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Morphological variations of leaves and fruits of *Sclerocarya birrea* in two climatic zones of Niger

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ABSTRACT: Variations in environmental factors induce morphological variations in the organs of plant species. This study was conducted to determine the morphological variations of leaves and fruits of Sclerocarya birrea along an aridity gradient North-South (Gaya - Dogondoucthi) to enable the selection of interesting ideotypes for the domestication of the species. For the methodology, thirty (30) individuals per site were chosen. The measurements were based on thirty (30) fruits and fifteen (15) leaves per individual. For fruits, the morphological descriptors chosen were length, width and weight and for leaves, the length of the leaf, length of the petiole, number of leaflets, length and width of the leaflet were considered. The obtained data were related and the averages were compared. The results showed significant differences between the zones for the weight of the fruit and the size of the leaflets. Fruit weights ranged from 16.03g to 14.75g, respectively, for the Sahelian and Sahelo-Sudanian zones. Leaflet lengths ranged from 2.48cm to 2.19cm, and leaf widths ranged from 1.37cm to 1.28cm, respectively, for the Sahelo-Sudanian and Sahelian zones. Significant and positive correlations were also observed between fruit and leaf parameters. Therefore, the existence of a water deficit adaptation strategy for Sclerocarya birrea, following the climatic gradient was noted. These results, although preliminary, confirm the possibility of using morphological traits to select interesting ideotypes for domestication of the species.

KEYWORDS: *Sclerocarya birrea,* climatic gradient, adaptation, ideotypes, domestication.

1 INTRODUCTION

In Sub-Saharan Africa, rainfall deficit combined with various pressures on forest ecosystems cause considerable damage to natural resources, leading to the progressive loss of certain plant species [1]. Faced with this situation, many species are threatened, hence the need to adopt conservation strategies for agroforestry species of major socio-economic interest [2]. Among these strategies, the domestication of local fruit trees proves to be a convincing solution [3]. The domestication of a species requires the identification of good seed producers, knowledge of morphological characteristics and the development of propagation techniques [4]. In West Africa, several studies have focused on the morphological variability and domestication of local species, including those of [5] on *Parkia biglobosa,* [6] on *Tamarindus indica,* [7] on *Detarium microcarpum,* [8] and [9] on *Adansonia digitata,* [10] on *Senegalia senegal* and [11] on *Sclerocarya birrea*. However, very few scientific studies have given importance to the evaluation of the morphological diversity of the species (*Sclerocarya birrea).* The only existing reference on the morphological description of *Sclerocarya birrea* is the work of [11] who characterized the morphological variation of a sample in Burkina. The African plum, *Sclerocarya birrea* (A. Rich.) Hochst., is an Anacardiaceae widespread in the Sahel-Sudan region from Senegal to Ethiopia and Eritrea, and south to Namibia, Botswana, Zimbabwe, Mozambique, South Africa, Swaziland and Uganda, where it has significant traditional interest [12]. It has three subspecies [13]. *Sclerocarya birrea subsp birrea* is common in West Africa, *Sclerocarya birrea subsp multifolialata* (Engl.) kokwaro is distributed mainly in Tanzania and *Sclerocaya birrea subsp caffra* (Sond.) kokwaro is abundant in Southern Africa (ref). In Niger, the species is found in the southern part of the country. It is widely used by rural populations. Its economic, dietary, nutritional, health, social, cosmetic and pharmacological importance has been documented [14], [15], [16]. However, the sustainable use and management of trees or shrubs requires an analysis of the variability of their plant material on a morphological level in order to differentiate individuals [7]. This variability analysis makes it possible to target interesting morphotypes to produce and to know those which are linked to environmental factors [17]. Therefore, the present study proposes to study the variation of some morphological characters of the organs of *Sclerocarya birrea* in two (2) climatic zones of Niger.

2 MATERIALS AND METHODS

2.1 STUDY AREA AND SITE SELECTION

This study was conducted in two climatic zones of Niger, the Sahelian zone and the Sudano-Sahelian zone. One transect per climatic zone was chosen based on species dominance. This was the Dogondoutchi-Dankassari transect for the Sahelian zone and the Gaya-Tanda transect for the Sahelo-Sudanian zone (Figure 1). These transects share agrosystems occupied by *Sclerocarya birrea* formations and exploited by populations for various goods and services.

The Sahelo-Sudanian zone is located in the north of the country, characterized by an average annual rainfall of between 600 and 800 mm [18]. The climate is Sahelo-Sudanian with an average temperature of 29°C. The soils are predominantly tropical ferruginous. The ecosystems present are characteristic of transition zones. The vegetation consists of shrub or wooded savannahs with a fairly varied coverage rate.

As for the Sahelian zone, it is located in the center of the country, with an average annual rainfall of between 350 and 600 mm [18]. The climate is Sahelian with an average temperature of around 30 °C. The soils are mainly sandy and the vegetation is characterized by the presence of open savannahs.

The socio-economic activities of the local populations of the two areas are dominated by agriculture, livestock breeding, crafts and trade.

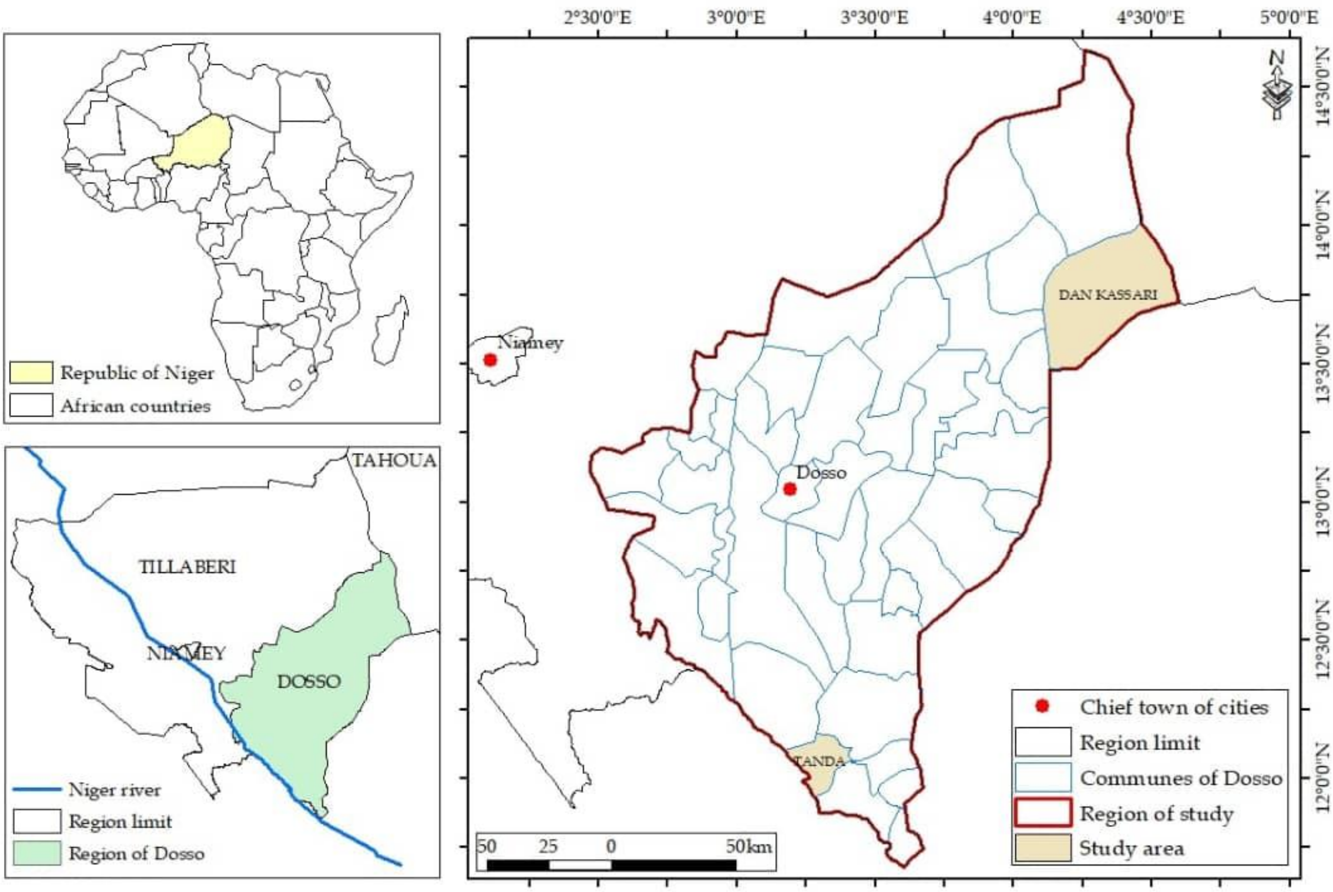

Fig. 1. Geographical location of the municipalities of Tanda and Dan Kassari

2.2 METHOD

2.2.1 SAMPLING

In this study, all *Sclerocarya birrea* individuals from each climatic zone were considered a population. For the morphological description of the fruits and leaves, a set of descriptors was chosen based on the descriptors proposed in the work of [19]. Thirty (30) individuals were selected per zone, for a total of sixty (60) individuals for both zones. The individuals selected were at least 20 meters apart for each population studied in order to avoid collecting material from individuals who are physically and genetically close. This prevented the selection of genetically similar individuals due to suckering.

Inter-population variability was assessed using the scale used by [20]:

CV = 0-10%: small variation

CV = 10-15%: medium variation

CV = 15-44%: fairly large variation

(CV > 44%): large variation

2.2.2 DATA COLLECTION

2.2.2.1 MORPHOLOGICAL DESCRIPTORS OF THE FRUITS

Fruit collection was carried out in May and June 2023. This period corresponds to the time when the fruits reached maturity in the Sahel-Sudanian and Sahelian zones, respectively. Collection was carried out by shaking branches, climbing the tree, or picking up mature fruits that had fallen under the tree. Thirty (30) fruits were collected from each individual. On each fruit, the dimensions of the two axes were measured using a caliper. The first axis is considered from the point of attachment of the fruit to the peduncle to its tip, and the second axis is taken perpendicular to the first. The weight of the fruits was weighed individually using a 2000 g electric scale. Figures 2 shows the collection and measurement of the axes and weight of the fruits, respectively.

Fig. 2. Collecting by climbing the tree (A) and picking the fruit under the tree (B) Measurement of axes (C) and weight of fruits (D)

2.2.2.2 MORPHOLOGICAL DESCRIPTORS OF LEAVES

The survey was carried out in September 2023 corresponding to the period when the species no longer produces new leaves and the leaves have reached their maximum development. On each individual, the collection for descriptive measurements involved 15 fully developed and unparasitized leaves, i.e. a total of nine hundred (900) leaves on all sixty (60) individuals in the two areas. They were collected and stored in a herbarium and the measurements were carried out in the laboratory. Based on the work of [21], five (5) parameters were considered for the characterization of the leaves. These are: leaf length (Lf), petiole length (Lp), length (Lfo) and width (lfo) of the leaflets and the number of leaflets per leaf obtained from a simple count. The different measurements on the leaves were carried out with a ruler graduated in cm and are illustrated in Figure 3.

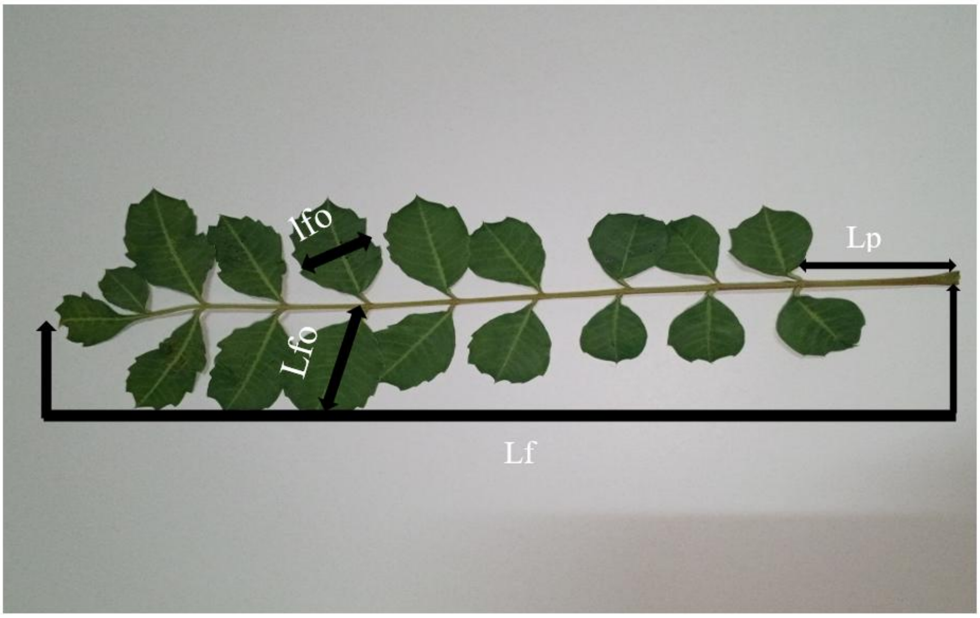

Fig. 3. Measurements taken on the leaves

2.2.2.3 MORPHOLOGICAL DATA ANALYSIS

From the measurements taken, the mean and standard deviation of the shape parameters were calculated according to climatic zones. The same was true for the ratio between fruit length and width and leaflet length and width. These data were subjected to an analysis of variance (ANOVA) to compare the means of the morphological characteristics. The ANOVA test at the 5% threshold was performed using R software by downloading the agricolae package.

The shape of leaflets and fruits was determined (Figure 4) according to the classification used by Clopton (2004).

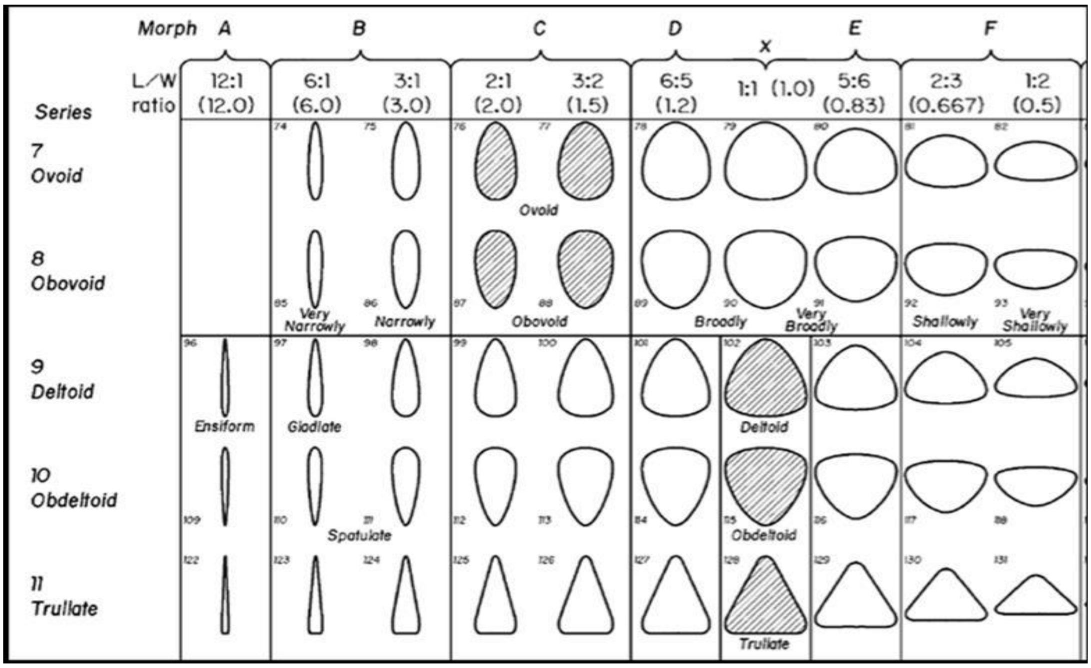

Fig. 4. Extract from the table of uniform nomenclature of plane shapes with vertical symmetry without re-entrant margins (Clopton, 2004)

3 RESULTS

3.1 MORPHOLOGICAL CHARACTERIZATION OF SCLEROCARYA BIRREA FRUITS

The analysis of the results showed that there were significant differences between the morphological descriptors of the fruits of the two (2) zones with the exception of the shape coefficient (figure 5). For all parameters, the largest values were observed in the Sahelian zone, such as 2.79cm; 2.62cm and 1.08cm respectively for the length (length_Fr), the diameter (width_Fr) and the weight (weight) of the fruit. Regarding the shape coefficient (length_Fr/weigth_Fr), no significant difference was observed (p=0.94).

The coefficient of variation remained generally low for all parameters except for weight, for which it varied from medium to quite high depending on the zones. Indeed, the coefficient of variation varied from 5 to 10 for the length, the diameter of the fruit and the shape coefficient across all zones. For the weight of the fruit, it is medium (15%) in the Sahel-Sudanian zone and quite high (18%) in the Sahel zone.

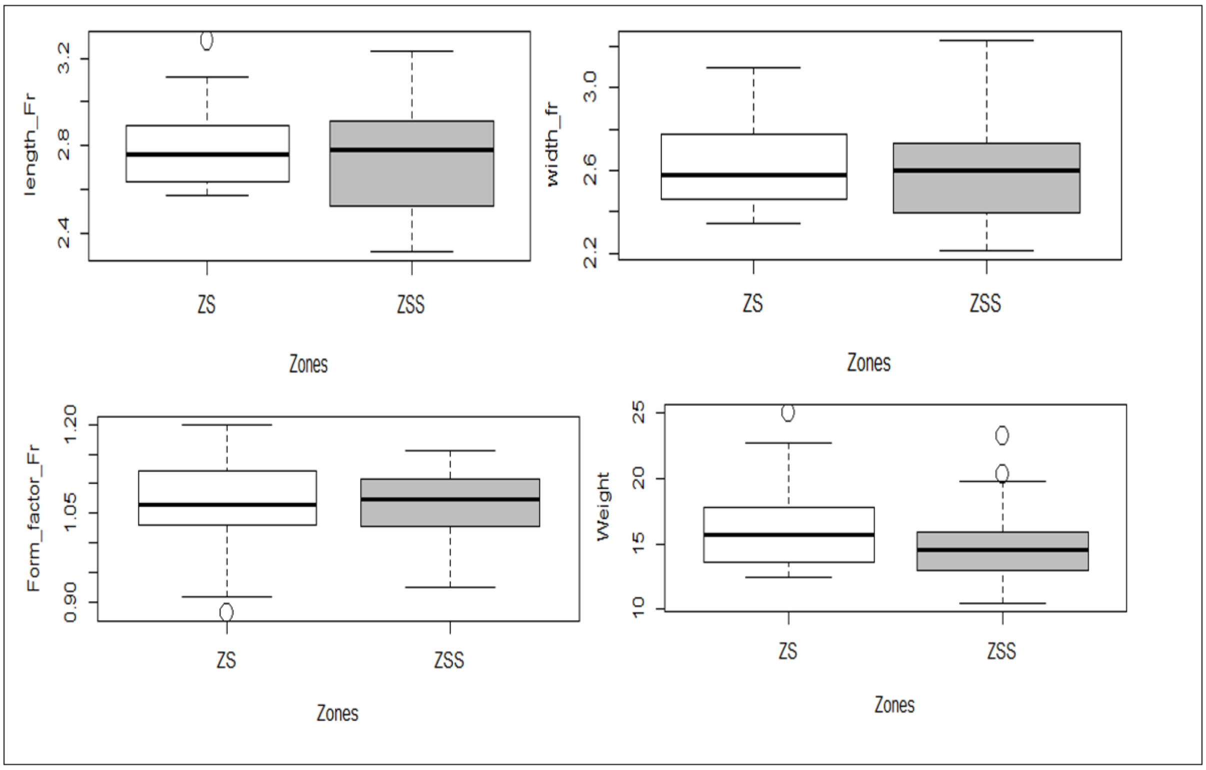

Fig. 5. Comparison of morphological characteristics of fruits according to climatic zones

Length_Fr: *fruit length;* ***width_Fr****: fruit diameter;* ***Form_factor****_Fr: fruit length/fruit diameter; weight: fruit weight; a, b: means followed by the same letter on the same line are not significantly different (Duncan method).*

Fig. 6. Variation in the size and shape of fruits in the Sahel-Sudanian zone (A) and the Sahelian zone (B)

3.2 LEAF MORPHOLOGICAL CHARACTERISTICS

The comparison of the average leaf morphological characteristics across climatic zones presented in Table 2 shows that there was no significant difference (P > 0.05) for leaf characteristics, such as leaf length, petiole length, leaflet number, and leaflet shape coefficient. However, a highly significant difference (P = 0.00) was observed for leaflet characteristics, particularly leaflet length and width. Thus, the largest leaflets are observed in the Sahel-Sudanian zone.

The coefficient of variation remained generally low to medium for all traits, with the exception of leaflet number in both zones and petiole length in the Sahelian zone, for which the coefficient of variation was quite high.

Table 1. Comparison of leaf morphological traits by climatic zone

Characters	Sahelo-soudanian zone	Coefficient of variation (%)	Zone sahelian	Coefficient de variation (%)	P-Value
Length F	15,18 (1,81)[a]	11,92	15,96 (1,92)[a]	12,03	0,07
Nber fo	14,8 (2,76)[a]	18,64	16,06 (2,6)[a]	16,18	0,09
Length P	3,18 (0,31)[a]	9,74	3,14 (0,49)[a]	15,6	0,77
Length fo	2,48 (0,24)[a]	9,67	2,19 (0,29)[b]	13,24	0,00
Width fo	1,37 (0,11)[a]	8,02	1,28 (0,14)[b]	10,93	0,00
Cf_fo	1,82 (0,21)[a]	11,53	1,71 (0,22)[a]	12,86	0,06

Long F: leaf length; Nbre fo: number of leaflets; Long P: petiole length; Long fo: leaflet length; larg fo: leaflet width; Cf_fo: leaflet length/leaflet width; a, b: means followed by the same letter on the same line are not significantly different (Duncan method).

The appearance of leaflet edges varies depending on the age of the branches. Older branches have leaflets with entire (smooth) edges, while young plants and offshoots have toothed to serrated edges.

Fig. 7. Variation of leaflet edges depending on branch age

3.3 Correlations Between Parameters

The correlation matrices between the studied traits (Tables 2 and 3) show that there were numerous and highly significant correlations between fruit and leaf traits.

Sahel-Sudanian Zone

Some important correlations among fruit and leaf traits are as follows:

- Fruit length (length_Fr) and fruit width (width_Fr), with r = 0.8
- Fruit length (length_Fr) and fruit weight (weight_Fr), with r = 0.83
- Fruit width (width_Fr) and fruit weight (weight_Fr), with r = 0.87
- Number of leaflets (Nbre fo) and leaf length (Long F), with r = 0.58
- Number of leaflets (Nbre fo) and leaflet width (larg fo), with r = -0.44
- Leaf length (Long F) and petiole length (Long P), with r = 0.52

No significant correlation was found between fruit and leaf traits.

Table 2. Correlation matrix between fruit and leaf parameters in the Sahel-Sudanese zone

	length_Fr (cm)	width_Fr (cm)	weigth_Fr (g)	Nber fo	length F (cm)	length P (cm)	length fo (cm)
width_Fr (cm)	**0,8* (000)**						
weigth_Fr (g)	**0,83** (000)**	**0,87** (000)**					
Nber fo	0,21 (0,26)	0,4 (0,02)	0,27 (0,14)				
length F (cm)	0,05 (0,78)	0,16 (0,39)	0,14 (0,44)	**0,58** (0,001)**			
lengtht P (cm)	-0,31 (0,8)	-0,12 (0,51)	-0,23 (0,21)	0,21 (0,25)	**0,52** (0,003)**		
lenght fo (cm)	0,03 (0,87)	0,03 (0,86)	0,09 (0,63)	-0,17 (0,36)	0,29 (0,11)	0,21 (0,24)	
width fo (cm)	-0,14 (0,43)	-0,11 (0,55)	-0,12 (0,52)	**-0,44*(0,01)**	-0,28 (0,12)	-0,13 (0,46)	0,29 (0,11)

length_Fr: length of the fruit; width_Fr: width of the fruit; weight_Fr: weight of the fruits; Long F: length of the leaf; Nber fo: number of leaflets; Length P: length of the petiole; Length fo: length of the leaflets; width fo: width of the leaflets

SAHELIAN ZONE

In the Sahelian zone, the following significant correlations were noted:

- Fruit length (length_Fr) and fruit diameter (width_Fr), with r = 0.46
- Fruit length (length_Fr) and fruit weight (weight_Fr), with r = 0.64
- Fruit width (width_Fr) and fruit weight (weight_Fr), with r = 0.6
- Number of leaflets (Nber fo) and leaf length (Length F), with r = 0.95
- Leaf length (Length F) and petiole length (Length P), with r = 0.49
- Petiole length (Length P) and Number of leaflets (Nber fo), with r = 0.58
- Leaf length (Length F) and Leaflet width (Length fo), with r = -0.39

No significant correlation was established between the traits fruits and those of leaves.

Table 3. correlation matrix between fruit and leaf parameters in the Sahelian zone

	length_Fr (cm)	width_Fr (cm)	weigth_Fr (g)	Nber fo	length F (cm)	length P (cm)	length fo (cm)
width_Fr (cm)	**0,46** (0,009)**						
weigth_Fr (g)	**0,64** (0,000)**	**0,60** (0,000)**					
Nber fo	0,25 (0,17)	0,02 (0,89)	0,12 (0,49)				
length F (cm)	0,27 (0,14)	0,11 (0,53)	0,18 (0,32)	**0,95** (0,000)**			
length P (cm)	0,20 (0,28)	-0,09 (0,63)	-0,01 (0,93)	**0,58** (0,001)**	**0,49** (0,006)**		
length fo (cm)	-0,08 (0,64)	-0,29 (0,11)	-0,21 (0,24)	-0,35 (0,05)	0,05 (0,78)	0,32 (0,07)	
width fo (cm)	0,13 (0,47)	-0,05 (0,77)	-0,08 (0,64)	0,09 (0,63)	**-0,39* (0,02)**	0,25 (0,17)	0,32 (0,07)

length_Fr: length of the fruit; width_Fr: width of the fruit; weight_Fr: weight of the fruits; Length F: length of the leaf; Nber fo: number of leaflets; Length P: length of the petiole; Length fo: length of the leaflets; width fo: width of the leaflets

4 DISCUSSION

The results of this study revealed varying fruit sizes of *Sclerocarya birrea* in the two (2) study areas, but no significant difference was observed in fruit shape (P-value > 0.05). Indeed, fruit size varies along the rainfall gradient (P-value < 0.001). Thus, *Sclerocarya birrea* populations from the Sahelian zone have larger fruits compared to those from the Sahelo-Sudanian zone. Although the Sahelian zone receives less rainfall than the Sahelo-Sudanian zone, fruits from this zone have the largest values (length, diameter, and weight). This is due, on the one hand, to the pruning of *Sclerocarya birrea* plants, which is widely practiced in the Sahelian zone, and, on the other hand, to the physiology of the species, which differs in these two zones. Indeed, in the Sahel-Sudanian zone, trees enter leafing very early, which means that part of the nutrients are used for fruiting and the other part for leafing. This prevents the fruits from fully benefiting from the energy available for their growth. These results are similar to those obtained by [22] who mentioned a significant variation in fruit weight in *Sclerocarya birrea*. They are also similar to those of [23] who found larger fruits in the dry zone. These results are different from those observed by [24] on *Balanites aegyptiaca* which reveals that individuals from the Sahel-Sudanian zone produce larger fruits than other less watered bioclimatic zones. According to this author, trees in the most watered zone produce more of the largest fruits linked to significant photosynthetic activities due to water availability.

The low coefficient of variation values observed for fruit descriptors (CV < 12%) across the entire study area, with the exception of weight, indicate low variability among *Sclerocarya birrea* trees for these traits. However, for weight, the average coefficient of variation values (12 < CV < 25%) obtained across the two areas explain a fairly significant variation in this parameter among individuals of the species. This variation is explained more by the genotype of individuals than by environmental conditions and, to a lesser extent, by microvariations in soil characteristics [25] and anthropogenic effects such as pruning. Indeed, within the same area, it is common to find trees with fruits of different sizes.

The ratio between the length and width of *Sclerocarya birrea* fruits, according to Clopton's (2004) classification, is between the 6: 5 and 5: 6 levels, which gives a broadly ovoid to obovoid shape of the fruit described in the literature.

Regarding the leaves, no significant difference was observed between the two zones regarding the total length of the leaf, the length of the petiole and the number of leaflets. On the other hand, a significant difference was obtained in the length and width of the leaflets. Indeed, the leaflets of the Sahelo-Sudanian zone are longer and wider than those of the Sahelian zone. Thus, they have leaves with small leaflets in the Sahelian zone and leaves with large leaflets in the Sahelo-Sudanian zone. The variation in the size of the leaflets observed between the zones is explained by environmental conditions, particularly rainfall. Moreover, the north-south gradient due to latitude, along which temperature, sunshine and edaphic conditions are subject to variations [26] induces a decrease in rainfall which is more significant in the Sahelo-Sudanian zone. In response to water deficit, plants, to limit water losses due to the transpiration process, make a morphological adjustment and invest less or no resources in leaf growth. This morphological adjustment is often manifested by a reduction in leaf surface area and biomass productivity [27]. The values of the parameters considered at the level of leaf morphology across all areas show that they constitute a criterion for differentiating individuals of the species. There is therefore for *Sclerocarya birrea* a capacity for readjustment of organs (size of leaflets) for adaptation to water deficit. The same morphological variations were observed by [28] who revealed that leaf dimensions constitute a criterion for differentiation in *Jatropha curcas* Linn. in Benin. These results are contrary to those found by [29] in *Sclerocarya birrea* and [21], for individuals of *Balanites aegyptiaca* in Chad who reported that variations in leaflet length and width were not significantly different.

The lack of a significant effect on leaf length does not necessarily imply the absence of an adaptation mechanism to water deficit. This could be explained by very low morphological variation or a certain resistance to water deficit.

The coefficient of variation values obtained for leaf morphological descriptors are low in the Sahelo-Sudanian zone, with the exception of leaflet number. However, these values are average in the Sahelian zone. This demonstrates that variations at the leaf level are greater in the Sahelian zone than in the Sahelo-Sudanian zone for the parameters considered. These variations are explained by the highly varied soil conditions at the collection sites in the Sahelian zone.

The very strong correlations observed between fruit traits and leaf traits indicate that it is possible to identify several traits that can contribute to the formation of a fruit or leaf "ideotype" by combining a number of desirable characteristics.

The lack of significant correlation between fruit and leaf parameters indicates that it is impossible to predict fruit size from leaf characteristics and vice versa. This shows that correlations between the different traits of *Sclerocarya birrea* were not well established. These findings confirmed the results of [22] which reported that it is difficult to establish clear links between the different morphological traits. For leaflet shape, the ratio between leaflet length and width is 2: 1 and 3: 2, giving a shape that varies from oblong to elliptical.

5 CONCLUSION

This study analyzed the morphology of *Sclerocarya birrea* fruits and leaves along a north-south climatic gradient. The results showed that the highest values were observed in the Sahelian zone for fruits and in the Sahelo-Sudanian zone for leaves. For other traits, namely fruit shape and leaf length, no significant differences were observed along this gradient. The values of the measured parameters show variations along the gradient, which could therefore be an expression of the species's adaptation mechanisms within the various environments it colonizes. It could therefore be said that *Sclerocarya birrea* adapts the morphology of its fruits and leaves according to its environment, which could allow it to colonize environments with different climatic characteristics. This work will allow the selection of interesting morphotypes that meet the needs of farming communities and the market. It will also contribute to improving knowledge on the morphological descriptors of *Sclerocarya birrea* and serve as a basis for domestication programs.

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