FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 8 No. 2, April, 2024, pp 79 - 86
DOI: https://doi.org/10.33003/fjs-2024-0802-2209

LEAF ANATOMICAL ADAPTATIONS OF FOURTEEN TREE SPECIES GROWING IN LAGOS STATE UNIVERSITY, OJO CAMPUS. LAGOS, NIGERIA

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ABSTRACT

Plants growing in different locations exhibit various anatomical adaptations which make them survive in their various habitats. Therefore, this study examined the leaf anatomical adaptations of fourteen tree species namely *Acacia auriculiformis, Albizia lebbeck, Anacardium occidentale, Azadirachta indica, Carica papaya, Delonix regia, Gmelina arborea, Lagestroemia speciosa, Mangifera indica, Polyalthia longifolia, Tectona grandis, Terminalia catappa, Terminalia ivoriensis* and *Yucca gigantea* growing in Lagos State University, Ojo Campus.. The leaf epidermal layers were isolated using nail polish; and were observed under the light microscope to determine the stomata features, epidermal cell and trichome types. The results showed that all the species were hypostomatic, with the exception of *Acacia auriculiformis* and *Terminalia ivorensis* that were amphistomatic. Eight stomatal complex types such as anomotetracytic, staurocytic, anisosytic, brachyparacytic, paracytic, pericytic, brachyparatetracytic and anomocytic were observed among the species. The stomatal density ranged from 46.05 mm^{-2} 342.11 mm^{-2} on both leaf surfaces. The stomatal index ranged from 16.17% - 91.23% on both leaf surfaces. Trichomes were found in *Albizia lebbeck*, *Delonix regia*, *Gmelina arborea*, *Polyalthia longifolia*, *Tectona grandis* and *Terminali aivorensis.* The anticlinal cell wall patterns observed were round, curved, wavy and straight; while the epidermal cell shapes were irregular, isodiametric and polygonal. This study revealed that leaf anatomical adaptations such as amphistomatic leaf type, presence of stomatal complex types (anomocytic, anomotetracytic, brachyparatetracytic, staurocytic and anisocytic) with many subsidiary cells; high stomatal density and index; absence of trichomes; and wavy anticlinal cell wall pattern might be responsible for survival of the species in their locations.

Keywords: Leaf epidermis, Stomatal features, Leaf adaptations, Trichomes, Epidermal cells

INTRODUCTION

Plants growing in various habitats show various anatomical adaptations that allow them to thrive in a particular environment (Metcalfe and Chalk, 1988; Oyeleke *et al*., 2004; Omolokun and Oladele, 2010). Leaf anatomy is highly responsive to climatic conditions. However, studies on the leaf epidermis revealed that there are variations in the distribution, size, shape, type and frequency of stomata, trichomes, and epidermal cells (Ogunkunle and Oladele, 2008; Gostin, 2009; Omolokun *et al*., 2023).

Plants that have adapted to specific climatic conditions must have exhibited some leaf anatomical features to cope with the environment (Nawazish *et al*., 2006). The leaves of trees have a number of adaptive features such as size, number, location, and chlorophyll content of chloroplasts; size, number and structure of stomata; thickness of epicuticular wax and cuticle; leaf stiffness and strength; and the size, number and spacing of veins (Ogunkunle *et al*., 2013; Amulya*et al*., 2015). However, some of the studied tree species such as *Mangifera indica* and *Anacardium occidentale* have been reported to be economically useful to the inhabitants of Dutse (Lawal *et al*., 2018).

Plant strategies for coping with adverse conditions are usually characterized by morphological, eco-physiological and reproductive adaptations (Kleyer *et al*., 2008). In Nigeria, little information is available on the adaptive leaf anatomical features responsible for the survival of plant species in wet regions.

Therefore, the aim of this study was to elucidate leaf anatomical traits that might be responsible for the survival and continued existence of some tree species growing in Lagos State University, Ojo campus.

MATERIALS AND METHODS

Collection and Identification of Plant Specimens

Fresh matured leaf samples were collected in February, 2023from the lower canopy portion of the tree specimens located at the Lagos State University, Ojo campus. The identification of the plant species was authenticated at the Lagos State University Herbarium.

Sampling and Isolation of Leaf Epidermal Layers

Three matured leaves of each specimen were collected randomly taken from the sample areas for anatomical study.The leaf sections of an area of 1cm square from each species were cut from identical regions of the leaf samples, typically from the mid-way between the apex and base of the leaf lamina including the margin. The isolation of the leaf epidermal layers was carried out using the nail polish method. It was done by rubbing transparent nail polish on the abaxial and adaxial surfaces of each leaf. The nail polish was allowed to dry. After drying, a short clear cellophane tape was tightly affixed over the dried nail polish on the leaf surfaces. The tape was carefully peeled from the leaf and attached to a clean slide for microscopic study (Alege and Shaibu, 2015).

Microscopic Observation

The observation was carried out on a binocular light microscope at a magnification of (x40 objective) to determine the leaf nature, stomatal complex type, stomatal density, stomatal index, anticlinal cell wall pattern and epidermal cell shape. Sample size of 30 was used for each of the parameters.Photomicrographs of good preparations were taken using binocular light microscope fitted with Amscope Camera (Model MU 1000).

Identification of Stomatal Complex Type
The identification of the stomatal types was carried out according to Dilcher (1974) and Metcalfe and Chalk (1988).

Determination of Stomatal Density
The mean stomatal density was determined as the number of stomata per square millimetre based on the entire leaf surface. That is, the number of stomata in 0.152mm^2 field of view (Holland and Richardson, 2009).

Determination of Stomatal Index
The mean stomatal index was determined as the number of stomata per square millimetre divided by the number of stomata plus the number of ordinary epidermal cells per square millimetre multiplied by 100. It was expressed mathematically according to Hussin *et al*. (2000) using the formula below:
SI = S/E + S x 100
Where:
SI = stomatal index; S = number of stomata per square millimetre.
E = number of ordinary epidermal cells per square millimetres.

Identification of Epidermal Cell Shape, Anticlinal Wall Pattern and Trichome Type
The epidermal cell shape, anticlinal cell wall pattern and trichome types were identified according Dilcher (1974) and Metcalfe and Chalk (1988).

Statistical Analysis
The data collected were analyzed using Statistical Packages for Social Sciences (SPSS) version 20.0 software. Means were calculated using one way analysis of variance. The means with significant difference were separated using Duncan's Multiple Range Test (DMRT) at P<0.05.

RESULTS AND DISCUSSION
Leaf Anatomical Study
The leaf epidermis (i.e. stomata features, epidermal cell and trichome features) were examined on fourteen (14) plant species from the studied site (Table 1). The stomata features consist of the stomata complex types and their frequency, stomata density and stomata index; the epidermal cell comprises of the epidermal cell shape and anticlinal cell wall pattern; while the trichome features is made up of trichome type (Plates 1-2; Tables 2 - 4). The leaf epidermal structures are shown in Plates 1 and 2; the stomata features are shown in Table 2; while the epidermal cell and trichome features are shown in Tables 3 and 4.

Table 1: Information on Studied Plant Species

S/N	Plant Species	Common Name	Family	Location
1.	*Acacia auriculiformis* A. Cunn. Ex Benth.	Earleaf	Fabaceae	LASU, Ojo Campus
2.	*Albizia lebbeck* (L.) Benth.	Siris	Fabaceae	LASU, Ojo Campus
3.	*Anarcadium occidentale* L.	Cashew	Anarcadaceae	LASU, Ojo Campus
4.	*Azadirachta indica* A. Juss.	neem tree, dogoaro, Indian lilac	Meliaceae	LASU, Ojo Campus
5.	*Carica papaya* L.	Pawpaw	Caricaceae	LASU, Ojo Campus
6.	*Delonix regia* (Boj. ex Hook.) Raf.	Flame of the forest	Fabaceae	LASU, Ojo Campus
7.	*Gmelina arborea* Roxb. ex Sm.	beechwood, gmelina, white teak	Lamiaceae	LASU, Ojo Campus
8.	*Lagerstroemia speciosa* (L.) Pers.	banaba, pride of India, queen of flowers	Lythraceae	LASU, Ojo Campus
9.	*Mangifera indica* L.	Mango	Anacardiaceae	LASU, Ojo Campus
10.	*Polyalthia longifolia* (Sonn.) Thwaites.	mast tree, the false ashoka, masquerade or police tree	Annonaceae	LASU, Ojo Campus
11.	*Tectona grandis* L.f.	Teak	Lamiaceae	LASU, Ojo Campus
12.	*Terminalia catappa* L.	Country almond, Indian almond, Malabar almond, sea almond, tropical almond	Combretaceae	LASU, Ojo Campus
13	*Terminalia ivorensis* A. Chev.	idigbo, framiré, blackafara	Combretaceae	LASU, Ojo Campus
14.	*Yucca gigantean* Lem.	Spineless yucca	Asparagaceae	LASU, Ojo Campus

LASU- Lagos State University

Stomatal Types, Stomatal Density and Stomatal Index
The studied plant species were hypostomaticand amphistomatic in nature.Eight stomatal complex types such as anomotetracytic, staurocytic, anisosytic, brachyparacytic, paracytic, pericytic, brachyparatetracytic and anomocytic were observed in the investigated species (Plates 1 and 2).
The stomatal density ranged from 78.95 mm-^{2}to 342.11 mm^{-2} and 46.05 mm-^{2}to 296.05 mm^{-2}on the abaxial and adaxial surfaces respectively. The maximum stomatal density (342.11 mm^{-2}) was found in both *Carica papaya*; while the minimum stomatal density (78.95 mm-^{2}) was found in *Gmelinaarborea*on the abaxial surface (Table 2). The maximum stomatal density (296.05 mm^{-2}) was found in both *Acacia auriculiformis*; while the minimum stomatal density (46.05 mm-^{2}) was found in *Terminalia ivoriensis* on the adaxial surface (Table 2).
The stomatal index ranged from 41.38% to 91.23% and 16.17% to 56.25% on the abaxial and adaxial surfaces respectively. The maximum stomatal index (91.23%) was present in *Carica papaya*, while the minimum stomatal index (41.38%) was found in *Gmelina arborea* on the abaxial surface (Table 2). The maximum stomatal index (56.25%) was present in *Acacia auriculiformis*, while the minimum stomatal index (16.17%) was found in *Terminalia ivoriensis* on the adaxial surface (Table 2).

Table 2: Stomatal Features of Studied Plant Species

S/N	Plant Species	Leaf Surface	Stomatal Complex Type	Frequency (%)	Stomatal Density (mm-^{2})	Stomatal Index (%)
1.	*Acacia auriculiformis*	Abaxial	Anisocytic	34.04	309.21^{a}	70.15^{a}
			AnomotetracyticBrachyparacyticParacytic	6.38		
				21.28		
			Staurocytic	25.53		
		Adaxial	Anisocytic	12.77	296.05^{a}	56.25^{a}
			AnomotetracyticBrachyparacyticParacytic	28.89		
				8.89		
			Staurocytic	17.78		
				26.67		
				17.78		
2.	*Albizia lebbeck*	Abaxial	Brachyparacytic	100.00	190.79^{d}	70.73^{a}
		Adaxial	-	-	-	-
3.	*Anarcadium occidentale*	Abaxial	Brachyparacytic	100.00	296.05^{b}	76.28^{a}
		Adaxial	-	-	-	-
4.	*Azadirachtain dica*	Abaxial	Anomocytic	100.00	210.53^{c}	47.76^{bc}
		Adaxial	-	-	-	-
5.	*Carica papaya*	Abaxial	Anisocytic	46.15	342.11^{a}	91.23^{a}
			AnomotetracyticAnomocytic	19.23		
			Staurocytic	19.23		
		Adaxial	-	15.38	-	-
				-		
6.	*Delonix regia*	Abaxial	Brachyparacytic	100.00	236.92^{c}	67.92^{a}
		-	-	-	-	-
7.	*Gmelinaa rborea*	Abaxial	Anisocytic	16.67	78.95^{f}	41.38^{c}
			BrachyparacyticParacytic	75.00		
				8.33	-	-
		Adaxial	-	-		
8.	*Lagersroemiaspe ciosa*	Abaxial	Anisocytic	10.00	184.21^{d}	73.68^{a}
			Anomocytic	50.00		
			Anomotetracytic	30.00		
		Adaxial	Brachyparatetracytic	10.00	-	-
			-			
9.	*Mangiferain dica*	Abaxial	Anomocytic	100.00	190.79^{cd}	46.03^{bc}
		Adaxial	-	-	-	-
10.	*Polyalthialo ngifolia*	Abaxial	Anomocytic	100.00	236.84^{b}	56.25^{abc}
		Adaxial	-	-	-	-
11.	*Tectonag randis*	Abaxial	Anomocytic	20.00	125.00^{e}	55.88^{abc}
			Brachyparacytic	80.00		
		Adaxial	-		-	-
12.	*Terminalia Catappa*	Abaxial	Anisocytic	66.67	118.42^{e}	66.67^{ab}
			Anomocytic	22.22		
			Brachyparatetracytic	11.11		
		Adaxial	-	-	-236.84^{b}	-
13.	*Terminalia Ivorensis*	Abaxial	Anisocytic	22. 22		69.23^{a}
			Anomocytic	8.33		
			Anomotetracytic	13.89		
			Brachyparacytic	41.67		
			Paracytic	13.89		
		Adaxial	Anisocytic	71.43	46.05^{b}	16.17^{b}
			Brachyparatetracytic	28.57		
14.	*Yucca gigantea*	Abaxial	Pericytic	100.00	105.74^{e}	55.18^{b}
		Adaxial	-	-	-	-

Means with same letters along the column are not significantly different at $p \leq 0.05$

Epidermal Cell Shape, Anticlinal Cell Wall Pattern and Trichome Type

The epidermal cell shapes were irregular, isodiametric and polygonal. The anticlinal cell wall pattern observed among the studied species were round, curved, wavy and straight.There was presence of unicellular, peltate and capitates trichomes (Plates 1 and 2; Tables 3 and 4).

Table 3: Abaxial Surfaceof Epidermal Cell and Trichome Features of Studied Plant Species

S/N	Plant species	Epidermal cell shape	Anticlinal cellwall pattern	Trichome type
1.	*Acacia auriculiformis*	Polygonal	Straight	-
2.	*Albizia lebbeck*	Irregular	Round, curved	Unicellular
3.	*Anarcadium occidentale*	Irregular	Wavy	-
4.	*Azadirachta indica*	Irregular	Straight, Curved	-
5.	*Delonix regia*	Irregular, Polygonal	Straight, curved	Unicellular
6.	*Carica papaya*	Irregular	Curved	-
7.	*Gmelinaarborea*	Irregular	Curved	-
8.	*Lagersroemiaspeciosa*	Irregular	Straight,Curved	-
9.	*Mangiferaindica*	Isodiametric	Round	-
10.	*Polyalthia longifolia*	Irregular	Straight, Curved	-
11.	*Tectona grandis*	Irregular	Wavy	Capitate, Long unicellular Unbranched and Peltate
12.	*Terminalia catappa*	Irregular	Curved, Wavy	-
13.	*Terminalia ivorensis*	Irregular	Curved, Wavy	-
14.	*Yucca gigantea*	Irregular	Wavy	-

Table 4: Adaxial Surface of Epidermal Cell and Trichome Features of Studied Plant Species

S/N	Plant species	Epidermal cell Shape	Anticlinal cell wall Pattern	Trichome Type
1.	*Acacia auriculiformis*	Polygonal	Straight	-
2.	*Albizia lebbeck*	Irregular	Curved	-
3.	*Anarcadiumoccidentale*	Irregular	Wavy	-
4.	*Azadirachta indica*	Irregular	Curved, Straight	-
5.	*Carica papaya*	Polygonal	Straight	-
6.	*Delonix regia*	Polygonal	Straight	Unicellular
7.	*Gmelina arborea*	Irregular	Curved, Straight	Unicellular
8.	*Lagersroemiaspeciosa*	Irregular	Curved, Straight	-
9.	*Mangifera indica*	Irregular	Straight, Round, Curved	-
10	*Polyalthialongifolia*	Irregular	Curved, Straight	-
11.	*Tectona grandis*	Isodiametric	Round	-
12.	*Terminalia catappa*	Irregular	Wavy	-
13.	*Terminaliaivorensis*	Irregular	Curved, Straight, Wavy	Unicellular
14.	*Yucca gigantean*	Irregular	Wavy	-

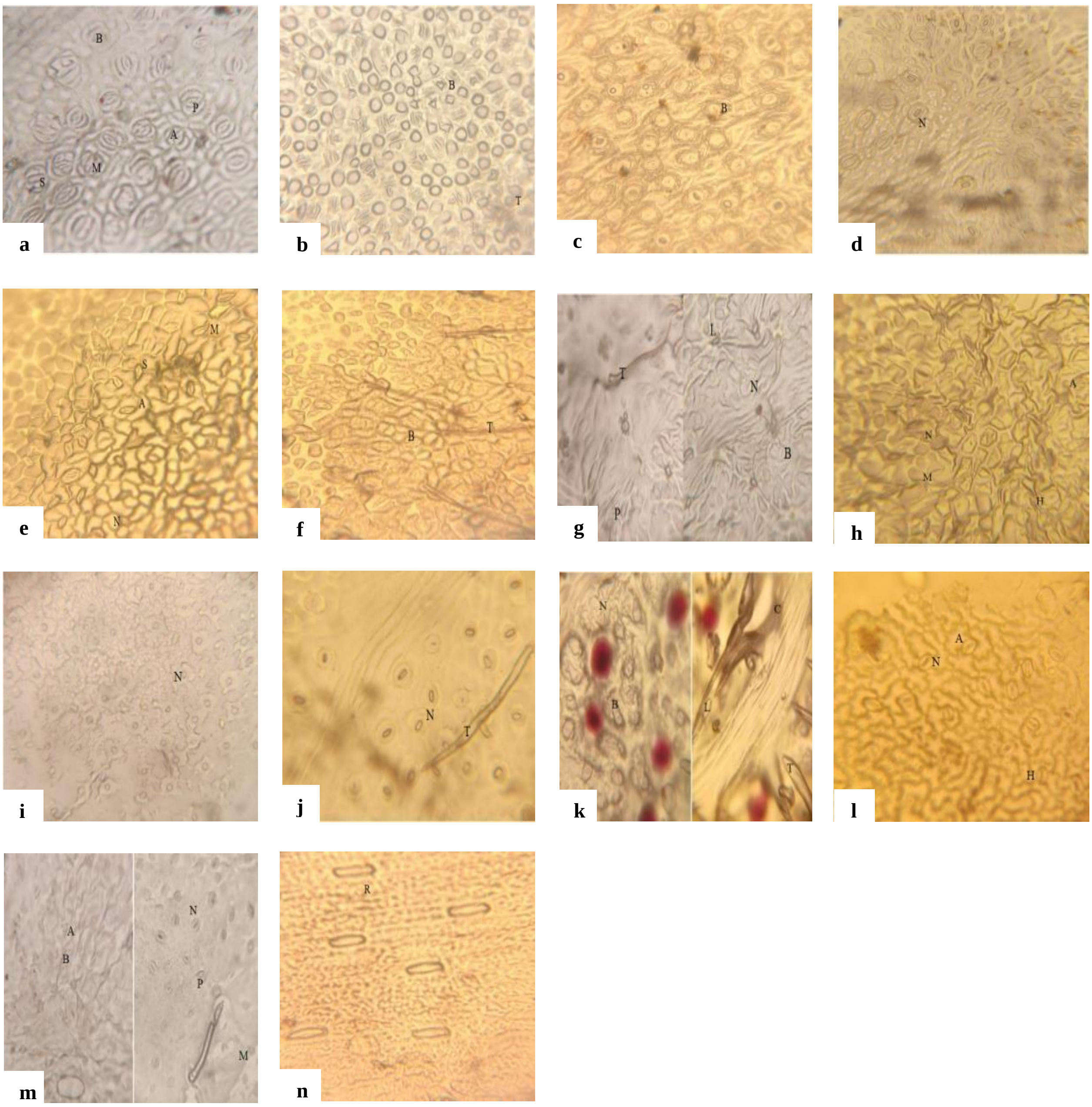

Plate 1: Photomicrographs of abaxial surface of fourteen tree species showing leaf epidermal features. *Acaciaa uriculiformis* (a), *Albizia lebbeck* (b), *Anacardium occidentale* (c), *Azadirachta indica* (d), *Carica papaya* (e), *Delonix regia* (f), *Gmelina arborea* (g), *Lagestroemia speciosa* (h), *Mangifera indica* (i), *Polyalthia longifolia* (j), *Tectona grandis* (k), *Terminalia catappa* (l), *Terminalia ivoriensis* (m) and *Yucca gigantea* (n). (M – anomotetracytic stomata, S – staurocytic stomata, A – anisosytic stomata, B – brachyparacytic stomata, P – paracytic stomata, R –pericytic stomata, H – brachyparatetracytic stomata, N - anomocytic stomata, E - epidermal cell shape; T – unicellular trichome; C – capitates trichome; P – peltate trichome). All magnifications at × 2000.

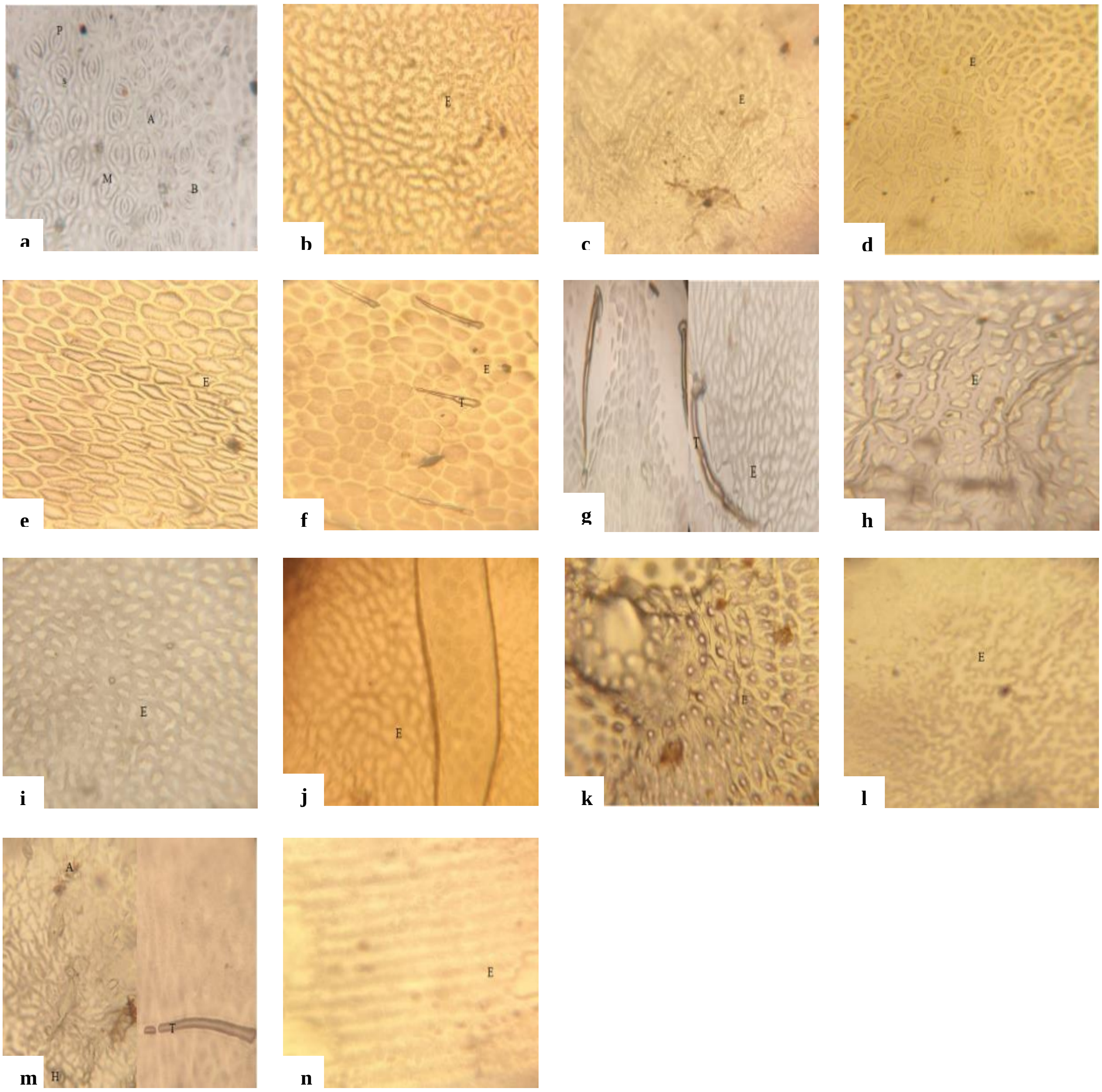

Plate 2: Photomicrographs of adaxial surface of fourteen tree species showing leaf epidermal features. *Acacia auriculiformis* (a), *Albizia lebbeck* (b), *Anacardium occidentale* (c), *Azadirachta indica* (d), *Carica papaya* (e), *Delonix regia* (f), *Gmelina arborea* (g) *Lagerstroema speciosa* (h), *M. indica* (i) *P. longifolia* (j) *T. grandis* (k), *Terminalia catappa* (l), *Terminalia ivoriensis* (m) and *Yucca gigantea* (n). (M - anomotetracytic stomata; S - staurocytic stomata; A - anisosytic stomata; B - brachyparacytic stomata; P - paracytic stomata; H –brachyparatetracytic stomatal; E - epidermal cell shape; T - unicellular tricomes). All magnifications at × 2000.

Discussion

The leaf anatomical adaptations responsible for the survival of selected tree species in Lagos State University, Ojo Campus (i.e. wet locations) were examined. The species respond to their environment by modifying certain anatomical features to improve their adaptations. Significant variations occurred among the investigated species based on their leaf anatomical traits.

The studied species possessed hypostomatic and amphistomatic leaf type. The species such as *Albizia lebbeck*, *Anarcadium occidentale*, *Azadirachta indica*, *Carica papaya*, *Delonix regia*,*Gmelina arborea*, *Lagerstroema speciosa*, *Mangifera indica*, *Polyalthia longifolia*, *Tectona grandis*, *Terminalia catappa* and *Yucca gigantea* were hypostomatic. Similar trend was observed by Aworinde and Ogundairo (2009); Ajuziogu *et al.* (2018) and Omolokun *et al.* (2023) on leaf epidermal features of some species of Solanaceae, Sterculiaceae, Verbenaceae and Moraceae. The studied species that possessed amphistomatic leaf type are *Acacia auriculiformis* and *Terminalia ivoriensis*. This conforms to the work of Saadu *et al*. (2009) and AbdulRahaman *et al*. (2013) on some tuber and shade tree species respectively.

The stomatal complex types observed were anisocytic, anomocytic, anomoteracytic, brachyparacytic, brachyparatetracytic, paracytic, pericytic, and staurocytic. This conforms to the observation of some researchers (Ezeibekwe *et al.*, 2013; Alege and Shuaibu, 2015; Omolokun, 2019). Stomatal density and stomatal index vary from species to species. Similar pattern was observed by Obiremi and Oladele (2001); Oyeleke *et al*. (2004); Omolokun *et al*., (2023) on some tree species.

The epidermal cell shapes (i.e. irregular; isodimetric and polygonal); anticlinal cell wall pattern (i.e.curved, round, straight and wavy) and trichomes (i.e. unicellular, peltate and capitate) vary from species to species. Similar trend was observed by some scientists (Oladipo and Ayo-Ayinde, 2014; Bano and Deora, 2017 and Bolarinwa*et al*., 2018; Omolokun *et al*., 2023).

The amphistomatic leaf nature observed in the studied species such as *Acacia auriculiformis* and *Terminalia ivoriensis* was an ecological advantage for survival in wet environment than those species with hypostomatic leaf nature, due to the presence of stomata on both leaf surfaces. This is due to the fact that the presence of stomataon both the abaxialand adaxialsurfaces may lead to increase in transpiration rate, since the amount of water vapour lost through the leaf would be increased. This affirmation supports earlier investigation by AbdulRahaman *et al.* (2013) and Omolokun (2019) on some shade trees and wasteland species respectively.

The occurrence of stomatal complex types with higher frequency of many subsidiary cells (anomocytic, anomotetracytic, brachyparatetracytic, staurocytic and anisocytic) in the leaves of studied plant species such as *Azadirchta indica*, *Mangifera indica*, *Polyalthia longifolia*, *Terminalia catappa*, *Lagerstroemia speciosa*, *Acacia auriculiformis* had been considered as an adaptive feature for survival in wet locations. This implies that stomata with higher number of subsidiary cells have a tendency to open more rapidly than those with lower number of subsidiary cells. This corroborates with the report of Obiremi and Oladele (2001); AbdulRahaman and Oladele (2009) and Saadu *et al.* (2009).

Stomatal density and stomatal index were high and varied from species to species. However, the presence of high proportion of stomata on the leaf surface of all the studied species might be attributed to their continued survival in wet region. This is based on the fact that high stomatal density and stomatal index lead to high rate of water loss to the atmosphere due to the presence of more stomata on the leaf surface. Similar trend was observed by Omolokun (2019).

The presence of trichomes on the leaf surfaces tends to reduce water loss through transpiration (Quarrie and Jones, 1977; Karabourniotis *et al*., 1995; Smith and Hare, 2004; Franks and Farquhar, 2007), Based on this fact, the absence of trichomes in the leaves of the studied plant species such as *Acacia auriculiformis, Anacardium occidentale, Azadirachta indica, Carica papaya*, *Lagestroemia speciosa*, *Mangifera indica*, *Terminalia catappa*, *Yucca gigantea* had been considered as an adaptive feature to survive wet locations. This affirmation was in line with the report of Omolokun (2019).

Stace (1965) reported that drier habitat species have straight and curved cell wall, while humid areas species have undulate cell wall type. Based on this fact, the studied species such as*Anacardium occidentale, Tectona grandis, Terminali acatappa*, *Terminalia ivoriensis* and *Yucca gigantea* with undulate cell wall would be more suitable for survival in wet locations.

CONCLUSION

This studies revealed that leaf anatomical adaptations such as presence of amphistomatic leaf type in *Acacia auriculiformis* and *Terminalia ivoriensis*; stomatal complex types with many subsidiary cells in *Acacia auriculiformis, Azadirachta indica, Carica papaya, Gmelina arborea, Lagestroemia speciosa, Mangifera indica, Polyalthia longifolia, Tectona grandis, Terminalia catappa, Terminalia ivoriensis*; high stomatal density and index in all the studied species; absence of trichomes in *Acacia auriculiformis, Anacardium occidentale, Azadirachta indica, Carica papaya*, *Lagestroemia speciosa, Mangifera indica,Terminalia catappa,Yucca gigantean*, and wavy anticlinal cell wall pattern in *Anacardium occidentale, Tectona grandis, Terminalia catappa, Terminalia ivoriensis* and *Yucca gigantea* might be responsible for the survival of the studied species in their locations.

RECOMMENDATION

This study recommends that the ecological, morphological and physiological adaptations of the studied species should be carried out for effective afforestation purpose.

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