Research Journal of Botany

ISSN 1816-4919

Academic Journals Inc.

www.academicjournals.com

Research Journal of Botany 8 (1): 1-14, 2013
ISSN 1816-4919 / DOI: 10.3923/rjb.2013.1.14

The Value of Leaf Epidermal Characters in Diagnosing Some Nigerian Species of *Ficus* L. (Moraceae)

A.T.J. Ogunkunle
Environmental Biology Unit, Department of Pure and Applied Biology, Ladoke Akintola University of Technology, P.M.B. 4000, Ogbomoso, Nigeria

ABSTRACT

This study presents data on 41 leaf epidermal features in 17 Nigerian species of *Ficus* L. (representing 3 out of the 4 subgenera and 4 out of the 7 sections identified in Africa). It examines the taxonomic significance of these features in the genus, presents a diagnostic key to the species and a synoptic key (which reflects the earlier infrageneric classifications) that is usable for recognizing the representative species of each of the higher infrageneric categories as a separate entity. The concept of botanical diagnosis is viewed beyond its conventional usage (i.e., as identification) to include classification (which shares a narrow line of divide with identification) and plant prospecting (the practice of establishing the utility potential of a plant in reference to those plant raw material resources of its kind). The significance of the characters employed in this study is discussed alongside the three-dimensional view of botanical diagnosis of the Nigerian *Ficus*, with the conclusion that they are of notable diagnostic value in the genus and potentially so in the other genera within the family Moraceae.

Key words: Artificial key, *Ficus*, leaf epidermis, natural key, plant identification taxonomic key

INTRODUCTION

Forty-one species of *Ficus* L. have been identified in Nigeria (Keay, 1989), some of which are potentially useful in the food, chemical, drug and wood-based industries (Ogunkunle, 2006; Ogunkunle and Oladele, 2008a).There is the need to bring these species into focus for closer taxonomic evaluation with a view to realizing their full potentials. Out of the four principal activities in plant taxonomy (i.e., naming, identification, classification and description), identification has been acknowledged as particularly important because the correct name of a plant is the key to its literature i.e., identification enables us to retrieve, utilize, communicate and accumulate information about any plant of interest.

Among the non-reproductive organs in plants, leaves are the most widely used in taxonomy (Stace, 1965, 1984). Keay (1989) has however observed that the leaf shape in the genus *Ficus* is very variable, even in the same tree and warned that leaf morphological characters should be used with caution to identify the species. As a result of this, efforts have recently been made to examine the systematics of the genus from the points of view of fruit and leaf morphology (Sonibare *et al*., 2004) and leaf anatomy (Sonibare *et al*., 2006). Moreover, Ogunkunle and Oladele (2008b) have elucidated 42 leaf epidermal features in 20 Nigerian species of the genus as a contribution of data for subsequent diagnostic and taxonomic studies in the genus. Variations in the leaf epidermal characters have been experimentally shown to be gene-dependent as they are only slightly influenced by environmental conditions (Cutler and Brandham, 1977; Barthlott, 1981; Oladele,

1983; Adegbite, 1995). Their proven genetic stability and high structural diversity have been the basis for their use in identification and classification of many groups (Gill and Nyawaume, 1990; Egbedo, 1990, 1991; Oladele, 1991; Nwokeocha,1996; Ogunkunle and Oladele, 2000; Abubakar and Yunusa, 1998; Ayodele and Gbadebo, 2000; Ogundipe and Ayodele, 2000; Pant and Verma, 1974).

In systematic botany, diagnosis is usually defined strictly as the process of identifying a plant i.e., of determining its correct name in relation to an already established system of identification (Sharma, 1993). Also, a distinction is often drawn between identification and classification, the latter being the placement of plants into groups or categories according to artificial criteria, phenetic similarities or phylogenetic relationships (Radford,1986). One of the aims of classification is to establish a suitable method of identification (Sharma, 1993) and among the purposes of plant identification are for their classification, description and utilization. Therefore, botanical diagnosis can assume a wider dimension to mean determining the name and properties of a plant, placing it in its right position in a classification scheme and establishing its potential among those plant raw material resources of its kind (Ogunkunle, 2006). This three-dimansional view of botanical diagnosis has been upheld in defining the goal of this study.

Taxonomists frequently identify plants by making use of taxonomic keys, two categories of which have been listed namely, diagnostic or artificial keys and synoptic or natural keys. In a diagnostic key there is a limit of choice of plant characteristics to those considered to be most reliable, convenient and available under certain conditions, the arrangement being solely for the convenience of identification (Pankhurst, 1991). This is opposed to a synoptic key, which is characterized by many features of the plants that may not be easily observable and whose main thrust is to reflect as close as possible, the scientific classification of the plants (Pankhurst, 1991). The aim of this study is to examine the taxonomic implications of the epidermal features among the species of *Ficus* with a view to providing diagnostic and synoptic keys to the infrageneric categories and taxa in the genus. The results of this study can have the prospect in contributing information towards future taxonomic revisions of *Ficus* and in establishing the utility potentials of members of the genus in Nigeria.

MATERIALS AND METHODS

Plant materials: Fresh and/or dried leaf specimens of 17 Nigerian species of *Ficus* were collected on which qualitative and quantitative leaf epidermal data were drawn for this study (Table 1). The collection represented 3 out of the 4 subgenera and 4 out of the 7 sections of the genus identified in Africa (Weiblen, 2000). Details of voucher information, data collection and character definition are contained in Ogunkunle (2006) and Ogunkunle and Oladele (2008b).

Definition of characters: In addition to the familiar characters of leaf epidermis commonly used for taxonomic purposes (Pant and Verma, 1974; Wilkinson, 1979; Sharma, 1993; Pandey, 2004) three other leaf epidermal features were specially defined in this study on account of their observed variations among the species studied. These characters formed part of the 42 that were described by Ogunkunle and Oladele (2008b), 41 of which were used in this study (Table 2-5). The three specially defined characters are as follows:

Table 1: Infrageneric classification of the Nigerian species of *Ficus* studied according to Berg (1989)[a]

Species	Subgenus	Section	Subsection
F. exasperata Vahl.	*Ficus*	*Sycidium*	NA
F. capreifolia Del.	*Ficus*	*Sycidium*	NA
F. asperifolia Miq.	*Ficus*	*Sycidium*	NA
F. mucuso Welw ex Ficalho	*Sycomorus*	*Sycomorus*	NA
F. sur Forssk.	*Sycomorus*	*Sycomorus*	NA
F. vallis-choudae Del.	*Sycomorus*	*Sycomorus*	NA
F. ovata Vahl.	*Urostigma*	*Galoglychia*	*Caucolarpae*
F. umbellata Vahl.	*Urostigma*	*Galoglychia*	*Caucolarpae*
F. ottonifolia (Miq.) Miq.	*Urostigma*	*Galoglychia*	*Caucolarpae*
F. polita Vahl.	*Urostigma*	*Galoglychia*	*Caulocarpae*
F. thonningii Blume	*Urostigma*	*Galoglychia*	*Chlamydorae*
F. natalensis Hochst	*Urostigma*	*Galoglychia*	*Chlamydorae*
F. leprieuri (Miq.) C.C. Berg	*Urostigma*	*Galoglychia*	*Chlamydorae*
F. lutea Vahl- Fl. Cam.	*Urostigma*	*Galoglychia*	*Galoglychia*
F. Sagittifolia Warb.ex Mildbr. and Burret	*Urostigma*	*Galoglychia*	*Cyathistipulae*
F. elasticoides De Wild	*Urostigma*	*Galoglychia*	*Crassicostae*
F. ingens (Miq.) Miq.	*Urostigma*	*Urostigma*	NA

NA: Not applicable, [a]Ogunkunle and Oladele (2008b)

- **Units of veins:** The geometric-shaped surface impressions of the veinlets formed by repeated branching of the main vein from the mid rib. Each unit, which is variable in shape (square, rectangle, triangle or polygon), bounds a variable number of stomata in the different species studied
- **Basal cells of glands:** In-between the veins on the leaf surfaces of the species studied, two modes of attachment of glands were defined namely, the attachment to unmodified basal cells of the epidermis and attachment to variable number of radially- elongated cells. Two types of the latter were observed. In Type I, the radial walls of the basal cells do not extend right into the centre but curve backwards, leaving a somewhat circle or star-shaped base on which the gland is seated (Fig. 1a, c). In Type II basal cells, the radial walls extend to meet at a central point on which the gland is seated (Fig. 1b)
- **Multicellular bases of prickle-like hairs:** Each of the prickle-like or sharp-pointing stiff hairs observed in some of the species studied was characteristically attached to the leaf surface by one or more concentric series of tiny cells, which altogether appear much like a gland in surface view and with variable diameters (Fig. 2a-c)

Screening and selection of diagnostic characters: From the 41 leaf epidermal (i.e., 14 qualitative and 27 quantitative) features, the means of all the quantitative characters where applicable, were statistically compared by subjecting their replicated values to one-way ANOVA and thereafter, Duncan's multiple range tests using the 11.0 version of the computer-based SPSS. Those characters whose means showed significant differences from these discriminant analyses at $p = 0.05$ were regarded as being diagnostic among the species and were used to define homogeneous groups within the genus (Table 3, 4). These and the qualitative features that showed discontinuous variations were used to construct leaf epidermal-based diagnostic and synoptic keys for identification of the infrageneric categories of *Ficus* studied.

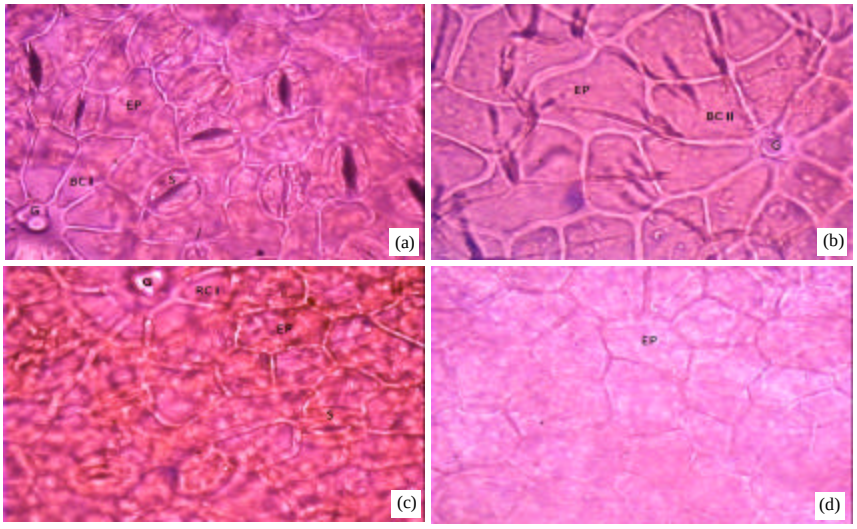

Fig. 1(a-d): Morphology and arrangement of cells on the leaf blades of two Nigerian species of *Ficus*. (a, b) abaxial and adaxial surfaces respectively of *F. thonningii* (600X) and (c, d) Abaxial and adaxial surfaces respectively of *F. polita* (600X), EP: Epidermal cell, G: Gland, BC I: Type I radial basal cells of gland, BC II: Type II radial basal cells of gland, S: Stoma

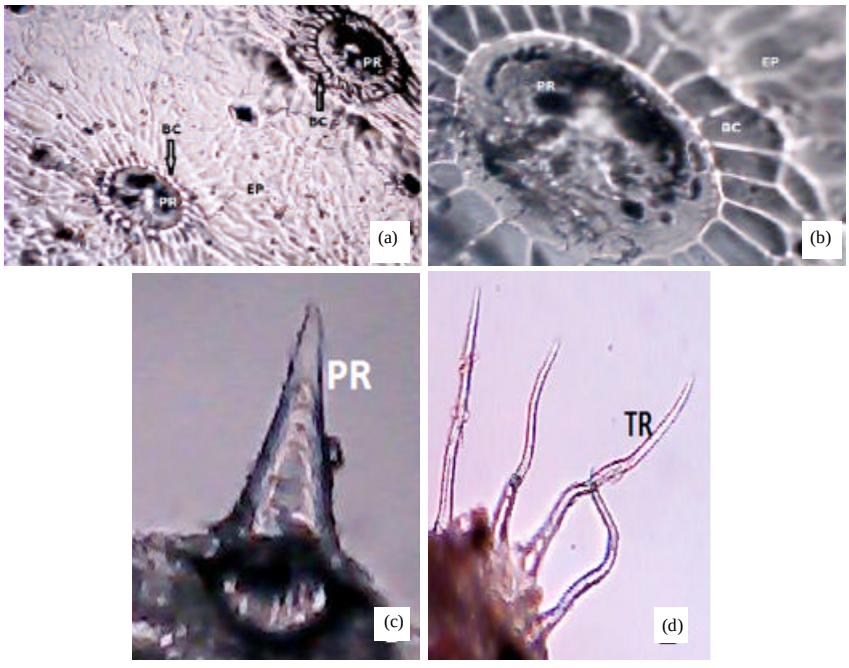

Fig. 2(a-d): Morphology and attachment of some trichomes found on the leaf blades of *Ficus* exasperata, (a) Adaxial surface showing prickle-like (stiff, sharp-pointing) hairs in surface view (100X), (b) Surface view of a prickle-like hair at higher magnification (400X), (c) Side view of prickle-like hair (100X) and (d) Morphology of unicellular non-glandular hairs (100X), EP: Epidermal cell, BC: Basal cells of gland, TR: Trichome

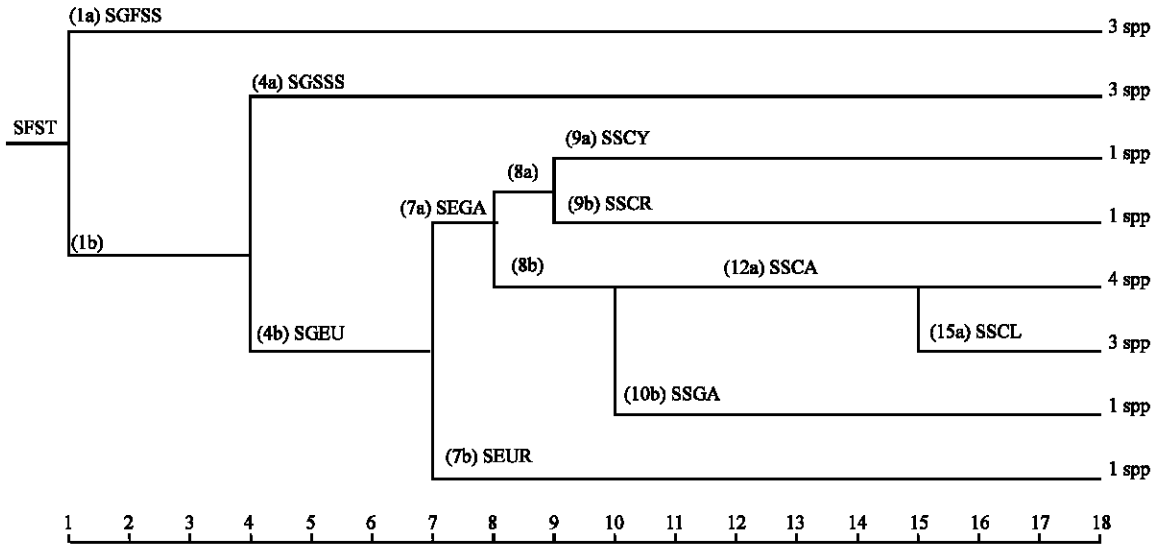

Fig. 3: A tree-like diagram showing leaf epidermis-based phenetic relationships among some infrageneric groups of Nigerian *Ficus*. Items in parentheses show the leads in the respective couplets distinguishing plant groups. SFST, species of Ficus studied; SGFSS, subgenus *Ficus* section Sycidium; SGSSS, subgenus *Sycomorus* section *Sycomorus*; SGEU, subgenus *Urostigma*; SEGA, section Galoglychia; SEUR, section Urostigma; SSCY, subsection Cyathistipulae; SSCR, subsection Crassicostae; SSGA, subsection Galoglychia; SSCL, subsection Chlamydorae; spp, species

RESULTS AND DISCUSSION

The results of this study are shown in Table 2-7 and Fig. 1-3. A careful look through the qualitative and quantitative characters obtained from the 17 species of *Ficus* (Table 3-5; Fig. 1, 2) shows that many of the features are diagnostic of the individual species investigated in the genus (Table 1, 6). Table 6 is therefore an artificial key (Pankhurst, 1991) to these Nigerian species of *Ficus*. It is confirmatory of the reliability of leaf epidermal features in the diagnostic studies of angiosperms (Dean and Ashton, 2008) and establishes the taxonomic applicability of these characters in the genus.

Some of the features observed are also useful in distinguishing the 3 subgenera, the 4 sections and the 5 subsections of *Ficus* investigated as taxonomic entities (Table 2-5, 7). In Table 7, leads 1a and b separate the three representative species of subgenus *Ficus* section *Sycidium* as an entity from the other two subgenera, while leads 4a and b establish that these two subgenera (namely, subgenus *Sycomorus*, section *Sycomorus* and subgenus *Urostigma*) are different groups. Moreover, couplet number 7 distinguishes between the two sections of subgenus *Urostigma* (i.e., sections *Galoglychia* and *Urostigma*) while the five subsections of the section *Galoglychia* are separated into distinct groups at various levels with leads 9a, 9b, 10b,12a and 15a (Table 7). If one serially transforms the successive leads establishing these phenetic relationships (Table 7) into 'stems' and 'branches', one obtains a tree-like diagram (Fig. 3) which is a quasi- representative of the phylogeny in the genus. The three subgeneric groupings according to Berg (1989) correspond to the three main stems in Fig. 3 clearly compartmentalized by leads 1a, 4a and 4b.

Table 2: Some qualitative features of the leaf epidermis in some Nigerian species of *Ficus*

Species	STV	SEP	PAW	LST	TLN	LTG	SSS	BCG
F.exasperata	AD-	Tab	Straight	-	Prk (Inv and Vein)	-	-	-
	AB Squ; Rec; Tri*	Tab	Straight;	Inv	Sim (Inv);	Clb (Vein)	-	-
			Wavy		Prk (Inv and Vein*)			
F.capreifolia	AD-	Iso*; Tab	Straight	-	Prk (Inv and Vein)	-	-	-
	AB Squ; Rec; Poly	Iso	Straight	Inv; Vein	Prk (Inv and Vein)	-		-
F. asperifolia	AD-	Iso; Tab*	Straight;	-	Prk (Inv and Vein)			
	AB Squ; Rec **	Irregular	Curved	Inv; Vein	Sim (Inv); Prk	-	-	-
	Poly *		Straight; Wavy		(Inv and Vein)	-		
F. mucuso	AD-	Iso	Straight;	-	-	-	-	-
	AB Squ; Rec	Iso	Curved Curved	Inv	-	Blb (Inv and Vein*)	Circular (Uni)	Radial (Type I)
F. sur	AD-	Iso	Straight	-	-	-	-	-
	AB Squ; Rec; Tri*	Irregular	Wavy	Inv; Vein *	-	Blb (Inv and Vein)	Circular (Uni)	Radial (Type I)
F. vallis-	AD -	Iso	Straight	-	-	Flk (Inv and Vein)	-	Radial (Type I)
choudæ	AB Squ; Poly*	Tab	Curved	Inv	-	Flk (Inv and Vein)	-	
F. ovata	AD-	Iso; Tab	Straight	-	-	Sca; Clb (Inv andVein)	Circular (Uni)	Radial (Type I)
	AB Squ; Rec*	Irregular	Slightly curved	Inv	-	Sca;Clb(Inv andVein*)	Circular (Uni)	Radial (Type I)
F. umbellata	AD-AB Squ; Rec	Iso; Tab	Straight	-	-	Sca (Inv)Sca(Inv*);	Circular (Uni)	Radial (Type I)
		Tab	Slightly curved	Inv	-	Clb (Vein)	Circular (Uni)	Radial (Type I)
F. ottonifolia	AD-	Iso; Tab	Straight	-	-	Sca (Inv and Vein)	Circular (Uni)	Unmd; Radial (Type II*)
	AB Squ; Rec*	Tab	Curved	Inv; Vein*	-	Blb (Inv andVein*); Clb (Inv*)	Circular (Uni) and oval	Radial (Type I)
F. Polita	AD- AB- Squ*	Iso	Straight	-	-	Blb (Inv)	Circular (Uni)	Unmd*, Radial (Type I)
	Rec; Pen*	Iso; Tab	Slightly curved	Inv	-	Blb (Inv and Vein*); Clb (Vein*)	Circular (Uni)	Radial (Type I)
F. natalensis	AD-	Iso	Slightly	-	-	Sca (Inv)	Oval (Uni)	Radia (Type I)
	AB Squ; Rec* Tri*	Irregular	curved Wavy	Inv; Vein*	-	Sca (Vein)	Oval (Multi)	-
F. thonningii	AD-	Iso; Tab	Curved	-	-	Sca (Inv and Vein*)	Circu/Oblong (Uni)	Unmd; Radial (TypeI)
	AB Squ*; Rec	Iso; Tab	Slightly curved	Inv; Vein	-	Clb (Inv and Vein*)	-	Unmd; Radial (TypeI)
F. leprieuri	AD-	Iso*; Tab	Straight	-	-	Blb (Inv)	Circular (Uni)	Unmd; Radial (Type I)
	AB Squ*; Rec; Poly	Iso*; Tab	Curved	Inv	-	Clb (Inv)	-	Unmd; Radial (Type I)
F. lutea	AD-	Iso; Tab	Straight	-	-	Blb (Inv)	Circular (Uni)	Radial (Type II)
	AB Squ; Rec*; Tri*	Iso; Tab	Curved	Inv; Vein	-	-	-	-
F. sagittifolia	AD-	Iso; Tab**	Straight	-	-	-	-	-
	AB Squ*; Rec	Iso; Tab*	Straight	Inv				
F. elasticoides	AD-	Iso;Squ*,Tab		Straight	-	-	-	- -
	AB NA	Iso;	Straight	Inv; Vein	-	-	-	-
F. ingens	AD-	Tab	Straight	-	-	-	-	-
	AB Squ; Tri*	Tab; Iso*	Slightly curved	Inv	-	Blb (Inv)	Circular (Uni)	Radial (Type I)

STV: shape of terminal units of veins i.e., the geometric-shaped boundaries of groups of stomata formed by repeated branching of the main vein, SEP: Shape of epidermal cell, PAW: Pattern of anticlinal walls of epidermal cells, LST: Location of stomata on abaxial leaf surface, TLN: Types and locations of non-glandular trichomes, LTG: Locations and types of glands, SSS: Surface shape of scales or other sessile glands, BCG basal cells of glands in -between the veins (In type I, the radial walls of the basal cells do not extend right into the centre but they curve backwards or outwards leaving a somewhat circular or star-shaped base for the gland; In type II, the radial walls extend to meet at a point), AD: Adaxial leaf surfac, AB: Abaxial leaf surface, Squ square: Rec rectangle, Tri: Triangle, Pen: Pentagon, Poly: Polygonal, Iso: Isodiametric, Tab: Tabular, Inv: in-between veins, Vein: On the veins, Sca: Scales, Blb bulbous; Clb club-shaped; Uni unicellular; Multi multicellular; Prk prickle-like hairs; Sim simple hairs; Flk flask-shaped hairs; NA not applicable (due to the parallel arrangement of the veins)

Table 3: Mean epidermal cell and stomatal dimensions on the leaf blades of some Nigerian species of *Ficus*[1]

	Epidermal cells		Stomatal dimensions					
Species	Mean No. of sides	Density/mm^2	Length (µm)	Breath (µm)	GCA (µm^2)	Density/unit of veins	Density (mm^2)	Index
F. exasperata	AD 6 or 7*	446^c	-	-	-	-	-	-
	AB 5 or 6	398^a	16.13^a	11.52^a	146.15^a	131^b	177^c	30.67^b
F. capreifolia	AD 5,6 or 7	173^a	-	-	-	-	-	-
	AB 5,6 or 7*	391^a	18.43^a	13.34^a	193.93^a	83^a	108^b	21.69^b
F. asperifolia	AD 5*, 6 or 7*	300^b	-	-	-	-	-	-
	AB 5 or 6	365^a	19.97^a	14.08^a	222.32^a	87^a	203^d	35.76^b
F. mucuso	AD 5 or 6	267^b	-	-	-	-	-	-
	AB 5 or 6	332^a	20.99^a	14.85^a	244.44^a	95^a	119^b	26.39^b
F. sur	AD 6	390^b	-	-	-	-	-	-
	AB 4*, 5 or 6	265^a	18.43^a	9.73^a	142.55^a	168^b	265e	34.65^b
F. vallis-choudae	AD 5,6 or 7*	386^b	-	-	-	-	-	-
	AB 4, 5 or 6	394^a	16.89^a	12.54^a	166.74^a	30^a	98^b	19.93^b
F. ovata	AD 4*, 5, 6 or 7	478^c	-	-	-	-	-	-
	AB 4* 5 or 6	369^a	25.09^b	18.18^a	361.26^a	89^a	200^d	35.06^b
F. umbellata	AD 5*, 6, 7* or 8*	685^d	-	-	-	-	-	-
	AB 5* 6 or 7*	294^a	30.21^c	19.97^a	472.54^b	23^a	87^b	23.27^b
F. ottonifolia	AD 5, 6* or 7	269^b	-	-	-	-	-	-
	AB 5* or 6	291^a	25.09^b	20.48^a	404.49^a	64^a	119^b	28.79^b
F. polita	AD 6 or 7*	497^c	-	-	-	-	-	-
	AB 5* or 6	367^a	23.80^b	17.66^a	330.38^a	54^a	92^b	20.55^b
F. natalensis	AD 5* or 6	459^c	-	-	-	-	-	-
	AB 5, 6 or 7	314^a	26.88^b	18.69^a	393.74^a	150^b	120^b	28.12^b
F. thonningii	AD 4*,5,6 or 7*	213^a	-	-	-	-	-	-
	AB 4*, 5, 6 or 7*	314^a	23.81^b	16.13^a	301.57^a	112^b	92^b	22.67^b
F. leprieuri	AD 5, 6, 7, 8*	343^b	-	-	-	-	-	-
	AB 4*, 5, 6, 7*	315^a	25.60^b	18.69^a	377.21^a	-	76^b	19.37^b
F. lutea	AD 5 or 6	218^a	-	-	-	-	-	-
	AB 5* or 6	543^b	26.11^b	19.71^a	394.19^a	69^a	205^d	27.45^b
F. sagittifolia	AD 5*, 6, 7 or 8*	545^c	-	-	-	-	-	-
	AB 4*, 5 6, 7 or 8*	290^a	18.94^a	15.62^a	233.64^a	220^e	231e	43.47^c
F. elasticoides	AD 3, 4 , 5 ,6, 7*	572	-	-	-	-	-	-
	AB 5 or 6	354^a	34.56^d	27.39^b	746.19^c	-	36^a	9.11^a
F. ingens	AD 6 or 7*	221^a	-	-	-	-	-	-
	AB 5* or 6	790^c	19.97^a	11.01^a	173.94^a	75^a	210^d	21.14^b

[1]AD: Adaxial leaf surface, AB: Abaxial leaf surface. In each column, the means for AD or AB with the same superscript are not significantly different at $p \geq 0.05$, while the means for AD or AB with different superscripts are significantly different at $p < 0.05$, *Not frequent

From the foregoing, the linked-dichotomous key in Table 7, as it were, is functionally 'artificial' and 'natural'. In the first place, it is usable as a diagnostic key (Table 6), solely for identifying the species investigated (Pankhurst, 1991) and secondly, it has corroborated the morphology-based infrageneric classification of the genus according to Berg (1989). As such it can be applied in diagnosing higher infrageneric taxa in the genus as separate entities. That Table 7 is a synoptic or natural key is strengthened by the fact that its construction was based on data requiring specialized tools, techniques and environments other than the field to obtain. Figure 3 should not

Table 4: Mean and ranges of trichome dimensions on the leaf blades of some Nigerian species of *Ficus*

Species	Length of simple hair (SH) µm	Height of stiff hair (ST) µm	Non-glandular trichomes (SH and/or ST)		Club-shaped glands (CG)*		Diameter of sessile glands (SG)*	Glandular trichomes (CG and/or SG)		
			Density/mm^2	Index	Height (µm)	Stalk length (µm)		No. of basal cells	Density/mm^2	Index
F. exasperata	AD 332.80	143.59^b	10^a	2.09^a	-	-	-	-	-	-
	AB -	185.54^c	66^a	14.19^a	47.12^a	23.25^a	-	-	24^b	5.73^b
F. capreifolia	AD -	25.33^a	40^c	18.73^b	-	-	-	-	-	-
	AB -	21.50^a	61^a	13.54^a	-	-	-	-	-	-
F. asperifolia	AD -	51.72^a	28^b	8.62^a	-	-	-	-	-	-
	AB 247.81	139.26^b	58^a	13.79^a	-	-	-	-	-	-
F. mucuso	AD -	-	-	-	-	-	-	-	-	-
	AB -	-	-	-	-	-	21.76^a	8-12	20^a	5.59^b
F. sur	AD -	-	-	-	-	-	-	-	-	-
	AB -	-	-	-	-	-	12.29^a	8-13	31^c	10.56^c
F. vallis-choudae	AD -	-	-	-	-	-	-	11-14	4^a	1.13^a
	AB -	-	-	-	-	-	-	11-16	26^b	6.23^b
F. ovata	AD -	-	-	-	73.73	12.03^a	62.21^b	5-8	11^a	2.33^b
	AB -	-	-	-	80.38^b	17.41^a	71.68^c	6-9	7^a	1.78^a
F. umbellata	AD -	-	-	-	-	-	16.44^a	6-8	7^a	0.99^a
	AB -	-	-	-	54.27^a	23.81^a	67.07^c	7-10	13^a	4.34^b
F. ottonifolia	AD -	-	-	-	-	-	79.87^c	4-8	17^b	5.91^d
	AB -	-	-	-	45.82^a	18.69^a	15.62^a	10-14	17^a	5.47^b
F. polita	AD -	-	-	-	-	-	52.74^a	5-7	24^c	4.56^c
	AB -	-	-	-	59.39^a	19.46^a	58.37^b	7 or 8	5^a	1.41^a
F. natalensis	AD -	-	-	-	-	-	50.18^a	6-9	21^c	4.44^c
	AB -	-	-	-	-	-	56.32^b	-	16^a	4.94^b
F. thonningii	AD -	-	-	-	-	-	88.58^d	5 or 6	6^a	2.91^b
	AB -	-	-	-	52.35^a	28.37^a	-	5-7	4^a	1.05^a
F. leprieuri	AD -	-	-	-	-	-	14.34^a	5-7	8^a	2.28^b
	AB -	-	-	-	50.94^a	21.25^a	-	6-9	20^a	6.11^b
F. lutea	AD -	-	-	-	-	-	53.76^a	5 or 6	8^a	3.62^b
	AB -	-	-	-	-	-	-	-	-	-
F. sagittifolia	AD -	-	-	-	-	-	-	-	-	-
	AB -	-	-	-	-	-	-	-	-	-
Elasticoides	AD -	-	-	-	-	-	-	-	-	-
	AB -	-	-	-	-	-	-	-	-	-
F. ingens	AD -	-	-	-	-	-	-	-	-	-
	AB -		-	-	-	-	9.75^a	9-13	12^a	1.57^a

AD: Adaxial leaf surface, AB: Abaxial leaf surface. In each column, the means for AD or AB with the same superscript are not significantly different ($p \geq 0.05$),while the means for AD or AB with different superscripts are significantly different ($p<0.05$), *Usually stalked with distinct head, sometimes without stalk, **Include scales and bulbous glands on leaf surfaces

Table 5: Percent frequencies of the stomatal complex types in some Nigerian species of *Ficus*

	Frequency of stomatal complex types (%)*					
Species	Anisocytic (Three)	Poly (Four)	Poly (Five)	Poly (Six)	Poly (Seven)	Poly (Eight)
F. exasperata	-	-	61.0	31.0	8.0	-
F. capreifolia	-	50.4	50.6	-	-	-
F. asperifolia	-	14.3	64.3	21.4	-	-
F. mucuso	-	36.8	63.2	-	-	-
F. sur	11.0	30.0	59.0	-	-	-
F. vallis- choudae	-	-	-	40.0	46.7	13.3
F. ovata	-	49.0	42.0	9.0	-	-
F. umbellata	-	29.0	54.0	17.0	-	-
F. ottonifolia	-	12.0	65.0	24.0	-	-
F. polita	-	36.8	63.2	-	-	-
F. natalensis	-	6.5	41.9	29.0	22.6	-
F. thonningii	-	37.0	56.0	7.0	-	-
F. leprieuri	-	-	15.0	60.0	25.0	-
F. lutea	8.0	36.0	51.0	5.0	-	-
F. sagittifolia	18.8	62.5	18.8	-	-	-
F. elasticoides	-	70.0	30.0	-	-	-
F. ingens	-	30.8	61.5	7.7	-	-

Poly: Polycytic stomatal complex, *No. of subsidiary cells is shown in parentheses

Table 6: A diagnostic key to the Nigerian species of *Ficus* studied

1a: Club-shaped glands, found on abaxial leaf surface……2

2a: Club-shaped glands also found on adaxial leaf surface, abaxial epidermal cells irregular in shape; the anticlinal walls being slightly curved or way; sessile glands found on abaxial surface in-between and on the veins……*F. ovata*

2b: Club-shaped glands, absent on adaxial leaf surface……3

3a: Mean number of stomata per unit of veins, relatively small, usually not above 65 and can be as small as 20; unicellular sessile glands on abaxial surface……4

4a: Mean number of epidermal cells mm^{-2} on adaxial surface, 500 or more; sessile glands and stomata are located only in -between the veins (and not on the veins)……5

5a: Stomatal complexes, of three types namely, the polycytic complexes with 4, 5 and 6 subsidiary cells; mean density of glandular trichomes, lower on the adaxial than abaxial surface……*F. umbellata.*

5b: Stomatal complexes, of two types i.e. polycytic with 4 and with 5 subsidiary cells; density of glandular trichomes, higher on the adaxial than the abaxial surface……*F. polita.*

4b: Mean number of epidermal cells mm^{-2} on adaxial surface, about 270; sessile glands and stomata , located on the veins and in-between the veins……*F. ottonifolia.*

3b: Mean number of stomata per unit of veins relatively high, usually not below 100, sometimes much more, otherwise the surface impressions of veins on the epidermis would not be drawn into geometric units (i.e., the veins appear more or less parallel); unicellular sessile glands, absent on abaxial surface……6

6a: Sharp-pointing stiff hairs present on both surfaces of the leaves; simple unicellular trichomes present on abaxial surface, club-shaped glands on abaxial surface, restricted to the coastal areas of the leaf ……*F. exasperata*

6b: Sharp-pointing stiff hairs and simple uniseriate trichomes, absent on both surfaces of the leaves; club-shaped glands founds on both the costal and intercostal areas……7

7a: Abaxial epidermal cell walls, slightly-curved; sessile glands on adaxial surface, circular or oblong scales distributed on the costal and intercostal areas; few (about 4) per mm^2 of leaf area, with mean diameter of about 90 μm……*F. thonningii.*

7b: Abaxial epidermal cell walls, conspicuously-curved; sessile glands on adaxial surface are all, the bulbous type (not scales), all circular in shape and restricted to the intercostal areas, relatively high in number (about 20) per mm^2 of leaf area with mean diameter of about 15 μm…… *F. leprieuri.*

1b: Club-shaped glands, not found on abaxial leaf surface……8

Table 6: Continue

8a:	Surface impressions of veins on abaxial epidermis, drawn into units i.e. variable geometric shapes i.e. squares, rectangles etc; veins never parallel to one another, mean number of stomata mm^{-2}, rarely below 100; stomatal index, never below 20 ……..9
9a:	Sharp-pointing stiff hairs, found on leaf surfaces……10
10a:	Stomatal complexes of two types found on abaxial leaf surface namely polycytic with 4 and with 5 subsidiary cells, abaxial epidermal cells, isodiametric in shape with straight anticlinal walls; simple uniseriate trichomes, absent on leaf surfaces ……*F. capreifolia.*
10b:	Stomatal complexes of 3 types found on abaxial leaf surface namely, polycytic with 4, with 5 and with 6 subsidiary cells; abaxial epidermal cells, irregular in shape with slightly-wavy anticlinal walls; simple uniseriate hairs found on leaf surfaces …… ……*F. asperifolia.*
9b:	Sharp-pointing stiff hairs, not found on leaf surfaces……11
8b:	Surface impressions of veins on abaxial epidermis, parallel to one- another i.e., not drawn into units of geometric shapes such as squares, rectangles etc, mean number of stomata mm^{-2}, relatively low (typically less than 40), mean stomatal index less than 10……*F. elasticoides.*
11a:	Leaf abaxial epidermal cells, irregular in shape, anticlinal walls, wavy……12
12a:	Sessile glands, present on adaxial leaf surface, oval in shape, unicellular and restricted to intercostals areas; sessile glands, also found on abaxial surface with mean diameter being about 60 μm and density of about 16 mm^{-2} …… ……*F. natalensis*
12b:	Sessile glands, absent on adaxial but present on abaxial surface; mean diameter of glands, about 13 μm and relatively high density of 31 mm^{-2}……*F. sur*
11b:	Leaf abaxial epidermal cells, usually isodiametric or tabular in shape; anticlinal walls, straight, slightly-curved or curved ……..13
13a:	Stomata, found on both intercostal and costal areas of abaxial leaf surface; mean length of stomata, over 26 μm; mean breadth, about 20 μm……*F. Lutea.*
13b:	Stomata, found only on the intercostal areas of abaxial leaf surface; mean length of stomata, hardly above 20 μm, never above 21 μm; mean breadth, about 15 μm……14.
14a:	Mean number of stomata mm^{-2}, hardly up to 120, sometimes below 100 mm^{-2} of leaf surface; mean number of glands/mm^2 on abaxial surface, high, never below 20 and can be as high as 31 mm^{-2}……..15
15a:	Stomatal complexes, usually the polycytic with 5 subsidiary cells, sometimes with 4 subsidiary cells, circle-shaped glands, found on the abaxial leaf surface……*F. mucuso*
15b:	Stomatal complexes, usually the polycytic with 6 or with 7 subsidiary cells, sometimes with 8 subsidiary cells, circle-shaped glands, absent; flask- shaped glands found on both leaf surfaces……*F. vallis-choudae*
14b:	Mean number of stomata mm^{-2}, high, never below 210 mm^{-2} and can be above 230; glands, if present, of low density (about 10 mm^{-2}), mean number of stomata per unit of veins, about 30……16
16a:	Mean density of epidermal cells, relatively low (220 mm^{-2}) on the adaxial, but high (790 mm^{-2}) on the abaxial surface; sessile glands, found on both leaf surfaces……*F. ingens*
16b:	Mean density of epidermal cells, high (550 mm^{-2}) on the adaxial, but low on the abaxial surface (about 290 mm^{-2}); sessile glands, absent on the leaf surfaces…… *F. sagittifolia.*

Table 7: A synoptic key to the Nigerian species of *Ficus* studied

1a:	Prickle-like (i.e., sharp- pointing, stiff) hairs, present on both adaxial and abaxial leaf Surfaces……subgenus *Ficus*, section Sycidium……2
2a:	Simple uniseriate hairs, present on abaxial leaf surface; abaxial epidermal cell walls, with straight and wavy patterns intermixed; mean number of epidermal cells on adaxial surface, 300 mm^{-2} and above; mean height of stiff hairs on abaxial surface, 100μm and above; mean density of non- glandular trichomes, less than 30 mm^{-2} of adaxial surface …… ……..3
3a:	Abaxial epidermal cells, tabular in shape with mean density of about 450 mm^{-2} of leaf surface; club-shaped glands, present on abaxial surface; mean stomatal density/unit of veins, about 130; stomatal complex types, polycytic with 5, with 6 and with 7 subsidiary cells on abaxial surface; mean height of stiff hairs on adaxial and abaxial surfaces, 144 μm and 185 μm, respectively; mean density of non- glandular trichomes on adaxial surface, about 10 mm^{-2}……*F. exasperata*

Table 7: Continue

3b: Abaxial epidermal cells, irregular in shape with mean density of about 300 mm^{-2} of leaf surface; club-shaped glands, absent on abaxial surface; mean stomatal density/unit of veins, less than 90; stomatal complex types, polycytic with 4, with 5 and with 6 subsidiary cells on abaxial surface; mean height of stiff hairs on adaxial and abaxial surfaces, about 52 μm and 140 μm, respectively; mean density of non-glandular trichomes on adaxial surface, about 28 mm^{-2}……*F. asperifolia*

2b: Simple uniseriable hairs, absent on abaxial leaf surface; abaxial epidermal cell walls, with straight patterns only; mean number of epidermal cells on adaxial surface, about 170 mm^{-2}, mean height of stiff hairs on abaxial surface, 20 μm, mean density of non-glandular trichomes, about 40 mm^{-2} on adaxial surface……*F. capreifolia*

1b: Prickle-like (i.e., sharp-pointing, stiff) hairs, absent on both adaxial and abaxial leaf surfaces ……4

4a: Adaxial epidermal cells, all isodiametric in shape……..subgenus *Sycomonus*, section Sycomonus ……5

5a: Bulbous glands, unicellular and circular, found in-between and on the veins of abaxial surface; polycytic stomatal complexes with 4 and with 5 subsidiary cells, found on abaxial surface, those with 6, with 7 and with 8 subsidiary cells being absent ……6

6a: Abaxial epidermal cells, isodiametric in shape, with curved anticlinal walls; stomata, located in-between the veins only; stomatal complex types, only those with 4 and with 5 subsidiary cells found; mean stomatal density/unit of veins, less than 100 ……*F. mucuso*

6b: Abaxial epidermal cells, irregular in shape with wavy anticlinal walls; stomata, located in-between and on the veins; anisocytic stomatal complexes (i.e., with subsidiary cells), found along with those of 4 and 5 subsidiary cells; mean stomatal density/unit of veins, about 168……*F. sur*

5b: Bulbous glands, absent, instead, flask-shaped glands are present in -between and on the veins of abaxial surface; polycytic stomatal complexes with 6, with 7 and with 8 subsidiary cells, found on abaxial surface; those with 3, 4 and with 5 subsidiary cells, absent……*F. vallis-choudae.*

4b: Adaxial epidermal cells of variable shapes intermixed, including isodiametric, tabular, square and irregular……..subgenus *Urostigma*……7

7a: Epidermal cell density on abaxial surface, rarely above 500 mm^{-2}, adaxial epidermal cells, frequently isodiametric and tabular and sometimes irregular in shape…… ……...section Urostigma……..8

8a: Stomata complexes with 4 subsidiary cells, very frequent on abaxial surface (60-70% of all the types of stomatal complex types); adaxial leaf surface, glabrous with absence of any glands……..9

9a: Surface impressions of veins on abaxial epidermis, drawn into units i.e., variable geometric shapes such as square, rectangle etc; veins, never parallel to one another; stomata, found only in -between the veins; mean stomatal density, about 230 mm^{-2}; mean stomatal length and breadth, about 19 μm and 16 μm, respectively; stomatal complex type with 3 subsidiary cells (i.e., anisocytic), found on abaxial surface along with other types……*F. sagittifolia* (subsection Cyathistipulae)

9b: Surface impressions of veins on abaxial epidermis, more or less parallel to one another i.e., not drawn into units of geometric shapes such as square, rectangle etc.; stomata, found in- between and on the veins; mean stomatal density, about 36 mm^{-2}; mean stomatal length and breadth, about 35 μm and 27 μm, respectively; stomata with 3 subsidiary cells (i.e., anisocytic), absent on abaxial surface.. ... *F. elasticoides* (subsection Crassicostae).

8b: Stomata complexes with 4 subsidiary cells, either not frequent on abaxial surface (usually less than 40% of all the stomatal complex types) or absent; adaxial leaf surface, with scales or bulbous glands ……10

10a: Abaxial surface, with one or more types of glands (scales, bulbous, club-shaped); mean epidermal cell density on abaxial surface, 543 mm^{-2}; stomatal complex with 3 subsidiary cells (anisocytic), not found along with other types on abaxial surface ……11

11a: Unicellular scales with circular shape or other sessile glands (unicellular and circular), found on abaxial surface; mean stomatal density per unit of veins, less than 90……12

12a: Glandular trichomes on abaxial surface, of two types namely, the scales and the club-shaped glands; basal cells of glands in -between the veins on the adaxial surface, one type (i.e. radial type I); mean density of glands on adaxial surface, 11 mm^{-2}, proportion of stomatal complexes with 5 subsidiary cells, rarely above 50%.....subsection Caulocapae.....13

13a: Mean diameter of sessile glands on adaxial surface, about 62 μm; mean height of club-shaped glands on abaxial surface, 80 μm ……..*F. ovata*

Table 7: Continue

13b: Mean diameter of sessile glands on adaxial surface, about 16 μm; mean height of club-shaped glands on abaxial surface, about 54 μm……..*F. umbellata*

12b: Glands on abaxial surface, two types i.e., the bulbous and the club-shaped glands; basal cells of glands in -between the veins on adaxial surface, two types i.e., the unmodified type and radial type (I or II); mean density of glands on adaxial surface, 17-24 mm^{-2}, proportion of stomatal complexes with 5 subsidiary cells, up to 60% or more……14

14a: Scale, present in -between and on the veins of adaxial surface; radial basal cells of glands in -between the veins on adaxial surface, two types, the unmodified and radial type II; mean adaxial epidermal cell density, about 270 mm^{-2}, mean density of glandular trichomes, 17 mm^{-2}; diameter of sessile glands on adaxial surface, about 80 μm; stomatal complex with 6 subsidiary cells, found on leaf surface; number of radial basal cells of glands on abaxial surface, 10 to 14……*F. ottonifolia*

14b: Scales, absent, bulbous glands, present in –between the veins on adaxial surface; radial basal cells of glands in- between the veins on adaxial surface, two types, the unmodified and radial type I; mean adaxial epidermal cells density, about 500/mm^2; mean density of glandular trichomes, 24/mm^2; diameter of sessile glands on adaxial surface, about 53 μm, stomatal complexes with 6 subsidiary cells, absent on leaf surface, number of radial basal cells of glands on abaxial surface, 7 to 8…..*F. polita*

11b. Unicellular scales with circle-shape and other sessile glands, absent on abaxial surface; mean stomatal density per unit of veins, where applicable, ranges between 112 and 150……15

15a. Club-shaped glands, found on abaxial leaf surface; abaxial epidermal cells, isodiametric or tabular in shape; scales or other sessile glands, all unicellular and circle- shape on adaxial surface, mean adaxial epidermal cell density, about 340/mm^2, mean number of glands per mm^2 on adaxial surface, about 8……. ……..subsection Clamydorae……16

16a Stomatal complex types with 4 subsidiary cells, found, constituting about 37%, those with 5 subsidiary cells constitute about 56% while those with 6 subsidiary cells constitute about 7%; adaxial epidermal cell walls, curved……*F. thonningii* 16b. Stomatal complex type with 4 subsidiary cells, absent on leaf surface, those with 5 subsidiary cells constitute about 15%; those with 6 constitute about 60%, and those with 7 subsidiary cells, 25%; adaxial epidermal cell walls, straight……*F. leprieuri*

15b: Club-shaped glands, absent; scales, found on adaxial surface, abaxial epidermal cells, irregular- shaped, scales or other sessile glands, all unicellular; some, circular; others, oblong in shape on adaxial surface, mean adaxial epidermal cell density, up to 460/mm^2; mean number of glands on adaxial surface, up to 20/mm^2.*F. natalensis* 10b. Abaxial surface, devoid of any type of glands; abaxial epidermal cell mean density, below 400/mm^2; stomatal complexes with 3 subsidiary cell (i.e. anisocytic), found along with other types on abaxial surface……*F. lutea* (subsection Galoglychia).

7b Epidermal cell density on abaxial surface, relatively high (about 800/mm^2) , adaxial epidermal cells, tabular in shape……*F. ingens* (section Urostigma).

be interpreted to depict relationships by descent in the genus since neither these results nor those of Berg (1989) was a product of phylogenetic studies. It does however, along with Table 6 and 7, establishes that leaf epidermal characters are diagnostic of *Ficus* species, that they are of notable value in circumscribing taxa within the genus and potentially useful for taxonomic investigations of other genera in the family Moraceae.

REFERENCES

Abubakar, B.Y. and A.I Yunusa, 1998. Epidermal structure and stomatal ontogeny of some species of *Acacia* (Leguminosae-Mimosoidieae) from Nigeria. Nig. J. Bot., 11: 117-123.

Adegbite, A.E., 1995. Leaf epidermal studies in three Nigerian species of aspilia (Heliantheae-Asteraceae) and two hybrids. Nig. J. Bot., 8: 25-33.

Ayodele, A.E. and J.O. Gbadebo, 2000. Foliar epidermal characteristics and preliminary phytochemistry of *Ixora coccinia* Linn and *Ixora parviflora* Vahl. Biosci. Res. Commun., 11: 73-79.

Barthlott, W., 1981. Epidermal and seed surface characters of plants: Systematic applicability and some evolutionary aspects. Nordic J. Bot., 1: 345-354.

Berg, C.C., 1989. Classification and distribution of *Ficus*. Cellular Mol. Life Sci., 45: 605-611.

Cutler, D.F. and P.E. Brandham, 1977. Experimental evidence for the genetic control of leaf surface characters in hybrid Aloineae (Liliaceae). Kew Bull., 32: 23-42.

Dean, M. and P.A. Ashton, 2008. Leaf surfaces as a taxonomic tool: The case of *Carex* section *Phacocystis* (Cyperaceae) in the British Isles. Plant Syst. Evol., 273: 97-105.

Egbedo, F.O., 1990. Taxonomic value of epidermal characters in three genera: *Trichoscypha*, *Sorindeia* and *Lannea* (Anacardiaceae) in Nigeria. Bio. Res. Commun., 2: 67-79.

Egbedo, F.O., 1991. Epidermal morphology of some members of the tribes Mangiferae, Spondieae and Rhoideae (Anacardiaceae) in Nigeria. Bisosci. Res. Commun., 3: 191-199.

Gill, L.S. and H.G.K. Nyawaume, 1990. Phylogenetic and systematic value of stomata in bicarpellatae. Feddes Repertorium, 101: 453-498.

Keay, R.W.J., 1989. Trees of Nigeria. 2nd Edn., Oxford Science Publication, New York, ISBN: 0-19-854560-6, pp: 476.

Nwokeocha, C.C., 1996. Foliar epidermal studies in *Oryza punctata*. Nig. J. Bot., 9: 49-58.

Ogundipe, O.T. and A. Ayodele, 2000. Foliar epidermal characters in the genus *Brachystegia* Benth. Biosci. Res. Commun., 12: 89-95.

Ogunkunle, A.T.J. and F.A. Oladele, 2000. Diagnostic value of trichomes in some Nigerian species of *Ocimum* L., *Hyptis* Jacq. and *Tinnea* Kotschy and Peyr. (Lamiaceae). J. Applied Sci., 3: 1163-1180.

Ogunkunle, A.T.J. and F.A. Oladele, 2008a. Structural dimensions and paper making potentials of wood in some Nigerian species of *Ficus* L. (Moraceae). Adv. Natl. Applied Sci., 2: 103-111.

Ogunkunle, A.T.J. and F.A. Oladele, 2008b. Leaf epidermal studies in some Nigerian species of *Ficus* L. (Moraceae). Plant Syst. Evolution, 274: 209-221.

Ogunkunle, A.T.J., 2006. The diagnostic value of leaf epidermis and wood structure in some Nigerian species of *Ficus* L. Ph.D. Thesis, Department of Plant Biology, University of Ilorin, Ilorin, Nigeria.

Oladele, F.A., 1983. Patterns of cuticular sculpture in the hybrid *Cypressocyparis leylandii* (Jackson and Dallimore) Dallimore and its putative parents. New Phytol., 94: 293-295.

Oladele, F.A., 1991. Foliar fibres and trichomes in *Vitellaria paradoxa*. Biosci. Res. Commun., 3: 227-230.

Pandey, B.P., 2004. Plant Anatomy: Including Embryology and Morphogenesis of Angiosperms. 6th Edn., S. Chand and Co., Ram Nagar, New Delhi.

Pankhurst, R.J., 1991. Practical Taxonomic Computing. Cambridge University Press, Cambridge, UK., ISBN-13: 9780521417600, Pages: 214.

Pant, D.D. and B.K. Verma, 1974. Taxonomy of the genus *Ephedra*. Significance of stem and leaf epidermis and cuticle. Bot. J. Linn. Soc., 69: 287-308.

Radford, A.E., 1986. Fundamentals of Plant Systematics. Harper and Row, New York.

Sharma, O.P., 1993. Plant Taxonomy. Tata McGraw-Hill Education, New Delhi, India, ISBN-13: 9780074603734, Pages: 482.

Sonibare, M.A., A.A. Jayeola and A. Egunyomi, 2004. A morphometric analysis of the genus *Ficus* Linn. (Moraceae). Afr. J. Biotechnol., 3: 229-235.

Sonibare, M.A., A.A. Jayeola and A. Egunyomi, 2006. The taxonomy of species of *Ficus* Linn. of subgenus *Urostigma* (sections Urostigma and Galoglychia) in Nigeria. Sci. Focus, 11: 31-37.

Stace, C.A., 1965. Cuticular studies as an aid to plant taxonomy. Bull. Br. Museum Bot., 4: 3-78.

Stace, C.A., 1984. Plant Taxonomy and Biosystematics. University Park Press, Baltimore.

Weiblen, G.D., 2000. Phylogenetic relationships of functionally dioecious *Ficus* (Moraceae) based on ribosomal DNA sequences and morphology. Am. J. Bot., 87: 1342-1357.

Wilkinson, H.P., 1979. The Plant Surface (Mainly Leaf). In: Anatomy of the Dicotyledons, Metcalf, C.R and L. Chalk (Eds.), 2nd Ed. Vol. I, Oxford Press, Oxford.