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ECOLOGICAL DIVERSITY AND PULP, SEED AND KERNEL PRODUCTION OF THE BAOBAB (*ADANSONIA DIGITATA*) IN BENIN

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ABSTRACT. — This study was carried out in the Sudanian (9°45’-12° N), Sudano-Guinean (7°30’-9°45’ N) and Guinean (6°25’ - 7°30’ N) zones of Benin. The distribution and relative abundance of the baobab was studied by means of megatransects and by surveying a number of selected sites. In each zone, an estimate was made of pulp, seed and kernel production from 1200 fruits harvested from 30 individuals. In the Sudanian zone and in some regions of the Dahomey-Gap in the Guinean zone, a population density of 5 baobabs per km^2 was recorded. In the Guinean zone, a density of only 1 baobab per km^2 was recorded. The baobab population’s occurred on sandy soils in the Sudanian and Guinean zones and on sandy–clayey soils in the Sudano-Guinean zone. Flowering and fruiting of the baobab is seasonal. The morphology and productivity of individual baobabs varied significantly from one zone to another. The zones with high values of potential evaporation, rainfall, relative humidity, temperature, pH_{water} and percentage of fine silt are associated with a low seed and fruit pulp production. The higher the pH_{KCl}, the percentage of total nitrogen, organic carbon and organic matter, the higher the number of seeds produced by an individual baobab. The higher the clay and crude silt content of the soil, the better the productivity.

KEY WORDS. — Baobab, Benin, climatic zones, ecological diversity, organ production assessment.

INTRODUCTION

Until fairly recently much of the work on forest resources was concerned with ecology, forest management, productivity and the improvement of harvesting techniques for timber production and has neglected the importance of non-wood forest products. Information available on non-timber forest resources is generally qualitative and lacks the quantitative analysis required for the development of economic opportunities, such as local alternatives to imported products, social development and environment management. However, the importance of these resources for conservationists, decision makers and the rural people has led to many attempts of promoting their use and their value as a means of ensuring the well being of the poor. In the case of the baobab (*Adansonia digitata*) for example, several international development agencies have financed research on the baobab in the developing countries (e.g., NORAD in Kenya and SIDA in Tanzania ; Sidibé & Williams 2002). Studies carried out on the species in Nigeria and Mali provided information on its food value and agronomic potentialities (Yazzie *et al.* 1994, Igboeli *et al.* 1997, Barminas *et al.* 1998, Sidibé & Williams 2002). In addition, several works have focused on the ethnobotanical knowledge and the socio-economic importance of the baobab in Africa (Baumer 1995, Codjia *et al.* 2001, 2003). However, information about the ecology, the morphological and genetic variation within and between populations and the productivity of its various organs is lacking (Sidibé & Williams 2002). The objective of this paper is to evaluate the ecological diversity in Benin of *A. digitata* populations across the climatic gradient, and to quantify the average productivity of its pulp, seeds and kernel.

STUDY AREA

This study was conducted in the three bioclimatic zones of Benin (112 622 km^2 and 6 752 569 inhabitants in 2002), located between 6° and 12°50 N, and 1° and 3°40 E in West Africa. The studied zones are : the Sudanian zone, located between 9°45'-12°25' N, the Sudano-Guinean zone, located between 7°30'-9°45' N, and the sub-humid Guinean zone (Dahomey Gap), located between 6°25'-7°30' N (White 1983).

The Sudanian zone

The annual mean rainfall in the Sudanian zone is often less than 1000 mm and the relative humidity varies from 18% during the harmattan period (December-February) to 99% in August. The temperature varies from 24°C to 31°C. The Sudanian zone has hydromorphic soils, well-drained soils, and lithosols. The vegetation of this zone is composed of savannas and gallery forests with trees of smaller size. The main activities of local people in this zone, like in the rest of Benin, are agriculture, extensive animal husbandry, and the illegal and heavy logging of woodland and gallery forests.

The Sudano-Guinean zone

The rainfall in the Sudano-Guinean zone is unimodal, from May to October, and lasts for about 113 days with an annual total varying between 900 mm and 1110 mm. The annual temperature ranges from 25°C to 29°C, and the relative humidity from 31% to 98%. The soils in this zone are infertile mineral soils and ferruginous soils of variable fertility. The vegetation of the Sudano-Guinean transition zone is characterized by a mosaic of woodland, dry dense forests, tree and shrub savannas and gallery forests.

The Guinean zone

The rainfall regime in the Guinean zone is bimodal with peaks from April to June and from September to November, with a mean annual rainfall of 1200 mm. The mean temperature varies between 25°C and 29°C and the relative humidity between 69% and 97%. The soils are either deep ferrallitic, and of low fertility (700 000 ha) or alluvial and heavy clay soils (360 000 ha). The latter soil type occur in the valleys of the Mono, Couffo and Oueme rivers, and in the Lama depression. These soils are rich in clay, humus and minerals. The vegetation in this zone has been strongly affected by various agricultural activities and now forms a mosaic of cultivated land and small relict forest patches. The original vegetation was dense semi-deciduous forests and Guinean savannas. This zone represents about 10 % of the area of Benin and supports 60 % of the country's inhabitants.

MATERIAL & METHODS

Assessing the ecological diversity of *A. digitata* in Benin

The distribution and relative abundance of the baobab was studied by means of megatransects and by surveying a number of selected sites in each zone (Fig. 1). The megatransects surveyed were : (I) Sudanian zone : Bassila-Natitingou-Boukombé-Tanguiéta-Porga (approximately 400 km long) and Parakou-Kandi-Karimama-Malanville (approximately 300 km long) ; (II) Sudano-Guinean zone : Bohicon-Dassa-Parakou (approximately 300 km long) ; (III) Guinean zone : Bohicon-Azovè-Comè-Cotonou-Sèhouè(Lama)-Kétou-P.Novo (approximately 450 km long).

The study sites selected around villages are shown in Table 1. From the centre of each village, four tran-

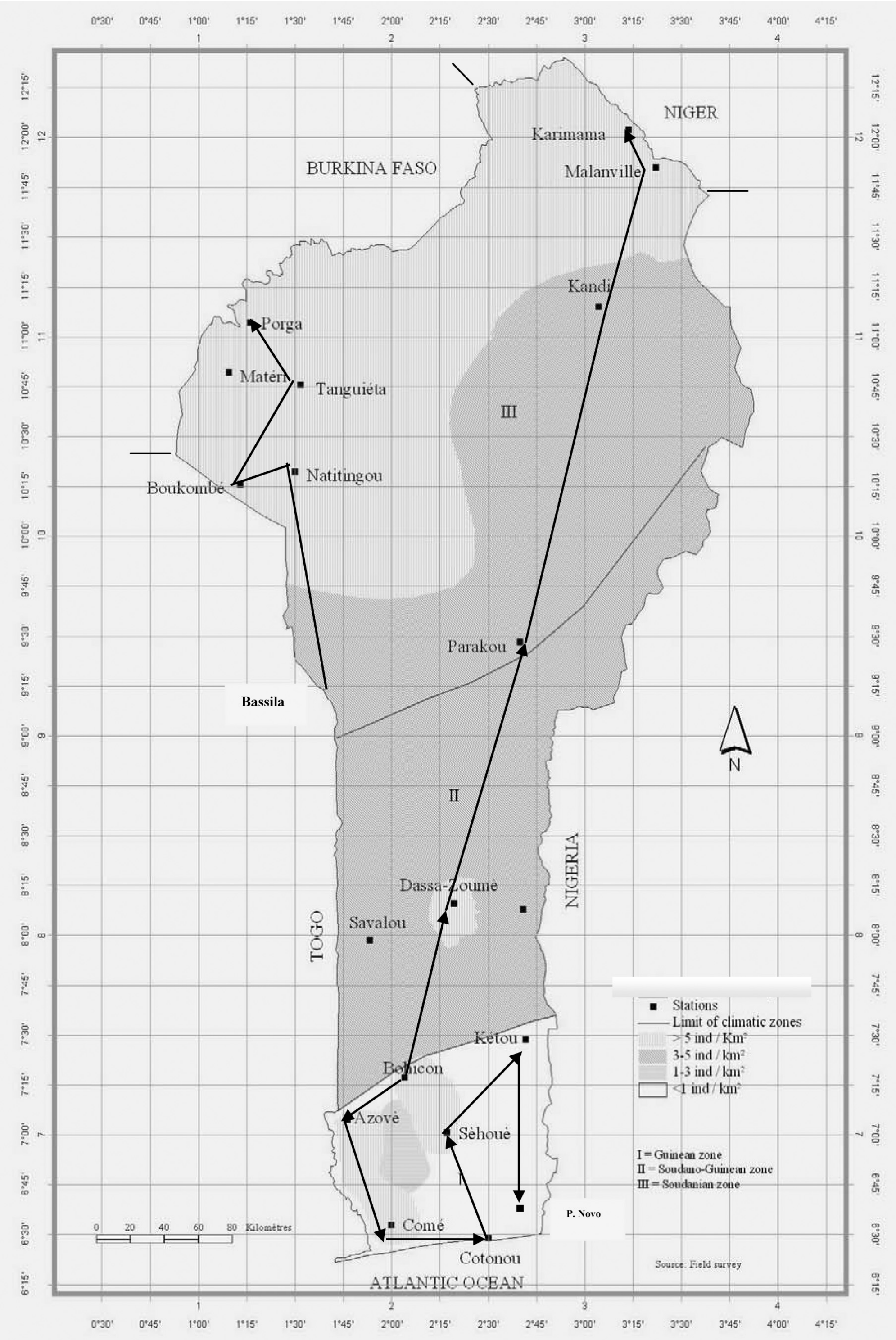

FIG. 1. — Distribution and relative abundance of *A. digitata* in Benin. Arrows represent the megatransects surveyed.

sects of 3 km were established, each oriented either north, south, west or east. The average width of observations along the megatransects and village transects was 500 m. This allowed an estimate of the Baobab density in each zone (number of baobabs per km^2). During the surveys every individual baobab was recorded thus permitting the identification of zones of high and low baobab density, and the mapping of the species distribution throughout the different zones of Benin (Fig.1).

The habitat and morphological characteristics of each baobab were studied at the above-mentioned sites. Along the transects, rectangular plots of 50 m × 30 m were established around each baobab and the trunk diameter was measured at 1.3 m height (DBH). Tree height, crown diameter and the number of branches were also determined for each baobab. If the baobabs were close to each other (i.e., the distance between baobabs was less than 10 m), only one individual was measured within a single plot. In all, 127 baobabs were measured in the Sudanian zone, 90 in the Sudano-Guinean and 122 in the Guinean zone. If fruiting, the number of capsules was counted and their shape noted.

On sites with at least five baobabs per ha, the soil was sampled to an average depth of 40 cm. The samples were analysed at the Soil Science Laboratory of the Faculty of Agronomy, University of Abomey-Calavi (Benin). The following variables were determined : percentage of clay, silt and sand, pH_{water}, pH_{KCl}, organic matter, carbon, and nitrogen, and carbon to nitrogen ratio (C/N).

Climatic data for over 30 years were obtained for each site from the national weather service (ASECNA). The data collected were : rainfall, evapotranspiration (PET), temperature, and relative humidity.

The phenology of 30 mature baobabs from each zone was surveyed (Fig. 2). From March 2003 to March 2004 monthly records were made on the presence or the absence of leaves, flowers and fruits for each tree. The climatic data collected for each study site were then used to assess the impact of the climate on the phenology.

Estimating the average yield in pulp, kernels, and seeds

To estimate the productivity in pulp, seeds and kernels, 40 fruits were randomly collected on each tree. This corresponds to a total of 1200 fruits sampled in the each climatic zone. Each fruit was weighed, broken, open and the contents (pulp + seeds) weighed. The seeds were then removed by soaking the contents in water. The seeds were counted and then oven-dried at 50 to 60°C for 48 hours. The dry seeds were boiled for 30mn in order to remove the seed coat, which is a traditional technique for extracting the kernel. Kernels were dried at 40 to 50°C for 48 hours and weighed.

The weight of the pulp (WP) in each fruit was obtained by the following formula :

$$WP = W_{sp} - W_s,$$

where W_{sp} is the weight of the capsule's contents (seed with pulp), and W_s is the weight of the seed without pulp. For each product (pulp, seeds or kernel), the mean fruit productivity was calculated over the 40 fruits harvested per tree. The total productivity of the trees was then estimated for each product by multiplying the mean fruit productivity by the number of fruits produced. Finally, the average yield was computed for each zone (over the 30 sampled trees).

Data analyses

The analysis of variance and the Newman and Keuls test were used to describe and compare the different zones. In order to determine the variables associated with each other and the way they are correlated, a principal component analysis (PCA) was used. To find the driving environmental variables behind the differences in baobab characteristics, a PCA was performed only on the abiotic variables. In a next step the PCA factor scores of each sample were correlated with the biotic variables using a Spearman rank correlation coefficient.

RESULTS

Distribution, abundance and characteristics of *A. digitata* habitats

The areas with high baobab densities, i.e. more than 5 individuals per km^2 (Fig. 1) were : Boukoumbé, Tanguiéta, Porga and Karimama in the Sudanian zone ; Dassa in the Sudano-Guinean zone ; and Bohicon and Comè in the Guinean zone (Dahomey-Gap). Ketou in the Guinean zone had the lowest density, with less than 1 baobab per km^2. The other sites had a mean density of 2-3 baobab per km^2. Most of the baobabs were recorded from around villages or on farms. The baobab density decreased with increasing distance from the village according to the following equation :

$$y = -2.91 \, \mathrm{Ln}(x) + 6.03 \quad (R^2 = 0.99 \; ; P < 0.001),$$

where y is the density and x is the distance from the village. This suggests that there is a relationship between man and the occurrence of baobabs. According to the local farmers the baobab occurs naturally in the Sudanian Zone where it is usually associated with habitation. However, some cases of transplanting and sowing of seeds were recorded from the Karimama district and in some areas of the Dahomey Gap. It remains debatable whether man come because of the baobab or man was responsible for dispersing the seeds around villages.

The following species were the most frequent trees and shrubs associated with *A. digitata* throughout the studied zones : (I) in the Sudanian and the Sudano-Guinean zones : *Vitellaria paradoxa, Parkia biglobosa, Borassus aethiopum, Tamarindus indica, Vitex doniana, Balanites aegyptiaca, Zanthoxylum zanthoxiloides, Blighia sapida, Bombax costatum, Azadirachta indica, Diospyros mespiliformis, Sarcocephalus latifolia, Strychnos spinosa, Ficus* sp. ; (II) in the Guinean zone : *Parkia biglobosa, Borassus aethiopum, Tamarindus indica, Vitex doniana, Blighia sapida, Mangifera indica, Azadirachta indica, Ficus* sp.
The baobab was found on neutral sandy soils in the Sudanian zone, on sandy - clay soils in the Sudano–Guinean zone and on basic sandy soils in the Guinean zone (Table 1). All soils had a normal nitrogen content except for Comé in the Guinean zone, where the nitrogen content was high. This was attributed to the frequent use of inorganic fertilizers by the local farmers. The organic matter was high. The C/N ratios were also high (over 20), which suggest poor organic matter degradation, except for the Lama depression, were the C/N ratio was less than 19.75.

Phenology

The baobab retains its leaves for almost throughout the year, except at the peak of the dry season (October to April) when most of the trees loose their leaves (Figs. 2 and 3). This loss of old leaves favours the development of new leaves in January and February. The baobab's flowering period coincides with the rainfall in the Sudanian zone (Figs. 2 and 3). The peak of the dry season corresponds to the maturation period of the fruits. In this period, we observed no flowering individuals in any of the zones, in contrast with the rainy season when the flowering peak was observed. Fruiting is seasonal (Fig. 2) and begins at the peak of the rainy season, i.e. between July and August in the Sudanian zone, and between the two rainy seasons in the Guinean zone (Fig. 3). Fruiting reaches a peak in October, which corresponds to the beginning of the dry season in the three zones. Fruits mature in December and January, which is the dry period of the year. At this time, local people start harvesting the fruits, especially in the Sudanian zone where the species has a great economical value. In the Dahomey Gap, the species

Table 1

Physico – chemical characteristics of soils sampled at baobab sites

Bio-climatic Zones	Sites	Chemical characteristics						Granulometry (%)			
		pH_{water}	pH_{KCl}	% N	% C	% O	C/N	Clay	Crude silt	Fine silt	Sand
Sudanian	Karimama	6.73 (0.01)	6.07 (0.04)	0.06 (0.00)	1.78 (0.02)	3.05 (0.04)	29.67	8.12 (0.46)	11.49 (0.31)	7.00 (0.34)	73.4 (0.19)
	Boukombé	6.44 (0.07)	5.52 (0.06)	0.07 (0.00)	1.93 (0.23)	3.31 (0.40)	27.57	11.66 (0.65)	13.6 (0.20)	71.97 (0.77)	71.97 (0.77)
Sudano-Guinean	Dassa	6.89 (0.04)	6.27 (0.04)	0.07 (0.00)	2.41 (0.00)	4.15 (0.00)	34.43	12.63 (1.07)	4.98 (0.60)	9.95 (0.44)	72.23 (0.33)
Guinean	Comé	7.42 (0.03)	6.97 (0.04)	0.1 (0.00)	2.99 (0.16)	5.14 (0.28)	29.9	13.23 (1.79)	8.82 (0.32)	15.09 (1.22)	62.88 (0.25)
	Bohicon (Lama)	7.57 (0.08)	7.16 (0.04)	0.08 (0.00)	1.58 (0.12)	2.71 (0.20)	19.75	11.63 (0.02)	2.46 (0.19)	9.96 (0.16)	76.13 (0.04)

Note. Figures in brackets are standard deviation (n = 3). N = nitrogen ; C = carbon ; O = organic matter.

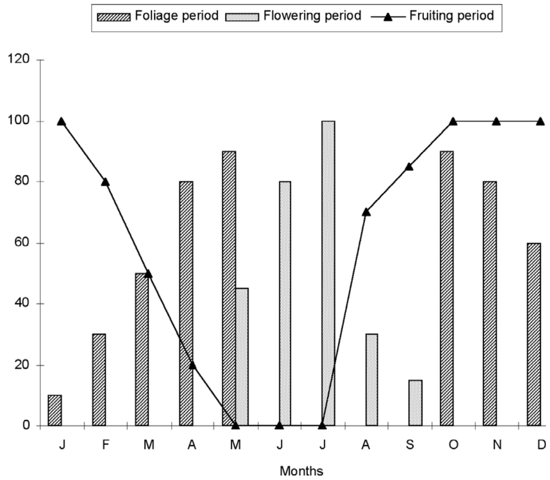

FIG. 2. — Phenological diagram of *A. digitata* from March 2003 to March 2004.

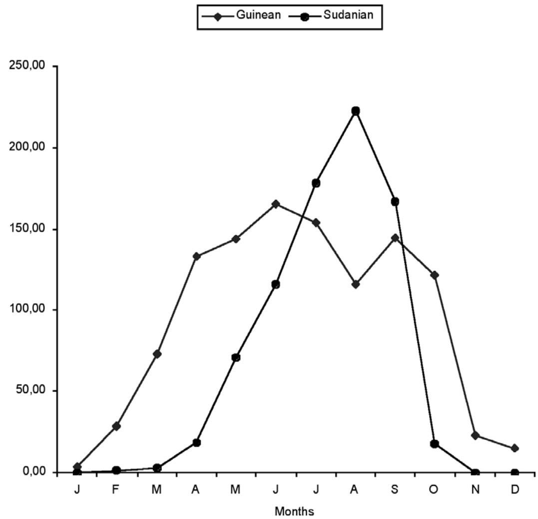

FIG. 3. — Mean monthly rainfall (average on 30 years data) distribution in the Sudanian (9°45' to 12°25N) and Guineo-Congolean (6°25' to 7°30'N) zones.

has less value for the local people and fewer fruits are harvested. In the Dahomey Gap, the fruiting period persists beyond February when more than 50 % of the trees still bear fruits.

CHARACTERIZATION OF THE CLIMATIC ZONES ACCORDING TO BAOBAB MORPHOLOGICAL DATA AND FRUIT PRODUCTION

Morphological data and productivity in baobab populations varied significantly ($P < 0.05$) from one climatic zone to another. In the Sudanian zone (zone I), the baobabs had large girths and crowns, and numerous fruits with a high pulp, seed, and kernel content (Table 2). In this zone, some trees reached 500 cm in diameter at breast height (DBH) compared to the other zones where the baobabs rarely reached 400 cm dbh (Fig. 4). The distribution of the diameter classes shows that the species is facing a natural regeneration problem ; there were very few individuals recorded with a diameter less than 100 cm.

Individual baobabs in the Sudano–Guinean zone (zone II) were short with a very large diameter at breast height (Figs. 4 and 5). Populations in this zone produced the highest yields of pulp, seeds and kernels (Table 2). In the Guinean zone (zone III), the individuals were tall but of a small diameter at breast height (Fig. 5). Baobab in the Guinean zone produced only a small number of fruits with a low pulp, seed and kernel productivity (Table 2).

RELATIONSHIP BETWEEN PRODUCTION, TREE AND HABITAT CHARACTERISTICS

The result of the principal component analysis (PCA) performed on the abiotic variables showed that the first three axes explained 83.98 % of the observed variation. Therefore, only the first three axes were used to describe the relationship between the habitat characteristics of baobab populations (Figs. 6 and 7). Based on the correlations between the different variables and the three PCA axes selected (Table 3) the following variables were considered on the first axis (axis 1) : temperature (T), relative humidity (RH), potential evaporation (PET), pH_{water}, pH_{KCl}, total percentage of nitrogen (N), organic carbon (C), organic matter (O) and percentage of fine silt (FSi). On the second axis (axis 2), the following variables were considered : rainfall, C/N ratio, percentage of sand (S), clay, and crude silt (CSi). On the third axis (axis 3) the following variables were considered : C/N ratio, percentage of crude silt (CSi) and rainfall.

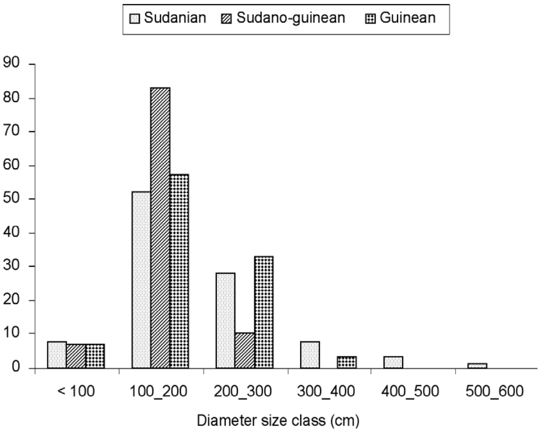

FIG. 4. — Diameter class (DBH) distribution of *A. digitata* according to climatic zones.

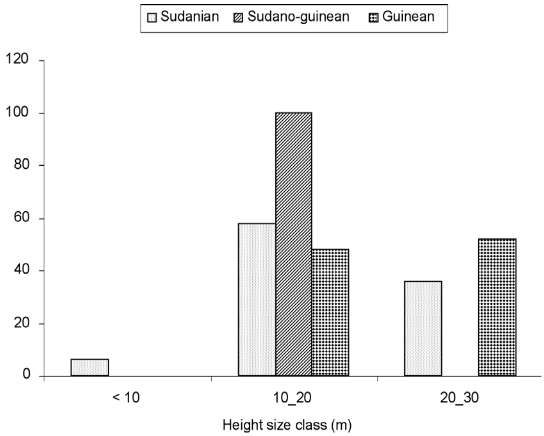

FIG. 5. — Height class distribution of *A. digitata* according to climatic zones.

TABLE 2

Dendrometric characteristics and mean production per individual according to climatic zones

	Zones					
	Sudanian (zone 1)		Sudano-Guinean (zone 2)		Guinean (zone 3)	
	mean	s	mean	s	mean	s
Diameter at 1.3m (cm)	**201.7**[a]	94.5	175.8[b]	61.7	149.8[c]	38.6
Height	17.1[a]	4.6	13.8[c]	3.4	**19.6**[b]	1.9
Crown diameter (m)	**17.3**[a]	4.9	**18.3**[a]	5.2	13.3[b]	3.5
Number Branches/Tree	7[a]	2.7	10[b]	5.2	7[a]	3
Number Fruits/Tree	124.6[a]	121.4	**157.4**[b]	166.1	57.1[c]	45.1
Total weight Fruit/ Tree (kg)	27.3[a]	25.9	**35.4**[b]	29.9	13.7[c]	11.4
Weight Pulp/Tree (kg)	4.8[a]	2.6	**6.3**[b]	4.9	2.4[c]	2
Number Seeds/Tree	20570[a]	19359.7	**27527**[b]	31149.1	10923[c]	9072.5
Weight Seeds/Tree (kg)	8.9[a]	5.4	**11.9**[b]	8.5	4.7[a]	2.9
Weight Kernel/Tree (g)	2980.9[a]	1806.4	**3977.7**[b]	2889.4	1575.2[c]	1308.8

Note. In the same row, figures with the same letter are not significantly different.

On the first PCA axis, the variables T, RH, PET, pH_{water} and FSi are positively correlated with the axis 1 and opposed to the variables pH_{KCl}, N, C, O (Table 3). Moreover, the correlation between PCA factor scores with the biotic variables (Table 4) showed that the first factor (PCA1) is negatively correlated with the seed and fruit pulp production of baobab. This means that the number of seeds and the amount of fruit pulp produced by the baobab increased with the pH_{KCl} and the percentages of total nitrogen, organic carbon and organic matter in the soil. On the contrary, high values of PET, RH, T, pH_{water}, and high percentages of FSi are associated with low seed and fruit pulp production.

The percentage of sand in the soil was positively correlated with the PCA axis 2 and opposed to the percentage of clay and crude silt (Table 3). The correlation between PCA factor scores with the biotic variables (Table 4) shows that PCA axis 2 is positively correlated with the number of branches (Nbranches) and seed production, and

TABLE 3
Correlation between baobab abiotic variables and canonical variables

	Factor1	Factor2	Factor3
PET	**0.92394**	-0.17795	-0.30211
Rainfall	0.20955	0.33094	**0.85279**
RH	**0.78753**	**0.57831**	-0.15344
T	**0.97979**	-0.11532	-0.09460
pH_{water}	**0.81716**	0.46805	-0.03040
pH_{KCl}	**-0.94986**	0.26959	-0.02808
N	**-0.96267**	0.22755	-0.02176
C	**-0.96281**	0.23063	-0.02351
O	**-0.94095**	0.32346	-0.07677
C/N	0.20336	**0.53156**	**0.53224**
Clay	-0.20609	**-0.85725**	-0.22727
CSi	-0.16168	**-0.66592**	**0.60412**
FSi	**0.73250**	-0.33249	0.24386
S	0.26146	**0.83542**	-0.25989

Note. PET = potential evaporation ; RH = relative humidity ; T = temperature ; N = total nitrogen ; C = organic carbon ; O = organic matter ; C/N = carbon to nitrogen ratio ; CSi = crude silt ; FSi = fine silt ; S = sand.

TABLE 4
Correlation between PCA factor scores of abiotic variables with the biotic variables

Variables	z1		z2		z3	
	r	*P*	*r*	*P*	*r*	*P*
Hm	0.081	0.221	0.101	0.125	**-0.170**	**0.009**
Dcrown	0.007	0.913	-0.033	0.619	**-0.248**	**0.000**
NBranches	0.066	0.319	**0.168**	**0.010**	**-0.325**	**<.0001**
Ncaps	0.029	0.655	0.009	0.895	**-0.204**	**0.002**
Nseedscaps	0.029	0.655	0.035	0.590	**-0.162**	**0.013**
DBH	0.109	0.097	**-0.200**	**0.002**	**-0.268**	**<.0001**
Wkernel	0.038	0.568	0.032	0.625	**-0.162**	**0.014**
WCaps	0.012	0.859	0.021	0.750	**-0.169**	**0.010**
Wseeds	0.020	0.758	0.036	0.581	**-0.162**	**0.013**
WP	**-.236**	**0.000**	0.082	0.213	**-0.174**	**0.008**

Note. Hm = height of tree ; Dcrown = diameter of the crown ; NBranches = number of branches ; Ncaps = number of capsules ; Nseedscaps = number of seeds per capsule ; DBH = diameter at breast height ; Wkernel = weight of kernel ; WCaps = weight of capsules ; Wseeds = weight of seeds ; WP = weight of pulp ; *r* = correlation coefficient ; *P* = probability.

negatively correlated with the crown diameter (Dcrown). The percentage of sand had a positive effect on the number of branches and seed productivity and a negative effect of the crown diameter. This contrasts with the percentages of crude silt and clay.

The C/N ratio and the rainfall are positively correlated with PCA axis 3. The correlation between the PCA factor scores with the biotic variables (Table 4) indicates that PCA axis 3 was positively correlated to all of the biotic variables. It was concluded that the high values of C/N ratio and rainfall were negatively associated with the biological characteristics of baobab.

DISCUSSION

BAUM *et al.* (1998) argued that the genus *Adansonia* originated in Madagascar and migrated to Africa by long-distance dispersal before the breaking of West Gondwana blocks at the beginning of the Cretaceous. From a biogeographic point of view, *A. digitata* is found in the Sahelian, Sudano-Sahelian and Sudanian zones, where the average annual rainfall is respectively of 300, 500 and 800 mm (FAO 1981, 1988, WICKENS 1982, SIDIBÉ & WILLIAMS 2002). *A. digitata* has also been definitely introduced in the very wet forest belt with more than 4000 mm of annual rainfall such as in Gabon, in parts of Democratic Republic of Congo and in southern Cameroon (WICKENS 1982). However, if the climatic variations observed from 20000 to 10000 BP and from 2800 to 2000 BP (SOSEF 1994, MALEY 1996, 1997, MALEY & BRENAC 1998), characterized by the replacement of the dense forests of Equatorial Africa by savannas are considered, it is also likely that *A. digitata* got naturally established in Central Africa during these periods of climatic change. Complementary paleontology studies on the baobab must consider the period of establishment in its current distribution range, as it has been done in the case of the oil palm tree (*Elaeis guineensis* ; MALEY 1999).

The occurrence of high density stands of *A. digitata* patches and of other associated, typical dry zone species such as *Vitellaria paradoxa* and *Borassus aethiopum* within the Guinean zone, which has the highest rainfall in Benin, may be explained by the phenomenon of Dahomey-Gap, a dry corridor from the plain of Accra in Ghana to Benin in the Guinean Zone of Africa. In Dahomey-Gap the savannas interrupt the forest block and reach the seacoast. The baobab probably reappeared in the late Holocene, about 3700 yr BP, which must be associated with the reappearance of the "little dry season" inland and with the upwelling of cold water in the Benin Gulf (MALEY 1991).

It has been suggested that the close association of the baobab with villages indicates that the tree must have been introduced by man. This may certainly be true for some sites but according to WICKENS (1982), there are also many villages that have been settled so as to take advantage of the existing shade and economic potential of an indigenous baobab.

With regard to the temperature (optimum of 20 to 30°C and even 40 to 42°C, see SIMPSON 1995), and the soil types, *A. digitata* is in its ecological optimum in Benin. The species thrives on a broad range of soils, from lateritic and rocky soils (THOMPSON 1910) to clayey soils (HARRISON & JACKSON 1958), over sandy (ROSEVEAR 1937) and loamy soils (ASTLE *et al*. 1969).

The variability in the flowering period from one country to another and even from one zone to another has a direct consequence on the period of fruit availability. In Benin, the fruit maturation period extends from December to March, approximately 6 to 7 months after the beginning of flowering. This also corresponds to the season of food shortage.

The diameter and height class distributions of *A. digitata* showed that individuals might reach a diameter of 6 m and a height of 25 m in Benin. These values are less than what SIDIBÉ & WILLIAMS (2002) found : 10 m in diameter and 30 m in height. The size class distribution of the species showed the quasi-absence of natural regeneration, which may be due to the wild bush fires and other anthropogenic activities such as land clearing and browsing. The same has also been noticed in Mali where the traditional protected parklands are being gradually replaced by cotton farms (SIDIBÉ & WILLIAMS 2002). This seriously affects the survival of *A. digitata* in its natural habitat.

The morphology and productivity of individual baobabs varied significantly according to the climatic zones. Environmental effects on the biotic variables have also been observed in other edible trees in Africa. MARANZ & WIESMAN (2003) showed for the shea tree (*Vitellatria paradoxa*) a significant relationship between trait values (fruit size and shape, pulp sweetness, and kernel content of the species) and abiotic variables (temperature and rainfall) in sub-Saharian Africa north of the equator. Also, SOLOVIEV *et al.* (2004) showed for *Balanites aegyptiaca* and *Tamarindus indica* (the savanna trees) the significant influence of different climatic zones of Senegal on fruit pulp production. To date, it seems that none of the work has dealt with the genetic determinism of the studied characters. Although it may well be that the variation observed in productivity and other studied characters is determined mostly by environmental factors, much more work is needed to elucidate patterns of genetic diversity in relation to distribution, ecology and morphological variables found in these trees.

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