International Journal of Plant & Soil Science
5(1): 25-39, 2015; Article no.IJPSS.2015.057
ISSN: 2320-7035

SCIENCEDOMAIN *international*
www.sciencedomain.org

SCIENCEDOMAIN

Morphological Variation and Ecological Structure of *Chrysophyllum albidum* G. Don

S. Dadegnon[1], C. Gbemavo[1], C. Ouinsavi[1*] and N. Sokpon[1]

[1]Faculty of Agronomy, Laboratory of Forestry Studies and Research, University of Parakou, BP 123 Parakou, Benin.

Authors' contributions

This work was carried out in collaboration between all authors. Author SD designed the study, wrote the protocol, and wrote the first French draft of the manuscript. Author CG performed statistical analyses of the study author CO managed the literature searches and the experimental process, translated and wrote the english draft of the manuscript. Author NS followed up the whole study, read and corrected the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2015/11385
Editor(s):
(1) Bin Gao, Department of Agricultural and Biological Engineering, University of Florida, USA.
Reviewers:
(1) Anonymous, Centro Universitário Hermínio Ometto, Araras, SP, Brazil.
(2) Marisa Jacqueline Joseau, Department of Plant production. National University of Cordoba, Argentina.
(3) Anonymous, Federal University of Minas Gerais, Brazil.
(4) Joan Bruno Silva, Department of Botany, Universidade Federal de Pernambuco, Brazil.
Complete Peer review History: http://www.sciencedomain.org/review-history.php?iid=779&id=24&aid=7182

Original Research Article

Received 13th May 2014
Accepted 5th August 2014
Published 10th December 2014

ABSTRACT

Chrysophyllum albidum is a tropical forest species which plays tremendous socioeconomic role in west Africa because of its fruits large comsuption and trade.
Morphological variation and ecological structure of *Chrysophyllum albidum* G. Don were assessed in Benin in order to contribute to the species domestication. Dendrometric parameters such as diameter at breast height, total height, and bole heigt were measures from 120 individual trees across two ecological zones and four different provenances. In addition, morphometric parameter related to fruits and seeds such as fruit length, fruit width, fruit weigh, seed length, seed width and seed weigh were measured for 1,800 fruits and 1,800 seeds. Principal component analysis was performed on the untransformed morphometric data using the correlation matrix.
Diameter and height classes distribution of *C. albidum* in each ecological zone adjusted to Weibull distribution showed a bell shaped curve with left dissymmetry, characteristic of young stands (form coefficient between 1 and 3.6). From principal component analysis, no differentiation was observed, indicating that accessions from different agroecological zones were similar

**Corresponding author: E-mail: ouinsch@yahoo.fr;*

morphologically. However analysis of variance performed separately on morphometric data revealed some significant difference among agroecological zones and among provenances as far as bole height (*P = .000*) and fruits and seeds size (*P = .021*) are concerned.

Although morphological variability in *C. albidum* between provenances and between agro-ecological zones is low there is pathways for selection purposes since bole height as well as fruits and seed weight exhibited large morphological variability among agro-ecological zones.

Keywords: Variability; morphology; Chrysophyllum albidum; Benin.

1. INTRODUCTION

The West Africa in general and Benin in particular are characterized by population pressure causing overexploitation of plant resources. This situation has increased nowadays causing scarcity of "Non Timber Forest Products. "Plants commonly called "Non Timber Forest Products" or "Forest Food Products" [1], without producing lumber and veneers play an important socio-economic role. They help greatly to feed rural people in West Africa [2] and contribute significantly to improving the livelihoods of local populations [3,4]. *Chrysophyllum albidum* G. Don, is a species that belong to the family of Sapotaceae and it is part of the list of the priority Food Woody Species (FWS) in Benin. This is a NTFP whose habitat seems to be limited to urban areas [5] traditional agroforestry systems, remnant semi-evergreen forests where it is often protected for religious purposes [6,7].

Chrysophyllum albidum, commonly called white star apple, is native to Central America and sometimes from West America. *C. albidum* is widely distributed in West Africa through Central Africa and East Africa [8]. It is often planted in Benin and in many countries in West Africa like Nigeria for its edible fruits [9]. *Chrysophyllum albidum* is found in Benin on lateritic soils [10]. Fig. 1.a shows the species distribution area in Benin. *Chrysophyllum albidum* a species of tropical lowland forests that can reach 25-37 m height at maturity with a circumference ranging from 1.5 to 2 m. *Chrysophyllum albidum* is a plant that plays a significant socio-economic role in West Africa. The species is an important source of income for rural people (especially women) of Benin. *Chrysophyllum albidum* became in the recent past a plant of commercial value in Nigeria [11]. The fruit is consumed directly by rural and urban populations of Benin [12] and Nigeria [13]. The fruit pulp contains iron and vitamin C and is a good source of raw materials for industries [13,14]. The leaves, seeds, bark, roots are used by local people of Benin and elsewhere in traditional medicine [12,15]. The seeds of *C. albidum* absorb metal ions and could be used for the development of a cheap technology for effluent treatment [16]. Given the socio-economic, industrial and therapeutic importance of *C. albidum*, it is urgent to address the lack of scientific knowledge on this plant as far as the ecological, biochemical and genetic are concerned in order to assist in the development of conservation strategy for the sustainable management of its culture.

The process of species conservation strategy development for its sustainable management includes the analysis of the species' morphological variability. This variability of plant species is generally expressed in terms of characteristics of the vegetative and/or reproductive organs [17]. According to [18] Dosba et al., varietal characterization must involve individuals who have adapted to specific ecological conditions. The aim of this work was to study the morphological variation and the ecological structure of *C. albidum* in order to contribute to his domestication.

2. MATERIALS AND METHODS

2.1 The Study Area

The study was carried out in two agro-ecological zones (Fig. 1b) within *C. albidum* natural distribution area in Benin [19]. The classification of these areas is based on the definition of relatively homogeneous areas using agro-pedological parameters, cropping systems, the spatial distribution of people and vegetation. The two agro-ecological zones identified for the study were: Zone VI called Lateritic Land Zone and Zone VIII, called Zone of Fishermen. The main features and possible activities of the two zones are shown in Table 1.

Localities of study in both agro-ecological zones are located in the departments of Atlantic and Oueme.

2.2 Sampling

In each agro-ecological zone, two municipalities were selected based on accessibility and the effective presence of *C. albidum* trees. So in Zone VI, Allada and Adjara districts were selected while Abomey-Calavi and Dangbo districts were chosen in zone VIII. In the current study, all individuals of *C. albidum* from each municipality were considered as a provenance. Then from each provenance, 30 individuals of *C. albidum* spaced at least 20 meters apart [20,21] were randomly selected for the collection of morphological data. This space between trees was observed to prevent harvesting equipment on related individuals.

According to the literature, the minimum sample size is twenty five (25) independent and supposedly unrelated individuals for seed collection in forestry in order to have the best chance of maximum diversity [22]. *Chrysophyllum albidum* trees selected have either been planted at home or pushed spontaneously in urban areas. Regeneration under the mature sampled trees was recorded and mature trees were marked and geographically recorded using a GPS.

2.3 Morphometric Analysis

A set of agro- morphological parameters including bearing and architectural parameters (diameter at the breast height DBH, total height TH, bole height BH) and descriptive parameters of fruits and seeds (length, circumference, and weight) was selected following [20] Kouyaté and Van Damme, [23] Ouinsavi and Sokpon and used to assess morphological variability. Sampled trees were measured *in situ* for their circumference at 1.30 m from ground level, their total height as well as their bole height. Fifteen (15) fruits and 15 seeds per tree were also measured for their long, circumference. In addition fruits and seeds weight were determined using an electronic scales. A total of 1,800 fruit, 1,800 seeds and 120 individuals trees were measured. DBH of trees was determined from the trees circumference at 1.30 m above the ground. Rainfall data was collected from the meteorological station of the Agency for Safety and Air Navigation in Africa and Madagascar (ASECNA).

Different ratios such as DBH/TH and DBH/BH were used to minimize the effect of the unevenness age of trees [23]. A Principal Component Analysis (PCA) was performed on the morphological parameters using the correlation matrix. Cluster analysis was also performed on standardized data using [24] InfoStat 2008 software. Populations were separated on the basis of euclidian distance using average linkage.

2.4 Morphological Variation of *Chrysophyllum albidum* and its Relationship with Rainfall

Descriptive statistics for each parameter of the plant has been performed for all of the fruits, seeds and trees analyzed. Two ways analysis of variance (Provenance and Agroecological zone as fixed factor) was conducted to test the effects of these factors on the morphological parameters and production of *C. albidum*. The Student-Newman - Keuls homogeneity test were used to identify homogeneous groups in case of significant difference. These analyzes were performed using R Software. The classification of the variability between provenances on one hand and among agroecological zones on the other hand was made using a scale proposed and tested on bio- systematics of west African provenances of *Parkia biglobosa* [25] and Malian provenances of *Andosonia digitata* [26] as follow: Low variation (CV = 0-10%); medium variation (CV = 10-15%); sizeable variation (CV = 15-44%); significant variation (CV > 44%).

To analyze the impact of rainfall on the morphology of the species, a Principal Component Analysis (PCA) was performed on the morphological parameters with significant variability. Pearson correlation was also performed using SAS version 9.2 [27].

2.5 Structural Analysis of *Chrysophyllum albidum* Trees

Chrysophyllum albidum trees distribution within provenances and according to the agroecological zones was adjusted to the Weibull function, commonly nowadays used in Forestry surveys [28]. The Weibull distribution is as follows:

$$f(x) = \frac{c}{b}\left(\frac{x-a}{b}\right)^{c-1} \exp\left[-\left(\frac{x-a}{b}\right)^{c}\right]$$

a = position parameter; a = 10 cm (diameter); a = 5 or 7 m (Height according to the sites); b = scale parameter or size parameter; c = form parameter linked with the observed structure.

According to [29], the use of Weibull distribution probability density function is becoming increasingly popular for modeling the diameter distributions of both even and uneven-aged forest stands. The popularity of Weibull is derived from its flexibility to take on a number of different shapes corresponding to many different observed unimodal tree- diameter distributions. In addition, the cumulative distribution function of Weibull exists in closed form and thus allows for quick and easy estimation of the number of trees by diameter class without integration of the probability density function once the parameters have been fitted.

3. RESULTS

3.1 Principal Component Analysis and Morphological Variation among *Chrysophyllum albidum* Individuals

The results of the Principal Component Analysis performed on the morphometric parameters of *C. albidum* show that the first two axes explained 59.7% of the total variation (Table 2). The first axis is positively correlated with the parameters of the fruit, expressing the fruit productivity. Axis 2 is positively correlated with DBH / HT ratio and parameters related to seed indicating that the second axis is expressing the size of the trunk and morphology of seeds (Table 3). The projection of individuals in the system of axes 1 and 2 (Fig. 2) did not discriminate individuals according to provenances. All accessions studied appear to belong to the same population. However, analysis of the distribution of individuals in the factorial plane formed by the two axes shows that individuals of framing (B) have the longest, widest, and largest fruits, with high seed weight shorter and wider seed (Fig. 2). These fruits come from the shortest trees of small size (Fig. 2) interesting for breeding programs for the species for fruit production. These individuals are mostly from Abomey-Calavi, Allada and Dangbo provenances. In addition the result of cluster analysis (Fig. 3) separated provenance from Adjarra from the rest and revealed that two populations of two different agro-ecological zones are more similar than to their population of respective zone (correlation coefficient=0.96, Fig. 3).

3.2 Patterns of Morphological Variation of *Chrysophyllum albidum* among Provenances and Agroecological Zones

Tables 4 and 5 show respectively the variations of the morphological parameters between the different provenances and between agroecological zones.

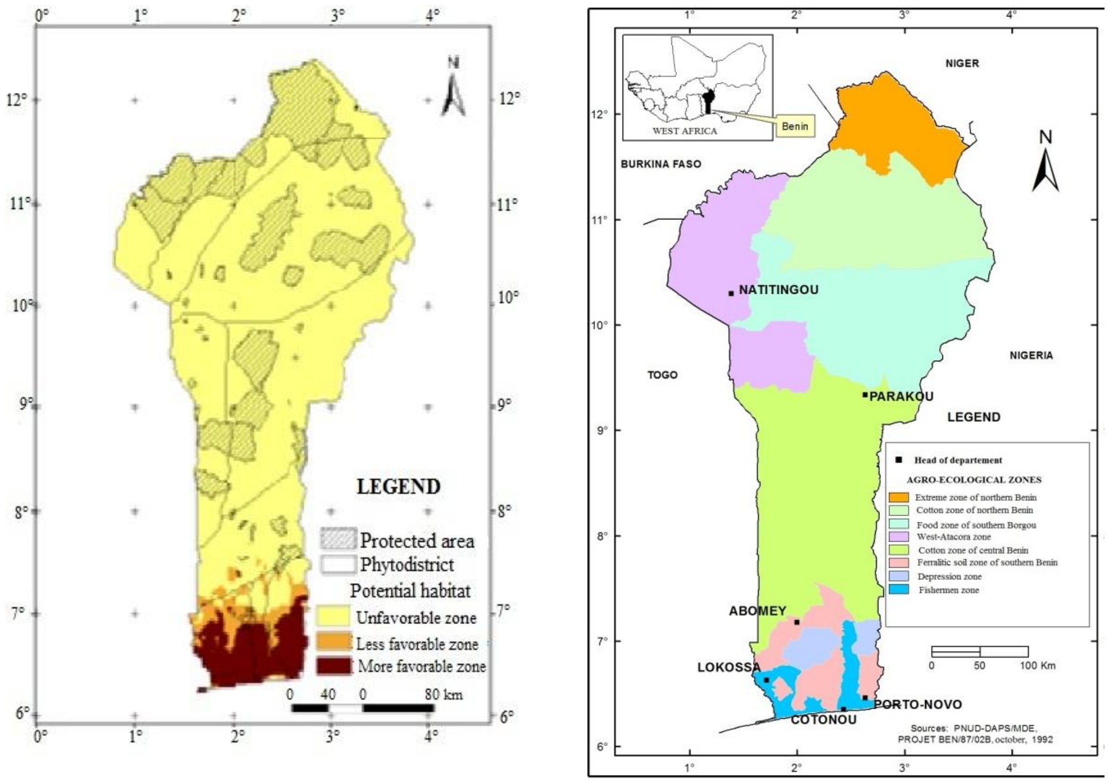
Tree diameter of stem varies from 15.20 to 127.4 cm with an average of 45.51 (±1.92) cm. Total height varies from 6.5 to 25.5 m with an average of 14.65 (±0.38) cm while the bole height varies from 1.5 to 16.90 m with an average of 5.39 (±0.28) .

Intra- provenance variation of trees diameter was somewhat considerable (15% < CV < 44%) in Abomey-Calavi, Allada and Dangbo and very high (coefficient of variation > 44%) Adjarra (Table 4). Intra-agroecological zone variation was somewhat considerable (15% < CV < 44%) in the agro -ecological zone of fishermen and significant (coefficient of variation > 44%) in the lateritic soil zone (Table 5). Inter – provenances variation of diameter is important (CV > 44%).

Intra- and inter- provenance variation as well as inter agroecological zone variation was high as far as total height is concerned (15% < CV < 44%).

There was high similarity between agro-ecological zones and among provenances as far as DBH and total height are concerned. To the contrary, there is a significant difference among provenances (*P* = .000) and among agroecological zones (*P = .013*) as far as bole height is concerned.

Three groups of provenances were distinguished for bole height from Student Newman- Keuls homogeneity test at the 5%: (i) Dangbo individuals with highest trees (7.22 m), (ii) Provenances of Abomey-Calavi (4.94 m height) and (iii) Individuals from Allada (3.48 m).



(a) (b)

Fig. 1. Map of the study area (a) = natural distribution of *Chrysophyllum albidum* in Benin (b) = agroecological zones in Benin [19]

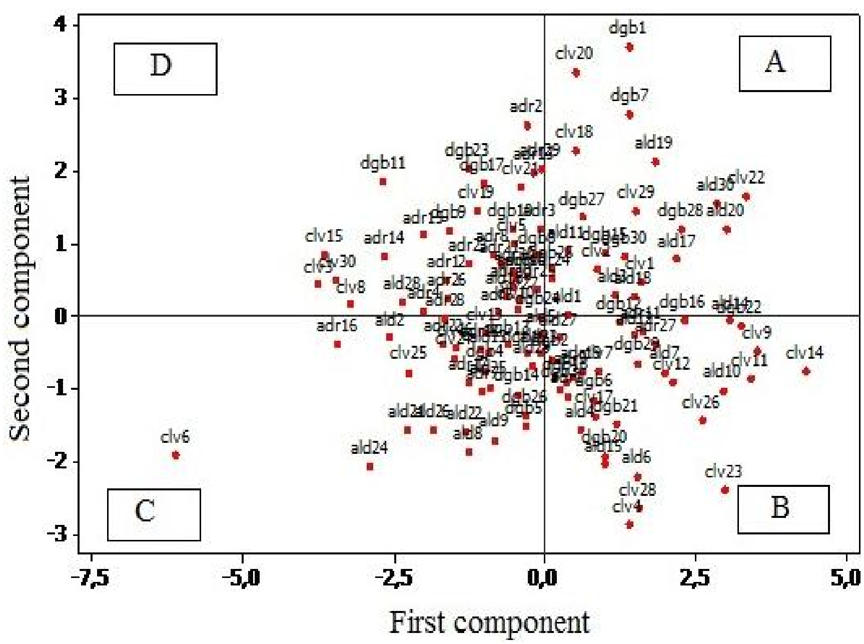


Fig. 2. Projection of individuals of *Chrysophyllum albidum* in the space of the first and second principal components. Dgb = Dangbo; clv = Calavi; ald = Allada; adr = Adjarra. Abbreviation numbers refer to trees number

Table 1. Main features of the agroecological zones

Zones	Main features				
	Climate	**Soils**	**Vegetation**	**Others**	**Cultivation systems**
Lateritic land zone	Soudano-guinean with 2 rainy seasons: 600 to 1200 mm / year at west; 1000 to 1400 mm at East	Lateritic soil on continental terminal; deep easily exploitable mostly destroyed	Essentially anthropic; shrub bush where palm oil trees and cereals are abundant with some remnant forest patches	Absence of mineral and organic restitutions CVP = 240 days	Main crops: mays, groundnut, cassava, yam, abundant palm oil trees, some cotton plants; flat cultivation at west and on ridge at east
Zone of Fishermen	Soudano-guinean (2 rainy seasons: 1000 to 1400 mm / year	Highly fertile alluvial soils; infertile sandy soils along the coast	Grassland, prairie marshland, some mangroves	Farming combined with fishing. Lake area CVP = 240 days	Essential bases: corn at the top of rotation + cowpea and vegetables; domination of corn in non-sandy areas; crops on ridges or flat

CVP = cultural vegetation period

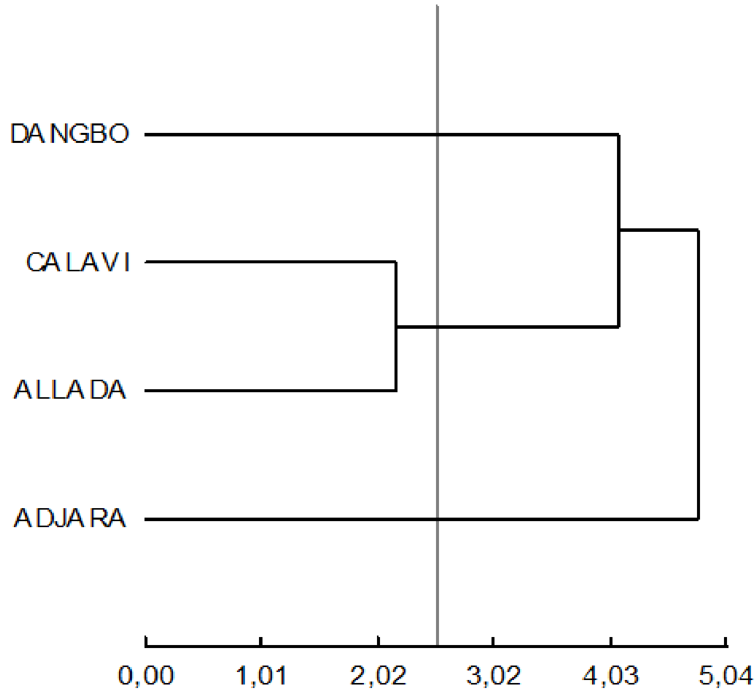


Fig. 3. Cluster analysis based on Euclidean distance and average linkage

Table 2. Eigenvalues and variances derived from PCA

Eigenvalues	3.187	1.592
Variance	0.398	0.199
Cumulative variance	0.398	0.597

Table 3. Correlation between *Chrysophyllum albidum* parameters and axes

Variables	**PC1**	**PC2**
DBH/TH	*.014*	.430
DBH/BH	*.010*	.110
Fruit Length	.494	-0.090
Fruit Width	.479	-0.167
Fruit Circumference	.448	-0.156
Fruit Weigh	.482	-0.034
Seed Length	.297	.527
Seed Width	.070	.681

Numbers with bold front indicate highly correlated variables

The fruit length of *C. albidum* ranges from 3.33 to 5.11 cm with an average of 4.04 (±0.02) cm. The width of the fruit varies from 2.64 to 4.55 cm with an average of 3.46 (±0.02) cm while the circumference of the fruit varies from 11.4 to 15.58 cm with an average of 13 32 (±0.07) cm. Seed weight ranges from 21.03 to 53.97 g with an average of 40.33 (±0.55) g. The seeds length ranges from 1.86 to 2.46 cm with an average of 2.21 (±*.01*) inches while the width of the seeds ranges from 1 to 1.62 cm with an average of 1.27 (±*.01*) cm (Table 4).

Intra-provenances and intra-agroecological zones variability was low for fruit and seeds length, fruit circumference and seed width (0 % < CV < 10 %).

There is a significant difference between provenances (*P* = *.021*) and between agro-ecological zones (*P* = *.020*) for the different parameters of fruits and seeds.

Two significantly different groups of provenances were distinguished for the length of the fruit of *C. albidum* from homogeneity test of Student Newman- Keuls test at 5%.

The first group is composed of provenance Dangbo, of Abomey-Calavi and Allada with a length higher in Abomey-Calavi fruits average (4.07 cm). The second group is represented by the provenance of Adjara (3.93 cm). On the width of the fruit two groups significantly different provenances are distinguished. This is the group consisting of from Dangbo and the group consisting of provenance from Adjarra. The provenance of Allada and Abomey-Calavi are intermediate to these two groups. Moreover, the average width of the fruit from Dangbo is highest compared to other sources (3.49 cm). The average circumference of the fruit of the four sources is significantly different with provenance from Allada having larger fruits (13.63 cm). Three groups significantly different of provenances were distinguished for the weight of the fruit. The first group consists of provenances from Dangbo and Allada, the second is the provenance of Abomey-Calavi and the third is from the Adjarra and Dangbo.

For the different parameters of fruit and seed as well as bole height, the highest averages were recorded for the trees from the zone of fishermen than the lateritic soil zone.

3.3 Influence of Rainfall on Morphological Variation of *Chrysophyllum albidum*

Principal Component Analysis performed on *C. albidum* parameters which present high variability show that the first two axes explained 78,64% of total variation. The first axis was positively correlated with stem parameters (DBH, total height and bole height). The second axis was positively correlated with fruit weight only (Table 6).

The Pearson correlation between the first principal component and rainfall reveals a non-significant positive impact (Table 7). This reflects that the rainfall did not significantly influence the parameters of the stem of *C. albidum* (DBH and total height). The correlation between the second principal component and rainfall reveals a significant negative impact (Table 7). With this result it appears that rainfall in a negative influence on fruit weight. An increase rainfall leads to an increase of the stem characteristics and increasing fruit weight.

3.4 Ecological Structure of *Chrysophyllum albidum* Trees

Fig. 4 showed the class distribution of *C. albidum* trees diameter at breast height according to the different agroecological zones. The Weibull distribution of *C. albidum* trees per DBH classes shows a left dissymmetric bell shaped curve with a c form coefficient comprised between 1 and 3.6 for both agroecological zones (c = 2.18 for agroecological zone of Fishermen and c = 1.55 for agroecological zone of lateritic soil). This value of c means that the stands were dominated by young trees of 30 to 40 cm diameter.

Fig. 5 showed the total height class distribution of trees of *C. albidum* according to the three agroecological zones. This distribution well-adjusted to the Weibull function showed a bell shaped curve with a left dissymmetry ($1 \leq c \leq 3.6$). Like the diameter class distribution, the stands were dominated by young trees. In the lateritic soil agroecological zone, trees of class (12 - 14 m) were dominant in the stand while in the agroecological zone of Fishermen trees of height class (16 - 18 m) were dominant in the stands.

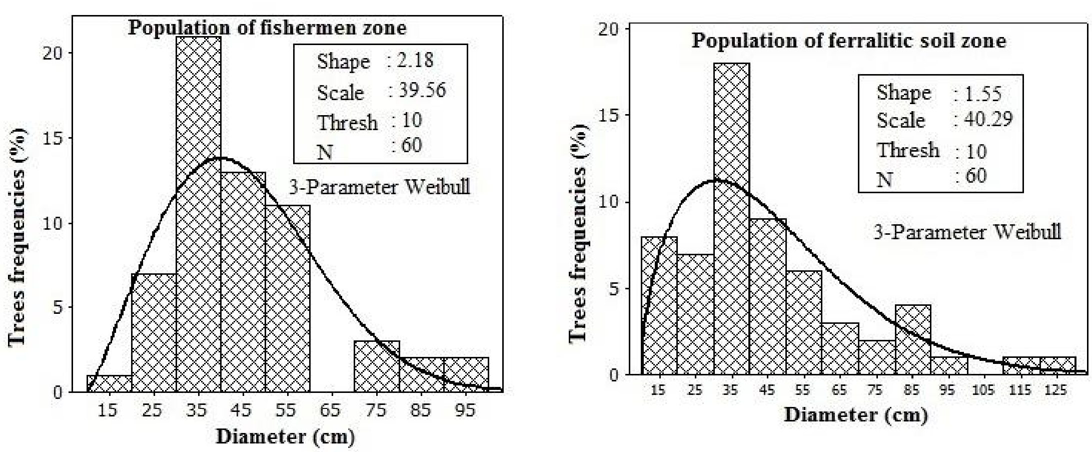


Fig. 4. Diameter class distribution of *Chrysophyllum albidum*

Table 4. Morphological variation of *Chrysophyllum albidum* provenances

Zones	Morphotypes	Summary measures	Stem			Fruit				Seed	
			Diameter (cm)	Bole height (m)	Total height (m)	Fruit lenght (cm)	Fruit width (cm)	Fruit circumference (cm)	Fruit weigh (g)	Seed length (m)	Seed width (cm)
ZLS	ADJARA	Minimum	15.20	1.50	6.50	3.53	3.00	11.56	28.17	2.02	1.14
		Means	48.73 a	5.89 ab	14.82 a	3.93 b	3.40 b	12.87 d	37.56 c	2.22 b	1.29 a
		Maximum	127.40	15.70	25.50	4.82	4.24	13.8	42.66	2.39	1.45
		SD	5.63	0.63	1.03	.05	0.04	0.09	0.72	0.01	0.01
		Cv	63.25	58.49	37.92	6.59	7.49	4.05	10.62	3.60	6.71
	ALLADA	Minimum	16.20	1.50	7.80	3.62	3.06	12.69	30.37	1.93	1.05
		Means	43.50 a	3.48 c	14.58 a	4.07 a	3.47 ab	13.63 a	41.86 a	2.18 c	1.22 c
		Maximum	89.00	6.50	20.50	4.65	3.95	15.11	53.63	2.46	1.45
		SD	2.92	0.26	0.60	0.05	0.04	0.10	1.16	0.02	0.01
		Cv	36.75	42.29	22.68	7.06	7.11	4.32	15.23	6.94	8.15
ZF	CALAVI	Minimum	28.30	1.50	9.00	3.33	2.64	11.4	21.03	1.86	1.00
		Means	48.65 a	4.94 b	14.49 a	4.09 a	3.46 ab	13.47 b	40.00 b	2.19 c	1.25 b
		Maximum	94.30	15.0	24.00	4.94	4.38	15.58	53.97	2.44	1.44
		SD	3.10	0.55	0.67	0.06	0.06	0.22	1.57	0.02	0.02
		Cv	34.86	61.13	25.66	8.73	10.45	9.10	21.55	6.07	9.72
	DANGBO	Minimum	19.70	2.50	7.00	3.34	2.78	12.48	37.67	2.14	1.12
		Means	41.16 a	7.22 a	14.71 a	4.07 a	3.49 a	13.29 c	41.90 a	2.25 a	1.3 a
		Maximum	93.30	16.90	24.60	5.11	4.55	13.96	49.07	2.46	1.62
		SD	3.08	0.54	0.72	0.05	0.05	0.08	0.55	0.01	0.02
		Cv	40.97	41.18	26.81	6.98	8.68	3.40	7.27	3.92	9.32
	General minimum		15.20	1.50	6.50	3.33	2.64	11.4	21.03	1.86	1.00
	General means		45.51	5.39	14.65	4.04	3.46	13.32	40.33	2.21	1.27
	General maximum		127.40	16.90	25.50	5.11	4.55	15.58	53.97	2.46	1.62
	General SD		1.92	0.28	0.38	0.02	0.02	0.07	0.55	0.01	0.01
	General Cv		46.30	57.76	28.59	7.48	8.48	6.06	15.15	5.38	8.85

Number with the same letter are not significantly differentCv = Coefficient of variation; SD = Standard Deviation
Agroecological zones: Zone VI = Lateric Land Zone (ZLS); Zone VIII = Zone of Fishermen (ZF)

Table 5. Morphological variation of *Chrysophyllum albidum* in agroecological zones

Morphotypes	Summary measures	Stem			Fruit				Seed	
		Diameter (cm)	Bole height (m)	Total height (m)	Fruit length (cm)	Fruit width (cm)	Fruit circumference (cm)	Fruit weigh (g)	Seed length (m)	Seed width (cm)
ZF	Minimum	19.70	1.50	7.00	3.33	2.64	11.40	21.03	1.86	1.00
	Means	44.91 a	6.08 a	14.60 a	4.08 a	3.48 a	13.38 a	40.95 a	2.22 a	1.27 a
	Maximum	94.30	16.90	24.60	5.11	4.55	15.58	53.97	2.46	1.62
	SD	2.22	0.41	0.49	0.04	0.04	0.11	0.83	0.01	0.01
	Cv	38.27	52.38	26.04	7.85	9.52	6.88	15.83	5.23	9.71
ZLS	Minimum	15.20	1.50	6.50	3.53	3.00	11.56	28.17	1.93	1.05
	Means	46.11 a	4.68 b	14.70 a	4.00 b	3.44 b	13.25 b	39.71 b	2.20 b	1.26 b
	Maximum	127.40	15.70	25.50	4.82	4.24	15.11	53.63	2.46	1.45
	SD	3.16	0.37	0.59	0.03	0.03	0.08	0.73	0.01	0.01
	Cv	53.09	61.72	31.11	7.00	7.31	5.09	14.35	5.52	7.89
General minimum		15.20	1.50	6.50	3.33	2.64	11.40	21.03	1.86	1.00
General means		45.51	5.89	14.65	4.04	3.46	13.32	40.33	2.21	1.27
General maximum		127.40	15.70	25.50	5.11	4.55	15.58	53.97	2.46	1.62
General SD		1.92	1.03	0.38	0.02	0.02	0.07	0.55	0.01	0.01
General Cv		46.30	37.92	28.59	7.48	8.48	6.06	15.15	5.38	8.85

Number with the same letter are not significantly differentCv = Coefficient of variation; SD = Standard Deviation
Agroecological zones: Zone VI = Lateric Land Zone (ZLS); Zone VIII = Zone of Fishermen (ZF)

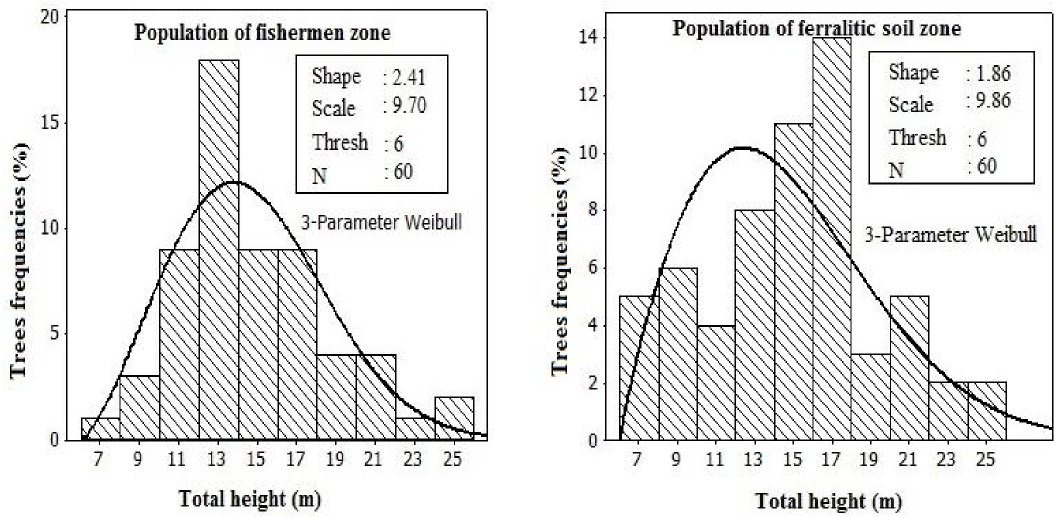


Fig. 5. Total height class distribution of *Chrysophyllum albidum*

Table 6. Correlation among principal components

Variables	Axis 1	Axis 2
DBH	0.84	-0.04
Bole height	0.76	-0.25
Total height	0.89	.01
Fruit weight	0.22	0.96

Table 7. Correlation among principal components and rainfall

Climatic parameter	Axis 1	Axis 2
Rainfall	0.14 ns	-0.24 **

*ns = non significatif; **Significatif at .01.*

4. DISCUSSION

4.1 Morphological Variation in *Chrysophyllum albidum*

The results of this study show that the bole height of *C. albidum* trees varies significantly from one provenance to another and from one agro-ecological zone to another. Similar variation was observed in the parameters of fruit and seed. Some previous studies such as the research on *Adansonia digitata* in Senegal [30] and Benin [31] have also shown as in *C. albidum* that there are significant differences in the fruit length [32]. Maranz and Wiesman have also indicated important variability in *Vitellaria paradoxa* fruit and seeds sizes in relation with a gradient of climate found throughout the entire sub-Saharan Africa zone located at the northern part of the equator. The significant difference found for these traits among provenances and agro-ecological zones could be related to differences in soil characteristics between agroecological zones.

The characterization of a plant is the recording of variability of the characteristics which are highly heritable, easily visible to the eye and expressed in all environments [33]. This study highlights the relationship between the morphological characters of *C. albidum* and ecological conditions of the two agro-ecological zones of southern Benin. Regarding the characteristics of the trunk our results showed that from an individual to another largest, variabilities are usually observed for the bole height. Variation within the region was more important for Adjarra as far as trees diameter and total height are concerned, and for Abomey- calavi is as far as bole height is concerned. The results for the height to the first branch are consistent with those obtained by [25] Ouedraogo for West African populations of *Parkia biglobosa*. Determination of the height of the first basal branching helps to identify low branching individuals for which fruit harvesting will be less painful. Such accessions are then so necessary for selection programs and breeding for fruit production [34]. The variability obtained for this parameter in the current study is then a good indicator of plant breeding for this character.

Regarding *C. albidum* fruit and seed features, the most important variability within provenances was observed in fruit weight. The results of [20] Kouyaté and Van Damme on the morphological characterization of *Detarium microcarpum* in Mali showed that there was an inter- population variability on fruit and seed. Low variability between fruit from the same individual doesn't corroborate several research results like those on *Tamarindus indica* L. [35], *Detarium microcarpum* Guill. and Perr. [20], *Dacryodes edulis* (G. Don) HJ Lam [36], *Adansonia digitata* L. [31,37], *Canarium indicum* L. [38], *Balanites aegyptiaca* L. [39] and *Blighia sapida* KD Koenig [40]. Such a low variability of fruit may be the result of non- influence of environmental factors on *C. albidum* Fruit weight and could therefore be of an important consideration in breeding programs for good fruit production.

4.2 Structural Characteristics of *Chrysophyllum albidum* Trees

Diameter class distribution of a species depends on its temperament [41]. According to [42] Durrieu de Madron and Forni the structure of a species may vary at a site range or across its whole distribution area. *C. albidum* trees exhibited a bell-shaped diameter and total height distribution. Such a structure may be supported by the species temperament as light demanding species are known to show such distribution. They are gap demanding for their regeneration and mortality is higher in earlier stage under closed forest canopy [43,44]. They typically have fewer number of stem in the smaller and larger diameter classes and more in the intermediate classes as observed for a well-thinned tree population structure. However linking evolution and demography of a species in the landscape is a challenge for modern ecology and has led to many theoretical models and field studies [45]. The bell shaped function obtained with the diameter or total height classes distribution of *C. albidum* trees with a left dissymmetry corroborate the results of [23] Ouinsavi et al. with african fan palm (*Borasus aethiopum*) trees population in Benin as well as those of Cassou et al. [46] with the African fan palm population of Wolokonto in Burkina- Faso. Similar results were also obtained by Kperkouma et al. [47] with the Shea butter (*Vitellaria paradoxa*) trees of Donfelgou in Togo. Also Bonou et al. [29] obtained the same distribution as far as *Afzelia africana* trees populations are concerned in Benin. However this structure might not be derived only from the species temperament but also from human pressure and anthropogenic conversion.

5. CONCLUSION

Chrysophyllum albidum is a multipurpose plant which is very important for people in West Africa. The analysis of the morphological variability of the species shows that the most important variability of stem among provenances and among agroecological zones is generally recorded for bole height. As far as fruit and seed are concerned, the largest variability obtained within provenances is from fruit and seed weight. Such variability is a good indicator for selection for domestication. The plus trees to be used for selection could then be done within Abomey Calavi provenance. This study shows that *C. albidum* trees from both studied agro-ecological zones have similar diameter and height distribution.

At the end of this research, it appears that morphological variability in *C. albidum* between provenances and between agro-ecological zones is low except the bole height as well as fruits and seed weight that exhibit large morphological variability among agro-ecological zones.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Wickens GEForest management problem: Valuation of non -timber forest products. Unasylva. 1991;165(42):3-8.
2. Freiberger CE, Vander Jagt DJ, Pastuszyn A, Glew RS, Mounkaila G, Millson M, Glew RH. Nutrient content of the edible leaves of seven wild plants from Niger. Plant Food Hum. Nutr. 1998;53:57–69.
3. Avocèvou-Ayisso C, Sinsin B, Adégbidi A, Dossou G, Van Damme P. Sustainable use of non-timber forest products: Impact of fruit harvesting on *Pentadesma butyracea* regeneration and financial analysis of its products trade in Benin. Forest Ecology and Management. 2009;(257):1930–1938.
4. Gouwakinnou GN, Lykke AM, Assogbadjo AE, Sinsin B. Local knowledge, pattern and diversity of use of *Sclerocarya birrea*. Journal of Ethnobiology and Ethnomedicine. 2011;7:8. DOI: 10.1186/1746-4269-7-8.

5. IPGRI. Forest Genetic Resources Programme in Africa south of the Sahara. Network " Woody Species Food". Minutes of the first meeting of the Network. CNSF Ouagadougou, Burkina Faso. 2000;241.
6. Adomou AC. Vegetation patterns and environmental gradients in Benin: Implications for biogeography and conservation. PhD thesis Wageningen University, Wageningen; 2005. ISBN 90-8504-308-5.
7. Akoègninou A, van der Burg WJ, van der Maesen LJG. (Eds). Analytical Flora of Benin. Backhuys Publihser: Cotonou & Wageningen; 2006.
8. Keay RWJ. Trees of Nigeria. Clarendon Press, Oxford. 1989;476.
9. Okafor JC. Edible indigenous woody plants in the rural economy of the Nigerian forest zone. In: D.U.U. Okali, (ed). The Nigerian rainforest ecosystem. Proc. Of M.A.B. Workshop on the Nigerian Rainforest Ecosystem, Nigeria, University of Ibadan, Nigeria; 1979.
10. Akoegninou A. Les forêts denses humides semi-décidues du Sud-Benin. Journal de la Recherche Scientifique de l'Université du Bénin. 1998;(2):125–131.
11. Oyebade BA, Ekeke BA, Adeyemo FC. Fruits categorization and diagnostic analysis of *Chrysophylum albidum* (G. Don) in Nigeria. Advances in Applied Science Research. 2011;2(1):7-15.
12. Houessou LG, Lougbegnon TO, Gbesso FGH, Anagonou2 LES, Sinsin B. Ethno-botanical study of the African star apple (*Chrysophyllum albidum* G. Don) in the Southern Benin (West Africa). Journal of Ethnobiology and Ethnomedicine. 2012;8:40.
13. CENRAD. Centre for Environmental Renewable Natural Resources Managements, Research and Development. Jericho Ibadan Publication number CEN. 1999(11);85.
14. Adisa SA. Vitamin C, Protein and mineral contents of African Apple (*Chrysophillum albidum*) In: Proceedings of the 18th annual conference of NIST (eds) Garba SA, Ijagbone IF, Iyagba AO Iyamu AO, Kilani AS, Ufaruna N. 2000;141-146.
15. Adewusi HA. The African Star Apple *Chrysophylum albidum* indigenous knowledge IK from Ibadan, Southwestern Nigeria. In: Proceedings of a National workshop on the potentials of the star apple in Nigeria (eds) Denton OA, Ladipo DO, Adetoro MA, Sarumi MB. 1997;25-33.
16. Oboh IO, Aluyor EO, Audu TOK. Use of *Chrysophyllum albidum* for the removal of metal ions from aqueous solution. Scientific Research and Essay. 2009;4(6):632-635.
17. Mars M, Marrakchi M. Study of the intra-tree variability in the pomegranate (*Punica granatum* L.). Application to fruit sampling. Fruits. 2000;347-355.
18. Dosba F, Saunier R. Fruit varietal characterization in France. C.R. Acad. Agric. Fr. 1998;1-236.
19. Gbesso FGH, Tente BHA, Gouwakinnou NG, Sinsin BS. Influence of climate change on the geographic distribution of *Chrysophyllum albidum* G. Don (*Sapotaceae*) in Benin. Int. J. Biol. Chem. Sci. 2013;7(5):2007-2018.
20. Kouyaté AM, Van Damme P. Morphological *Detarium microcarpum* Guill. and Perr. in southern Mali. Fruits. 2002(57):231–238.
21. Kouyaté AM, Decaluwé E, Guindo F, Diawara H, Diarra I, N'diayeI,Van Damme P. Morphological variability of the baobab (*Adansonia digitata L.)* in Mali. Fruits, 2000;66:247–255.
DOI:10.1051/fruits/2011032.
Available:www.fruits-journal.org
22. Graudal L. Development of a national strategy and action plan for the conservation of forest genetic resources. Communication at the regional training workshop on the conservation and sustainable use of forest genetic resources. Ouagadougou, Burkina Faso. 1998;16-27.
23. Ouinsavi C, Sokpon N. Morphological variation and ecological structure of Iroko (*Milicia excelsa* Welw. C. C. Berg) populations across different biogeographical zones in Benin. International Journal of Forestry Research; 2010. Article ID 658396:10. DOI:10.1155/2010/658396.
24. Info Stat. Versión. GrupoInfo Stat. Di Rienzo JA, Casanoves F, Balzarini MG, Gonzalez L, Tablada M, y Robledo CW. Versión. Grupo Info Stat, FCA, UNC, Córdoba, Argentina; 2008.
25. Ouédraogo AS. *Parkia biglobosa* (Fabaceae) in West Africa. Biosystematics

and improvement. Thesis. Univ. agron . Wagening. Inst. For. Nat. Res. IBN-DLO. Netherlands. 1995;205.

26. Kouyaté AM. Ethnobotanical aspects and study of the morphological variability, biochemical and phenological D. microcarpum Guill and Perr. PhD thesis, University of Ghent , Belgium. 2005;207.
27. SAS Institute Inc. SAS Online Doc. Version 9,2. Cary, N.C.: Sas Institute Inc; 1999.
28. Ouinsavi C, Gbemavo C, Sokpon N. Ecological structure and fruit production of African fan palm (*Borassus aethiopum*) populations. American Journal of Plant Sciences. 2011;(2):733-743.
    DOI:10.1016/j.foreco.2004.10.069.
29. Soloviev P, Niang TD, Gaye A, Totte A. Variability of physico- chemical characteristics of the fruits of three woody species gathering harvested in Senegal: *Adansonia digitata, Balanites aegyptiaca* et *Tamarindus indica*. Fruits. 2004;(59):109–119.
30. Assogbadjo A, Sinsin B, Van Damme P. Morphological and production of capsules baobab (*Adansonia digitata* L.) in Benin. Fruits. 2005;60(5):327-340.
31. Maranz S, Wiesman Z. Evidence for indigenous selection and distribution of the shea tree, *Vitellaria paradoxa,* and its potential significance to prevailing parkland savanna tree patterns in sub-Saharian Africa, north of the equator. J. Biogeogr. 2003;(30):1505–1516.
32. IBPGR. Working group to review the tropical fruit descriptors and strategy for collection, evaluation, utilization and conservation. Bangkok. Thailand. 1980;8.
33. Kouyaté AM. Ethnobotanical aspects and study of the morphological variability, biochemical and phenological D. microcarpum Guill. et Perr. PhD thesis, Université de Gand, Belgique. 2005;207.
34. Fandohan AB, Assogbadjo AE, GlèlèKakaï RL, Sinsin B. Variation in seed morphometric traits, germination and early seedling growth performances of *Tamarindus indica* L. International Journal of Biological and Chemical Sciences. 2010;4(4):1102-1109.
35. Leakey R, Tchoundjeu Z, Smith R, Munro R, Fondoun J-M, Kengue J, Anegbeh P, Atangana A, Waruhiu A, Asaah E. Evidence that subsistence farmers have domesticated indigenous fruits (*Dacryodes edulis* and *Irvingia gabonensis*) in Cameroon and Nigeria. Agroforest System. 2004;(60):101-111.
36. Assogbadjo AE, GlèlèKakaï RL, Edon S, Kyndt T, Sinsin B. Natural variation in fruit characteristics, seed germination and seedling growth of *Adansonia digitata* L. in Benin. New Forests. 2011;(41):113–125.
37. Leakey R, Fuller S, Treloar T, Stevenson L, Hunter D, Nevenimo T, Binifa J, Moxon J. Characterization of tree-to-tree variation in morphological, nutritional and medicinal properties of *Canarium indicum* nuts. Agroforestry System. 2008;(73):77-87.
38. Abasse T, Weber J, Boubacar K, Moussa B, Mahamane L, Antoine K. Morphological variation in *Balanites aegyptiaca* fruits and seeds within and among parkland agroforests in eastern Niger. Agroforestry System. 2010;10.
39. Savi M. Endogenous perceptions of changes and study of the phenotypic variability of fruit Blighiasapida KD Köenig in the Sudanian zone of Benin: Kandi Community of the cases and Ségbana Toucountouna. Thesis agronomist, FSA/UAC. 2011;69.
40. Rollet B. Architecture humid lowland evergreen forests. CTFT, France. 1974;298.
41. Durrieu de madron L, Forni E. Forest management in eastern Cameroon; Stand structure and operation frequency. Bois et Forêts des Tropiques. 1997;(254):39-49.
42. Geldenhuys CJ. The use of diameter distributions in sustained-use management of forests: Examples from Southern Africa. in The Ecology and Management of Indigenous Forests in Southern Africa. Proceedings of an International Symposium, Piearce GD and Gumbo DJ, Eds. Zimbabwe Forestry Commission/SAREC, Victoria Falls, Zimbabwe. 1993;154–167.
43. Sokpon N, Biaou SH. The use of diameter distributions in sustained-use management of remnant forests in Benin: Case of Bassila forest reserve in North Benin. Forest Ecology and Management. 2002;161(1–3):13–25.
44. Stearns SC. The Evolution of Life Histories. Oxford University Press, Oxford; 1992.

45. Bonou W, Glèlè Kakaï R, Assogbadjo AE, Fonton HN, Sinsin B. Characterization of *Afzelia africana* Sm. Habitat in the lama forest reserve of Benin. Forest Ecology and Management. 2009;258:1084-1092.
46. Cassou J, Depommier D, Ouédraogo SJ. Le parc à rônier (*Borassus aethiopum* Mart.) de Wolokonto dans le sud-ouest du Burkina Faso: Structure, dynamique et usages de la rôneraie. Draftpaper. 1997;10.
47. Kperkouma W, Sinsin B, Guelly K, Kokou K, Akpagana K. Typology and structure of parkland in the prefecture of Donfelgou. *Sécheresse*. 2005;16(3):209-206.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=779&id=24&aid=7182