UNIVERSITY OF ILORIN

THE TWO HUNDRED ANDTWENTY-NINETH(229TH) INAUGURAL LECTURE

''THE TINY GIANT OF THE UNSEEN THAT EXPLAINS THE SEEN''

By

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PREAMBLE

The presentation of an inaugural lecture is a significant milestone in the academic career of a full professor and provides a platform to share past research and introduce new ideas to a diverse academic and non-academic audience. For the new Professors, the lecture provides an opportunity to present their career so far, update colleagues on current and future research plans, and introduce their field of expertise to wider audiences.

I thank the Almighty Allah for giving me this day to address this auspicious gathering about my journey so far in the academic arena. This is the 229th edition of the Inaugural Lecture of the University of Ilorin; the 3rd from the Department of Plant Biology, and the 2nd in Plant Anatomy and Taxonomy. I started my career as a Science Teacher after I obtained Nigerian Certificate in Education in 1992 under the then Ilorin West Local Government Education Authority (IWLGEA) and was posted to Hi Iwanu Nasirudeen LGEA, Ilorin in 1992. I was later transferred to Ansarul Islam LGEA, Okekere,

Ilorin. My career as a teacher in primary school lasted for 10 years (1992 to 2002).

In 1995, Ilorin West Local Government Education Authority (IWLGEA) approved "A Study Leave With Pay" for me so as to pursue my University education, after I secured admission to study Botany in the Department of Biological Sciences in the 1993/1994 Academic Session. In 2002, immediately I obtained M.Sc. Botany, my supervisor, Professor Felix Ayotunde Oladele (1949 – 2016) strongly recommended me for appointment at the then Department of Biological Sciences mainly because of paucity of staff in his area of specialization; Plant Anatomy and Systematics, and this was the beginning of my academic history. I was appointed as an Assistant Lecturer in 2002 and rose to the rank of Professor in 2018.

INTRODUCTION

Botany (Plant Biology or Plant Science) is a branch of Biological Sciences which deals with plants. It studies the physiology, genetic make-up, chemical composition, responses to objects, morphology, anatomy, habitats, respiration, ecology, feeding and classification of the plants. Botany is one of the **natural sciences** which form the basis for applied sciences and focus on the universe and rules of nature. Biology (Botany and Zoology), chemistry and physics are among the major study areas of the discipline.

Furthermore, the natural sciences are more suitably referred to as **basic sciences.** The basic sciences are defined as scientific disciplines of mathematics, physics, chemistry and biology. They are called basic sciences because they provide a fundamental understanding of natural phenomena and the processes by which natural resources are transformed. On the other hands, applied science is the use of the scientific method and knowledge obtained via conclusions from the method to attain practical goals (Bunge, 1966). It includes a broad range of disciplines such as engineering and medicine. Applied science is often contrasted with basic science, which is focused on advancing scientific theories and laws that explain and predict events in the natural world.

It is becoming a thing of concern that some of the basic sciences programmes in our Universities are becoming endangered. Some of the newly created universities especially the private, and some state-owned universities are not offering these courses especially Botany and Zoology. To make these courses relevant, some universities

were engaged in nomenclatural wars by adopting a more catching names such as Plant Biology (as the case here at the University of Ilorin), Plant Science, Plant Biology and Biotechnology etc. It has become an annual event for us in the Department of Plant Biology to emphasize the essence of studying the course to the newly admitted students.

Plant Biology or Botany is a course that is little understood by students and general public in Nigeria with respect to its significance and professional relevance to humanity. In other to stimulate the interest of the students, lectures were delivered annually to educate our new intakes on the various prospects and economic potentials of the course. To solve this problem, in 2015 a book titled ***Career Prospects in Plant Biology*** was authored by late Prof. Felix Ayotunde Oladele and myself to serve this purpose.

Plant Anatomy and Systematics

Plant anatomy is a core course in the study of plant biology. In the study of plant structure, it is important to recognize that there is a fundamental difference between plant and animal development. In plants, the environment plays a greater role in regulating development. As a result, plant cells are more adapted to changes. The internal structure of the same plant can be slightly different when grown in different environments. Although, distinct cell layers and tissues can be seen, different cell and tissue types do not occur as large homogeneous masses and no sharp demarcation exists as in animal organs. To complicate matters further, an apical to basal as well as a radial gradation of "age" exists within the plant body. Plant anatomy plays an important role in the understanding of plant biology. A realistic interpretation of morphology, physiology, and phylogeny must be based on a thorough knowledge of the structure of cells and tissues. Furthermore, the knowledge of plant structure is also essential to solve many challenges such as the identification of unknown plants, food contaminants, and forensic issues.

On the other hand, Systematics or Taxonomy is the study of the various kinds of organisms and their relationships in terms of similarities and differences. Systematists collect and study the variety of plants and animals and group them according to patterns of variation. They are also vitally interested in determining the evolutionary history of species and the features that result in adaptation to the environment. Taxonomy and systematics are two concepts related to the study of diversification of living forms and the

relationships of living things through time. The main difference between taxonomy and systematics is that taxonomy is involved in the classification and naming of organisms whereas systematics is involved in the determination of evolutionary relationships of organisms. This means that, systematics ascertain the sharing of the common ancestry by different organisms. In taxonomy, different organisms are scientifically named and grouped in different taxonomic levels. Organisms are grouped based on their evolutionary relationships. Taxonomy can be considered as a branch of systematics. Both taxonomy and systematics studies use morphological, behavioral, genetics, and the biochemical observations.

MY AREA OF RESEARCH

Plant Anatomy and Plant Taxonomy are my areas of specialization in which I worked tirelessly with my supervisor, mentor and academic father, Prof. F. A. Oladele for many years before his demise in 2016. For more than two decades (precisely 20 years, 2 months and 7 days today), we have used our knowledge of Plant Anatomy and Taxonomy to unravel different interesting phenomenon in plants. He guided me all through the rough times, and he was successful in putting my legs on the right path. With his relentless efforts, I started focusing my research efforts on **thetiny,unseen** part of the plant body called **stoma** (pl. **stomata**).

Stomata are microscopic epidermal cells in the surfaces of the plants, especially on the leaf surfaces, more prominent on the abaxial/lower surfaces of many plants. They are also seen on the stem epidermis, petioles and floral parts. A stoma is made up of two specialised parenchymatous cells called **guard cells** which are bean-shaped or kidney-shaped in dicot plants, or dumb-bell shaped or hour glass-shaped in monocots (Fig. 1). The stoma may be surrounded by cells which may or may not differ in shape and content from other epidermal cells. According to Oladele (2002), when these cells are clearly distinct, they are called **Subsidiary cells** or **Accessory cells** (Fig. 2). The adjacent cells participate in the osmotic changes involved in the movement of the guard cells. Both types of cells i.e. guard cells and subsidiary cells are organised to form an anatomical unit called **Stomatal Complex** or **Stomatal Apparatus** (Fig. 2). Based on the relationships between these cells and on the number and arrangement of the subsidiary cells, **types of stomatal complex** (e.g. paracytic, diacytic, anisocytic, anomocytic etc) could be determined as shown in Fig. 3 below.

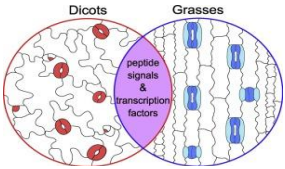

Fig. 1: Stomata of dicot and monocot plants
(**Source:** Science Direct)

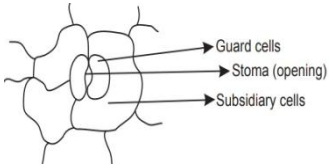

Fig.2: Stomatal complex showing subsidiary cells

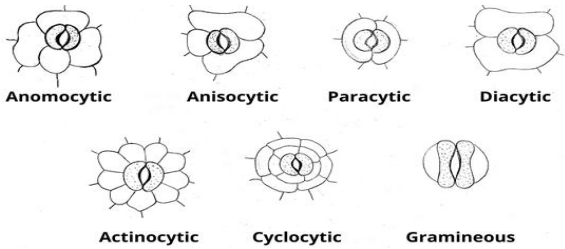

Fig. 3: Stomatal complex types

Stomata have **two main functions**; they allow for **gas exchange**, acting as an **entryway for carbon dioxide (CO_2) and releasing the Oxygen (O_2)** that we breathe. The other main function is **regulating water movement through transpiration**. Stomata vary in shape and size, being able to change to adapt to the different environmental factors, thus ensuring optimum conditions for photosynthesis. Just as animals breathe, plants do so too through the stomata. The gaseous exchange that they are responsible for, facilitate photosynthesis by letting in the essential CO_2. Carbon dioxide is used as the fuel to drive photosynthesis, which generates oxygen as a byproduct, which is then released to the atmosphere. Now, how can stomata facilitate photosynthesis? They can do so by playing an important role in transpiration. Transpiration is defined as the absorption of water into the plant, its distribution within it and its final release to the atmosphere from the aerial parts. Transpiration through stomata creates water potential within the plant, which in turn, favours the passive water absorption in the roots, which will then be transported throughout the plant by the xylem.

Stomata regulate transpiration and CO_2 intake by changing its size depending on the environmental signals. In optimum conditions,

stomata are wide open, allowing gaseous exchange with the atmosphere. **Guard cells are responsible for changing pore size**; they do so by expanding or contracting themselves effectively for opening and closing stomata (Fig. 4). For stomatal opening, water is rushed into the guard cells due to osmosis, which is dependent on potassium concentration in the cells. Potassium enters and leaves the cells through active transport, depending on environmental triggers. Such other triggers include ion exchange, temperature, light, hormone signaling, CO_2 concentration etc.

The essence of the stomata activities cumulating in photosynthesis and respiration especially right from a seedling will ensure steady growth and development of a plant, a bigger and **giant** object that can be **seen** with unaided eyes. Thus, because of these roles in relation to their microscopic size, stomata are **thetiny giants**. And are therefore, **the unseen that explains the seen**.

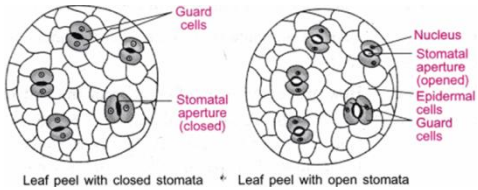

Fig. 4: Stomatal opening and closing (Source:https://www.cbsesamplepapers.info/cbse/cbse-class-10-science-practical-skills-stomata)

MY CONTRIBUTION TO KNOWLEDGE

Mr. Vice Chancellor sir, plant anatomy and taxonomy have been the focus of my research. The outcomes of which have been utilized to solve myriad of human challenges. I have graduated 5 Ph.D. (with other 5 ongoing), 21 M.Sc., and numerous B.Sc. students who formed parts of my research team. To date, I have published over one hundred manuscripts comprising ninety-six (96) journal articles, two (2) conference proceedings, five (5) books, and three (3) chapters-in books. These publications are hereby presented as my contributions to knowledge:

A. Unraveling some taxonomic issues

Mr. Vice Chancellor sir, there is a popular saying that "the name of a plant is the literature to its usefulness." The import of this is that a plant without a name, no matter how useful it is, is useless. Taxonomy (or systematics) is a vast study area that employs virtually all available

evidence to identify, classify and name plants. Features such as morphology, anatomy, cytology, chemical composition, karyotype, DNA sequencing, molecular biology, serology, habitat, and many others are good taxonomic tools used by taxonomists and systematists to delimit plant taxa.

I have published several papers to show that Foliar and Wood Anatomical characters can be conveniently used to solve identification problems in plants. Many of these papers have been cited globally. Mostly, I employed the leaf epidermal features where **thetiny giants** majorly reside, along with other tools such as Sodium Dodecyl Sulphate-Polyacrylamide Gel Electrophoresis (SDS-PAGE electropherograms), numerical taxonomy, molecular characterisation, leaf chlorophyll content, chemotaxonomy, and seed electrophoretic to delimit many plant species. Leaf epidermal study is becoming more important because taxonomists, drug industry workers, nutritionists or food scientists, toxicologists (especially the animal toxicologists), and investigators have all found it helpful in plant identification.

1. **Foliar micromorphological studies,** especially the stomatal anatomy. I carried out a foliar micromorphological study on some plant species to determine the patterns of variation in their epidermal characteristics and search for useful and stable anatomical characters that could be used for their identification:

a. **Species of genus *Ocimum*L. [Lamiaceae](AbdulRahaman and Oladele, 2005)**. *Ocimum* (basil; efinrin – Yoruba; nchanwu – Igbo; daidoya - Hausa) is of considerable economic importance in West Africa, with about 150 species (Dutta, 1979). In West Africa, six species were found growing mainly in the forest regions of the south, while few others are found in the savannas of the north (Hutchinson and Dalziel, 1963). *Ocimum* is used in curing many diseases and as a culinary, insect repellant, and anthelminthic, among other known uses (Cantino *et al.*, 1992). Earlier researchersused calyx and corolla for their delimitation, which are usually lacking in commercial samples. To augment this, the focus was on the microscopic examination of the six *Ocimum* species (*O. basilicum* L., *O. gratissimum* L., *O. canum*Sims.,*O. suave* Willd., *O. lamifolium* Hochst. and *O. irvinei* J.K.

Morton) as taxonomic and diagnostic features among the genus. The results showed that three types of the stomatal complex,namely diacytic, paracytic and anisocyticwere present, with diacytic and paracytic being most frequently occurring on both surfaces of all the species. Anisocytic type occurred only in three species on one surface –

abaxial in *O. gratissimum* and *O. basilicum*, while it occurred on adaxial in *O. canum*. Glandular and non-glandular trichomes occurred in five species except *O. irvinei* which has only glandular type. Stomatal density, index and size, trichome density and index, and frequencies varied from species to species. These features are very useful as an additional tool in identifying the six species, and a key was drawn.

b. **Species of *Dioscorea* L. [Dioscoreaceae] (AbdulRahaman *et al.*, 2009)**. In this study, anatomical analysis was used to provide baseline data that may be useful for further studies on the genus *Dioscorea* (yam; isu, esuni – Yoruba; doya, duru - Hausa). The results revealed that *Dioscorea alata* L. (white yam, water yam; isu ewura) has three stomatal complex types (paracytic, anisocytic and tetracytic), while *Dioscorea bulbifera* L. (potato yam) showed paracytic and anisocytic types. Only anisocytic stomata was found in *Dioscorea cayenensis* Lam. (yellow yam) Features such as stomatal index ranges from 24 in *D. alata* to 47 in *D. cayenensis*. Variation in stomatal size was also observed. To this end, an indented dichotomous key based on the foregoingstomatal features was constructed to distinguish and identify the species.

c. **Some *Jatropha* species L. [Euphorbiacae] (AbdulRahaman and Oladele, 2010d)**. Flower colour has been used to identify the species of *Jatropha* (pignut, fignut; lapalapa – Yoruba; ncheogba - Igbo) but this character has a limited use as it is applicable when the plants are flowering. The essence of our study is to therefore use a more fundamental method like anatomicalfeatures. Anatomically, paracytic stomata occur in all the species with 100 % frequency while anisocytic and anomocytic types are also present in *J. multifida* and *J. podagrica* respectively. Stomatal size is large (60.05 µm) in *J. curcas* and small (26.64 µm) in *J multifida*. Stomatal density is highest (44 mm^{-2}) in *J. podagrica* and lowest (10 mm^{-2}) in *J. multifida*. Epidermal cell is large (243 µm) in size on adaxial surface of *J. neriifolia* and small (56.33 µm) on abaxial surface of *J. podagrica*. Trichome is present only in *J. neriifolia*. These epidermal features (i.e. stomata and trichomes) are used to complement species delimitation in *Jatropha*.

d. **Speciesof *Amaranthus* L. [Amaranthaceae] (AbdulRahaman and Oladele, 2010b)**. Some species of the genus *Amaranthus* (amaranth; tete, efo tete – Yoruba; aleyefo danye – Hausa; akwukwo – Igbo) (e.g., *A. caudatus* and *A. tricolor*) are important ornamentals.

Some are often cultivated or harvested from the wild, and leaves are used as spinach, e.g., *A. hybridus*, *A. viridis*, *A. tricolor*, *A. cruentus*, and *A. dubius* in part of West Africa. Others, like *A. spinosus* are troublesome weeds of cultivated land and waste places (Akobundu and Agyakwa, 1998). However, many species of *Amaranthus* are not easy to identify because they cross-fertilize readily (Dupriez and De Leener, 1989).

Leaf anatomical studies of eight *Amaranthus* species (*A. caudatus* L., *A. cruentus* (L.) Sauer, *A. dubius* (L.) Mart ex Thell., *A. graecizans* L., *A. hybridus* L., *A. spinosus* L., *A. tricolor* L. and *A. viridis* L.) were carried out. Each species possesses one or more anatomical character(s) as its diagnostic feature(s). Stomata occur in all eight species, but only 5 have trichomes; trichomes are conspicuously absent in *A. tricolor*, *A. graecizans*, and *A. viridis*. *Amaranthus spinosus* has high frequency of anomocytic stomata (30 %) and uniseriate trichomes (100 %) on both surfaces; *A. caudatus* possesses high stomatal density (375 mm^{-2}) on abaxial surface and high trichome index (4.92 % and 10.57 %) on both surfaces, respectively. *A. dubius* has 100 % frequency of tetracytic stomata and 100 % frequency of prickle trichomes; among other species with heterogeneous stomatal types, *A tricolor* has higher frequency of tetracytic stomata (80 %). *A. cruentus* has the highest number of stomata heterogeneity, 4 types and glandular peltate trichomes; pericytic stomata occurs only in *A. viridis*; high stomata index on abaxial (49.53) and adaxial (38.64 %) surfaces occur in *A. hybridus*, it also has multicellular scale trichomes; and *A. graecizans* has equal distribution of stomata (i.e. index and density) on both surfaces.

e. **Species of the family Malvaceae Juss. (AbdulRahaman and Oladele, 2010a)**. Leaf epidermal features of three species of the family Malvaceae, namely, *Hibiscus rosa-sinensis* L.(garden hibiscus, bissap, zobo; ako-ifin - Yoruba; kekeke - Igbo), *H. sabdariffa* L. (roselle, zobo; karelawar maciji, sobo - Hausa), and *Abelmoschus esculentus* (L.) Moench (okra, okro; illa, ilasa - Yoruba; kubeewaa, tasawa - Hausa; okweje, ọkwurụ - Igbo) were studied. Four (4) types of stomatal complex (paracytic, anisocytic, tetracytic and anomocytic), and two (2) types of trichomes (unicellular and multicellular) were recognized in the thee species. A high percentage of paracytic stomata and trichome density were found only in *A. esculentus*. These data supported its separation from the genus *Hibiscus*. Tetracytic stomata are also exclusive to *H. sabdariffa*. Based on the occurrence of stomata

on the leaf surface, leaves are either amphistomatic or hypostomatic. Epidermal cells are irregular in shape, and their anticlinal walls are undulating, curved, or straight. These features varied from one species to the other and are thus considered good taxonomic characters to complement the physical morphological features.

f. **Species of *Lannea* A. Rich. in Guillem. [Anacardiaceae] (AbdulRahaman *et al.*, 2014b)**. Leaf epidermal morphology of seven species of *Lannea* (*L. acida, L. egregia, L. fruticosa, L. kerstingii, L. microcarpa, L. schimperii* and *L. welwitschii*) was studied.The study revealed that several interesting characters, such as anticlinal cell wall pattern, epidermal cell wall shape, epidermal cell size, stomatal complex types, stomatal density, stomatal index, stomatal size, and trichomes, are constant and variable within and between some species. Anticlinal wall patterns are straight, curved, round, and undulate in all the sevenspecies. Epidermal cell wall shapes are polygonal on both leaf surfaces, except in *L. fruticosa*. Stomata occur only on the abaxial surface in all the studied species. Cyclocytic and anomocytic stomata are the only two types found. The anomocytic type occurred in five species (*L. acida, L. egregia, L. kerstingii, L. schimperii,* and *L. welwitschii*). Only three species possessed trichomes namely *L. kerstingii, L. schimperii* and *L. fruticosa*.

g. **Varieties of *Capsicum annuum* L. [Solanaceae] (Zhigila *et al.*, 2015a)**. *Capsicum annuum* (sweet peppers, chili pepper, bell peper; ata rodo, ata wewe - Yoruba; barkoonoo, tattasai – Hausa; ose oyinbo, totoshi - Igbo) are often used as a bulking agent in ready-made meals and take-away food on account of being cheap, colourful and strong flavour. The colour of pepper increases the visual appeal of the food, making it more appetizing. Foods containing peppers, especially chilli peppers, have a strong aftertaste which is due to the presence ofcapsinoids (Grubben *et al*., 2004). The classification of *Capsicum* species has been a subject of debate and argument among botanists and taxonomists. In resolving this problem, leaf epidermal micro-morphological features were studied in five (5) varieties of *C. annuum* (var. *abbreviatum*, var. *accuminatum*, var. *annuum*, var. *glabriusculum* and var. *grossum*) both quantitatively and qualitatively to evaluate the reliability of these characters for taxonomic consideration. The leaves are amphistomatic with two (2) types of stoma(anisocytic and tetracytic) in all the five varieties. There was high frequency of anisject of debate and argument amocytic stomata (66.67 % – 95.24 %) and low tetracytic stomata (4.76 – 33.33 %). Trichomes were absent on both

leaf surfaces of var. *grossum* and var. *abbreviatum*; it was present on both surfaces (amphitrichomatic) of var. *accuminatum*,while it was epitrichomatic and hypotrichomatic in varieties *glabriusculum* and *annuum* respectively. These features were found to be of good and reliable taxonomic tools for delimiting the five varieties of *C. annuum*.

h. ***Eriospermum abyssinicum* Baker [Asparagaceae] (AbdulRahaman *et al.*, 2020)**. Only a few genera of the family Asparagaceae have been subjected to analyticalstudies (Adeyemi, 1981). This accounts for the little or no information on *Eriospermum*. In West Africa, *E. abyssinicum* (cottonseed lily) occurs in northern Nigeria, Ghana, Upper Volta and Guinea (Hepper, 1968). Herbarium records show that it is found in Ilorin, Nupe, Zaria, Mambila Plateau and Yola. *Eriospermum abyssinicum* (cotton-seed lily) is medicinally useful as molluscicides i.e. an agent for destroying molluscs such as snails (Adewumi and Sofowora, 1980).

The Ilorin population of the *E. abyssinicum* has two distinct morphological forms (i.e. big and small corms which need to be studied to confirm their taxonomic status. This study elucidated the morphological and physiological features of available samples of *E. abyssinicum* (both live and herbarium specimens) in Ilorin, Nigeria. Though there are differences between these two forms in external features, anatomical observations and transpiration rates, splitting the species is yet to be substantiated. Hence, there is need for further studiesin molecular, phytochemistry and cytology to delimit the two morphological forms into taxonomic status.

2. **Palynological and carpological features (AbdulRahaman *et al.*, 2014a)**. Mr. Vice Chancellor sir, in this study, the authors intended to document pollen, fruit, and seed characteristics of 4 members of the genus *Jatropha* (*J. curcas* L., *J. gossypifolia* L., *J. multifida* L. and *J. podagrica* Hook.) and examine how these characters relate to our current understanding of the systematics of these plants. Four types of pollens (panporate, syncolpate, monovesiculate and bivesiculate) were seen in the 4 species. Panporate occurs in all the species with 100 % frequency in *J. curcas* and *J. multifida*. Syncolpate, and monovesiculate and bivesiculate pollens occurred only in *J. gossypifolia* and *J. podagrica* respectively. The values of the lowest mean fruit and seed length (12.10 mm and 6.17 mm respectively) and width (13.44 mm and 4.14 mm respectively) were in *J. gossypifolia*. The highest mean fruit and seed length

(27.52 mm) and width (12.44 mm) values were recorded in *J. multifida* respectively. Our study revealed that a combination of palynological and carpological features is important in the taxonomy and systematics of the four *Jatropha* species.

3. **Seed electrophoretic characterization**: Protein electrophoresis has been utilized successfully to study heredity of various plants and its germplasm for its usage in crop breeding programme (Javaid *et al.*, 2004). In all biochemical techniques, SDS-PAGE is widely utilized due to its legitimacy and simplicity for describing the genetic structure of plants germplasm (Javaid *et al.*, 2004). Protein electrophoresis has been utilized successfully to study the hereditary of various plants and their germplasm for its usage in crop breeding programme. The relevance of SDS-PAGE in plant taxonomy is established in the following studies:

a. **Accessions of *Abelmoschus esculentus* (L.) Moench [Malvaceae] in Nigeria (AbdulRahaman *et al.*, 2015b)**. *Abelmoschus esculentus* (okra; illa – Yoruba; bubewa, kubewa – Hausa; okuru, oku, okuko, okpara, okpo - Igbo) is an economically important vegetable crop grown in tropical and sub-tropical parts of the world. Electrophoresis of seed proteins showed a total of 11 bands in NGB01288 and NGB01280; also all the intensity was presence, whereas for rest of the genotypes some bands were absent. The critical bands for identification were the bands at Rf values 0.877, 0.729, 0.491, 0.237, 0.147 and 0.082 which formed the 2^{nd}, 4^{th}, 7^{th}, 9^{th}, 10^{th} and 11^{th} bands respectively. Dendrogram was formed and clustered into different groups which revealed a close relationship among all the accessions. Hence, the present study obviously indicated the relevance of SDS-PAGE profile electrophoresis for delimitation of the okra gynotypes.

b. **Species of subtribe Cassiinae (Kolawole and AbdulRahaman, 2019)**. Genus *Cassia* consists of annual or perennial herbs, shrubs, and trees that have been differentiated based on the number of leaflets, fertile and sterile stamens in single flowers, and glands on the leaves (Deshmukh *et al.*, 2014). Irwin and Barneby (1981) and (Irwin, 1982) raised the genus *Cassia* L senso lato to the level of subtribe and elevated previous subgenera to generic rank viz *Senna* Mill and *Chamaecrista* Moench under the subtribe Cassiinae and tribe Cassieae Bronn ex Irwin and Barneby of Caesalpiniaceae. Previously, the taxonomic treatments of the genus *Cassia* L senso lato have been done in some countries, namely, Malaysia (de Wit,

1956), Pakistan (Ali and Quraishi, 1967), and Nigeria (Saheed and Illoh, 2010). Ogundipe *et al.* (2009) and Saheed and Illoh (2010) reviewed the genus using leaf epidermal characters, while Soladoye *et al.* (2010) employed leaf morphological characters in delimiting the taxa.

This study also employed the SDS-PAGE electrophoretic techniques to evaluate the taxonomic implications of 15 species in the subtribe Cassiinae (Caesalpiniaceae) using total leaf proteins. Results revealed that the protein pattern was taxon-specific, as no two species had same banding patterns. Distance polymorphism in electrophoretic banding patterns of the leaf was observed through a total of forty-one (41) polypeptide bands. Variation existed not only in the number of bands but also in the intensity of bands in the leaf samples studied. The coefficient similarity range is between 0.076 – 0.845. The hierarchical cluster analysis (dendrogram) for the 15 species revealed two major clusters. The first group includes *Senna spectabilis, S. alata, S. hirsuta, Chamaecrista rotundifolia, Ch.Mimosoides* and *S. biflora*, and the second group are *S. podocarpa, S. sophera, S. occidentalis, S. obtusifolia, Cassia italica, S. siamea, C. singueana, C. sieberiana* and *C. fistula*. An artificial key for the studied species of subtribe-Cassiinae based on their bands are additional characters that can be used for species delimitation in subtribe Cassiinae.

c. **Some accession of *Corchorus olitorius* L. [Malvaceae] (AbdulKareem *et al.*, 2019a)**. Nigeria has several native leafy vegetables that have been neglected; *Corchorus olitorius* (jute plant, bush okra; ewedu - Yoruba; malafia, turgunuwa, lallo, ayoyo - Hausa; ahihiara, kerenkere -Igbo)) belongs to this group. Sixteen (16) polypeptide bands were obtained from five (5) accessions of *C. olitorius* ranging from 12.29 KDa to 170 KDa indicating variations in the binding patterns of the accessions. Dendrogram grouped the five accessions into three clusters with four groups showing 60 % of the accessions in one group. The greatest similarity (96 %) observed was between NGB00194 and NGB00196 while the lowest similarities (32 %) were in NGB00191 and (40 %) NGB00187.Adopting this technology, plant varietal identification and registration of new plant varieties will become easier. We observed that NGB00191 was distantly related to the other accessions and as such could be used in a breeding programme. This is because distantly related accessions when crossed give rise to offspring that are viable. It also reduces

the risk of inbreeding depression thereby giving rise to generation of plants with better yield when compared to the parent plant.

4. **Morphometric study/Numerical taxonomy**: Mr. Vice Chancellor sir, numerical taxonomy, also known as mathematical taxonomy or taximetrics (Mayr, 1957) or phenetics (Pandey and Misra, 2009), has emerged as a branch of taxonomy which received a great impetus with the development and advancement in computers (Zhigila and Oladele, 2014). It refers to applying various mathematical procedures to numerically encoded character state data for plant species under study. This approach results in a classification based on a greater number of characters from sets of data (multivariate) to develop an entirely phenetic classification of maximum predictivity (Pandey and Misra, 2009). Morphometric study has the ability to integrate data from a variety of sources, such as anatomy, cytology, ecology, genetics, geography, physiology, palynology, chemistry etc. (Soladoye *et al.*, 2010) as show in the following works:

a. **Varieties of *Adansonia digitata* L. [Bombacaceae] (Zhigila *et al.*, 2015b)**. *Adansonia digitata* (baobab tree; oshe – Yoruba; kuka – Hausa; bakko - Fulfulde) belongs to the family Bombacaceae. The family includes about 30 genera, 6 tribes and about 250 species (Assogbadjo *et al*., 2006). The wide range of uses of the naturalized trees in the world have in the recent time witnessed increasing demand for their foliar, bark, root, fruit and seed products in nutritional, fibre and medical applications. The upsurge demand for these products needs to be balanced with new varieties of improved performance to meet the supply chain. To achieve this, our study aimed at setting the foundation of variability analysis based on morphological features to detect promising varieties for mapping out of future breeding schemes of this multi-purpose tree, *A. digitata*.Some morphological characters indicated close affinity amongst the 25 varieties of *A. digitata.* Features of taxonomic importance amongst the varieties which were used to delimit them include leaf surface, pod surface, leaf stalk surface, pod end form, pod colour, pod size, stalk size, number of seeds per pod, leaf size, seed size, occurrence of leaflet number and leaflet size. Numerical analysis of the qualitative and quantitative data using cluster analysis – average linkage, single linkage, complete linkage and centroid linkage methods delimit all the Operational

Taxonomic Units (OTUs) into four varieties hence, infraspecific classification of *A. digitata* was proposed.

b. **Species of the genus *Jatropha* L.[Euphorbiaceae] (AbdulRahaman *et al.,* 2016a)**. *Jatropha* is a morphologically diverse and geographically widespread genus of 150 – 175 woody species (Dehgan, 1982). Highly significant positive correlations have been noted, while a negative correlation was observed between leaf width and leaf length/width ratio, fruit width and leaf length/width ratio between five (5) *Jatropha* species, namely, *J. curcas* L., *J. gossypifolia* L., *J. integerrima*Jacq.,*J. podagrica* Hook. and*J. multifida* L. Traits such as leaf length, width, and length/width ratio contributed significantly, along with other traits, to discriminate the studied *Jatropha* species. *Jatropha podagrica* and *J. integerrima* have more similarities, with a stronger coefficient of agglomeration (69.072) than *J. curcas* and *J. podagrica*, with 315.028 coefficient of agglomeration, respectively. The generated dendrogram showed the relationship between the studied *Jatropha* species, whereas great affinity was noted between *J. podagrica* and *J. multifida* as compared with *J. gossypifolia* and *J. integerrima*, which are distantly related. The closeness observed between *J. podagrica* and *J. multifida* is in line with their current sub-generic grouping.

c. **Some species of the subtribe Cassiinae in Nigeria (Kolawole *et al.,* 2021)**. It has been established that it is difficult to identify some species of *Cassia* and sub-species Cassiinae due to their morphological complexes (Boonkerd *et al.*, 2005). Considering the close affinities between individuals of the sub-species, this study employed a numerical method to identify features that contributed significantly to their delimitation. Twelve morphological parameters were studied from the leaves, fruits, and pedicels of fifteen (15) species. Characters such as leaflet length, leaflet width, and leaflet length/width ratio contributed significantly to the delimitation of the species studied. While *Cassia italica* and *Chamaecrista mimosoides* are the most closely related taxa, *C. fistula* and *C. singueana* are most distantly related, as reflected by the cluster coefficients. Further illustrations revealed by the dendrogram and scatter plot generated, placed the 15 studied species into three groups. While we acknowledge the relevance of phylogenetic analysis in taxonomy studies as it is in recent times,

we strongly support the application of numerical taxonomy to complement findings.

5. **Computerized system for identification of plants (AbdulRahaman *et al.*, 2010; AbdulRahaman *et al.*, 2012b)**. One of the tools used in Plant Taxonomy to identify plants is the taxonomic keys e.g. dichotomous keys. While these tools are functional and helpful, their use is usually time-consuming and cumbersome. There are thousands of plant species, which have been classified into 150 – 500 plant families. As a result of high number of plants on earth identifying them may at times be tasking and difficult to do. It usually takes a long process of checking and checking cabinets in herbarium looking for like species that will serve as template for identifying plants. Due to this reason, there is, therefore, need for an efficient and convenient means or system by which this identification process can be executed with ease.

In an attempt to make identification of plants easy and less cumbersome, computer-based software called **LEASYS** was developed (Fig. 5). It is a computerized version of a field key prepared for on-the-spot identification of savanna tree species in Nigeria **(AbdulRahaman *et al.*, 2010)**. The Leasys system was based on the simultaneous narrowing of two classification systems, vertical and horizontal characters, and supplying these systems with an appropriate Boolean operator (the AND operator preferably). The system was based on the leaf morphology of some savanna tree species in Nigeria. For the purpose of this study, selected plants were identified based on possession of either simple or compound leaves. The system is amenable to expansion to identify other species in the plant kingdom.

Fig. 5: Leasys logos for identification of plants

With success recorded in the first attempt, **LEASYS 1.1(AbdulRahaman *et al.*, 2012b)** was developed as an improved version of the earlier version developed by the same authors **(AbdulRahaman *et al.*, 2010)**. This version is more expansive than the first version and thus has more features which make identification

process faster and easier. Incorporated in Leasys 1.1 are some other features that make it more robust, flexible and versatile. Leasys has a database of two hundred (200) different savanna trees. The system has the potential and capacity to accommodate very large number of species and very large number of taxonomic characters. Leasys also has the great potential for progressive upgrading.

The softwares (**LEASYS** and **LEASYS 1.1**) were designed mainly to contribute to the process of plant identification in the Herbarium of the Department of Plant Biology, and other herbaria. Our effort on the development of the virtual herbarium was patented in 2010 (Computerized System for Identification of some Savanna Tree Species in Nigeria NG/P/2010/336).

B. Production of paper from non-woody plants

Nigeria was in the paper production business shortly after her independence in 1969. The paper factory relied upon imported pulp from other countries. By 1986, three pulp and paper mills had been commissioned, but the output of newsprint and industrial paper grades was less than half the anticipated 265,000 tonnes. This inadequate performance stemmed partly from insufficient supplies of long-fibred pulp. In line with this was the assertion by a report in Daily Trust of 2019 that the absence of long fibre pulp has been identified as one of the major factors that incapacitated Nigeria's efforts to be self-sufficient in paper production. Some industry experts believed that it led to the closure of the country's foremost paper mills, forcing us to mostly depend on the importation of writing, printing, and newsprint papers (Adegbehin and Omijeh, 1989).

In the era before the discovery of oil, self-sufficiency in paper manufacturing was one of the government's key cardinal goals in the 1960s and 1970s. This was evidenced by the establishment of three integrated pulp and paper mills between 1969 and 1976. Two of the mills – the Nigeria Paper Mill, Jebba, and the Nigeria Newsprint Manufacturing Company, Oku Iboku – performed optimally, and paper importation faded out in the 1980s.

Mr. Vice Chancellor sir, in our efforts to revive the industry, we researched into the potentials of using weeds to produce pulp and paper as shown in the following works:

1. **Paper production from wild plant species (AbdulRahaman *et al.*, 2018b)**. The pulp and paper potentials of four wild plants, namely, *Jatropha curcas* L. [Euphorbiaceae] (physic nut; lapalapa funfun, botuje – Yoruba; bini da zugu – Hausa; olulu idu - Igbo), *J.*

podagrica Hook. [Euphorbiaceae] (bottleplant shrub, purging-nut; lapalapa), *Sida acuta* Burm.f. [Malvaceae] (wire weed; ewe-ifin, iseketu, osepotu - Yoruba; udo, akoko-edo - Igbo), and *Ricinus communis* L. (castor oil plant; ewe laa - Yoruba; kulkula, zuman nasara - Hausa) were investigated. Pulp was produced by soda pulping procedure at a liquor-to-solid ratio of 7:1 and bleached with hydrogen peroxide in a basic medium. The four species were found to be good candidates as raw materials for pulp and paper production due to their possession of appropriate raw material features (fibre length, fibre diameter, cell wall thickness, lumen density, and Runkel ratio flexibility coefficient, and relative fibre length). The pulp yields of *J. curcas, J. podagrica, S. acuta,* and *R. communis* were 70 %, 87 %, 80 % and 81 %, respectively.

2. **Fungal modification of wood fibres.** The pulp and paper industry has been categorized as one of the industries that are both labour and capital-intensive. The instability of electricity in Nigeria has contributed to the comatose state of the Nigerian pulp and paper industry. The use of alternative energy-generating sets further increased the cost of production. It is therefore, becomes necessary to seek alternative methods aimed at reducing chemical pulping duration and improving pulp characteristics. Treatment of wood chips with lignin-degrading fungi prior to pulping has been shown to have great potential for mechanical and chemical pulping.

In a M.Sc. work of my student (Sofiat Katibi) in 2017, treatment with two white rot fungi had different effects on the characteristic of *Gmelina arborea* Roxb. [Verbenaceae] (Gmelina, white teak; igi melina - Yoruba; melaina – Hausa) pulp. The effects of fungi treatment could be seen on the kappa number and pulp yield as the incubation time did not affect the pulp yield of the *G. arborea* wood pre-treated with all the fungi, but it affected kappa number of the pulp obtained after kraft pulping process. *Gmelina arborea* wood treated with *P. ostreatus* and *G. lucidum* incubated at 45 days produced the best pulp quality with high pulp yield and lower kappa number. Fungal pre-treatment of wood fibres of *G. arborea* improved the fibres, and these characteristics conform to the standards of bio-pulping and the Technical Association of Paper and Pulp Industries. Thus, the potential of white rot fungi could be harnessed in the pulping industries by pre-treating fibres with fungi prior to pulping processes.

C. Food security

Food security means having, at all times, **both physical and economic access to sufficient food to meet dietary needs for a productive and healthy life**. A family is food-secured when its members do not live in hunger or fear of hunger. One of the problems facing the Nigerian population is the lack of adequate food supply coupled with attendant nutritional diseases. The majority of the food vendors are lacking in nutritionally balanced food items. There is a need to think inwardly about producing healthy food products. It was also established that several health problems, such as excessive body weight and its secondary implications common in developed societies, are connected to a lack of dietary fibre in daily meal **(AbdulRahaman *et al.*, 2013b)**.

1. **Production of fibre-rich breads** (**AbdulRahaman *et al.*, 2012a; AbdulRahaman *et al.*, 2013b, 2013c, 2013g; AbdulRahaman *et al.*, 2016a**). Our contributions in this regard include the production of fibre-rich breads from *Vitellaria paradoxa*C.F. Gaertn.**(AbdulRahaman *et al.*, 2012a)**, *Gliciridia sepium*(Jacq.) Steud. **(AbdulRahaman *et al.*, 2013b)**, *Daniellia oliveri* (Rolfe) Hutch and Dalz **(AbdulRahaman et al., 2013c)**, *Ficus exasperata*Valh**(AbdulRahaman *et al.*, 2013g)**, and *Amaranthus hybridus* L. **(AbdulRahaman *et al.*, 2016a)**.

Doughs of bread produced were presented in Fig. 6. The anatomical features (Fig. 7; Table 1) of the plants used as sources of dietary fibres showed that they could easily blend with wheat flour for bread production. With the results of these studies, we, therefore, recommend the woods of *F. exasperata* (sandpaper plant, ficus tree; erepin, epin, ewe-ipin - Yoruba; gimi - Hausa), *G. sepium* (quickstick, gliciridia), *D. oliveri* (African copaiba balsam, Ilorin balsam; igi iya, iya - Yoruba; maje, kadura - Hausa; ozabwa - Igbo), *A. hybridus*, and *V. paradoxa* (shea butter tree; emi, igi emi - Yoruba; ka'danya, kadanya, balili - Hausa; osisi - Ibo) as cheap potential sources of cellulose for human consumption and also recognize bakery products as a means of low-calorie food intake.

Fig. 6: Fibre-rich bread containing varying amounts of wood fibres (a – 0 g, b – 0.25 g, c - 0.5 g, and d – 1 g)

Fig. 7: Transverse section (a), transverse longitudinal section (b), and isolated fibres (c) of *Ficus exasperata wood*

Table 1: Some dimensional characteristics of *Ficus exasperata* wood

Mean values	**Fibre dimensions**	**Vessel dimensions**
Length (µm)	1242.11±97.42	
Diameter (µm)	21.25±1.08	178.62±6.70
Lumen width (µm)	14.85±1.07	164.09±6.83
Wall thickness (µm)	2.94±0.38	7.26±0.84
Relative fibre length (µm)	5.76±3.65	
Coefficient of flexibility	0.72±0.02	

2. **Glandular trichomes and essential oil production (AbdulRahaman and Khan, 2017).** Trichomes on the leaves, stems and flowers of *Ocimumbasilicum* L. [Lamiaceae] (basil, scent leaf, tea-bush, hairy; efirin-wewe - Yoruba; daɗɗoyar masar, yar kan masalachi - Hausa; nchanwu - Igbo) and *O. sanctum* L. [Lamiaceae] (holy basil) were studied. Three types of trichomes are present in the two species, namely multicellular-non glandular, peltate glandular and capitate glandular trichomes, and this formed the basis for essential oil extraction from these parts. There is a

correlation between the density of the glandular trichomes within and between the three parts of the two plants. The density of the glandular trichomes is higher in the plant parts that produced higher essential oil. Percentage oil yield is higher in the leaves of *O. sanctum* (19.85%) and *O. basilicum* (13.58%), followed by the flowers and stem in the two plants. In line with the percentage oil yields, the density of the glandular trichomes also followed a similar pattern; with higher density in the leaves (86.6mm^2 and 21.50mm^2) for *O. sanctum* and *O. basilicum* respectively, followed by the flowers and stem. Comparing the two species, *O. sanctum* has a higher oil yield and higher density of glandular trichomes in all its parts than *O. basilicum*.

3. **Mutagens and anatomical features (AbdulKareem *et al.*, 2019; AbdulRahaman *et al.*, 2013a; AbdulRahaman *et al.*, 2018a).** Chemical mutagens (i.e. sodium azide and nitrous acid) are important tools in crop improvements because they produce resistance against pathogens in crops to improve their yield and quality traits. This study investigates the morphological and anatomical effects of sodium azide and nitrous acid on *Jatropha curcas*, *Citrullus lanatus* (Thunbery) Matsum & Nakai [Cucurbitaceae] (cow melon, red fleshed melon; gunar shanu, kankana - Hausa) and *Moringa oleifera* Lam. [Moringaceae] (drumstick tree, moringa tree; igi iyanu, malero, ewele, ewé ilé – Yoruba; zogalle, barambo, jagalandi – Hausa; okwe oyibo, okwe olu - Igbo) at various concentrations (1 mM, 2 mM, 3 mM and 4 mM) for 4 hours, and planted in plastic pots for 12 weeks.

   The effect and prospect of sodium azide to induce favourable mutation into the morphology and anatomy of the test plants has been clearly shown to be of greater advantage since it increases the seedling height and several other anatomical features that promote the growth production and yield of the plants. Sodium azide, and to some extent, nitrous acid, are therefore recommended for effective use by the farmers to improve certain traits in plants and ultimately increase the possibility of isolating beneficial mutants for improvement of the economic crops such as the test plants i.e., *J. curcas*, *C. lanatus*, and *M. oleifera*.

   Also, ultraviolet UV radiant seedlings of *Capsicum annuum*, *C. chinense* and *C. frutescens* where studied anatomically to observe the UV effects on the leaf epidermis, stem and root ultrastructures. While there was a higher percentage of a stomatal

index in the UV-exposed plants compared to the controlled, unexposed plants, there was no correlation between the stomatal density and stomatal size. There was also no correlation between the stomatal size and density in both treatments (exposed and unexposed) in all the plants. Significant differences were observed in the stomatal index on both leaf surfaces between the exposed and controlled plants of *C. frutescens* and *C. annuum*. Cell walls of the stem and root were thicker than in the UV-exposed plants.

4. **Anatomical basis for budding and grafting (Abinde *et al.*, 2022).** Propagation of *Anacardium occidentale* L. [Anacardiaceae] (cashew; kaju, kasu – Yoruba; kanjuu, fisaa, jambe – Hausa; akwe, akwe olu, kansu - Igbo) for mass production is hitherto faced with problems of appropriate means of production for mass commercial purposes. Cashew is a plant that experiences a high variety of constraints of natural regeneration. The seed of *A. occidentale* has been found to be less viable by researchers, affecting the cashew nut's production. However, the propagation of cashew through seeds results in a high level of genotypic and phenotypic variations. In view of the challenges attached to this method of propagation (i.e. seeds), grafting is adopted commercially for the multiplication of varieties of outstanding qualities (Ohler, 1979).

   Anatomical features of the bud and graft unions of three accessions of *Anacardium occidentale* (i.e. Brazilian Jumbo, Brazilian extra-large and Indian madras) using the T-budding and wedge grafting techniques responsible for compatibility and incompatibility of the unions were investigated (Fig. 8). The results obtained shows that the success of the graft and bud union depends on the following factors: the choice of grafting methods; high relative humidity; proper matching of the components; early callus formation and formation of the cambium and vascular tissues. The success recorded in our

study shown that vegetative propagation appears to be the right option for reviving a balanced proportion of the plant.

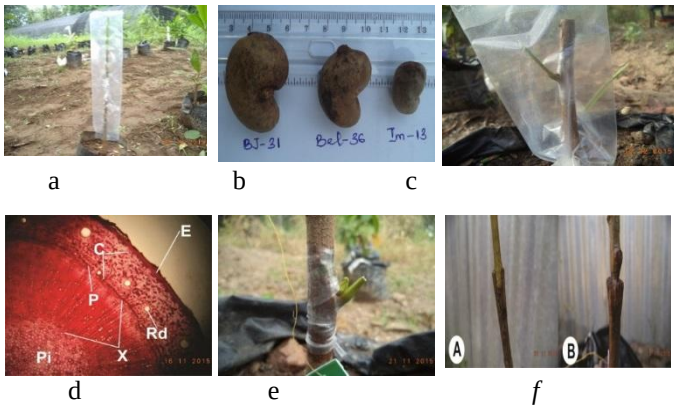

Fig. 8: (a) Seeds of three accessions of *Anacardium occidentale* obtained from Cocoa Research Institute of Nigeria (CRIN), Ibadan, Oyo State, Nigeria; (b) A typical wedge graft of *Anacardium occidentale* (Bel-36 on Im-13); (c) A typical T-bud of *A. occidentale* (Im-13 on BJ-31); (d) A light micrograph showing the transverse sections of the stems of A, BJ-31; B, Bel-36 and C, Im-13; (e) [A] A typical successful wedge grafted *A. occidentale* (BJ-31 onIm-13). [B] A typical successful T-bud *A. occidentale* (Bel-36 onBJ-31); and (f) Morphology of *Anacardium occidentale* wedge graft union. [A] 60th day union between Im-13 (scion) and BJ-31 (rootstock) while [B] 70th day union between Bel-36 (scion) and Im-13 (rootstock); and (h) [A] A typical failed wedge grafted of *Anacardium occidentale* (Im-13/Bel-36). [B] A typical failed T-bud *Anacardium occidentale* (BJ-31/Im-13). (Pi - pith; X - xylem; P - phloem; C - cortex; Rd - resin duct and E - epidermis)

D. Water use efficiency of plants

The water cycle, water stress, transpiration, and plants with stomatalopening and closing potentials are inseparable. Many empirical explanations have been postulated on the four. Production of food, especially sugars, by the plants, is through photosynthesis which involves absorption of carbon dioxide (CO_2) through openings (i.e. stomata) in the leaves, but as CO_2 comes into the leaves, water vapour also escapes outward to the atmosphere (Xu and Zhou, 2008).

Therefore, water loss is an inevitable consequence of stomatal opening for photosynthetic carbon gain (Caird *et al.*, 2007), and this contributes significantly to water stress in plants and, consequently, poor growth and development of plants. With current water scarcity in the world where water availability per head is too low, there may be no room for water wastage on irrigation.

The problem of water scarcity cannot be over emphasis in Nigerian content. Since independent to date various administrations have tried with some levels of success but the story is still on going. Many towns, villages and hamlets are still depending of well water and bore holes as sources of water for their domestic and agricultural needs. With this in mind, we tried to research into some anatomical features that serves as indices for water conserving in plants:

1. **Anatomical features as indices for water requirement (AbdulRahaman and Oladele, 2003)**. Stomatal anatomy has been shown to affect the transpiration rate in some *Citrus* species (Obiremi and Oladele, 2001). It is envisaged that the water-need indicators may be in guiding or moderating the use of water for irrigating the vegetables. Six (6) vegetables (*Sesamum indicum* L., *Corchorus olitorius* L., *Vernonia amygdalina* Del., *Amaranthus cruentus* L., *Talinum triangulare* (Jacq) Willd and *Celosia argentea* L.) were studied anatomically with focus on the stomatal density, density, index, size, stomatal complex types, and their frequencies. Our results revealed the stomatal features that are of relevance to water economy namely:

i. High frequency of paracytic stomata and stomatal index of 30 for *Talinum triangulare* (water leaf; gbure, gure - Yoruba);
ii. High frequency of anisocytic stomata and stomatal index of 14 for *Corchorus olitorius* (Jute plant, bush okra; ewedu - Yoruba; malafia, turgunuwa, lallo, ayoyo - Hausa; ahihiara, kerenkere – Igbo);
iii. High frequency of tetracytic stomata and stomatal index of 10 in *Vernonia amygdalina* (bitter leaf; ewuro, ewuro ile - Yoruba; chusa-doki shiwaka, shuwaka - Hausa; onugbo, onugbu - Ibo);
iv. High frequency of anisocytic and tetracytic stomata and stomatal index of 7 for *Celosia argentea* (Lagos spinash; soko, efo shoko, shokoyokoto - Yoruba; rimi - Hausa; erimonu - Igbo);

v. High frequency of anisocytic and tetracytic stomata and stomatal index of 20 for *Sesamum indicum* (white-sesame, beniseed; eku - Yoruba; ridi - Hausa; isasa - Igbo); and
vi. High frequency of anisocytic and tetracytic stomata and stomatal index of 35 for *Amaranthus cruentus* (red amaranth; tete, olorungbin - Yoruba).

This listing is interpreted to be in decreasing order of stomatal capacity to conserve water and increasing order of need for water supply.

2. **Trichomes as indices for water use (AbdulRahaman and Oladele, 2004)**. Fresh leaves of six (6) vegetable species (*Sesamum indicum* L., *Corchorus olitorius* L., *Vernonia amygdalina* Del., *Amaranthus cruentus* L., *Talinium triangulare* (Jacq) Willd and *Celosia argentea* L.) were studied to examine their trichome features with aim of using these features as indices of the plant's water requirement, vis-à-vis the frequency of watering them either in the nursery or in the field. In this study, our attention was focused on the latter factor i.e. trichomes. This is a follow up to the early work on stomata complex types by Obiremi and Oladele (2001) and **AbdulRahaman and Oladele (2003)**.

   In *S. indicum*, the most frequent trichome type is long-unbranched uniseriate, followed by capitate glandular, scale, short-unbranched uniseriate and stallate. In *A. cruentus*, the most frequent trichome type is glandular peltate, followed by unbranched uniseriate, branched uniseriate, and capitate glandular. In *T. triangulare*, the most frequent trichome type is glandular peltate, followed by capitate glandular and unbranched uniseriate. In *V. amygdalina*, the most frequent trichome type is glandular peltate, followed by unbranched uniseriate and capitate glandular. In *C. argentea*, the most frequent trichome type is capitate glandular, followed by glandular peltate and unbranched uniseriate. In *C. olitorius*, the trichome is exclusively multiseriate-capitate glandular. Trichome density is higher on the abaxial surfaces of *S. indicum, V. amygdalina* and *C. argentea,* while it is higher on the adaxial surfaces of *C. olitorius, A. cruentus,* and *T. triangulare. Vernonia amygdalina, C. argentea,* and *S. indicum*, with high trichome density on the abaxial surface of leaves, probably have the capacity to conserve water. Therefore, these plants raised either in the nursery or in the field may not need to be

watered daily or as frequently for such species as *C. olitorius* and *A. cruentus* with low or moderate trichome density.

3. **Anatomical basis for water use in mesophytic and xerophytic plants (AbdulRahaman and Oladele, 2011a; AbdulRahaman and Oladele, 2012)**. Plants were subjected to 5 varying soil moisture gradients, i.e., 1.2 %, 2.5 %, 5 %, 10 % and 20 %, and subjected to 4 watering frequencies i.e., daily, weekly, biweekly and monthly. This was to determine the anatomical adaptations of the species to water stress to determine the low-watering regimes that can sustain them. In the mexophytic plants, *Jatropha curcas* was the most tolerant of water stress, with the capacity to survive and thrive at a daily watering regime of 25 cc to 100 cc. This was possibly attributable to the presence of trichome density and low transpiration rate of 4.53x10-9 mol/m^2/sec (abaxial) and 3.77x10-9 mol/m^2/sec (adaxial). *Canna indica* L. (Cannaceae) was the least tolerant of water stress, possibly due to the absence of trichomes and high transpiration rate of 4.72x10-5 mol/m^2/sec (abaxial) and 3.88x10-5 mol/m^2/sec (adaxial).

   For the xerophytic plants, *Euphorbia milii* Des Moul. (Euphorbiaceae) was the most xerophytic species having a relatively lower rate of transpiration than *Aloe vera* L. (Burm.f) (Asphodelaceae) and *Agave Americana* L. (Asparagaceae). It was suggested that the high transpiration rate in *A. vera* and *A. americana* may be due to the large tetracytic stomata compared to the small paracytic stomata of *E. milii*. In conclusion, we recommended daily watering regimes of 25 to 100 cc for *J. curcas*, 200 cc for *J. gossypifolia*, and 400 cc for *C. indica* (Indian shot, African arrowroot). It was also observed that *A. vera* was least tolerant of high soil moisture in daily watering and low in the monthly regime. *Agave Americana* (century plant) and *E. milii* (crown-of-thorns) were more robust species and could cope well with low and high watering regimes than *A. vera*.

E. Authentication of commercial honey

Honey is characterized as a natural and raw foodstuff that can be consumed not only as a sweetener but also as medicine due to its therapeutic impact on human health. Honey is prone to adulterants caused by humans that manipulate the quality of honey. Although honey consumption has remarkably increased in the last few years all around the world, the safety of honey is not assessed and monitored regularly. Since the number of consumers of honey adulteration has

increased in recent years, their trust and interest in this valuable product have decreased.

Melissopalynology (i.e. the study of pollen in honey) is an essential tool in determining the floral sources upon which the bees foraged to produce honey. Each plant species has a unique pollen grain, which, using proper techniques, may be studied to determine the honey's geographical origin and major floral sources. The information gained from a given honey sample is useful when substantiating claims of a particular honey source and is also of great importance for quality control and helps to ascertain whether honey is adulterated (Molan, 1998; Terrab *et al*., 2003). Authenticity and adulteration status of some honey products are presented below:

a. **Uni-flora and multi-flora honey (AbdulRahaman *et al.*, 2013h)**. Two honey samples produced by the University of Ilorin at the Jatropha Plantation and Unilorin Apiary Farm were collected and studied melissopalynologically to isolate and identify pollen types in the honey. Thus, the study aimed to determine whether the honey samples were uni-flora or multi-flora. Based on the pollen grain frequency, the pollens in the two honey samples could be categorized as ''important minor or important isolated pollen'' and '' rare or isolated''. In estimating PK (pollen grain) frequencies, the *Jatropha curcas, Guio gracilis* and *Capsicum annuum* were considered rich in the honey of Jatropha Plantation. In the honey of Unilorin Apiary Farm, *Tridax procumbens, Mangifera indica, Melastoma polyanthum* and *Psidium guajava* produced rich pollens. The pollen grains in the two honey samples indicated that the honey samples were not adulterated but pure and not uni-floral but multi-floral.

b. **Pollens in bee-breads (AbdulRahaman *et al.*, 2013e).** As done earlier for honey **(AbdulRahaman *et al.*, 2013h**) from the Unilorin Apiary Farm and Jatropha Plantation, bee breads were collected from the same sources to authenticate the natural sources of the commercial honey produced. The 9 pollen types observed include monoporate, salcate, triporate, tricolpate, pericolpate, panporate, biporate and vesculate. Monoporate, colpate, triporate and panporate pollen types most frequently occurred in all colonies, followed by salcate, biporate and tricolpate. The least frequent types are pericolpate and vesiculate pollens only in colony A.Some impurities were detected in colonies B, C and E. Panporate pollen of *Jatropha curcas* was highly frequent in the

only colony of Jatropha Plantation, indicating that honey bees visited the Jatropha plants more frequently. So, the honey from the Plantation might contain a high percentage of panporate pollens. Honey is poly-floral or multi-floral type rather than uni-floral or monofloral because it contains many types of pollen, indicating its source from more than one plant source or more than one nectars of different entomophilous plants exhibiting the presence of some anemophilous pollens.

c. **Commercial honey (AbdulRahaman *et al.*, 2017b).** Laboratory and microscopic studies on 40 honey samples collected from 13 places (Majekodunmi, Itoku, Lafenwa, Somaarin, Odo-eran, Randa, Crescent University, Obantoko, Sanni, Iyana Cele, Osiele, Sabo and Atinsola) in Abeokuta, Ogun State, and 15 places (University of Ibadan, Moor Plantation, Molete High School, Alegongo, Olegede, Agara, Ring Road, Aleshinloye, Basorun, Kasumu, Oremeji, Mapo, Apata, Oluyole and Adelabu area) in Ibadan, Oyo State, revealed that out of 40 honey samples, 16 samples were adulterated with no pollen grains and the remaining 24 samples contained 12 pollen types from 81 plant taxa. In total, 168 pollen grains were extracted and identified (Figs. 9 and 10). The frequency of the bee's visit to each identified plant species was also determined based on the pollen grain frequency in each honey sample. The pollen grains in the 24 honey samples clearly indicated that those honeys were not adulterated; they were pure and multi-floral.

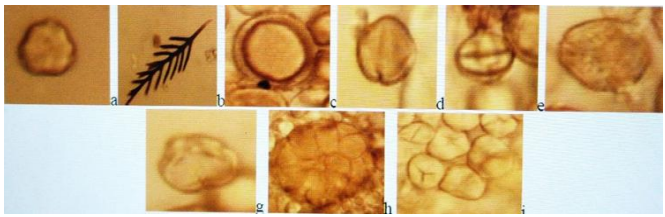

Fig. 9: Pollen samples (a – *Combretum guienzii*, c – *Trema guineensis*, d – *Gunnera chilensis*, e – *Acidanthera brevicollis*, f – *Entada abyssinica*, g – *Tilia americana*, h – *Parkia inundabilis*, i – *Piptadenia africana*) and impurity (b – leaf-like) obtained from the honey collected in Kusumu, Ibadan, Oyo State, Nigeria

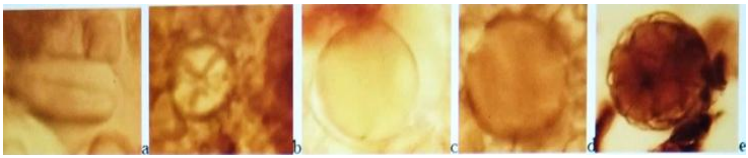

Fig. 10: Pollen samples (a – *Acidanthera brevicollis*, b – *Piptadenia africana*, d – *Clifftortia nitidula*, e – *Poliostigma reticulatum*, f – *Parkia bussei*) obtained from the honey collected in Lafenwa, Abeokuta, Ogun State, Nigeria

F. Production of starch from alternative sources

Starch is an important industrial raw material for food, pharmaceutical, textile, chemical industries, paper sizing and bonding, adhesives, oil well drilling, drinks and beverages, confectionery, textile sizing and strengthening battery and household products manufacturing, and many more. Its production is far below demand by these industries and the consuming population in domestic services. Starch is often a highly sought-after commodity both by consumers and manufacturers, and as such, it is gaining prominence in the Nigerian market. It is estimated that Nigeria's starch needs run into several thousands of tonnes annually worth billions of naira (www.infoguidenigeria.com/starch-market-nigeria/; www.guardian.ng/features/tapping-economic-benefits-of-rising-cassava-starch-industry-in-nigeria/).

In Nigeria and indeed globally, starch is produced primarily from cassava and corn. These two crops are reliable sources of sustenance for humans; many households consume cassava and corn in various forms, depending on their preferences. This has put pressure on the two crops over the years; hence, it is necessary to identify alternative sources for starch production. With aim of producing commercial flour and starch from wild plant species, in a M.Sc. work of my student (Agbale, 2017), proximate and mineral composition of flour and physicochemical characterization of the extracted starch from the alternative sources from the modified stem of three (3) wild plants: *Anchomanes difformis* (Blume) Engl. Pallidus (Araceae), *Icacina trichantha* Oliv. (Cacinaceae), and *Colocasiaesculentus* (L.) Schott (Araceae) were investigated. Results showed that the flour and the starch of the studied plants compared favourably with the conventional flour and starches.

G. Tissue culture using glandular trichomes

Tissue culture is the growth of tissues or cells in an artificial medium separate from the parent organism. This technique is also called **micropropagation** or***in vitro*** **regeneration**. This is typically facilitated by using a liquid, semi-solid, or solid growth medium, such as broth or agar. It is a biotechnological tool that is being used today to enhance sustainable agricultural production and food security. It was developed when any part of the plant could grow into a whole plant (totipotency), and raising plants in the laboratory where they can be made to multiply or produce roots (plasticity) before taking them to the farm. Some selected plant species were studied by exploiting tissue culture to increase their production.

Callus induction from glandular trichomes (Adebomojo and AbdulRahaman, 2020). *Ocimum* plants were richly endowed with both non-glandular and glandular trichomes, which are present on all the vegetative parts of these species. These studies (Adebomojo, 2017; **Adebomojo and AbdulRahaman, 2020**) described an efficient protocol for callus induction from glandular trichome explants of *O. basilicum*, *O. canum* and *O. sanctum*, and essential oil content and composition from glandular and non-glandular trichomes. It also evaluated biosynthesized Nano silver's efficiency in surface sterilising *Ocimum* seeds and tissues and its effect on callus induction. It was revealed from this work that biosynthesized Nano silver could function as an antimicrobial agent as 100% decontamination was achieved with no adverse effect on explant viability and callus formation but rather had a stimulating effect on callus formation. It was concluded that callus tissues initiated from glandular trichome explants could be harnessed for essential oil production and also extends the frontiers of the potential application of biosynthesized Nano silver in tissue culture.

H. Healthcare delivery system (herbal medicine)

Plants are natural remedies for many diseases. They are endowed with natural constituent components that possess the power to ameliorate diseases and disease conditions. To Plant Scientists (especially Botanists or Plant Biologists), all plants are useful, i.e., there are no unwanted plants. This belief is because research findings are still ongoing on all kinds of plants; who knows which possess the compounds for preventing or controlling HIV-AIDS, Ebola or Coronavirus? Medicinal plants have always played a pivotal role as sources for drug lead compounds. Despite developing more researched

and formulated orthodox medicines, herbal medicines continue to be well-patronized for people worldwide (Ameade *et al.*, 2018).

The problem of adulteration of herbal medicine has been increasing recently, and thus efforts must be put in place to prevent this practice and its attendant consequences. Herbal medicine is a popular means of medical management in some parts of the world, especially in Africa, India and China. Practitioners, researchers and students use fresh and dried samples of herbs for their works and research. The source of dry samples is usually in the local market, where adulteration of herbal materials occurs. Contributing our knowledge to ensuring reduction in herb drug adulteration, microscopic analyses of some medicinal and industrial plants were researched:

1. **Rhizomes and powdered materials of turmeric and ginger (AbdulRahaman *et al.*, 2015c).** Turmeric and ginger are spices derived from the rhizomes of *Curcuma longa* L. and *Zingiber officinale* Roscoe (Zingiberaceae), respectively. These two plants are well known for their medicinal values in folklore medicine. The authenticity of these plants' powdered materials microscopically showed similarities in the anatomical or microscopical features of both fresh and dry samples of *C. longa* and *Z. officinale*. Observations on the microscopic studies of the fresh rhizomes of turmeric and ginger revealed possession of oil duct and spiral xylem vessels. Similarly, phytomorphology of the powdered rhizomes of ginger and turmeric revealed the presence of tracheid and compartment of vessels. Similar anatomical features in fresh and ground samples confirmed the authenticity or adulteration of the powdered samples.
2. **Species of the family Cucurbitaceae Juss. (AbdulRahaman *et al.*, 2011b)**. The family Cucurbitaceae has many herbaceous species with medicinal properties, hence its choice for anatomical study. The 14 species studied were *Coccinia barteri* (Hook.f.) Keay, *Coccinia grandis* (L.) J. Voiet, *Citrullus lanatus* (Thunb.) Matsum.,*Citrullus colocynthis* (L.) Schred.,*Cucumis melo* Mill., *Cucumis sativus* L., *Lagenaria breviflorus* (Benth.) Roberty, *Lagenaria siceraria* (Molina) Standl.,*Luffa acutangula* (L.) Roxb.,*Luffa cylindrica* (L.) Roem.,*Momordica charanthia* L., *Momordica foetida* Schum., *Telfairia occidentalis* Hook. f. and *Trichosanthes cucumerina* L.

   Stomata were found on the adaxial and abaxial leaf surfaces of *Luffa cylindrica*, *Cucumis melo*, *Lagenaria*

breviflorus, Lagenaria siceraria, Citrullus colocynthis Citrullus lanatus, Luffa acutangula and *Momordica foetida*, and are thus amphistomatics. Others are hypostomatics. *Cucumis melo* stands out as a species with a higher stomatal density of 800 mm^{-2} and above on both leaf surfaces, possibly due to the small size of the stomata, while *Cucumis sativus* has a low stomatal density of 45 mm^{-2} and stomata occurring on the abaxial leaf surface only. *Momordica foetida* has stomata on leaf surfaces, while *M. charantia* has stomata on the abaxial surface. *Lagenaria breviflorus* is characterized by paracytic and diacytic stomata, and *Lagenaria siceraria* by paracytic and staurocytic stomata. *Telfairia occidentalis* is characterized by paracytic stomata, and *Trichosanthes cucumerina* by diacytic stomata. Conclusively, an indented dichotomous key was constructed to highlight the significance of the epidermal features in the family.

3. **Leaf epidermal features as biomarkers (AbdulRahaman *et al.*, 2016b).** Similarly, a study was conducted on leaf epidermal features to identify and authenticate dry samples of twenty-five (25) plant materials collected in Ibadan and Ilorin, Nigeria (Table 2). Anatomical studies were done on the plants' fresh and dry samples. The results revealed that the leaf epidermal anatomy of the plants does not show any significant variations within a species in their stomatal complex types, stomatal frequency, size and shape of guard cells. Meanwhile, variations were observed between the fresh and dry samples of different species. Leaf epidermal anatomy, therefore, proved to be an effective tool for the resolution of taxonomic confusion of dried samples of these plants.
4. **Powdered drug plants (AbdulRahaman *et al.*, 2021).** The anatomy of air-dried powdered samples and non-powdered samples of unground or intact leaves, flowers and barks in eight (8) medicinal plant species, namely, *Vernonia amygdalina, Ocimum gratissimum, Trichilia monadelpha, Bridelia ferruginea, Lophira alata, Alstonia boonei, Dialium guineensis* and *Enantia chloranthia* were studied to identify the original plant part used in the preparation of the drugs. The microscopic studies of leaves of *V. amygdalina* and *O. gratissimum* revealed the presence of similar stomatal complex types and trichomes in both ground and unground samples. The anatomy and palynology of *T. monadelphia* flower revealed that bipolar, inaperturate, monopolar,

monoporate, tetracolporate and triporate pollens are present in both samples. The microscopic study of the barks of *L. alata, B. ferruginea, A. boonei, D. guineensis* and *E. chlorantha* showed similar cells in ground and unground samples. Conclusively, the anatomical features were, therefore, elucidated to authenticate the originality of the medicinal plants.

I. Forensic science

Forensics (or criminalistics) is the scientific discipline utilized to solve crimes. Forensic investigation is collecting and analyzing all crime-related physical evidence to determine a suspect's culpability. Blood, fluid, fingerprints, residue, hard drives, computers, and other technologies will be examined by investigators to determine how a crime was committed.

Mr. Vice Chancellor sir, meanwhile, a forensic botanist looks to plant life in order to gain information regarding possible crimes. Leaves, seeds, and pollen found either on a body or at the scene of a crime can offer valuable information regarding the timescales of a crime and if the body has been moved between two or more different locations. The forensic study of pollen is known as forensic palynology and can often produce specific findings of the location of death, decomposition, and time of year. The knowledge of systematics at a crime scene enables the identification of evidence. The morphological and anatomical study uncovers evidence from crime scene sample collection and *in vitro* evaluation. It leads to proper submission of evidence in court of law (www.en.wikipedia.org/wiki/Forensic_biology#Forensic_botany).

Advocating the essence of forensic palynology, the soil palynomorphs were studiedto link people or objects to crime scenes to establish or strengthen an association **(AbdulRahaman *et al.*, 2018a**). This was done by determining the degree to which pollen assemblages of topsoil samples differ within the same area. Samples within the same localized area (the control site) showed a high degree of similarity, suggesting that pollen assemblages of topsoil samples from within a localized area are heterogeneous. The results indicated that the cast of footprints and palm prints provided evidence of a two-way transfer of materials between the palms and feet and the soil of the grassy area. Pollen analysis of the soil that had adhered to the palms and feet showed that the perpetrator of the imprint had been standing in the grassy area. The analysis of the interface between the body parts (palms and feet) and soil is, therefore, a potentially lucrative source of

information for forensic reconstruction. This analysis shows that pollen can be used to associate perpetrators with crime scenes and should be seen as a valuable tool in analysing hitherto unrecognized forensic materials in forensic palynology.

J. Environmental Concerns: The use of anatomical indices

It is no more news that the whole planet Earth is experiencing undue warming, popularly termed global warming. The cause of this phenomenon could partly be traced to the rate at which trees are being cut in the forest. According to Oladele (2002) during his Inaugural Lecture (the 62nd Edition) titled "The Only One We Have" in 2002, deforestation, which is an environmental concern, is a process of progressive removal of forest cover through such human activities as indiscriminate tree-felling and bush burning. As if this is not enough, the problem of oil spillage is almost everywhere, including automobile shops and the like, the release of effluents from the manufacturing industries into the water bodies, and pollution of almost every sphere of our life with heavy metals to mention few of human efforts to destroy the greener world.

In order to monitor the environmental degradation, I (in collaboration with my colleagues) investigated the responses of plants to pollutants.

1. **Deforestation (AbdulRahaman *et al.*, 2006; AbdulRahaman *et al.*, 2008)**. In 2006 survey exercise was carried out in 5 LGAs of Ilorin Emirate in Kwara State, Nigeria. The survey revealed extensive use of economic trees as timber and fuel woods. The forest resources are indiscriminately exploited by the poor inhabitants who solely depend on the forest to earn their livelihood. Tree species such as *Pterocarpus erinaceus, Parkia biglobosa, Prosobis africana, Trichilia emetica*, *Anogeissus leiocarpus, Danielia oliveri* (Rolfe) Hutch & Dalz, *Khaya senegalensis, Tectonia grandis* L.F., *Milicia excelsa* Welw, and *Vitellaria paradoxa* Gaertn F. are popular among the inhabitants as fuelwoods, with *V. paradoxa* being the most frequently used. Among the timber woods, *Pterocarpus erinaceus* is the most highly demanded by artists, casket builders, and furniture workers.

   In 2008, a similar survey in Irepodun LGA revealed that *V. paradoxa, Milicia excelsa, Anogeissus leiocarpus* (DC) Duill. &Perr., *Afzelia africana* Sm., *Isoberlina doka* Craib & Stapf, *Pterocarpus erinaceus, Daniellia oliveri, Tectonia grandis,* and *Gmelina arborea* Roxb are the most frequently exploited species

used either as fuelwoods or timbers, and thus are recognized to be threatened. High illiteracy, unemployment and poverty are significant factors responsible for the involvement of old and young people in the extensive forest destruction observed in these LGAs. The hitherto harmonious relationships between the people and the plants, whereby the people of a particular culture use plants to cure many inherent diseases and for other natural benefits have been defeated. Presently, the relationships have turned to destroying many forests and endangering many species of trees. Thus many forests have been turned into mere woodlands in the study areas.

2. **Soil and atmospheric pollution.** Our studies are predominantly concentrated on atmospheric and soil pollution as it affects plants. In contributing to this global issues, we researched and published the following articles:

a. **Grass species and diesel fuel contaminated soil (AbdulRahaman *et al.*, 2012c)**. The environmental consequence of soil pollution causes adverse effects on the soil microflora and reduces soil fertility (Torstenssen *et al*., 1998). Contamination of soil also results in poor growth; depending on the degree of contamination, the soil may remain unsuitable for plant growth for months or several years. Meanwhile, in this work, among the 6 grass species studied, *Sorghum bicolor* exhibited a moderate germination, plant height and leaf length at 5 % and 10 % diesel contaminations, and thus can be used for phytoremediation of diesel contaminated soils.

b. **Dual purpose kerosene (DPK), growth, and leaf epidermal features (AbdulRahaman *et al.*, 2011a)**. Effects of DPK concentrations are evidenced significantly ($p<0.05$) on reduction of plant height as the pollutant's concentration increased compared with the control. Leaf epidermal features in terms of stomatal density, index, and size were significantly greater in the control plants than those obtained from plants in polluted soils. Other effects of DPK on the plants included stunted growth, chlorosis, and death of the test plants as the concentration of the pollutant increased. These results suggest that DPK could potentially impair plant growth and reduce some leaf epidermal features of the test plants.

c. **Cement dust pollution and leaf epidermal (Ogunkunle *et al.*, 2013b)**. The cement factory close to human habitats could be

hazardous to the health of the inhabitants and the vegetation in such areas. A study in the vicinity of the Lafarge-Cement WAPCO Factory, Sagamu, south-west, Nigeria carried out to determine the anatomical features of the leaf epidermis that could be used as biological markers for the presence of cement dust pollutants in the leaves. Two plants, *Pennisetum purpureum* Schumach (Poaceae) and *Sida acuta* Burm.f. (Malvaceae), growing around the cement factory were examined using leaf epidermal modifications that enhance their tolerance and continued survival in cement dust pollutants. *Pennisetum purpureum* (elephant grass; dawar kadda, kyambama - Hausa; esu-funfun, eesu – Yoruba; achara - Igbo) did not show any anatomical modification to the pollution, which may indicate that the dose-response level of the pollutants has not been reached in the grass. Meanwhile, modifications in the stomatal size, density, and index in the leaves of *S. acuta* (wire weed, broom; ewe-ifin, iseketu - Yoruba; udo, akoko-edo - Igbo) could be favourable anatomical adaptations to a polluted environment. In conclusion, the anatomical features of the leaf epidermis of *S. acuta* and *P. purpureum* can be used as biological markers for the presence of cement dust pollutants.

d. **Pharmaceutical effluents and anatomical responses (Ogunkunle *et al.*, 2013a).** In Nigeria, most urban farmers divert effluents (treated or untreated) to farmlands to irrigate their vegetables (Fatoba *et al.*, 2011; Uaboi-Egbenni *et al.*, 2009). Reports have it that vegetables are produced throughout the year in Nigeria due to the availability of industrial effluents to irrigate (Fatoba *et al.*, 2011). However, there should be cautious use of effluents for irrigating tender and herbaceous crops, like vegetables.

Anatomical studies were carried out on the leaves, stems, and roots of *Amaranthus hybridus* (red amaranth, or slim amaranth; efo, efo tete, tete - Yoruba; maalankoochi, allayahu - Hausa; inine, opotoko - Igbo) which were subjected to 10 %, 20 %, 30 %, and 40 % concentrations of pharmaceutical effluents to identify the responses of this plant to the treatments. Leaf structures showed no significant change in the effects of the effluents. A significant reduction was observed in the trichome density and the number of epidermal cells on the adaxial surface. The stomatal size was significantly reduced on both leaf surfaces, while stomatal density increased significantly on the adaxial surfaces. Tetracytic and

anisocytic stomatal complex types were observed on both surfaces. Vessel walls were thickened, and their width reduced significantly, while the phloem cells progressively lost structural integrity in both the stems and roots. All changes occurred from 20 % effluent concentration upward ($p<0.05$). It was conclusively deduced that the pharmaceutical effluents have toxic effects on *A. hybridus* and the effects were more pronounced as from 20 % concentration.

e. **Aearopalynological investigation (AbdulRahaman *et al.*, 2015a).** Palynology is the study of dust, strew, sprinkle, or particles that are strewn. The term is sometimes narrowly used to refer to a subset of the discipline, which is defined as the study of microscopic objects of macromolecular organic composition (i.e. compounds of carbon, hydrogen, nitrogen, and oxygen), not capable of dissolution in hydrochloric or hydrofluoric acids (Sarjeant, 2002). The study of these particulates in the air is referred to as aeropalynology. However, medical palynological and aeropalynological studies are scarce in Nigeria, and little or no known aero-pollen data is available for the Ilorin metropolis. Thus, in 2015, a research was carried out to identify the concentration of air-borne pollen/fungal spores and the effect of some meteorological parameters on its concentration at the University of Ilorin, Ilorin, Nigeria. The amount of pollens and spores on the University campus for four months (December 2012/January 2013 to March/April 2013) was determined. The amount of pollen/spore was higher in March/April than in other months. It was observed that the meteorological factors influenced pollen/spore concentrations; hence there is a need for us always to determine the amount of these pollen/spore concentrations all years round as it will help to predict the vegetation of a given area as well as helping hay fever sufferers manage their allergies effectively.

f. **Industrial effluent irrigation (AbdulRahaman *et al.*, 2017c)**. The effects of industrial effluents (25 %, 50 %, 75 %, and 100 %) from two industries in Ilorin (i.e., Global Soap and Detergent Industry Limited and Peace Standard Pharmaceutical Industry) were used to irrigate three (3) varieties of *Sesamum indicum* (NGB 00931, NGB 00937 and NGB 00939). Although the control plants possessed larger leaves and longer stems than the effluent-treated plants, the plant growth is relatively higher at lower concentration. A gradual decrease in the germination of seeds and seedling growth with an increase in effluent concentration was observed.

The best germination and growth were observed at the 25 % concentration. Leaf epidermal features (stomatal density, stomatal index, stomatal size, trichome density, trichome index, trichome size, and number of epidermal cells) are more influenced in the effluent-treated plants than in the control plants from the Peace Standard Pharmaceutical Industry than in the effluent from the Global Soap and Detergent Industry Limited. Thus, the industrial effluents can be safely used for irrigation with proper treatment and dilution at 25 %.

3. Mitigating climate change: atmospheric purification and humidification

Mr. Vice Chancellor sir, the world is now facing an unprecedented climate change crisis from the accumulation of greenhouse gases such as carbon dioxide, methane, and nitrous oxide. The rise in the earth's temperature referred to as global warming or greenhouse effect has caused, with increased frequency and intensity, such events as droughts, windstorms, wildfires, and flooding.

That the atmosphere is becoming polluted at a higher rate is not a baseless fact. This is partly related to urbanization and industrialization, whereby many impurities are released into the atmosphere uncontrollably. Plants are used as an efficient cleaning system for the environment in a process known as "Phytoremediation," which can be done via various techniques in which plants clear the environment of pollutants (Pilon-Smits, 2005). Presented below are some of our works on the potentials of the stomata to purify and humidify the atmosphere:

1. **Purification and humidification potentials of plants (AbdulRahaman and Oladele, 2009, 2010; AbdulRahaman *et al.*, 2013f; Oyeleke *et al.*, 2004; Saadu *et al.*, 2009)**. Possession of stomata with many subsidiary cells (e.g. tetracytic and anomocytic types) plays a vital role in reducing greenhouse gases, especially carbon dioxide. This was demonstrated in studies of the relationship between the stomatal complex types and transpiration rate in some selected *Citrus* species (Obiremi and Oladele, 2001), afforestation tree species (Oyeleke *et al.*, 2004), *Borassus aethiopum*, *Oreodoxa regia* and *Cocos nucifera*(**AbdulRahaman and Oladele, 2009**), tropical tuber species (Saadu *et al.*, 2009) and shade plants **(AbdulRahaman and Oladele, 2010c; AbdulRahaman *et al.*, 2013f)**. In all these studies, stomatal complex types with many subsidiary cells transpired higher than those with smaller subsidiary cells (e.g. paracytic and diacytic

types). This translates to means that the latter opens faster than the former. Moreover, the other implication of the stomatal opening that favour water loss to the atmosphere (i.e., encouraging a high rate of transpiration) is also advantageous by humidifying the atmospheric air.

2. **Leaf size and transpiration rate (AbdulRahaman *et al.*, 2017a; AbdulRahaman and Oladele, 2017; AbdulRahaman *et al.*, 2019)**. To further justify the essence of stomatal complex types and the number of subsidiary cells, a study by **AbdulRahaman and Oladele (2017)** investigated the influence of the leaf area on transpiration in *Agave americana* and *Aloe vera*. The transpiration rate varied from $1.05x10^{-5}$ mol m^{-2} sec^{-1} to $1.14x10^{-4}$ mol m^{-2} sec^{-1} on the abaxial and adaxial leaf surfaces, in *A. americana.* In *A. vera*, the transpiration rate ranged from $6.17x10^{-5}$ mol m^{-2} sec^{-1} on the abaxial surface to $4.70x10^{-4}$ mol m^{-2} sec^{-1} on the adaxial surface. Although the leaves are larger in *A. americana* than in *A. vera*, the transpiration rate was higher in *A. vera* than in *A. americana*.

   However, leaf area alone could not determine the rate of transpiration because, in many cases, large leaves gave a low rate of transpiration and vice versa. In these situations, the determinant factors would obviously be the type or kind of stomatal features (i.e. stomatal complex types, stomatal density, index, and size) present in the leaves that influenced the rate of transpiration in *Jatropha curcas* and *J. gossypifolia*(**AbdulRahaman, 2009**). These two *Jatropha* species are good hedges, and ornamental plants found around residential houses.

   In furtherance of the early works on leaf size and transpiration rate **(AbdulRahaman *et al.*, 2017a; AbdulRahaman and Oladele, 2017**), a question was posed on the influence of the leaf size on the rate of transpiration as "**Is leaf size a factor in determination of the rate of transpiration".** Answering this question, a study was conducted on two (2) ornamental plants (*Canna indica* and *Euphorbia milii*). The leaves were larger in *C. indica* (105 mm^2 – 436 mm^2) than in *E. milii* (36 mm^2 – 142 mm^2), while transpiration rates were higher in *E. milii* (1.78 x 10^{-4} mol/m^{-2}/sec^{-1} – 2.56 x 10^{-3} mol/m^{-2}/sec^{-1}) than in *C. indica* (2.48 x 10^{-4} mol/m^{-2}/sec^{-1} – 3.70 x 10^{-5} mol/m^{-2}/sec^{-1}). With these results, the size of the leaf area has no effect on the transpiration rate in these two plants. Meanwhile, we concluded that the absence of evidence

of transpiration on the adaxial surface of the leaves of *E. milii* (where there are no stomata) suggested that other anatomical features, such as stomata rather than the leaf area, might determine the rate of transpiration in plants **(AbdulRahaman *et al.*, 2019**).

K. Stomata and pathogenesis

Pathogenesis could be defined as a multi-factorial process which depends on several circumstances such as the nature or virulence of the species of microorganism, the number of these microorganisms in the initial exposure and the immune status of the host. In pathogenesis, pathogenic penetration is one of the basic steps in disease development. For foliar bacterial, natural openings, such as stomata and wounds, are important entry sites for foliar bacterial plant pathogens. These openings have been considered passive points of entry for plant pathogenic bacteria. The following studies expantiate on the interactions between the stomata and pathogens:

1. ***Pseudomonas syringae* Van Hall [Pseudomonadaceae] infection and stomatal anatomy (AbdulRahaman *et al.*, 2013d).** In this study, we anatomically examined *P. syringae* infects *Lycopersicon esculentum* Mill (syn. *Solanum lycopersicon* L). The results revealed that rupture of guard cells, reduced in size of stomata and occurrence of small dark microscopic spots on the stomata are features which serve as an indication of pathogenic penetration. Also, morphological growth parameters assessed revealed significant reduction in plant height, leaf length, leaf area and leaf weight in the test plant compared with the control. The results suggest that disruption of stomatal anatomy by the bacterium will translates to low yield.
2. **Fungal filtrates, seed germination and leaf anatomy (Garuba *et al.*, 2014).** This studyinvestigated the effects of 7-day old fungal filtrates of *Aspergillus niger* van Tieghem and *Penicillium chrysogenum* Thom isolated from maize seeds on percentage germination, morphological and leaf anatomical structures of maize seedlings. Results showed that the percentage germination of the seed treated with culture filtrates of *A. niger* and *P. chrysogenum* (65.33 % and 79.6 % respectively) were lower than the control (100 %). The leaf area followed similar pattern as recorded for germination. Tetracytic stomatal complex type and wavy anticlinal walls remained constant in all the treatments and control. The stomatal index of seed treated with *A. niger* on abaxial leaf surface (43.61 %) showed significant difference with adaxial

leaf surface (31.97 %). The treatments had no significant difference on stomatal density at abaxial surfaces. Reduction in stomatal size and density suggests physiological implication.

CONCLUSION

Mr. Vice Chancellor sir, in the last 45 minutes, I have extensively discussed my research area. I have established that, without this **tiny** (**stomata**) microscopic structure that lucidly **explains the seen** in terms of plant growth and development, delimitation of species into taxa, response of plants to both biotic and abiotic factors, contribution to criminal investigation, plant identification for pharmacological and medicinal studies, food adulteration and safety, water use efficiency in the face of climate change and, awareness of the need to check deforestation and protection of endangered plant species, the study of plant anatomy and taxonomy/systematics would have been a mirage.

RECOMMENDATIONS

Mr. Vice Chancellor sir, distinguished ladies and gentlemen, drawing from my lecture, as part of our care for the green vegetation on earth, I wish to make the following submissions by way of recommendations:

1. Plant Anatomy laboratories should be established and well equipped with the state of the art equipment such as electron microscopes (Transmission Electron Microscope and Scanning Electron Microscope), microtomes (cryostat microtome, precision rotary microtome, sledge microtome, rotational microtome, ultramicrotome, hand microtome, Cambridge rocking microtome, freezing microtome), light microscopes, dissection microscopes, trinocular microscopes with screen, digital microscopes, diamond pencils, dissecting instruments, micrometers, basic plant anatomy slides, microslide, paraffin embedding bath, and hot plate etc. This will bring the best out of the Plant Anatomists to further contribute to knowledge;
2. Similarly, befitting herbarium should be put in place to aid plant identification processes for the benefits of Plant Biology researchers and students, and other relevant scientists. In some World renowned Universities, a whole building is dedicated for herbarium;
3. The main laboratory in the Department of Plant Biology should be well equipped and maintained. The present situation at the

University of Ilorin needs urgent attention. The Administration should, therefore, as matter of urgency come to the aid of the Department by providing a befitting building well equipped with modern equipment that can enhanced research and teaching;

4. Students of the Departments of Plant Biology (Departments of Botany) should further be engaged in regular field trips to increase their familiarities with and interest in plants;
5. Students should also be engaged to go on mandatory excursions to relevant industries apart from the normal annual Students Industrial Work Experience (SIWES). The industrial excursion should be enshrined in the curriculum at 300 and 400 levels. This will enable the students to appreciate the essence of the course of study i.e. Plant Biology/Botany; and
6. Our manufacturing industries should come up with policies that are not profit-oriented but that are also environmental-friendly. Production systems must now lay more emphasis on drastic reduction in emission of industrial effluents which constitute environmental pollutants especially the green-house gases;
7. To prevent further destruction of our forests, government should enact a law to subsidised kerosene to the extent that citizens (especially the rural dwellers and the poor) should just enter the filling stations and collect it free of charge. If this is not possible, 5 litres of kerosene should be sold for as low as 50 naira so that it will be affordable for the masses to buy. This will go a long way to reduce the incidences of deforestation.

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