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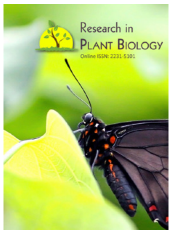
Research Article



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Leaf and fruit characteristics of *Parkia biglobosa* (Jacq.) Benth according to agro climatic zones and land use in Southern Mali

Bokary Allaye Kelly[1]*, Amadou Malé Kouyaté[2], Sidiki Gabriel Dembélé[3]

[1]Institut d'Economie Rurale, Programme Ressources Forestières, Centre Régional de la Recherche Agronomique de Sikasso, BP 16 Sikasso, Mali, [2]Institut d'Economie Rurale, Centre Régional de la Recherche Agronomique de Sotuba, Bamako, Mali, [3]Institut Polytechnique Rural de Formation et de Recherche Appliquée (IPR/IFRA) de Katibougou, Koulikoro, Mali

ABSTRACT

A study was conducted in Southern Mali to characterized *Parkia biglobosa* populations in the aim to contribute to the domestication of the species. Fields and fallows in the North Sudanian, south Sudanian and North Guinean zones were concerned. Adult trees were marked in plots of 0.25 ha each and leaves and fruits were harvested from each tree for characterization. Petiole and laminar length, number of pairs of pinnae and leaflets, pedicel and pod length, pod wide, pod and seed weight, number of seed per pod were measured. The North Guinean zone showed the highest number of pairs of pinnae and leaflets, the longest pods (23.06±9.91 cm in the fields), the highest mean seed weight (3.74±0.96 g in the fields) and the highest mean number of seeds per pod (17 ± 3 seeds in the fields). The South Sudanian zone showed the longest pedicels (3.85±1.08 cm in the fallows), the highest mean laminar length (18.02 cm) and mean petiole length (6.45 cm) in the fields but the same mean number of seeds per pod as for the North Guinean. The North Sudanian zone showed the widest (17.88±7.98 cm in the fields and 18.24±2.11 cm in the fallows) and heaviest (14.87±3.95 g in the fallows) pods. Leaf variables like the number of pairs of pinnae and leaflets seem to be influenced by the climatic gradient. The others leaf, pod and seed variables seem not to be influenced by the climatic gradient. These findings suggest that many leaf and fruit variables are controlled by endogenous factor that could be genetic. However, the manifestation of the endogenous factor seems to be influenced by factors such as environment and management practices.

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***Corresponding Author:**
Bokary Allaye Kelly
E-mail: bokarykelly@gmail.com

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INTRODUCTION

Forest tree species are under high human pressure in degrading ecosystems as observed in recent decades. The drastic decline in crop production and the loss of genetic diversity are the real risks to be observed in the long term (Ouinsavi & Sokpon, 2010). In the context of climate change, trees could express new potentialities in response to bioclimatic factors (Dicko *et al.*, 2019). Consequently, studies on the ecological adaptation of fruit trees along the climatic gradient are important for predicting their productivity in the future (Glèlè *et al.*, 2011). Tree species are characterized by high genetic diversity linked to geographical origin and to the difference between individuals within the same population (Goba *et al.*, 2019). The diversity is important for adaption of species to various climatic and environmental conditions. Within climatic zones, environmental conditions are known to induce a large spatial variability in the morphology and productivity of fruit trees (Arbonier, 2002) and environmental conditions can cause significant variations in the morphological characteristics of species populations (Dicko *et al.*, 2019). Hence, variability studies are needed to increase plant productivity and also for future breeding work (Freigoun *et al.*, 2017).

The diversity within a species can be assessed through morphological and molecular traits (Ikabanga *et al.*, 2017; Avana-Tientcheu *et al.*, 2019). Phenotypic variability of a species could be assessed by identifying morphological descriptors and morphological data from geographical origins have been used in first studies of genetic diversity of tree species (Kouonon *et al.*, 2020). According to Samim *et al.* (2018), morphological descriptors are the basis for the characterization of plant genotypes on the basis of their phenotype.

Many studies had concerned the variability of species showing great interest to the local populations. Studies addressing morphological variability of species have concerned: *Adansonia digitata* in Mali and Benin (Assogbadjo, 2006; Kouyaté *et al.*, 2011), *Argania spinosa* in the South-West Morocco (Zahidi *et al.*, 2013), *Sclerocarya birrea* in Benin and in Burkina Faso (Bationo, 2008; Gouwakinnou, 2011), *Prosopis africana* in Benin (Houètchegnon *et al.*, 2015), *Vitellaria paradoxa* in Mali (Kelly & Senou, 2017). Recent studies have been focused on the variability of morphological traits and to the identification of morphological descriptors of several tree species like *Adansonia digitata* (Bamba *et al.*, 2019), *Lophira lanceolata* (Dicko *et al.*, 2019; Lankoande *et al.*, 2020), *Pterocarpus erinaceus* (Johnson *et al.*, 2020), *Parkia biglobosa* (Avana-Tientcheu *et al.*, 2019; Kouonon *et al.*, 2020).

Parkia biglobosa is a forest tree species of the family of Leguminosae/ Fabaceae (Sancandé *et al.*, 2016), common in agroforestry parklands in the Sudanian zone. Ayihouenou *et al.* (2016) reported that its conservation and domestication for the diversification of agricultural production depend on its ability to adapt to climate change. Lompo *et al.* (2017) reported that, a sound conservation strategy for *P. biglobosa* and the promotion of its sustainable management should be based on scientific information about threats as well as ecological and genetic processes affecting this species. Assessment of the variation of the morphological traits of this species in relation to agro-climatic zones could contribute to this scientific information needed for a successful conservation strategy. Also, it is essential to know the phenotypical variability of this species for domestication purposes so that to preserve goods and services provided by *P. biglobosa* (Kouonon *et al.*, 2020).

In Mali, *P. biglobosa* is one of the most important parkland tree species, present in the north and the south of Sudanian zones in the regions of Kayes, Koulikoro, Ségou, Sikasso and in the North Guinean zones in the regions of Kayes and Sikasso (Fagui, 2015). It is a forest tree species which regenerates naturally. The cultivation of *P. bigolobsa* began only recently and it is still very limited. Nursery experiments for seedlings production and on-field plantation experiments started in Mali in the 1990's.

P. biglobosa is a multi-purpose tree species having almost the same uses in the three study sites. The species provides food for human beings (e.g., pulp and grains used to produce the spice called "soumbala" or "dawadawa"). This spice is rich in proteins and contains lipids, essential amino acids, essential fatty acids, vitamins and mineral compounds (Ouoba *et al.*, 2003). It is particularly appreciated and widely used in Africa. *P. biglobosa* provides food for animals also (pulp) and contributes to generate income for rural populations. Therefore, the species contributes fighting poverty. It provides medicine and sometimes craft wood (mainly in the north and south Sudanian zones).

Populations of this species are highly threatened in large parts of its range due to over-exploitation and environmental degradation (Lompo *et al.*, 2017). Nowadays, the density of *P. biglobosa* trees is very low in farmed fields as well as in the fallows. The low density could be explained by several causes like natural mortality, density reduction by farmers in the field to reduce competition with associated crops (mainly cash crops like cotton which was in expansion in the whole Southern Mali) and the weak natural regeneration in the fallow. These constraints in addition to climate change could lead, in the adaptation strategies of the species, to a variability of leaf and fruit characteristics, which is important to assess. Lompo *et al.* (2017) reported that, in the light of climatic changes, safeguarding the genetic diversity of the species is crucial to foster adaptation and to support its long-term survival.

The objective of the study was to contribute to the domestication of the species in Mali. More specifically, it aimed (i) to assess the variability of leaf and fruit characteristics according to land use and agro-climatic zones along the North-South climatic gradient, (ii) to identify morphological descriptors important for the resilience of the species.

MATERIAL AND METHODS

Study sites

The study was conducted in three agro-climatic zones (the North Sudanian NS, the South Sudanian SS, and the North Guinean NG). These zones were selected based on climatic and environmental conditions as well as management practices (land use and tree management systems). In the NS zone, the mean annual rainfall varies from 500 to 800 mm. It is a zone of slightly undulated plains, lowlands and depressions with heavy soils quite wet, and actively cultivated. It also contains extensive, fine-textured plains. The natural vegetation is constantly being degraded, and the existing woody species are those spared by man. In the SS zone, the mean annual rainfall varies from 800 to 1100 mm. Soils are deep alluvial, often the most fertile in the country, used for continuous cultivation and short fallow systems. The soils on rocky foundations are shallow or moderately deep. There are open or moderately dense woody stands on shallow soils. In the NG zone, the rainfall is over 1100 mm per year. The valleys in this area are cultivated in a continuous regime. Fallow system is longer and the density of woody species is higher. It is an excellent zone of timber exploitation. It is important to notice that the average altitude of parcels of studied populations of *P. biglobosa* increased from north to south but the difference in altitude was not very substantial. These altitudes in average were 276 m in NS zone, 312 m in the SS zone and 332 m in the NG zone.

Land and parkland trees are managed differently in the study sites. In the NG zone, land is less scarce and shifting cultivation still exists whereas in the other two zones, due to land scarcity, the same parcels are used continuously or with short fallow period. *P. biglobosa* is 432 officially protected by national legislation in Mali. Despite this protection, the species is cut for various purposes according to zones. In the NG zone, vegetation is relatively abundant and *P. biglobosa* trees are less exploited for purposes like fuel wood, charcoal or craft wood in contrary to the Sudanian zones, where cases of *P. biglobosa* exploitation were observed. Hence, *P. biglobosa* tree densities in the Sudanian zones are lower compare to the NG zone and because of the use of the same parcels continuously, *P. biglobosa* trees are older and bigger. They are often pruned to favour associated crops.

In each zone, one site was selected based on the availability of *P. biglobosa* populations in fields and fallows, the accessibility in all seasons, and the willingness of farmers to collaborate in research activities. Selected sites were Somasso (district of Bla) in the NS zone, Zanzoni (district of Koutiala) in the SS zone and Diou (district of Kadiolo) in the NG zone. Figure 1 shows the localization of the three study zones within southern Mali and Figure 2 shows the localization of the sites within the respective districts.

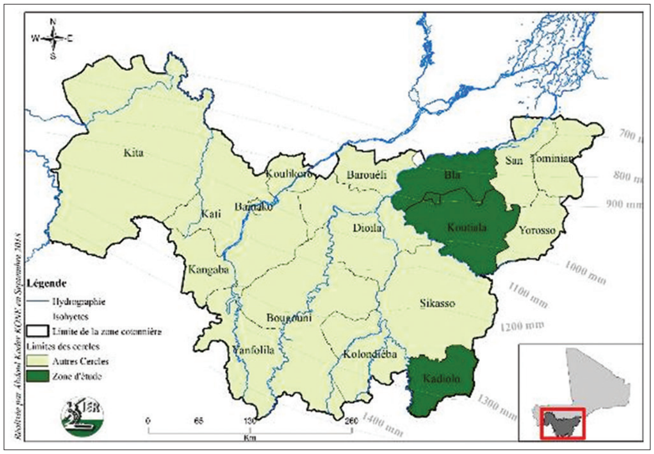

Figure 1: Localization of study zones (green areas) within southern Mali

The site of Somasso (51°31'N, 36°27'W) in the NS zone, has a little uneven relief composed of cultivable plains. The climate is north Sudanian, characterized by two seasons (the long dry season from October to May and the short rainy season from June to September). Agriculture is the main activity and the cultivated areas are large, dominated by cereal crops. Cotton and groundnuts are the cash crops. Vegetation is shrubby savannah with some big trees spared in the fields such as *Parkia biglobosa*, *Vitellaria paradoxa*, *Faidherbia albida* (PDESC, 2019). The site of Zanzoni (36°52'N, 32°05'W) in the SS zone, has little hilly relief composed of plains favourable for off-season crops. The climate is south Sudanian, with also two seasons with length similar to those of the site of Somasso. Agriculture concerns cereals production and cash crops such as cotton and peanuts. Vegetal resources are similar to those of the site of Somasso but, some protected forests and sacred woods are present (PDESC, 2019). The site of Diou (35°46'N, 58°33'W) in the NG zone, has a slightly uneven relief. The climate is North Guinean, with a dry season from November to May and a rainy season from May to October. Agriculture is the main activity and cereal production is mainly composed of Maize, while Cotton is grown as a cash crop. There are important natural stands of forest resources, artificial plantations of exotic species and sacred woods (PDESC, 2017).

Study design

The study design consisted of square plots of 50 m x 50 m = 2500 m^2 (0.25 ha). Two factors were studied:

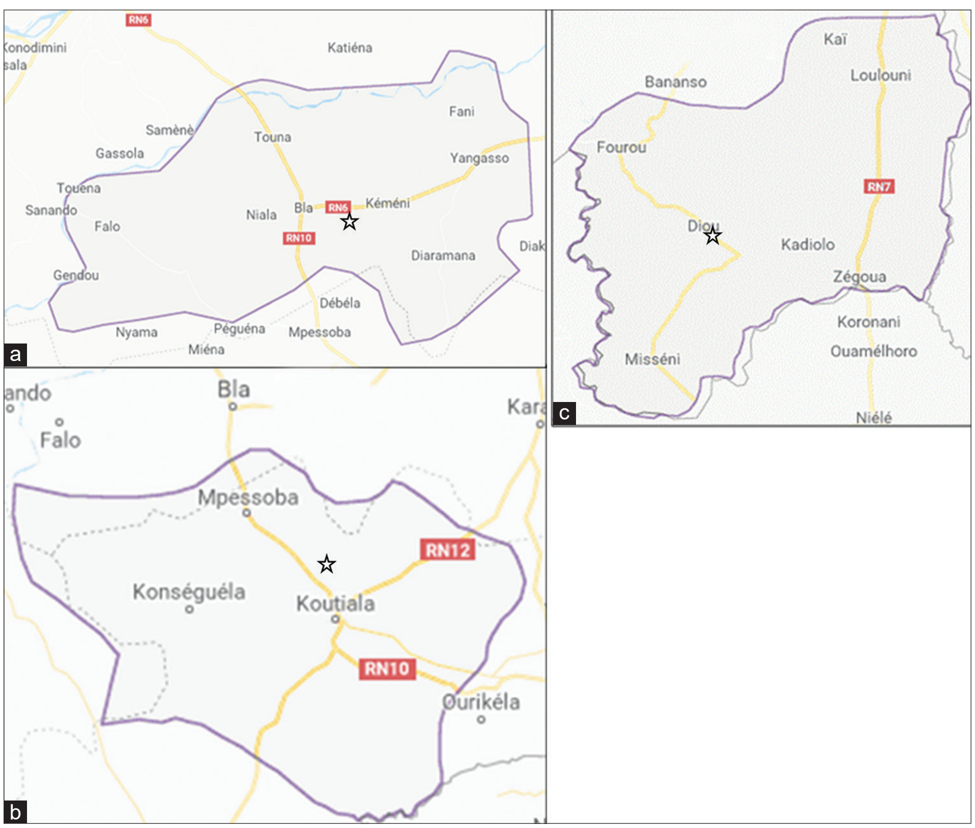

Figure 2: Localization of selected sites within the respective districts, each indicated by a star (2a Somasso in the district of Bla, 2b Zanzoni in the district of Koutiala and 2c Diou in the district of Kadiolo)

the factor agro-climatic zones (ACZ) with three levels (NS, SS and NG) and the factor land use "called stand in the paper" with two levels (fields and fallows). Three plots were installed in each stand within each zone giving six plots per agro-climatic zone. A total of eighty (18) populations (6 plots x 3 agro-climatic zones) of *P. biglobosa* was concerned. All adult *P. biglobosa* trees (DBH ≥ 10 cm) in the plots were marked and measured. Geographical position of each tree was recorded using a GARMIN eTrex 10 GPS (accuracy ± 3 m).

Data collection and analysis

Fruits and leaves were harvested from all trees in the plots. For leaf characterization, 50 leaves were sampled per tree. Laminar and petiole length was measured, the number of pairs of pinnae (NPP) was counted as well as the number of pairs of leaflets (NPLt) of the pinnae at the basis, at the middle and at the top of the laminar. For fruit characterization, 50 pods were harvested from trees having sufficiently fruited. Pods weight (PoWe) was determined using electronic balance AND GR 202 (precision ± 0,1 mg), pod length (PodL) and pedicel length (PediL) were measured using ruler and their width (PodWi) was measured using Vernier calliper SUNRISE (precision ± 0,02 mm). After pulp removal, the number of seeds per pod (Nseeds) was counted and fresh seeds weight (SeedWe) was determined using electronic balance.

Descriptive statistics were computed. The correlations of leaf variables with each other and with dendrometric parameters of the trees were assessed. The same assessment was done for fruit variables. Analysis of variance was used to determine the effect of studied factors at 5% significance level. For factors whose effects were significant, multiple comparison of the means was made to distinguish the levels of the factor that were significantly different according to Bonferonni's method.

RESULTS

Summary statistics and correlations

Statistics for tree and leaf variables were shown in table 1. Some tree variables (DBH, MCD) and some leaf variables (LL, PL) showed a relative high variability.

Correlations matrix between variables were shown in table 2. Correlations of leaf variables with tree parameters were weak and most of them were negative. Correlations of leaf variables to each other were also weak (Table 2). The only relatively high correlation was that between laminar length and the number of pairs of pinnae (0.64). However, high correlations were observed between some tree parameters. DBH was highly and positively correlated with MDC and TH, these last two parameters were also highly and positively correlated (Table 2).

Summary statistics for tree and fruit variables were shown in table 3. Some tree variables (DBH, MCD) and fruit variables (PediL, PodL, PodWe, Nseeds, SeedWe) showed a relatively high variability (Table 3).

Table 1: Summary statistics for tree and leaf variables

	Mean	Stand dev.	Cv %	Mini	Maxi
DBH (cm)	59.23	20.12	33.97	17.00	114.00
MCD (m)	13.24	3.65	27.57	4.42	20.25
TH (m)	11.83	2.22	18.77	4.80	16.00
LL (cm)	17.79	4.15	23.33	4.00	40.00
PL (cm)	6.06	1.53	25.25	2.00	16.500
NPP	10	2	20.00	2	17
NPLtBP	31	6	19.35	7	62
NPLtCP	41	6	14.63	13	79
NPLtTP	32	7	21.88	5	60

DBH=diameter at body height, MCD=mean crown diameter, TH=total height, LL=laminar lenght, PL=petiole lenght, NPP=number of pairs of pinnae, NPLtBP=number of pairs of leaflets for pinnae at the basis of the laminar, NPLtCP=number of pairs of leaflets for pinnae at the centre, NPLtTP=number of pairs of leaflets for pinnae at the top

Correlations matrix between variables were shown in table 4. Correlations of fruit variables with tree parameters were weak and some of them were negative. Correlations of fruit variables to each other were also weak (Table 4). Relatively high correlations were observed between pod length and pod weight (0.79), pod length and seeds weight (0.65), number of seeds and seed weight (0.72), pod weight and seed weight (0.75). Some relatively high correlations were also observed between tree parameters (Table 4). DBH was positively correlated with MDC (0.68) and TH (0.61). These last two parameters were also positively correlated (0.76).

Leaf characteristics of *P. biglobosa*

The analysis of variance showed a significant effect of ACZ for all the leaf variables ($p < 0.001$). The effect of stand was also significant for most of variables, but the interaction between the two factors was not significant. The means of measured variables were shown in table 5.

For leaf size variables, the highest mean laminar length (18.02 cm) was observed in the SS zone. This zone was not significantly different to the NG zone and both, showed significant higher means compared to the NS zone (Table 5). The highest mean petiole length also was observed in SS zone (6.45 cm) which was significantly higher than that observed in the NS and NG zones. Fields showed significant higher means for leaf size variables and for the number of pairs of pinnae compared to fallows (Table 5).

For the number of pairs of pinnae and leaflets, the NG zone showed significant higher means compared to the SS and NS zones. These latter were also significantly different for the number of pairs of leaflets for pinnae at the centre and at the top of the laminar, the NS zone showing significant higher means compared to the SS zone (Table 5). Fields and fallows were not significantly different for the number of pairs of leaflets for pinnae at the basis and at the top of the laminar, but they were significantly different for the number of pairs of pinnae (NPP) and for the number of pairs of leaflets at the centre of the laminar (NPLtCP). Fields showed highest mean for NPP, while fallows showed highest mean for NPLtCP.

Table 2: Correlation matrix for tree and leaf variables

DBH	1.000								
MCD	0.700	1.000							
TH	0.702	0.713	1.000						
LL	-0.007	-0.094	0.014	1.000					
PL	0.065	-0.043	0.027	0.363	1.000				
NPP	-0.242	-0.195	-0.179	0.639	0.035	1.000			
NLtBP	0.006	0.026	0.104	0.102	0.223	0.075	1.000		
NLtCP	-0.033	0.019	0.047	0.175	0.093	0.201	0.500	1.000	
NLtTP	-0.031	0.015	0.063	0.088	0.052	0.106	0.347	0.440	1.000
	DBH	MCD	TH	LL	PL	NPP	NPLtBP	NPLtCP	NPLtTP

Numbers in bold indicate relative high correlation between variables DBH=diameter at body height, MCD=mean crown diameter, TH=total height, LL=laminar lenght, PL=petiole lenght, NPP=number of pairs of pinnae, NPLtBP=number of pairs of leaflets for pinnae at the basis of the laminar, NPLtCP=number of pairs of leaflets for pinnae at the centre, NPLtTP=number of pairs of leaflets for pinnae at the top

Table 3: Summary statistics for tree and fruit variables

	Mean	Stand dev.	Cv %	Mini	Maxi
DBH (cm)	62.29	18.34	29.44	31.00	105.00
MCD (m)	13.89	3.10	22.32	6.65	18.45
TH (m)	12.24	1.79	14.60	8.55	15.00
PediL (cm)	3.623	1.151	31.772	1.000	9.000
PodL (cm)	20.95	4.53	21.60	4.70	35.50
PodWi (mm)	16.95	2.42	14.28	5.22	29.25
PodWe (g)	13.05	3.77	28.85	2.98	27.81
Nseeds (n)	16	4	25.68	3	42
SeedWe (g)	3.333	1.066	31.992	0.590	8.380

DBH=diameter at body height, MCD=mean crown diameter, TH=total height, PediL=pedicel length, PodL=pod length, PodWi=pod wide, PodWe=pod weight, Nseeds=number of seeds, SeedWe=seed weight

Fruit characteristics of *P. biglobosa*

The analysis of variance showed a significant effect of ACZ for the fruit variables excepted seed weight ($p = 0.303$). Stand effect was also significant for the fruit variables excepted for pedicel length ($p = 0.264$). For all fruit variables, a highly significant interaction between site and stand was observed ($p < 0.001$). The means of fruit size parameters were shown in Table 6.

The longest pedicels were observed in the fallows in the SS zone (3.85±1.08 cm). This mean pedicel length was not significantly different than those observed in the fields in the NS and SS zones and in the fallows in the NG zone. The shortest pedicels were observed in the fields in the NG zone which showed the longest pods (23.06±9.91 cm), significantly higher than all other observed means for that variable (Table 6). The shortest pods were observed in the fields and fallows in the NS zone which showed the widest pods (17.88±7.98 cm and 18.24±2.11 cm respectively), significantly higher than the means observed in the stands of the other two agro-climatic zones (Table 6). The means of pod and seed parameters were shown in table 7.

The heaviest pods were observed in the fallows in the NS (14.87±3.95 g), significantly higher than all observed means for that variable (Table 7). The lowest mean pod weight was observed in the fallows in NG zone, while the fields of that zone showed the highest mean seed weight (3.74±0.96 g). This mean seed weight was not significantly different than that observed in the fields in the SS zone (Table 7). The highest mean number of seeds per pod (17 ± 3 seeds) was observed in the fields in the SS and NG zones. The lowest mean number of seeds per pod (15 ± 4) was observed in the fields in the NS zone and in the fallows in SS and NG zones (Table 7).

DISCUSSION

Leaf variables such as NPP, NPLtBP, NPLtCP and NPLtTP seem to be influenced by the climatic gradient. Means of these variables observed in the wettest zone (NG) were higher than those observed in dryer zones (NS and SS). The reduction of the number of organs (pinnae and leaflets) in the dryer zone could be a strategy for adaptation to environmental conditions. Hence, *P. biglobosa*, to survive in less favorable zone, would reduce the organs that could contribute to the excessive consumption or loss of water by respiration or evapotranspiration. These variables could be considered as morphological descriptors of the species resilience strategies. For leaf size variables (PL, LL) as well as for pod and seed variables, variations according to ACZ did not show a climatic gradient effect. In the majority of cases, means observed in the dryer zones (NS and SS) were higher than those observed in the wettest zone (NG). A similar phenomenon was observed for *V. paradoxa* in Nigeria by Ugese *et al.* (2010), in Ghana by Nyarko *et al.* (2012), in Uganda by Gwali *et al.* (2012), in Chad by Djekota *et al.* (2014) and in Mali by Kelly and Senou (2017). This result suggests a possible control of some agro-morphological traits of leaves and fruits by the genetic factor as it was reported for forest tree species in previous studies. For instance, Ouédraogo (1995) reported geographical variation in the provenance of *P. biglobosa* seeds in Sudano-Sahelian countries with rainfall below 1200 mm. According to this author, such results imply significant genetic variability in *P. biglobosa*. Several other studies have demonstrated genetic differences between provenances of same species (Ouédraogo, 1986; Brown & Hardner, 2000; Ræbild *et al.*, 2003).

Regarding the zone effect, a significant difference was observed between sites for several leaf and fruit variables. Differences between sites for leaf and fruit variables of *P. biglobosa* have been reported by several authors through studies in the sub-region. For instance, Oyerinde *et al.* (2018) observed a significant difference among 3 sites in southwestern Nigeria for several fruit variables (number of pods, pod weight, pod length and width, and seed weight). Their results showed that, for many variables, the wettest and the dryer sites were not significantly different, which was consistent with our results. These authors believe

Table 4: Correlation matrix for tree and fruit variables

DBH	1.000								
MCD	0.684	1.000							
PodWi	0.215	0.182	1.000						
TH	0.606	0.763	0.227	1.000					
PodL	0.058	0.058	0.276	0.053	1.000				
PediL	0.114	0.100	0.011	0.096	-0.027	1.000			
Nseeds	-0.055	0.049	0.091	-0.009	0.549	-0.051	1.000		
PodWe	0.128	0.178	0.520	0.172	0.786	-0.032	0.554	1.000	
SeedWe	-0.014	0.069	0.329	0.020	0.649	-0.073	0.725	0.748	1.000
	DBH	MCD	PodWi	TH	PodL	PediL	Nseeds	PodWe	SeedWe

Numbers in bold indicate relative high correlation between variables DBH=diameter at body height, MCD=mean crown diameter, TH=total height, PediL=pedicel length, PodL=pod length, PodWi=pod wide, PodWe=pod weight, Nseeds=number of seeds, SeedWe=seed weight

Table 5: Mean leaf variables by agro-climatic zones and by stand

Mean leaf variables						
ACZ/Stands	LL (cm)	PL (cm)	NPP	NPLtBP	NPLtCP	NPLtTP
North Sudanian (NS)	17.39±4[b]	5.91±1[b]	9±2[b]	30±6[b]	41±6[b]	32±7[b]
South Sudanian (SS)	18.02±4[a]	6.45±2[a]	9±2[b]	30±6[b]	40±6[c]	31±7[c]
North Guinean (NG)	17.96±4[a]	5.81±1[b]	11±2[a]	32±6[a]	43±5[a]	33±7[a]
Fields	18.17±4[a]	6.16±1[a]	10±2[a]	31±6[a]	41±5[b]	32±7[a]
Fallows	17.40±4[b]	5.95±1[b]	9±2[b]	31±6[a]	42±6[a]	32±7[a]
Avarege (all ACZ and stands)	17.79±4	6.06±1	10.17±2	31.16±6	41.84±6	32.40±7

Means with the same letter were not significantly different. ACZ=agro-climatic zone, LL=laminar length, PL=petiole length, NPP=number of pairs of pinnae, NPLtBP=number of leaflets for pinnae at the basis of the laminar, NPLtCP=number of leaflets for pinnae at the centre, NPLtTP=number of leaflets for pinnae at the top

Table 6: Mean fruit size variables by stand in agro-climatic zones

Fruit size parameters						
ACZ	Mean PeL (cm)		Mean PoL (cm)		Mean PoWi (mm)	
	Fields	Fallows	Fields	Fallows	Fields	Fallows
NS	3.81±1.12[a]	3.38±1.22[bc]	20.94±3.86[c]	21.00±4.41[c]	17.88±7.98[a]	18.24±2.11[a]
SS	3.71±1.25[a]	3.85±1.08[a]	21.78±5.23[b]	19.14±4.26[d]	16.47±3.18[b]	15.91±1.76[b]
NG	3.17±0.77[c]	3.61±1.10[ab]	23.06±9.91[a]	19.16±4.04[d]	16.49±1.42[b]	15.88±1.55[b]

For each variable, means with the same letter were not significantly different. ACZ=agro-climatic zone, NS=north Sudanian, SS=south Sudanian, NG=North Guinean PeL=pedicel length, PoL=pod length, PoWi=pod wide, PoWe=pod weight, NS/Po=number of seeds per pod, SWe=seed weight per pod

Table 7: Mean pod and seeds weight by stand in agro-climatic zones

Pod and seed parameters						
ACZ	Mean PoWe (g)		Mean SWe/Po (g)		Mean NS/Po	
	Fields	Fallows	Fields	Fallows	Fields	Fallows
NS	13.45±3.55[b]	14.87±3.95[a]	3.12±1.06[c]	3.49±0.99[b]	15±4[c]	16±3[b]
SS	12.99±3.77[b]	11.63±3.36[c]	3.60±1.13[ab]	2.96±0.98[c]	17±3[a]	15±4[c]
NG	13.29±2.85[b]	10.28±3.16[d]	3.74±0.96[a]	2.99±0.88[c]	17±3[a]	15±4[c]

For each variable, means with the same letter were not significantly different. ACZ=agro-climatic zone, NS=north Sudanian, SS=south Sudanian, NG=North Guinean PeL=pedicel length, PoL=pod length, PoWi=pod wide, PoWe=pod weight, NS/Po=number of seeds per pod, SWe=seed weight per pod

that the difference between sites was due to the combined effects of rainfall, temperature, soil types, tree distribution and land use type.

P. biglobosa fruit traits we observed were significantly lower than those reported by Olorunmaiye *et al.* (2011). These authors reported pod length ranged from 14.54 to 48.52 cm with an average of 24.72 cm against 4.7 to 35.5 cm with an average of 20.95 cm for this study; pod width ranged from 12.05 to 31.04 mm with an average of 23.23 mm against 5.22 to 27.81 mm with an average of 16.94 mm for this study; pod weight ranged from 53.09 to 224.2 g with an average of 157.25 g against 2.92 to 27.81 g with an average of 13.05 g for this study. According to Oyerinde *et al.* (2018), the variations in fruit and seed characteristics of *P. biglobosa* were consistent with the results reported for *Irvingia gabonensis* by Atangana *et al.* (2001), which stated that the high diversity of fruit among states could be due to climatic, edaphic and cultural factors.

In Benin, Koura *et al.* (2013) observed a significant difference between four subpopulations of *P. biglobosa* with respect to leaf, fruit and seed variables. The means observed by these authors for variables such as pod length, number of seeds per pod, and pod weight were close to those we obtained in this study. However, it should be noted that, these authors did not explicitly identify the factors underlying the variations they observed, but they cited several other authors (Kouyaté, 2005; Sanou *et al.*, 2006), which stated that, the existence of morphological variations at the level of subpopulations of a species can be explained by ecological and genetic variations. Koura *et al.* (2013) concluded that, a characterization of *P. biglobosa* subpopulations identified in their study was necessary on the climato-pedological and genetic levels. Beyond the sub-region, in Africa and Madagascar, Hopkins (1983) observed variation in leaves and leaflets of *P. biglobosa* along the latitudinal gradient. This trend of latitudinal variation was also observed for several aspects of *V. paradoxa* like morphological characters of leaves and fruits (Sanou, 2008), fat content (Davrieux & Piombo, 2008), chemical composition of butter (Maranz *et al.*, 2004; Davrieux *et al.*, 2010).

Regarding the stand effect, a significant difference was observed between fields and fallows. For most of leaf and fruit variables, the means were higher in the fields compared to the fallows. This result suggests that trees benefit from the reduced competition with other plants in the fields and also from care brought to crops. Oyerinde *et al.* (2018) reported a possible effect of land use type on the difference between sites with respect to *P. biglobosa* fruit variables. For *V. paradoxa* (another parkland tree species), several authors have reported that human activities have a positive influence on fruit production and this positive effect is partly due to agricultural practices like reduction of tree density, plowing, weeding and crops fertilization, tree selection (Lamien *et al.*, 2004; Okullo *et al.*, 2004; Kelly *et al.*, 2007; Bondé *et al.*, 2013; Kelly *et al.*, 2019). A significant effect of land use on fruit production has also been reported for *Sclerocaya birrea* (Shackleton *et al.*, 2002) and for *Lannea microcarpa* (Haameyer *et al.*, 2013). In contrast, land use was not found to significantly influence fruit production of *Adansonia digitata* and *Bombax costatum* (Ouédraogo *et al.*, 2004; Schumann *et al.*, 2010).

CONCLUSIONS

Findings of this study suggest that many *P. biglobosa* leaf and fruit variables are rather controlled by an endogenous factor that could be genetic. Other exogenous factors such as environment and management practices seem to also have a significant influence in the variation of these organs of *P. biglobosa*. The findings also confirm results of previous studies regarding the variation of morphological traits of forest tree species particularly those of agroforestry parklands in the terms of adaptation strategies and influencing forces. In developing a program for the domestication of *P. biglobosa*, theses aspects should be considered.

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