Contribution of ethnobotanical results in the process of domestication of an agroforestry plant with morphological variability (Adamawa, Cameroon)

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Research

Abstract

Background: Knowing how, when and why to use local knowledge, the human being is at the center of ethnobotanical studies. For multiple uses (food, carbon sequestration, etc.), many plants living in nature (forest, savannah, etc.) without protection are selected by humans and introduced by appropriate techniques into systems (fields, etc.) controlled daily by him. This process is called domestication and this type of plant, agroforestry plant. The species *Syzygium guineense* var. *macrocarpum* encountered in the agro-ecological zone of the Guinean savannahs highlands (Adamawa, Cameroon), is an agroforestry plant whose ethnobotanical studies reveal the presence of four sub-varieties complicated by the morphological variability of the leaves and fruits which slow down its domestication. The determination of significant morphological descriptors of these leaves and fruits appears to be a prerequisite for the domestication of this plant. This study is moving in this direction.

Methods: The method used in three different localities is a split plot. The repetitions involved three leaves and three fruits from each of the eleven trees retained per sub-variety, ie three hundred and ninety-six respective units.

Results and Discussion: Ultimately, the qualitative morphological descriptors of the leaves (whole margin, acute apex, etc.) and fruits (sweet taste, ovoid shape, etc.) were significant. Quantitative descriptors of tree accessibility especially accessibility to tree brightness (HTE); Fruiting (SAF, LAF, FWE and RLFSF) and vegetative development (DPE, SWI, PLE, LSH, NLN, NRN, SNL and RNL) were more significant in the Tello area.

Conclusions: Molecular studies (genomic DNAs) are recommended to elucidate the origin of the variability observed within this plant.

Keywords: Loss of traditional knowledge, Impact of climate change, Morphological descriptors, Agroforestry plants, sub-variety, Conservation, *Syzygium guineense* var. *macrocarpum*, Cameroon

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Résumé

Introduction: Sachant comment, quand et pourquoi utiliser le savoir local, l'être humain est au centre des

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études ethnobotaniques. Pour des usages multiples (aliments, séquestration du carbone, etc.), de nombreuses plantes vivant dans la nature (forêt, savane, etc.) sans protection sont sélectionnées par l'Homme et introduites par des techniques appropriées dans des systèmes (champs, etc.) contrôlés quotidiennement par lui. Ce processus est nommé domestication et ce type de plante, plante agroforestière. L'espèce *Syzygium guineense* var. *macrocarpum* rencontrée dans la zone agro-écologique des hautes savanes guinéennes (Adamaoua, Cameroun), est une plante agroforestière dont des études ethnobotaniques révèlent la présence de quatre sous-variétés complexifiée par la variabilité morphologique des feuilles et des fruits qui ralentissent sa domestication. La détermination des descripteurs morphologiques significatifs de ces feuilles et fruits semble être une condition préalable à la domestication de cette plante. Cette étude s'engage dans cette direction.

Méthodes: La méthode utilisée dans trois localités différentes est un plan factoriel. Les répétitions concernaient trois feuilles et trois fruits de chacun des onze arbres retenus par sous-variété, soit trois cent quatre-vingt-seize unités respectives.

Résultats et Discussion: En définitive, les descripteurs morphologiques qualitatifs des feuilles (marge entière, un apex aigu, etc.) et fruits (goût sucré, une forme ovoïde, etc.) ont été significatifs. Les descripteurs quantitatifs de l'accessibilité à l'arbre surtout l'accessibilité à la luminosité de l'arbre (HTE) ; fructification (SAF, LAF, FWE et RLFSF) et développement végétatifs (DPE, SWI, PLE, LSH, NLN, NRN, SNL et RNL) ont été plus significatifs dans la zone de Tello.

Conclusions: Des études moléculaires (ADN génomique) sont recommandées pour élucider l'origine de la variabilité observée au sein de cette plante.

Mots-clés: perte du savoir traditionnel, impact des changements climatiques, descripteurs morphologiques, plante agroforestière, sous-variété, conservation, *Syzygium guineense var. macrocarpum*, Cameroun

Background

The impacts of climate change on the environment are of increasing concern to the international community (Nature Québec 2009, Nelson *et al*. 2009, Reid *et al*. 2014, Wolverton *et al*. 2014, Sultan 2015). To cope, many solutions are proposed (Tardieu 2011, Lazard 2017, Torquebiau 2017, Le Foll *et al*. 2018). Among these, agroforestry is one of the most sustainable (Chevallier *et al*. 2015). Indeed, the presence of at least one well-known tree of riparian populations in an existing peasant production system reveals many long-term benefits. This genuine knowledge of local resources is indexed by ethnobotanical studies. However, Ramirez (2007) reports a significant loss of this knowledge in the 21st century. In the type of association tree (s), crops and / or animals, the added value of the tree can be cultural, ecological, economic and / or social. The ecological role (carbon sequestration, etc.) enabling the tree to contribute significantly to adaptation to climate change. Yet this idealistic view of the tree in an agroforestry system becomes questionable for plant species with morphological variability. Such a case is found in the agro-ecological zone of the high Guinean savanna of Cameroon. Indeed, ethnobotanical studies recently conducted on the species *Syzygium guineense* (Willd.) DC. var. *macrocarpum* (Engl.) F. White, report that populations in this area distinguish four sub-varieties of this multipurpose plant from fully mature fruit (Lamy *et al*. 2018). According to these populations, as long as the fruits of the plant are not ripe, it is not possible to differentiate between its sub-varieties. As a result, these populations use four main criteria to discriminate the four sub-varieties of the plant. These criteria of peasant distinction are the color of the immature fruit, the color of the ripe fruit, the outer color of the endocarps of the fruit and the taste of ripe fruit. To confirm the statements of riparian populations, field trips have allowed to observe a morphological variability on organs of the plant. The manifestations of this variability were remarkable especially on the leaves which are simple, stalked with an opposite phyllotaxy having a polymorphism important. Figure 1a illustrates the leaves of the plant on a vegetative fragment. On observation, the ripe fruits of the plant were indeed different in color (Figure 1b). By observing the leaves of the plant more closely, several forms of the apex (Figure 1c, d and e) were similarly visible for the bases (Figure 1c, d and e) and the edges (Figure 1c, d and e) of those -this. Given the various pressures faced by plants, they still live in the wild in this agro-ecological zone of which *S. guineense* var. *macrocarpum* is the most overexploited (Tchotsoua *et al*. 2000, Tchotsoua *et al*. 2010, Tchobsala *et al*. 2010, Tchobsala & Mbolo 2013, Tchobsala *et al*. 2016). Base on the above, the Laboratory of Biodiversity and Sustainable Development of University of Ngaoundere initiated a domestication program for endangered species among which *S. guineense* var. *macrocarpum* (Mapongmetsem 2017, Mapongmetsem *et al*. 2015). According to

Doumara and Mapongmetsem (2013), the domestication of *S. guineense* var. *macrocarpum* is possible in particular by vegetative propagation of the stem. According to these authors, the sawdust (50%) / black earth (50%) mixture and the position of node 3 significantly improve the rooting capacity of the plant. In addition, the results of Mapongmetsem and Diksia (2013) indicate that *S. guineense* var. *macrocarpum* is easily propagated by air layering. In fact, the selected branches of average diameter ≤ 6.67 cm give roots after 3 months. All these domestication techniques are less expensive and easily accessible by local residents. Unfortunately, these researchers face a difficulty, which of the reproducibility of the significant results on several tests. This difficulty could be linked to the existence of sub-varieties of the plant. Indeed, ignoring the existence of sub-varieties of the plant, these researchers use the same technique of domestication on the fragments of stems or roots belonging to different sub-varieties and obtain different results. Fortunately, a recently published article in the ethnobotany field, highlighting the existence of sub-varieties of *S. guineense* var. *macrocarpum* provides a solution to this problem (Lamy *et al*. 2018). In view of the morphological variations observed on the parts of the four sub-varieties of the plant and the difficulty of domesticating them, it is urgent to determine the significant qualitative and quantitative morphological descriptors of fruits and leaves to be considered during the domestication of these plants. Taking these results into account will be useful for tree conservation and selection efforts to domesticate it so that harvest pressures on its wild populations can be reduced. This will enable the tree to perform its immediate economic functions more efficiently while also contributing to the ecological functions of agroforestry and forests in general. Taking into account the results of ethnobotanical studies in the plant domestication process is not new (Zarate 1999, Cunningham 2001, Volpato *et al*. 2004, Neto *et al*. 2014). The problem of the morphological variability of many plants in tropical Africa has already been addressed by many researchers in West Africa (Kouyaté *et al*. 2002, Assogbadjo *et al*. 2005, Djé *et al*. 2005, Kouyaté *et al*. 2005). Djé *et al*. 2007, Koffi *et al*. 2011, Osawaru *et al*. 2013, Dadegnon *et al*. 2014, Agoyi *et al*. 2015). Despite the volume of literature devoted to this problem in West Africa on various species, nothing has been done on the species *Syzygium guineense* (Willd.) DC var. *macrocarpum* (Engl.) F. White. In Cameroon, such works are rare, except those of Baye-Niwah (2015) and Baye-Niwah *et al*. (2018) on *Moringa oleifera*. The objective of this study is to determine the significant qualitative and quantitative morphological descriptors of the four sub-varieties of *S. guineense* var. *macrocarpum* in the Guinean Savannahs Highlands of Adamawa, Cameroon.

Material and methods

For the study, the leaves and fruits of the four sub-varieties of *Syzygium guineense* var. *macrocarpum* were collected in three different localities belonging to the agro-ecological zone of the Guinean Savannah Highlands of Adamawa, Cameroon (Figure 2). At all three sites, one hundred and thirty-two fruit bearing trees spaced at least twenty meters apart were randomly selected and marked with white paint to deter residents (Kouyaté 2005). Indeed, because of the rarity of some sub-varieties, the sampling rate was eleven feet of trees per sub-varieties. On each selected foot, three fresh, ripe and non-parasitized fruits and then three fresh and healthy leaves were randomly sampled for the different measurements. The measures concerned respectively a set of three hundred and ninety-six fruits and leaves of the four sub-varieties of the plant. The experimental plan is a split plot (3 x 4 x 11 x 3) with:

- 33 (11x3) for the experimental unit;
- 3 for the number of study sites;
- 4 for the number of sub-varieties;
- 3 for the number of repetitions (3 leaves and 3 fruits on each foot).

The main treatment consists of the study sites while the secondary treatment is represented by the sub-varieties.

Overall, thirty descriptors based on morphological characters that were previously used (Bonny & Djé 2011, Koffi *et al*. 2011), including sixteen quantitative and fourteen qualitative were measured (Table 2; Table 3).

On the feet of each sub-variety, the determination of the height of the tree (HTE) was carried out using a dendrometer. The use of a decametre made it possible to measure the diameter of the treetop (DTP). On the trunks of different sub-varieties were measured at 1.30 m from the ground: the tree circumference (CTE), the height of the first large living branch (HFB) and the breast height diameter (BHD). The location of the feet of the selected sub-varieties was done using Global Positioning System (GPS) (Table 1).

For each selected sheet, the descriptors measured using a millimeter sheet and a 30 cm long ruler included: the width of the sheet (SWI), the length of the sheet (LSH), petiole length (PLE) and petiole diameter (DPE) (Table 2). The length of the leaf was measured from the end of the petiole which is

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inserted on the stem to the apex of the leaf. The width of the leaf was measured at half the length of the leaf. The petiole length was measured between the petiole base and the leaf insertion point (Kouyaté 2005, Baye-niwah 2015, Hamawa 2015).

The sliding caliper made it possible to measure the descriptors of the fruit, namely: the long axis (LAF) measured from the point of attachment to the branch to the end of the fruit, the small axis (SAF) (Table 2) evaluated in the middle of the large axis of the fruit, then the relationship between the long axis and the small axis was established (RLF/SAF) (Kouyaté 2005, Hamawa 2015). A miniaturized scales of precision made it possible to determine the fresh weight of each fruit by weighing.

Analysis

An analysis of variance (ANOVA) to compare the various data described was performed (Table 4). Significant traits were then subjected to principal components analysis (PCA) and hierarchical ascending classification (HAC). The software exploited is Statgraphics plus for ANOVA and XLSTAT (2019) for PCA and HAC.

Results and discussion

Qualitative morphological descriptors

Since the measurements concerned 396 leaves and 396 fruits belonging to the four sub-varieties of *Syzygium guineense* var. *macrocarpum*, the different descriptors identified were evaluated by percentage. A value of 100% has been assigned to all (396) leaves or fruits. The sub-varieties of *Syzygium guineense* var. *macrocarpum* are distinguishable from the descriptor "shape" apex of its leaves (Table 3). Indeed, the apex has six different "shapes". The major variants of the descriptor "shape" are respectively acute (26.52%), rounded (20.20%) and acuminate (20.20%). Nevertheless, the variable truncated is less (6.57%) remarkable. The results revealed by this study on the shape of the leaf apex of *Syzygium guineense* var. *macrocarpum* (acute and obtuse) are similar to those previously reported (Ash *et al*. 1999).

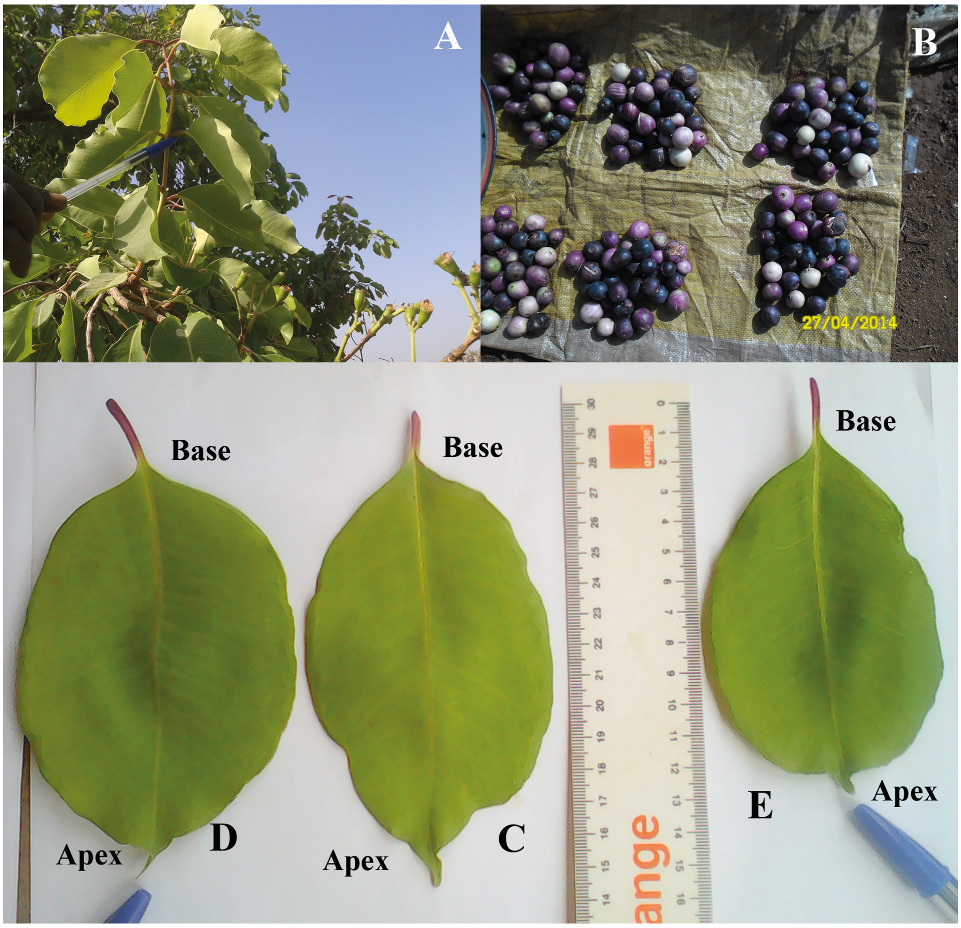

Figure 1. Vegetative fragment (a), fruits (b), leaf margins (c, d and e), leaf bases (c, d and e) and leaf apex forms (c, d and e) of *Syzygium guineense* var. *macrocarpum* from Adamawa, Cameroon (Photo. LAMY).

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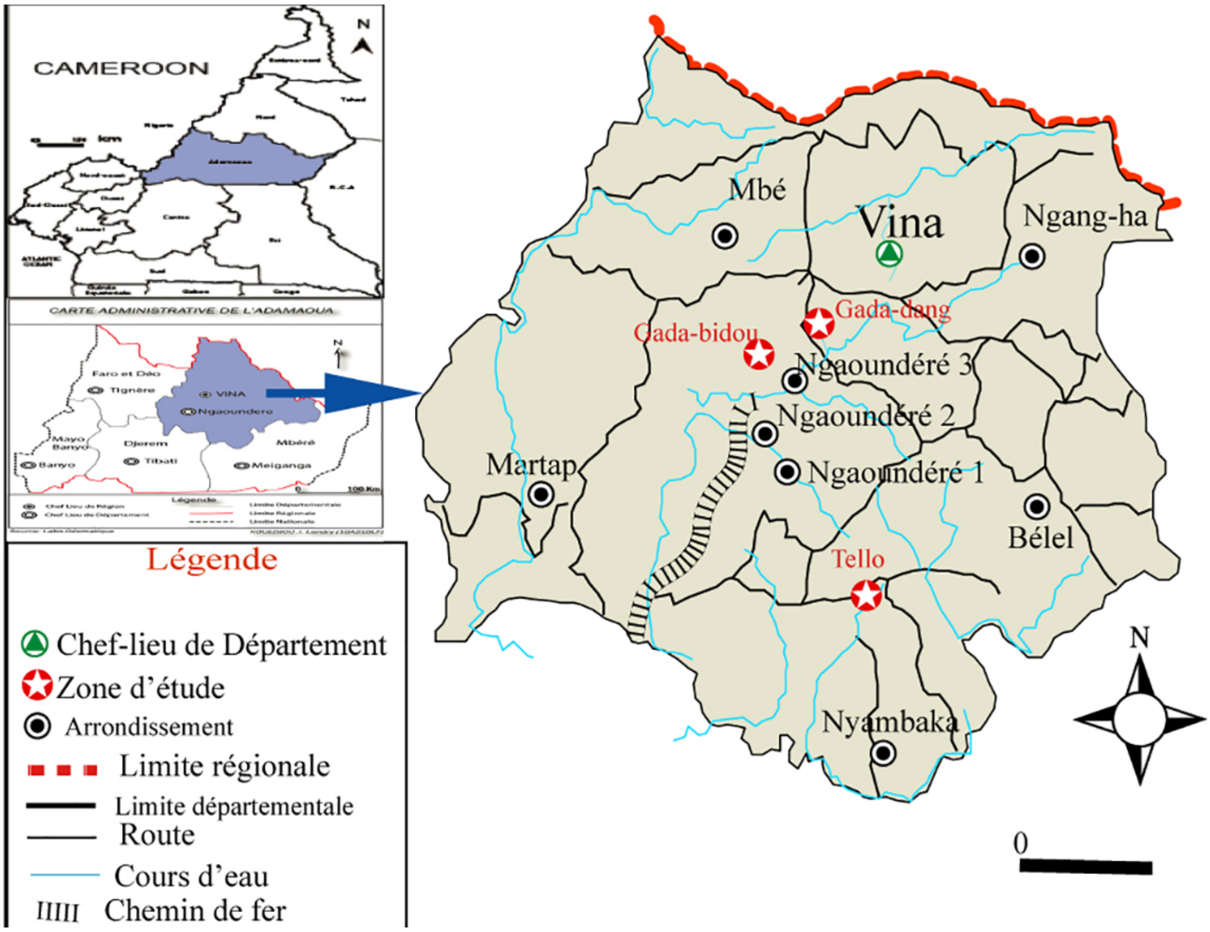

Figure 2. Location of study zones

Table 1. Geographical coordinates of the sub-varieties of *Syzygium guineense* var. *macrocarpum* (Adamawa, Cameroon)

Location Sites	Latitude (E)	Longitude (N)	Altitude (m)	Sub-varieties (Sv)
***Gada-bidou* (Gb)**	013°33.878'	07°25.222'	3589	**Sv** 1 (*Langaou 1*)
	013°33.877'	07°25.216'	3583	**Sv** 2 (*Langaou 2*)
	013°33.884'	07°25.209'	3590	**Sv** 3 (*Gormagna*)
	013°33.883'	07°25.208'	3585	**Sv** 4 (*Lembali ngambgwar*)
***Gada-dang* (Gd)**	013°31.026'	07°25.333'	3596	**Sv** 1 (*Langaou 1*)
	013°30.359'	07°26.499'	1115	**Sv** 2 (*Langaou 2*)
	013°30.339'	07°26.498'	1217	**Sv** 3 (*Gormagna*)
	013°31.367'	07°25.489'	3562	**Sv** 4 (*Lembali ngambgwar*)
***Tello* (To)**	014°08.592'	07°10.115'	4807	**Sv** 1 (*Langaou 1*)
	014°08.427'	07°10.339'	4780	**Sv** 2 (*Langaou 2*)
	014°08.345'	07°10.287'	4736	**Sv** 3 (*Gormagna*)
	014°08.351'	07°10.293'	4755	**Sv** 4 (*Lembali ngambgwar*)

Legend: Sv 1, Sv 2, Sv 3 et Sv 4 respectively Sub-variety 1, 2, 3 et 4

Table 2. Quantitative morphological characteristics of leaves and fruits of *Syzygium guineense* var. *macrocarpum* sub-varieties (Adamawa, Cameroon)

Quantitative Morphological Characteristics (Leaf)	Associated codifications
(**1**) Length of the sheet	LSH (cm)
(**2**) Sheet width	SWI (cm)
(**3**) Petiole length	PLE (cm)
(**4**) Diameter of the petiole	DPE (cm)
(**5**) Number of right secondary nervures	NRN (cm)
(**6**) Number of left secondary nervures	NLN (cm)
(**7**) Right secondary nervure length	RNL (cm)
(**8**) Secondary left nervure length	SNL (cm)
(**9**) Circumference of the tree	CTE (cm)
(**10**) Height of the tree	HTE (m)
(**11**) Diameter of the treetop	DTP (m)
(**12**) Height of the first big branch	HFB (cm)
Quantitative Morphological Characteristics (Fruit)	**Associated codifications**
(**13**) Fruit weight	FWE (g)
(**14**) Long axis of the fruit	LAF (cm)
(**15**) Small axis of the fruit	SAF (cm)
(**16**) Long axis ratio of fruit on small axis of fruit	RLF/SAF (cm)

Regarding the leaf of the plant, the descriptor "shape" has three variables including cordate (26.6%), oval (30%) and elliptical (43.4%) (Table 3). Thus, in the study area, the leaf shape of the most representative plant is elliptical. Many studies showed that the shape is used to recognize the leaves of plants (Chaki & Parekh 2011, Munisami *et al*. 2015).

The descriptor "shape" of the leaf base of *S. guineense* var. *macrocarpum* ranges from obtuse (20%), to acute (33.3%), passing from oblique (20%) and acuminate (26.7%) (Table 3). Some revealed variants of the base (acute and obtuse) of the plant leaves are already known (Ash *et al*. 1999, Nandyal *et al*. 2013).

The whole "shape" is the descriptor characterizing predominantly (76.52%) leaf margins of the plant's sub-varieties in the study area. This result is consistent with that reported by Wilson *et al*. (2001) who states that whole leaves are among the distinguishing characteristics of the Myrtaceae family.

Numerous leaf descriptors to differentiate the sub-varieties of *S. guineense* var. *macrocarpum* are in agreement with previously established leaf characterization standards (University of Florida 2012). According to Chebbi *et al*. (1995), some traits such as leaf morphology are a significant tool for distinguishing plant species.

The morphological descriptors for differentiating the plant's sub-varieties from the fruit are 'color', 'shape', 'taste' and 'cracks' (Table 3). The sweet taste is the most important (50%), the ovoid form the most remarkable (40%), the presence of cracks on the fruits mostly of purple color (40%) being significant (93,3%). These results are different from those reported according to which the fruit of *Syzygium guineense* var. *macrocarpum* is globose to elliptic, smooth, 1.2 to 1.8 cm long, crowned at the apex by the calyx scar, mature, shiny and purplish black (Arbonnier 2009).

The descriptors of the leaves and fruits of the sub-varieties of *Syzygium guineense* var. *macrocarpum* whose has not yet been reported reflects variation over the years in the plant. This variation would explain the existence of the sub-varieties of this plant of the Myrtaceae family. The study of the variability of qualitative morphological descriptors of *S. guineense* var. *macrocarpum*, reveals mainly a very significant variability in the study area.

Quantitative morphological descriptors

Whatever the quantitative descriptor analyzed, the Tello study area (site 1) is in pole position followed by Gaga-Bidou (site 2) and finally Gada-Dang (site 3) (Table 4). The positioning of choice Tello area compared to the others could be explained by the peculiarity of soil and climatic parameters encountered in it. Indeed, Tello is a locality where the biodiversity especially the plants is still valued by the population. Thus, the nature of the substrate to be

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taken into account during the domestication of the sub-varieties of *S. guineense* var. *macrocarpum* will have to be decisive. Indeed, it will be question of determining for example between the sand, the black earth, the sawdust, the mixture between substrate, etc. which substrate (s) give (s) significant results in the domestication of the sub-varieties of the plant. In the study area, the mean fruit axis ratio of fruit (RLF / EF) is 0.53 ± 0.01 mm (Table 4). The values of this descriptor oscillate between 0.48 mm (site 3) and 0.65 mm (site 1). The long axis ratio of fruit on small axis of the fruit (RLF / EF) reveals an average of 0.53 mm. According to Clopton (2004), this ratio makes it possible to determine the shape of a fruit according to the value found. Indeed, this author claims that the ovoid form belongs to the series 7 whose value of the ratio RLF / EF is equal to 0.50. So, the fruits of *S. guineense* var. *macrocarpum* have an ovoid form in the Guinean Savannah Highlands of Adamawa, Cameroon. The qualitative results (Table 3) showing that the most represented form of the fruit is ovoid are in agreement with the quantitative ones.

There is a significant difference (0.000 < 0.05) between the study sites regardless of the quantitative morphological descriptor analyzed. This result shows that all the sixteen quantitative morphological descriptors used in this study are discriminating for the sub-varieties of the plant. Thus, all these descriptors were used for hierarchical ascending classification (HAC) and principal component analysis (PCA). The variations observed from one study site to another could be explained by the combination of pedological, climatic and molecular factors. Indeed, there would are interactions between the soils harboring the sub-varieties of the plant, the climate of the study area and the genomic DNAs (Desoxyribo Nucleic Acid) of each sub-variety.

Table 3. Qualitative morphological descriptors of the organs of the sub-varieties of *Syzygium guineense* var. *macrocarpum* of the Guineans Savannahs Highlands of Adamawa, Cameroon

Qualitatives morphological characters			**Distribution**	
Plant parts	**Descriptors**	**Observations and Codifications**	**Proportions**	**(%)**
(**1**) Apex	Shape	Acute (FAP 1)	105	26,52
		Rounded (FAP 2)	80	20,20
		Acuminate (FAP 3)	80	20,20
		Emarginate (FAP4)	66	16,67
		Obtuse (FAP5)	39	9,84
		Truncate (FAP 6)	26	6,57
	Total		**396**	**100**
(**2**) Bark of the tree	Exterior appearance	Rough (CDA 1)	44	33,33
		Smooth (CDA 2)	44	33,33
		Smooth-rough (CDA 3)	44	33,34
	Total		**132**	**100**
(**3**) Bark of the tree	Color	Light gray (CDE 1)	33	25
		Dark gray (CDE 2)	33	25
		Yellowish (CDE 3)	33	25
		Blackish (CDE 4)	33	25
	Total		**132**	**100**
(**4**) Leaf	Color	Purplish (CFE 1)	92	23,23
		Light green (CFE 2)	184	46,47
		Dark green (CFE 3)	120	30,30
	Total		**396**	**100**
(**5**) Leaf	Shape	Cordiform (FF 1)	105	26,6
		Elliptical (FF 2)	172	43,4
		Oval (FF 3)	119	30
	Total		**396**	**100**
(**6**) Ripe fruit	Color	Green (CFM 1)	39	10
		Violet (CFM 2)	158	40
		Striped purple green (CFM 3)	93	23,3
		Black (CFM 4)	106	26,7
	Total		**396**	**100**
		Yes (FF 1)	369	93,3

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(**7**) Ripe fruit	Crack	No (FF 2)	27	6,7
	Total		**396**	**100**
(**8**) Ripe fruit	Shape	Ovoïd (FFo 1)	158	40
		Ovoïd-globular (FFo 2)	132	33,4
		Globular form (FFo 3)	106	26,6
	Total		**396**	**100**
(**9**) Ripe fruit	Taste	Sweet (GFM 1)	132	50
		Not very sweet (GFM 2)	198	33,3
		Bitter (GFM 3)	66	16,7
	Total		**396**	100
(**10**) Seed	Endocarp color	White (CEG 1)	40	10
		Violet (CEG 2)	356	90
	Total		**396**	**100**
(**11**) Base	Shape	Acute (BAL 1)	133	33,3
		Acuminate (BAL 2)	105	26,7
		Oblique (BAL 3)	79	20
		Obtuse (BAL 4)	79	20
	Total		**396**	**100**
(**12**) Margin	Shape	Entire (BOL 1)	303	76,52
		Crenate (BOL 2)	53	13,38
		Lobate (BOL 3)	20	05,05
		Undulate (BOL 4)	20	05,05
	Total		**396**	**100**
(**13**) Petiol	Color	Green front face (CP 1)	106	26,7
		Purple face-back (CP 2)	158	40
		Purple above, green low (CP 3)	132	33,3
	Total		**396**	**100**
(**14**) Petiol	Size	Short (DDP 1)	132	33,33
		Medium (DDP 2)	132	33,33
		Long (DDP 3)	132	33,34
	Total		**396**	**100**

NB. **396** represents repectively the total number of fruits and leaves of plant sub-varieties used. **132** represents the total number of trees sub-varieties selected.

Distribution of trees in space

The proper values and percent variance of each factor (axes) are reported in Table 5. Only the factors (axes) with proper values greater than one were selected for the principal component analysis (N'DA *et al*. 2014) carried out using the XLSTAT software (2019). Thus, the first two axes of eigenvalue > 1, which alone describe 77.91% of the total variability observed within the sub-varieties of the plant, were retained.

The representation of the sub-varieties and study areas according to the F1 and F2 axes gives groups that can be characterized by certain descriptors (Fig. 3). Thus, we distinguish two groups:

- The first group is distinguishable by a circled blue (color that allows to establish the difference with the second group). This group, located on the positive side of the F1 axe is characterized by the descriptors involved in the vegetative development including the length of the leaf (LSH) and the number of left lateral veins (NLN) and by descriptors with favorable flowering and fruiting, namely fruit thickness (SAF), fruit length (LAF) and fruit thickness to fruit length ratio (RLFEF). This group highlights the sub-varieties of the plant with significant flowering and fruiting and a fairly considerable vegetative development in the study area.

- The second group materialized by the circle of green color (which makes it possible to establish the difference with the first group) is located on the negative side of the axis F2. This group is characterized by descriptors mainly involved with accessibility to the favorable tree, particularly the

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height of the tree (HTE), the height of the first big living branch (HFB), tree circumference (CTE) and crown diameter (DTP). In addition, descriptors implicated moderately to vegetative development such as fruit width (SWI), petiole length (PLE), length of right lateral vein (RNL), length of left lateral vein (SNL), the petiole diameter (DPE) and the number of right lateral veins (NRN) are observed in this group. Finally, only one descriptor including the fruit weight (FWE) involved in flowering and fruiting is observed in this second group. The second group highlights the sub-varieties of the plant having mainly a significant tree accessibility, a fair vegetative development and a weak flowering and fruiting stage.

Principal component analysis (PCA) of the morphological descriptors of the sub-varieties of *S. guineense* var. *macrocarpum* shows that structuring of morphological variability is done by the descriptors of tree accessibility (HFB, CTE and DTP) especially of the accessibility to the brightness of the tree (HTE); fruiting (SAF, LAF, FWE and RLFSF) and vegetative development (DPE, SWI, PLE, LSH, NLN, NRN, SNL and RNL). These results show that the different plant sub-varieties are distributed randomly in the Guinean Savannah Highlands of Cameroon. Similar results have previously been reported for other species (Kouyaté *et al*. 2002, Assogbadjo *et al*. 2005, Djé *et al*. 2005, Djé *et al*. 2007, Koffi *et al*. 2011). The contribution of these variables to this structuring of morphological variability could be explained by the fact that they are extremely important in the selection criteria used during plant selections by riparian populations. Indeed, the height of the tree (HTE) contributes to the decrease of the speed of the wind by offering a resistance to displacements of the air (Lessard & Boulfroy, 2008). Foliage observations of the plant in the field based on the venation and margins indicate simple leaves (whole, etc.) with secondary veins (NRN, RNL, NLN and SNL). According to Bouzid (2016), a plant leaf is described by different observable characters.

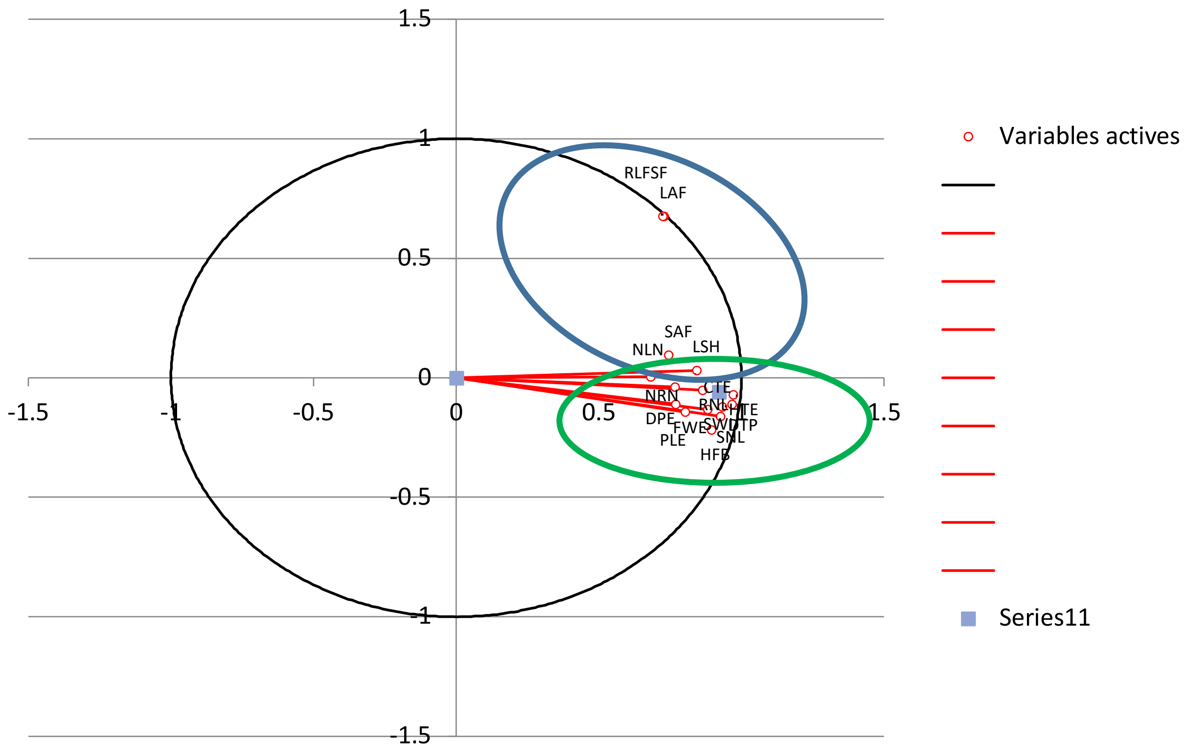

Figure 3. Projection of plant sub-varieties descriptors on the plane formed by axes 1 and 2. Circled blue materialized to the first group and circle of green color to the second group. DPE (Diameter of the petiole), FEW (Fruit weight), HFB (Height of the first big branch), LAF (Long axis of the fruit), LSH (Length of the sheet), NRN (Number of right secondary nervures), PLE (Petiole length), RLF/SAF (Long axis ratio of fruit on small axis of fruit), SAF (Small axis of the fruit), SNL (Secondary left nervure length).

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Depending on the disposition of the veins on the limb (called venation), we distinguish different types of leaves. Single leaves (pennate and palmatinerves) with a medial or principal vein separating the limb into two parts and emitting secondary veins (or nerves) and compound leaves (paripeneous and impariparous). Conducting vessels in the veins of the leaf provide the water and mineral salts necessary for photosynthesis. The absence of the study sites and the feet of the sub-varieties of the distribution in space according to the two main axes could be explained by the fact that these zones of study and these trees were not been taken into account among the main components having an proper value greater than one.

Table 4. Analysis of variance (ANOVA) of the morphological descriptors of the fruit, leaf and tree of the plant sub-varieties in 3 study sites of the Guinean Savannah Highlands of Adamawa, Cameroon

	Leaf morphological descriptors							
Study areas	**DPE (mm)**	**SWI (mm)**	**PLE (mm)**	**LSH (mm)**	**RNL (mm)**	**SNL (mm)**	**NRN**	**NLN**
1 (*Tello*)	15,06 ± 0,18	101,05 ± 0,70	25,07 ± 0,32	153,29 ± 1,03	45,04 ± 0,37	44,04 ± 0,25	22,39 ± 0,20	23,53 ± 0,30
2 (*Gada-Bidou*)	12,05 ± 0,18	79,97 ± 0,70	20,0 ± 0,32	112,27 ± 1,03	34,05 ± 0,37	34,40 ± 0,25	18,31 ± 0,20	18,40 ± 0,30
3 (*Gada-Dang*)	08,64 ± 0,18	61,82 ± 0,70	13,23 ± 0,32	106,20 ± 1,03	27,48 ± 0,37	22,98 ± 0,25	16,0 ± 0,20	16,17 ± 0,30
Means	**11,91 ± 0,18**	**80,94 ± 0,70**	**19,43 ± 0,32**	**123,92 ± 1,03**	**35,52 ± 0,37**	**37,89 ± 0,25**	**18,9 ± 0,20**	**19,31 ± 0,30**

	Fruit morphological descriptors				Tree morphological descriptors			
Study areas	**FWE (g)**	**SAF (mm)**	**LAF (mm)**	**RLF/EF (mm)**	**CTE (cm)**	**DTP (m)**	**HTE (m)**	**HFB (cm)**
1 (*Tello*)	23,88 ± 0,23	10,59 ± 0,09	6,84 ± 0,06	0,65 ± 0,01	76,57 ± 0,74	7,80 ± 0,03	10,00 ± 0,04	113,05 ± 0,99
2 (*Gada-Bidou*)	14,15 ± 0,23	07,76 ± 0,09	05,07 ± 0,06	0,48 ± 0,01	46,24 ± 0,74	4,89 ± 0,03	06,35 ± 0,04	87,28 ± 0,99
3 (*Gada-Dang*)	05,99 ± 0,23	07,65 ± 0,09	05,06 ± 0,06	0,48 ± 0,01	25,46 ± 0,74	2,18 ± 0,03	03,96 ± 0,04	50,38 ± 0,99
Means	**14,67 ± 0,23**	**8,19 ± 0,09**	**05,65 ± 0,06**	**0,53 ± 0,01**	**49,42 ± 0,74**	**4,18 ± 0,03**	**6,77 ± 0,04**	**83,57 ± 0,99**

Table 5. Principal component and proper values selected

Principal component	**F1**	**F2**	**F3**
Proper values	**11,38**	**1,08**	0,59
Variability (%)	71,12	6,79	3,73
% Cumulated	71,12	77,91	81,64

Hierarchical ascending classification

Significant quantitative morphological descriptors were subjected to hierarchical ascending classification (Fig. 4). The sixteen morphological descriptors of the four sub-varieties of *Syzygium guineense* var. *macrocarpum* were grouped according to their similarity in descending order from descriptors with the highest percentage of similarity. The number of groups decreases as the percentage decreases while the number of descriptors cluster. The descriptors of all the sub-varieties are different for a similarity of 100%. At the 64.95% similarity level, no descriptors of the sub-varieties are found without a subgroup. Indeed, all these descriptors belong to one of the four subgroups formed. The first subgroup (1) is formed by twelve descriptors (LSH, SWI, PLE, DPE, NRN, RNL, SNL, CTE, HTE, DTP, HFB and FWE) belonging to the four different sub-varieties of the plant from the three study zone. The second (2) and fourth (4) subgroups consist respectively of a single NLN and SAF descriptor. While the third (3) subgroup has two descriptors (LAF and RLFSF). The hierarchical ascending classification (CAH) allowed to divide the morphological descriptors of the sub-varieties of the plant into four subgroups reflecting a strong morphological variability of *Syzygium guineense* (Willd.) DC. var. *macrocarpum* (Engl.) F. White, in the Guinean Savannah Higlands of Cameroon.

Conclusions

From the results of ethnobotanical studies reporting four sub-varieties of *Syzygium guineense* var. *macrocarpum* with morphological variability in leaves and fruits, significant qualitative and quantitative descriptors of these organs have been identified. Thus, the leaves of the sub-varieties of *Syzygium guineense* var. *macrocarpum* to be taken into account when domestication of the plant should be characterized by an entire margin, an acute apex, an acute base and a light green color. As for the fruits, they should be characterized by the presence of cracks, a violet color, a sweet taste and an ovoid shape. In the study area, the locality of Tello is recommended for the sub-varieties whose descriptors are significantly involved in the accessibility to the tree (HFB, CTE and DTP) especially the accessibility to the brightness of the tree (HTE); fruiting (SAF, LAF, FWE and RLFSF) and vegetative development (DPE, SWI, PLE, LSH,

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NLN, NRN, SNL and RNL). Molecular studies (genomic DNA) will have to be carried out as a result of this work. It will definitively conclude on the environmental or molecular origin of the variability observed within *Syzygium guineense* var. *macrocarpum* in the study area.

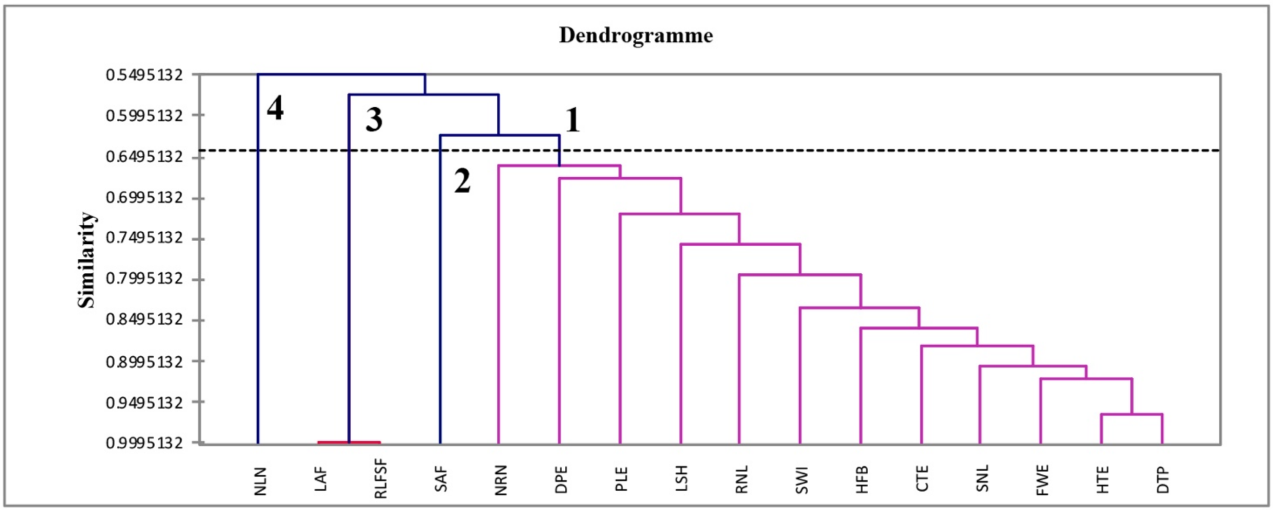

Figure 4. Grouping of the 16 quantitative morphological descriptors of the 4 sub-varieties of the plant around 4 subgroups.1, 2, 3 and 4 are respectively the first, second, third and fourth subgroup. CTE (Circumference of the tree), DPE (Diameter of the petiole), DTP (Diameter of the treetop), FEW (Fruit weight), HFB (Height of the first big branch), HTE (Height of the tree), LAF (Long axis of the fruit), LSH (Length of the sheet), NLN (Number of left secondary nervures), NRN (Number of right secondary nervures), PLE (Petiole length), RLF/SAF (Long axis ratio of fruit on small axis of fruit), RNL (Right secondary nervure length), SAF (Small axis of the fruit), SNL (Secondary left nervature length), SWI (Sheet width).

Declarations

List of abbreviations:

Abbreviations: Significations
ANOVA: Analysis of variance
CTE: Circumference of the tree
DNA: Desoxyribo Nucleic Acid
DPE: Diameter of the petiole
DTP: Diameter of the treetop
FWE: Fruit weight
GPS: Global Positioning System
HAC: Hierarchical ascending classification
HFB: Height of the first big branch
HTE: Height of the tree
LAB2D: Laboratory of Biodiversity and Sustainable Development
LAF: Long axis of the fruit
LSH: Length of the sheet
NLN: Number of left secondary nervures
NRN: Number of right secondary nervures
PCA: Principal component analysis
PLE: Petiole length
RLF/SAF: Long axis ratio of fruit on small axis of fruit
RNL: Right secondary nervure length
SAF: Small axis of the fruit
SNL: Secondary left nervure length
SWI: Sheet width

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Consent for publication:“Not applicable”.

Availability of data and materials*:* No datasets have been deposited in public repositories.

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