TYPOLOGY AND STRUCTURAL CHARACTERIZATION OF *LOPHIRA LANCEOLATA* POPULATIONS IN BENIN (WEST AFRICA)

Aliou DICKO[1]*, Armand Kuyema NATTA[1] , Honoré Samadori Sorotori BIAOU[1], Rodrigue BALAGUEMAN[1], Gérard GOUWAKINNOU[2]

Abstract

Understanding population structure is crucial for the efficiency of management programs. The present study aimed at assessing the typology and structure of the multipurpose tree *Lophira lanceolata* (Ochnaceae) in Benin. We established seventy squared plots of 50mx50m size and measured on each individual the diameter at breast height (DBH), total height (Ht), crown diameter (Dm), leaf length (Lmf) and leaf width (lmf). A matrix relating six structural variables (6 columns) and seventy plots (70 rows) were submitted to a Principal Components Analysis (PCA) for discriminating populations. Results revealed four groups of *L. lanceolata* populations of which three were well-discriminated including populations of (1) large and long leaves (2) tall trees with large crown, and (3) large size trees and high density. Structural variables that contributed to the well-discrimination were crown diameter, total height, leaf length and width and trees density. Structural variables differed significantly between discriminated groups ($p<0.001$, F=12.21-89.33). Diameter size classes distribution showed either J-inverted or bell-shaped suggesting the species is undergoing severe anthropogenic pressure. This study provided baseline information on *L. lanceolata* population structure which relevant for the species conservation in Benin. However, in order to gain further insight into structural variation, deep studies are needed on genetic variability of *L. lanceolata* population using molecular markers. There is also need of studies on the species regeneration system in order to set judicious strategies for its conservation.

Key Words: Typology, Functional traits, Demographic structure, *Lophira lanceolata*, Benin

Résumé

TYPOLOGIE ET CARACTERISATION STRUCTURALE DES POPULATIONS DE *LOPHIRA LANCEOLATA* AU BENIN (AFRIQUE DE L'OUEST)

La connaissance de la structure des populations d'une espèce est importante pour l'efficacité des programmes d'aménagement. La présente étude a porté sur la typologie et la structure des populations de *Lophira lanceolata* Tiegh. ex Keay (Ochnaceae) au Bénin. Nous avons installé soixante-dix (70) placeaux de forme carrée de dimensions (50cm x 50cm) et nous avons mesuré sur chaque individu d'une placette, le diamètre à hauteur de poitrine d'homme (DBH), la hauteur totale et le diamètre de la couronne. Une matrice de données composée de six colonnes (six variables structurales) et soixante-dix lignes (70 placeaux) est soumise à une Analyse en Composantes Principales (ACP) pour la discrimination des populations. Les résultats révèlent quatre groupes parmi lesquels trois ont présenté une bonne discrimination. Il s'agit des populations faites d'arbres (1) à feuilles larges et longues, (2) de grande taille avec de grande couronne, (3) de gros arbres et ayant une densité à l'hectare élevée. Les variables structurales ayant contribué à une bonne discrimination sont le diamètre de la couronne, la hauteur totale, la longueur et largeur des feuilles et la densité. Ces variables structurales diffèrent significativement entre groupes de populations ($p<0,001$, F=12,21-89,33). Du point de vue structure, les groupes présentaient une structure en cloche ou en J renversé et suggère que les populations de *L. lanceolata* sont sous forte pression anthropique. Cette étude a fourni des informations de base sur la structure des populations de l'espèce nécessaires pour sa conservation. Cependant, des études génétiques sont nécessaires pour mieux expliquer la variabilité des traits structuraux entre groupes. Aussi le mode de régénération de l'espèce reste à être documenté afin de définir des stratégies judicieuses pour sa conservation.

Mots clés : Typologie, Traits fonctionnels, Structure démographique, *Lophira lanceolata*, Bénin

[1]Laboratory of Ecology, Botany and Plant Biology, Department of Natural Resources Management, Faculty of Agronomy, University of Parakou, Republic of Benin. 03 PO Box 125 Parakou, Benin.

[2]School of Wildlife and Protected Areas Management, Kandi, University of Parakou, Republic of Benin, PO Box 287 Kandi, Benin.

* Corresponding author: Aliou DICKO, 03 PO Box 125 Parakou, Benin

INTRODUCTION

Non Timber Forest Products (NTFP) are the main sources of food, energy, medicine, building materials and other numerous needs in most African rural areas (Ambrose, 2003; Lescuyer, 2010). They provide substantial incomes for rural communities and contributed to insure their food security (Diallo *et al.*, 2008; Avocèvou-Ayisso, 2011). In West Africa, NTFP are harvested from a wide range of trees species mostly found in savanna landscape (White and Abernethy, 1996; Ouédraogo *et al.*, 2005). This is the case of the multipurpose-use *Lophira lanceolata* (Mapongmetsem, 2007) that generates socioeconomic potential for the rural communities as reported by previous studies (Dossa, 2011; Dicko *et al.*, 2017). In Benin, this species is harvested for to meet various needs but is mainly used in traditional medicine commonly for treating malaria (Dicko *et al.*, 2017). Its seeds provide important economic values to the local populations through their oil extraction. Oil extracted is commercialized in local markets and has significantly improved women incomes in three localities (Natitingou, Toucountouna, Kouandé) of Benin (Dossa, 2011). Moreover, *L. lanceolata* seeds contain important nutritive qualities with many virtues (Kouaro and Tasso, 2010).

Although the species provide numerous socioeconomic advantages, its populations are currently under severe anthropogenic pressures (Kouaro and Tasso, 2010). Indeed, the branches are highly pruned and even individuals are entirely logged by women while harvesting seeds (Dicko *et al*., 2017). One of seeds harvesting drawbacks is the long-term absence of regeneration in some natural habitats (Dossa, 2011).

Previous studies revealed that branches pruning may retard trees growth and affect the species reproductive capacity (Gaoue *et al*., 2008; Anten *et al.,* 2003). There is now growing evidence that NTFP harvesting may cause decreasing of population density (Hall and Bawa, 1993; Ndangalasi *et al*., 2007) and shifting of population structure (Laurance *et al*., 2009; Yosi *et al*., 2011, Amahowé *et al*., 2017). Anyway, population melting may result from either anthropogenic pressures or change in climatic conditions (Laurance *et al*., 2009).

Several studies have provided relevant information about *L. lanceolata* conservation. Studies have broadly discussed its socioeconomic importance (Etuk *et al*., 2009; Erakhrumen, 2009 ; Kouaro et Tasso, 2010 ; Tchacondo *et al*., 2011 ; Diallo *et al*.,2012 ; Haxaire, 2012 ; Salifou *et al*., 2013, Dicko *et al*., 2017), and biochemical properties (Kyari, 2008; Fariku and Kidah, 2008; Sani *et al*., 2010; Lohlum *et al*., 2010; Ali *et al*., 2011; Nonviho *et al*., 2014; Nonviho *et al*., 2015). But, there is up to now poor understanding of its reproduction system, population dynamic and its population structure. There is therefore need to understanding the species morphological and structural aspects in order to set sustainable conservation strategies (Mensah *et al*., 2014). As reported previously, morphological characters analysis can also help to discriminate population (Koura *et al*., 2013).

This study has made a country scale analysis of *L. lanceolata* typology and population structure using the species structural traits. The following two main questions were addressed in the study: (1) Are *L. lanceolata* population homogenous in structural traits? (2) What are the structural traits that better discriminates population?

METHODOLOGY

Study area

Benin is a tropical country located between 6°10' and 12°25'N in West Africa (Figure 1). It covers a land area of about 112 622 km² with a population size of 10 160 566 inhabitants (INSAE, 2013). The mean annual rainfall ranges from 900 mm to 1400 mm from the North to the South. The mean annual temperature ranges from 26°C to 28°C and can reaches 40°C in the dry zone. The southern part of Benin is dominated by ferralitic soils whereas ferruginous soils account for much in the northern part. The major types of vegetations include semi-deciduous forests, dry woodlands, woodlands and savannas. Figure 1 shows the distribution of surveyed plots across the country with the line transects (main roads) followed for plots establishment.

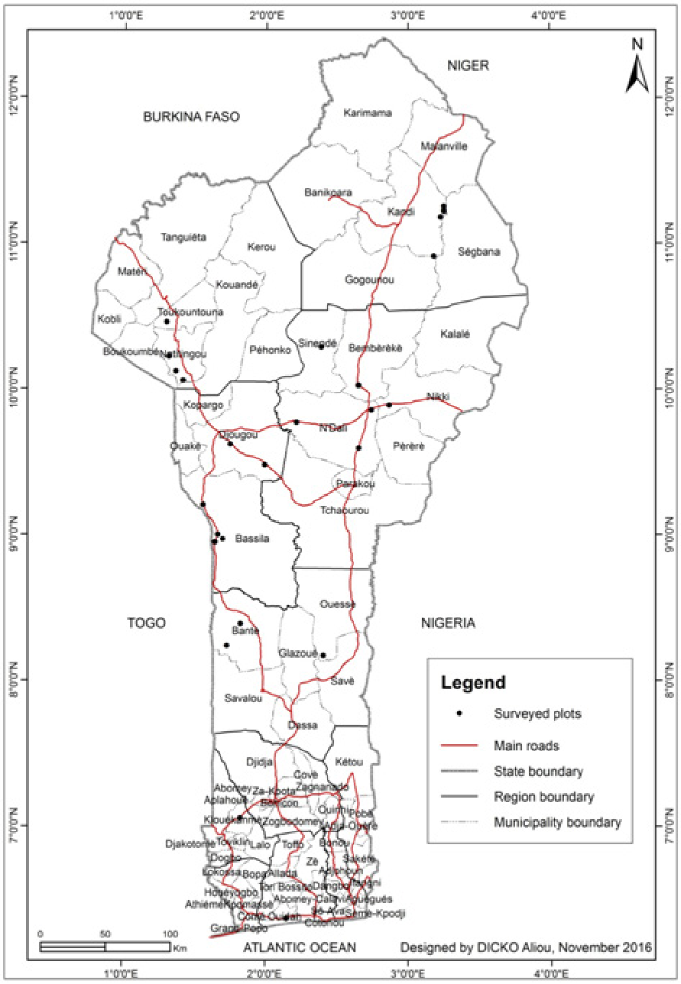

Figure 1: Map showing distribution of surveyed plots and line transects (Main roads) followed for plots establishment across the 77 municipalities of Benin.

Study species

L. lanceolata, also known as the red oak is a tree species that may reach 16(-24) m tall (Mapongmetsem, 2007). Its leaves are simple, entire, and alternate but clustered at the end of branches (Persinos and Guimby, 1968). Its inflorescence is a terminal, pyramidal, lax panicle with 15 to 20 cm long. Flowers are bisexual, regular and white in color. Fruits are assimilated to conical shape. Seed are ovoid in shape, chestnut-colored and glabrous (Mapongmetsem, 2007).

L. lanceolata is widely distributed across the Sudano-Guinean savannas (Persinos and Guimby, 1968) from Senegal through the Central African Republic and northern of Congo to Uganda (Mapongmetsem, 2007). It is majorly met in fields and fallows and is established on sandy or gravelly soils. The species can tolerate fire at adult stage, but seedlings are affected by regular bushfires (Mapongmetsem, 2007).

L. lanceolata is a multipurpose use species widely used in several localities of Benin as timber, firewood and charcoal (Dicko *et al*., 2017).

Data collection

We preliminarily identified the species populations by interviewing local communities following line transects (state roads or local roads) from the North to the South of the country. At each locality level, we investigated local populations on the frequency at which they meet the species in their surrounding vegetation using its leaves and fruits as specimens. When the species presence is confirmed, we afterward prospected surrounding vegetations and recorded the UTM coordinates of population using the Garmin (GPS 62). We established one or more squared plots of (50mx50m) size in each population depending on the size of population. A distance of 100m was observed between two given populations in order to avoid edge effect.

We measured on each individual, morphological variables such the diameter at breast height (DBH) using diameter tape, the total height (Ht) using the SUUNTO for individuals with DBH ≥ 5cm, length of leaf and width of leaf using the caliper and crown diameter using the centimeter.

Statistical analysis

Typology of L. lanceolata population

We made the typology based on six structural variables (adult trees density, basal area, height, crown diameter, leaf length and leaf width). To estimate crown diameter, trees crown area was projected on the ground and the two diameters of the projected area were measured since crown are not circular in shape. Then, crown diameter was estimated as the arithmetic mean of the two projected diameters (Goudegnon *et al.*, 2016).

In order to discriminate the species populations a matrix of six columns (six structural variables) and seventy rows (each row affected to one plot) was submitted to a PCA using R software (R Core Team Development, 2015, www.R-project.org). One-way analysis of variance (One-way ANOVA) was after used to test whether structural variables differ among discriminated groups.

Structural characterization of L. Lanceolata groups

The diameter size classes distribution and height-diameter allometric relationship were used to assess population structure. We estimated the skewness for each distribution in order to appreciate distribution pattern. The skewness is defined as a measure of the relative proportion of small and large stems in a given population (Bendel *et al.*, 1989) and is a better indicator for appreciating the distribution pattern in ecology (Doane and Seward, 2011). In the present study the skewness was estimated using skewness function in the R book (Crawley, 2007).

Diameter-Height relationship is very important in understanding species life strategies in heterogeneous environment (Feldpausch *et al.*, 2011; Sumida *et al.*, 2013). We tested whether the linear correlation between diameter (DBH) and Height was strong using Pearson correlation test.

RESULTS

Typology of L. lanceolata population

The PCA results showed two significant axes which are sufficient to explain relations between population and structural variables (PC1 and PC2, Figure 2). The first axis (PC1) explained 59.10% of the total variance and the second axis (PC2) accounted for 27.23% (Figure 2). By cumulating the proportions of variances, both axes explained 86.33% of the total variance. Two groups were discriminated on the first axis: G1 fairly linked to leaf length and width which was opposed to G3 strongly linked to crown diameter and total height. Only G4 was well-discriminated on the second axis and was strongly linked to population density. G2 was discriminated but was not linked to any structural variable. Globally, three groups were well-discriminated (G1, G3, G4, Figure 2). These include populations of (G1) large and long size leaves, (G3) tall and large crown individuals, (G4) large size trees and high density.

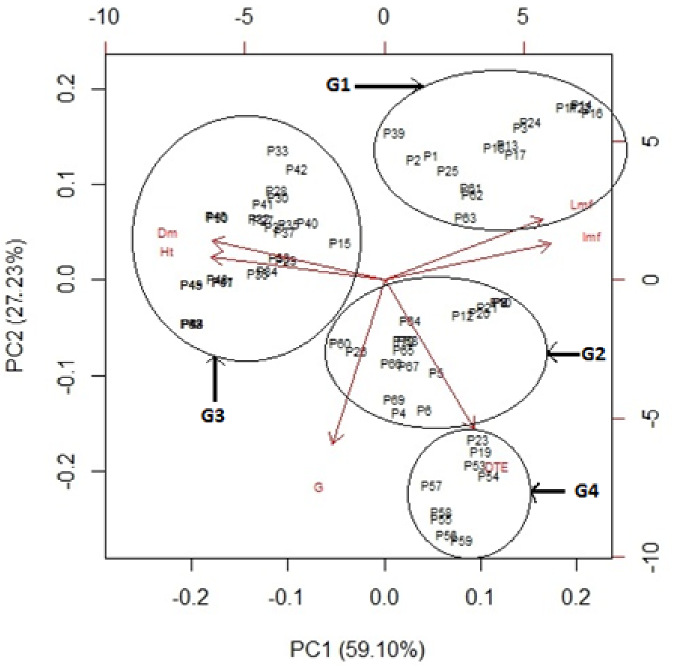

Figure 2: Principal Components Analysis ordination based on measured discriminators

Legend: DTE = mean trees density, G=mean basal area, Ht=mean total height, Dm=mean crown diameter, Lmf=mean leaf length, lmf=mean leaf width

Surveyed plots and corresponding groups : **G1** (17,24,18,25,1,2,3,11,42,36,37,38,39,40,13,16,14,22,63,61,62,26,60);**G2** (64,67,68,65,70,66,69,20,21,4,5,6,12,10,9,7,8);**G3** (44,48,52,43,47,51,46,50,45,49,15,34,29,35,33,32,27,41,28,30,31);**G4** (57,55,58,53,54,56,59,19,23)

The structural variables that accounted much for discrimination were crown diameter, total height, leaf length, leaf width and population density. Significant variations of structural variables were observed between groups (Table 2, analysis of variance). Indeed, population density varied significantly between groups ($p<0.001$, $F=89.33$) and was in average higher in G4 (243±11.19 trees/ha, Table 1). There was significant difference of basal area only between G1 and G4 ($p<0.001$, $F=12.1$). The highest average basal area was observed in G4 (8.27±0.83 m^2/ha). The total height and crown diameter differ significantly ($p<0.001$, $F=44.95$ to 63.91) between groups. The highest crown diameter

(15.65±0.62 m) and tree height (18.56±0.35 m) were observed in G3. There was no difference of total height and crown diameter between the others groups (Table 1). Length and width of leaf were significantly lower (p<0.001, F=29.46 to 32.55) in G3 than in the other three groups. The lowest length of leaf (14.76±0.44cm) and leaf width (2.81±0.12cm) was observed in G3. But there was no significant difference of leaf length and leaf width between the other three groups.

Table 1: Mean of descriptive variables across discriminated groups from the ANOVA

Groups	Bassila (G1)	N'da_Na (G2)	Kandi (G3)	T_O (G4)
	mean±e	mean±e	mean±e	mean±e
DTE (stems/ha)	56±2.33[a]	155±4.84[b]	40± 0.09[c]	243± 11.19[d]
G (m^2/ha)	1.87±0.45[a]	4.52±0.41[b]	4.38± 0.41[b]	8.27± 0.83[c]
Ht (m)	9.45±1.34[a]	8.22±0.27[a]	18.56±0.35[b]	7.69±0.18[a]
Dm (m)	5.45±1.17[a]	3.35±0.10[a]	15.65±0.62[c]	2.22±0.24[a]
Lmf (cm)	25.22±1.39[a]	20.88±1.03[a]	14.76±0.44[c]	21.54±0.76[a]
Lmf (cm)	4.39±0.25[a]	4.14±0.13[a]	2.81±0.12[c]	4.18±0.13[a]

Note: values with the same letter were not significantly different at 5% of threshold by ANOVA

Legend: N'da_Na=N'dali_Natitingou, T_O=Toucountouna_Ouidah, DTE=mean trees density, G=mean basal area, Ht=mean total height, Dm=mean crown diameter, Lmf=mean leaf length, lmf=mean leaf width, e=standard error

Table 2: ANOVA table for means comparison of descriptive variables between groups

Variables	Df	Sum sq	Mean sq	F	p	Df.resid	Mean sq.resid	Sum sq.resid
DTE	3	130737	43579	89.33	p<0.001	73	35615	488
G	3	124.9	41.63	12.21	p<0.001	73	248.9	3.41
Ht	3	1872	624.0	44.95	p<0.001	73	1013	13.9
Dm	3	2305.3	768.4	63.91	p<0.001	73	877.7	12.0
Lmf	3	1897	632.3	29.46	p<0.001	73	1566	21.5
lmf	3	63.06	21.019	32.55	p<0.001	73	47.14	0.646

Legend: DTE=mean trees density, G= basal area, Ht=mean total height, Dm=mean crown diameter, Lmf=mean leaf length, lmf=mean leaf width, Df=degree of freedom, Sum sq=sum square, Mean sq=mean square, F=Fisher statistic, P=probability, Df.resid=residuals of degree of freedom, Mean sq.resid=residuals of mean square, Sum sq.resid=residuals of sum square.

Diameter size classes distribution of discriminated groups

The distribution was J-inversed with a positive skew (Skewness=0.81 to 1.17) for G1 (Bassila locality) (Figure 3.a), G2 (N'dali and Natitingou localities) (Figure 3.b) and G4 (Ouidah and Toucountouna localities) (Figure 3.d) whereas a bell-shaped pattern was found for G3 (Kandi locality).

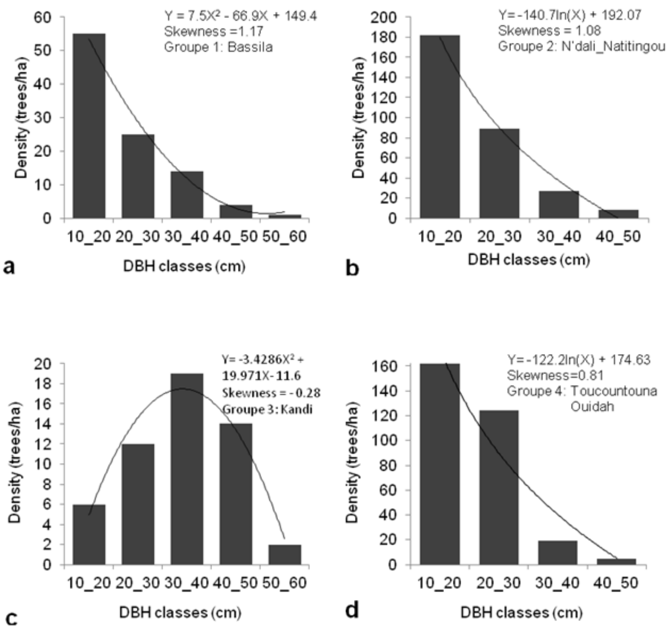

Figure 3: Diameter class-size distribution of *L. lanceolata* populations

Relationship between DBH and Ht for cluster groups

The linear relationship between diameter and total height was positive and strong (r=0.61 to 0.79) for G1 (Figure 4.a) and G2 (Figure 4.b). The slope of regression for both groups (G1 and G2) was smaller than 1 (0.17 and 0.23) indicating fast growing in radial of trees in both groups. The regression was not strong in the last two groups (G3 and G4) (Figure 4.c, Figure 4.d).

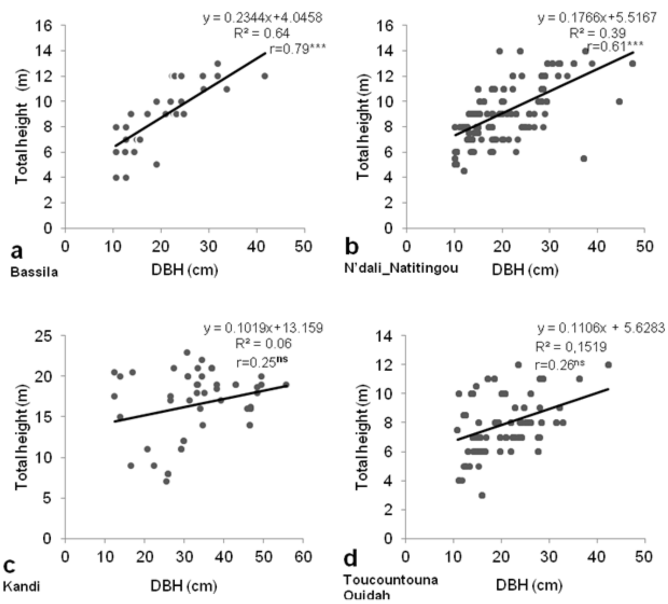

Figure 4: Relationship between height and diameter for *L. lanceolata* trees.

*Legend: ns = non-significant (p>0.5), *** =highly significant (p<0.001)*

DISCUSSION

Typology of L. lanceolata populations in Benin

This study revealed the existence of four (4) groups of *L. lanceolata* population in the study area and variation of structural traits trees between groups. Individuals with smaller leaf size (leaf length and leaf width) were observed at Kandi (G3) comparing to the other three groups that showed similarly higher leaf length and width. This may be explained by variation in environmental conditions especially climate and soil types (Casas *et al*., 1999; Bruschi *et al*., 2003; Ouinsavi and Sokpon, 2010). Indeed, leaf is sensitive to changes in environment and become plastic to abiotic stress such the light supply (Sack et Grubb, 2002; Coste, 2008; Rozendaal *et al.*, 2009) and water supply (Cescatti and Zorer, Xu *et al.*, 2008). For example, a study has investigated the habitats effects on leaf morphological variable plasticity in *Quercus acutissima* and revealed that leaf size decreases with low supply of light and water. Authors concluded that leave are narrower under drought conditions and larger under shade conditions (Xu *et al.*, 2008). Then, the lower leaf length and leaf width observed in Kandi populations may be the result of low water availability in this region of Benin as Kandi locality is marked by drought persistence across the year comparing to the other groups localities. The narrower leaf size under drought conditions may also translate an adaptive strategy to environmental conditions suggesting the investment of water and light resources in leaf toughness and stem thickness rather than in leaf development (Cornelissen *et al.*, 2003). For example, a recent study on the multipurpose use species *Afzelia africana* by Amahowé *et al.* (2017) revealed that the species allocated more resources for leaf toughness in water-limited environment.

Our results revealed a significant difference of height, basal area and diameter crown between the four groups. Highest values of average height and crown diameter were observed at Kandi (G3) and the highest value of average basal area was observed at Toucountouna and Ouidah (G4). This suggests that Kandi populations are represented by tall individuals with large crown whereas large individuals much discriminate population of Toucountouna and Ouidah. This is not surprising because population of Kandi were only met in gallery forests that may offer favorable climatic conditions for trees growth. Our finding is consistent with previous studies suggesting that biggest and tallest trees were associated to colder and wetter zones for *Vitellaria paradoxa* (Glèlè Kakaï *et al.*, 2011) and *Afzelia africana* (Sinsin *et al.*, 2004; Mensah *et al.*, 2014). However, some large size trees were observed at Toucountouna (G4) which is a dry zone and where no population was recorded in gallery forests. This may translate an adaptive strategy by *L. lanceolata* in water-limited environment suggesting that when water becomes limited, species would prefer investing more resources in stem thickness rather than investing in growth (growth-survival tradeoff) (Garnier and Navas, 2012) which is a physiological response to drought stress. However, there is need of climatic and soil data for accurate explanation.

Population density was significantly higher in G4 than in the other three groups. This makes sense and may be the result of longtime traditional conservation methods developed by local population in these group localities. This is the case of Toucountouna where populations still remain natural. In fact Toucountouna was the locality where oil of *L. lanceolata* seeds are more extracted and commercialized in local markets (Dicko *et al.*, 2017) and therefore local populations are expected to give more interest to the conservation of the species habitats. However, intensive frequency of seeds collection can negatively impact natural regeneration development (MacDonald *et al.*, 2004). But studies are needed on the regeneration system or our species for accurate discussion. The fact that population density was lower in the other three groups may suggests that *L. lanceolata* is undergoing severe anthropogenic pressure in these localities and certainly because the species shows no interest for the local population. .

Structure of L. lanceolata populations

Our results revealed a bell-shape distribution for population of G3 (Kandi locality) whereas an inverse-J distribution was observed for the other three groups. The bell-shape distribution translates that *L. lanceolata* population are characterized by low regeneration potential and low density of large individuals (Sokpon and Biaou, 2002). The low regeneration potential may be the result of repeated vegetation fires combined with grazing that affect negatively trees recruitment (Biaou, 2009, Schumann *et al.*, 2011). Other possible reason is the drought persistence in this zone which might not offer facilitation conditions for regeneration (Biaou *et al.*, 2011) as Kandi is a drought persistence zone. Similarly, low regeneration was observed for *Pentadesma butyracea* in Benin (Natta *et al.*, 2011a) and for *Parkia biglobosa* in southern Africa (Koura *et al*., 2013; Ouédraogo, 1995).The marginal number of large individuals may be explained by selective logging (Sinsin *et al.*, 2004; Mensah *et al.*, 2014) and agricultural encroachment (Nacoulma *et al.*, 2011).

The inversed–J distribution translates the dominance of the population by individuals with small diameters (Sokpon and Biaou, 2002). This indicates high regeneration potential for G1, G2 and G4 comparing to G3 and makes sense because populations of G1, G2 and G4 were all recorded in semi-moisture (Bassila and N'dali) and moisture (Ouidah) regions. Therefore the high regeneration potential may be facilitated by favorable climatic conditions especially soil moisture content (Biaou *et al.*, 2011). Similar distribution pattern was observed for *Pentadesma butyracea* populations (Natta *et al.*, 2011b) and for *Isoberlinia spp* in Wari-Maro forest reserve in Benin (Glèlè kakaï and Sinsin, 2009). Globally, large size individuals number were marginal in *L. lanceolata* population however the distribution and confirms previous studies trend (Dossa, 2011) revealing a high anthropogenic pressure on the species.

The allometric relationship between tree height and diameter is crucial to identify both present trees (beyond minimum logging diameter) and future trees (under minimum logging diameter) (Oldeman, 1974a). This relationship provides relevant information on how climate and human constraints affect the species strategies (Feldpausch *et al.*, 2011; Sumida *et al.*, 2013). In the current study, the slope of regression was smaller than 1 for Bassila population and the one of N'Dali-Toucountouna suggesting that individuals grow faster in radial than in height. This tendency translates the strategy of biomass investment in radial growth rather than in height growth (Cheng *et al.*, 2011). In other way, our species allocates more biomass for stem thickness in order to meet environmental constraints such violent winds and pathogens attacks (de Gouvenain and Silander, 2003).

CONCLUSION

This study has discussed the typology and structural variation of *L. lanceolata* populations in Benin. Four groups of *L. lanceolata* population were discriminated but three of them were well-discriminated including populations of individuals with large and long leaves, tall and large crown individuals, large size trees and higher density. Structural variables have significantly varied between groups and have provided sounding information on the species adaptation strategies to abiotic stress. However, there is need of deep studies to check whether structural variation between groups is linked to genetic variability.

The structural pattern suggests that the species is undergoing severe anthropogenic pressures. But there is need of studies to address its regeneration system in order to establish judicious approaches for its conservation. We recommend to national programs for species conservation to promote *L. lanceolata* domestication in agro-ecosystems.

ACKNOWLEDGEMENTS

Our acknowledgement to the International Foundation For Science (IFS) for having funded our Ph.D project.

REFERENCES

Ali S.A., Abdulraheem R.O., Abdulkareem S.S., Alemika E.T., Ilyas M., 2011. Structure determination of betulinic acid from the leaves of *Lophira lanceolata* Van Tiegh. Ex Keay (Ochnaceae). Journal of Applied Pharmaceutical Science, 01: 244-245.

Amahowe O.I., Biaou S.H., Natta A.K., Balagueman R.O., 2017. Multiple disturbance patterns and population structure of a tropical tree species, *Afzelia africana* (Leguminosae–Caesalpinioideae), in two contrasting bioclimatic zones of the Republic of Benin. Southern Forests, 1–9. DOI: 10.2989/20702620.2016.1274940

Ambrose, O.J.I.B., 2003. The contribution of NTFPs to the livelihoods of the « forest poor » Evidence from the tropical forest zone of South-West Cameroon. International Forestry Review, 5(2):106-117.

Anten N.P.R., Martinez-ramos M., Ackerly D., 2003. Defoliation and growth in an understory palm: quantifying the contributions of compensatory responses. Ecology Letter, 84: 2905-2918

Avocèvou-Ayisso C.M.A., 2011. Etude de la viabilité des populations des *Pentadesma butyracea* Sabine et de leur socio-économie au Bénin. Thèse de doctorat, Université d'Abomey-Calavi, Bénin. 223p.

Bendel R.B., Higgins S.S., Teberg J.E., Pyke D.A., 1989. Comparison of skewness coefficient, coefficient of variation, and Gini coefficient as inequality measures within populations. Oecologia, 78: 394-400.

Biaou S.H., Holmgren M., Sterck F.J., Mohren G.M.J., 2011. Stress-Driven Changes in the Strength of Facilitation on Tree Seedling Establishment in West African Woodlands. Biotropica, 43(1): 23–30.

Biaou S.H., 2009. Tree recruitment in West African dry woodlands: The interactive effects of climate, soil, fire and grazing. PhD thesis, Wageningen University, Wageningen, The Netherlands, 182p.

Bruschi P., Vendramin G.G., Bussotti F., Grossoni P., 2003. Morphological and molecular diversity among Italian populations of *Quercus petraea* (Fagaceae). Annals of Botany, 91(6): 707-716.

Casas A., Caballero J., Valiente-Banuet A., Soriano J.A., D´avila P., 1999. Morphological variation and the process of domestication of *Stenocereus stellatus* (Cactaceae) in Central Mexico. American Journal of Botany, 86(4): 522-533.

Cescatti A., Zorer R., 2003. Structural acclimation and radiation regime of silver fir (Abies alba Mill.) shoots along a light gradient. Plant, Cell and Environment 26:429–442.

Cheng X., Kiyoshi U., Tsuyoshi H., Shao P., 2011. Height growth, diameter-height relationships and branching architecture of *Pinus massoniana and Cunninghamia lanceolata* in early regeneration stages in Anhui Province, eastern China: effects of light intensity and regeneration mode. Forestry Studies in China, 13 (1): 1-12

Cornelissen J.H.C., Lavorel S., Garnier E., Díaz S., Buchmann N., Gurvich D.E., Reich P.B., terSteege H., Morgan H.D., Morgan Van Der Heijden M.G.A., Pausas J.G., Poorter H., 2003. A handbook of protocols for standardised and easy measurement of plant functional traits worldwide. Australian Journal of Botany, 51: 335-380.

Coste S., 2008. Diversité et plasticité des traits foliaires en forêt tropicale humide. Thèse de Doctorat, 324p.

Crawley M.J., 2007. The R book. John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex PO19 8SQ, England. 951p.

de Gouvenain R.C., Silander J.A., 2003. Do Tropical Storm

Regimes Influence the structure of Tropical Lowland Rain Forests? Biotropica, 35 (2):166-180.

Diallo B.O., Mckey D., Chevallier M-H., Joly H.I., Hossaert-Mckey M., 2008. Breeding system and pollination biology of the semi-domesticated fruit tree, *Tamarindus indica* L. (Leguminosae: Caesalpinioideae): Implications for fruit production, selective breeding, and conservation of genetic resources. African Journal of Biotechnology, 7(22): 4068-4075.

Diallo A., Traore M.S., Keita S.M., Balde M.A., Keita A., Camara M., Miert S.V., Pieters L., Balde A.M., 2012. Management of diabetes in Guinean traditional medicine: An ethnobotanical investigation in the coastal lowlands, Journal of Ethno pharmacology, 144: 353-361.

Dicko A., Natta A.K., Biaou S.S.H., 2017. Connaissances ethnobotaniques et conservation de *Lophira lanceolata* (Ochnaceae) au Bénin (Afrique de l'Ouest). Annale des Sciences Agronomiques, 21 (1):19-35.

Doane P.D., Seward L.E., 2011. Measuring Skewness: a forgotten Statistic ? Journal of Statistics Education. 19 (2):1-18.

Dossa A.D., 2011. Structures et dynamiques des populations rémanentes de *L. lanceolata* Van Tiegh. ex Keay dans le département de l'Atacora au Nord-Ouest du Bénin, Université de Parakou, Mémoire de 3ème cycle pour l'obtention du DESS en Aménagement et Gestion Durable des Ressources Naturelles, 99p.

Etuk E.U., Muhammad A.A., Igbokwe V., Okolo R.U., 2009. Sexual stimulatory effects of aqueous stem bark extract of *Lophira lanceolata* in male Sprague Dawley rats. Journal of Clinical Medicine and Research, 1(2):18-21

Erakhrumen A.A., 2009. Energy value as a factor of agroforestry wood species selectivity in Akinyele and Ido local government areas of Oyo State, Nigeria. Biomass and Bioenergy, 33: 1428-1434.

Fariku S., Kidah M.I., 2008. Biomass potentials of *Lophira lanceolata* fruit as a renewable energy resource, African Journal of Biotechnology, 7(3): 308-310.

Feldpausch T.R., Banin L., Phillips O.L., Baker T.R., Lewis S.L., Quesada C.A., Affum-Baffoe K., Arets E.J.M.M., Berry N.J., Bird M., Brondizio E.S., de Camargo P., Chave J., Djagbletey G., Domingues T.F., Drescher M., Fearnside P.M., França M.B., Fyllas N.M., Lopez-Gonzalez G., Hladik A., Higuchi N., Hunter M.O., Iida Y., Salim K.A., Kassim A.R., Keller M., Kemp J., King D.A., Lovett J.C., Marimon B.S., Marimon-Junior B.H., Lenza E., Marshall A.R., Metcalfe D.J., Mitchard E.T.A., Moran E.F., Nelson B.W., Nilus R., Nogueira E.M., Palace M., Patiño S., Peh K.S.-H., Raventos M.T., Reitsma J.M., Saiz G., Schrodt F., Sonké B., Taedoumg H.E., Tan S., White L., Wöll H., Lloyd J., 2011. Height-diameter allometry of tropical forest trees. Biogeosciences, 8: 1081-1106.

Gaoue O.G., Ticktin T., 2008. Impacts of bark and foliage harvest on *Khaya senegalensis* (Meliaceae) reproductive performance in Benin. Journal of Applied Ecology, 45:34-40.

Garnier E., Navas M.L., 2012. A trait-based approach to comparative functional plant ecology: concepts , methods and applications for agroecology. Review article, 32: 365-399.

Glèlè Kakaï R., Sinsin B., 2009. Structural description of two Isoberlinia dominated vegetation types in the Wari-Maro Forest Reserve (Benin). South African Journal of Botany, 75: 43–51.

Glèlè Kakaï R., Akpona T. J. D., Assogbadjo A. E., Gaoué O. G., Chakeredza S., Gnanglé P. C., Mensah G. A., Sinsin B., 2011. Ecological adaptation of the shea butter tree (*Vitellaria paradoxa* C.F. Gaertn.) along climatic gradient in Bénin, West Africa. Afr. J. Ecol., 49: 440–449.

Goudegnon E.O.A., Gouwakinnou G.N., Houessou L.G., Oumorou M., 2016. Fruit and pulp production of the African grape *Lannea microcarpa* Engl. & K. Krause from dry and humid Sudanian zone in Northern Bénin, West Africa. Int. J. Biol. Chem. Sci., 10(3): 1114-1121.

Hall P., Bawa K., 1993. Methods to Assess the Impact of Extraction of Non-Timber Tropical Forest Products on Plant Populations. Economic Botany, 47 (3): 234-247.

Haxaire C., 2012. La folie de l'arc-en-ciel ou la longue errance de Bwila, Revue d'ethnoécologie, DOI : 10.4000 / ethnoecologie.797

INSAE, 2013, Résultats provisoires du RGPH4, Bénin, 8 p

Kouaro O.M., Tasso F., 2010. *Lophira lanceolata* dans la Commune de Toucountouna : Entre exploitation et conservation d'une espèce naturelle à usages multiples. Revue de géographie du Bénin, 7: 94-115.

Koura K., Mbaide Y., Ganglo J.C., 2013. Caractéristiques phénotypique et structurale de la population de *Parkia biglobosa* (Jacq.) R. Br. Du Nord-Bénin. Int. J. Biol. and Chem; Sci. 7(6): 2409-2425.

Kyari M.Z., 2008. Extraction and characterization of seed oils, Int. Agrophysics, 22:139-142.

Laurance S.G.W., Laurance W.F., Nascimento H.E.M., Andrade A., Fearnside P.M., Rebello E.R.G., Condit R., 2009. Long-term variation in Amazon forest dynamics. Journal of Vegetation Science, 20: 323-333.

Lescuyer, G., 2010. Importance économique des produits forestiers non ligneux dans quelques villages du Sud-Cameroun. Bois et Forêts des Tropiques, 304 (2):15-24.

Lohlum S.A., Maikidi G.H., Solomon M., 2010. Proximate composition, amino acid profile and phytochemical screening of *Lophira lanceolata* seeds. AJFAND, 10(1): 2012-2023.

MacDonald G.B., Cherry M.L., Thompson D.J., 2004. Effect of harvest intensity on development of natural regeneration and shrubs in an Ontario boreal mixed wood stand. Forest Ecology and Management, 189: 207-222.

Mapongmetsem P.-M., 2007. *Lophira lanceolata* Tiegh. ex Keay In: van der Vossen, H.A.M. & Mkamilo, G.S. (Editeurs). PROTA 14: Vegetable oils/Oléagineux. [CD-Rom]. PROTA, Wageningen, Pays Bas.

Mensah S., Houehanou T.D., Sogbohossou E.A., Assogbadjo A.E., Glèlè Kakaï R., 2014, Effect of human disturbance and climatic variability on the population structure of *Afzelia africana* Sm. ex pers. (Fabaceae–Caesalpinioideae) at country broad-scale (Bénin, West Africa). South African Journal of Botany, 95: 165-173.

Nacoulma I.M.B., Traoré S., Salifou Karen H., Thiombiano A., 2011. Impact of land use types on population structure and extent of bark and foliage harvest of *Afzelia africana and Pterocarpus erinaceus* in Eastern Burkina Faso. International Journal of Biodiversity and Conservation, 3(3): 62-72.

Natta A.K., Yédomonhan H., Zoumarou- Wallis N., Houndéhin J., Ewédjè E.B.K., Glèlè Kakaï R.L., 2011a. Typologie et structure des populations naturelles de *Pentadesma butyracea* dans la zone soudano-guinéenne du Bénin, Annales des Sciences Agronomiques, 15 : 217-243.

Natta A. K., Adomou A.C., Tchabi V.I., Sogbegnon A.R., Mensah G.A., Sinsin B.A., 2011b, Inventaire, typologie et structure des populations naturelles de *Pentadesma butyracea* (Clusiaceae) de la chaîne de l'Atacora au Nord-Ouest du Bénin, Bulletin de la Recherche Agronomique du Bénin, 70 : 10-24

Ndangalasia H.J., Bitarihob R., Dovie D.B.K., 2007. Harvesting of non-timber forest products and implications for conservation in two montane forests of East Africa. Biological Conservation, 134: 242-250.

Nonviho G., Paris C., Muniglia L., Sessou P., Agbangnan D.C.P., Brosse N., Sohounhloué D., 2014. Chemical characterization of *Lophira lanceolata and Carapa procera* seed oils: Analysis of Fatty Acids, Sterols, Tocopherols and Tocotrienols. Research Journal of Chemical Sciences, 4(9): 57-62.

Nonviho G., Paris C., Muniglia L., Sohounhloué D., Brosse N., 2015. *Lophira lanceolata* seed oil extraction method (ancestral or modern) modifies the properties of the oil**.** Industrial Crops and Products, 67: 49–54.

Oldeman R.A.A., 1974. L'architecture de la forêt guyanaise. Mem. O.R.S.T.OM., 73, 204p.

Ouédraogo A-S., 1995. Parkia biglobosa (Leguminosae) en Afrique de l'Ouest : Biosystématique et Amélioration. Thèse de doctorat de l'Université Agronomique de Wageningen, Institute for Forestry and Nature Research, IBN-DLO, Wageningen, Netherlands, 205 p

Ouédraogo A., Thiombiano A., Hahn-Hadjali K., Guinko S., 2005. Structure du peuplement juvénile et potentialités de régénération des ligneux dans l'Est du Burkina Faso. Etudes sur la flore et la végétation du Burkina Faso et des pays avoisinants, Etudes flor. vég. Burkina Faso, 10: 17-24.

Ouinsavi C., Sokpon N., 2010. 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, 10 p, DOI:10.1155/2010/658396.

Persinos G.J., Quimby M.W., 1968. Studies on Nigerian Plants V. Comparative Anatomy of *Lophira lanceolata* and *Lophira alata*. Economic Botany, 22(3): 206-220

Rozendaal D., Poorter L., 2006. Plasticity in leaf traits of 38 tropical trees species in responses to light: relationship with light and adult stature. Functional Ecology, 20**:** 207-216

Sack L., Grubb P.J., 2002. The combined impacts of deep shade and drought on the growth and biomass allocation of shade-tolerant woody seedlings. Oecologia, 131: 175-185

Salifou S., Offoumon F.O.T., Gouissi F.M., Pangui L.J., 2013. Endogenous recipes for controlling arthropod ectoparasites of domestic poultry, Rev. Bras. Parasitol. Vet., Jaboticabal, 22: 119-123.

Sani A. A., Alemika T.E., Abdulraheem O.R., Sule I.M., Ilyas M., Haruna A.K., Sikirat A.S., 2010. Isolation And Characterisation of Cupressuflavone From The Leaves Of *Lophira Lanceolata*. Journal of Pharmacy and Bioresources, 7: 14-26.

Schumann K., Wittig R., Thiombiano A., Becker U., Hahn K., 2011. Impact of land-use type and harvesting on population structure of a non-timber forest product-providing tree in a semi-arid savanna, West Africa. Biological Conservation, 144: 2369-2376

Sinsin B., Eyog Matig O., Assogbadjo A.E., Gaoue G.O., Siandouwirou T., 2004. Dendrometric characteristics as indicators of pressure on *Afzelia africana* Sm. Dynamic changes in trees found in different climatic zones of Benin. Biodiversity and Conservation, 13:1555-1570.

Sokpon N., Biaou S.H., 2002. The use of diameter distribution in sustained-use management of remnant forest in Benin: Case of Bassila forest reserve in North Benin. Forest Ecology and Management, 161: 13-25.

Sumida A., Miyaura T., Torii H., 2013. Relationships of tree height and diameter at breast height revisited: analyses of stem growth using 20-year data of an even-aged *Chamaecyparis obtusa* stand. Tree Physiol. 33(1): 106-118.

Tchacondo T., Karou S.D., Batawila K., Agban A., Ouro-Bangna K., Anani K.T., Gbeassor M., de Souza, C., 2011. Herbal remedies and their adverse effects in tem tribe traditional medicine in Togo, Afr. J. Tradit. Complement. Altern. Med., 8(1): 45-60.

White L., Abernethy K., 1996. Guide de la végétation de la Réserve de la Lopé, Gabon. Projet Ecofac, Libreville, Gabon. 224p.

Yosi C.K., Keenan R.J., Fox J.C., 2011. Forest dynamics after selective timber harvesting in Papua New Guinea. Forest Ecology and Management, 262: 895-905.