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RESEARCH ARTICLE

Morpho-stomatal variation of *Acacia* species in some parts of the Sudano-Sahelian savanna zone of Nigeria

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Abstract

Acacia is a member of the Fabaceae family, but classifying its species has proven challenging due to their extensive distribution. A study was conducted to assess the morphological differences in the leaves, thorns and inflorescence of various *Acacia* species located in the Sudano-Sahel region for accurate taxonomic identification. Eleven *Acacia* species were classified based on qualitative and quantitative morpho-stomatal traits. Generally, most species had alternate, bipinnate compound leaves with oblong pinnules. However, *A. senegal* showed obovate pinnules, *A. auriculiformis* had simple curved (sickle-like) leaves and *A. gourmanensis* featured bilobed simple leaves. Leaf textures varied from smooth (glabrous) to hairy (pubescent) and all species exhibited entire leaf margins. Inflorescence and leaf lengths were generally less than 0.9 cm, except for *A. auriculiformis* and *A. gourmanensis*, which had 13.25 cm and 1.29 cm, respectively. Leaf width and leaf area were highest in *A. auriculiformis*, with 1.00 cm and 2.73 cm^2, respectively, whereas the remaining investigated species had values lower than 1.00 cm. All flower pedicel length results were less than 0.10 cm. *A. auriculiformis* and *A. gourmaensis* had 0.07cm, while *A. nilotica* and *A. senegal* had the lowest recorded values at 0.01 cm. There was no significant variation in the trichomes and stomatal type of foliar micro-morphological features; they only differ in terms of size, which can be attributed to their adaptation. Future study on the vascular bundle and the chemical composition of the documented species is paramount.

Keywords: *Acacia;* anatomy; leaf anatomy; morphometric; Nigeria; Sudano-Sahelian savanna

Introduction

Genus *Acacia* was first formally described in 1754 by Philip Miller, based on *Acacia nilotica*, which is commonly known as the Egyptian thorn (1). The name "Acacia" is thought to derive from the Greek word Akazo, meaning "to sharpen," referring to the sharp spines found in many African and Asian species (1). It is estimated that, globally, there are over 1300 species of *Acacia* with more than 950 natives to Australia and the rest distributed across Africa, Asia and the Americas (2). Africa hosts approximately 115 species (3), while in Nigeria, 14 species and three varieties have been recorded (4).

Acacia species serve important roles across various sectors, including medicine, agriculture and cultural practices. In Nigeria, species like *A. albida, A. nilotica, A. gourmaensis, A. senegal and A. tortilis* are commonly used as animal fodder. Gums extracted from *A. nilotica, A. senegal, A. seyal and A. tortilis* have wide industrial applications, including use in pharmaceuticals, cosmetics, confectionery, inks, paints and shoe polish (4).

For decades, botanists have debated the classification of *Acacia*, arguing that the genus is overly large and not monophyletic, prompting proposals for its division based on sub -generic groupings identified by previous researchers (5). Numerous taxonomic studies have utilized morphological, anatomical, developmental and phytochemical characteristics to aid in classification (6-8). However, intrageneric classification remains contentious (9).

Morphology is simply defined as the study of external plant forms (10), has long served as a fundamental tool in taxonomy, preceding molecular and anatomical methods and remains crucial for species delimitation. While global studies on plant morphology abound (11-13) there is limited research on the morphological traits of Nigerian *Acacia* species. This study seeks to fill that gap by assessing the morphological diversity of *Acacia* species within the Sudano-Sahelian ecological zone of Nigeria, contributing to future taxonomic revisions of the genus.

Materials and Methods

Study area

The Sudano-Sahel Savannah of Northern Nigeria is located within longitude 96°01'51" E to 98°06'01" E and latitude 90°02'1N to 11° 032'1N, with a Guinea Savanna vegetation belt. Annual rainfall starts in April and ends in October. The states of the sample collection cover some parts of Bauchi, Kano, Jigawa and Sokoto, as shown in the map (Fig. 1).

Sample collection

Monthly expeditions and a floristic survey were carried out to collect the specimens. A stratified sampling technique was used in sample collection. Each savanna zone was regarded as a cluster. Two states from each cluster were selected randomly and all eleven specimens were found in those states except *A. gourmaensis* and *A. auriculiformis,* which are specific to a particular region. Fifteen samples of each of the species are collected every month. To minimize environmental confounding effects, sampling was conducted under similar conditions and only from mature, healthy trees are collected. The samples were collected for twelve months. The specimens were taken to the Herbarium of the Department of Botany, Ahmadu Bello University, Zaria, Nigeria, for authentication. Voucher numbers were assigned to each specimen after authentication, as shown in Table 1 and scientific names were confirmed from https://wfoplantlist.org/

Morphological study

A total of fifty leaf samples were collected for each *Acacia* species to assess their morphological traits, following the method outlined previously (14). Observations were made on key features such as leaf type, arrangement, shape and texture of pinnules and the nature of pinnule margins. Additionally, the length of each leaf (cm) was measured and the leaf width, leaf area, flower pedicel and length of inflorescence (cm) were measured with a vernier calliper.

Microscopic studies of leaf for stomata and trichomes

The microscopic examination of leaves was followed the protocol of former researchers (15). A small portion of the macerated leaves was stained in 1 % aqueous solution of Safranin for about 5 min. Excess stain was rinsed off and a drop of glycerin was added and observed under and a drop of glycerin was added for observation under the microscope. The leaf's surface structures, such as stomatal length and stomatal pore sizes, were determined. The stomatal numbers were counted at the abaxial and adaxial parts. Presence or absence of trichomes, type and length of trichomes of

Table 1. *Acacia* species investigated in this study

S/N	SPECIES NAME	VOUCHER NO.	FORM
1	*Acacia sieberiana* Tausch	ABU0 438	Tree
2	*Acacia sieberiana var.* sing (Guill. & Perr.) Roberty	ABU0 90248	Tree
3	*Acacia nilotica* (L.) Willd. ex Delile	ABU0 6924	Tree
4	*Acacia sayel* Delile	ABU0 8012	Tree
5	*Acacia albida* Lindl.	ABU0 877	Tree
6	*Acacia ataxacantha* DC.	ABU0907	Tree
7	*Acacia gourmaensis* A.Chev.	ABU0321	Tree
8	*Acacia macrostachya* Rchb. ex DC.	ABU04175	Shrub
9	*Acacia polyacantha* Willd	ABU0 1905	Tree
10	*Acacia auriculiformis* A.Cunn. ex Benth.	ABU0783	Tree
11	*Acacia senegal (L.)* Willd.	ABU0 332	Tree

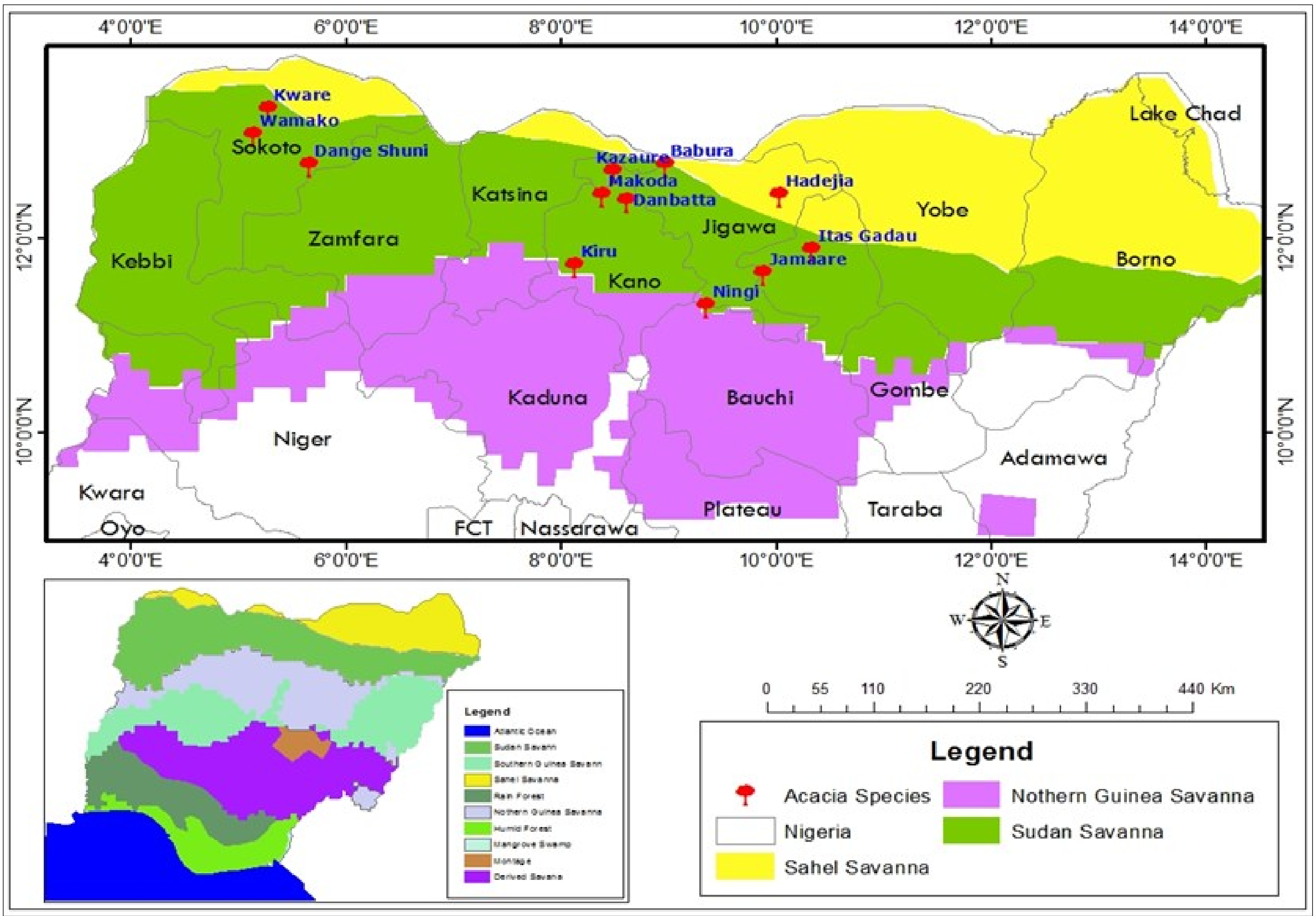

Fig. 1. A map of Sudan Sahel savannah showing the location of *Acacia* species sampled in the zone (GIS Dept.2021).

each species were determined. Photomicrographs of the specimens were made using a Digital Camera Model IXUS185.

Data analysis

The means of all the characters generated were subjected to Kruskal-Wallis ANOVA and Principal Component Analysis (PCA) was used to show the relationship between the morphological and microscopic characters and the species sampled. Duncan's multiple range tests were employed to separate the means where they were significant. For all analyses, the significance level was set at $p < 0.05$.

Results and Discussion

The results for the leaf and floral morphological features of the Eleven *Acacia* species found in the Sudano-Sahel are presented in Table 2. The result showed that among the eleven *Acacia* species, pairs of leaves were highest in *A. ataxacantha*, followed by *A. macros* and *A. sieberiana* (Fig. 2). The lowest value of this parameter was recorded in *A. auriculiformis* (Table 3). The trend in inflorescence length was different because it was highest in *A. polyantha*. However, most values for this parameter were generally less than 1.00 cm, with a few exceptions. Usually leaf length results were generally typically usually less than 0.9 cm, except for *A. auriculiformis* and *A. gourmaensis,* which had 13.25 cm and 1.29 cm, respectively. In contrast, leaf width and leaf area were highest in *A. auriculiformis*, with 1.00 cm and 2.73 cm, respectively, whereas the remaining investigated species had values lower than 1.00 cm. All the flower pedicel length results were less than 0.10 cm and *A. auriculiformis* and *A. gourmaensis* were the highest at 0.07 cm, while *A. nilotica* and *A. senegal* had the lowest recorded values at 0.01 cm. Non-parametric Kruskal-Wallis ANOVA revealed that the differences in morphological parameters between the investigated species were significant ($p<0.05$), Table 2. However, eleven collected species have bipinnate compound leaves, except *A. auriculiformis* and *A. gourmaensis*, which have simple leaves and simple bilobed leaves, respectively (Table 4). In line with this, all the leaves were arranged alternately, but the pinnules of different species, however, showed variations in their shape and texture.

The changes in morphological parameters across all the *Acacia* species were statistically significant (Table 4).

Principal Component Analysis (PCA) showing the interrelationship between the *Acacia* species and their morphological characteristics

Accal showed a strong positive correlation with Acnl and Accsn, but an inverse correlation with the flower pedicel, leaf length, leaf area and leaf width. A weak positive correlation with inflorescence length and no correlation with petiole length. The species Asvr, Accsy, Accat, Accmc and Accsb exhibited a strong positive correlation with each other. Additionally, petiole length

Table 2. Qualitative foliar characters of *Acacia* species found in Sudano-Sahel savannah

	SPECIES NAME	FOLIAR MORPHOLOGY
1	*Acacia sieberiana*	Leaves alternate, bipinnate, leaflet glabrous, oblong and entire
2	*Acacia sieberiana-varvillosa*	Leaves alternate, bipinnate, leaflet glabrous, oblong and entire
3	*Acacia nilotica*	Leaves alternate, bipinnate, leaflet glabrous, oblong and entire
4	*Acacia sayel*	Leaves alternate, bipinnate, leaflet glabrous, obovate
5	*Acacia albida*	Leaves alternate, bipinnate, leaflet linear, oblong and entire
6	*Acacia ataxacantha*	Leaves alternate, bipinnate, leaflet linear more or less glabrous and entire
7	*Acacia gourmaensis*	Leaves alternate, simple bilobed
8	*Acacia macrostachy*	Leaves alternate, bipinnate, leaflet linear, pubscent and entire
9	*Acacia polycantha*	Leaves alternate, bipinnate, leaflet linear, pubscent and entire
10	*Acacia auriculiformis*	Leaves alternate, simple, linear and oblong and entire
11	*Acacia senegal*	Leaves alternate, bipinnate, leaflet glabrous and obovate

2a. *A. sieberiana* **2b.** *A. sieberiana -varvillosa* **2c.** *A. nilotica* **2d.** *A. albida*

2e. *A. ataxacantha* **2f.** *A. gourmaensis* **2f.** *A. senegal* **2g.** *A. auriculiformis*

Fig. 2. Plates of some *Acacia* species from wild.

Table 3. Descriptive statistic mean and standard deviation in (parentheses) of the morphological parameters of the genus *Acacia*

Scientific names	PLT(cm)	IFL(cm)	LVL(cm)	LW(cm)	LA(cm²)	FLP(cm)
Acacia nilotica	12.60(3.00) N = 50.0	0.30(0.04) N = 50.0	0.45(0.05) N = 50.0	0.17(0.01) N = 50.0	0.02(0.00) N = 50.0	0.01(0.00) N = 50.0
Acacia polycantha	14.16(1.08) N = 50.0	42.82(0.90) N = 50.0	0.51(0.08) N = 50.0	0.29(0.05) N = 50.0	0.03(0.01) N = 50.0	0.05(0.00) N = 50.0
Acacia albida	12.63(0.58) N = 43.0	4.70(0.91) N = 43.0	0.30(0.00) N = 43.0	0.10(0.02) N = 43.0	0.00(0.00) N = 43.0	0.03(0.01) N = 43.0
Acacia ataxacantha	43.56(1.51) N = 50.0	5.47(0.09) N = 50.0	0.56(0.11) N = 50.0	0.10(0.00) N = 50.0	0.11(0.02) N = 50.0	0.05(0.00) N = 50.0
Acacia auriculiformis	6.47(1.79) N = 49.0	8.00(0.00) N = 49.0	13.25(0.44) N = 49.0	1.00(0.00) N = 49.0	2.73(0.59) N = 49.0	0.07(0.00) N = 49.0
acia gourmaensis	7.56(0.54) N = 50.0	0.70(0.00) N = 50.0	1.29(0.16) N = 50.0	0.81(0.09) N = 50.0	0.20(0.04) N = 50.0	0.07(0.00) N = 50.0
Acacia macros	42.74(0.94) N = 50.0	0.55(0.07) N = 50.0	0.30(0.01) N = 50.0	0.10(0.00) N = 50.0	0.01(0.00) N = 50.0	0.04(0.00) N = 50.0
Acacia sayel	27.46(1.46) N = 50.0	0.30(0.01) N = 50.0	0.87(4.06) N = 50.0	0.09(0.01) N = 50.0	0.01(0.00) N = 50.0	0.03(0.01) N = 50.0
Acacia senegal	14.36(1.08) N = 50.0	3.53(0.14) N = 50.0	0.38(0.02) N = 50.0	0.01(0.00) N = 50.0	0.10(0.10) N = 50.0	0.01(0.01) N = 50.0
Acacia sieberiana	25.25(5.40) N = 57.0	0.91(1.42) N = 57.0	0.38(0.03) N = 57.0	0.02(0.03) N = 57.0	0.00(0.00) N = 57.0	0.05(0.01) N = 57.0
Acacia sieberiana var.	30.68(0.82) N = 50.0	0.28(0.04) N = 50.0	0.16(0.02) N = 50.0	0.07(0.11) N = 50.0	0.00(0.00) N = 50.0	0.06(0.01) N = 50.0

PLT(Petiole length),IFL(Inflorescences length), LVL(Leave Length), LW(Leave Width), LA(Leave Area) FLP(Flower Pedicel)

Table 4. Variation in stomatal characteristics in upper and lower leaf of microscopic parameters of the genus *Acacia*

Scientific name	USN	LSN	LTN	UTN	TL (µm)	TN	NEC
Acacia albida	12.30(2.67) N = 50.0	13.52(1.27) N = 50.0	12.48(3.93) N = 50.0	12.44(3.91) N = 50.0	17.76(2.88) N = 50.0	2.96(0.61) N = 50.0	11.50(1.76) N = 50.0
Acacia ataxacantha	13.06(2.77) N = 51.0	13.76(1.57) N = 51.0	19.04(4.34) N = 51.0	17.22(2.72) N = 51.0	16.61(1.73) N = 51.0	2.45(0.54) N = 51.0	11.71(1.51) N = 51.0
Acacia auriculiformis	9.58(4.15) N = 50.0	4.14(2.09) N = 50.0	6.50(2.20) N = 50.0	5.76(1.81) N = 50.0	16.90(3.27) N = 50.0	2.40(0.55) N = 50.0	30.50(2.46) N = 50.0
Acacia gourmaensis	12.18(2.37) N = 50.0	13.38(2.86) N = 50.0	19.34(3.17) N = 50.0	14.86(2.77) N = 50.0	15.82(2.79) N = 50.0	2.82(0.66) N = 50.0	21.04(2.46) N = 50.0
Acacia macros	11.08(3.36) N = 50.0	14.96(3.20) N = 50.0	11.32(4.43) N = 50.0	11.62(4.62) N = 50.0	17.06(3.35) N = 50.0	1.36(0.53) N = 50.0	12.42(0.81) N = 50.0
Acacia nilotica	14.80(2.42) N = 50.0	15.42(2.04) N = 50.0	15.48(2.80) N = 50.0	15.28(2.22) N = 50.0	25.68(9.27) N = 50.0	2.06(0.68) N = 50.0	13.62(0.67) N = 50.0
Acacia polycantha	13.67(2.26) N = 51.0	10.96(3.51) N = 51.0	10.55(3.35) N = 51.0	12.25(3.78) N = 51.0	21.88(3.21) N = 51.0	2.51(0.58) N = 51.0	12.49(1.07) N = 51.0
Acacia sayel	14.10(3.33) N = 50.0	14.98(2.55) N = 50.0	15.04(3.01) N = 50.0	13.52(2.49) N = 50.0	16.22(2.24) N = 50.0	3.08(0.75) N = 50.0	16.42(1.74) N = 50.0
Acacia senegal	13.80(2.51) N = 50.0	15.02(2.58) N = 50.0	15.50(1.64) N = 50.0	19.26(3.93) N = 50.0	14.32(1.02) N = 50.0	3.00(0.00) N = 50.0	14.70(0.93) N = 50.0
Acacia sieberiana	12.83(3.78) N = 48.0	14.00(2.13) N = 48.0	13.71(2.60) N = 48.0	15.08(4.32) N = 48.0	22.42(2.09) N = 48.0	3.17(0.38) N = 48.0	12.04(1.66) N = 48.0
Acacia sieberiana var	3.92(0.88) N = 50.0	6.38(1.72) N = 50.0	10.76(2.78) N = 50.0	18.32(3.67) N = 50.0	17.24(3.55) N = 50.0	3.06(0.89) N = 50.0	14.14(1.25) N = 50.0

USN (Upper Stomata Number) LSN (Lower Stomata Number) LTN (Lower Trichome Number) UTN (Upper Trichome Number) TL (Trichome Length) TN (Trichome Number) NEC (Number of Epidermal Cell)

showed a strong positive correlation, whereas the other parameters displayed a negative correlation. Accpl had a strong positive correlation with inflorescence length and no correlation with the different parameters. In contrast, Accar had a strong positive correlation with leaf width, leaf area, leaf length and flower pedicel but a negative correlation with petiole length and inflorescence. Accgr had a weak correlation with leaf width, leaf area, leaf length and flower pedicel, but a negative correlation with petiole length and inflorescence. The first two PCA components of the *Acacia* species and their morphological variations had 71.8 % of the total variance, where the variance represented by PC1 was 53.1 % and PC2 was 18.7 % (Fig. 3).

Microscopic characteristics of the investigated species are given in the Table 5. Upper stomata number for most of the species was greater than 10. *A. sieberiana* var had the lowest Upper stomata number value of 3.92, while *A. nilotica* had the highest value of 14.80. Lower stomata number, Lower stomata and upper trichome number were lowest in *A. auriculiformis*, while most of the investigated species had values that were equal to or greater than 10. Trichome length was highest in *A. nilotica* with a value of 25.68 µm and was closely followed by *A. siebriana* and *A. polycantha* with 22.42 µm and 21.88 µm, respectively. Trichome number values mostly 3.2, with *A. sieberiana* having the most significant value of 3.17 and *A. macros* having the lowest value of 1.36. *A. auriculiformis* presented the highest Number of Epidermal cells value of 30.50, followed by *A. gourmaensis* and *A. sevel* with 21.04 and 16.42, respectively. These variations in microscopic

Table 5. Non-parametric Kruskal-Wallis ANOVA of microscopic parameters of the genus *Acacia*

Variable	N	H_statistics	p-value
USN	550	204.78	0.00
LSN	550	291.02	0.00
LTN	550	314.13	0.00
UTN	550	256.60	0.00
TL	550	217.44	0.00
TN	550	212.28	0.00
NEC	550	422.96	0.00

The changes in microscopic parameters across all the *Acacia* species are statistically significant ($p<0.05$). **Key:** USN = Upper Stomata Number, LSN = Lower Stomata Number, LTN = Lower Trichome Number, UTN = Upper Trichome Number, TL = Trichome Length, TN = Trichome Number NEC = Number of Epidermal Cell

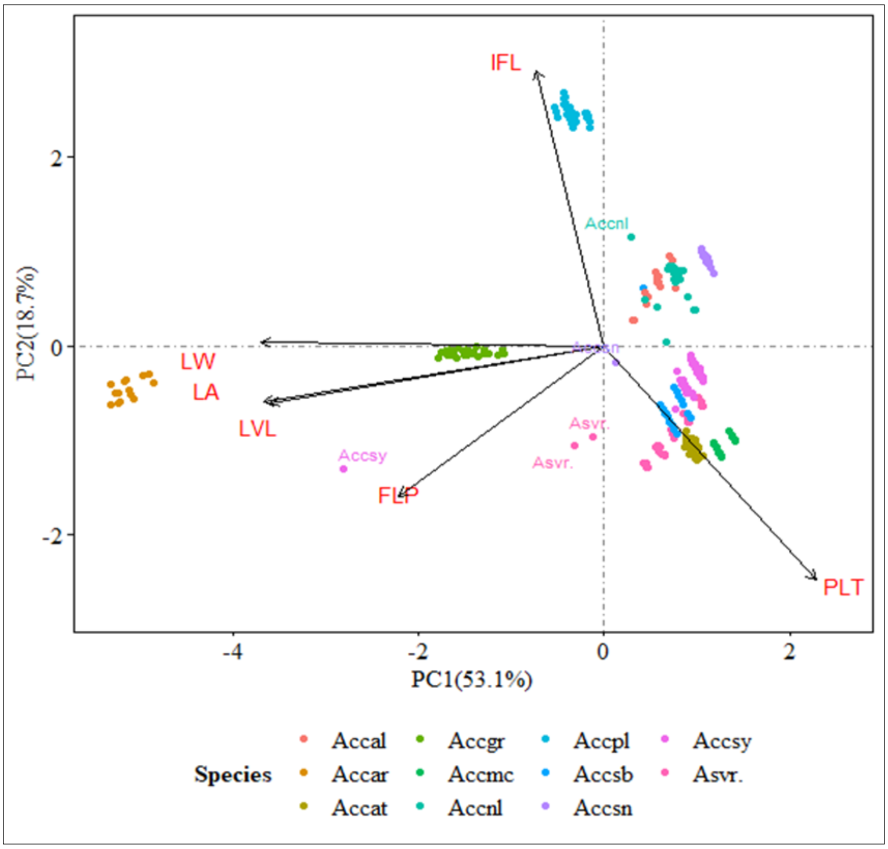

Fig. 3. PCA of microscopic traits across seven Acacia species. The PCA illustrates the relationships between species and measured variables. The PC1 (X) and PC2 (Y) explain 53.1 % and 18.7 % of the total variation in the dataset, respectively. The direction and length of the variables indicate the contribution and the influence of each of the trait PCA. Species close to each other share similar characteristics, while those positioned apart are morphologically distinct. **Key:** Accsv (*Acacia sieberiana* var.), Accal (*Acacia albida*), Accar (*Acacia auriculiformis*), Accat (*Acacia ataxacantha*), Accgr (*Acacia gourmaensis*), Accsy (*Acacia sayel*) and Accsn (*Acacia senegal*)

parameters were statistically significant with p values mostly around 0.00 (Table 5).

Relationship between microscopic characteristics and all the species

Accsv (*A. sieberiana* var.) had a weak positive correlation with upper trichome number, number of epidermal cells and trichome numbe but a negative correlation with the other microscopic parameters (Fig. 4). Accal (*Acacia albida*), Accar (*Acacia auriculiformis*), Accat (*Acacia ataxacantha*), Accgr (*Acacia gourmaensis*), Accsy (*Acacia sayel*) and Accsn (*Acacia senegal*) were strongly correlated with each other, which had a strong positive correlation with length of trichome, upper stomata number, lower stomata number, upper trichome number, Number of epidermal cell and trichome number, but a negative correlation with trichome length. Accmc (*Acacia macros*), Accnl (*Acacia nilotica*), Accpl (*Acacia polycantha*) and Accsb (*Acacia sieberiana*) had a strong relationship with each other while having a strong positive correlation with trichome length, a weak positive correlation with lower stomata number and Upper stomata number and a negative correlation with Length of trichome number (Table 6), upper trichome number, number of epidermal cells and trichome number as shown in Plates II-XXXIV (Supplementary file).

The study identified foliar morphological characters of *Acacia* species in Sudano-Sahelian zone of Nigeria which revealed that almost all the eleven species possessed compound leaves that are either bipinnate or alternate with oblong pinnules, although the pinnules of *A. senegal* were obovate. In *A. auriculiformis*, the leaves were simple and curved like a sickle, whereas in *A. gourmaensis*, they appeared as simple bilobed structures. The leaf texture among the species varied from smooth (glabrous) to hairy (pubescent). This set of common and distinct characteristics creates a complicated picture of evolution of the genus (14). These similarities may indicate a common ancestry, although the prominent contrasts between the leaf structure of some species are very strong evidence of a polyphyletic origin, i.e. that they were probably not descendants of the same ancestor. This conclusion is consistent with the findings of (16), who argued that *Acacia* species do not share a single common ancestor. The qualitative characteristics of this research are like the same characteristics described by previous researchers (17, 14), which reported specific morphological characteristics of different Acacia species. Although all species demonstrated variation in overall leaf morphology, the presence of both similarities and differences could influence the plants' productivity, a valid conclusion also supported by previous studies (18, 14). These common patterns of variation have enormous taxonomic value that can help in identification of various species of *Acacia* in the Sudano- Sahelian savanna. Similar observations regarding leaf differences were also highlighted earlier (19, 14). The use of foliar morphological characteristics for delimiting different *Acacia* species indicated the relative importance of such characters in the identification of the members of the genus *Acacia*. This conforms to the works of previous researchers (14, 20), which independently used morphological characteristics to taxonomically delimit *A. nilotica* and *A. sayel*, respectively. The difference in plant morphology may be ascribed to the ability of some plant species to grow naturally

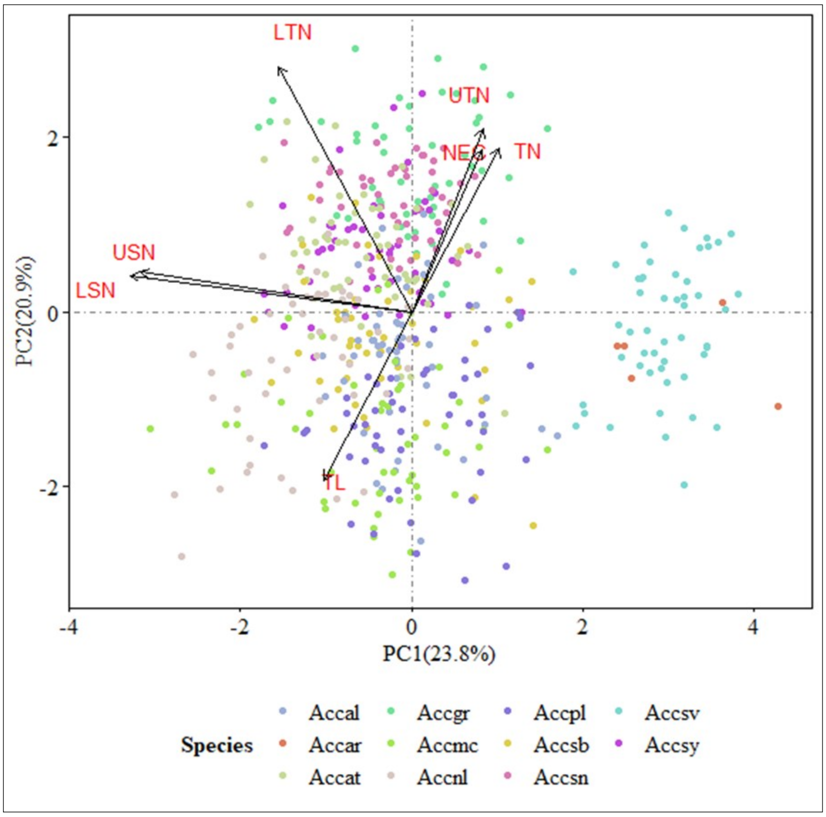

Fig. 4. PCA of microscopic traits across seven Acacia species. The PCA illustrates the relationships between species and measured variables. The PC1 (X) and PC2 (Y) explain 23.8 % and 20.9 % of the total variation in the dataset, respectively. The direction and length of the variables indicate the contribution and the influence of each of the trait PCA. Species close to each other share similar characteristics, while those positioned apart are morphologically distinct.

Key: Accsv (*Acacia sieberiana* var.), Accal (*Acacia albida*), Accar (*Acacia auriculiformis*), Accat (*Acacia ataxacantha*), Accgr (*Acacia gourmaensis*), Accsy (*Acacia sayel*) and Accsn (*Acacia senegal*)

Table 6. Trichome and stomatal type found in different *Acacia* species

S/N	SPECIES NAME	TYPES OF TRICHOME		STOMATAL COMPLEX	
		Abaxial	Adaxial	Abaxial	Adaxial
1	*Acacia sieberiana*	Glandular	Glandular	Paracytic	Anisocytic
2	*Acacia sieberiana var.*	Glandular	Glandular	Paracytic	Anisocytic Paracytic
3	*Acacia nilotica*	Glandular	Glandular	Paracytic	Anisocytic
4	*Acacia sayel*	Glandular	Glandular	Paracytic	Anisocytic
5	*Acacia albida*	Glandular	Glandular	Paracytic	Anisocytic
6	*Acacia ataxacantha*	Glandular	Glandular	Paracytic	Anisocytic
7	*Acacia gourmensis*	Glandular	Glandular	Paracytic	Anisocytic
8	*Acacia macrostachy*	Glandular	Glandular	Paracytic	Anisocytic
9	*Acacia polycantha*	Glandular	Glandular	Paracytic	Anisocytic
10	*Acacia auriculiformis*	non-Gandular	non-glandular	Paracytic	Anisocytic Paracytic
11	*Acacia senegal*	Glandular	Glandular	Paracytic	Anisocytic

in their habitat, while others are cultivated highlighting how environment influences the genetics constituents (17).

However, the study has revealed the variation patterns in the stomata of eleven *Acacia* species from the Sudan-Sahel savanna. The taxonomic relevance of epidermal morphology in taxa delimitation, recognition and establishment of affinities is well reported earlier (21). The presence of a varying number of stomata among the eleven species from the Sudano-Sahel conforms with the previous findings of previous studies (22-25). This can be attributed to the fact that essential developmental studies of leaves provide important information which has been used in the construction of artificial keys for identification purposes (19). The presence of anisocytic and paracytic stomata in the eleven *Acacia* species from the Sudano-Sahel conforms to the findings of previous studies (26) which reported such stomatal types as the most common among the various species of Fabaceae in Bangladesh. The observation of the shared presence of these stomatal types in the Acacia species being studied is indicative of an underlying similarity in the anatomy of the genus despite the additional morphological differences. This finding is like the previous report (27), which showed that paracytic and anisocytic types of stomata are found in *A. auriculiformis* and *A. sieberiana* var. This could be attributed to different leaf types and conspicuous thorns respectively possessed by these two *Acacia*. The variability in stomatal density and trichome characteristics among *Acacia* species may reflect ecological adaptations to the Sudano-Sahelian climate, like adaptations reported in Dipterocarpaceae and Lamiaceae (29, 30). The epidermal cells shape ranges from polygonal to irregularly shaped, with only *A. auriculiformis* having irregularly shaped epidermal cells on the abaxial side (27). This has proved the distant relatedness of the species to other and the presence of polygonal epidermal cells in both the remaining *Acacia* species from Sudano -Sahel Savanna indicated a close relationship between them. This is in line with the previous work (27), reported the presence of polygonal to irregularly shaped epidermal cells among different *Acacia* species in the Sudano-Sahel and suggested a close affinity.

Furthermore, other micro-morphological characteristics such as epidermal features of the studied taxa revealed some diagnostic characteristics that could be used for taxonomic decision. The presence of similar cell type (paracytic) type of stomata at the adaxial sides, polygonal epidermal cell type and trichomes in almost all the species of *Acacia* from Sudano Sahel savanna revealed some correlations among the studied taxa. This finding is also in conformity with similar foliar micro-morphological characteristics among twelve under-utilized legume species from Ogun State, Southwestern Nigeria (16). Similarly, foliar architecture and epidermal characteristics to delimit some taxa in Family Fabaceae was reported earlier (28). It is noteworthy that our findings, which show strong micro-morphological consistency within *Acacia*, differ from studies of other plant groups like Parashorea and Progostemon, where micro-morphological characters are key for telling species apart (29, 30). This variation suggests that the taxonomic influence of microscopic traits depends on each plant species, therefore must be assessed within a specific phylogenetic context.

Conclusion

The present study revealed that the differences in morphological parameters between the investigated species were significant at a 95 % significance level. The observed morphological variation can be attributed to both genetic adaptation to natural habitats and phenotypic responses under cultivation. While no significant variation was found in the trichomes and stomatal type of foliar micro-morphological features of the eleven *Acacia* species from Sudano-Sahel, the unique irregularly shaped abaxial epidermal cells of *A. auriculiformis* indicate a more distant phylogenetic relationship to the other species studied. Future study on the vascular bundle and the chemical composition of the documented species is paramount.

Authors' contributions

SN, AD and BYA performed the experimental work. AMD and AI prepared the initial draft of the manuscript. NS, AM, SWB, ABY, MMS, AAM, SWH and AMD conceptualized the study and contributed to its design and coordination. All authors read and approved the final version of the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

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References

1. Kyalangalilwa B, James SB, Barnabas HD, Olivier M, Michelle B. Phylogenetic position and revised classification of *Acacia* s.l. (Fabaceae: Mimosoideae) in Africa, including new combinations in *Vachellia* and *Senegalia*. Botanical J of the Linnean Society. 2013;172(4):500-23. https://doi.org/10.1111/boj.12047
2. Jansen C, Kumschick S. A global impact assessment of *Acacia* species introduced to South Africa. Biological Invasions. 2022;24 (1):175-87. https://doi.org/10.1007/s10530-021-02642-0
3. Marshall AR, Philip JP, Roy EG, William K, Simon K, Rob M. The genus *Acacia* (Fabaceae) in East Africa: distribution, diversity and the protected area network. Plant Ecology and Evolution. 2012;145 (3):289-301. https://doi.org/10.5091/plecevo.2012.597
4. Owolabi SM, Monday DO, Akinwumi JA, Abiodun EA. Wood anatomical features of some Nigerian species of *Acacia* Mill and their suitability for paper making. Plant Biology. 2021;11:1-7. https://doi.org/10.25081/ripb.2021.v11.6517
5. Maslin BR. Generic and subgeneric names in *Acacia* following retypification of the genus. Muelleria. 2008;26(1):7-9. https://doi.org/10.5962/p.292489
6. Jhade D, Sachin J, Ankit J, Praveen S. Pharmacognostic screening, phytochemical evaluation and *in vitro* free radical scavenging activity of *Acacia leucophloea* root. Asian Pacific J of Tropical Biomedicine. 2012;2(2):S501-5. https://doi.org/10.1016/S2221-1691(12)60261-5
7. Batiha GES, Nosheen A, Abdulrahman AA, Wafaa FA, Najla HA, Hazem MS, et al. Bioactive compounds, pharmacological actions and pharmacokinetics of genus *Acacia*. Molecules. 2022;27 (21):7340. https://doi.org/10.3390/molecules27217340
8. Alamgir ANM. Pharmacognostical botany: classification of medicinal and aromatic plants (MAPs), botanical taxonomy, morphology and anatomy of drug plants. In: Therapeutic use of medicinal plants and their extracts. Pharmacognosy. 2017;1:177-293. https://doi.org/10.1007/978-3-319-63862-1_6
9. Yagi S, Khristova P, Khalid SA. Chemotaxonomical and palynological studies on nine *Acacia* species occurring in Sudan. Journal of Plant Studies. 2012;1(2):61. https://doi.org/10.5539/jps.v1n2p61
10. Bailey J. Collins dictionary of botany. 2006: Collins.
11. Hayakawa H, Tunala YM, Katsura I, Stephen G, Jun Y, Ryo A, et al. Comparative study of leaf morphology in *Aster hispidus* Thunb. var. *leptocladus* (Makino) Okuyama (Asteraceae). American J of Plant Sciences. 2011;3(1):110-13. https://doi.org/10.4236/ajps.2012.31011
12. Díaz S, Kattge J, Cornelissen J. The global spectrum of plant form and function. Nature. 2016;529(7585):167-71. https://doi.org/10.1038/nature16489
13. Viscosi V, Cardini A. Leaf morphology, taxonomy and geometric morphometrics: a simplified protocol for beginners. PLoS One. 2011;6(10):e25630. https://doi.org/10.1371/journal.pone.0025630
14. Soladoye MO, Onakoya MA, Chukuma EC, Sonibare MA. Morphometric study of the genus *Senna* (Mill) in south-western Nigeria. African Journal of Plant Science. 2010;4(3):44-52.
15. Shaheen S, Jaffer M, Khalid S, Khan MA, Hussain K, Butt MM. Microscopic techniques used for the identification of medicinal plants: a case study of *Senna*. Microscopy Research and Technique. 2019;82(10):1660-7. https://doi.org/10.1002/jemt.23332
16. Agbolade J. Comparative study on the epidermal features of twelve under-utilized legume accessions. 2011.
17. Kamble A, Kadav S, Shinde P, Tamboli A. The qualitative and quantitative analysis of fruit of *Acacia nilotica*. Indian Journal of Integrative Medicine. 2023;3(1):14-20.
18. Abdel-Hameed UK, Magly UI, Ishaq IF, Tantawy ME. A contribution to the specification of *Caesalpinioideae* (L) based on morphological and molecular criteria. Beni-Suef University J of Basic and Applied Sciences. 2013;2(2):120-7. https://doi.org/10.1016/j.bjbas.2013.03.004
19. Sanghamitra Sanyall SS, Paria ND. Seedling morphology as a tool for taxonomic study in some members of *Leguminosae* (Fabaceae). 2015.
20. Nassar MHR, Ibrahim H. Morphological characteristics of vegetative and reproductive growth of *Senna sophera* (L.) Roxb. (Caesalpiniaceae). J of Horticulture Science & Ornamental Plants.

2012;4:299-306.

21. Miller JT, Seigler D. Evolutionary and taxonomic relationships of *Acacia* s.l. (Leguminosae: Mimosoideae). Australian Systematic Botany. 2012;25(3):217-24. https://doi.org/10.1071/SB11042

22. Tripathi S, Mondal AK. Taxonomic diversity in epidermal cells (stomata) of some selected *Anthophyta* under the order *Leguminales* (*Caesalpiniaceae*, *Mimosaceae* and *Fabaceae*) based on numerical analysis: a systematic approach. International J of Science and Nature. 2012;3(4):778-98.

23. Beck SL, Visser G, Dunlop RW, Hare DP. A comparison of direct (flow cytometry) and indirect (stomatal guard cell lengths and chloroplast numbers) techniques as a measure of ploidy in black wattle, *Acacia mearnsii* (De Wild). South African Journal of Botany. 2005;71(3-4):354-8. https://doi.org/10.1016/S0254-6299(15)30109-5

24. Otieno DO, Schmidt MWT, Adiku S, Tenhunen J. Physiological and morphological responses to water stress in two *Acacia* species from contrasting habitats. Tree Physiology. 2005;25(3):361-71. https://doi.org/10.1093/treephys/25.3.361

25. Kumar A. *Cassia occidentalis* Linn. Morphological and anatomical study. Science. 2009;2.

26. Begum A, Rahman MO, Begum M. Stomatal and trichome diversity in *Senna* Mill. from Bangladesh. Bangladesh Journal of Plant Taxonomy. 2014;21(1):43-51. https://doi.org/10.3329/bjpt.v21i1.19264

27. Ogundipe OT, Kadiri A, Adekanmbi OH. Foliar epidermal morphology of some Nigerian species of *Senna* (Caesalpiniaceae). 2009. https://doi.org/10.17485/ijst/2009/v2i10.4

28. Bouchenak-Khelladi Y, Maurin O, Hurter J, Van der Bark M. The evolutionary history and biogeography of *Mimosoideae* (Leguminosae): an emphasis on African *Acacia*s. Molecular Phylogenetics and Evolution. 2010;57(2):495-508. https://doi.org/10.1016/j.ympev.2010.07.019

29. Noraini T, Cutler D. Leaf anatomical and micromorphological characters of some Malaysian *Parashorea*. J of Tropical Forest Science. 2009;21(2):156-67.

30. Rusydi A, Talip N, Latip J, Rahman RA, Sharif I. Morphology of trichomes in *Pogostemon cablin* Benth. (Lamiaceae). Australian J of Crop Science. 2013;7(6):744-9.

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