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Perceived variation of fruit traits, and preferences in African locust bean [*Parkia biglobosa* (Jacq.) Benth.] in Benin: implications for domestication

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Abstract Understanding folk classification system of perceived variation and preferences in fruit traits are necessary to effectively engage farmers in the domestication of wild edible fruit tree species. Social attributes can help to better understand perception of variation, and preferences. We focused on *Parkia biglobosa* (Jacq.) Benth., a valuable fruit tree in Benin, examining the folk classification systems and preferences for fruit morphotypes, and the extent to which they are related to social attributes in the two major climatic zones of its occurrence in Benin. Using random sampling, we selected 648 informants for individual semi-structured interviews which focused on recognized morphotypes, local classification system, and both desirable and undesirable traits related to pod, pulp, and seeds. Data were analyzed using relative frequency of citation, and principal component analysis. Informants used similar criteria to differentiate fruits of species including pod shape (RFC = 100%), pulp yield (RFC = 100%) and number of seeds per pod (RFC = 99.84%), color (RFC = 100%) and taste (RFC = 99.84%) of pulp as well as brightness (RFC = 99.07%) and color (RFC = 100%) of seed. Informant's preferences were marked for fruits containing large number of seeds with larger size and of good seed quality. Sweetness of the pulp was also mentioned, though some differences were noted among gender and sociolinguistic groups. Our findings provide essential information for decision-making for effective domestication initiatives. To advance further domestication, while conserving essential genetic resources, quantitative morphological and molecular characterization of the observed variations in *P. biglobosa* are needed.

Keywords African locust bean · Domestication · Agroforestry systems · West Africa

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Introduction

Consistent with Souto and Ticktin (2012), empirical work has illustrated that folk classification systems of plant species mostly rely on social attributes of local communities (Loko et al. 2018; Mekbib 2007). As a result, these studies generally support the hypothesis

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that folk classification systems of phenotypic trait in fruit trees can be determined by the socio-cultural and demographic characteristics of informants with some meaningful variations. Furthermore, previous findings showed that these variations can be linked to climatic conditions related to local environment of rural communities (Sop et al. 2012). Thus, an improved understanding of the role that social attributes play in determining perception of variation and preferences for locally acknowledged morphotypes from different climatic zones is needful (Diarassouba et al. 2008; Howard 2003). Such knowledge is relevant, as it allows to elucidate the necessary actions to ensure the sustainable management of indigenous fruit trees. This has been seen as the first step for fruit tree domestication and part of diversified household economy (Leakey 2019; Michon and De Foresta 1997).

A growing number of studies show that folk classification systems of the locally acknowledged morphotypes could provide a basis for setting domestication and conservation actions of many plant species (Jianchu et al. 2001; Mekbib 2006). For example, local people traditionally defined taxa or classifications for a given species based on phenotypic differences observed on its particular parts (e.g. fruits, seeds, leaves, pulp, etc.) or life stages (Rivera et al. 2006). In addition, the folk classification systems of biological resources are well known to be organized and culturally structured across the rural communities (Brown 1993; Holman 2002). As a result, folk classification based on species traits can serve as a valuable starting point for understanding variations in key phenotypic traits of plant species (Vodouhê et al. 2011) and therefore guide domestication. For example, folk classification system by distinguishing different morphotypes of a given species can highlight desirable and undesirable traits and therefore guide the selection of individuals with desirable traits while defining actions to ensure that individuals with undesirable traits are saved in secured places. In instance, classification systems of locally recognized morphotypes of tamarind has been used to select interesting genotypes for its domestication (Fandohan et al. 2011).

Parkia is a pantropical genus of about 30–40 tree legume species of considerable evolutionary, taxonomic, biological and economic importance in Africa, Asia and South America (Luckow and Hopkins 1995). In the genus, *Parkia biglobosa* (Jacq.) Benth. is a multipurpose tree legume of considerable importance from West African savanna. The species, also known as African locust bean, constitutes one of the most common species of traditional agroforestry systems providing several non-timber forest products (Ouédraogo 1995). Thus, *P. biglobosa* plays an important role in the livelihoods of local people such as food, supply of timber, firewood, fodder, green manure, fuel, pulp and restoration of soil fertility (Koura et al. 2011; Nyadanu et al. 2017). For example, whole pods are eaten by local people including cattle. The young seedlings are nutritious and heavily browsed by livestock. It is also used for domestic and medicinal purposes as a mouthwash, vapour inhalant for toothache, or for ear complaints. Bark is macerated in baths for leprosy and used for bronchitis, pneumonia, skin infections, sores, ulcers, and washes for fever, malaria, diarrhoea, and sterility. Roots are used in a lotion for sore eyes. Pulp is used as water purifier and disguises taste of foul water (Dedehou et al. 2016; Ouédraogo 1995). During food shortage and drought periods in the region, *P. biglobosa* serves as food and nutrition security plant (Koura et al. 2011). Mature fruits are collected for food or condiment at the beginning of food shortage season when other foods become scarce. Despite its socio-economic importance for local people in this region, the species remains under constant pressure due to demographic pressure, animal rearing, expansion of agricultural activities, and overexploitation of its fruits (Lamien et al. 2011). Lack of effective conservation measures put at risk the remnant population of African locust bean trees in their natural habitats. Examining the classification systems underlying the locally acknowledged fruit trait variation with local preferences in *P. biglobosa* could provide important information to further the domestication and conservation of the species. Such studies can shed light on the state of conservation and development programs of African locust bean trees that mainly contribute to food, nutrition and income of rural communities from sub-Saharan Africa.

Here, we examined perception of variation and preferences in *P. biglobosa* fruit traits in Benin. Specifically, the study involves an ethnobotanical survey among local people encountered in two climatic zones (*semi-arid* vs *sub-humid*) where *P. biglobosa* is predominantly found in order to (1) document folk classification systems of fruits of *P. biglobosa*, and (2) determine local preferences in

terms of both desirable and undesirable traits regarding *P. biglobosa* fruits as well as reasons supporting those preferences. Such study would give important insights towards advancing the domestication of this IFT and the intensification of plant production through traditional agroforestry systems in Benin.

Material and methods

Study species

Parkia biglobosa also known as "néré" or "African locust bean" is a perennial tree belonging to the Mimosoideae family. The natural range of *P. biglobosa* covers a broad area extending from Senegal in the West to Uganda in the East and includes Sudanian and Guineo-Congolese zones (Hall et al. 1997). In Benin, *P. biglobosa* is mainly found in semi-arid and sub-humid zones where it occurs in savannahs and woodlands, sometimes on rocky slopes, stony ridges and sandstone hills (Adomou 2005). Together with shea butter tree (*Vitellaria paradoxa* C. F. Gaertn.), *P. biglobosa* constitutes one of the major components of traditional agroforestry parklands in Benin. For instance, this fruit tree serves as source of wood, food, fodder, and medicine for local people (Koura et al. 2011). However, the species is subject to high anthropogenic pressure due to extensive agriculture, livestock-population pressures, and uncontrolled exploitation of its fruits, which have consequences such as rapid decline in natural stands, increase of landscape fragmentation and biodiversity erosion (Lamien et al. 2011). Therefore, elaboration of sustainable management policies and conservation actions are necessary for this intensively harvested fruit tree species across sub-Saharan Africa.

Study area

The study was conducted in the two climatic zones of Benin where *P. biglobosa* predominantly occurs: the semi-arid zone (between 9° 45′ N–12° 25′ N and 0° 45′ E–3° 55′ E) and the sub-humid zone (between 7° 30′ N–9° 45′ N and 0° 45′ E–3° 55′ E) (Akoègninou et al. 2006). Field data were collected in the districts of Bembèrèkè, Sinendé, Tanguiéta, Matéri, Toucountouna, and Natitingou in the semi-arid zone. For the sub-humid zone, they were collected in the districts of Nikki, Tchaourou, Bassila, Djougou, Savè and Djidja (Fig. 1). Each climatic zone encompasses three phytodistricts (Atakora Chain, Mekrou-Pendjari and North-Borgou) in the semi-arid zone, and (Bassila, South-Borgou and Zou) in the sub-humid zone (Adomou et al. 2011). In the semi-arid zone, mean annual rainfall is often less than 1000 mm and relative humidity varies between 18 and 99% with mean annual temperature ranging from 24 to 31 °C. The climate of the sub-humid zone is characterized by a unimodal rainfall pattern with an annual rainfall of 900–1110 mm. Temperature often varies between 25 and 29 °C annually with a relative humidity from 31 to 98%. Soils in this zone are ferruginous with variable fertility whereas hydromorphic soils, ferruginous soils and lithosols are the major soil types of the semi-arid zone. Native vegetation in the zone is characterized by woodlands, tree and shrub savannas whereas the vegetation in the sub-humid zone is dominated by a mosaic of woodlands, dry dense forests, tree and shrub savannas, and gallery forests (Adomou 2005). The study area is characterized by the rural communities belonging to a wide range of sociolinguistic groups practicing especially agriculture. Besides, the processing and trading of African locust bean fruits constitute other activities in which women are globally involved across the study locations.

Sampling scheme and data collection

Sampling

Based on the previous studies and early exploration in the study sites, the localities of abundance of *P. biglobosa* were identified across the phytodistricts of the two climatic zones in Benin encompassing various sociolinguistic groups. In each of these zones, the number (n) of informants to be surveyed was determined using the normal approximation of the binomial distribution (Dagnelie 1998):

$$n = \frac{U^2_{1-\frac{\alpha}{2}} p(1-p)}{d^2}$$

with n, the sample size considered in the given climatic zone; p the proportion of informants who hold knowledge and had experience on African locust bean tree. To compute the proportion p, a rapid survey on 50 informants was conducted for determining the sample

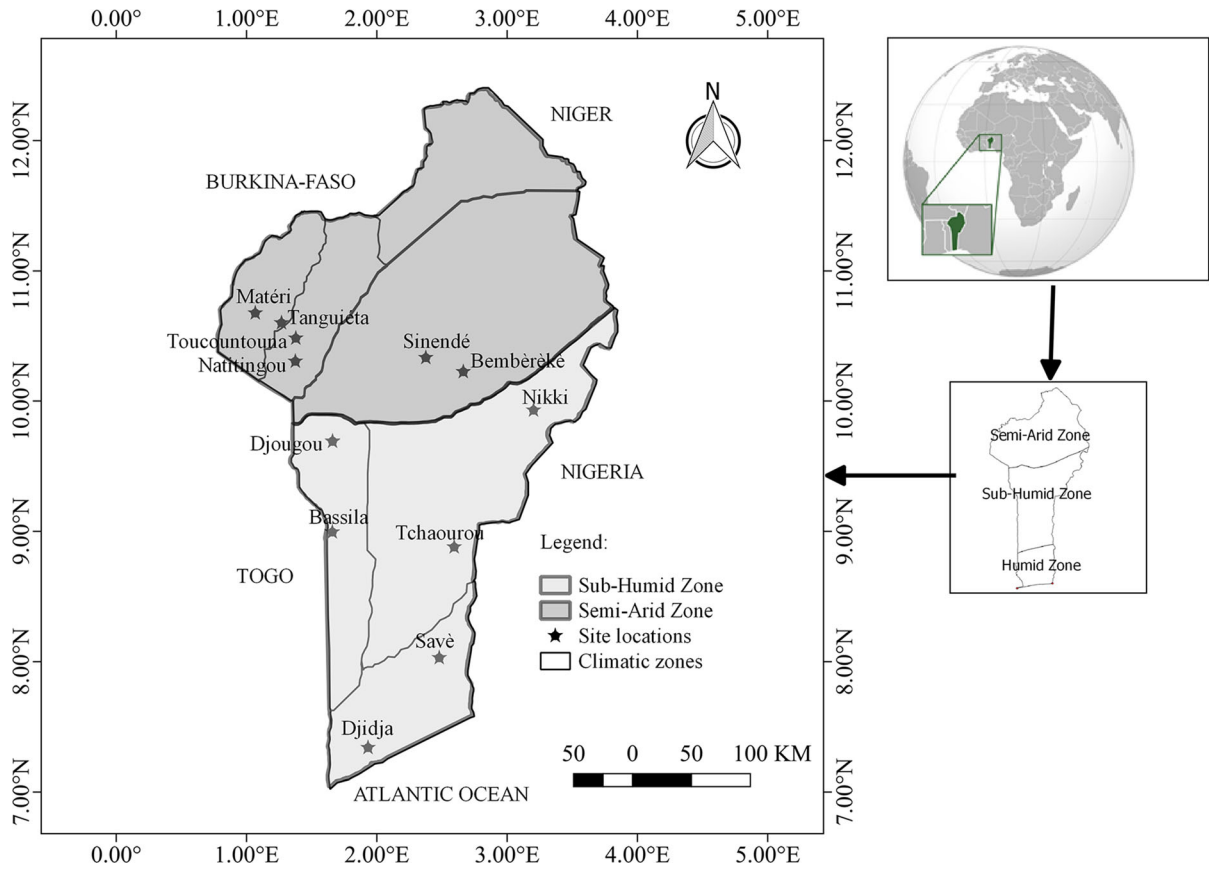

Fig. 1 The study area showing the two climatic zones and locations of selected districts

size. $U_{1-\alpha/2}{}^2$ is the value of the normal random variable for a probability value of $\alpha = 0.05$; $U_{1-\alpha/2}{}^2 = 1.96$. *d* is the expected error margin which was fixed at 8%. In whole, 648 informants were randomly selected and surveyed from the two climatic zones with 303 in the sub-humid zone (47%), and 345 in the semi-arid zone (53%). Informants were randomly selected in villages where the species is present, abundant, and fruits are known and used by local communities. The selection was based on the list of inhabitants (based on the most recent census of inhabitants in each village and available with the chief of village). More specifically, the informants were distributed among different villages of each district as follow: Frignon (37) and Tchétou (27) in the district of Bassila, Partago (17) and Onklou (38) in the district of Djougou, Guinirou (21) and Goro (17) in the district of Tchaourou, Gnanhoun (20) and Ourarou (21) in the district of Nikki, Savè-Centre (28) and Gobé (18) in the district of Savè, Dan (20) and Setto (39) in the district of Djidja across the sub-humid zone. Informants from the semi-arid zone were distributed as follow: Koudengou (39) and Bongou-Yotitingou (31) in the district of Natitingou, Cocota (38) and Nabarga (18) in the district of Toucountouna, Biakou (28) and Kountitéhoun (33) in the district of Tanguiéta, Kantchékoun (18) and Tampinti-Yérou (46) in the district of Matéri. Ina1 (27) and Ina2 (23) in the district of Bembèrèkè, and Kossia (21) and Kokabo (23) in the district of Sinendé.

Data collection

Prior to data collection, permission was granted by the heads of localities who were informed so as to facilitate our work. Then, an ethnobotanical survey was conducted throughout the study area using freely consented face-to-face individual semi-structured interviews. The survey targeted the rural communities of both sexes (men and women), different sociolinguistic groups and categories of age: young

(i < 30 years), adults (30 ≤ i < 60) and old people (i ≥ 60) following Assogbadjo et al. (2008) who hold knowledge and exploited different parts (organs) or derived products from African locust bean tree. Data were collected among these communities using the photos of the species organs (fruit, pulp, and seeds). The questionnaire had four parts (1) socio-demographic characteristics of the informant (age, gender, sociolinguistic group, and climatic zones), (2) vernacular names of species and meaning in the language of the informant, (3) folk knowledge on different fruit morphotypes of African locust bean tree, with criteria used to distinguish between them, and (4) preferences in terms of desirable and undesirable traits for fruit morphotypes derived from African locust bean tree with reasons supporting them such preferences.

Data analysis

Folk classification systems of fruits of African locust bean in Benin

The relative frequency of citation (RFC; Friedman et al. (1986) was computed to assess the importance of the criteria used in the folk classification. Those criteria were related to pod, pulp and seed and used by informants to distinguish morphotypes of *P. biglobosa* fruits. RFC was defined as followed:

$$\mathrm{RFC}(\%) = \frac{\mathrm{n}}{\mathrm{N}} * 100$$

with *n*, the number of informants citing a specific criterion; *N* the total number of informants surveyed.

To examine whether there is an association between socio-demographic factors and the criteria used by local people, informants were first grouped according to their social attributes namely gender, and sociolinguistic group making 22 sub-groups. Then a matrix presenting whether a criterion (in columns) is used (Yes = 1, No = 0) and informants (in lines) was submitted to multiple correspondence analysis. Unfortunately, no variation was detected among this matrix in order to perform such analysis.

Desirable and undesirable traits of fruits of P. biglobosa

RFC of desirable *vs* undesirable traits derived from the pod, pulp, and seed of *P. biglobosa* as perceived by informants were calculated in order to determine local preferences. To describe the relationships between desirable and undesirable traits and sub-groups (22 combining gender and sociolinguistic characteristics), the RFC of significant traits (with RFC ≥ 5%) (Gouwakinnou et al. 2011) were considered. This matrix was then submitted to a Principal Component Analysis (PCA). The same analysis was performed on the reasons supporting local preferences for given traits.

All statistical analyses were performed using the R software version 3.3.2. (R Core Team 2016). Thus, the principal component analyses were implemented in R software using the packages *FactoMineR* (Lê et al. 2008) and *Factoextra* (Kassambara 2017).

Results

Socio-demographic characteristics of informants

The socio-demographic characteristics of informants are summarized in Table 1. Both men and women were interviewed, with more men across the study sites (68.52%). In addition, most of informants were adults (84.10%) and young (11.58%). The Bariba (20.83%), the Waama (16.20%) and the Berba (14.81%) were the dominant sociolinguistic groups in the study area. The Anii, the Lokpa, the Yom, the Kotokoli, the Idaatcha and Mahi were encountered only in the sub-humid zone while Berba and Natimba were settled only in the semi-arid zone.

Vernacular names of *P. biglobosa* and their meaning

Informants named *P. biglobosa* using different local designations (Table 2). As can be expected, the designations differed across sociolinguistic groups. However, close groups used similar designations (e.g. Nago and Idaatcha). The designations were in reference to the role of the species in food and nutrition security during food shortage and drought periods (Table 2). For example, *P. biglobosa* was referred to as condiment tree, nourishing tree or protein fruit tree. Except the Anii, Nago and Peulh sociolinguistic groups who reported meaning of local designations of the species, no meaning was recorded among the other sociolinguistic groups.

Table 1 Socio-demographic profile of the informants across the study area

Characteristics	Modalities	Climatic zones		Total (n = 648)	Proportion (%)
		Sub-humid zone (n = 303)	Semi-arid zone (n = 345)		
Gender	Men	214	230	444	68.52
	Women	89	115	204	31.48
Age category (years)	Young: i < 30	31	44	75	11.58
	Adult: 30 ≤ i < 60	258	287	545	84.10
	Old: i ≥ 60	14	14	28	4.32
Sociolinguistic groups	Anii	51	-	51	7.87
	Lokpa	24	-	24	3.70
	Otamari	08	23	31	4.79
	Yom	31	-	31	4.79
	Bariba	52	83	135	20.83
	Nago	61	01	62	9.57
	Fon	61	02	63	9.72
	Waama	03	102	105	16.20
	Berba	-	96	96	14.81
	Natimba	-	29	29	4.48
	Others*	12	09	21	3.24

*Kotokoli, Idaatcha, Mahi and Peulh; Number n in parentheses is the sample size

Table 2 Local designations of *P. biglobosa* and meaning among sociolinguistic groups

Sociolinguistic groups	Local names	Meaning
Anii	*Gorê*	Condiment tree
Lokpa	*Sourourou*	-
Otamari	*Mounoua*	-
Yom	*Dobira*	-
Kotokoli	*Sourourou*	-
Bariba	*Donkoro/Donbourou*	-
Nago	*Egui-ougba*	Nourishing tree
Idaatcha	*Egui-ougba*	-
Fon	*Ahwatin*	-
Mahi	*Ahwatin*	-
Peulh	*Narely*	Protein fruit tree
Waama	*Doorbou*	-
Berba	*Nouorgue*	-
Natimba	*Norna*	-

–, No meaning reported

Folk classification systems and preferred traits of fruits, pulp and seeds of African locust bean tree

Criteria used to distinguish between fruits morphotypes of African locust bean

Local people used seven criteria to differentiate the fruits of African locust bean (Table 3). These criteria were related to the characteristics of the pod (shape, amount of pulp, and number of seed), pulp (color, taste), and seed (color, brightness). Thus, based on locally acknowledged variants, different morphotypes of fruits derived from *P. biglobosa* were distinguished in Benin (Fig. 2). Nine types of fruits were distinguished by local people using pod shape as criteria including Short-thick, short and less thick, elongated-thick, elongated and less thick, short-thick and heavy, short-less thick and heavy, elongated-thick and heavy, elongated-less thick-heavy and slight. Based on the amount of pulp and seed per pod as criteria, local people distinguished respectively fruits with low and high amount of pulp as well as fruits with high and low number of seeds. Using color and taste of pulp as criteria, two types were respectively distinguished by local people including yellowish and light-yellow color as well as sweet and slightly-acid taste. In terms of the color and brightness of seed, two types were respectively distinguished including brownish and blackish color as well as dull and bright in seeds of *P. biglobosa*.

Desirable and undesirable traits related to P. biglobosa fruits among rural communities

Informants reported several desirable and undesirable traits of the fruits of African locust bean tree (Table 3). More specifically, informants mostly desired the short-thick (8.80%), elongated-thick (17.44%),

Table 3 Relative frequency of citation (RFC, %) of criteria, distinguished traits, both desirable and undesirable traits in relationships to locally recognized morphotypes of *P. biglobosa* fruits

Fruit components	Criteria	RFC (%)	Perceived traits	RFC (%)	Desirable traits (%)	Undesirable traits (%)
Whole pod	Pod shape	100	Short and thick	99.85	8.80	4.78
			Short and less thick	99.85	0.46	11.42
			Elongated and thick	100	17.44	0.46
			Elongated and less thick	99.85	8.95	6.94
			Short, thick and heavy	89.20	88.12	0.00
			Short, less thick, and heavy	89.20	8.33	0.77
			Elongated thick heavy	77.62	83.18	0.00
			Elongated, less thick, and heavy	77.62	3.40	0.77
			Slight	77.62	0.00	87.35
	Amount of pulp per pod	100	Low	100	100	0.00
			High	100	0.00	100
	Amount of seed per pod	99.84	Low	99.84	0.00	100
			High	99.84	100	0.00
Pulp	Color	100	Yellow	100	77.47	0.31
			Light yellow	100	0.31	77.62
	Taste	99.84	Sweet	99.84	75.31	0.00
			Slightly acid	99.84	0.00	75.31
Seed	Color	100	Brownish	100	97.22	2.01
			Blackish	100	2.16	97.38
	Brightness	99.07	Bright	99.07	4.32	95.80
			Dull	99.07	95.06	3.58

Fig. 2 Variation in fruit traits of *P. biglobosa*: **a** pods harvested from trees, **b** pulp collected from harvested pods, **c** distinguished seed color of *P. biglobosa*, **d** short-less thick fruit, **e** short-less thick-heavy fruit, **f** slight fruit, **g** short-thick fruit, **h** short-thick-heavy fruit, **i** elongated-less thick fruit, **j** elongated-less thick-heavy fruit, **k** elongated-thick fruit, **l** elongated-thick-heavy fruit

elongated-less thick (8.95%), short-thick-heavy (88.12%), short-less thick-heavy (8.33%) and elongated-thick-heavy fruits (83.18%) with respect to pod shape. Similarly, the species' fruits containing a low amount of pulp (100%) with high amount of seed (100%) were desired regarding amount of pulp and seed per fruit. Informants also desired the fruits having yellow color (77.47%) and sweet taste (75.31%) of pulp in addition to the brownish (97.22%) and dull seeds (95.06%) derived from fruits.

In contrast, the short-less thick (11.42%), and slight fruits (87.35%) were mainly considered as undesirable by informants according to pod shape. The fruits containing a high amount of pulp (100%) with low amount of seed (100%) were also considered as undesirable by informants in addition to those that had

a light-yellow color (77.62%) and slightly-acid taste of pulp (75.31%). Moreover, only the blackish (97.38%) and bright seeds (95.80%) in fruits were considered as undesirable traits by local people regarding color and brightness of seeds.

Relationships between fruit traits and social attributes as perceived by local people

Informants reported several fruit traits of the species that were considered both as desirable and undesirable. Results from the PCA (Table 4) performed on the desirable traits data revealed that the elongated-thick-heavy and short-thick-heavy fruits were often positively associated with brown and dull seeds but negatively associated with short-thick, elongated-thick and elongated-less thick fruits (first principal component, PC 1). Short-thick fruits were to some extent negatively associated with a low amount of pulp but positively associated with both elongated-less thick and short-less thick-heavy fruits (second principal component, PC 2). Thus, the projection of desirable traits related to species' fruits per gender and sociolinguistic group on the first two axes (Fig. 3a) showed that Anii men and women, Fon women and Otamari men preferred the short-thick-heavy and elongated-thick fruits with dull seeds. However, Bariba men and both women and men in less

Table 4 Correlation between preference for fruit's traits of *P. biglobosa* and PCA axes

Preference for fruit' traits	PC1	PC2
Desirable traits		
Short and thick	− 0.60	− 0.59
Elongated and thick	− 0.88	− 0.16
Elongated and less thick	− 0.59	0.57
Short, thick and heavy	0.79	0.49
Short, less thick, and heavy	− 0.46	0.83
Elongated thick heavy	0.94	− 0.03
Low amount of pulp	0.22	− 0.56
High amount of seed	0.00	0.00
Yellow pulp	0.26	0.22
Sweet pulp	0.19	0.22
Brown seed	0.53	0.38
Dull seed	0.70	− 0.45
Undesirable traits		
Short and less thick	− 0.92	0.28
Slight	0.93	− 0.29
High amount of pulp	0.23	0.79
Low amount of seed	0.00	0.00
Light yellow pulp	0.31	0.51
Slightly acid pulp	0.15	0.45
Black seed	0.60	0.55
Bright seed	0.70	0.10

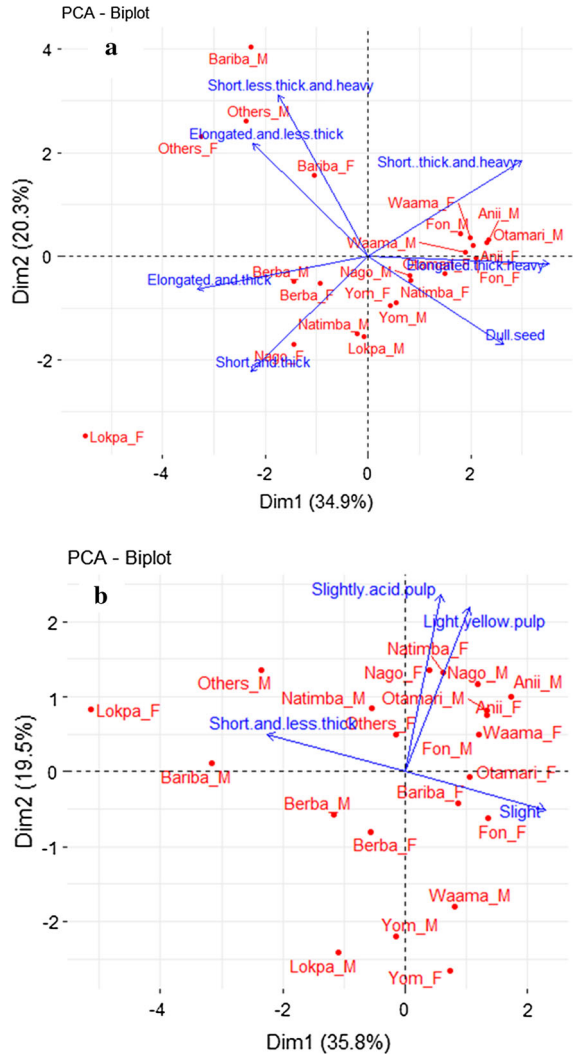

Fig. 3 Biplot from the PCA showing the relationships between sub-groups and distinguished traits in *P. biglobosa*: **a** relationships between sub-groups and desirable traits of fruits derived from species in one hand and **b** between these sub-groups and undesirable traits of species' fruits in other hand. The sub-groups combine the sociolinguistic groups and gender with *F* = Women and *M* = Men

represented (other) sociolinguistic groups preferred the short-less thick-heavy and elongated-less thick fruits as compared to Lokpa women who basically preferred the short-thick fruits (Fig. 3a).

The PCA analysis (Table 4) performed on the undesirable traits data revealed that the slight fruits were often positively associated with black and bright seeds but negatively associated with the short-less thick fruits (PC 1). Fruits containing a high amount of pulp were positively associated with both black seeds and light-yellow pulp (PC 2). Thus, the projection of undesirable traits related to species' fruits per gender and sociolinguistic group on the first two axes (Fig. 3b) showed that Bariba men and Lokpa women with men in less represented (other) sociolinguistic groups mentioned the short-less thick fruits as undesirable contrary to Anii men, Fon women and Otamari men who considered the slight fruits as undesirable (Fig. 3b). Similarly, Nago men and women with Natimba women mostly considered the light-yellow pulp in fruits as undesirable (Fig. 3b).

Relationships between reasons supporting local preferences and social attributes

Informants reported several reasons supporting preferences for fruits' traits derived from *P. biglobosa*. The main reasons supporting preferences for seed traits of *P. biglobosa* included the fruit content in big seeds, high small seeds, high-quality seeds and seed profitability while those related to the pulp traits concerned good quality, sweet taste, ripe and no reason. Thus, the relative frequency of citation of the supporting reasons of preference for seed traits were 84.25%, 9.56%, 0.92% and 0.30% for content in big seeds, high small seeds, high-quality seeds and their profitability respectively. Moreover, the relative frequency of citation of those supporting preference for pulp traits were 63.73%, 21.45%, 0% and 20.52% for good quality, sweet taste, ripe and no reason respectively.

The PCA analysis (Table 5) performed on reasons supporting local preferences for fruit traits of *P. biglobosa* revealed that species' fruits containing big seeds were often negatively associated with sweet pulp but positively associated with pulp of good quality (PC 1). Besides, the species' fruits containing high small seeds were negatively associated with their profitability (PC 2). Thus, the projection of reasons supporting local preferences for species' fruit traits among social attributes on the first two axes (Fig. 4) showed that the Lokpa men, Yom men and women preferred species' fruits due to their content in pulp of good quality as compared to women in Nago, Natimba and Waama sociolinguistic groups who were guided by sweet taste of the pulp and the seed profitability (Fig. 4).

Table 5 Correlation between reasons supporting preferences for fruit' traits of *P. biglobosa* and PCA axes

Reasons	PC1	PC2
Preference for seed traits		
Big seeds	0.66	0.05
High small seeds	0.10	0.93
Profitable	− 0.23	− 0.72
High quality seeds	− 0.25	− 0.36
Preference for pulp traits		
Good quality	0.92	0.02
Sweet taste	− 0.78	0.43
Ripe	-	-
No reason	− 0.31	0.23

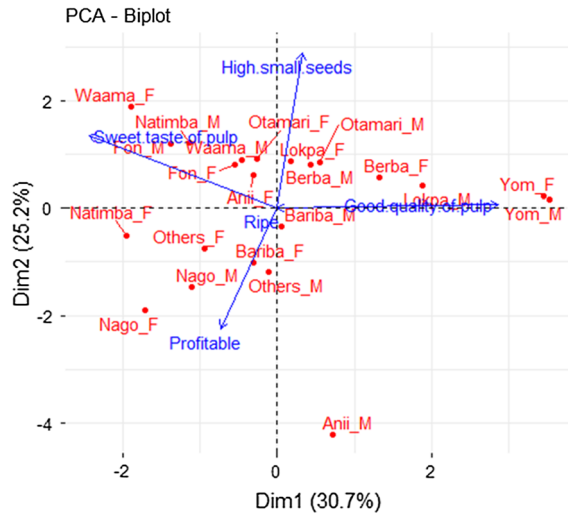

Fig. 4 Biplot from the PCA showing the relationship between sub-groups and reasons supporting preferences in *P. biglobosa fruits*. The sub-groups combine the sociolinguistic groups and gender with *F* = Women and *M* = Men

Discussion

Understanding how socio-demographic factors such as gender, age, and sociolinguistic group shape folk classification systems, both desirable and undesirable traits of plant species has important implications for effective participative domestication and conservation of plant genetic resources (Loko et al. 2018; Souto and Ticktin 2012). This study focused on *P. biglobosa*. It examined the folk classification systems of *P. biglobosa* fruits, explored preferences for the distinguished fruits morphotypes derived from African locust bean as perceived by informants, and discussed the implications for domestication and conservation of its genetic resources.

Folk classification systems of fruits morphotypes in *P. biglobosa* from Benin

This study provides detailed information on folk classification of morphotypes of fruits derived from *P. biglobosa* that could be taken into account in projects targeting domestication of this multipurpose species. Our results revealed that the criteria used by local people to classify fruits of *P. biglobosa* and distinguish the derived morphotypes were similar across the sub-humid and semi-arid zones of Benin. This trend suggests a large consensus on local criteria reported by informants as well as no influence of climatic conditions on the traditional fruit's morphotypes distinguished. This suggests the possibility to implement similar domestication strategies for *P. biglobosa* across two climatic zones. Indeed, all these criteria are related to the characteristics of the pod (shape, amount of pulp, amount of seed), pulp (color, taste), and seed (color, brightness). This confirms earlier findings highlighting that the plant's visible phenotypic traits are basically the primary criteria used by farmers in folk classification systems (Mazzocchi 2006).

The similarity in criteria used by informants to classify fruits' species can be a result of long-term contact with their environment when covering the necessities that arise over their lives (Godoy et al. 2009; Zambrana et al. 2007). In this case, the similarity in criteria used for the folk classification may be explained by the fact that most of informants viewed *P. biglobosa* as a valuable resource having many uses needful for them and therefore, they could establish a same classification system of its fruits based on contact with their environment and intensive fruit harvesting. This result corroborates prior ethnobotanical findings and support the general assumption that folk classification systems are mostly applied for local biological resources with high priority for rural communities (Gwali et al. 2011; Kakudidi 2004).

However, folk classification of fruits derived from *P. biglobosa* was not influenced by gender and sociolinguistic groups suggesting that men and women use similar criteria to distinguish the morphotypes of fruits derived from *P. biglobosa* among rural communities. This can be explained by the rich culture of knowledge transmission across social attributes among local people. Similarly, Millar Wood (2008) reported that social factors had no influence on folk classification systems of shea tree (*Vitellaria paradoxa*) in contrast to a significant influence of sociolinguistic group on this classification found in East Africa by Gwali et al. (2011). Such variation in folk classification systems among different sociolinguistic groups may be due to the intensity of utilization of biological resources by local people for various purposes from food, medicine and other domestic uses.

Furthermore, the relative frequency of citation (Table 3) was a reflection of the proportion of the local people using criteria to distinguish morphotypes of fruits derived from African locust bean trees. Thus, high relative frequency of citation was therefore indicative of the strong use of fruit characteristics derived from pod shape, amount of pulp per pod, amount of seed per pod, pulp color, pulp taste, seed color, and seed brightness in folk classification systems of species. This finding suggests that folk classification is strongly based on morphological and organoleptic attributes of fruit' species across the sub-humid and semi-arid zones in Benin. This result is congruent with previous findings and support the general assumption that rural communities are usually very much aware of the specific features derived from particular plants that are important for everyday life (Assogbadjo et al. 2008; Choudhary et al. 2008). Therefore, local people use their own criteria to characterize the phenotypic variation in indigenous fruit trees across traditional agroforestry systems in Africa (Gwali et al. 2011; Karambiri et al. 2017). As a result, these local criteria of species' fruits identified require further studies based on the morphological and

genetic diversity in order to confirm perceived phenotypic variations. Such investigations are worth addressing, especially for the conservation and domestication purposes of *P. biglobosa* in sub-Saharan Africa.

Preferences for the morphotypes of fruits derived from African locust bean tree as perceived by informants

Our results revealed that the short-thick, elongated-thick, elongated-less thick, short-thick-heavy, short-less thick-heavy and elongated-thick-heavy fruits containing a low amount of pulp, high amount of seed with yellow and sweet pulp as well as brown and dull seeds are generally preferred among rural communities from Benin. Contrary to preferred traits identified by local people, the undesirable features included the short-less thick, and slight fruits that contain a high amount of pulp, low amount of seed with light-yellow and slightly-acid pulp as well as black and bright seeds. Thus, the selection or breeding programs related to germplasm sampling and improvement of African locust bean should basically focus on the fruits having preferred traits as distinguished by local people.

Furthermore, these preferred morphotypes identified by local people can be related not only to the high economic value of seeds derived from fruit's harvesting but also to their socio-cultural importance across various sociolinguistic groups as evidenced by the PCA results. Indeed, reasons supporting these preferences as perceived by local people probably come from the fruit's profitability due to their composition in big seeds, high small seeds, and good quality of pulp suggesting the existence of potential market niches. Therefore, seed marketing and processing into food condiment can generate substantial income for rural women who mostly prefer the fruits that contain a high amount of seeds. This is why informants had mostly preferred the large, heavy and sweet fruits that contain more dull seeds. Thus, this trend corroborates the previous findings that highlighted the potential of *P. biglobosa* fruit harvesting as source of income for rural communities in West Africa (Vodouhê et al. 2011; Zinsouklan et al. 2015). Additionally, the reasons that fruits containing yellow pulp and brown seeds are respectively preferred because of their sweet taste and good quality in preparation of food condiment could be explained by the nutritional content. Indeed, the pulp derived from species' fruits is rich in sucrose while the seeds are known to be rich in carbohydrates, proteins and lipids thus, constituting an important source of energy (Djakpo 2005). For example, the yellow pulp can be eaten raw, used in local meats or mixed with water to make a refreshing drink also suitable for infants (Nyadanu et al. 2017).

However, local preferences of fruit' traits derived from species vary according to gender and sociolinguistic group. This result confirms a general hypothesis assuming that knowledge about indigenous plant species depends on culture, ways and customs of communities (Sundriyal et al. 2004). Thus, this variation among local preferences could be attributed not only to living conditions and main activities of each sociolinguistic group but also to wide range of products made by seed processing using low technology inputs. Therefore, this variation in local preferences of desirable traits among sociolinguistic groups suggests that the conservation strategies of African locust bean should be specific to each community through semi-arid and sub-humid zones in Benin.

Implications for sustainable management and domestication of African locust bean

The present study provides an important information in understanding influence of socio-demographic factors on folk classification systems, and desirable and undesirable traits of African locust bean trees from the two climatic zones in Benin. Our findings revealed that rural communities used the similar criteria in folk classification systems of fruit's species suggesting the existence of a large consensus on these criteria with the possibility to implement similar domestication strategies for African locust bean in Benin. Moreover, our findings showed that pod shape, amount of pulp, seed per pod as well as the color and taste of pulp were the most important preferred traits identified by local people on the fruit's morphotypes derived from *P. biglobosa* with differences among gender and sociolinguistic groups. Therefore, the sustainable management and conservation programs should target not only African locust bean trees with these preferred traits but should also integrate those differences among social attributes in future domestication processes. Given the importance of folk classification systems in the domestication process of multipurpose

tree species (Fandohan et al. 2011), the distinguished fruit morphotypes of *P. biglobosa* reported in this study can pave the way for understanding the links between the different fruit traits (desirable vs. undesirable) and the social attributes perceived by rural communities. Thus, our results would help breeders to quickly capture any desirable fruit character needed for multi-trait selection in African locust bean for the sustainable conservation of tree genetic resources in West Africa.

In addition, further research should address both morphological and molecular variations in African locust bean as folk classification may not ultimately result in genetic differentiation (Karambiri et al. 2017). Further studies should also examine if some additional preferred traits including seed color with seed brightness observed actually result from environmental drivers rather than genetics. Nevertheless, conservation in gene banks of planting materiel derived from African locust bean trees with undesirable traits would be suitable because of the negative influence that can result from artificial selection in traditional agroforestry systems. Thus, the cultivation of *P. biglobosa* combined to its maintenance across natural gene pools in traditional agroforestry systems would contribute to conservation of African locust bean genetic resources. As a result, the implementation of these suggested management strategies should strengthen the availability of this fruit tree species across traditional agroforestry systems from Benin in West Africa.

Conclusion

African locust bean is one of the most harvested fruit tree species which covers the necessities that arise over the maintenance of rural livelihoods in Benin. Understanding folk classification systems of variation as well as preferences in fruit traits derived from *Parkia biglobosa* is critical for sustainable management and decision-making processes for this IFT from West Africa. Our findings showed that local people used similar criteria in classification of the traditionally fruit' morphotypes distinguished with identification of preferred morphotypes based on morphological and organoleptic attributes of species' fruits. As a result, this study highlights the importance to examine folk classification systems for distinguishing the fruits morphotypes of African locust bean as the first step in future domestication initiatives. However, further research should address both morphological and molecular studies in *P. biglobosa* as folk classification may not ultimately result in genetic differentiation, and allow the integration of African locust bean in formal conservation policies as contribution to sustainable management of this harvested fruit tree across traditional agroforestry systems from West Africa.

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Data availability The datasets generated during and/or analyzed during the present study are available from the authors upon request.

Compliance with ethical standards

Conflict of interest Authors declare that they have no conflict of interest.

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