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Agro-morphological variability of shea populations (*Vitellaria paradoxa* CF Gaertn) in the Township of Bassila, Benin Republic

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Shea (*Vitellaria paradoxa* CF Gaertn) is a multipurpose forest tree species. This is one of the most integrated species in the cropping systems in the central and northern regions of Benin. It is also an important source of income for the population. Observations were made on some shea trees randomly selected in three vegetation types namely forests, fallows and farms. Data collection on quantitative and qualitative parameters such as length and width of leaves and fruits, tree diameter, fruit shape, crown shape, shape of leaf apex were made on 90 shea trees. The results show that the average density of shea trees per hectare varies (not significantly different) according to the three vegetation types (farms, fallow, and forests). The average diameter of tree trunk at man chest level was 37.35 ± 7.78 cm with a coefficient of variation (CV) within population was 21.09%. Variations between Shea populations in the study area were quite important and show the diversity of natural populations of the species. Leaves were predominantly oblong shape with an average length of 18.33 ± 3.21 cm and an average width of 6.92 cm ± 1.28; the leaf apex was in "pointed" shape. The fruits were dominantly oblong in the three vegetation types. The fruits had an average length of 4.49 ± 0.77 cm and a mean diameter of 3.56 ± 0.48 cm. The crown in shape of broom was observed so frequently in the different vegetation types. The longest and widest leaves and the longest and largest fruits were found in fields and fallows, while the smallest leaves and fruits were found in the forests.

Key words: Vegetation types, *Vitellaria paradoxa*, morphological diversity, Benin.

INTRODUCTION

Shea (*Vitellaria paradoxa* CF Gaertn) (Sapotaceae) is a tropical tree with multi-usage playing a socio- economic role in sub- Saharan Africa. In Africa, the area of distribution of shea tally with the area of Sudano-Sahelian climate. The species covers a geographical band from eastern Senegal to northwestern Uganda on a stretch of

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5000 km long, 500 to 700 km wide between 600 and 1500 mm isohyets (Hemsley, 1968; Boukoungou, 1987; Salle et al., 1991; Hall et al., 1996). Two subspecies have been identified presently (Djekota et al., 2014), *V. paradoxa* subsp. paradoxa is found in West and Central Africa (Salle et al., 1991; Fontaine et al., 2004; Sanou et al., 2005; Allal et al., 2008; Nyarko et al., 2012 while V. paradoxa subsp. nilotica is common in East Africa (Okullo et al., 2004; Byakagaba et al., 2011; Okiror et al., 2012; Gwali et al., 2011; Djekota et al., 2014). In the collection area in Benin, the species while enjoying the full protection of the forestry legislation is also saved by farmers during agricultural clearings. It is found in the form of natural population, and its predilection area goes from the region of Zou River (Atchérigbé latitude) to Malanville (Gbédji, 2003; Gnanglè, 2005), and is between 07°06' and 12°03' of north latitude. Its fruit plays socio-economic role of vital importance for the people of northern and central Benin. Almond obtained from the seed is transformed into shea butter and widely used in culinary cooking and strongly marketed in the sub-region and in the world. This oil is also used in the manufacture of cosmetics and pharmaceutical products. It is also used in traditional and social rituals such as marriages, funerals, coronations and rainmaking (Hall et al., 1996; Ferris et al., 2004; Moore, 2008; Gwali et al., 2012; Djekota et al., 2014). The wood of the shea butter tree is used for charcoal, mortar and pestle, furniture and construction, and the latex for glue making (Lovett and Haq, 2000a).

In term of agro-forestry importance in Benin, shea ranks second behind palm oils (Agbahungba et al., 2001). Shea is also the third Beninese largest export crop after cotton and cashew. Benin is the fourth shea almond producer in Africa after Mali, Burkina Faso and Nigeria (Dah-Dovonon and Gnanglè, 2006).

Despite the importance of this species, it is, however, subject to menace of all kinds especially related to high demography pressure, its low natural regeneration, the current practices of bushfires, these represent the leading cause of destruction of shea populations. The second cause of degradation of shea parks in Benin is their invasion by parasites, epiphytes and fungi. Promoting shea sector is a good lever to diversify agricultural production, fight against desertification and boost the development in the northern Benin. To this end, a better understanding of the variability within the gene pool of the species is necessary for its domestication, its conservation, continuation and improvement. Many studies have shown the existence of a high intra-specific variation (Chevalier 1943; Ruyssen 1957) among shea trees. Many authors have also shown a phenotypic variation and a correlation between its different physical properties Lovett and Haq (2004) in Ghana, Sanou et al. (2006) in Mali, Diarrassouba et al. (2007) and Djekota et al. (2014) in Chad. Therefore, a study on the shea diversity is necessary for a good conservation, good management and a selection of the best genetic resources of this tree species.

The objective of the present work was to study the agro- morphological variability among three vegetation types namely forests, fallows and farms for a better knowledge of individuals in their natural environments.

MATERIALS AND METHODS

Study area

The study was carried out in the northwest of Benin, in Bassila Township. The Township of Bassila is divided into four (4) districts and is covered on more than two fifths of its territory by forests. It extends over an area of 5,661 km^2 and is situated between 1º15' and 2º22' East longitude, 8º31' and 9º30' North latitude (Figure 1). There is a Sudano-Guinean climate and two (02) seasons in rotation. The rainy season starts from mid-April to mid-October and a dry season from mid-October to mid-April.

The average annual rainfall is between 1200 and 1300 mm and sometimes beyond 1500 mm in forest ecosystems (ASECNA, 2008).

The annual average temperature varies between 26 and 27ºC. Minimum temperatures of 17ºC was recorded in December-January and maximum of 40ºC in March-April (ASECNA, 2008).

Selection of villages

Six villages (Figure 1) were selected based on the following criteria: easy access to villages, the inhabitants of these villages should be part of one of the three major ethnic groups (Nago, Ani or Kotokoli), the inhabitants who participated in the workshop training organized by the Project for Conservation and Management of Natural Resources (ProCGRN) on improved techniques for collecting, processing and packaging of nuts and almond Shea and on butter manufacturing. It is about of village select by district: Bassila (Kikélé ; Adjiro); Manigri (Manigri-akanni); Pénéssoulou (Pénelan ; Nagayilé ; Kodowari) (Figure 1).

Experimental design

In each of the six selected villages, the same vegetation types were also selected (fallow, farms and forests). In each village and within each vegetation type, a plot of 1000 m^2 (50 m × 20 m) was delimited so a total of 18 plots. The geographical coordinates of the each plot was taken using a Geographical Positioning System apparatus (Garmin). Within each plot, five fruiting trees were randomly selected, then for the 18 plots a total of 90 Shea trees were selected. On each of the five trees, the length and width of 10 adult leaves were measured. Leaves and fruits were collected from the four (04) corners of the tree (North, South, East, and West). The same thing was done for the length and the diameter of 10 ripe fruits and the diameter of trunk up to a man chest, 1.30 m (DBH). Observations were noted on a morphological characterization of the tree and the describers analyzed.

Plants materials

The plant material consists of shea trees randomly selected in three vegetation types namely: farms, forests and fallows and in six villages. The selected trees were mature, at reproductive stage. Although, the sampling was randomly performed considering trees

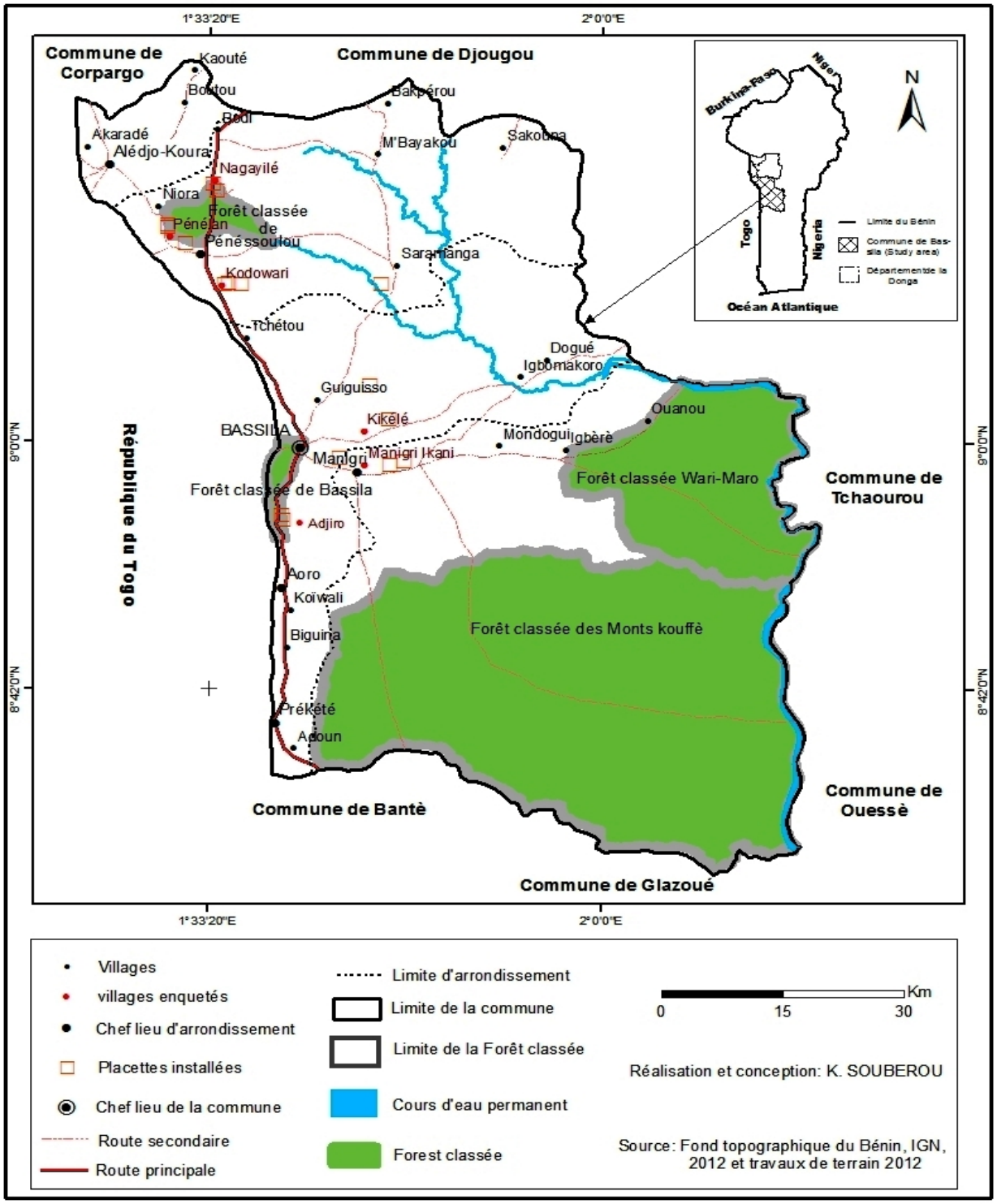

Figure 1. Geographical and Administrative Map of Bassila Township showing plots installed in the vegetation types.

that were spaced at least 10 m from each other to avoid the mixture of fallen fruits from two (02) different shea trees. For qualitative values, the following parameters were considered: the color of the bark, the shape of the crown, foliage density, the shape of the branches on the tree, the leaf shape, the shape of fruit, fruit type, and the appearance of the trunk.

Statistical analysis

The data collected at each site were encoded and saved in Microsoft Excel 2007 software. For quantitative data, the analysis of variance was carried out using SPSS (Statistical Package for the Social Sciences) for Window 16.0 and significant differences

Table 1. Average density of shea trees per hectare and per vegetation type.

Vegetation types	Farm	Forest	Fallow
Average density (shea tree/ha**)**	7.333	6.0	6.667

Table 2. Mean diameter of trees in different vegetation types.

Formations variables	Population			
	Farms	Forests	Fallows	Average inter-population
Average population (cm)	38.09[a]	38.19[a]	37.15[a]	37.35
Standard deviation	7.31	8.76	7.28	7.78
CV (%)	19.19	22.75	19.59	21.09

between means were detected using Newman-Keuls test. For leaf and fruit variables which conditions of normality and equality of variances were not satisfied, those variables are transformed and the test of Krsuskal-Wallis was used (a non-parametric alternative test analysis of variances) to separate averages at P= 0.05.

The classes of variations proposed and tested by Ouédraogo (1995) and Kouyaté (2005) in their study of West African populations of *P. biglobosa* composed of 1.663 individuals from five countries (Senegal, Mali, Burkina Faso, Niger and Chad) and on ethno-botanical aspects of the morphological, biochemical and phenological variability of *Detarium microcarpum,* were used to evaluate intra-and inter-population variation. The scale proposed by these authors is as follows:

1. Low variation (CV = 0 -10%)
2. Average variation (CV =10 -15%)
3. Moderate variation (CV=15 - 44%)
4. High variation (CV > 44%)

RESULTS

Inventory of Shea trees per hectare

Table 1 shows the results of the counting of the average density of shea trees per hectare and per vegetation type.

The analysis of Table 1 shows that the number of shea tree per vegetation type and per hectare was at least of 6 trees. These results show that the variability of density according to the three (03) vegetation types is not significantly. The density of shea trees in the farms, forests and fallows is almost the same. The highest (not significantly different) densities were found in the farms and forests while they were low in the fallows.

Morphological characterization of trees

Diameter of vegetation types

The average diameter of trees in different vegetation types is presented in Table 2. The analysis of Table 2 shows that the average diameter of shea trees in the farms and forests was almost identical that is these trees had almost the same size. The analysis of variance shows that there is no significant difference between the mean diameters of the three vegetation types. The trees of both vegetation types (farms and forests) show an average diameter greater than that of fallow 0.94 cm and 1.04 cm respectively.

The inter-population variation of trunk diameter was large enough for the CV (21.09) was between 15 and 44%.

Leaf size

All quantitative parameters measured on the leaf including: leaf length (LL) and leaf width (LW) were subjected for normality. The probability (P = 0.010) associated with this test was less than 0.05 therefore, the data were not normal. The main condition for using the test of variance analysis was not verified. The non-parametric test of Kruskal-Wallis was used in this case. The analysis of this test showed significant differences for the two quantitative parameters of the leaves (P = 0.001). The probability was less than 0.05, therefore, the median of length and width of leaf vary significantly between the three (03) vegetation types (Table 3). The leaves were longer in the farms than in the forests and fallows. The intra-and inter-populations for the length and width of leaves were large enough for the coefficients of variation were between 15 and 44%.

Fruits

Table 4 shows that the length and diameter of fruits vary according to vegetation types. Its value decreases from the farms to the forests through the fallows. The average length for inter-population of fruit observed was 4.49 cm. The longest fruits (4.69 cm) and the largest fruits (3.73 cm) were observed in the farms, while the smallest fruits were recorded in forests. The test of Kruskal-Wallis

Table 3. Average Length and width of leaves in different vegetation types.

Traits	Populations				
	Formations variables	**Farms**	**Forests**	**Fallows**	**Average inter population**
Leaf length	Average population (cm)	19.4[a]	18.35[b]	17.26[b]	18.33
	St. deviation	2.91	3.24	3.5	3.21
	CV (%)	15.02	17.64	20.31	17.65
Leaf width	Average population (cm)	7.2	6.63	6.95	6.92
	St. deviation	1.11	1.46	1.29	1.28
	CV (%)	15.45	22.11	18.65	18.73

Table 4. The average length and diameter of fruits from the different vegetation formation.

Traits	Formations population				
	Variability	**Farms**	**Forests**	**Fallows**	**Average inter population**
Fruit length	Average (cm)	4.69[a]	4.27[b]	4.52[b]	4.49
	St. deviation	0.96	0.61	0.74	0.77
	CV (%)	20.56	14.45	16.51	17.17
Fruit diameter	Average (cm)	3.73	3.4	3.57	3.56
	St. deviation	0.48	0.52	0.44	0.48
	CV (%)	12.99	15.42	12.37	13.59

showed a highly significant difference for all quantitative parameters of fruits (P = 0.001). The probability associated with the test was less than 0.05. Variations intra- and inter-populations for the length of the fruit were quite important because the coefficient of variation was between 15 and 44%. On the other hand, these intra-and inter population variations for diameter of the fruit were average because its coefficient of variation was between 10 and 15%.

Qualitative parameters

The color of the bark of trees sampled varies from black to light gray through the dark gray. The frequency of the black color of the bark was in increasing proportion from the farm (30%) to the forest (46.67%) and other colors (dark gray and light gray (ash) were in variable frequency within the three (03) vegetation types (Figure 2).

The trunk all the shea trees were rough in appearance. The shea trees studied had a crown in shape of a ball, broom, elliptical, or other (Figure 3). The broom shape (34.33%) was frequent in the three vegetation types. The ball shape was frequent in fallows and farms. The other forms of the crown were found in the forests.

The foliage density was average for almost the tree observed with opposite branches compared to the whorled branches in the forests and fallows.

The different shape of leaves observed (Figure 4) within the vegetation types were oblong (41 .66%), Elliptical (27.34%) and Oboval (31%). The leaves of the tree studied had almost oblong form with an apex in pointed shape (93%).

The regular fruit shape in the three (3) vegetation types (farms, forests and fallows) was oblong shape (68,33%) followed by spherical form and other forms (ovoid, elliptical (Figure 5) but in low percentage (31.67%). These different shapes vary from one village to another and from a vegetation type to another.

Correlation between leaf and fruit descriptors in the different vegetation types

The correlation values between quantitative parameters of fruits and leaves are presented in Table 5. The analysis of Table 5 shows that there was positive and significant correlation (r) between the length of fruits and fruit diameter in the farms (r = 0.579), forests (r = 0.145) and fallows (r = 0.503) as well as for the length and width of leaves (r = 0.157) in the farms. Similarly, there was negative and significant correlations between leaf length and fruit length in fallows (r = -0.189), leaf length and diameter of fruits in the farms (r = -0.176) as in the fallows (r = -0.186).

DISCUSSION

The study of agro- morphological characterization of

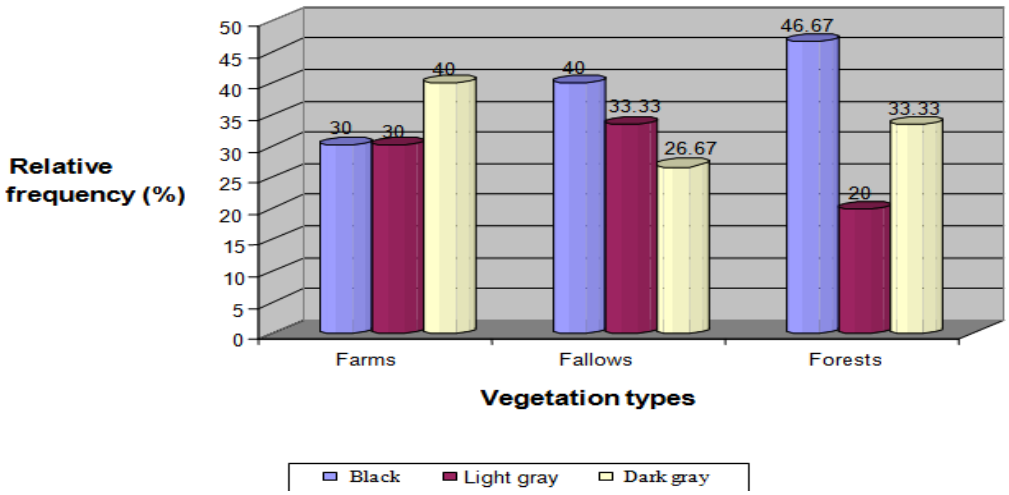

Figure 2. The color of the bark of trees per vegetation type.

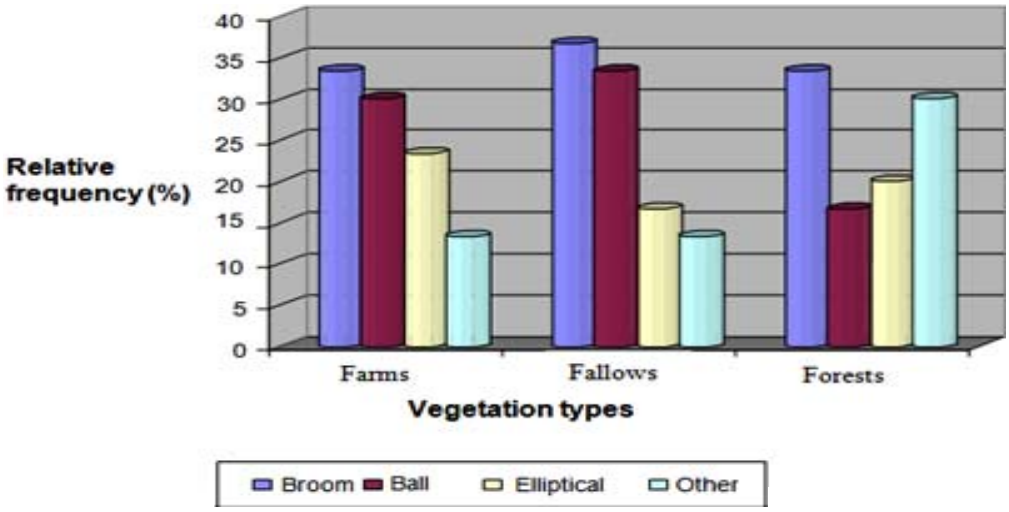

Figure 3. The color of the crown of shea trees per vegetation type.

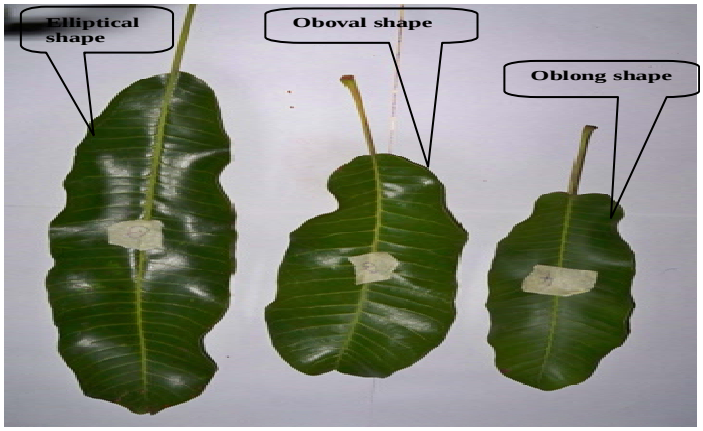

Figure 4. Leaf shape of *V. paradoxa* collected.

Figure 5. Different shapes of shea fruits.

Table 5. Correlations between quantitative parameters of leaves and fruits per vegetation type.

Parameters measured	Fruit length	Fruit diameter	Leaf width	Leaf length
Farm				
Fruit length	1	**0.579***	**0.213***	0.098
Fruit diameter	0.579*	1	0.238*	-0.176
Leaf width	0.213*	0.238*	1	0.157*
Leaf length	0.098	-0.176*	0.157*	1
Forest				
Fruit length	1	0.145*	0.023	0.179*
Fruit diameter	0.145*	1	0.038	0.055
Leaf width	0.023	0.038	1	0.006
Leaf length	0.179*	0.055	0.006	1
Fallow				
Fruit length	1	0.503	0.005	-0.189*
Fruit diameter	0.503*	1	0.122*	-0.186*
Leaf width	0.005	0.122*	1	-0.056
Leaf length	-0.189*	-0.186*	-0.056	1

*Values represent significant correlations.

populations of *V. paradoxa* in the northern Benin and more specifically in Bassila Township shows that the density of shea trees in the farms, forests and fallows is almost the same. However, the trees of *V. paradoxa* are more numerous in the farms within than the remaining two (02) habitats. The shea tree is threatened in forests and fallows because of the fires of vegetation, fraudulent cuts (industry use) and parasites (borers, fungi, epiphytes). The larger number of shea trees in the farms could be justified by the strong protection and maintenance of trees by farmers in this habitat because of the socio-economic importance of the species. In addition, of all the parameters measured, it appears that the highest values were observed in the farms. The values of parameters of trees recorded in forests are lower than those found in farms and fallows. Similar observations were reported by Sanou and Lamien (2011). Forest trees are smaller than those commonly found in farms and fallows because of the competition observed in forested areas. The trees are better distributed in the farms than in forests or fallows because of human intervention.

The average length and width observed in the populations of shea trees in Bassila Township were within the range of values defined by Thioulouze et al. (1997); length (minimum 5.4 cm and maximum 21.3 cm) and width (minimum 2.2 cm and maximum cm 6.8 cm). However in Chad zone, the lamina length is ranged from 15.5 to 26.3 cm, while the width of lamina varied from 3 to 5.4 cm (Djekota et al., 2014). Leaves of V. paradoxa found in Chad are not width than those found in other zones of West Africa. This shows that *V. paradoxa* is very diversified. Taking into account the agro-climatic zone, especially the Sudano-Guinean zone in which Bassila Township is, the average values measured were larger than those reported by Sanou et al. (2006) and Lovett and Haq (2000). The values obtained by these authors were respectively the Sudanian zone of 13.65 and 14.9 cm in length and 3.88 and 4.9 cm in width and for the Guinean area of 14.24 and 3.97 cm. The differences observed between the trees in Bassila Township and those of Ghana and Mali are caused by genotype or by the diversity of environmental conditions in each area of study and predetermine the behavior of a plant. The dimensions of the fruit of the Shea tree (length 3.6 cm diameter and 3.1) reported by Sanou et al. (2006) are low compared to the results of this study. Concerning the dimensions of the fruit, our results are low compared to those obtained by Djekota et al. (2014). These differences might be related to genotype or ecological conditions. In relation to the different coefficients of variation for most of the parameters measured, they were between 15 and 44% either within or between populations. This shows a fairly large variation in the populations of Shea tree in Bassila Township. In the present work, the coefficients of variation obtained between populations (farms, fallows and forests) are quite important compared to significant variations observed by Lovett and Haq in 2000 when studying the diversity of V. paradoxa in semi -arid areas of Ghana from 294 individuals distributed on twenty-four sites and 18 locations. This difference between the coefficients of variation could be explained by the fact that the study sites of Lovett and Haq were more numerous and varied on one hand and secondly the trees on which these researchers also worked were also many. The fairly large inter-population variation obtained shows the effect of the environment on the behavior of trees.

The values of correlation of leaf and fruit characteristics were low while they were high between the characteristics of the same organ, as shown by the results of Sanou et al. (2004) in Mali.

The results of qualitative morphological characteristics show that the color of the bark of Shea trees in Bassila Township was black contrary to the gray and light gray colors observed by Boukoungou (1987) and Chevalier (1943). The tree habit is quite variable. The crown of the tree was in ball, broom, elliptical shape. These shapes are similar to those obtained by Boukoungou (1987) and Diarrassouba et al. (2009). But the author also observed other shapes of the crown. According to Boukoungou (1987) the different shapes observed were not due to varietal differences but result from the action of bushfires during the formation of the structure of the tree by the disappearance of the lower branches and the destruction of small branches. The shape of the observed branches varies between opposite and whorled branches. The foliage density observed was similar to that reported by Desmarest (1958) except that observed in more densely manner by the author. The dominant shape of leaves and fruits of shea trees in the sampled population was oblong. This same observation was made by Chevalier (1943) with regard to leaf shape. In relation to fruit shape observed in Bassila Township, it was variable: oblong, spherical, ovoid and elliptical. In this study, four shapes of fruit were observed comparing to the results of Djekota et al. (2014) and Diarrassouba et al. (2009) who obtained respectively three in Chad region and five in Ivory Cost. Four shapes of fruit were noted in the farms contrary to Knight (1943) who observed two shapes (elliptical, spherical). This could be explained by the reduced number of Shea trees on which the researcher worked and also by phenotypic and genotypic differences (Lovett and Haq, 2000, Fontaine et al., 2004). The variations observed in different zones can be explained by some factors: natural and/or human selection, gene flow mediated from genetic drift, out crossing, environment (Yadina 1991; Irwin, 2000; Okullo et al., 2003; Vaughan et al., 2007; Tremblay et al., 2010; Abasse et al., 2011; (Djekota et al., 2014).

Conclusion

Agro-morphological characterization of populations of *V.*

paradoxa contributes to improve our better understanding of the species in Bassila Township. A high morphological variation was observed within shea populations from three different habitats. The variation intra and inter population is quite important for the length of the fruit while it was average as regards the diameter of the fruit. The study of qualitative parameters shows that the appearance of the trunk of all the Shea trees studied was rough. For the color of the trunk black was dominant with rectangular cracks. The shape of the crown was broom, with a relatively high frequency of into a ball and broom shapes in the farms and fallows. Foliage density was average for most of the observed trees with more opposite branches than whorled ones in the farms than in the forests and fallows. The leaves of the tree studied were mostly an oblong shape with an apex in pointed shape. The shape of leaves and fruits is discriminative. To ensure sustainable management of the shea sector, it would be desirable to continue this study by expanding to other ecological regions of Benin and integrating quality aspects of the pulp and amount of oil of almond of trees.

Conflict of Interest

The authors have not declared any conflict of interest.

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