Journal of Horticulture and Forestry

Volume 7 Number 6 June 2015
ISSN 2006-9782

Academic Journals

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academicJournals

Vol. 7(6), pp. 149-159, June, 2015
DOI: 10.5897/JHF2014.0374
Article Number:13B49A953936
ISSN 2006-9782

http://www.academicjournals.org/JHF

Journal of Horticulture and Forestry

Full Length Research Paper

Uses and preferences of woody species in two protected forests of Dan Kada Dodo and Dan Gado in Niger

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Received 10 October, 2014; Accepted 26 March, 2015

An ethnobotanical survey was carried out on 31 woody species recorded in the protected forests of Dan Kada Dodo and Dan Gado in south-central Niger. Semi-structured interviews with local population were conducted between June and September 2012 in seven bordering villages in which five are predominantly from the Hausa ethnic group and two are from the Fulani ethnic group. A total of 256 people were randomly selected and interviewed. Plant parts and species use-value and preferences were evaluated. Local populations were found to use forest resources for varied and vital needs. The use category wood energy was dominant (20.38%), followed by medicinal uses (19.42%). Wood leaves and roots were the most used parts of the plants. There is significant difference (P<0.01) in use importance between different tree components by the local population. *Balanites aegyptiaca* (Del), *Hyphaene thebaica* (L.) Mart., *Tamarindus indica* (L.), *Ziziphus mauritiana* (Lam), *Sclerocarya birrea* (A. Rich) Hochst and *Guiera senegalensis* (J. F. Gmelin) had high ethnobotanical use-values and were the most preferred by local communities. These important species should be considered for long-term biodiversity conservation and management programmes.

Key words: Quantitative ethnobotany, use category, use-value, multipurpose trees, agroforestry, prioritization, domestication.

INTRODUCTION

The socio-economic, demographic and ecological changes experienced by Sahelian countries in recent decades have affected natural ecosystems and their management (Wezel and Haigis, 2000; Wezel and Lykke, 2006). This has resulted in not only a reduction of forest area and tree density but also the extension of areas without vegetation after extensive cultivation (Larwanou and Saadou, 2012). In Niger, for example, an estimated 1% annual loss of forest areas is due to deforestation, against an average of 0.49% per year in Africa (FAO, 2010). However, the natural forests play a highly important role in meeting the needs of local populations

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and constitute a reservoir of biodiversity. Depending on the season, leaves, fruits, roots or barks are harvested to serve as staple food during food shortage (Codjia et al., 2003; Ayantunde et al., 2009; N'Klo et al., 2010; Sop et al., 2012). Moreover, in the context of extreme poverty, wood and non-wood forest products contribute to household income (Shackleton et al , 2004; Wynberg and Laird, 2007). Trade of these products is most common. In Niger for example, the sale of soap from *Balanites aegyptiaca*, fruits of *Ziziphus mauritiana* and *Tamarindus indica*, gum arabic from *Acacia senegal* (L.) Willd. and *A. seyal* (*Del.)*, and leaves and fruits of *Adansonia digitata* (L.) and *Moringa oleifera* (Lam) allow many households to buy food and meet some family needs. The recognition of the socio-economic role of natural forests has increased interest of various stakeholders in ecosystem conservation and management (Roose et al., 2011; Bernoux et al., 2013; Noubissié-Tchiagam and Bellefontaine, 2005). Therefore, an integrated approach that takes into account the opinion of local people who have strong links with these natural resources deems necessary.

In this context, ethnobotanical knowledge is being considered in forest resource management as it provides new opportunities for understanding ecological processes as they relate to the knowledge of local populations (Douglas et al., 2004; Wynberg and Laird, 2007; Belem et al., 2008-a; Ayantunde et al., 2009; Sop et al., 2012). Several authors (Wynberg and Laird, 2007; Ayantunde et al., 2008; Lougbegnon et al., 2011) argued that local knowledge of spontaneous plant species can guide their prioritization or their domestication in the near future in order to promote rural development and biodiversity conservation (Mapongmetsem et al., 2012). In this regard, quantitative methods with different indices have been developed to study the ethnobotanical importance of different woody species by highlighting their local preferences. The use-value technique was chosen because it is considered objective, reproducible and appropriate for statistical analyses. In the Sudanian Zone of Togo (West Africa), Atakpama et al. (2012) used four use indices (reported use, plant part value, specific reported use and intraspecific use-value) to identify use-values knowledge of *Sterculia setigera* tree. Schumann et al. (2012) performed a quantitative analysis using different measures of knowledge distribution among genders and different villages, document uses and management of the baobab (*Adansonia digitata*) in eastern Burkina Faso. They found some differences in uses and management of baobab between genders and villages emphasizing the importance of gender and region related management recommendation.

The objective of this study was to investigate the use preferences for woody species by local populations in the classified forests of Dan Kada Dodo and Dan Gado in order to guide the restoration and management of these forests. These two forests were chosen because of their importance in providing the livelihoods to local communities.

Study area

The classified forests of Dan Kada Dodo and Dan Gado are located between latitudes 13° 27' and 13° 35' North and longitudes 07° 34' and 07° 43' East in the Maradi region of south-central Niger. The climate is characterized by a short rainy season, three to four months (June to September) and a longer dry season (October to May). The average annual rainfall over the last 10 years was 483.74±124.36 mm. Average annual daily temperatures range from 22.4°C in January and 33.8°C in April. The wooded steppe vegetation is degraded with dominant tree species including *Guiera senegalensis, Combretum micranthum* (G. Don*), Sclerocarya birrea, Acacia nilotica* (L.) Willd.*, A. senegal, Balanites aegyptiaca* and *Cassia singueana* (Delile*)*. Herbaceous vegetation is mostly dominated by annual species including *Cenchrus biflorus* (Roxb.)*, Eragrostis tremula* (Lam.) Steud*., Brachiaria spp.* and *Sida cordifolia* (Linn.).

In 2011, the population of the villages of the study area was estimated at 386,000 people with a density of 137 inhabitants/km^2 (INS, 2012). Two main ethnic groups are present, viz. Hausa and Fulani. The local economy is based mainly on agriculture and livestock. Agriculture is the main activity for the Hausa and is extensive with major food crops including millet, sorghum, groundnut and cowpea. Livestock (especially cattle, sheep, goats and camels) is the main activity for the Fulani, but is secondary for Hausa.

METHODS

Selection of study villages and sampling

Following an exploratory mission in the study area, a stratified sampling, based on ethnicity and proximity to protected forests for the selection of villages, was undertaken. In this regard, seven villages, five Hausa and two Fulani (reflecting the relative importance of ethnic groups in the study area) were sampled.

In total, 256 people – including 163 men (63.67%) and 93 women (36.33%) were randomly selected within strata and belonging to both ethnic groups (195 Hausa and 61 Fulani) were interviewed, representing approximately 5% of the total population of each of the ethnic group.

Data collection

An ethnobotanical survey was conducted from June to September 2012. The surveyed woody species were selected based on the results of the floristic inventory (Abdourhamane et al., 2014). An open-end semi-structured interview technique was used to collect information. The principles of quantitative ethnobotany described by Höft et al. (1999) were used to obtain incremental responses on a scale that provides information on the importance that each interviewee accords to each species with respect to use categories defined by Belem et al. (2008-a). The use category is the set of uses of a similar nature. These are: (i) human food,(ii) veterinary pharmacopoeia, (iii) human pharmacopoeia, (iv) wood energy, v) service wood, (vi) handicraft and (vii) fodder. Three scores were set to assess the level of species used in each use category: 2 = very important or highly used; 1 = moderately important or medium used and 0 = species unimportant or without use.

During the survey, each respondent was asked the following three groups of questions:

(i) What uses are you making with each one of the listed tree species?
(ii) In the seven use categories previously presented what score are you given to each listed tree species?
(iii) What are the used parts of the plants (roots, stem, leaves, flowers, fruits, seeds, bark, sap, others)?

In view of the various uses, each respondent was asked to provide:

(i) A list of 15 suitable tree species for the restoration of the classified forests. The preferential classification method was then used to make the respondents' preferences for the five priority woody species. This technique involves comparing pairs of selected species to get the preferred ones. Thus, the sum of collected choices per species gave it a ranking score.
(ii) This ranking score is used to get a list of five priority species (in descending order) for the restoration of the protected forests.

Data analysis

Response rate of used plant parts

The response rate of used parts per species is expressed by:

$$F = 100\frac{S}{N}$$

where F is the calculated response rate, S is number of respondents who gave a positive response (Yes) for the use of the given part, and N is total number of people interviewed.

This rate shows the most used parts for each species in a given forest and varies from 0 to 100. A 0 value indicates that the part is not used and 100 indicates that it is used by all respondents. The Kruskal-Wallis test was used (due to the non-normality of the data) to compare the level of use of a given part in both ethnic groups.

Species ethnobotanical use value

The species ethnobotanical use value (UV) was calculated according to the method used by Philips and Gentry (1993). This method is used by several authors (Lykke et al., 2004; Belem et al., 2008-a; Camou-Guerrero et al., 2008; Ayantunde et al., 2009; Nguenang et al., 2010; Dossou et al., 2012).

The use value of a given species in a use category is represented by its mean use score within that category. It is calculated by the formula:

$$\mathrm{UV(k)} = \frac{\sum_i^n Si}{n}$$

Where, UV (k) is the ethnobotanical use value of species k within a given use category, Si is the use score assigned by respondent i and n is the number of respondents.

The total ethnobotanical use value of species k is calculated by the sum of use values of this species within different categories of use by the formula:

$$\mathrm{TUV} = \sum_1^p UV \quad \text{where,}$$

Where, TUV represents the total ethnobotanical use value of a species; UV is the use value of species for a given use category; and p is the number of use categories. In this study, for each species, the total ethnobotanical use values for the seven use categories ranged from 0 (minimum) to 14 (maximum).

The use value of a species reflects its importance to the informants (Höft et al., 1999; Ayantunde et al., 2009). Thus, a Fisher test (assuming that the data follow a normal distribution) was used to test the difference in species TUV between ethnic groups.

The correlation matrix of the seven use categories for the 31 species studied was subjected to principal component analysis (PCA) to determine the relationships between species and uses.

To assess differences in the local use of woody species according to respondents age (≤50 and >50 years), sex (male and female) and ethnicity (Hausa, Fulani) the species ethnobotanical total use values in the use categories were compared using the Mann-Whitney non-parametric test since the data were not normally distributed.

Priority species for conservation and forest restoration

The Spearman rank correlation test was used to assess if the priorities of forest restoration and conservation are characterized by the same species. The same test was performed on the priorities of forest restoration and use value.

The Spearman rank correlation coefficient "sr" indicates the degree of connection between the rankings of two variables (x and y). If sr = 1 rankings along x and y are identical; if sr = -1, they are different and if sr = 0, then the two variables are independent. All statistical analyses were performed by. Minitab 16.0 software.

RESULTS

Profile of respondents

From the sampling, 76.17% of the respondents belong to the Hausa ethnic group which is mainly represented in the study area. The age distribution shows that young (≤50 years) constitute 68.1% of the respondents while the elderly (>50 years) represent 31.9%. The average age of respondents was 43 years. The maximum age is 90 years and the minimum age of 22 years. The majority of respondents (80.86%) are farmers, livestock herders (5.08%), traders (5.47%) and other activities (8.59%).

Use categories of woody species in the classified forests

Figure 1 shows the relative importance of use categories and the percentage of uses of woody species in a given use category. It appears that wood energy is the dominant use category (20.38%) for local populations in both forests. It is followed by human pharmacopoeia (19.42%), fodder (18.21%), veterinary pharmacopoeia

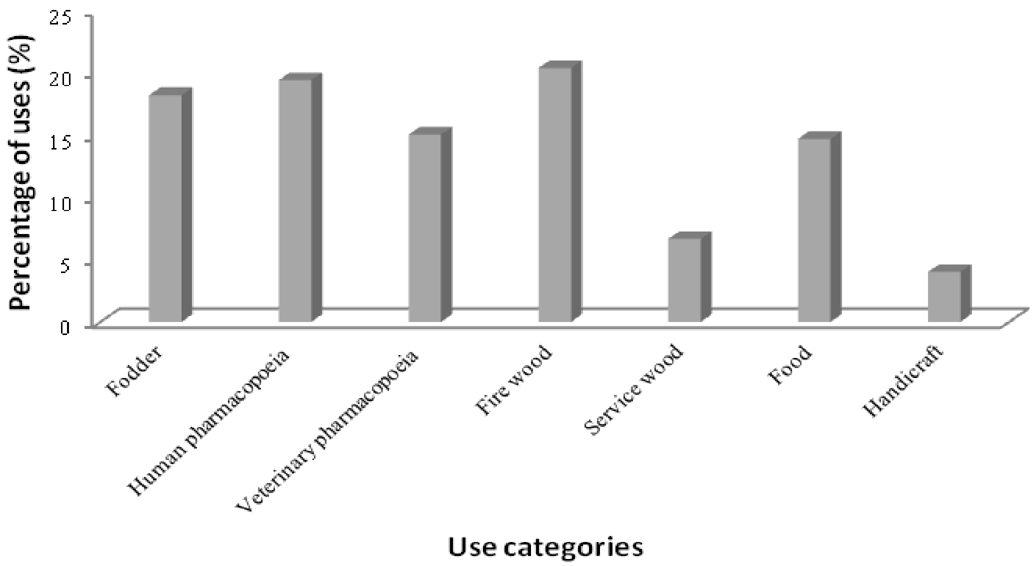

Figure 1. Percentage of uses of woody species by use category.

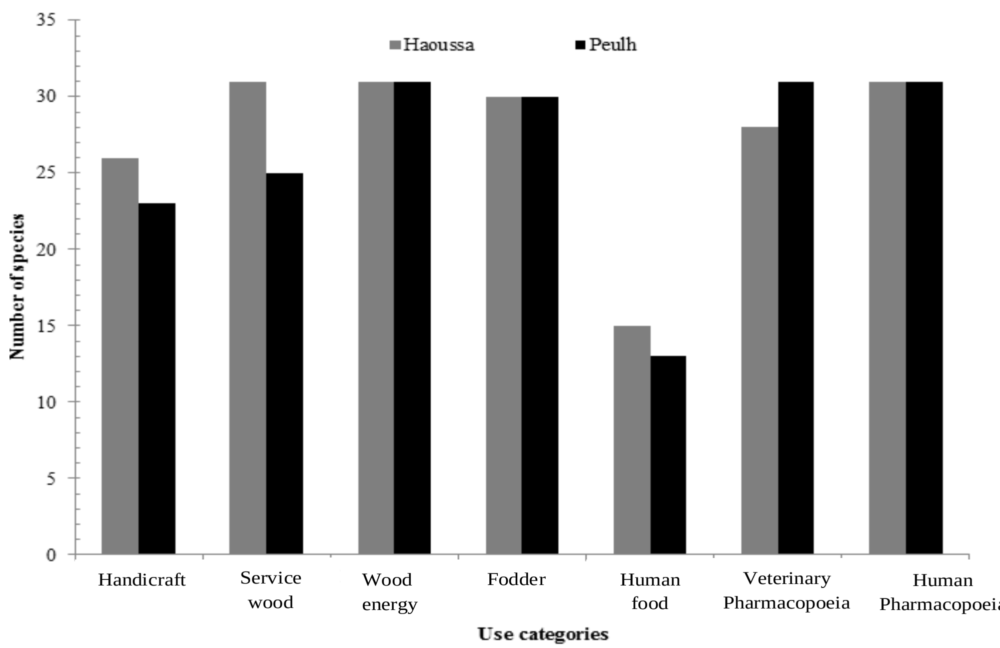

Figure 2. Number of used species by use category and ethnic group.

(15.05%) and human food (14.70%), while wood service and handicraft represent 8.21 and 4.01% respectively.

Exploitation of woody species

Woody species are used for different purposes. They are both a source of food, medicinal and wood for the populations (Figure 2).

The number of species per use category shows that for the two ethnic groups, all (100%) the species are used for wood energy and traditional medicine (human and veterinary); for human food, leaves and edible fruits are, respectively being used at 48.39 and 41.94%. In general, the number of species used seems higher in the Hausa ethnic group especially for food (sauce and edible fruits), craft uses (agricultural tools) and in services. The number of species used in veterinary pharmacopoeia is higher

Table 1. Parts use response rate (%) by the populations of 2 ethnic groups leaving around the forests**.**

Species	Hausa					Fulani				
	Wood	Roots	Bark	Leaves	Fruits	Wood	Roots	Bark	Leaves	Fruits
Acacia laeta	92.31	11.79	1.54	82.56	0.51	96.72	24.59	1.64	85.25	1.64
Acacia nilotica	98.46	58.46	4.62	96.41	40.00	100.00	59.02	-	100.00	16.39
Acacia radiana	56.92	2.56	-	56.92	4.10	81.97	11.48	-	80.33	1.64
Acacia senagal	96.41	4.10	0.51	94.36	1.54	100.00	3.28	-	98.36	-
Acacia seyal	92.82	2.05	0.51	95.38	1.03	100.00	4.92	1.64	100.00	-
Adonsonia digitata	58.46	1.03	-	98.97	18.97	50.82	-	-	100.00	29.51
Annona senegalensis	95.38	6.15	4.62	77.95	77.95	96.72	4.92	-	60.66	88.52
Azadirachta indica	97.44	-	-	67,69	32,82	96,72	-	-	85,25	21,31
Balanites aegyptiaca	98.46	13,85	1.03	98.46	95.38	100.00	37.70	6.56	100.00	96.72
Bauhinia rufescens	95.38	0.51	3.08	100.00	0.51	98.36	11.48	8.20	100.00	-
Bombax costatum	85.13	1.03	1.54	81.54	26.67	88.52	-	3.28	96.72	24.59
Boscia salicifolia	95.90	-	2.05	89.74	90.26	93.44	-	-	96.72	95.08
Boscia senegalensis	97.95	1.54	1.54	97.44	88.21	100.00	3.28	1.64	100.00	96.72
Cassia siberiana	84.62	5.13	74.87	33.85	0.51	85.25	4.92	81.97	18.03	-
Cassia singueana	84.62	2.56	3.59	94.36	0.51	96.72	3.28	-	98.36	-
Combretum glutinosum	100.00	30.26	3.59	95.90	4.62	100.00	45.90	-	100.00	-
Combretum micranthum	99.49	1.54	-	94.87	0.51	100.00	3.28	-	98.36	-
Commiphora africana	92.31	0.51	6.15	91.79	1.54	96.72	-	-	95.08	-
Diospyros mespiliformis	88.72	5.13	2.56	82.56	99.49	98.36	-	1.64	90.16	100.00
Faidherbia albida	99.49	12.82	1.54	99.49	88.72	100.00	16.39	-	100.00	91.80
Guiera senegalensis	99.49	23.59	2.56	98.97	-	96.72	18.03	1.64	96.72	-
Hyphaene thebaica	97.44	-	0.51	79.49	98.46	93.44	-	-	80.33	100.00
Lannea microcarpa	91.79	1.03	8.72	93.85	93.85	96.72	-	3.28	100.00	95.08
Maerua crassifolia	97.95	-	2.56	99.49	-	100.00	4.92	1.64	100.00	-
Parkia biglobosa	81.54	-	1.54	76.92	95.38	90.16	3.28	4.92	95.08	96.72
Piliostigma reticulatum	99.49	4.10	3.08	99.49	77.95	100.00	1.64	1.64	100.00	80.33
Prosopis africana	96.92	23.08	8.72	96.92	6.67	100.00	34.43	8.20	100.00	3.28
Sclerocarya birrea	98.46	0.51	2.05	98.46	94.87	100.00	-	-	96.72	95.08
Sterospermum kunthianum	94.87	2.56	4.10	91.79	6.15	98.36	8.20	-	98.36	1.64
Tamarindus indica	98.97	3.59	2.56	95.90	100.00	98.36	8.20	9.84	98.36	95.08
Ziziphus mauritiana	97.95	3.08	7.69	97.44	94.36	95.08	4.92	6.56	95.08	95.08

among the Fulani.

Use of exploited parts of woody species

The communities living around forests use different parts of woody species. For all studied species, wood, roots, bark, leaves and fruits are used (Table 1). The Kruskal-Wallis test shows that the different parts do not have the same use importance by the local communities (P<0.01). The used parts vary greatly from one species to another. The leaves of *B. rufescens*, *F. albida*, *P. reticulatum* and *M. crassifolia* are cited as the most widely used for livestock feed. Roots of *A. nilotica*, *C. glutinosum* and *P. africana* are often used in traditional medicine. Fruits that have predominantly in food uses are of *T. indica, D. mespiliformis, H. thebaica, P. biglobosa* and *S. birrea*.

Ethnobotanical use value

The ethnobotanical use value of 31 woody species in the two classified forests show that for Hausa ethnic group, 14 species have a high use value with TUV greater than 4.5 (Table 2). These are *B. aegyptiaca, H. thebaica, T. indica, Z. mauritiana, S. birrea, G. senegalensis, P. africana, B. senegalensis, L. microcarpa, D. mespiliformis, A. indica, B. salicifolia, A. nilotica* and *P. biglobosa*.

In the Fulani ethnic group, 16 species with TUV greater than 4.5 are: *H. thebaica, Z. mauritiana, B. aegyptiaca, G. senegalensis, P. africana, T. indica, D. mespiliformis, S. birrea, L. microcarpa, B. senegalensis, P. biglobosa, A. indica, A. nilotica, B. salicifolia, C. glutinosum* and *A. senegalensis*.

With regard to use categories, the test of Fisher shows

Table 2. Use value of woody species by ethnic group.

Species	Hausa		Fulani	
	TUV	Rank	TUV	Rank
Acacia laeta	3.05	27	3.30	27
Acacia nilotica	4.73	13	4.93	13
Acacia radiana	2.15	31	2.85	29
Acacia senegal	3.54	22	3.61	25
Acacia seyal	3.32	26	3.26	28
Adansonia digitata	4.06	21	3.39	26
Annona senegalensis	4.11	20	4.56	16
Azadirachta indica	4.89	11	4.95	12
Balanites aegyptiaca	6.16	1	6.33	3
Bauhinia rufescens	3.53	23	3.72	22
Bombax costatum	2.74	29	2.85	30
Boscia salicifolia	4.79	12	4.66	14
Boscia senegalensis	5.38	8	5.11	10
Cassia siberiana	1.95	32	2.51	32
Cassia singueana	2.65	30	2.85	31
Combretum glutinosum	4.29	16	4.64	15
Combretum micranthum	4.14	19	4.16	19
Commiphora africana	2.92	28	3.75	21
Diospyros mespiliformis	5.24	10	5.62	7
Faidherbia albida	4.20	18	4.21	18
Guiera senegalensis	5.71	6	6.02	4
Hyphaene thebaica	6.13	2	6.90	1
Lannea microcarpa	5.33	9	5.38	9
Maerua crassifolia	3.47	24	3.69	23
Parkia biglobosa	4.56	14	5.11	11
Piliostigma reticulatum	4.23	17	4.28	17
Prosopis africana	5.48	7	5.79	5
Sclerocarya birrea	5.82	5	5.46	8
Sterospermum kunthianum	3.40	25	3.62	24
Tamarindus indica	6.08	3	5.74	6
Ziziphus mauritiana	5.97	4	6.38	2

that there is no significant difference (p = 0.445) in knowledge related to woody species ethnobotanical use between ethnic groups.

Species by use category

The five most used species in each of the seven use categories by ethnic group are shown in Figure 3. It appears that, for the two ethnic groups, species like *P. africana*, *A. indica*, *A. nilotica* and *H. thebaica* are the most used/preferred by locals for handicraft (Figure 3A). Species like *G. senegalensis*, *F. albida*, *Z. mauritiana* and *S. birrea* are most used for fodder by the two ethnic groups (Figure 3D).

The most widely used species for food (Figure 3E) are: *D. mespiliformis* (fruits), *A. digitata* (fruits and leaves), *T. indica* (fruit), *P. biglobosa* (fruit, seeds), *S. birrea* (fruit, seeds), *B. aegyptiaca* (fruit and seeds), *L. microcarpa* (fruits) and *Z. mauritiana* (fruits). The species use index for veterinary pharmacopoeia differs from one ethnic group to another (Figure 3F).

Use of woody species by ethnic group, sex and age

For both ethnic groups, species with highest ethnobotanical use-values are: *H. thebaica*, *B. aegyptiaca*, *T. indica*, *P. africana*, *G. senegalensis*, *Z. mauritiana* and *S. birrea*.

The total ethnobotanical use-values for use categories did not differ significantly (P<0.1) by ethnic group, with the exception of veterinary pharmacopeia where there are significant difference (P<0.01) with sex and age (Table 3).

Priority species for conservation and restoration of classified forests

The priority species for restoration activities and forest conservation are presented in Table 4. Similarity between species identified as most important for the conservation by the two ethnic groups was observed (Table 4). *M. crassifolia* has been highlighted as important by the Fulani only. *P. reticulatum*, *F. albida* and *L. microcarpa* rank high for the two ethnic groups. But, the priorities expressed for forest restoration show variability between ethnic groups. Two species (*S. birrea* and *L. microcarpa*) are listed in a regular ranking order for the restoration as well as for the conservation of the forests.

There is a strong correlation (R^2 = 0.983, p = 0.017) priorities of ethnic groups and conservation. Meanwhile, a weak correlation was observed between species with high ethnobotanical use value and priority species for conservation (R^2 = - 0.264, p = 0.407) and those for forest restoration (R^2 = 0.197, p = 0.539).

DISCUSSION

Use of parts of woody species

The plant used parts vary from one species to another, but wood and leaves are most in demand as shown in this study. Comparable results were found by Lougbegnon et al. (2011) in Benin. The harvest of these parts (roots, leaves, bark, wood) for various uses sometimes lead to lower productivity and is very often detrimental to the life of the plant. Belem et al. (2008-a) emphasize that in the Sudano-Sahelian part of Burkina Faso, fodder tree species like *S. birrea* and *B. aegyptiaca* are excessively being pollarded for fodder collection. This abusive exploitation of woody species by local communities

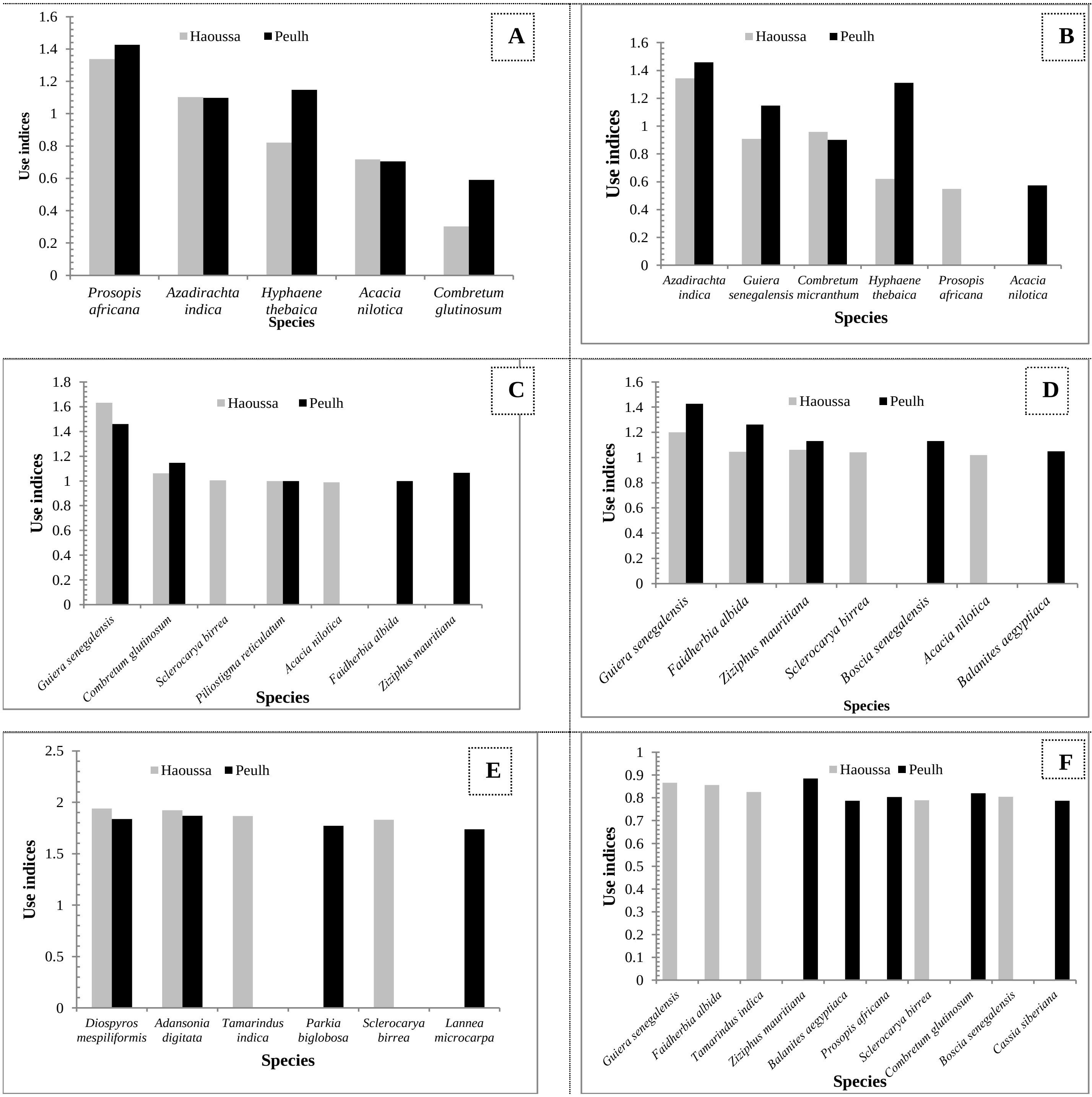

Figure 3. Species use indices by use category. A: Handicraft, B: Service wood, C: Wood energy, D: Fodder, E: Human food, F: Veterinary pharmacopoeia.

may be an amplifying factor of the degradation of natural forests and reduction of biodiversity (Emanuel et al., 2005; Ganaba et al., 2005). Therefore, all multipurpose species and those with high use indices deserve special attention in developing future forest management strategies.

Relative importance of multipurpose trees (based on use value)

The results of the study showed that local communities use forest resources for a variety of daily needs. This finding is in agreement with the work by Ayantunde et al.

Table 3. Ethnobotanical use value per use category of species according to ethnic groups, sex and age (mean ± standard deviation).

	n	Handicraft	Service wood	Wood energy	Fodder	Human food	Veterinary pharmacopoeia	Human pharmacopoeia
Ethnic group								
Hausa	195	0.20±0.36	0.27±0.34	0.90±0.23	0.81±0.28	1.37±0.73	0.68±0.11	0.85±0.13
Fulani	61	0.27±0.42	0.37±0.42	0.95±0.18	0.91±0.24	1.52±0.48	0.63±0.15	0.91±0.15
p-value		*0.3727*	*0.2831*	*0.1198*	*0.2311*	*0.7822*	*0.1356*	*0.0441*
Sex								
Male	163	0.22±0.38	0.31±0.35	0.93±0.21	0.85±0.27	1.59±0.50	0.70±0.11	0.89±0.11
Female	93	0.19±0.37	0.30±0.36	0.89±0.25	0.77±0.31	1.22±0.75	0.62±0.13	0.83±0.16
p-value		*0.2315*	*0.9933*	*0.2398*	*0.1977*	*0.1405*	*0.0046*	*0.1249*
Age								
>50 years	79	0.25±0.39	0.30±0.35	0.90±0.24	0.81±0.28	1.41±0.70	0.61±0.10	0.84±0.13
<50 years	177	0.20±0.37	0.28±0.35	0.91±0.22	0.81±0.29	1.18±0.82	0.69±0.12	0.87±0.13
p-value		*0.4042*	*0.6005*	*0.6626*	*0.9198*	*0.4172*	*0.0083*	*0.3577*

Table 4. Order of decreasing ranking of the five priority species for conservation and restoration in the study area according to ethnic group.

Species	Priority rank for restoration			Priority rank for conservation		
	Study area	Hausa	Fulani	Study area	Hausa	Fulani
Piliostigma reticulatum	-	-	-	1	1	1
Faidherbia albida	-	4	-	2	2	2
Lannea microcarpa	3	1	3	3	3	3
Maerua crassifolia	-	-	-	5	-	4
Sclerocarya birrea	4	5	4	4	4	5
Combretum glutinosum	-	-	-	-	5	-
Balanites aegyptiaca	1	-	1	-	-	-
Acacia nilotica	2	-	2	-	-	-
Acacia senegal	5	2	5	-	-	-
Bauhinia rufescens	-	3	-	-	-	-

- = species not scored.

(2009) in south-western Niger, which showed that the majority of local species including lianas are used in traditional medicine, human consumption, fodder, construction and wood energy.

The ethnobotanical use value is widely recognized as a reliable tool to quantify the relative importance of a species for a community (Hoffman and Gallaher, 2007; Ayantunde et al., 2009). Species with highest ethnobotanical use values for the two ethnic groups are: *B. aegyptiaca*, *H. thebaica, T. indica* and *Z. mauritiana.* Abdourhamane et al. (2013) showed, however, that these species have low density in these classified forests. Moreover, according to Ayantunde et al. (2009), when the total ethnobotanical use value of a scarce species is high, it may reflect a high pressure on the species. This indication is expected to suggest specific conservation measures to avoid overexploitation. Caution should however be taken in interpreting the results of use values, because the method does not clearly distinguish between past, present and potential uses of the species (Albuquerque et al., 2005; Belem et al., 2008-a; Camou-Guerrero et al., 2008).

Species preferences in the use categories

The study showed that in the study area, when all use categories are considered, the two ethnic groups express the same preferences for woody species with regard to use categories. This convergence between ethnic groups could be linked to a homogenization of attitudes to the environment due to cultural mixing (Faye, 2010; Gouwakinnou et al., 2011). However, in the use of species in veterinary pharmacopeia, the two ethnic groups expressed species choice differences.

With regards to number of species per use category, both ethnic groups use the same species for fuelwood, fodder and human pharmacopoeia. The proportion of species is relatively low for other use categories by Fulani, with the exception of veterinary pharmacopoeia. This is true because Fulani ethnic group has a good knowledge in the role of plants in veterinary pharmacopoeia as well as in their lifestyle and activities. These results are similar to those obtained by Sop et al. (2012) in Burkina Faso. In the Sahelian zone of Niger, Ayantunde et al. (2009) also noted that the Fulani herdsmen use more fodder species than Zarma ethnic group who are mainly farmers.

When considering the age of the respondents class, a difference is noted in the species use value in veterinary pharmacopoeia. This difference can be explained by the level of knowledge and uses of these plants by local communities (Belem et al., 2008-a) and a good knowledge of the uses of local species by the elders (Sop et al., 2012). Several studies in semi-arid areas of West Africa reported that age is correlated to the knowledge and use of plants (Paré et al., 2010; Atakpama et al., 2012; Ayantunde et al., 2008). Indeed, the knowledge of plants accumulates over time as well as the continuous interaction with the natural environment.

S. birrea, *B. aegyptiaca*, *H. thebaica*, *T. indica* and *Z. mauritiana* are "multipurpose" tree species with the highest number of uses in the two classified forests. This prioritization by the local populations clearly highlights their status of preferred species. The "multi-purpose" character is synonymous to high preference, often resulting in increased pressure and thus the risk of decline of these species. Therefore, emphasis should be put on these species in terms of conservation and reforestation actions (Le Bouler et al., 2013) in order to meet the needs of local populations. In this regard, Non-Governmental Organisations, government and forestry research institutions should come in to develop simple vegetative propagation techniques of the best genotypes to domesticate these multipurpose species (Meunier et al., 2006; 2008-a,-b; Belem et al., 2008-b).

Species like *F. albida*, *S. birrea* and *Z. mauritiana* have the strongest use indices and very good nutritive value as fodder trees (Ouedraogo-Kone et al. 2008). These are very important species for grazing in the Sudano-Sahelian zone, easy to regenerate seminally or asexually (Bellefontaine, 2005). The current pressure linked to inadequate modes of exploitation and the climate change severely affects the structure of certain forests and multipurpose tree species such as *S. birrea*. This is also noted by Nacoulma et al. (2011) in the Sudano-Sahelian zone of Burkina Faso.

In our study area, the household energy needs are covered by wood collected in the bush. Lykke et al. (2004) and Ganaba et al. (2005) reported the preference of specific species for fuelwood in the Sahel; the current study shows that almost all available species are used. This is due to high population pressure in the area and was noted by Faye et al. (2008) in the groundnut basin in Senegal, where even baobab tree (*A. digitata*) is now used for wood energy.

Priority for forest restoration and species conservation

In Niger, woody species are an integral part of daily life of local people who maintain almost all species for their activities (Lykke et al., 2004; Larwanou et al., 2010; Larwanou and Saadou, 2011; Larwanou et al., 2012). It should be therefore noted that their preferences vary with objectives mainly for the restoration and long-term preservation of the forests. The current practice of introducing two agroforestry species (*A. senegal* and *B. rufescens*) by the Department of Environment since 2001, might have influenced the choice of local populations for restoration priorities of the forest. This indicates that the interventions by the state must reflect the needs of local stakeholders for effectiveness especially when cooperation is being developed between the technical services and local communities.

Conclusion

This ethnobotanical study showed that surrounding communities of the study areas are closely and dependently linked to the classified forests of Dan Kada Dodo and Dan Gado. The method of ethnobotanical use value has highlighted the importance of the multipurpose woody species in the study area. They play an important role in the daily life of local communities.

This study also ranked the preferred species by the people according to their own criteria. The preferred species could be integrated in the restoration and management programs of these protected forests. Therefore, their knowledge and opinions on the preferences of uses are crucial to consider in the development of future management programs of natural forests and the domestication of the best local genotypes aimed at maintaining long-term biodiversity.

Conflict of Interest

The authors have not declared any conflict of interest.

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Vol. 7(6), pp. 160-167, June, 2015
DOI: 10.5897/JHF2015.0394
Article Number:36FC49853940
ISSN 2006-9782

http://www.academicjournals.org/JHF

Journal of Horticulture and Forestry

Full Length Research Paper

Phenotypic traits of *Carapa procera* fruits from riparian forests of Burkina Faso, West Africa

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Received 11 April, 2015; Accepted 24 June, 2015

Investigating phenotypic variation in fruit traits constitute an important base for biodiversity assessment and domestication. The present study was carried out in order to assess the diversity of phenotypic traits of *Carapa procera* fruits. A total of 430 fruits were collected on 43 trees, and their surface aspect, length, width, weight, number of carpels and number and weight of seeds were recorded. Hierarchical clustering and principal component analysis were used firstly on the fruit variables to determine morphotypes and secondly on the morphotypes variables to relate their traits to tree characteristics. Analyses of variance were performed to test for differences in phenotypic traits between morphotypes. Three morphotypes of *C. procera* fruits were identified: Morphotype 1, morphotype 2 and morphotype 3 including crested fruits, goffering fruits and smooth fruits, respectively. Morphotype 1 and 2 grouped the largest and heaviest fruits, while the morphotype 3 grouped the smallest and lightest ones. The highest number of seeds per fruit was found in morphotype 2, whereas morphotype 3 had the lowest number. Morphotypes were not related to the tree size. Morphotype 2 provides the highest value traits and represents the best choice for plantation purposes.

Key words: Biological diversity, morphological traits, wild fruits, *Carapa procera*, oil tree, Burkina Faso.

INTRODUCTION

African forest systems contribute to household economy and conservation of biodiversity of forest resources (Shackleton et al., 2011; Yadav and Dugaya, 2013). However, many aspects of relevance for their conservation are still unknown, for instance tree phenotypic characteristics. The intraspecific variation of most plant species in natural populations could be a reflection of genetic variability and an adaptation to fluctuating environmental conditions (Padonou et al., 2014). In the case of within-species genetic variation, it is an important basis for selecting species for domestication or favored varieties suited for particular needs (Leakey et al., 2005; Ewédjè et al., 2012; Padonou et al., 2014). Knowing that the existing phenotypic variation is an essential component for selection and planning of sustainable management programs, studies on

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phenotypic variability of useful plant species like *Carapa procera* DC is of high importance.

Carapa procera, also known as African crab wood, is a woody species widely distributed in Africa (Thiombiano et al., 2012). It is a multipurpose species that offers various products for diverse uses (Mulholland et al., 2000). Several studies have highlighted the importance of *C. procera* oil and also wood (Weber et al., 2010; Zhang et al., 2011; Djenontin et al., 2012). *C. Procera* has a potential for oil production in Burkina Faso (Ouédraogo et al., 2013). An expectation of increasing demand for this oil could lead to possibilities for production development by local communities. Presently, *C. procera* is threatened because of different perturbations (habitat loss due to agricultural extension, seasonal bush fires and over exploitation of seeds). This situation could contribute to reduce the genetic diversity of the species if no appropriate conservation measures are undertaken. Unfortunately, very little is known about the patterns of phenotypic and genetic variations within natural populations of the species in West Africa.

Phenotypic variation in fruit traits constitutes an important base for diversity assessment and development of improved and sustainable management programs as well as further domestication investigations (Anegbeh et al., 2005). Morphological studies carried out on the fruits of *Pentadesma butyracea* provided important information used in the selection of superior individuals for its domestication (Ewédjè et al., 2012). Recent studies on morphological variation in fruits and seeds of *Afzelia africana* and *Jatropha curcas* showed the existence of different morphotypes and made it possible to select best specimens for cultivation (Padonou et al., 2013, 2014). Such studies are all the more important for high value wild tree species like *C. procera* as they represent potentials for alleviating local communities' poverty. The present study aims to (i) determine morphotypes of *C. procera* fruits (ii) assess phenotypic variation of fruits traits and (iii) test whether phenotypic traits of fruits are related to tree morphological traits.

MATERIALS AND METHODS

Taxonomy, ecology and use of *C. procera*

The genus *Carapa* belongs to the Meliaceae family. According to Weber et al. (2010), three species of this genus are known in West Africa: *C. microcarpa*, *C. procera* and *C. velutina*. However, recent studies indicated that the other two species can be considered as synonyms of *C. procera* (Sanogo et al., 2013). *C. procera* occurs in the gallery forests from Senegal to RD Congo and Angola (Thiombiano et al., 2012). In Burkina Faso, it grows in the south Sudanian zone, where the annual rainfall is around 1000 mm. *C. procera* is a tree with composite and alternate leaves. Inflorescences are spikelets bearing small white flowers with a flowering period from January to April. The fruit is a capsule containing several seeds reaching maturity between May and June. Fruits are mainly exploited for oil production, as they have very high oil content (61.5%) in the seeds and an important concentration of oleic acid (59.1%) (Djenontin et al., 2012). This oil is used in cosmetic, parapharmaceutical and medical industries (Weber et al., 2010). It is also used in biological control against harmful insects (Onanga et al., 1997; Konan et al., 2003).

Study area

The study was carried out in the western Burkina Faso, mainly in two localities: Banfora (10°41'N - 4°56'W) and Orodara (11°05'N - 5°20'W) (Figure 1). Both localities possess a south Sudanian climate (Fontes and Guinko, 1995), with a mean annual rainfall up on 1000 mm and a rainy with 70 to 90 rainy days (May to October). The mean annual temperature is 26°C. The vegetation is dominated by tree savanna with patches of dry forests and gallery forests. Flora is characterized by high diversity of Sudanian species and some Guinean species (Schmidt et al., 2005; Gnoumou et al., 2011; Sambaré et al., 2011). Based on FAO (2008), the main soil types are vertisols, leptosols, luvisols and ferralsols and the relief is hilly. Two major ethnic groups constitute the local population, Gouin and Senoufo. Agriculture, livestock farming and non-timber forest product (NTFPs) exploitation are the main income generation activities among local communities.

Sampling design and data collection

Fruits were collected targeting at least ten fruit-bearing trees per encountered shape type (visual aspect of fruit surface, e.g. crested, goffering, smooth). Sampled trees were located at least100 m from each other. All growth stages, from young to adult were considered. For each tree, trunk diameter at breast height (dbh), height and crown diameter were measured and all the fruits were counted. Ten mature fruits (unopened) were randomly collected from each tree. The variable length (using a slide ruler with ± 0.02 mm precision), circumference at the middle (using a metric tape with ± 0.1 mm precision), weight (using a balance with ± 0.01 g precision), number of carpels and number of seeds, weight of seeds (using a balance with ± 0.01 g precision) were recorded for each fruit.

Fruit description included the apex, the grooves and the epicarp aspect. Apex was characterized as long, short or none, and grooves as deep, few or none. The epicarp aspect concerned the visual appearance of the fruits surface.

Data analysis

Hierarchical clustering (HC) using Ward's method and Ecludian distance was performed on following variables: Length, width (provided by the conversion of the circumference which has been measured), number of carpels, number of seeds, weight of seeds, type of apex and grooves (Struyf et al., 1997). The HC allow identifying the different morphotypes. Principal component analysis (PCA) was used to establish relations between the fruit variables. One way ANOVA without transformation was performed to test differences in the phenotypic traits and also in fruit production between different morphotypes, at 5% threshold. Normality was tested by using the Shapiro Wilk test (Glèlè et al., 2006).

Additionally, morphological variation of fruits was determined within morphotypes through the size of fruits on the basis of ratio L/w where L and w are length and width, respectively. One way ANOVA was performed on L/w ratio to test for differences in morphological types between the individual trees. This analysis was followed by a post-hoc test.

Finally, HC and PCA were performed on tree variables (dbh,

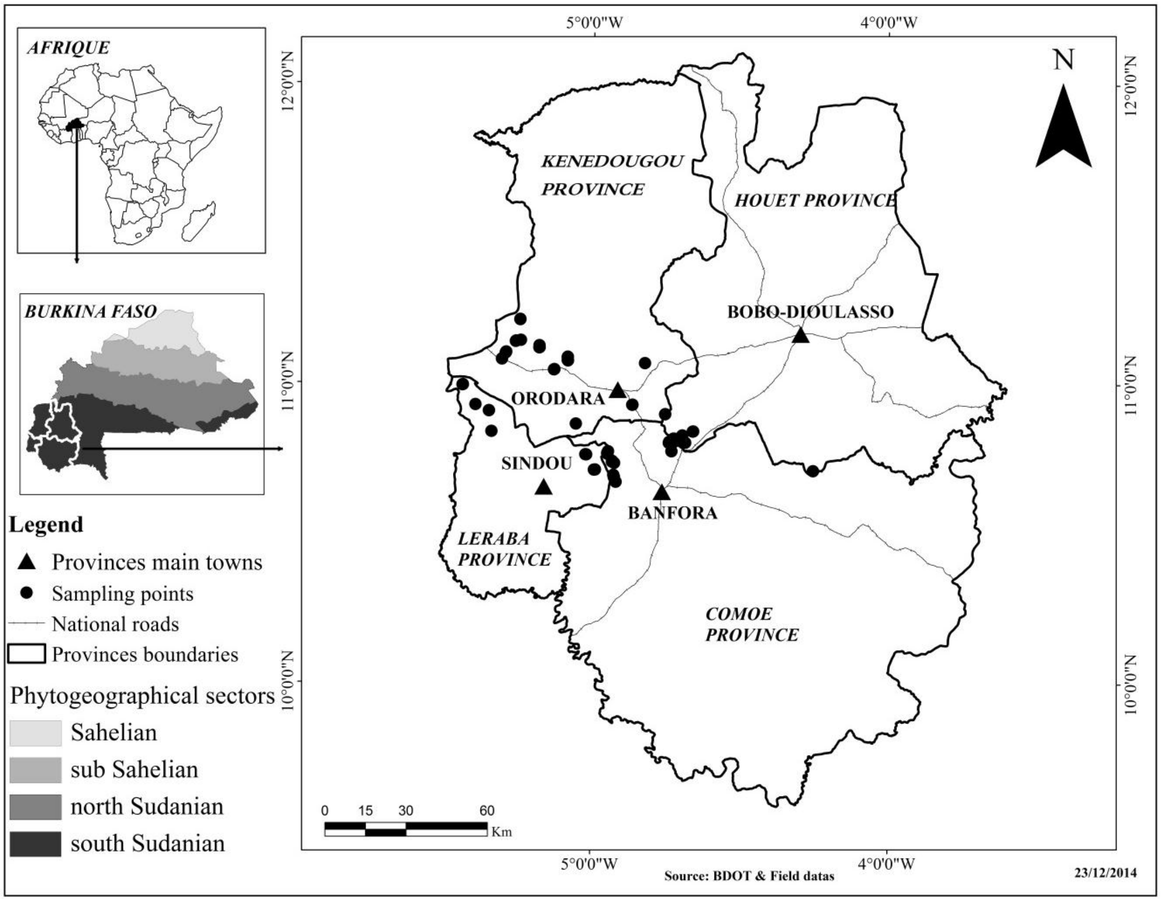

Figure 1. Study area location.

height and crown). The HC was used to determine the types of trees relative to the fruit morphotypes. The PCA was used to test the correlation between fruit characteristics and tree variables.

RESULTS

Phenotypic characteristics of the fruits of *C. procera*

The hierarchical clustering of fruit variables identified three morphotypes representing distinct groups, according to the epicarp aspect (Figure 2).

The morphotype 1, the morphotype 2 and the morphotype 3 included crested fruits, goffering fruits and smooth fruits, respectively. Crested fruits were characterized by the presence of projecting longitudinal crests on the epicarp, each crest corresponding to a carpel. Goffering fruits were characterized by the presence of nodosities on all the surface of the epicarp. Smooth fruits exhibited smooth epicarp surface without clear appearance of carpels contiguous lines (Figure 3).

The PCA ordination of the three fruit morphotypes showed that the first two axes explained 66% of the total variation in the phenotypic traits (Figure 4). The first axis discriminated morphotypes according to fruit length, width, weight and number of seeds. The second axis discriminated morphotypes according to groove depth and apex length. Morphotypes 1 and 2 had large and heavy fruits with a deep groove and long apex. Morphotype 3 had the smallest and lightest fruits with the absence of groove and apex.

Phenotypic variation between morphotypes

The fruits of *C. procera* generally consisted of an orbicular capsule with 5 carpels. One fruit had an average weight of 0.5 ± 0.2 kg and contained 5 to 20 seeds. The ANOVA performed on fruit traits showed significant differences between the three morphotypes. Significant differences were found among morphotypes for the number of seeds per fruit (Table 1). Morphotype 2 contained the highest number of seeds per fruit while morphotype 3 contained the lowest number. The width, length and weight of fruits were similar between morphotype 1 and morphotype 2, but differed significantly

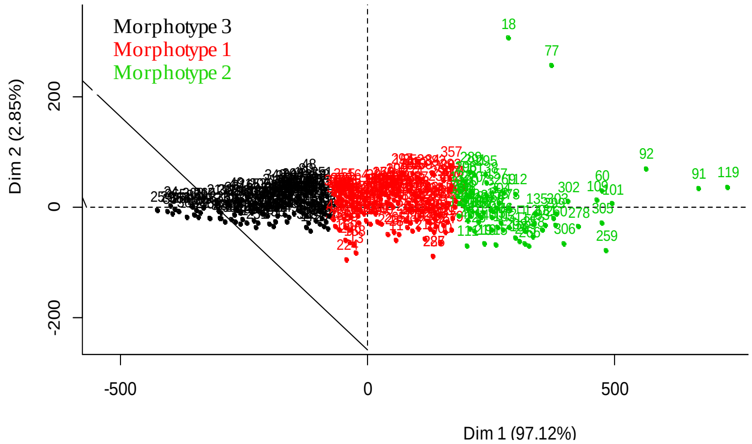

Figure 2. Projection of the three morphotypes of *C. procera* fruits onthe clustering axes (dimensions 1 and 2) defined by phenotypic traits.

Figure 3. Morphotypes of *C. procera* fruits, (a) crested fuit, (b) goffering fruit and (c) smooth fruit.

from morphotype 3. Morphotype 3 exhibited the lowest mean values for all the traits.

Phenotypic variation within morphotypes

The L/w ratio of fruits varied significantly ($p = 0.001$) among fruits bearing trees. Three groups of fruits that we named submorphotypes were distinguished through the significant difference in the fruits ratio L/w within morphotypes at 0.05 threshold. These submorphotypes included short fruits (SM1), long fruits (SM3) and intermediate fruits (SM2) (Figure 5).

Tree dendrometric traits

The hierarchical clustering of tree variables revealed three groups of trees (that were named «tree-type»). The first tree-type included trees bearing crested fruits. The second included trees bearing goffering fruits and the third tree-type included trees bearing smooth fruits. The PCA ordination of tree variables indicated that the first two axes were highly significant ($P < 0.05$) and explained 77.8% of the variation (Figure 6). The coefficient of correlation between the two ordination axes and the tree-type characteristics indicated that the first axis discriminated tree-types according to the dbh, the total height and the crown cover. A larger dbh was correlated with large height and large crown. As for the second axis, it discriminated the tree-types according to the total number of fruits produced.

The Pearson correlation of the variables indicated that the tree variables (dbh, height and crown) had a weak correlation with fruit morphotypes ($r < 0.5$). The results from ANOVA confirmed that the characteristics of fruit morphotypes were not correlated with the tree size, neither with dbh ($p = 0.186$), height ($p = 0.299$), nor crown ($p = 0.616$). Concerning the variation on fruit production, the results showed that the number of fruits per tree was not significantly different ($p > 0.05$) between the three tree types. Likewise, the results indicated that

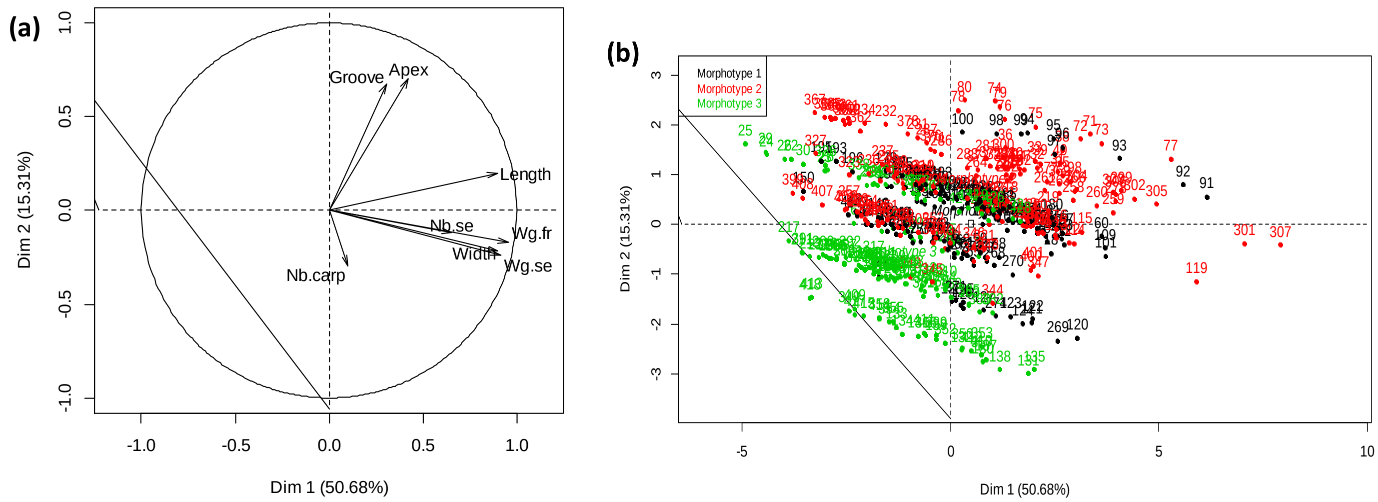

Figure 4. PCA ordination based on phenotypic traits of *C. procera* fruits [projection maps of variables factors (a) and individuals factors (b)]. Nb.carp = number of carpel per fruit; Wg.fr = weight of fruit; Wg.se = weight of seeds per fruit; Nb.se = number of seeds per fruit.

Table 1. Traits values (mean ± standard deviation) of *C. procera* fruits followed by ANOVA test (a, b, c).

Variable	Morphotype 1	Morphotype 2	Morphotype 3
Width	10.3±1.1[a]	10.0±1.7[a]	9.1±1.1[b]
Length	11.3±1.8[a]	11.9±2.8[a]	9.1±1.7[b]
Nb.se/fr	13.3±3.9[a]	14.5±3.5[b]	12.3±3.4[c]
Nb.carp	5.1±0.3[a]	5.0±0.3[a]	5.0±0.2[a]
Wg.fr	0.5±0.1[b]	0.5±0.2[b]	0.4±0.1[a]
Wg.se/fr	0.3±0.1[a]	0.3±0.1[a]	0.2±0.1[a]
Nb.fr/tr	78.6±55.4[a]	68.1±44.5[a]	74.6±48.8[a]
Apex	Short	Short	None
Groove	Low to deep	Deep	Low to none

Nb.se/fr = number of seeds per fruit; Nb.carp = number of carpels per fruit; Wg.fr = weight of fruit; Wg.se/fr = weight of seeds per fruit; Nb.fr/tr = number of fruits per tree; a, b, c are probability values derived from ANOVA and give the differences between the morphotypes: the same letter on the same line mean non-significant difference and different letters mean significant difference.

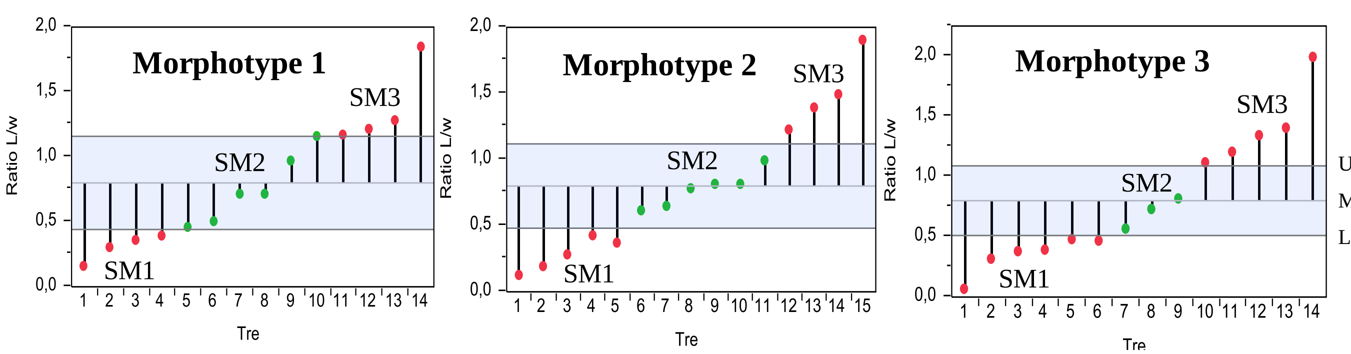

Figure 5. Distribution of submorphotypes of *C. procera* fruits within morphotypes. The submorphotypes are based on the L/w ratio. SM1 = submorphotype 1; SM2 = submorphotype 2; SM3 = submorphotype 3; UDL = upper decision limit at 5%; M = mean; LDL = lower decision limit at 5%.

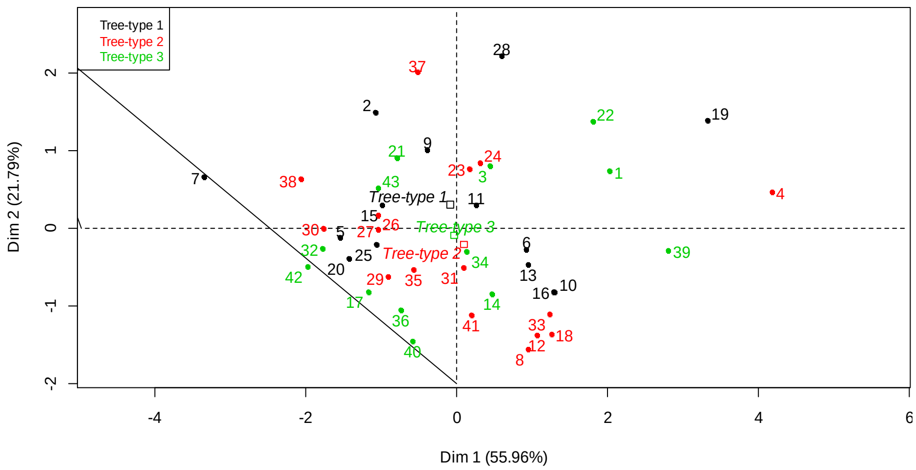

Figure 6. Projection of the three tree types of *C. procera* on the ordination axes (Dim 1 & 2) related to their characteristics.

the fruit traits of submorphotypes were not correlated with the tree dbh, height and crown.

DISCUSSION

Fruits are the most important product from *C. procera* and are a good source of income for local communities. The selection of fruit base on their characteristics is therefore very important for the domestication of the species (Leakey et al., 2005). The overall fruit size is indeed an important and easily selected trait for productive cultivars (Atangana et al., 2002).

In the present study, considerable variations in fruit traits were observed among *C. procera* populations, which revealed three different fruit morphotypes. Some traits of the fruits are important assets for selection needs. They are the large size and weight of fruits and the high number of seeds. Similar diversity of fruits traits were recorded across the local distribution range of the species, which means variations cannot be attributed to a specific population or a provenance. Likewise, these variations cannot be attributed to environmental or climatic factors as reported for other species in previous studies (Anegbeh et al., 2005; Ewédjè et al., 2012; Padonou et al., 2014). The evidence is the environmental and climatic conditions are similar at our study area scale for all the trees populations. In this situation the important factors that may have affected the morphological traits of the fruits are the age and the genotype of trees (Assogbadjo et al., 2005, 2006). In the present study, the data were collected as well in the young trees as in adult ones, which indicated non-correlation with tree size. The PCA and ANOVA results showed that the variations in fruits were not related to the tree parameters. So, the final possible factor that could explain the phenotypic variations in the fruits of our study population of *C. procera* may be the genotype of trees. The phenotypic differences between fruits with genetic origin could result from adaptation of the species to diverse environmental conditions (Mathur et al., 1984). This possible genetic variation in *C. procera* fruits could be an important source for varietal selection. Within each morphotype, the significant variation in fruit size showed that the submorphotype 3, which provided biggest fruits, should be more desirable in terms of selection. Consequently, any improvement program must also take these valuable traits into account and select trees that combine large fruit size with high weight and number of seeds.

The tree-to-tree variation in fruit characteristics is consistent with results from other indigenous fruit trees, such as *P. butyracea* (Ewédjè et al., 2012). As in the case of this later riparian forest species of West Africa, the phenotypic assets coupled with the market opportunities for fruit products represent domestication opportunities for *C. procera*. Similar studies highlighted the variation in fruit and kernel traits of *Irvingia gabonensis* and *Dacryodes edulis* in West Africa and indicated that farmers have obtained a gain of 40 to 65% in fruit mass by their own procedures of genetic selection (Atangana et al., 2002; Anegbeh et al., 2005). In the case of *C. procera*, increasing fruit mass could lead to oil yield increasing, which is a positive element for oil production improvement. It is clear from the results of this study that there is opportunity to identify and promote individual trees with high valuable fruit characteristics.

Conclusion

This study provides interesting basic knowledge about the extent of variation in *C. procera* fruit traits. Trees of the species exhibited three morphotypes of fruits based on phenotypic traits. One morphotype raises higher number of seeds than the two other ones and includes a submorphotype with the biggest fruits being the best candidate to selection and domestication for oil production purposes. This study provides evidence that there is considerable intraspecific variation in fruit traits of importance to genetic selection. Based on these results, programs of participatory domestication can be developed for *C. procera* in Burkina Faso. Therefore, through the development of cultivars from the best trees, it should be possible to make substantial improvements to the quality of the marketable products. On a wider scale, it is expected that this approach may benefit not only on the livelihoods of people, but also on the sustainability of the species' genetic resources. A tree selection based on fruit morphotypes could be a basis for conserving natural populations of *C. procera* and, thus, could be valued to develop management programs aiming at genetic resources conservation as well as plantations with highly productive varieties of *C. procera*. In terms of fundamental research, the actual results may raise research questions on the taxonomic status of *C. procera* in West Africa with regard to the morphological diversity of fruits.

Conflict of Interest

The authors have not declared any conflict of interest.

ACKNOWLEDGEMENT

This work was carried out within the frame work of the QualiTree Research project funded by Danida (10-002AU), to which the authors are grateful.

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