations (positive and negative) between the different variables. The morphometric data analysis revealed significant differences among trees of different kola species with the most discriminative traits related to the plant size and fruit parameters such as fruit length, fruit thickness and fruit weight. *G. kola* was the tallest species displaying the largest fruit thickness while *C. acuminata* and *C. nitida* had comparably the longest and most weighted fruits. Important intraspecific variability was also detected within kola species with *C. acuminata* showing the lowest diversity. Cluster analyses conducted separately on species data revealed clear phenotypic organization among the analyzed trees with seven clusters identified in *C. nitida*, five in *G. kola* and four in *C. acuminata*. This study provided useful information on the genetic variability of three

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kola species and is a preliminary base that could be used in a breeding program.

Keywords Benin · Characterization · *Cola nitida* · *Cola acuminata* · Diversity · Fruit tree · *Garcinia kola* · Kola tree · Morphotype

Introduction

There is a great diversity of plants in Sub-Saharan Africa that are used for food and other purposes (Burkill et al. 1985; Almekinders and de Boef 2000). These plants are genetic resources that play a fundamental role in the satisfaction of many basic needs of local communities. Among these include *Cola nitida* (Vent.) Schott et Endl. and *Cola acuminata* (P. Beauv.) Schott et Endl. of the Sterculiaceae family yet incorporated in Malvaceae in the broad sense (Akoègninou et al. 2006). There is also *Garcinia kola* Heckel of the Clusiaceae family (Akoègninou et al. 2006). These species are important wild fruit trees in tropical Africa. The genus *Cola* has nearly 140 species (Adenuga et al. 2012) of African origin, among which 50 species have been described in West Africa (Adebola 2003). In Benin, seven species are encountered among which *C. nitida* and *C. acuminata* are marketed (Akoègninou et al. 2006). They are distributed along the west coast of Africa, from Sierra Leone to the Benin Republic (Opeke 2005). Besides, *G. kola*, commonly called false kola, is also a West-African tropical tree that grows from Nigeria to Sierra Leone (Mukhatr and Shuaibu 1999). Today, the majority of these species is threatened of disappearance due to the unsustainable exploitation that accompanies the growth of human population (Gebauer et al. 2002) and lack of attention from the governments and scientists. Little is known on the domestication of these useful plants in West Africa and the management of wild resources of kola nuts in particular. In Benin, very few studies have been conducted on the kola species and there is no reference on their genetic variability.

The domestication of indigenous fruit and nut plants for the diversification of subsistence agriculture can play a big role in the achievement of the Millennium Development Goal, providing weapons to combat poverty and hunger and mitigate environmental degradation in developing countries (Leakey et al. 2007). The studies on the biological variability of indigenous fruit tree species, their propagation using cheap and simple methods appropriate for rural development projects, and their suitability for domestication have been progressively expanded in West Africa over the last decades (Leakey et al. 2000). In addition, the plant genetic resources emphasizes the need for studies concerning genetic characterization, evaluation and development of core collection, as these studies are important in the effective classification of the collections and allow the users to access their information needs (FAO 1996).

Morphological parameters have been widely used in the evaluation of various crops (Kaemer et al. 1995). Exploitation of such traits increases our knowledge on the genetic variability available and strongly facilitates the breeding for wider geographical adaptability, with respect to biotic and abiotic stresses (Onomo et al. 2006a). In addition, genetic diversity needs to be described and measured if it is to be effectively incorporated into breeding strategies and management of plant genetic resources (Onomo et al. 2006a). This study therefore aimed to investigate inter- and intra-specific variability in Beninese kola trees (*C. nitida*, *C. acuminata* and *Garcinia kola*) based on morphological traits for better management and utilization in plant improvement.

Materials and methods

Study area

The study was conducted in 23 villages localized in the administrative departments of Ouémé and Plateau in southern of Benin (Fig. 1). The study area belongs to the Guinean zone between 6°25′–7°30′N and 2°33′–2°58′E where the rainfall is bimodal (April to June and September to November) with a mean annual rainfall of 1200 mm. The mean temperature varies between 25 and 29 °C and the relative humidity between 69 and 97 %. The vegetation in the study area has been strongly affected by various agricultural activities and now forms a mosaic of cultivated land and small relict forest patches (Assogbadjo et al. 2005). The department of Ouémé is characterized by reddish ferruginous, clay-sandy, alluvial and co-alluvial soils with

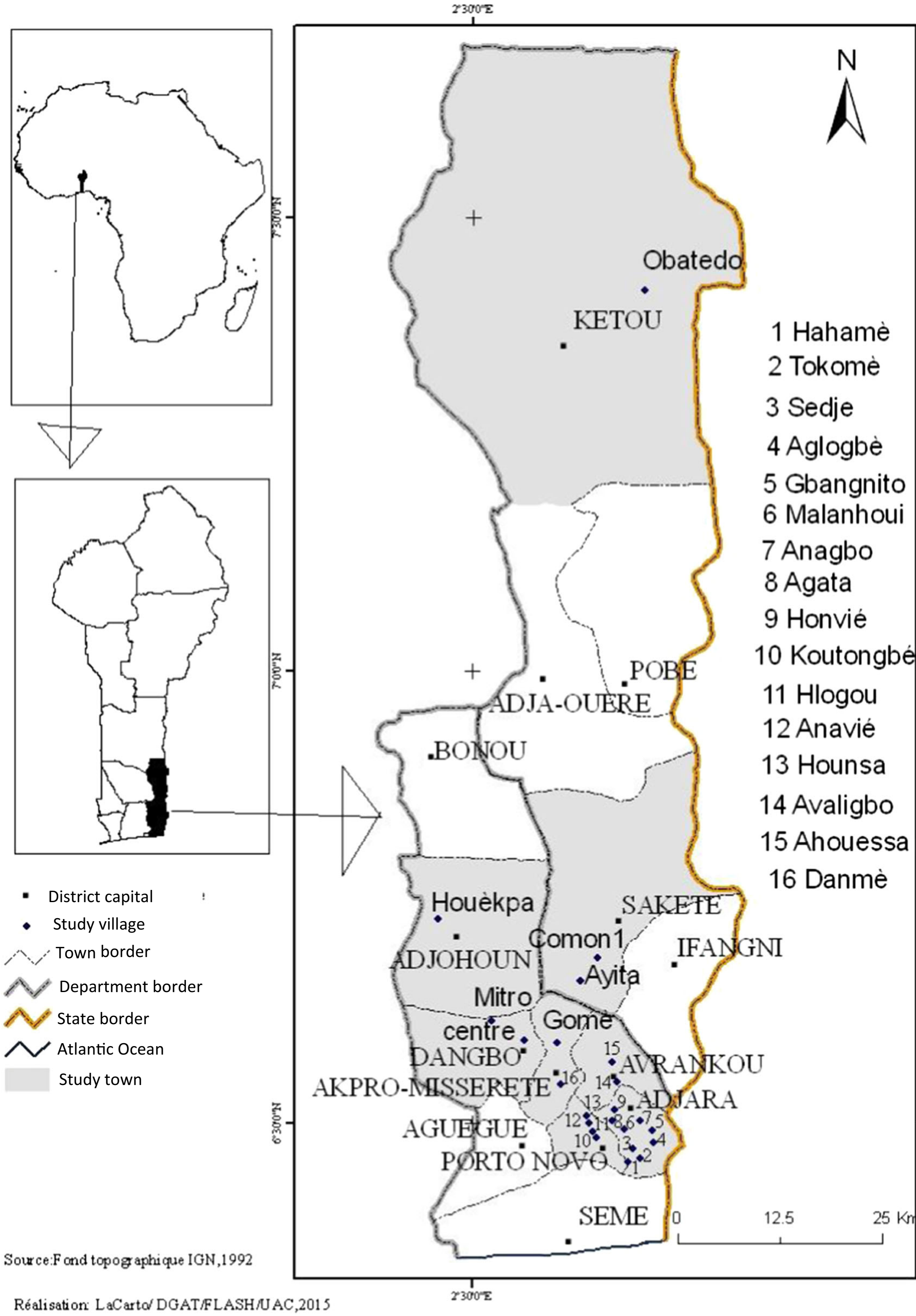

Fig. 1 Geographical localization of selected villages for kola trees sampling

essentially human-influenced vegetation consisting of grassy and shrubby savanna with dominance of *Daniellia oliveri*, grassland, raffia marshy formations, some relic forests, and some mangroves. The department of Plateau is characterized by tropical ferruginous, clay and deep soils. The climate is of Sudano-Guinean type. It also contains some forest relics (INSAE 2004).

Method of trees sampling

The work was carried out on non-homogeneous populations in flowering or/and fruit production. Trees were sampled within some age groups according to the procedure proposed by Diarrassouba et al. (2007). All these trees were marked and referenced with GPS (Global Positioning System) and a distance of 10 m × 10 m was maintained between trees of the same area. In total, 90 samples distributed as follows: 43 (*Garcinia kola*), 35 (*C. nitida*) and 12 (*C. acuminata*) were selected for our study.

Methods for data collection

The data were collected per period (flowering and fruiting times) between March 2014 and February 2015 based on some descriptors. For *G. kola*, data collection was done using the Recommendation established by Bioversity International (IPGRI 2004). In total, 19 quantitative traits were measured on each tree of this species (Table 1). For *C. nitida* and *C. acuminata*, the descriptors used were those established by Bioversity International (IPGRI 1995) on avocado (*Persea* spp.) and used by Adebola and Morakinyo (2006) because there are no descriptors for *Cola* and most of the avocado descriptors were found equally applicable to *Cola* (Adebola and Morakinyo 2006). Additional descriptors relating to the inflorescence and considered as informative were also used. A total of 26 quantitative traits and 11 qualitative traits were measured on each tree of the two species (Table 2). The quantitative and qualitative parameters measured were mainly related to vegetation (dendrometric measures), fruits, nuts, leaves and inflorescence (only for *C. nitida* and *C. acuminata*).

Quantitative data collection

Collection of dendrometric characteristics

The diameter of the tree (DBH) was determined by measuring the circumference (C) at 1.30 m above the

Table 1 List of measured descriptors in *Garcinia kola*

Type	Traits	Measured characters	Acronyms
Quantitative	Vegetative	Tree diameter (m)	DBH
		Collar diameter (m)	Dc
		Crown height (m)	Hhp
		Crown diameter (m)	Dhp
		First ramification height (m)	Hpr
		Tree total height (m)	H
	Fruit	Fruit length (mm)	Lfr
		Fruit thickness (mm)	Efr
		Fruit weight (g)	Pfr
		Husk weight (g)	Ppe
	Nut	Number of nuts per fruit	Ngr
		Number of damaged nuts	Ngrg
		Nut wet weight (g)	Pgr
		Nut length (mm)	Lgr
		Nut thickness (mm)	lgr
	Leaf	Leaf blade length (cm)	Llim
		Leaf blade width (cm)	llim
		Petiole length (cm)	Lp
		Petiole diameter (mm)	Dp

Table 2 List of measured descriptors in *C. nitida* and *C. acuminata*

Type	Traits	Measured characters	Acronyms
Quantitative	Vegetative	Tree diameter (m)	DBH
		Collar diameter (m)	Dc
		Crown height (m)	Hhp
		Crown diameter (m)	Dhp
		First ramification height (m)	Hpr
		Tree total height (m)	H
	Fruit	Fruit length (mm)	Lfr
		Fruit thickness (mm)	Efr
		Fruit weight (g)	Pfr
		Husk weight (g)	Ppe
	Nut	Number of nuts per pod	Ngr
		Nut wet weight (g)	Pgr
		Nut length (mm)	Lgr
		Nut thickness (mm)	lgr
		Cotyledon number	Nt
	Leaf	Leaf blade length (cm)	Llim
		Leaf blade width (cm)	llim
		Petiole length (cm)	Lp
		Number of primary leaf veins	Nnp
		Number of secondary leaf veins	Nns
	Flower	Number of male flowers per inflorescence	Nfm
		Number of hermaphrodite flower per inflorescence	Nfh
		Number of mixed inflorescence	NiM
		Length of male flower (cm)	Lfm
		Length of hermaphrodite flower (cm)	Lfh
		Number of stigmatic lobes	Nls
Qualitative	Vegetative	Tree crown shape	FrmArb
		Distribution of the branches	Dstr Br
		Axil angle of branch	Ang Br
	Fruit	Fruit color	Clr fr
		Pod texture	Tex fr
	Nut	Nut color	Clr gr
	Leaves	Axil angle of leaf petiole	Ang pe
		Leaf shape	Frm flle
		Leaf apex shape	Frma
		Leaf base shape	Frmb
		Leaf margin	Brd flle

ground using a tape meter and calculated by the formula:

$$\mathrm{DBH} = \frac{C}{\pi}. \quad (1)$$

To determine the DBH for the trees with more than one stems before 1.30 m above the ground, the formula proposed by Saïdou et al. (2012) was used:

$$\mathrm{DBH} = \sqrt{\mathrm{d1}^2 + \mathrm{d2}^2 + \cdots + \mathrm{dn}^2} \quad (2)$$

with $d1$, $d2$ and dn diameters of each stem.

To measure the total height of the tree, two sightings were made at a distance (L) of 15 m between the operators and the tree using a Suunto clinometer Finland. The first sighting (V1) was made at the foot of the tree and the second one (V2) at the top of the tree.

The total height (H) is determined using Rondeux (1999) formula:

$$H = \frac{(V2 - V1) \times L}{100} \quad (3)$$

The average crown diameter (Dhp) was determined from the following formula:

$$Dhp = \sqrt{\frac{D1^2 + D2^2}{2}} \quad (4)$$

with $D1$ the crown north–south diameter and $D2$ east–west diameter measured using a decameter.

In the case of several diameters of the crown measured, the average diameter was estimated by calculating the quadratic mean of individual diameters measured.

Measurement of parameters related to fruit and nut

For data collection, five fruits per tree were considered. The length, the thickness of the fruits as well as the width of the nuts were taken using slide foot (Fig. 2a, b). Fruit weight was recorded using a spring balance of maximum range of 350 g (Fig. 2c).

Measurement of parameters related to the inflorescence and leaves

All the parameters related to the inflorescence were measured on five inflorescences with five flowers per inflorescence and twenty-five flowers per tree. All leaf characters were taken on the fifth leaf of a flowering branch to ensure uniform treatment and all measurements were mean values of at least ten leaves per tree.

Qualitative data collection

These data were obtained on the one hand to subjectively interpretations by visual observation and touch (Fig. 2d–f); on the other hand by comparison with the descriptors established by Bioversity International (IPGRI 1995) on Avocado (*Persea* spp.).

Statistical analysis

The one way variance analysis (ANOVA) using the General Lineal Model (GLM) procedure was performed on the recorded quantitative data. Besides, a numerical classification of trees was made using SAS software package version 9.2 following the procedure described in Sossa et al. (2014). Trees cluster obtained were put into relation to the different variables using a Principal Component Analysis (PCA) according to Uguru et al. (2011) with the Minitab 14 software. Qualitative data were submitted to descriptive statistics with SPSS (Statistical Package for the Social Sciences) version 16.0.

Results

Taxonomy and botanical description

Cola nitida (Vent.) Schott et Endl., Meletem. Bot. 33 (1932); FWTA 1: 329; Purseglove 19682: 566; FT 470.

Syn.: *Sterculia nitida* Vent., Jardin Malm. vol. 2, sub t. 91, in adnot. 1804; *Cola vera* K. Schum. in Notizbl. Bot. Gart. vol. 3, 15. 1900.

Short description (Fig. 3a; see also van Eijnatten 1973; Purseglove 1978; Akoègninou et al. 2006).

Erect tree up to 25 m high (Fig. 3a), the tree diameter can reach 50 cm, and the bark is gray with longitudinal cracks. The leaves are broadly oblong (15–25 cm long and 6–10 cm wide) to elliptical, occasionally elliptical-oblanceolate with short acumen, petiole swollen at the base. The inflorescences are small bunches composed either of only male flowers, or of male and hermaphrodite flowers. The number of hermaphrodite flowers is positively correlated with performance. The main flowering period lasts 3 months. Between pollination and fruit maturity it takes 120–135 days. The fruits are composed of 2–6 woody follicles grouped in a star around the peduncle. Each follicle presents a dorsal crest and a ventral furrow, are 8–12 cm long and 4–8 cm wide. The fruits can contain 4–8 nuts arranged in two rows. White, dew or red in a fresh state, they have two cotyledons and weight between 6 and 25 g.

Cola acuminata (P. Beauv.) Schott et Endl., Meletem. Bot. 83 (1932); FWTA l: 329; Purseglove 19682: 565; FT 469; Pauwels 1993: 209.

Syn.: *Sterculia acuminata* (P. Beauv.), FI. Oware 1: 41, 24. (1805); C. *pseudo-acuminata* Engl., Pflanzenw. Afr. 3, 2: 465 (1921); *Cola macrocarpa* (G. Don) Schott et Endl., Meletem., 33. 1832; *Cola supfiana* Busse in Tropenpfl. Beiheft vol. 7, 222. 1906.

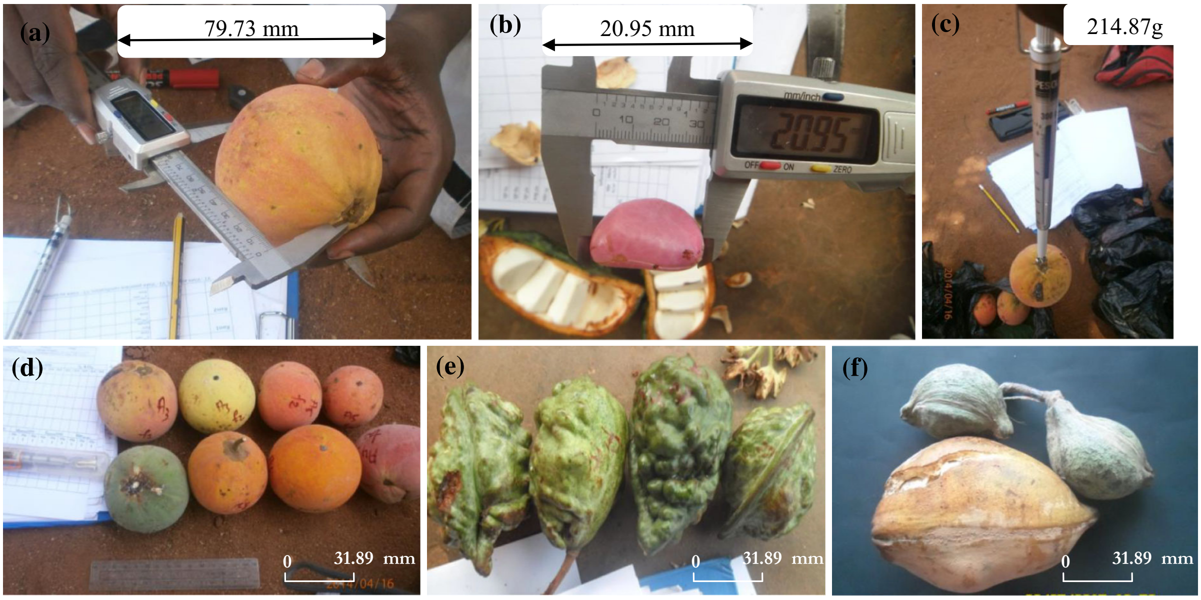

Fig. 2 Measure of fruit length (**a**), nut length (**b**), fruit weight (**c**) and some qualitative parameters: aspect, color, texture and shape of *Garcina kola* (**d**), *Cola nitida* (**e**) and *Cola acuminata* (**f**) (Photo D. Dah-Nouvlessounon 16.04.2014)

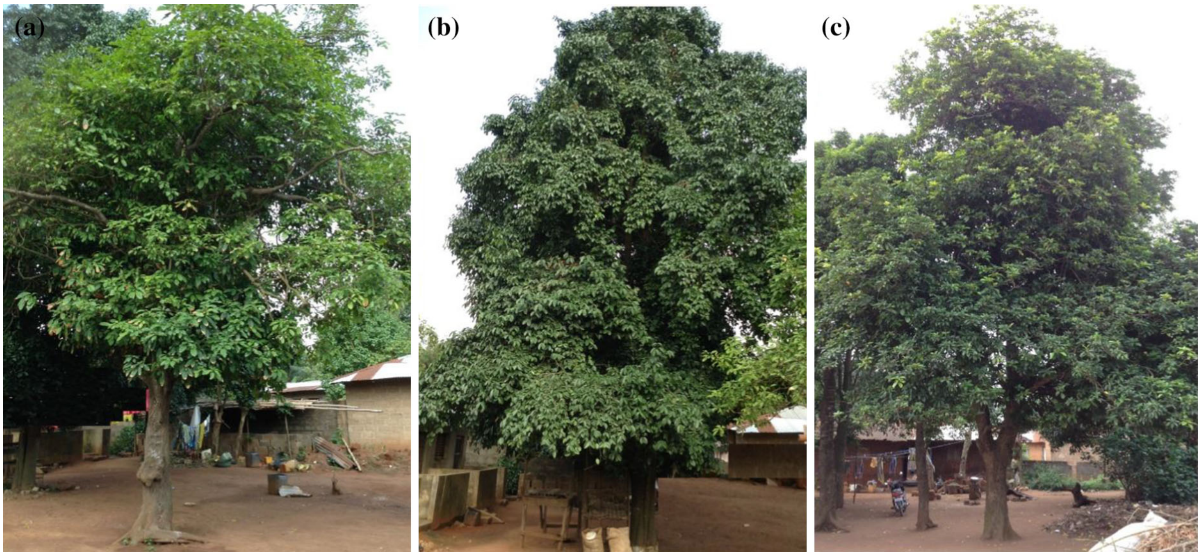

Fig. 3 Morphology of three trees in home gardens in southern Benin, **a** *Cola nitida*, **b** *Garcinia kola*, **c** *C. acuminata* (Photos: D. Dah-Nouvlessounon 28.04.15)

Short description (Fig. 3c, see also van Eijnatten 1969; Brummitt and Powell 1992; Akoègninou et al. 2006).

This is a tree whose circular section stem may reach 20 m in height (Fig. 3c). The bark is green, smooth and pubescent in young plants. The leaves are simple, alternate, oblanceolate to narrowly oblong (longer than wide) or elliptical, glabrous or glabrescent, it has a long petiole (0.5–11.5 cm). The inflorescence has several hermaphrodite or unisexual flowers by abortion that are not arranged in whorls and whose male flowers are smaller. The fruit has the appearance of a star and is composed of 5–6 ovoid, dehiscent and stretch follicles. Full fruit production is reached around 20 years and continues until 70–100 years of age. The follicles contain up to 14 large red or pink seeds. Each seed can have three to five cotyledons and is covered with a whitish or reddish aril.

Garcinia kola Heckel, J. Pharm. et Chim. 8: 88 (1883); FWTA 1: 294; FT 217.

Syn.: *Garcinia giadidi* De Wild. in Ann. Mus. Congo, ser. vol. 5, 2, 55. 1907; *Garcinia nitidula* Engl. in Bot. Jahrb. Syst. vol. 55, 395. 1919; *Garcinia ndongensis* Engl. in Bot. Jahrb. Syst. vol. 55, 394. 1919.

Short description (Fig. 3b, see also Dalziel 1973; Irvine 1961; Okwu 2005; Akoègninou et al. 2006; Adesanya et al. 2007).

The plant grows to a medium sized tree of about 12–14 m high and produces reddish, yellowish or orange colored fruit (Fig. 2d). Flowering occurs once a year and the period depends of plant environment. The fruits mature three times per year, the first time between December and February, the second between March and April, the third between July and August. Each fruit contains 2–4 yellow seeds and a sour tasting pulp. The seeds have a bitter astringent taste; hence, it is called bitter kola in Nigeria.

General inter-specific variability of common quantitative parameters

The Table 3 presents the one way variance analysis (ANOVA) of the quantitative data for the three kola trees. It appeared from the analysis that 68.75 % of measured parameters were discriminative traits and enabled to observe a variation between the species, while in 31.25 % of the cases, we noticed no significant difference of data between the three trees. Based on vegetative traits, the height of the crown (Hhp) and total tree height (H) displayed a very highly significant variation ($p < 0.001$) from one species to another. Specifically, among the three studied species, *G. kola* showed at the same time the highest average height of the crown (9.76 ± 0.51 m) and the largest in height (12.94 ± 0.57 m). This was directly followed by *C. nitida* (10.82 ± 0.36 m) while *C. acuminata* was the smallest of the three trees with an overall height of 8.42 ± 0.60 m. Except the husk weight (Pdspe) which didn't vary ($p > 0.05$) between the trees, all measures relating to the fruits have a difference which varied from one species to another. Indeed, this difference was very highly significant ($p < 0.001$) for the fruit length (Lgfr) and fruit thickness (Efr), while it less varied ($p < 0.05$) for their weight (Pfr). The comparative analysis of common parameters of fruit showed that *C. acuminata* and *C. nitida* had respectively the longest fruit followed by *G. kola* which displayed the largest (67.91 ± 1.60 mm) fruit width. Although the fruits of *G. kola* are the biggest, they did not weight as much as those of *C. acuminata* (181.74 ± 19.92 g) and *C. nitida* (174.39 ± 8.73 g). Regarding the nuts of the three species, there is also a variation between quantitative traits. This difference was highly significant ($p < 0.01$) for the nuts length (Lgr) and very highly significant ($p < 0.001$) between the number (Ngr), the wet weight (Pgr) and the thickness of the nuts (lggr). In term of seed production, the highest average value was observed in *C. nitida* (5.07 ± 0.36) while *G. kola* produced fewer seeds (2.91 ± 0.10). On the contrary, the longest nuts are observed in *G. kola* (34.03 ± 0.87 mm) and the shortest in *C. nitida* (29.53 ± 0.79 mm). Similarly, while *G. kola* and *C. nitida* respectively had the longest and most numerous nuts, those of *C. acuminata* weighted more than the other two species. At the level of the nut thickness, it was *C. acuminata* which had the widest nuts (26.24 ± 1.42 mm) followed by *C. nitida* (23.21 ± 0.81 mm) and finally *G. kola* (19.82 ± 0.39 mm). Among the three species, *C. nitida* showed the longest and the broadest leaves with highly significant differences.

Intra-specific variation in kola species

Quantitative variability in G. kola

The results of linear Pearson correlation analysis (Table 4) indicate important correlations between the evaluated descriptors. Regarding the vegetation, a highly significant ($p < 0.001$) positive correlation was observed between collar diameter (Dc) and tree diameter (DBH) on the one hand and between crown height (Hhp) and Dc one the other hand. Similarly, the total height (H) of the trees varied with the DBH, the Dc, the Hhp ($p < 0.001$) and Dhp ($p < 0.05$). The correlation between the vegetative parameters and those relating to the fruit and the nuts showed a positive variation between Lfr ($p < 0.01$) and Lgr

Table 3 General comparison between the common variables of the three species

Parameters	*G. kola*	*C. nitida*	*C. acuminata*	Probability
DBH	41.82 ± 2.49a	39.80 ± 2.74a	33.85 ± 1.50a	1.27 ns
Dc	53.21 ± 3.14a	50.82 ± 2.84a	52.35 ± 4.79a	0.16 ns
Hhp	9.76 ± 0.51a	7.97 ± 0.39b	5.88 ± 0.76c	9.32***
Dhp	8.04 ± 0.43a	8.53 ± 0.48a	9.20 ± 0.53a	0.93 ns
Hpr	3.37 ± 0.25a	2.85 ± 0.22a	2.54 ± 0.38a	1.92 ns
H	12.94 ± 0.57a	10.82 ± 0.36b	8.42 ± 0.60c	11.97***
Lfr	64.52 ± 1.56b	103.17 ± 3.39a	107.14 ± 4.22a	75.23***
Efr	67.91 ± 1.60a	56.35 ± 1.60b	62.09 ± 3.13ab	12.46***
Pfr	142.72 ± 9.96b	174.39 ± 8.73ab	181.74 ± 19.92a	3.47*
Ppe	134.95 ± 9.69a	164.13 ± 8.75a	148.88 ± 20.10a	2.28 ns
Ngr	2.91 ± 0.10b	5.07 ± 0.36a	3.77 ± 0.36b	20.09***
Pgr	7.76 ± 0.37c	10.26 ± 0.56b	16.75 ± 1.67a	33.16***
Lgr	34.03 ± 0.87a	29.53 ± 0.79b	32.86 ± 1.96a	6.56**
lgr	19.82 ± 0.39c	23.21 ± 0.81b	26.24 ± 1.42a	15.41***
Llim	10.78 ± 0.25c	17.36 ± 0.19a	13.34 ± 0.54b	178.29***
llim	4.86 ± 0.17b	6.36 ± 0.18a	4.31 ± 0.16b	26.35***

ns: not significant; DBH: tree diameter; Dc: collar diameter; Hhp: crown height; Dhp: crown diameter; Hpr: first ramification height; H: tree total height; Lfr: fruit length; Efr: fruit thickness; Pfr: fruit weight; Ppe: husk weight; Ngr: number of nuts per pod; Pgr: nut wet weight; Lgr: nut length; lgr: nut thickness; Llim: leaf blade length; llim: leaf blade width

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

($p < 0.05$) with the tree height (H) which had no effect ($p > 0.05$) on their weight. Regarding the relationships between fruit and nut parameters, positive and highly significant correlations ($p < 0.001$) were observed between Ngr, Pgr, Lgr and Lfr, Pfr, Efr.

The result of a hierarchical clustering of *Garcinia kola* trees based on quantitative descriptors is presented as a dendrogram (Fig. 4). Following the R^2 determination coefficient, the analysis showed a classification into five different size groups. The results of PCA on different groups of *Garcinia kola* and variables enabled to describe the relationship between them and refine their analysis. These results indicated that the two first axes explained 89.7 % of the total basic information. The projection of the different variables in the axis system defined by *G. kola* trees groups (Fig. 5) revealed that cluster 1 was more correlated with axis 2. The trees in this group were characterized by the highest fruit weight (Pfr), with a big husk fruit (Ppe) while they had at their leaves the smallest Dp. The cluster 5 meanwhile was positively correlated to the axis 1 and negatively to the axis 2. The individuals in this group expressed the highest values of vegetative descriptors (Dc, DBH, Hhp) and their fruits had fewer spoiled nuts (Ngrg). The trees of the cluster 4 were characterized by the greater heights of the first ramification of the trunk (Hpr) while the trees of the cluster 2 were intermediate.

The variance analysis of quantitative data relating to the description of different groups is presented in Table 5. The coefficient of variation (*CV*) ranged from 4.82 % (Lfr) to 125.32 % (Pgr), suggesting that important variation exists among *G. kola* trees for most of the studied characters. Nevertheless note that through the cluster some variables such as DBH, Efr, Pfr, Ppe, Lgr, lgr, Llim, llim and Dp displayed the lowest variation ($CV < 15$ %).

Quantitative variability within C. nitida

The Pearson linear correlation computed between the vegetative parameters indicated strong correlations between variables. These correlations were positive and very highly significant ($p < 0.001$) between Dc, Hhp, Dhp and DBH. Similarly, there was a positive correlation ($p < 0.001$) between the crown height (Hhp) and the overall tree height (H). Regarding the

Table 4 Linear Pearson correlation coefficients between different morphological variables of *G. kola*

	DBH	Dc	Hpr	Hhp	Dhp	H	Lfr	Efr	Pfr
Dc	0.797***								
Hpr	−0.017 ns	0.361							
Hhp	0.627 ns	0.560***	−0.131 ns						
Dhp	0.611***	0.379*	−0.065 ns	0.427**					
H	0.562***	0.623***	0.281 ns	0.862***	0.342*				
Lfr	−0.026 ns	0.114 ns	0.202 ns	0.258 ns	−0.086 ns	0.400**			
Efr	−0.082 ns	−0.006 ns	0.180 ns	0.100 ns	−0.047 ns	0.265 ns	0.919***		
Pfr	−0.233 ns	−0.144 ns	0.160 ns	−0.036 ns	−0.160 ns	0.121 ns	0.901***	0.938***	
Ppe	−0.231 ns	−0.139 ns	0.163 ns	−0.037 ns	−0.159 ns	0.119 ns	0.900***	0.934***	1.000***
Ngr	−0.008 ns	0.214 ns	0.273 ns	0.174 ns	0.193 ns	0.285 ns	0.510***	0.504***	0.454**
Ngrg	−0.211 ns	−0.030 ns	−0.077 ns	0.018 ns	−0.012 ns	−0.085 ns	−0.279 ns	−0.356*	−0.290 ns
Pgr	−0.214 ns	−0.219 ns	0.040 ns	0.019 ns	−0.160 ns	0.151 ns	0.679***	0.769***	0.739***
Lgr	−0.116 ns	−0.047 ns	0.183 ns	0.148 ns	−0.115 ns	0.307*	0.829***	0.783***	0.801***
lgr	−0.205 ns	−0.108 ns	−0.080 ns	0.110 ns	−0.306*	0.176 ns	0.552***	0.581***	0.519***
Llim	0.297 ns	0.049 ns	−0.241 ns	0.210 ns	0.148 ns	0.041 ns	0.090 ns	0.066 ns	0.054 ns
llim	0.266 ns	0.052 ns	−0.178 ns	0.128 ns	0.113 ns	0.007 ns	0.032 ns	0.028 ns	−0.014 ns
Lp	0.328*	0.100 ns	−0.324*	0.317*	0.435**	0.187 ns	0.024 ns	0.058 ns	−0.078 ns
Dp	0.127 ns	0.003 ns	−0.200 ns	−0.031 ns	0.044 ns	−0.208 ns	−0.285 ns	−0.290 ns	−0.255 ns

	Ppe	Ngr	Ngrg	Pgr	Lgr	lgr	Llim	llim	Lp
Dc									
Hpr									
Hhp									
Dhp									
H									
Lfr									
Efr									
Pfr									
Ppe									
Ngr	0.457**								
Ngrg	−0.283 ns	0.002 ns							
Pgr	0.721***	0.258 ns	−0.399**						
Lgr	0.792***	0.408**	−0.321*	0.826***					
lgr	0.502**	0.099 ns	−0.352*	0.808***	0.660***				
Llim	0.052 ns	−0.039 ns	0.027 ns	0.094 ns	0.050 ns	−0.047 ns			
llim	−0.017 ns	−0.061 ns	0.089 ns	0.067 ns	−0.033 ns	−0.036 ns	0.863***		
Lp	−0.086 ns	0.171 ns	−0.044 ns	0.142 ns	0.089 ns	0.157 ns	0.341*	0.266 ns	
Dp	−0.255 ns	−0.090 ns	−0.178 ns	−0.189 ns	−0.232 ns	−0.245 ns	0.471**	0.447**	0.129 ns

ns: not significant ($p > 0.05$); DBH: tree diameter; Dc: collar diameter; Hhp: crown height; Dhp: crown diameter; Hpr: first ramification height; H: tree total height; Lfr: fruit length; Efr: fruit thickness; Pfr: fruit weight; Ppe: husk weight; Ngr: number of nuts per fruit; Ngrg: number of damaged nuts; Pgr: nut wet weight; Lgr: nut length; lgr: nut thickness;; Llim: leaf blade length; llim: leaf blade width; Lp: petiole length; Dp: petiole diameter

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

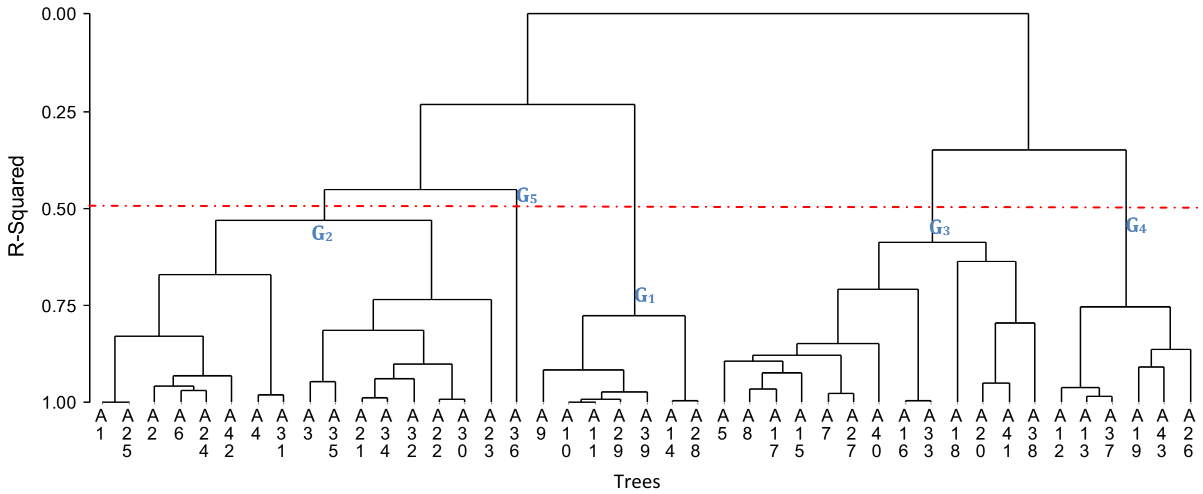

Fig. 4 Dendrogram constructed with quantitative variables showing the diversity and the classification of the different morphotypes of *Garcinia kola*

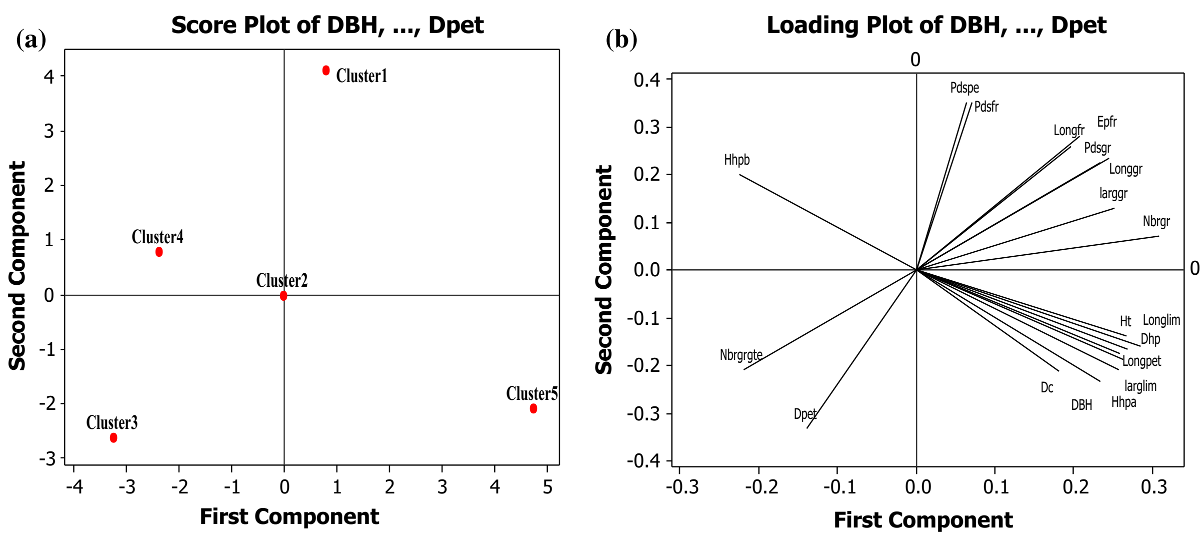

Fig. 5 Projection of *Garcinia kola* trees clusters (**a**) and the descriptors (**b**) in the factorial axis system

parameters related to fruit and nut, it appeared that fruit length (Lfr) was positively correlated with their thicknesses ($p < 0.01$), their weight and the number of nuts they contained ($p < 0.001$). On the contrary, the weight of the nuts did not affect ($p > 0.05$) the parameters related to the fruit while the nut length (Lgr) was positively and significantly ($p < 0.001$) correlated with the fruit thickness (Efr). The relationships between vegetative parameters and those of the fruits on one hand revealed positive correlations of fruit thickness (Efr) with the crown height ($p < 0.05$) and the total height of the tree ($p < 0.01$). In other hand, the same relationships were detected between foliar parameters and the crown diameter (Dhp), the length of the male flower ($p < 0.05$) and the length of hermaphrodite flower ($p < 0.01$). Besides, the length of the hermaphrodite flowers was positively correlated ($p < 0.01$) to the fruit thickness (Efr).

The numerical classification based on quantitative data showed a clustering of *C. nitida* trees into seven distinct groups (Fig. 6). In general, the groups 1 and 2 included more trees than the other

Table 5 Quantitative description of the different groups of *Garcinia kola* trees

Variables	Groups					*F*	CV
	1	2	3	4	5		
DBH	28.18 ± 1.06[c]	52.17 ± 3.42[b]	43.78 ± 2.44[b]	19.65 ± 0.86[c]	79.21[a]	18.44***	13.43
Dc	36.78 ± 2.23 [cd]	70.70 ± 3.60[ab]	52.39 ± 3.80[bc]	24.26 ± 1.74[d]	72.54[a]	20.40***	16.03
Hhp	8.18 ± 0.38[c]	12.09 ± 0.36[b]	9.36 ± 0.87[bc]	4.86 ± 0.53[d]	18.24[a]	18.54***	16.99
Dhp	8.39 ± 0.93[b]	7.69 ± 0.46[b]	9.37 ± 0.49[b]	4.11 ± 0.54[c]	17.31[a]	14.23***	21.09
Hpr	4.00 ± 0.15[a]	3.45 ± 0.54[a]	3.45 ± 0.41[a]	2.75 ± 0.44[ab]	0.30[b]	1.35 ns	31.10
H	12.54 ± 0.42[b]	15.42 ± 0.57[ab]	12.10 ± 0.91[b]	7.49 ± 1.15[c]	19.71[a]	11.32***	17.79
Lfr	78.53 ± 0.80[a]	69.68 ± 1.11[b]	53.55 ± 1.66[c]	57.70 ± 0.90[c]	67.52[b]	68.05***	4.82
Efr	82.96 ± 1.90[a]	71.42 ± 1.34[b]	56.04 ± 1.54[c]	65.84 ± 0.91[b]	73.28[b]	35.12***	5.38
Pfr	256.68 ± 11.29[a]	155.94 ± 7.57[b]	75.42 ± 5.49[c]	125.80 ± 1.82[b]	110.00[bc]	63.10***	12.17
Ppe	245.65 ± 11.18[a]	147.97 ± 7.60[b]	70.42 ± 5.35[c]	116.85 ± 1.90[b]	99.43[c]	58.14***	12.80
Ngr	3.40 ± 0.11[a]	3.03 ± 0.11[a]	2.57 ± 0.20[a]	2.63 ± 0.36[a]	3.70[a]	1.89 ns	17.31
Pgr	11.03 ± 0.52[a]	7.97 ± 0.35[b]	5.00 ± 0.35[c]	8.94 ± 0.36[b]	10.57[a]	67.44***	125.32
Lgr	42.67 ± 1.34[a]	34.83 ± 0.45[b]	28.37 ± 1.27[c]	33.17 ± 0.82[bc]	39.63[ab]	35.51***	13.11
lgr	21.44 ± 0.30[b]	20.61 ± 0.47[b]	17.04 ± 0.62[c]	21.28 ± 0.54[b]	23.01[a]	35.20***	7.17
Llim	10.62 ± 0.52[b]	11.06 ± 0.44[b]	10.49 ± 0.43[b]	10.33 ± 0.81[b]	13.78[a]	39.10***	6.49
llim	4.49 ± 0.79[b]	5.05 ± 0.30[b]	4.77 ± 0.28[b]	4.71 ± 0.53[b]	6.53[a]	13.21***	12.68
Lp	1.25 ± 0.08[b]	1.32 ± 0.03[b]	1.27 ± 0.05[b]	1.36 ± 0.04[b]	4.13[a]	15.78***	18.29
Dp	2.53 ± 0.36[a]	2.70 ± 0.47[a]	2.77 ± 0.47[a]	2.73 ± 0.51[a]	2.71	1.96 ns	7.84

ns: not significant ($p > 0.05$); DBH: tree diameter; Dc: collar diameter; Hhp: crown height; Dhp: crown diameter; Hpr: first ramification height; H: tree total height; Lfr: fruit length; Efr: fruit thickness; Pfr: fruit weight; Ppe: husk weight; Ngr: number of nuts per fruit; Ngrg: number of damaged nuts; Pgr: nut wet weight; Lgr: nut length; lgr: nut thickness;; Llim: leaf blade length; llim: leaf blade width; Lp: petiole length; Dp: petiole diameter

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

groups. The Principal Component Analysis of the data revealed that the first two axes explained 54.6 % of the total variation. At these two axes, 8 descriptors discriminated the different groups. The contribution of each discriminant variable to the formation of the two axes revealed that Hhp and H were positively correlated with axis 1 while the Ntr and Nns were negatively correlated to this axis. Furthermore, Lfr, Pfr, and Ppe Ngr were negatively correlated to the axis 2. Therefore, it appeared that the axis 1 explained the variation in vegetative parameters while the axis 2 indicated that in the fruits and the nuts.

The variance analysis (ANOVA) revealed that the coefficient of variation (*CV*) in plant parameters through the various groups varied from 3.35 to 39.04 (Table 6). Only some parameters such as Hpr Pgr, and lfe Nimf did not exhibit significant variation ($p > 0.05$).

Quantitative variation within Cola acuminata trees

The different variables studied in *C. acuminata* trees showed different levels of correlations. Indeed, a positive and highly significant ($p < 0.001$) correlation was detected between the fruit length (Lfr), their thicknesses (Efr) and their weight (Pfr). The same thing has been observed between the same parameters of the nuts. Furthermore, the parameters Ngr and Efr ($p < 0.01$) in the one hand; Ngr and Pfr ($p < 0.001$) in the other showed positive and highly significant correlations. Similarly, the leaf blade length (Llim) was positively correlated to the Dhp ($p < 0.05$) while the leaf blade width (lfe) was itself positively correlated ($p < 0.001$) to the total tree height (H). The number of male flowers per inflorescence (Nfmi) was negatively correlated with Hhp ($p < 0.001$) and H ($p < 0.001$). On the contrary, the number of hermaphrodite flowers per inflorescence (Nfh) was also

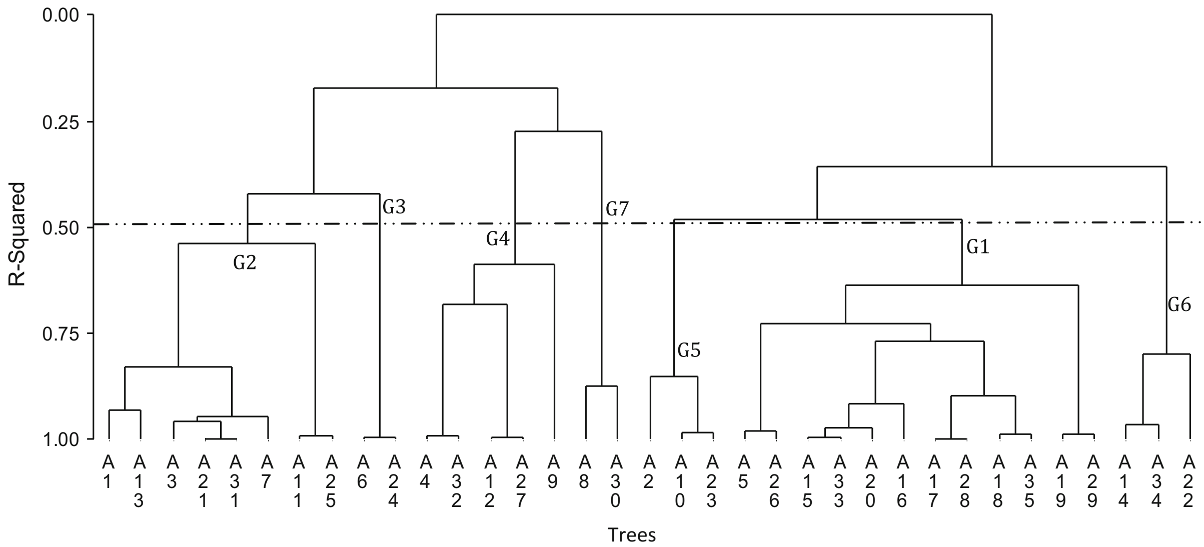

Fig. 6 Dendrogram showing the different clusters according to quantitative characters of *Cola nitida*

positively correlated with Dhp ($p < 0.05$) and Pfr, Efr, Ngr ($p < 0.01$).

From different parameters of trees set in relationship, a numerical classification has enabled constructing the dendrogram in Fig. 7. The analysis of this dendrogram revealed the clustering of *C. acuminata* trees into four phenotypic groups. The results of Principal Component Analysis (PCA) on different groups and the variables indicated that the first two axes explained 83.3 % of the total information. The projection of the different variables in the axis system defined by groups (Fig. 8) showed that the trees of group 1 were characterized by Efr, Ngr, Nfh, Ppe, Pfr parameters while the trees of group 4 revealed high correlations with lgr, Lgr, Pgr, Hpr. In the group 2, *C. acuminata* trees were mainly characterized by lfe, H while the group 3 was mostly characterized by Lfh and Lfm.

The analysis of variance ANOVA of various quantitative parameters revealed substantial variations in studied traits with a coefficient of variation varying from 5.24 to 51.09 %. The trait variability among the different groups of *C. acuminata* trees was of low significance. This shows quantitative parameters redundancy between theses clusters. Nevertheless some descriptors vary at different proportions from one group to another. For instance, Hhp, H, Efr, Nfh which exhibited significant variation ($p < 0.05$). The Ngr and Pfr meanwhile displayed a highly significant variation ($p < 0.01$) while the variability observed with the NiM was very highly significant ($p < 0.001$).

Descriptive analysis of qualitative data

The descriptive statistics in qualitative data related to *C. nitida* and *C. acuminata* species is presented in Table 7. The results show that the qualitative features varied from one species to another. Indeed in *C. nitida*, most trees had a rectangular shape (34.3 %) but also some were semi-circular (25.7 %). The branches were irregularly distributed (14.3 %) and were inserted at an angle greater than 90°. The leaves were dark green (82.9 %), they had an oblong-lanceolate shape (57.1 %) with a pointed acuminate apex (97.1 %) and were pointed at the base with entire margin (99.1 %). The male flowers had a cream-white color in the center pink (97.1 %) while the hermaphrodite flowers were all cream-white. The fruits displayed a green color and a regularly serrated texture containing red (54.3 %), wine-red (25.7 %) or white (20 %) nuts. Regarding *C. acuminata*, the trees had a semicircular shape with branches irregularly distributed. These branches carried leaves with a long acumen, very sharp and were more narrow and slender than those of *C. nitida*. The flowers were unisexual or hermaphrodite; the male flowers were yellow with pinkish color in the center while hermaphrodite ones developed creamy yellow color. The fruits are green (58.3 %) or

Table 6 Quantitative description of the different groups of *Cola nitida*

Variables	Clusters							*F*	CV
	1	2	3	4	5	6	7		
DBH	35.13^{b}	54.09^{a}	16.39^{c}	54.80^{a}	33.23^{cb}	23.46^{cb}	30.99^{cb}	6.44***	18.96
Dc	46.70^{bc}	66.45^{a}	21.32^{bc}	56.49^{ba}	47.42^{bc}	31.15^{dc}	62.90^{ba}	6.39***	15.10
Hpr	2.67^{b}	2.11^{b}	4.83^{a}	2.65^{b}	4.06^{ba}	3.08^{ba}	3.27^{ba}	1.84 ns	31.03
Hhp	7.47^{c}	8.43^{bc}	4.57^{d}	10.21^{ba}	6.22^{dc}	6.23^{dc}	12.12^{a}	60.7***	17.45
Dhp	6.58^{dc}	10.63^{ba}	5.92^{d}	12.10^{a}	8.73^{bc}	5.31^{d}	10.13^{ba}	11.30***	15.36
H	10.14^{c}	10.54^{bc}	9.40^{c}	12.86^{ba}	10.28^{bc}	9.32^{c}	15.40^{a}	4.91**	10.55
Lfr	86.61^{c}	111.70^{ba}	127.13^{a}	127.90^{a}	86.28^{c}	112.05^{a}	94.65^{bc}	9.89***	10.29
Efr	49.69^{d}	56.29^{dc}	62.98^{bc}	67.23^{ba}	55.98^{dc}	49.52^{d}	73.56a	8.10***	9.70
Pfr	132.15^{c}	210.41^{b}	283.75^{a}	208.20^{b}	119.81^{c}	154.18^{c}	202.10^{b}	19.42***	13.15
Ppe	122.16^{dc}	200.18^{b}	274.96^{a}	199.13^{b}	105.65^{d}	146.37^{c}	187.79^{b}	20.83***	13.96
Ngr	3.64^{d}	6.46^{bac}	8.75^{a}	6.82^{ba}	2.82^{d}	4.50b^{dc}	4.40^{dc}	7.60***	23.13
Pgr	9.98^{ba}	10.22^{ba}	8.79^{b}	9.07^{b}	14.16^{a}	7.88^{b}	14.30^{a}	1.88 ns	22.22
Lgr	27.32^{b}	27.06^{b}	29.35^{b}	31.40^{b}	36.84^{a}	28.89^{b}	38.21^{a}	6.62***	6.47
lgr	20.45^{c}	21.77^{c}	22.01^{c}	25.87^{bac}	31.52^{a}	22.71^{bc}	28.28^{ba}	5.00**	11.52
Ntr	2.00^{a}	2.00^{a}	2.00^{a}	2.00^{a}	2.00^{a}	2.00^{a}	1.97^{b}	4.40**	0.25
Lfe	17.59^{a}	18.00^{a}	17.08^{ba}	17.20^{ba}	18.25^{a}	16.08^{b}	14.70^{c}	6.54***	2.97
lfe	6.66^{a}	6.24^{a}	6.61^{a}	6.74^{a}	5.81^{a}	5.95^{a}	5.32^{a}	0.75 ns	13.15
Lp	5.18^{a}	4.54^{a}	4.67^{a}	4.19^{a}	4.18^{a}	2.98^{b}	4.17^{a}	4.07**	14.37
Nns	12.30^{a}	12.71^{a}	12.5^{a}	12.22^{a}	12.33^{a}	12.30^{a}	10.40^{b}	3.00*	4.48
Nfmi	6.03^{a}	5.37^{a}	5.50^{a}	4.32^{a}	7.06^{a}	3.20^{a}	4.33^{a}	0.92 ns	29.06
Nfhi	5.86^{b}	6.86^{b}	7.75^{b}	6.68^{b}	3.26^{c}	3.40^{c}	9.67^{a}	9.45***	13.73
Nimia	3.79^{ba}	3.74^{ba}	5.00^{a}	2.40^{b}	4.33^{a}	0.66^{c}	4.00^{a}	7.97***	39.04
Lfm	1.37^{cb}	1.28^{cb}	1.15^{c}	1.81^{a}	1.45^{b}	1.25^{cb}	1.47^{b}	6.35***	7.12
Lfh	2.22^{b}	2.11^{cb}	2.12^{b}	2.64^{a}	2.18^{b}	1.94^{c}	2.27^{b}	7.16***	6.71
Nls	5.15b^{a}	4.88^{bc}	4.90^{c}	5.47^{a}	4.74^{c}	5.13^{ba}	4.73^{c}	5.74***	3.35

ns: non significant ($p > 0.05$); DBH: tree diameter; Dc: collar diameter; Hhp: crown height; Dhp: crown diameter; Hpr: first ramification height; H: tree total height; Lfr: fruit length; Efr: fruit thickness; Pfr: fruit weight; Ppe: husk weight; Ngr: number of nuts per pod; Pgr: nut wet weight; Lgr: nut length; lgr: nut thickness; Ntr: cotyledon number; Lfe: Leaf blade length; lfe: leaf blade width; Lp: petiole length; Nns: number of secondary leaf veins; Nfmi: number of male flowers per inflorescence; Nfhi: number of hermaphrodite flower per inflorescence; Nimia: number of mixed inflorescence; Lfm: length of male flower; Lfh: length of hermaphrodite flower; Nls: number of stigmatic lobes

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

brown (41.7 %) with a smooth texture (96.35 %) and had the nuts most often red (50 %) and wine-red (46.7 %).

Discussion

This study shows the level of morphological diversity of kola trees in the southern Benin. It is the first step in the evaluation of genetic diversity which is very important in breeding process and conservation of plant genetic resources (Adoukonou-Sagbadja et al. 2007). In many regions over the world, several studies on morphological parameters in quantifying the genetic diversity have been conducted in other forest resources (Chandram and Pandya 2000; Kouyaté and Van Damme 2002; Maranz and Wiesman 2003; Soloviev et al. 2004; Fandohan et al. 2011) for the purpose to valorize them. Considering the three kola tree species, most (68.75 %) quantitative morphological descriptors were discriminating and enabled to identify them. Similarly, other studies (Dansi et al.

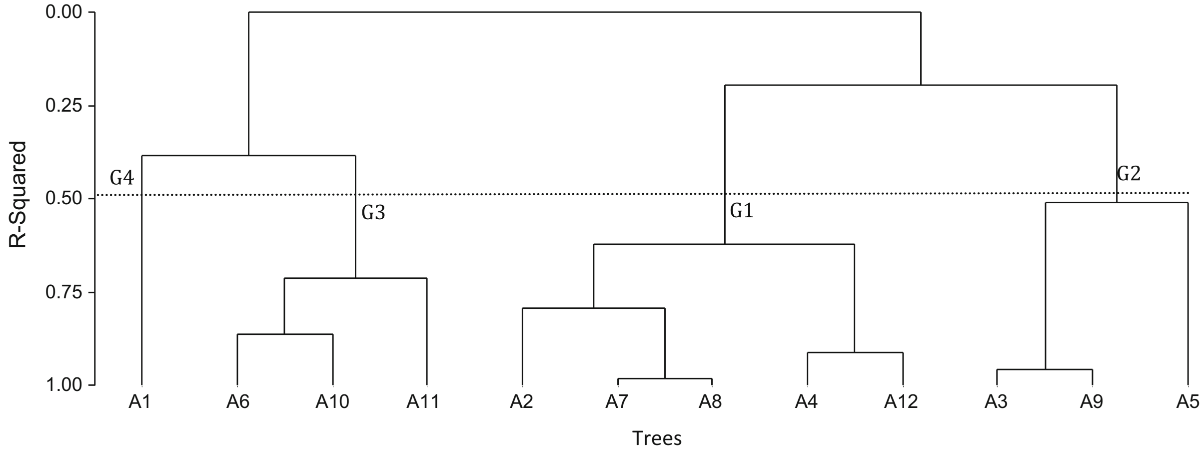

Fig. 7 Dendrogram showing the different clusters according to quantitative characters of *Cola acuminata*

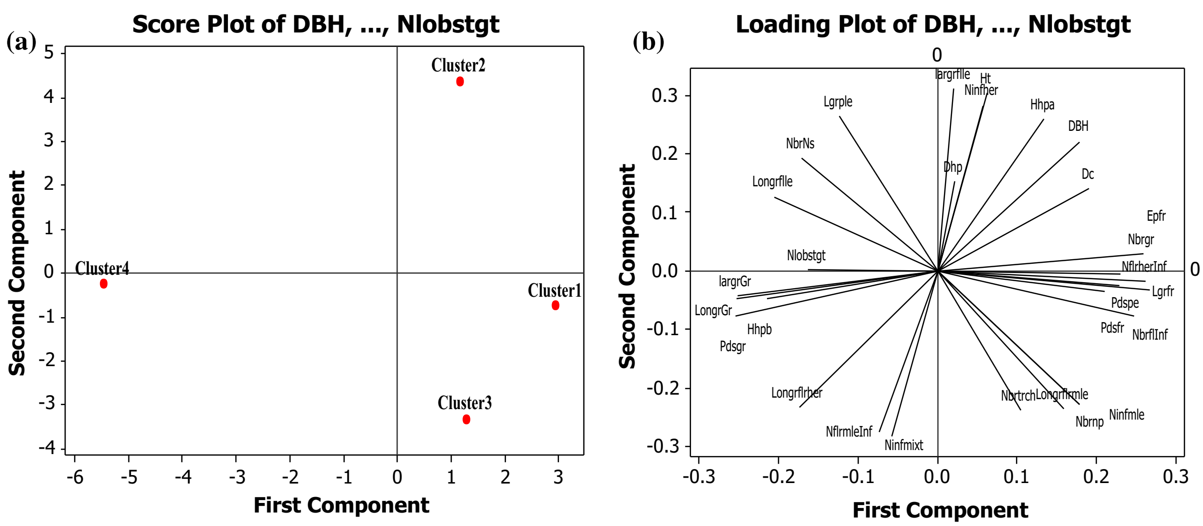

Fig. 8 Projection of *Cola acuminata* trees clusters (**a**) and the descriptors (**b**) in the factorial axis system

1999; Assogbadjo et al. 2005; Chabi Sika et al. 2015) have shown that during a morphological characterization not all the descriptors used are systematically discriminating. This fact attests the quantitative parameters redundancy observed in this study in *C. acuminata* in contrast to other kola species.

The discriminating descriptor states obtained in this study shows the degree of differentiation between the three studied species. The morphometric analysis of the data between the three kola trees shows that *Garcinia kola* is the tallest while *C. acuminata* is the smallest. Similar observations were reported by Adebola and Morakinyo (2006) for *C. nitida* and *C. acuminata*. The fruit length is a factor that easily discriminates the two tree families Clusiaceae (*G. kola*) and Sterculiaceae (*C. nitida* and *C. acuminata*). Apart from the floral and leaf characteristics that have been reported to be a strong taxonomic feature for species classification (Bekele and Butler 2000) and critical in their variability (Jendoubi et al. 2001), the descriptor fruit length (Lfr) has been important in taxonomy and systematic classification of the two tree families. In addition to the fruit length, the leaf blade length (Llim) allows for easy distinction between the two tree families in general but also between *C. nitida* and *C. acuminata* which belong to the same family.

Table 7 Qualitative descriptors characteristics of the species

Part	Character descriptors	Descriptor states	Frequency (%)	
			C. nitida	*C. acuminata*
Shaft	Tree shape	Columnar	22.9	16.7
		Pyramidal	5.7	–
		Obovate	–	25
		Rectangular	34.3	–
		Circular	5.7	8.3
		Semi-circular	25.7	41.7
		Semi-elliptic	–	8.3
		Irregular	5.7	–
	Distribution of branches	Ascendant	14.3	33.3
		Irregular	74.3	66.7
		Verticillate	11.4	–
	Axil angle of main branches	>90°	100	100
Leaves	Axil angle of leaf petiole	>90°	100	100
	Leaf shape	Obovate	5.7	16.7
		Oval	14.3	–
		Lanceolate	11.4	33.3
		Oblong	11.4	8.3
		Oblong-lanceolate	57.1	41.7
	Leaf apex shape	Very pointed	2.3	16.7
		Intermediate	–	16.7
		Pointed acuminate	97.1	66.7
	Leaf base shape	Pointed	100	100
	Leaf margin	Entire	99.1	100
		Undulate	0.9	–
Flower	Male flower color	Yellow cream	2.9	–
		Pink yellow	–	100
		White pink cream	97.1	–
	Hermaphrodite flower color	Yellow cream	20	100
		White cream	80	–
	Stigmatic lobe color	Yellow cream	25.7	100
		White cream	74.3	–
Fruit	Fruit color	Green	98.3	58.3
		Brown	1.7	41.7
	Fruit surface	Smooth	–	96.35
		Serrated	97.1	–
		Rough	2.9	3.65
Nut	Nut color	Red	54.3	50
		White	20	3.3
		Wine red	25.7	46.7

These findings are similar to those made by Morakinyo and Olorode (1984) in Nigeria, which reported that the leaf blade length and petiole length are minimum descriptors, distinguishing *C. nitida*, *C. acuminata* and their hybrid F1 (*C. nitida* × *C. acuminata*). Similarly Adebola and Morakinyo (2006) in Nigeria through the morphological variability, Morakinyo and Olorode (1984) through the cytogenetic study and Onomo et al. (2006b) in Cameroon through the isoenzymes variability showed a difference in characteristics between *C. nitida* and *C. acuminata*. Trees belonging to the same botanical family are apparently quite different in some morphological, cytogenetic and even biochemical characteristics.

Besides the inter-specific variation, there is also substantial intra-specific variation. Indeed several morphological groups (morphotypes) have been identified in the three kola trees. For instance, in *Garcinia kola*, five distinct tree clusters or morphotypes were detected; each group characteristics have different characteristics that, depending on the purpose for the valorization, could provide a basis for ongoing work in possible species breeding. In *C. nitida*, variability of morphological characteristics between different trees is well attested by Onomo et al. (2006a) in Cameroon who have also found isoenzyme variability between *C. nitida* individuals. Through the hierarchical ascending classification, seven distinct morphotypes were obtained from the studied accessions. Besides Bodard (1962) using Fischer values (F) and coefficients of variation (CV) showed a wide intra-specific variation, suggesting important polymorphism in *C. nitida*. Individuals with lower values for vegetative traits but higher in fruits and nuts are good candidates for the species valorization because fruit set are a very good yield index that can be effectively used as a selection criterion in kola breeding program (Adebola et al. 2002). Indeed, individuals of group 3 of this species have the lowest DBH, Dc, Hhp and Dhp but also the highest fruit length (Lfr) and nuts number (Ngr). However the average wet nut weight in this group is lower than those of clusters 5 and 7 which have fewer nuts and of which fruits do not reach the values in group 3. In view of the strong correlation between the fruits length and nut number which corroborates the results of Adebola and Morakinyo (2006) on the one hand and the nuts of high commercial and industrial potential (Yahaya et al. 2001; Asogwa et al. 2006; Oluyole et al. 2009) on the other hand, the characteristics of fruits and nuts of the three groups mentioned above may be effectively exploited in intraspecific hybridization programs. Other fruit character of agronomic importance that should not be overlooked is the pod thickness which can serve as a deterrent to borer pests and other insects attack (Bekele et al. 2001). At floral traits level, a highly significant change was observed ($p < 0.001$) between the number of hermaphrodite flowers per inflorescence, the number of mixed flowers and the number of stigmatic lobes which are useful characters of agronomic interest (Adebola and Morakinyo 2006). Among these traits, especially the number of stigmatic lobes should be taking into consideration because the success of pollination of all stigmatic lobes leads the development of each lobe in pod. Therefore a large number of stigmatic lobes imply potentially higher number of pod and consequently higher yield but this speculative hypothesis needs further confirmation.

As the previous two kola trees (*Cola nitida*, *Garcinia kola*), a variability in morphometric characters was also observed within *C. acuminata*. However, the characters variability in the various groups is lower compared to the other two species. Similar observations were also made in *C. acuminata* by Morakinyo and Olorode (1984) and Onomo et al. (2006a), attesting the relatively low intraspecific diversity in this kola species. Besides, *C. acuminata* known to be close to *Cola nitida* in many characteristics (Morakinyo and Olorode 1984), and given the meiotic irregularities observed in *C. nitida* and its possibility to evolve into another species (Olorode and Olopade 1978), some authors as Morakinyo and Olorode (1984) suggested that *C. acuminata* has evolved from *C. nitida*. This suggestion may explain the low variability of the characters observed in *C. acuminata* in our study.

Conclusion

Most of 19 descriptors of *Garcinia kola* and 38 of *Cola nitida* and *C. acuminata*, are discriminating traits and help to demonstrate inter- and intra-specific variability. These traits can therefore be included in a list of minimum descriptors for morphological characterization of kola trees used in Benin. The results revealed that these species possess many desirable traits for use in tree breeding. The intra-specific variability observed in each case leads to suggest to expand the study with a larger sample. Similarly more deeply work through molecular characterization will widen the descriptors catalog and better serve species selection in breeding programs.

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