Journal of Advances in Biology & Biotechnology

24(10): 26-45, 2021; Article no.JABB.68627
ISSN: 2394-1081

Ecological Adaptation of Endemic *Anthocleista* Species under Moisture Gradient in Parts of Niger Delta, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author EWNL designed the study, and wrote the protocol. Authors EWNL, OATE and IEP carried out field sampling and wrote the first draft of the manuscript, managed the literature searches and analyses of the study. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JABB/2021/v24i1030245
Editor(s):
(1) Dr. Joana Chiang, China Medical University, Taiwan.
Reviewers:
(1) Marcus Vinicius Sandoval Paixão, Instituto Federal do Espírito Santo, Brazil.
(2) Halil İbrahim Oğuz, Nevşehir Hacı Bektaş Veli University, Turkey.
(3) Tay Chia Chay, Universiti Teknologi MARA, Malaysia.
Complete Peer review History, details of the editor(s), Reviewers and additional Reviewers are available here: https://www.sdiarticle5.com/review-history/68627

Original Research Article

Received 01 April 2021
Accepted 01 June 2021
Published 13 December 2021

ABSTRACT

Background: Knowledge of the anatomy of *Anthocleista* species is crucial for understanding how these plants adapt to the environment.
Aim: This study was aimed at investigating the adaptive relationship of moisture gradient influence on the anatomy of four species in the genus *Anthocleista* (*A djalonesis* A Chev; *A. liebrechtsiana* De Wild & Th.Dur; *A. nobilis* G.Don; and *A. vogelii* Planch) in light of ecological niche adaptation.
Place of Study: parts of Akwa-Ibom, Bayelsa, Cross River and Rivers States in the Niger Delta.
Methods: Conventional classical anatomical techniques for structural sectioning were used.
Results: Though there are similarities and differences in vascular structure among the species, the study has revealed variance in anatomical responses to moisture gradient (ranging from dry mesophytic to mesophytic and wetland conditions) of adaptation. The most important and distinct features observed are the presence of sclerenchymatous idioblast, air sacs and sclereidal

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idioblast. Sclerenchymatous idioblasts are numerous in *A liebrechtsiana,* few in *A. nobilis* and *A. vogelii* but lacking in *A. djalonesis*. The sclerenchymatous idioblast in *A. liebrechtsiana*, *A. nobilis*, and *A*. *vogelii* confirmed these species to be mesophytic to semi-aquatic in their habitat adaptation; while *A. djalonesis* is dry-mesophytic in adaptation with thicker epidermal layer, multiple hypodermal layers, thicker mesophyll tissues with increased number of palisade layers and thick leaves. The stem and root modification had abundance sclereidal idioblast distribution in *A. liebrechtsiana*, and *A. nobilis,* moderate in *A. vogelii* and very low in *A. djalonesis*.

Conclusion: The variation observed in the leaf, petiole, stem and root anatomical characters are due to moisture gradient influence with the resultant effect of plant species evolving structures such as idioblast and modification to adapt to the niche and environment where they find themselves.

Keywords: Idoblast; air sac; leaves; stem; and root.

1. INTRODUCTION

One of the most critical features and influences of comparative analysis on plant characteristic variation and similarity in relation to eco-environmental adaptation depends on the degree of relationship of various aspect of function in anatomical characterization of plant [1] as well as phylogenetic relatedness among taxa [2]. Every plant found in any environmental positions either tropical or sub-tropical region has mechanism for its survival in such place. The adaptation potential may comprise of the plant physiological, and biochemical roles in adapting to the kind of environment found. This makes species partly dependent on any statistical inference, by relating the anatomical traits to ecological preferences which might be alternatively explained by phylogenetic inertia affecting both the similarity of anatomical traits among closely related taxa and the similarity of ecological niches such taxa occupy [1].

The Environment can be regarded as the sum total of all the external conditions (biotic and abiotic factors) affecting the development and life of an organism [3]. These environmental factors affect the growth, development and distribution of plant in different habitats. Plants species are known to have different requirement of environmental conditions which can directly or indirectly become sources of ecological stress or / and balance for such species ([4]. These have made plants develop a variety of strategies and mechanisms in terms of changes in morpho-anatomical structures to adapt to any changes in their environment. To survive and reproduce, all living organisms must adjust to conditions imposed on them by their environment. Thus, plants species respond positively or negatively to changes in their habitat in order to survive [5]. Such conformity between an organism and its environment is known as “Adaptation”. Adaptation is an evolutionary process whereby living things are better suited in tolerance to live in their environment or habitat [6]. It is a deliberate process of change or compromise which contributes to fitness and survival of a plant in anticipation or in response to external stimuli and stress. Invariably, it is the ability of an organism to adapt and survive in its environment in different ways; involving an increase or / and decrease in temperature, moisture, humidity, wind or light, dark movement [6].

The influence of ecological adaptation of organism in an environment, involve the integration of biotic and abiotic factors to the behavioral aspects of species such as plant in the environment [7]. Plant species of different families or same family has varied genetic potential to adopt wide range of environmental conditions. This adaptation potential might be due to varying physiological, biochemical and anatomical characteristics [8]. A number of environmental factors including available moisture are known to influence the anatomy of plant species. Variation in plants growth, distribution and productivity has often attributed to varying conditions of environmental factors [9, 10]. It was suggested that anatomical features in plants might be more important than morphological features systematically because anatomical features are less susceptible to environmental change. However, it was reported that variation in leaf anatomy might be useful in assessing strong environmental influences on plants [11].

The plants which characteristically grow in certain ecological niches often show a type of structure which is believed to be adapted to that particular environment besides the phenotype. Plant species inhabiting water or dry habitats exhibit a number of special features or adaptations in their morphology, anatomy and physiology which enables them to survive under such extreme ecological conditions [12]. It revealed that variation in anatomical structure is dependent on several forces of prevailing conditions in the habitat that lead to species adaptation [13]. Knowledge of the anatomy of *Anthocleista* species is crucial for understanding how these plants adapt to the environment. Such plants exhibit considerable variation in their requirements of water in natural soil habitat. The genus *Anthocleista,* Afzel.ex.R.Br., commonly called cabbage tree is a medium size tropical Africa genus composed of medium, small trees or shrubs with soft white wood belonging to the family Loganiaceae [14, 15]. It consists of 50 species, mainly native to tropical African mainland, Madagascar and Mascarene Island; with six (6) of the 50 species commonly found in Nigeria and economically significant [14]. For the six species in Nigeria, phytogeographical distribution study revealed that four (4) species of common occurrence with preference for diverse ecological adaptation were found in parts of Niger Delta [16, 15].

In search of understanding the phylogeny of the genus and relationship among the species in parts of Nigeria, several studies have been carried out. Among which includes: the origin and species composition of the genus [14, 17]; phytomorphological characterization, similarity and variation among species [18,16,19]; phytogeographical distribution, habitat adaptation of the species [14,15]; A Chemotaxonomic study of three species of *Anthocleista* [18]; histochemical localization of tannins in species of *Anthocleista* was found in parts of Niger Delta Tropical rainforest of Nigeria [20]. Others include foliar trichome morphology of the species of *Anthocleista* in Parts of the Niger Delta [19]; stomata morphology of species in parts of Niger-Delta [21]; the antiviral effect of *Anthocleista nobilis root* extract on the biochemical indices of poultry fowls infected with Newcastle disease virus [23]; Phytochemical screening, antimicrobial and antioxidant activity of *Anthocleista djalonesis* and *Anthocleista liebrechtsiana* [24,25], impact of *Anthocleista vogelii* root bark ethanolic extract on weight reduction of induced obesity in male Wister rat [22]; Morphology and Anatomy of *Anthocleista djalonesis* [26]; the ecological dynamics and trajectories of bioactive compounds of species in parts of Niger Delta [27] and evaluation of diverse potential in the genus *Anthocleista* [28]. The *Anthocleista* species occurring in the Niger Delta has shown tremendous ecological diversity with a view to adaptation preference among the species ranging from terrestrial dry habitat, mesophytic to swampy habitat [16]. Up to date, no research has been carried out on the relationship between the environmental adaptation and anatomical modification of the species.

There is a need to investigate the relationship in the anatomical modification of these species with respect to their prevailing habitat. This present study is significant hence it will provide some vital information on this genus, with the view that the variation observed in the anatomy of the species. This can help better understanding how they adapt to various ecological niches, determine the influence of environmental and ecological niche adaptation on the petiolar, foliar, stem and root anatomy of *Anthocleista* species found in parts of Niger-Delta. The information obtained is expected to aid in the assessment of taxonomic value of these features as well as their ecological niche adaptation. Also such useful information could possibly serve as a baseline in taxonomic delimitation of the different taxa and enhance the existing Floristic information on the species and generally add to the already existing information on the taxonomy and the ecographical amplitude of the species.

2. MATERIALS AND METHODS

2.1Description of Study Area, Location and Site

The Niger Delta area is the coastline parts of Nigeria approximately 853 kilometers facing the Atlantic Ocean and lying between latitude 4^{o} 10’ to 6^{o} 20’N and longitude 2^{o} 45’ to 8^{o} 35’E. Geographically the area is the Southern segment of Nigeria, created by myriads of Islands segmented by lagoons and channels, which empty into the Bight of Benin in the East Atlantic Ocean. The Delta is supplied with water by the Rivers Niger and Benue. These Rivers (now joined) break up at Ebu-Otor into the Rivers Nun and Forcados (including their tributaries). The portion of the Niger Delta traversed by the River Nun is the present Bayelsa State, while the present Delta State is traversed by the River Forcados. The Nun River breaks out into many channels and creeks such as Santa Barbara, St. Nicholas, Brass, Nun, Sangana, Fishtown, Koluama, Middleton, Digatoru, Pernnington, Dodo and Ramos Rivers, which empty into the Atlantic Ocean [29] (Fig. 1).

From the ecological perspective it is that portion of the Southern Nigeria stemming from Northern apex situated at Aboh, bounded in the East and West by the Imo and the Benin Rivers respectively and on the South by the Atlantic Ocean [30]. It is the Africa's largest Delta covering some 70,000 square kilometers (Km^2), of which one third of the area is made up of wetland [31]. The region is low lying and not more than 3.0 meters above sea level [32]. It possesses myriads of luxuriant landscape of sensitive vegetation and ecosystems ranging from coastal mangrove forest, brackish swamp forests, fresh water swamp forest, barrier island forest and low land rainforest which attribute in a large river delta in a tropical region [33]. The environmental condition of the area has two climatic seasons: a rainy season (April to November) and a dry season (December to March), with an annual rainfall ranging between 1500 and 4000mm [34]. The mean monthly temperature varies between 24^0C and 32^0C throughout the years, thus exhibiting maximum temperature of climatic regimes. Seasonal and latitudinal variations affect the maximum temperature, diurnal and seasonal ranges, relative humidity, high rainfall pattern, which is comparatively uniform due to the proximity of the region to the Atlantic Ocean [29]. The soil condition of the area is of sandy silt and clayey, often alkaline and salty, sometimes acidic. The Niger Delta based on ecological context of triangular deltaic basin alluvium formation consists of three core States: Bayelsa, Delta and Rivers State. Others based on regional and political context include Akwa Ibom, Cross River, and Edo, Abia, Imo and Ondo States. However, the study location in the Niger Delta study area include: parts of Rivers, Bayelsa, Akwa-Ibom and Cross River States (Fig. 1).

The study locations in their respective situate are: Akwa Ibom; between longitude (long.) 7^o40'9.444''E and 8^o12'34.802''E and latitude (lat.) 4^o31'42.65''N and 5^o33'14.959''N, Bayelsa; between longitude (long.) 5^o59'56.25''E and 6^o35'54.138''E and latitude (lat.) 4^o19'31.504''N and 5^o23'24.488''N, Cross River; between longitude (long.) 8^o40'50.132''E and 8^o45'44.015''E, and latitude (lat.) 4^o28'21.275''N and 6^o52'45.485''N and Rivers; between longitude (long.) 6^o39'49.206''E and 7^o13'6.808''E and latitude (lat.) 4^o23'26.326''N and 5^o42'26.22''N. These study locations lies on the coastal plain of the Eastern Niger- Delta with its land surface geology of fluvial sediments. The land surface can be grouped into three main divisions: the fresh water; the mangrove swamps and coastal sand ridges zone. These surfaces consist of three main soil groups: the fresh water brown loams and sandy loams, the fluvial marine sediments and Mangrove swamp alluvial soils. The States are characterized with high rainfall, which decreases Northward annually from

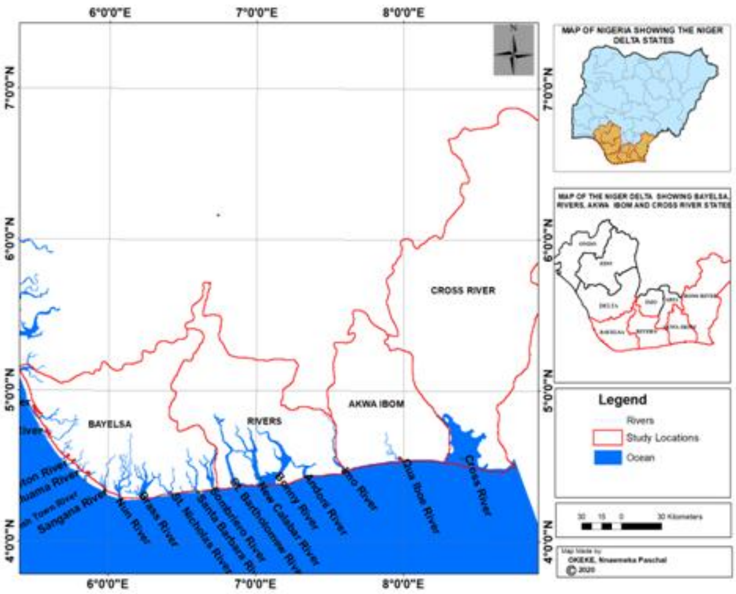


Fig. 1. Parts of Niger Delta study area showing parts of Akwa-Ibom, Bayelsa, Cross River and Rivers States study locations

4700mm on Coast to about 1700mm in north apex of the States. The rainforest vegetation occupies the upland area; the riverine area is divisible into three hydro-vegetation zones: the Salt water zone; the Beach ridge zone and the Fresh water zone [35]. In the various study locations with their local council areas, Akwa-Ibom State houses 31 local council areas including **Oruk-Anam** and **Itu study sites** (Fig. 2); Bayelsa State (with 8 council areas) including **Yenagoa study site** (Fig. 3); Cross River (with 18 council areas) including **Akpabuyo, Calabar Municipal, Calabar South** and **Akamkpa study sites** (Fig. 4) and Rivers State (with 23 local council areas) including **Obio / Akpor, Asari-Toru, Khana, Tai, Emuoha**, and **Ikwerre study sites** (Fig. 5).

The various study sites in their georeferenced situate with various sampled sites (Table 1) are commonly characterized with some isolated seasonal fresh water swamps, and mesophytic seasonally flooded terrestrial habitat common in the study location; dominated with sandy-silt and silty-clay textural soil property and characterized by maximum temperature, relative humidity and maximum rainfall. The vegetation type is a shrubby re-growth, predominated by shrubs, grasses herbs and luxuriant vegetation with few trees [36].

2.2 Field Species Collection

The spatial distribution of plant and location, their degree of habitat niche adaptation and the spatial distribution of sensitive habitats [15, 16] were some of the major aspects considered during field sampling. The Species of the *Anthocleista* genus were observed and collected from parts of the ecozone study sites (Figs. 2 – 5) at the following sample site situates: Ikot-Osuete (lat.04^{o} 40.618^{1} - 04^{o} 40.685^{1}N and long.007^{o} 31.027^{1} - 007^{o} 31.831^{1}E); Oku Iboku (lat. 5^{o} 10’ 59” - 5^{o} 12’ 34”N and long. 8^{o} 2’ 91” - 8^{o} 21’ 59”E); Ede-pie (lat. 05^{o} 02.819^{1} - $05^{o}$$03.005^{1}$N and long. 006^{o} 24.894^{1} - 006^{o} 25.153^{1}E); Okutukutu (lat. 4^{o} 53’ 52.17” - 4^{o} 57’ 43”N and long. 6^{o}21’ 19” - 6^{o} 54’ 56.79”E); Atimbo (lat. 04^{o} 57.922^{1} - 04^{o} 57.958^{1}N and long. 008^{o} 22.458^{1} - 008^{o} 22.640^{1}E); Akai Effa-Idundu (lat. 05^{o} 00.579^{1} - 05^{o} 00.610^{1}N and long. 008^{o} 22.011^{1} - 008^{o} 22.166^{1}E); New Calabar Airport (lat. 5^{o} 12’ 30”N and long. 8^{o} 21’ 65”E); Awi Forest (lat. 4^{o} 55’ 59”N and long. 8^{o} 19’ 25”E); UPTH- Alakahia (lat 4^{o} 53’ 00” -04^{o} 53.580”N and long. 6^{o} 54’ 56.79” - 006^{o} 55.672”E); UNIPORT-Biodiversity area (lat. 04^{o} 53.745” - 04^{o} 54.197”N and long. 006^{o} 54.671” - 006^{o} 54.955”E); Abalama (lat. 4^{o} 46’ 28” - 4^{o} 46’ 50”N and long. 6^{o} 49’ 43”- 6^{o} 50’ 28”E); Opu-Oko (lat. 04^{o} 40.974^{1} - 04^{o} 41.225^{1}N and long. 007^{o} 30.348^{1} - 007^{o} 30.896^{1}E);

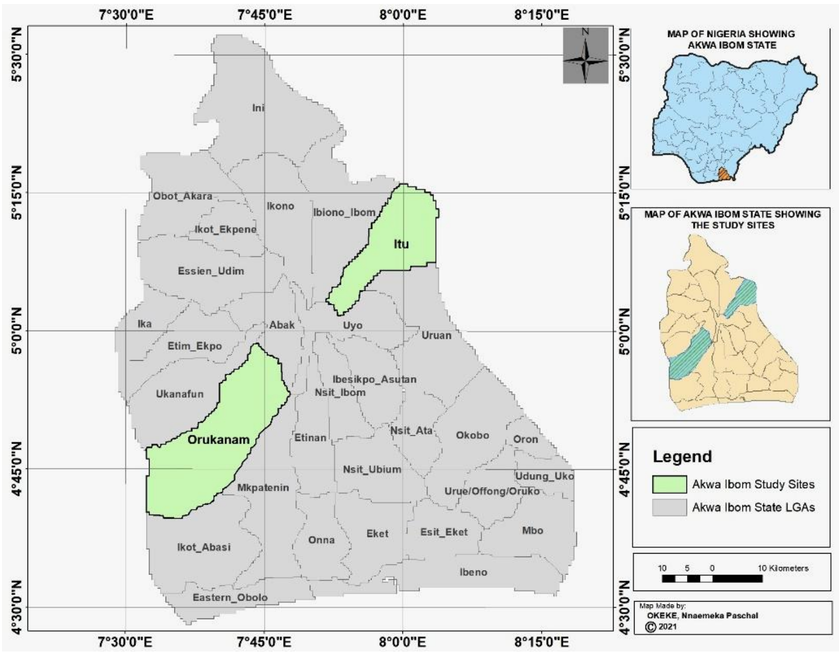


Fig. 2. Akwa-Ibom State (study location) showing study sites

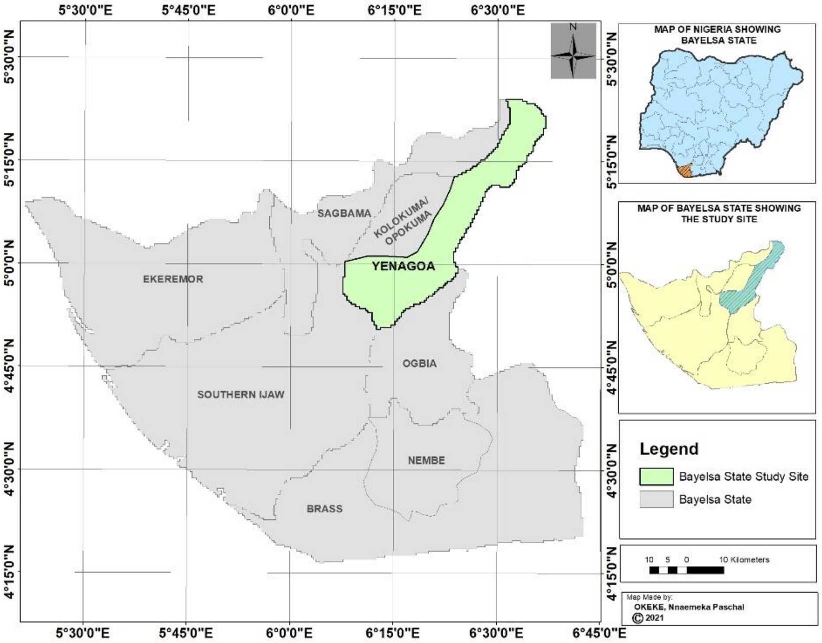


Fig. 3. Bayelsa State (study location) showing study site

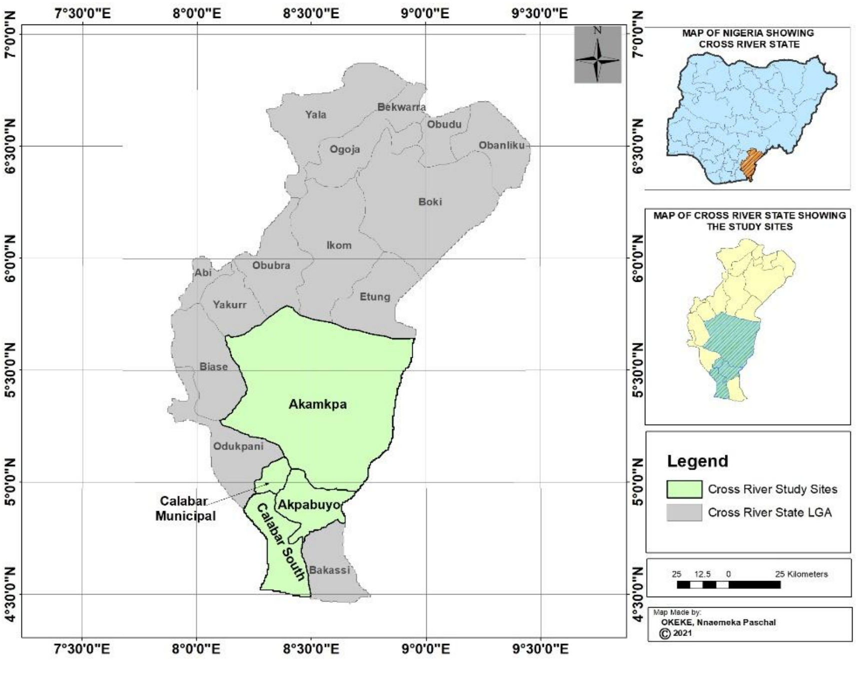


Fig. 4. Cross River State (study location) showing study sites

Sakpewa (lat. 04^{o} 43.087^{1}N and long. 007^{o} 16.081^{1}E); Isiodu (lat. 04^{o} 53.725^{1} - 04^{o} 53.732^{1}N and long. 006^{o} 53.813^{1} - 006^{o} 53.824^{1}E) and Aluu-Omuoko (lat. 04^{o} 54.980^{1} - 04^{o} 54.987^{1}N and long. 006^{o} 54.215^{1} - 006^{o} 54.219^{1}E). Despite the various hot spot in Niger Delta, the areas under study were chosen for the reason of accessibility, availability and prevalence of the species. A systematic random sampling based on simple ecological procedure was carried out in 15 sampled sites with various sampling points of different geographical precision coordinates noted in parts of the States under consideration (Table, 1). A hand-held Geographic Positioning

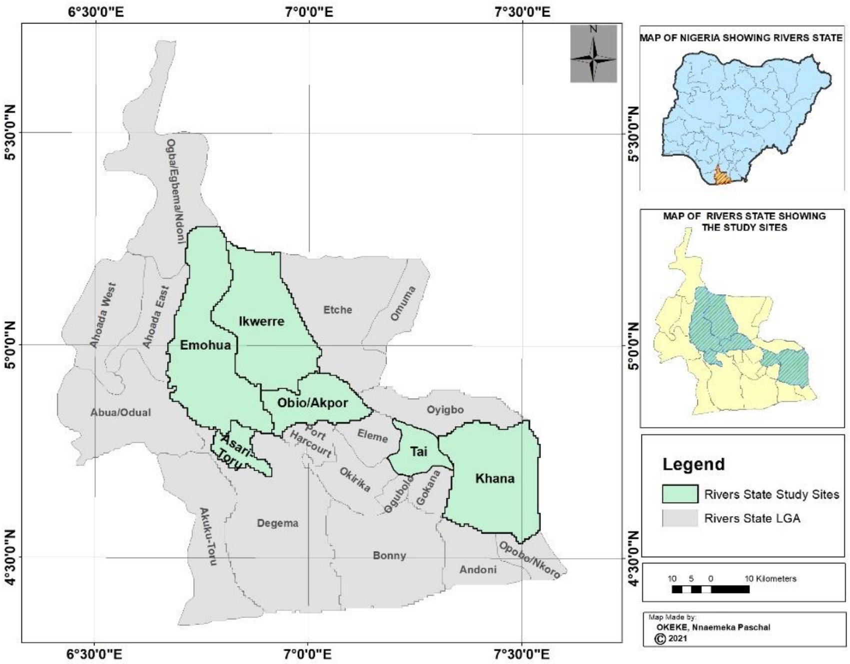


Fig. 5. Rivers State (study location) showing study sites

System (*GPS – Garmin Dakota 10 Model*) was used for the georeferencing of the sampled point for the distribution status of the *Anthocleista* species in the location under study. The four species samples found in parts of Niger Delta were collected based on the herbarium techniques involving plant press, processes of drying, chemical treatment to identification and authentication at the University of Port Harcourt Herbarium (UPH) by the Curator Dr. N. L. Edwin-Wosu and voucher specimen deposited at the Herbarium (Table 2).

2.3 Laboratory Anatomical Study

Fresh specimen of the leaf, petiole, root and stem of collected samples were fixed in FAA 1:1:18 (1 part formalin, 1 part glacial acetic acid, 18 parts of 70% ethanol (v/v)) for 48 hours [37]. The specimen were washed in two changes of distilled water to get rid of the fixative and passed through graded ethanol series in the order 30%, 50%, 70% and 95% (each for two hours) and finally absolute ethanol (overnight) [38]. Free hand sections were made using a razor blade to cut thin section (1 cell thick) by making horizontal cuts close to the surface. The first sections were discarded; subsequent sections placed in water, held in a glass Petri dish. The sections (leaf and petiole) were stained with 1% methyl blue, root and stem with 1% safranin and methylblue (canter staining), the sections were rinsed with distilled water to get rid of excess stain and then placed on a slide with a drop of glycerine and covered with a cover slip. The prepared slides were viewed under a microscope and photomicrograph was taken from good preparations.

3. RESULTS

The result of the spatial geographical distribution and herbarium voucher sample deposit are presented in Tables 1 and 2. The anatomical result interpretation of study observations on the leaf, petiole, root and stem of the species are presented below, while the photomicrographs of the sections as shown are presented in Plates 1-16.

3.1 Leaf-Midrib Anatomy

The transverse section of the leaf – midrib anatomy has revealed *Anthocleista djalonesis* A. Chev leaf (Plate 1) with two thick layer of epidermis, multiple hypodermis, thick layer of elongated palisade mesophyll parenchyma, layer of irregular spongy mesophyll parenchyma cell, several crescent shaped and bicollateral vascular bundles with single layer of endodermis. *Anthocleista liebrechtsiana* De Wild and Th. Dur (Plate 2) has two layer of epidermal cells, single layer of collenchymatous cells, single thick layer of elongated palisade mesophyll and irregularly shaped thick spongy mesophyll, stellate shaped idioblast in the spongy mesophyll tissue,

Table 1. GPS Coordinates of Distribution Status of the *Anthocleista* Species

S/N	Study location	Study site	Sample site	Lat. (N)	Long. (E)	Alt.	Species
1	Akwa-Ibom	Oruk-Anam	Ikot-Osuete	04^{o} 40.639^{1}	007^{o} 31.596^{1}	9	*A. liebrechtsiana*
				04^{o} 40.629^{1}	007^{o} 31.640^{1}	4	“ “
				04^{o} 40.617^{1}	007^{o} 31.687^{1}	2	“ “
				04^{o} 40.615^{1}	007^{o} 31.783^{1}	11	*A. nobilis*
				04^{o} 40.618^{1}	007^{o} 31.831^{1}	21	*A. nobilis*
				04^{o} 40.685^{1}	007^{o} 31.027^{1}	15	“ “
		Itu	Oku Iboku	5^{o} 10’ 79”	8^{o} 03’ 51”	12	*A. liebrechtsiana*
				5^{o} 12’ 34”	8^{o} 21’ 59”	25	*A. djalonesis*
				5^{o}10’ 79.5”	8^{o} 03’ 51.1”	22	*A. nobilis*
				5^{o} 10’ 59”	8^{o} 2’ 91”	18	*A. vogelii*
2	Bayelsa	Yenagoa	Ede-pie	05^{o}03.005^{1}	006^{o} 25.153^{1}	41	*A. liebrechtsiana, A. nobilis*
				05^{o} 02.963^{1}	006^{o} 25.098^{1}	30	*A. nobilis*
				05^{o} 02.892^{1}	006^{o} 24.994^{1}	58	*A. liebrechtsiana*
				05^{o} 02.819^{1}	006^{o} 24.894^{1}	44	*A. djalonesis*
			Okutukutu	4^{o} 56’ 29”	6^{o}21’ 19”	20	*A. nobilis, A. vogelii*
				4^{o} 57’ 43”	6^{o} 21’ 35”	14	*A. liebrechtsiana*
				4^{o} 53’ 52.17”	6^{o} 54’ 56.79”	10	*A. liebrechtsiana*
3	Cross River	Akpabuyo	Atimbo	04^{o} 57.958^{1}	008^{o} 22.458^{1}	5	*A. liebrechtsiana*
				04^{o} 57.950^{1}	008^{o} 22.503^{1}	26	“ “
				04^{o} 57.950^{1}	008^{o} 22.547^{1}	28	“ “
				04^{o} 57.954^{1}	008^{o} 22.578^{1}	26	*A. nobilis*
				04^{o} 57.922^{1}	008^{o} 22.640^{1}	12	“ “
		Calabar Municipal	Akai Effa-Idundu	05^{o} 00.579^{1}	008^{o} 22.011^{1}	15	*A. liebrechtsiana*
				05^{o} 00.582^{1}	008^{o} 22.025^{1}	11	“ “
				05^{o} 00.591^{1}	008^{o} 22.070^{1}	14	*A. nobilis*
				05^{o} 00.601^{1}	008^{o} 22.117^{1}	10	“ “
				05^{o} 00.610^{1}	008^{o} 22.166^{1}	20	*A. liebrechtsiana*
		Calabar South	New Calabar Airport	5^{o} 12’ 30”	8^{o} 21’ 60”	20	*A. liebrechtsiana*
				5^{o} 12’ 30”	8^{o} 21’ 65”	15	*A. djalonesis*
		Akamkpa	Awi Forest	4^{o} 55’ 59”	8^{o} 19’ 25”	10	*A. nobilis*
				4^{o} 55’ 59”	8^{o}19’ 21”	15	*A. vogelii*
4	Rivers	Obio/Akpor	UPTH- Alakahia	4^{o} 53’44.33”	6^{o} 55’52.06”	16	*A. djalonesis*

S/N	Study location	Study site	Sample site	Lat. (N)	Long. (E)	Alt.	Species
				4°53'43"	6°55'56"	16	" "
				4° 53'37.13"	6° 55'42.15"	11	*A. liebrechtsiana*
				4°53'43"	6°55'39"	11	" "
				4° 53'36.09"	6° 55'45.69"	11	*A. nobilis*
				4°53'37"	6°55'45"	11	" "
				4° 53'36.49"	6° 55'49.36"	13	*A. vogelii*
				4°53'38"	6°55'45"	13	" "
				04° 53.279"	006° 55.465"	99	*A. liebrechtsiana*
				04° 53.580"	006° 55.672"	49	*A. nobilis*
				4° 53' 39"	6° 55' 40"	14	*A. nobilis*
				4° 53' 81.1"	6° 54' 96.7"	12	" "
				4° 53' 39"	6° 55' 40"	12	*A. vogelii*
				4° 53' 84"	6° 54' 95"	13	" "
				4° 53' 41.97"	6° 55' 41.73"	12	*A. djalonesis*
				4° 53' 81"	6° 54' 96"	14	" "
				4° 53' 00"	6° 54' 90"	14	*A. liebrechtsiana*
				4° 53' 52.17"	6° 54' 56.79"	14	*A. liebrechtsiana*
			UNIPORT-Biodiversity area	04° 54.185"	006° 54.694"	37	*A. vogelii*
				04° 54.171"	006° 54.671"	38	*A. vogelii*
				04° 54.180"	006° 54.702"	48	*A. djalonesis*
				04° 54.197"	006° 54.751"	47	*A. nobilis*
				04° 53.745"	006° 54.913"	-16	*A. liebrechtsiana*
				04° 53.774"	006° 54.923"	37	" "
				04° 53.792"	006° 54.925"	47	" "
				04° 53.817"	006° 54.943"	27	*A. nobilis*
				04° 53.807"	006°54.952"	41	" "
				04° 53.868"	006° 54.955"	45	*A. vogelii*
		Asari-Toru	Abalama	4° 46' 29"	6° 49' 43"	9	*A. vogelii*
				4° 46' 50"	6° 50' 28"	11	*A. nobilis*
				4° 46' 28"	6° 49' 43"	8	*A. djalonesis*
		Khana	Opu-Oko	04° 41.225¹	007° 30.348¹	53	*A. vogelii*, *A. djalonesis*
				04° 40.974¹	007° 30.896¹	26	*A. nobilis*
		Tai	Sakpewa	04° 43.087¹	007° 16.081¹	-21	*A. vogelii*,

S/N	Study location	Study site	Sample site	Lat. (N)	Long. (E)	Alt.	Species
							A. djalonesis
		Emuoha	Isiodu	04^{o} 53.732^{1}	006^{o} 53.824^{1}	37	*A. liebrechtsiana*
				04^{o} 53.725^{1}	006^{o} 53.813^{1}	27	“ “
		Ikwerre	Aluu-Omuoko	04^{o} 54.987^{1}	006^{o} 54.215^{1}	70	*A. vogelii,* *A. djalonesis*
				04^{o} 54.980^{1}	006^{o} 54.219^{1}	48	*A. vogelii,* *A. djalonesis*

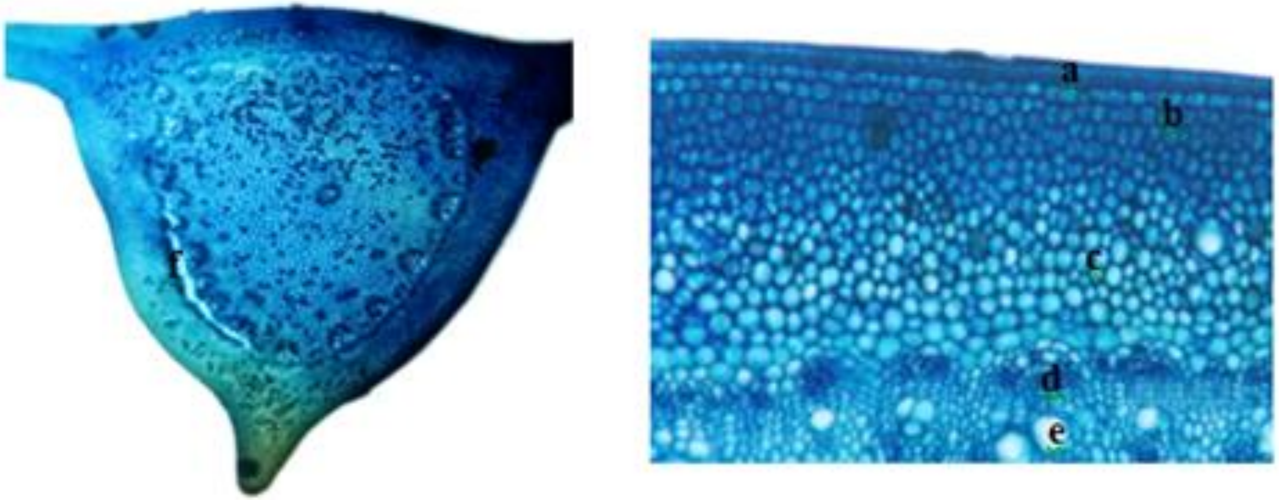


Plate 1. Transverse section of the Leaf/Midrib *Anthocleista djalonesis A. chev* (x 10) a: Epidermis; b: Hypodermis; c: irregular spongy mesophyll parenchyma; d: vascular bundle (phloem) e: vascular bundle (xylem); and f: endoderms

presence of air sacs (Lacunae) in the leaf lamina and vascular bundles. *Anthocleista nobilis* G.Don (Plate 3) recorded two layer of upper epidermis, a single layer of collenchymatous cells, a single layer of elongated palisade mesophyll and spongy mesophyll cells, several idioblastic sclereids, several bicollateral vascular bundles and fourteen medullary bundles, while *Anthocleista vogelii* Planch (Plate 4) had single layer of epidermal cells, single layer of collenchymatous cells and two layers of elongated palisade mesophyll and irregular layers of spongy mesophyll, crescent shaped vascular bundles, several bicollateral vascular bundles arranged in a concentric ring with eight medullary vascular bundles.

3.2 Petiole Anatomy

The petiole anatomy from the various species shows *Anthocleista djalonesis* A.Chev (Plate 5) with single layer of epidermal cell, 3 layers of collenchymatous cells, a layer of sclerenchyma cells, spongy parenchyma cells containing a lot of intercellular spaces. Vascular bundles are amphicribral bicollateral arranged in a concentric ring. There are seven medullary vascular bundles scattered within the pith representing vein traces.

Anthocleista liebrechtsiana De Wild and Th. Dur (Plate 6) transverse section recorded single layer of epidermal cell, 3 layers of collenchymatous cells, single layer of sclerenchymatous cell, numerous stellate shape idioblast and several bicollateral vascular bundles.

Anthocleista nobilis G.Don (Plate 7) had single layer of epidermis, two to three layers of collenchymatous cells, one layer of sclerenchyma cell and several bicollateral vascular bundles. sclerenchymatous idioblast are present, some with stellate shape, others with simple or complex branching, while *Anthocleista vogelii* Planch (Plate 8) with its heart shape, recorded single layer of thick epidermal cells, 2-3 layers of collenchymatous cells, a single layer of sclerenchymatous cell, and several bicollateral vascular bundles. It has numerous idioblast, some with stellate shape, others with simple or complex branching.

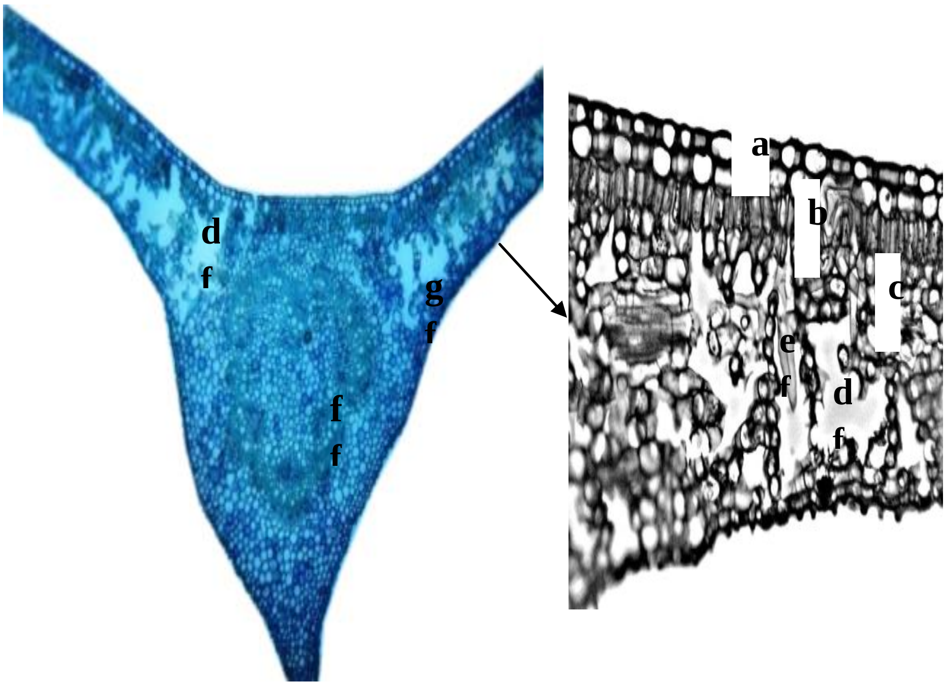


Plate 2. Transverse section of the Leaf / Midrib of *Anthocleista liebrechtsiana* De Wild and Th. Dur (x10)

a: Epidermis; b: Palisade mesophyll parenchyma; c: irregular spongy mesophyll cell; d: intercellular air space; e: Idioblatic sclereids; f: Vascular bundle; and g: Collenchyma.

Table 2. Herbarium voucher samples deposit

S/No	Species	Accession No	UPH No
1.	*A. vogelii*	001	UPH/V/1204
2.	*A. djalonesis*	002	UPH/V/1205
3.	*A .liebrechtsiana*	003	UPH/V/1206
4.	*A .nobilis*	004	UPH/V/1207

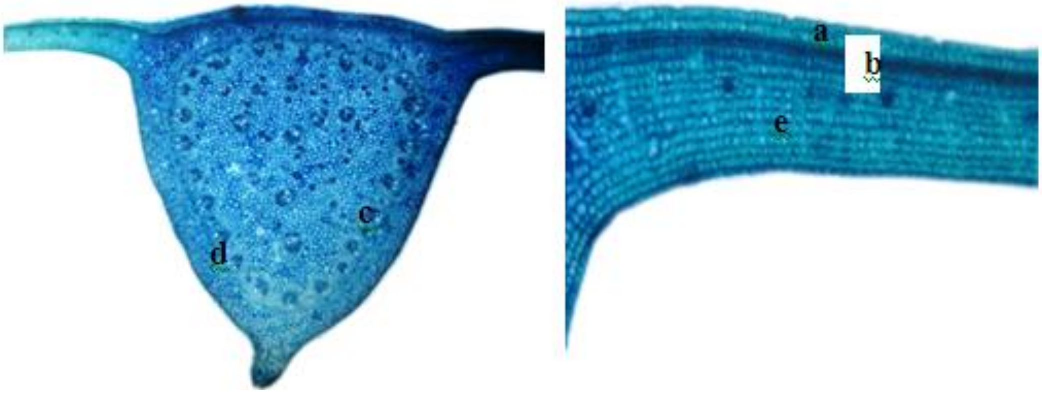


Plate 3. Transverse sections of the leaf/ midrib of Anthocleista nobilis G. don. (x10)a: Epidermis; b: Palisade mesophyll; c: Vascular bundles; d: Endodermis; e: collenchymas

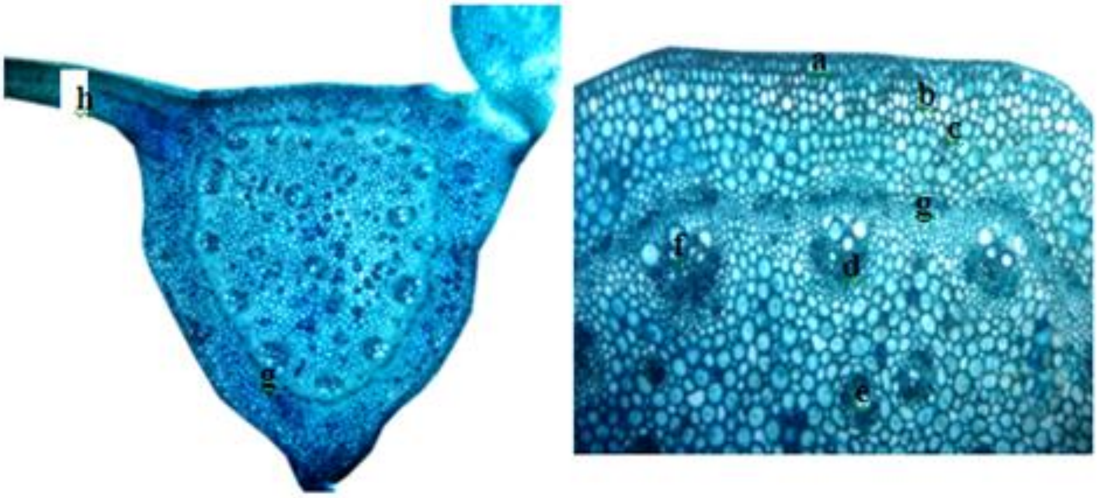


Plate 4. Transverese section of the midrib of Anthoclesta vogelii, Planch (x10) a: Epidermis; b: Palisade mesophyll; c: Spongy mesophyll; d: Crescent vascular bundle; e: Bicollateral vascular bundle (Phleom); f: Vascular bundle (Xylem); g: Endodermis

3.3 Root and Stem Anatomy

The transverse section of the root and stem anatomy illustrated the internal structure of the four species studied (Plates 9 – 16).

The root of *A. djalonensis.* A. Chev (Plate 9) had two layers of epidermis, cortex with the presence of air chamber, endodermis, pericycle, seven vascular bundles and pseudopith. *Anthocleista liebrechtsiana.* De Wild and Th. Dur., (Plate 10) recorded two layers of epidermis, exodermis, several air chambers, cortex, several sclereid, endodermis, 12 vascular bundles and pseudopith, while *A. nobilis.* G. Don (Plate 11) revealed two layers of epidermis, a layer of exodermis, cortex, several air chambers, endodermis, several vascular bundles, and several astrosclereid and pseudopith. *Anthocleista vogelii.* Planch (Plate 12) recorded two layers of epidermis, cortex, several air chambers, endodermis, pericycle, several vascular bundles and pseudopith.

The stem anatomy of *Anthocleista djalonensis,* A. Chev (Plate 13) presented a thick layer of epidermis, cortex, several astrosclereid, 9 layers of collenchyma, endodermis, several vascular buddle, and pseudopith. *Anthocleista liebretchsiana,* De Wild and Th. Dur (Plate 14) had a layer of epidermis, layers of collenchyma, endodermis, several vascular buddles, several astrosclereid and pseudopith. *Anthocleista nobilis.*G. Don (Plate 15) recorded pseudopith, several sclereid, vascular bundles, endodermis, collenchyma cells and epidermal cells. *Anthocleista vogelii.* Planch in Plate 16 shows layers of epidermis, layers of collenchyma, endodermis, several vascular buddles, and few sclereid.

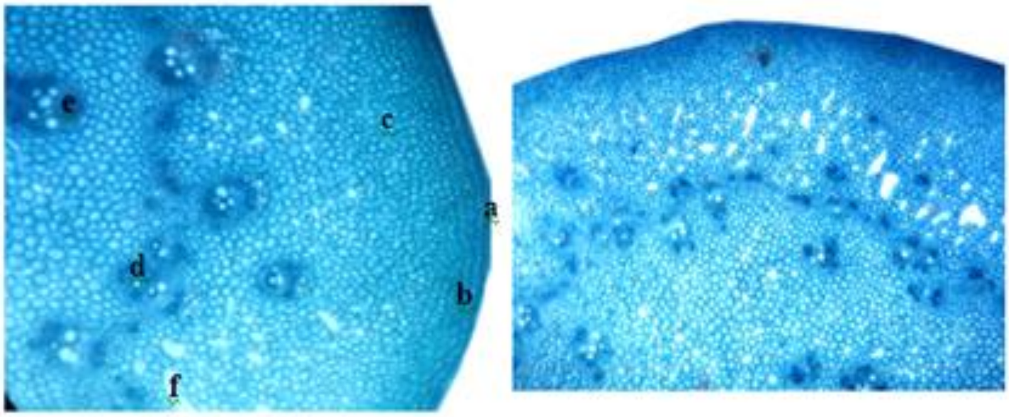
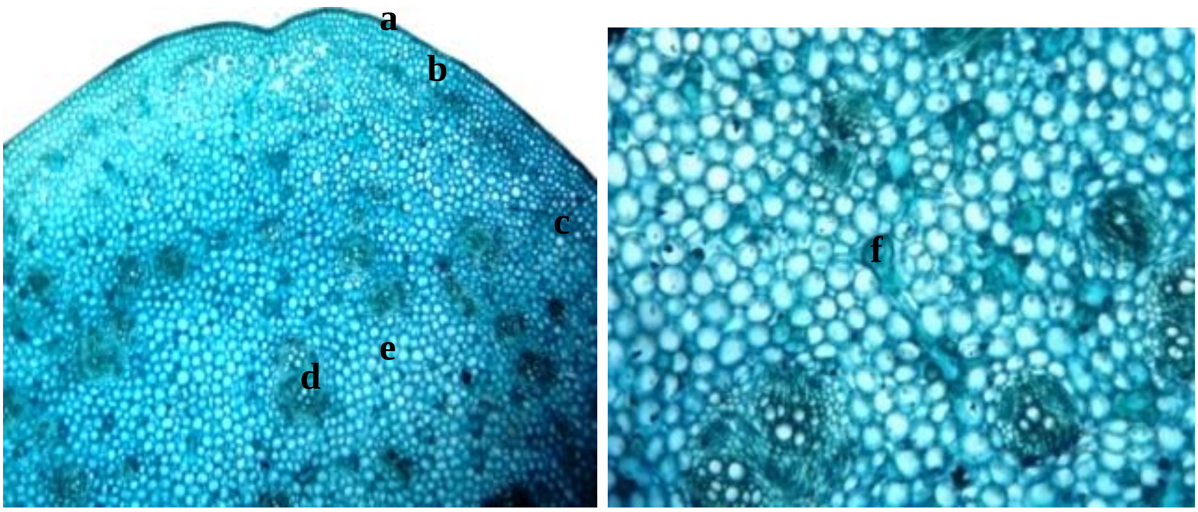


Plate 5. Transverse sections of the petiole of *Anthocieista djalonesis A. chev* x10. a: Epidermis; b: Collenchyma; c: Selernchyma; d: Bascular bundle; e: Medullary bundle f: Intervellular space



Plate, 6. Transverse section of the petiole of *Anthocleista liebrechtsiana* De Wild and Th. Dur (X10). a: Epidermis; b: Collenchyma; c: Vascular bundle; d: Medullary bundle; e: Sclerenchyma: f: Sclerenchymatuos idioblast

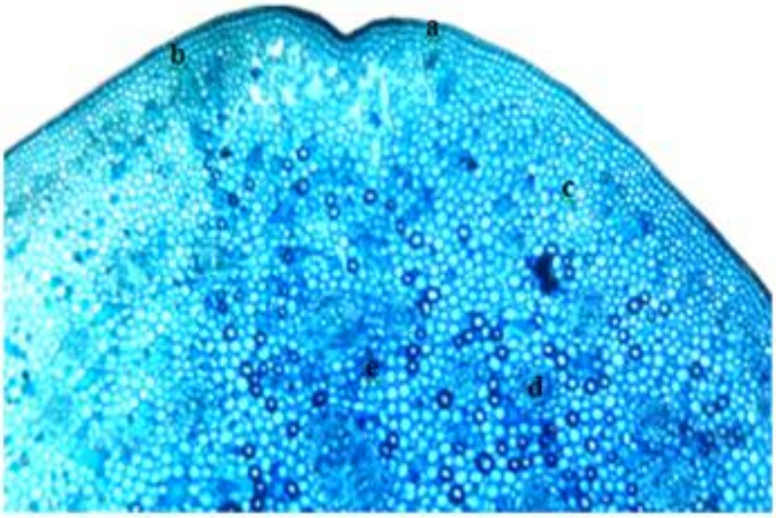


Plate 7. Transverse section of the petiole of *Anthocleista nobitis* G. Don x10, a: Epidermis; b: Collenchyma; c: Sclerenchyma; d: Vasculer bundle; e: Sclerenchymatous idioblast

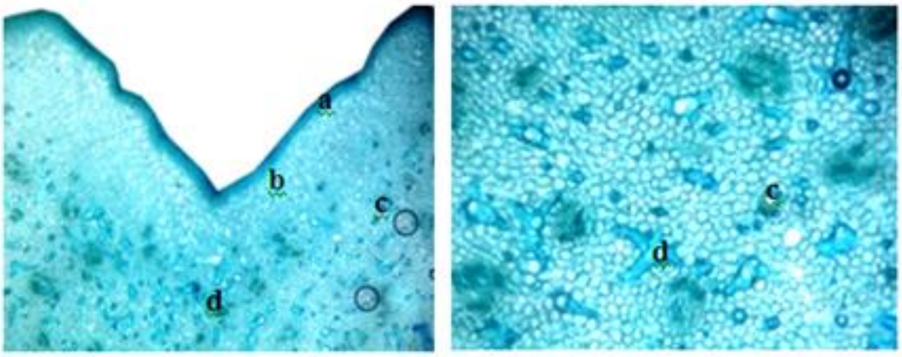


Plate 8. Transverse sections of the petiole of Anphocleista vogelii Planch (x10). A: Epidermis; b: Collenchyma; c: Vascular bundle; d: Selerenchymatous idioblast

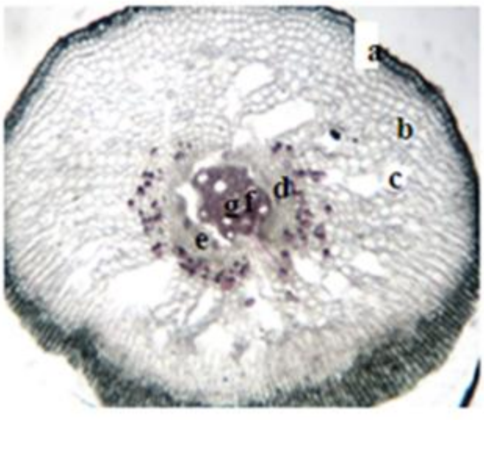


Plate 9. Transverse section of *A. djalonesis*. Root (x10), a: Epidermis; b: Cortex; c: Air chamber; d: Endodermis; e: Pericycle; f: Vascular bundles; g: Pseudopith

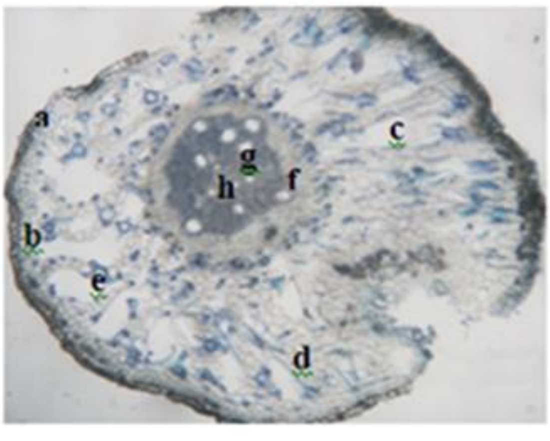


Plate 10. Transverse section of *A. liebretchsiana.* Root (x10), a: Epidermis; b: Exodermis; c: Air space; d: Cortex; e: Sclereid; f: Endodermis; g: Vascular bundles; h: Pseudopith

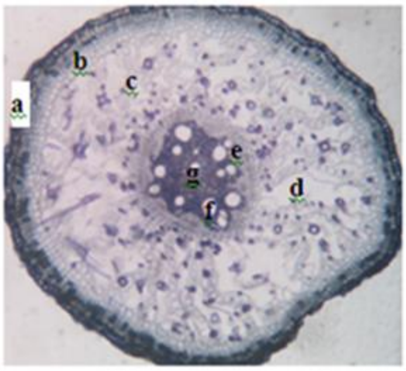


Plate 11. Transverse section of *A. nobilis.* Root (x10), a: Epidermis; b: Exodermis; c: Cortex; d: Air chamber; e: Endodermis; f: Vascular bundles; g: Pseudopith

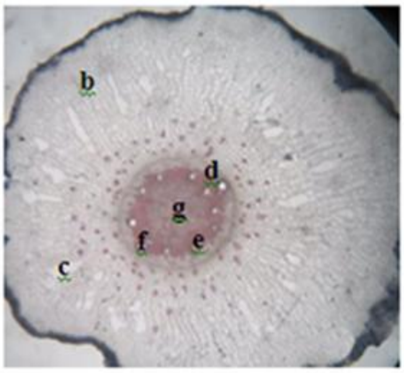


Plate 12. Tranverse section of the Root of *A. vogelii*, (x10). a: Epidermal cell; b: Cortex; c: Air chamber; d: Enodermis; e: Pericycle; f: Vascular bundles; g: Pseudopith

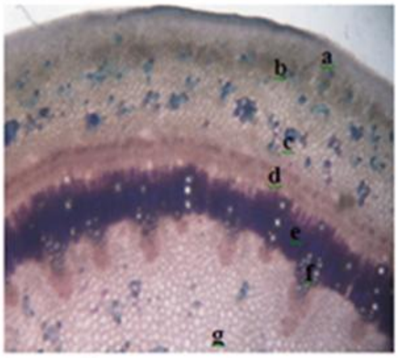


Plate 13. Transverse sections of *A. djalonesis* stem (x40), a: Epidermis; b: Cortex; c: Scleried; d: Endodermis; f: Vascular bundles; g: Pseudopith

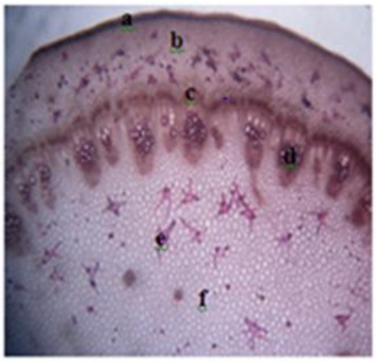


Plate 14. Transverse sections of of *A. liebretchsisna* stem (x40), a: Epidermis; b: Collenchyma; c: Endodermis; d: Vascular bundles; e: Sclereid; f: Pseudopith

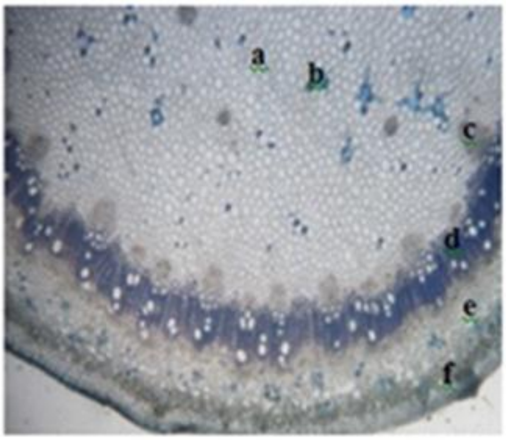


Plate 15. Transverse sections of of *A. nobilis* stem (x40). a: Pseudopith; b: Sclereid; c: Vascular bundle; d: Endodermis; e: Collenchyma cells; f: Epidermal cells

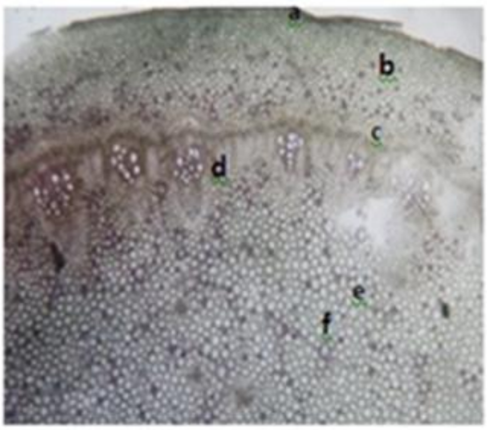


Plate 16. Transverse sections of of *A. vogelii* stem (x40), a: Epidermal cells; b: Collenchyma cells; c: Endodermis; d: Vascular bundle; e: Pseudopith; f: Sclereid

4. DISCUSSION

Plant species found in either tropical or sub-tropical region has mechanism for its survival in such place. The adaptation may be due to the plant physiological, and biochemical roles potential in adapting to the kind of environment found. This makes species partly dependent on any statistical inference, by relating the anatomical traits to ecological preferences which might be alternatively explained by phylogenetic inertia affecting both the similarity of anatomical traits among closely related taxa and the similarity of ecological niches such taxa occupy [1]. Plants species are known to have different requirement of environmental conditions which can directly or indirectly be sources of ecological stress or / and balance for such species [4]. To survive and reproduce, all living organisms must adjust to conditions imposed on them by their environment. These have made plants to develop a variety of strategies and mechanisms in terms of changes in morpho-anatomical structures to adapt to any changes in their environment. Thus Plants species have to respond positively or negatively to changes in their habitat in order to survive [5].

Plants species of different families or same family have varied genetic potential to adopt wide range of environmental conditions. This adaptation potential might be due to varying physiological, biochemical and anatomical characteristics [8]. A number of environmental factors including available moisture are known to influence the anatomy of plant species. This has informed the study on the ecological adaptation *Anthocleista* species under moisture gradient ranging from dry mesophytic secondary terrestrial forest and mesophytic to wetland condition in parts of Niger Delta.

The result obtained from this investigation has though revealed some similarities and differences among the four species of *Anthocleista* in term of distribution and abundance in the anatomical features adaptation to environmental conditions. It is suggested that anatomical in plants might be more important systematically than morphological features due to less susceptibility to environmental change; leaf anatomy appears to vary according to the environment [39]; however, it has been reported that variation in leaf anatomy might be useful in assessing strong environmental influences on plants [11]. Though the leaf anatomy has recorded similarities and differences in their vascular structure (Edwin-Wosu and Omoikhabon *in press*) in term of distribution and abundance, the present study observed that anatomical features are generally similar to all the species, which indicate a phylogenetic relatedness of the taxa.

Variation in anatomical features of plants has often been attributed to environmental factors [40]. The most striking feature observed was the presence of sclerechymatous idioblast reaffirming the assertion by Leeuwenberg and Leehourts [41]. The present study observed that sclerenchymatious idioblasts are numerous in *A. liebrechtisiana*, few in *A. nobilis* and *A. vogelii* but lacking in *A. djalonesis*. Earlier study has recorded *A. djalonesis* as a secondary terrestrial forest species with a dry mesophytic habitat adaptation [15]. This may be the reason why it lacks sclerenchymatous idioblast, and contains many intercellular spaces as well as its cuticle well developed to prevent excessive water loss. *Anthocleista nobilis* and *A. vogelii* exhibited greater ecological amplitude hence capable to establish in various habitat lying along an environmental gradient [15]. This also corroborates the assertion that landscape are never static, their element are in permanent temporal and spatial flux [42, 46]. The numerous sclerenchymatious idioblast and air sacs (Lacunae) observed in *A. liebrechtsiana* show the preference for adaptation is a semi-aquatic (Wetland) environment. The species is known for its low ecological amplitude with a localized distribution because of the narrow range of condition on which their growth depend [15]. Such species are called "*habitat specialist*" because they have a significant positive association with their habitat or they cannot survive outside their habitat [44]. Specialist species have narrow niche breadth and occur only in a small geographical range where appropriate resources are available.

Presence of sclerenchymatous idioblast and lacunae appear to be characteristics features of species growing in wetland associated with moisture gradient. Observation has shown that despite the species profound preference for tropical and mesophytic environment, they also display disparity in light of their features in restricted occurrence in certain ecological habitats [15, 16]. Similar study has indicated *A. djalonesis, A. nobilis*, and *A. vogelii* as prevalent and adapted to low land secondary vegetation forest while *A. liebrectsiana* is prevalent and adapted to fresh water swamp forest zone [16].

Plants which characteristically grow in certain niches often show a type of structure believed to be adapted to that particular environment; therefore sclerenchymatous idioblast has been identify as an adaptive feature of plants to watery niche [12].

The presence of sclereide of various shapes (sclerenchymatous idioblast) in leaves and other tissue is the characteristic of hydrophytes. The variation observed in the leaf anatomy was due to environmental variability of anatomical characters. Therefore the sclerenchymatous idioblast seen in *A. liebrectsiana*, *A. nobilis* and *A. vogelli* confirmed these species to be semi-aquatic while *A. djalonesis* is mesophytic in their habit adaptation. Related study of such environmental influence as low temperature, drought, light and elevation on responses of leaf structures and general ecological trend have been recorded [45, 46, 47]. Mesophytes are plants that are exposed to an environment where it is neither too dry nor too wet; they do not need any extreme adaptations. However, the mesophytic adaptation of *A. djalonesis* is associated with thicker epidermal layer, multiple layers of hypodermis, thicker mesophyll tissues with increased number of palisade layers and thicker leaves. This is consistent with Rocas *et al*. [46] where instances of plants in low temperature zones are characterized with smaller leaf area, thicker epidermis, thicker mesophyll tissue and thicker leaves. Similarly, increased number of palisade layers with small cell volume, decreased number of spongy layers with small cell volume and smaller intercellular spaces has been recorded among plants in zones of water shortage [48]. Smaller and thicker leaves; well-developed epidermal cuticles and trichomes; a thicker epidermal layer composed of small cells; the appearance of hypodermal layer; well-developed palisade tissues and tightly arranged spongy tissues have also been recorded among plants in zones of high light intensity [49, 50, 46]. In plants, leaf anatomy might provide insight to assess adaptive variation and ultimately evolutionary change [11].

The anatomical study has also revealed the internal structure of the stem and root of the four species of the genus *Anthocleista* studied under moisture gradients. The stem epidermis, collenchyma, endodermis, xylem, phloem, parenchyma and sclerenchyma cells are present in abundance distribution in the four species while sclereid is found in abundance distribution in *A. liebrechtsiana* and *A. nobilis*, moderate in the stem of *A. vogelii* and very low distribution in *A. djalonesis* which has a well-developed cortex. In the root; epidermis, cortex, endodermis and vascular bundles are present in abundance distribution in the root of the four species, air chamber is present in abundance distribution in the root of *A. liebrechtsiana* and *A. nobilis*, and moderate in distribution in the root of *A. vogelii* and *A. djalonesis*, which were also noted for the presence of pericycle while sclereid was observed in *A. liebrechtsiana* and *A. nobilis*. Anatomical characters may serve as reliable indicators in the study and understanding of ecological adaptation of living organisms. Therefore anatomical studies of leaf, petiole, stem and root could be used to deduce the influence of environmental and ecological niche adaptation on the anatomy of *Anthocleista* species found in parts of the Niger-Delta.

5. CONCLUSION

The result obtained from the anatomical studies of the four *Anthocleista* species shows that the environment and ecological niches of adaptation have an influence in their anatomical structures. The observed variation in the anatomical features of the plants can be attributed to environmental factors such as the moisture gradient beside other factors not considered in this study. The anatomical features seen in the plants have revealed ecological preference for both a normal terrestrial (dry mesophytic and mesophytic) and wetland (seasonally flooded environment) conditions by the *Anthocleista* species, hence the plant species had evolved structures such as sclerenchymatous idioblast and lacunae to adapt to the niche they occupy.

ACKNOWLEDGEMENT

The authors wish to acknowledge the effort and contributions of the laboratory technologist of the Anatomy Unit in the Department of Plant Science and Biotechnology for the anatomical sectioning of the sampled species as well the technologist in the herbarium for the processing, annotation, preservation and storage of the voucher specimens of the species.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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