Floral Diversity Using Microscopy (LM & SEM) of Takkar Wildlife Sanctuary, Sindh-Pakistan

By

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Floral Diversity Using Microscopy (LM & SEM) of Takkar Wildlife Sanctuary, Sindh-Pakistan

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In

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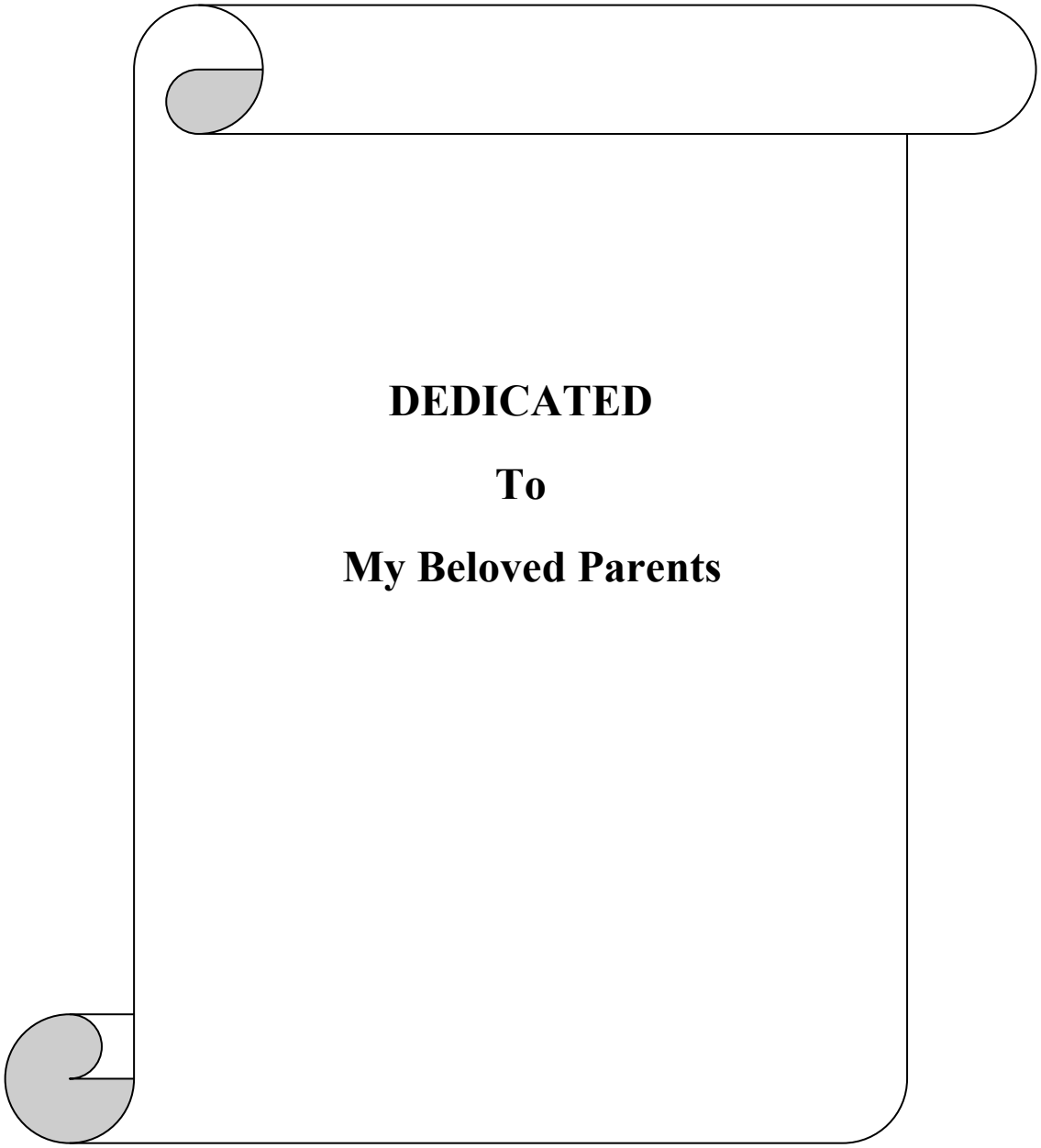

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ABSTRACT

This project is confined to presenting taxonomic information on angiosperms plant species from the Takkar wildlife Sanctuary Sindh-Pakistan. This study elucidates the micromorphological characterization of wild flora adapted to arid environment. Microscopic techniques can be applied to solve the taxonomic problems in field of plant systematic and are extremely of versatile in nature. This study was focused on the new approaches to visualizing the images of plant parts to cover the micro-structural features of leaf and pollen. We elaborate that comparative micromorphological attributes of pollen and leaf of wild floral species were analyzed using light (LM) and scanning electron microscope (SEM). A total of 56 plant species were categorized into 50 genera and 23 angiosperm families. Pollen grains of collected species were acetolyzed, observed and measured through statistical software. Wild floral species showed variation in shape, type, aperture, and exine sculpturing. Leguminosae was the dominant family revealed scabrate, reticulate-scabrate, psilate–scabrate, psilate-perforate, psilate-reticulate, reticulate, reticulate-verrucate, psilate exine wall peculiarities. The minimum exine thickness was recorded in *Erythrina suberosa* (0.75 µm) whereas *the* maximum thickness of exine in *Trifolium resupinatum* (5.24 µm). Foliar anatomical micromorphology of collected plant species was performed using lactic acid and nitric acid methods. Scanning electron microscopy was used to investigate various micro epidermal traits. Both leaf surfaces (adaxial and abaxial) revealed variations in the leaf anatomical traits including stomata types, epidermal cell form, anticlinal wall, and trichomes diversity. The epidermal cell shapes were observed as polygonal, wavy, isodiametric, and polygonal. The largest epidermal cells were examined in *Dalbergia sisso* (47.5 µm) on the adaxial side and *Prosopis cineraria* (38.5 µm) on the abaxial surface. Largest stomatal complex diameter was recorded for *Dalbergia sisso* (24.9 µm) on the abaxial surface. The non-glandular trichomes (NGTs) were observed long falcate, short conical, lipidote, capitate and filiform in *Astragalus hamosus*. Overall, the examined micromorphological leaf and pollen traits of plant species collectively have a significant taxonomic potential to identify and define species boundaries at the generic level and can be used as an additional tool to strengthen the taxonomic position and differentiate the flora of the Takkar Wildlife Sanctuary at the subfamilial, tribe, generic and specific level.

CHAPTER: 1

Introduction

1.1 Wildlife Sanctuaries

Wildlife sanctuaries are protected areas that are established to conserve and protect wildlife and their habitats. In Pakistan, there are three categories for conservation of flora and fauna: Game Reserves, wildlife Sanctuaries and National Parks. Sindh has very diverse ecosystems and natural habitats. Deserted eastern side flanked with India while the south has mangroves forest in Arabian sea and western parts are hilly mountains (Thangliankhup et al., 2023). They play an important role in the conservation of plants, in several ways:

i. **Protection of plant species**: Wildlife sanctuaries provide a protected environment for plants and their habitats. This helps to conserve rare and endangered plant species, which would otherwise be threatened by human activities such as habitat destruction, over-exploitation, and pollution (Maunder et al., 2001).

ii. **Preservation of biodiversity**: Wildlife sanctuaries are designed to protect a wide range of plant and animal species. This helps to preserve the biodiversity of the area and maintain a balance in the ecosystem (Oliveira, 2016)

iii. **Research and monitoring**: Wildlife sanctuaries provide opportunities for scientists and researchers to study plant ecology, physiology, and conservation. This helps to increase our understanding of plant biology and ecology, and to develop conservation strategies

iv. **Restoration of degraded habitats**: Wildlife sanctuaries are often used to restore degraded habitats, such as those that have been damaged by human activities. This helps to improve the quality of the habitat and to increase the diversity of plant species.

v. **Ecotourism**: Wildlife sanctuaries often attract ecotourists, who come to see the unique plant and animal species that live there. This can provide a source of income for local communities and can also raise awareness about conservation issues Cobbinah, P. B. (2015).

Overall, wildlife sanctuaries play a vital role in the conservation of plants by protecting rare and endangered plant species, preserving biodiversity, providing opportunities for

research and monitoring, and restoring degraded habitats. This helps to ensure the survival of plants and their habitats for future generations.

1.2 Plant Exploration from Protected Areas

Plants and humans have been deep relationship from prehistoric times. The dependence of humans on plants is long history from ancient times. Various ancient civilizations in prehistoric times, explored the uses of plants in their life. They use plants as fuel wood, food, vegetable, shelter, medicine and many other essential economical services. In the field of Botany, various uses of plants based products is studied and later on the proper field is developed named as “Ethano-botany” this term was applied by American botanist Hershberger in 1895 (Qureshi and Bhatti 2008). Plant exploration is an essential part of taxonomic study. To know the flora of specific area, field flora most be collected. In all over the world, many regnal and international floral inventories have been developed by many plant taxonomists researchers. Flora and flora are two different words with meaning given below:

i. **Flora:** inventory of the Plants
ii. **flora:** plants present in field or in wild

Plant exploration from the wild sanctuaries involves the collection and study of wild plant species in their natural habitats. This can include collecting samples for scientific research, identifying and cataloging new plant species, and studying the ecology and evolutionary history of the plants. Plant exploration can also involve the sustainable use and conservation of wild plant resources, such as the collection of medicinal plants for traditional medicine or the cultivation of wild plant species for food and other uses. Plant exploration is a vital part of taxonomic study, as it helps to increase our understanding of the diversity and complexity of the plant kingdom and can also lead to the discovery of new resources for human use (Janick, 2007).

1.3 Significance of Floral Inventory

Flora" refers to the plant life of a specific area or region. It encompasses all the plant species that grow in a particular location, including both wild and domesticated plants. Flora can include trees, shrubs, grasses, herbs, mosses, and other types of plants. The term is often used in the context of describing the plant life of a particular ecosystem, such as a forest, desert, or wetland (Nobis et al., 2019).

Flora is also used as a proper noun to refer to the scientific study of plants, also known as botany. Flora is usually used as a reference book that describes and illustrates the plant species found in a particular area or region. It includes information on the distribution, ecology, physiology, taxonomy and other aspects of the plants. Floras are often organized by family or genus, and they typically include detailed descriptions, illustrations, and keys to help identify the different plant species. In summary, "Flora" as a noun refers to the plant life of a particular area or region and as a proper noun, it refers to a reference book that describes and illustrates the plant species found in a particular area or region, it also refers to the scientific study of plants (Körner and Hiltbrunner, 2021).

1.4 Flora of Pakistan

Native flora of Pakistan is natural wealth/ Commodity and blessing for our country. Many floristic research studied has been published recently from Pakistan. For the purpose to known the Flora of region, Plant taxonomists have arranged many expeditions to collect plants of this region. Before the creation of Pakistan, at the times of British India, W. Moorcroft did collections in the period of 1820-1822 from Kashmir and Ladakh followed by V. Jacquemont from the areas of Kashmir and upper Punjab from 1828-1832. While at the time of partition of Sub-Continent of India, the only comprehensive book was “Flora of British India” written by J. D. Hooker (1872-1897). In this book, many important areas were not covered, such as Khyber Pakhtoon Khwa and Balochistan. The first plant collector from Sindh was Mr. N. Vicary, in 1838. At that contemporary, William Griffith also did collections from Khyber Pass and Balochistan. The great contribution, plants collection from all over Pakistan by R.R. Stewart (1890-1993) was always remarkable (Ali, 2008).

1.5 Significance of Plant taxonomy

Plant taxonomy is important field of Botany, which deals with nomenclature, theory and description of plants. Plant taxonomists, distinguishing species from each other by developing keys. Before the invention of Light Microscopy, Botanists were developed keys through Macro morphological features of Plants. Two major approaches are useful in the field of plant taxonomy for identification of plants is: macro-morphology and micro-morphology characteristics. In Classical taxonomy in which macro-morphological characteristics is the basic tool for identification,

description and classification. Classical taxonomists utilized external /macro-morphology for taxonomic studies. Modern biologists using various approaches of other discipline such as anatomy, palynology, cytology, paleo botany, ecology for identification, description of plants for correct identification. Within the genus and species, distinctive / peculiar characteristics are useful in delimitation of species (Nualart et al., 2017).

1.6 Digitization of Herbaria

Various herbaria of European countries and north as well south American are jointly working to digitize the floristic data to preserve specimens. The most recent update of crucial work was launching of World Flora Online (WFO) in May 2021. The data base of WFO is replacement of The Plant List (TPL). WFO is a comprehensive and vital database of taxonomic hierarchy of all known plants. Digital database of TPL was established in response to Target_1 of Global Strategy for Plant Conservation (GSPC) (Filardi et al., 2018). For the conservation of Plant diversity, all over the world 193 Countries have adopted the Convention on Biological Diversity (CBD). TPL was joint venture of Missouri Botanical Garden and Royal Botanic Gardens Kew by conglomeration of various Checklist of Plants by the help of computing algorithms (Soltis, 2017).

1.7 Plants Conservation & Restoration of Natural Habitats

Conservation and restoration of natural habitats involves protecting and preserving ecosystems and the plants and animals that live within them. This can be done through a variety of methods, such as creating protected areas, managing and reducing human impacts on the environment, and reintroducing endangered species. Restoration of natural habitats involves actively working to improve the health and function of ecosystems that have been degraded or destroyed. This can include removing invasive species, restoring degraded soils, and reintroducing native plant and animal species. Both conservation and restoration are important for maintaining biodiversity and ensuring the long-term health of the planet. In this regard, International Union for Conservation of Nature (IUCN) initiatives to focus on plant diversity which are declining day by day. To evaluate threatened status of plants are categorizing. (Romeiras et al., 2016).

1.8 Morpho-palynological Studies

Palynology is the scientific assay of Pollen gains produced by angiosperm plants. Pollen grains are produced by male part of plants for the purpose of reproduction. The term palynology was first coined by Hyde and William (1945). Nowadays, pollen grains are used in many applied sciences to solve the ambiguities. In the field of forensic palynology, in which investigation of various crimes made easy on the bases of pollen grains associated with items (Carter et al., 2018). Every environment has its peculiar type of species. Palynology also deals with the Pollen related allergy. Seasonal allergenic diseases caused by pollen grains effects almost 400 million people, reported by World Health Organization (WHO). Morphological examination of pollen grains solves the taxonomic problems of different families of flowering plants. Melissopalynology, is also the assay of pollen grains present in honey, which are collected by bees from specific flora of area. The analysis of honey traces the botanical and geographical origin of honey. By the assay of pollen types in honey, sources of nectar and foraging behavior can determine (Özbek et al., 2016).

Pollen grains are essential part of male reproductive cell. Through the pollination process plants produce fruits and seeds. Pollen grains produced inside the anther. Anthers are hold by filament. The collective name of filament and anther is Stamen. Pollen grains are very durable and resistant to many extreme weather conditions. Exine sculpturing refers to the surface patterning or ornamentation of the outer layer (exine) of a pollen grain. These patterns can be used to identify and classify different types of plants and can also play a role in pollen dispersal and germination. The exine is composed of a complex mixture of lipids and proteins, and the sculpturing patterns are formed by the arrangement of these molecules. Techniques such as scanning electron microscopy and transmission electron microscopy can be used to study exine sculpturing in detail (Božič, and Šiber 2020).

Pollen grains, generally made up of three layers: Intine, Exine and Sporopollenin. Intine is inner layer and composed of cellulose while the Exine is outer layer and utilized for taxonomic studies. The Sculpturing of exine is morphologically used to identify pollen. Further, exine is formed of two chemicals: ectexine and the endexine. Sporopollenin is also complex compound which water proof and highly resistant environment. Features of pollen grains are such as symmetry, Pollen-Unit,

polarity, grain size and shape are essential indicators of taxonomic and phylogenetic study. Pollen aperture or wall is more important for taxonomic study and through which pollen tube germinate. In studied taxa, the basic apertures ornamentation of studied taxa plays a primary role in the analysis of correlation, while the secondary role is played by exine surface ornamentation and pollen shape and size place in the tertiary category of connotation agree with earlier studies by (Erdtman,1952). Pollen aperture takes attention of the host of palynologists during the phylogenetic debate (Bahadur et al., 2018).

1.9 Significance of Microscopy in Palynology

Palynology is the study of pollen and spores, and the microscope is a critical tool in this field. The microscope allows palynologists to study the structure, size, and shape of pollen and spores, which can be used to identify and classify different plant species. Some key ways in which the microscope is used in palynology include:

i. Identifying plant species: Microscopes are used to observe the unique characteristics of pollen and spores, such as the shape and size of the grains and the ornamentation of the exine (outer layer). These features can be used to identify and classify different plant species, and to reconstruct past vegetation and climate (Mahbod et al., 2021).

ii. Studying pollen morphology: Microscopes are used to study the fine structure of pollen, including the ornamentation of the exine, the number and shape of the pores, and the shape and size of the pollen grains. This information is used to understand the evolutionary relationships between different plant groups and to reconstruct past vegetation.

iii. Analyzing pollen samples: Microscopes are used to study samples of pollen and spores collected from the air, water, or sediment. Palynologists use microscopes to count the number of grains of each type of pollen or spore in a sample, which can provide information on the types of plants present in a particular area or time period.

iv. Research on palaeoclimatology: Microscopes are used to study the pollen and spores preserved in sedimentary rocks, ice cores, and peat bogs. This information

can be used to reconstruct past climates and to understand how climate change has affected vegetation over time.

v. Paleoecology: Microscopes are used to study the pollen and spores preserved in sedimentary rocks, ice cores, and peat bogs. This information can be used to reconstruct past ecosystems and to understand how human activities have affected vegetation over time (Edwards, 2018).

Overall, the microscope plays a critical role in palynology, enabling scientists to study the intricate details of pollen and spores, identify and classify different plant species, and understand how vegetation and climate have changed over time.

1.10 Foliar Microanatomy

Foliar anatomical features of plants are important tool which are used to overcome the problem of identification. The leaf epidermal anatomical features of each plant species has unique epidermal features. Leaf epidermal anatomy is essential tool for systematic studies of plants. Two types of characteristics are utilized by taxonomists for correct identification of plant: macro-morphological and micro-morphological characteristics. Macro-morphological characteristics are visually observed by researcher and apply the taxonomic hierarchy on plant for correct identification (Raza et al., 2022). Initially observed characteristics are such as type of inflorescence, arrangement of leafs, stem surface and fragrance of plants. For corrected identification of plants, it's essential to examine the micro-morphological characteristics. Taxonomists used the anatomical features such as, epidermal cells, stomatal features, trichome and glands. Within the genus and species, distinctive / peculiar characteristics are useful in delimitation of species. epidermal layer of leafs has multiple function, it protects plant from excess loss of water during warm weather by transpiration. Opening and closing of stomata also regulates by epidermal layer of cells. In this assay, we observed in various types of stomata in plants such as; paracytic, anisocytic, anomocytic etc. while the different trichomes of plants also important taxonomic features, which could be utilized aid in identification of plants (Bano et al., 2020).

Leaf epidermal characters can be helpful in explaining the diverse taxonomic relationships at various levels (Nazir et al., 2013). In determining the taxonomic status of various taxa as well as in recognition, distinction and demarcation of these taxa anatomical analysis is a crucial tool. Phylogeny, species number and genera are also

determined by leaf epidermal features (Scatena et al., 2005). Several vital distinctive characters are owned by leaf epidermis that act as important keys in identification such as stomatal size, shape and orientation, subsidiary and guard cells, cell wall structural particularities as well as trichome types (Dickison, 2000).

Ahmad et al., (2010) analysed diversity of stomata in Euphorbiaceae and discovered elongated, polygonal, trapezoidal shaped epidermal cells with arched, sinuous or straight anticlinal walls. Ahmad et al., (2010) studied foliar epidermis of about forty angiosperm species belonging to thirty-eight genera from twenty-two families. Polygonal epidermal cells were recorded in most of the members of family Brassicaceae with little undulations. Five plant species belonging to family Brassicaceae including *Cardaria draba, Sisymbrium irio, Malcolmia africana, Capsella bursa-pastoris* and *Neslia apiculata* were investigated and were found to have pedate or antler trichomes (Khan et al., 2013). Ethnobotanical survey of family Brassicaceae was conducted in Leepa Valley, Muzaffarabad by (Ishtiaq et al., 2015) Chaudhari et al., (2014) conducted foliar epidermal anatomical analysis of twenty-nine grasses of ten tribes in Thal desert (Khushab).

In order to study the structural modifications of some grasses from Pakistan's Salt Range three possible salt-tolerant grassses i-e *Imperata cylindrica, Sporobolus arabicus* and *Cynodon dactylon* were gathered from salt-affected area in Salt Range (Pakistan) (Hameed et al., 2008). Ahmad, et al., (2009) carried out taxonomic investigation of grasses of Salt Range as well as their native uses. During 2005 to 2007 a comprehensive survey was conducted in order to examine nodulated legume weeds that grow in Pakistan's north-west (Dera Ismail Khan) (Marwat et al., 2009). Ahmad, et al., (2009) studied dicot flora in District Tank, N.W.F.P (Pakistan) to analyse taxonomic variations among stomata. Husain et al., (1994) conducted anatomical analysis of seed coat and leaf of seven plant species of genus *Medicago L.* from Pakistan using SEM. Ethnobotanical study was carried out in order to document ethnobotanical use of plants that belong to families Euphorbiaceae, Brassicaceae, Fabaceae and Moraceae in District Chakwal distant villages (Sultana, 2006).

1.11 Significance of Scanning Electron Microscopy (SEM)

The most important stage for every taxonomist is the taxonomic identification of any plant species. It depends on taxonomists' fundamental instincts, abilities, and knowledge. For identifying species, morphological methods were more used in the past. Modern taxonomy, however, also combines numerous approaches, such as anatomy, palynology, phytochemistry, genetics, molecular biology, embryology, serology, ecology, etc., as a result of scientific advancements (Arias et al., 2017). According to Blair and Turner (1972), one important tool for identifying plants and resolving their taxonomic issues is micromorphology. The development of the scanning electron microscope changed the use of micro morphological traits in plant taxonomy (SEM). The use of SEM in the identification of species has shown a variety of ultrastructural traits that could be very helpful in species identification (Sivaguru et al., 2012).

The introduction of the SEM has provided a new dimension to the morph-structural traits that are available for the detailed evaluation of the leaf surface. The trichome morphology was studied, and the taxonomic problem was resolved using the scanning visualization approach. The SEM technique revealed that the leaf surface was covered in different kinds of trichomes, and that the stomatal complex features had a significant systematic relevance (Beilstein et al., 2006). Researchers identify plants based on the comparison between pollen microscopic characters of examined specimens in order to determine differences between them. Scanning electron microscopy (SEM) is the advanced form of microscopy that is used for the characterization of pollen morphological features of plants (Gazer and Shalabi, 2016).

1.12 Justification of the Research Project

The study area of Takkar wildlife Sanctuary did not explore before to study the local flora of this protected area. In this research project, all collected plants has been observed on two aspects of the systematic study: Anatomy and Palynology. Anatomical study is crucial part of plant taxonomy. Foliar anatomy aid for identification of Plants. Mostly taxonomists emphasized on external morphology of plants before the industrial revolution of mid-18 centuries. After advancement in science and technology, Light microscope was utilized to observe micro-morphological features which can be peculiar and helpful in the identification of plants. Each plant family has distinguished anatomical features. In this present research project, various types of stomata and trichomes were studied which can be utilized for taxonomic study. This floristic

inventory of Takkar Wildlife Sanctuary also helpful for various agencies working for the conservation of biodiversity.

The majority of plant species growing on the flanks of the characteristic flat terrain found in Takkar wildlife sanctuary is the foot or base of the sand dune (Khaskheli et al., 2022). The most common alluvial soil components in depressions are clay and silt. A forest habitat exists in low-lying flat regions near the sand dunes, which sustain diversity of tall and ancient trees. These trees provide shade for animals during the warmest hours of the day. Saline lands formed as a result of stagnant rainwater on the flat plains of the depressions. Rainfall collected in depressions in neighboring valleys, bringing alluvial soil with it. Water evaporation from larger depressions causes salt deposition and the development of sodic soils. A number of saltwater lakes may be found in the region. Grass, reeds, and cattails dominate the ecosystem. These plants are examples of emergent vegetation, which has roots in water-soaked soil and leaves that cling to the surface of the water (Rajpar et al., 2019; Yaseen et al., 2019).

Perennial herbs and drought-resistant thorny bushes predominate in the majority of the regions. Droughts, catastrophes, and irregular rainfalls have severely harmed plant biodiversity in Takkar wildlife sanctuary over the previous century, due to global warming and fast climate change. *Acacia Senegal, Prosopis cineraria, Tecomella undulata, Commiphora wightii, Euphorbia tirucalli, Pedalium murex, Moringa concanensis, Cistanche tubulosa, Acacia jacquemontii, Senna occidentalis* and others are among the most significant medicinal species. Each wildlife sanctuary support habitat and landform of distinct flora and fauna, each with its own niche that is unique to the Takkar sanctuary. Plant species that are economically significant have become endangered (*Commiphora wightii, Tecomella undulata, Prosopis cineraria, Acacia nilotica, Tamarix aphylla, Cenchrus biflorus*, and *Calligonum polygonoides* are among the most significant floral species (Khan and Frost, 2001).

Many ethnomedicinal research has been conducted in Pakistan's northern areas and Punjab plains, but the wild floral diversity in the wildlife sanctuaries have been overlooked for a variety of reasons. Some of the primary causes are a lack of knowledge among the local population, a lack of amenities for foreign employees, and the lack of research and academic institutes in wildlife sanctuaries. Only a few research on provides only checklist and ethnobotanical documentation from wildlife sanctuary have

been undertaken. However, the majority of the reporetd studies from wildlife sanctuaries in Pakistan presents only checklist of plant species without any focus on possible ways of their taaxonomic characerization. In the recent, taxonomic specturum should be explaored with comprehensive information on related micromorphological characters to accurately identify the wild floral species from Takkar wildlife sanctuary.

1.13 Aims of the Study

- Enlist floristic inventory of wild flora along distribution localities around Takkar Wildlife Sanctuary.
- Microscopic characterization based on (LM & SEM) tools to evaluate the palyno-taxonomic and anatomical leaf structure for accurate species identification.
- Compare the taxonomic micromorphology of wild floral species based on palynomorphic and foliar anatomical traits at species, genus and family level.

CHAPTER: 2

Materials and Methods

2.1 Research Work Outline

The research project's approach is outlined in this section. The choice of the research area, the sampling method, and the experimentation protocols are described briefly. It also details the source of the sample data, as well as the process of data collection and analysis. The Takkar Wildlife Sanctuary located in the Sindh province was selected to collect wild floral species throughout the Takkar wildlife sanctuary during various field trips were carried out from moon soon season in August 2021 to spring February 2022. The study's main objective is to find out the taxonomic identification using diverse microscopic tools. The experimentation of the selected plants was performed in Plant Systematics and Biodiversity Laboratory Quaid-i-Azam University Islamabad. The study focuses on the palyno-anatomical perspectives of wild floral species from Takkar wildlife sanctuary.

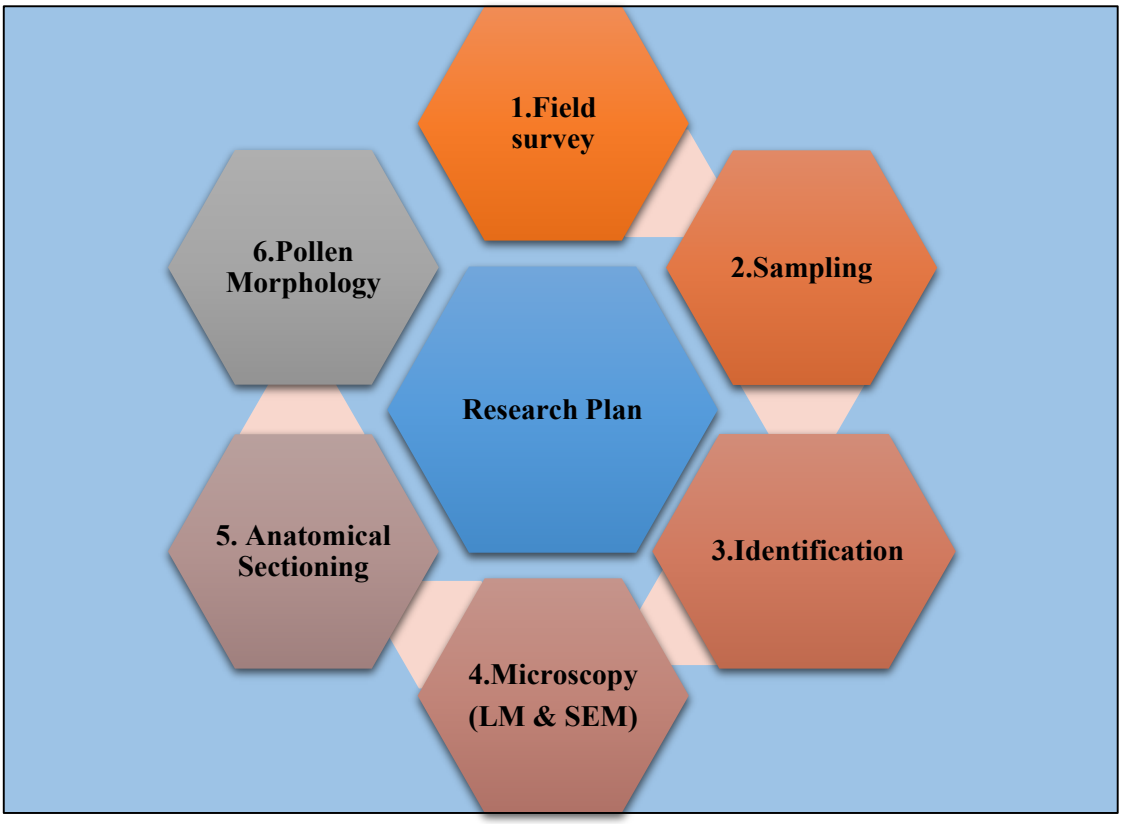

Figure 1. Flow chart showing research overview.

2.2 Study area: Takkar Wildlife Sanctuary

Takkar Wildlife Sanctuary is very diverse topographically. Eastern part of the sanctuary is deserted; with rocky plain area in some parts of this sanctuary. The sand dunes have covered Rocky Mountains. Takkar wildlife sanctuary is spread over 107,520 acres of land in two districts: Khairpur mir's and Sukkur of Sindh province, Pakistan (Figure 2). The historical heritage fort of Kot diji is also situated in this wildlife sanctuary. Takkar area falls within Nara tehsil of Khairpur district and Saleh pat tehsil of Sukkur district. It was declared "protected forest" vide Sindh government gazette notification of January 15, 1960 and subsequently it was declared a "reserve forest" through the west Pakistan gazette notification dated 17, 1967. In this wildlife sanctuary, local people are living and their main source of income is livestock domestic camels, goats and cows. Deficiency of water in area of Takkar is due to deep water table, indigenous people save the rain water in little dams for their animals and for domestic uses (Khaskheli et al., 2022)

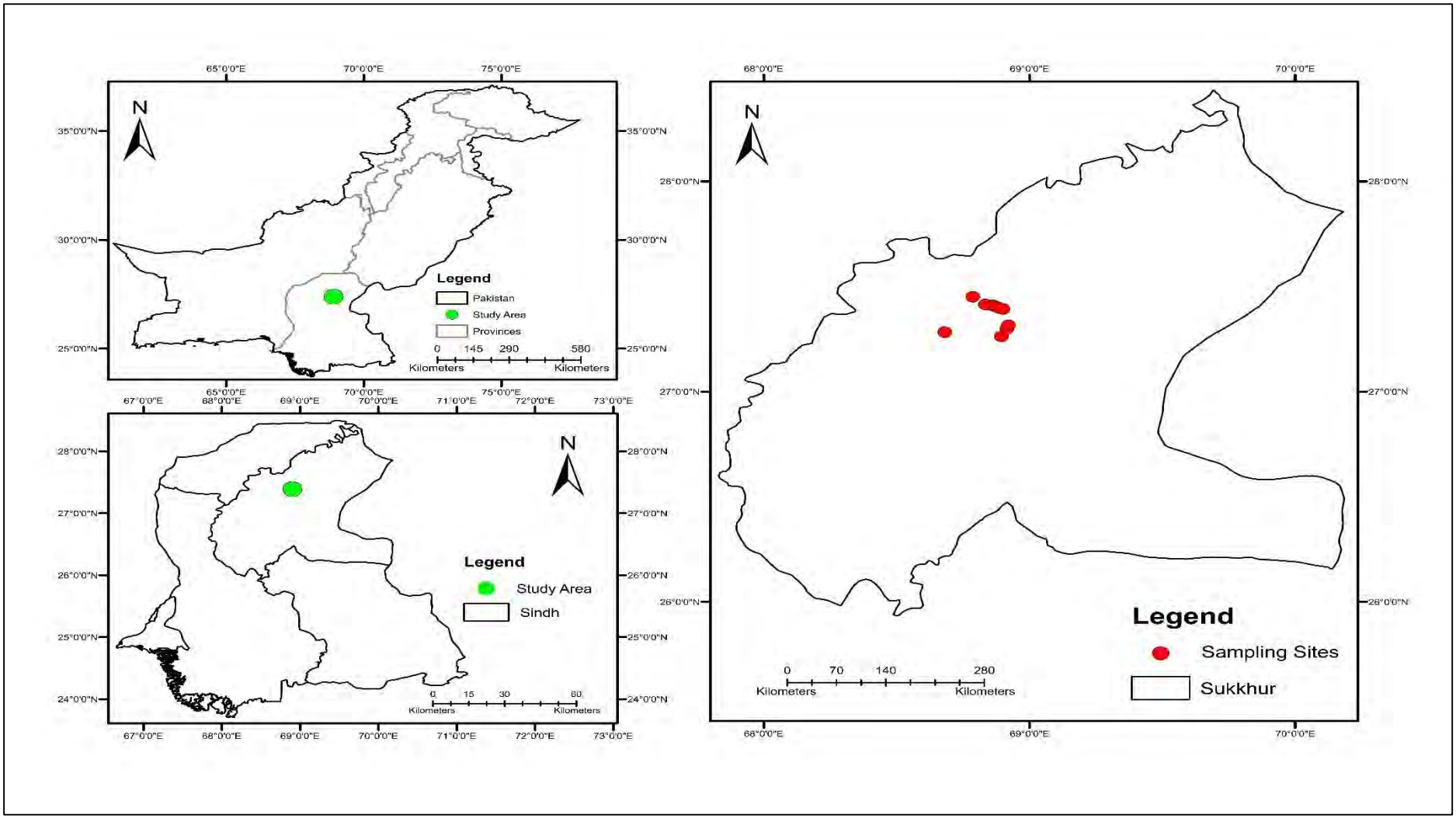

Figure 2. Map of the study area: Takkar Wildlife Sanctuary

Plate 1. Panoramic view of Takkar Wildlife Sanctuary; (a) Sultan Bhambhiro (b) Lal Juryo Khan Shambani

Plate 2. Panoramic view of Takkar Wildlife Sanctuary; (a) Wariwaro (b) Chubara Bangul Khan Chandio

2.3 Sampling of Takkar Wildlife floral diversity

Post monsoon is best time for collection of plants as mostly plants were in flowering stage. The main source of plants found in "Tarayoon" in local Sindhi language which means lower areas. In monsoon season water flows from mountains towards lower. The wild floral species of the wildlife sanctuary were explored and their field inventory was taken. Plants were collected with complete parts such as leaves, flowers. Filed photographs of each plant were taken by Panasonic ZS 20 camera (Figure 1) and plants kept in plastic zipper bags, habitat and geo-coordinates were noted of each plant. After collection from field, plants were dried in plants presser with blotter papers. Identification of plants made by comparing with already present specimens and also seeks help from various online flora such as http://www.worldfloraonline.org/. Collected wild species of Takkar wildlife sanctuary were mentioned in Table 1.

2.4 Plant Identification

Identification of plants is the most important and primary step in plant taxonomy. For identification of wild species, various sources were used including eflora of Pakistan Tropicos (https://www.tropicos.org/Project/Pakistan), compared plants with the already deposited herbarium specimens, and images of plants were searched through Google, various websites, articles, and literature. The identified plants were placed on a herbarium sheets and were stored in the Herbarium of Pakistan, QAU Islamabad (Ali, 1983).

2.5 Specimens Preservation and Mounting

Completely dried specimens were prepared for poisoning to save it permanently from fungus and other insects. The standard method was applied. Ethanol (absolute 99.8%) was taken in jar and then mercuric chloride (fine crystals) was mixed with it. When the solution was prepared, each plant was dipped in it. Caution was done during poisoning by wearing gloves, glasses, a lab coat and a mask as chemicals are volatile and can harm the body. The preserved samples were placed in the shade for some time to dry. After drying, plants were mounted on herbarium sheets of standard size i.e. 12×16 inch. Afterwards, specimens were mounted on sheets using glue, and tags were pasted on them on which required information such as specimen name, voucher number, locality, collector name, and date of collection, and collector names were

mentioned. For better preservation herbarium sheets were placed into zipper plastic bags so that spores and parts of plants remain to save and these plants can easily be used for different purposes of research. Three voucher specimens of each collected specimens were deposited in the ISL Herbarium (De Vogel, 1987).

Plate 3. Field plant collection from Takkar Wildlife Sanctuary; (a) *Arnebia hispidissima* DC. (b) *Lantana camara* L.

Plate 4. Collected Plant specimens (a) Preservation (b) Mounting on the herbarium sheets.

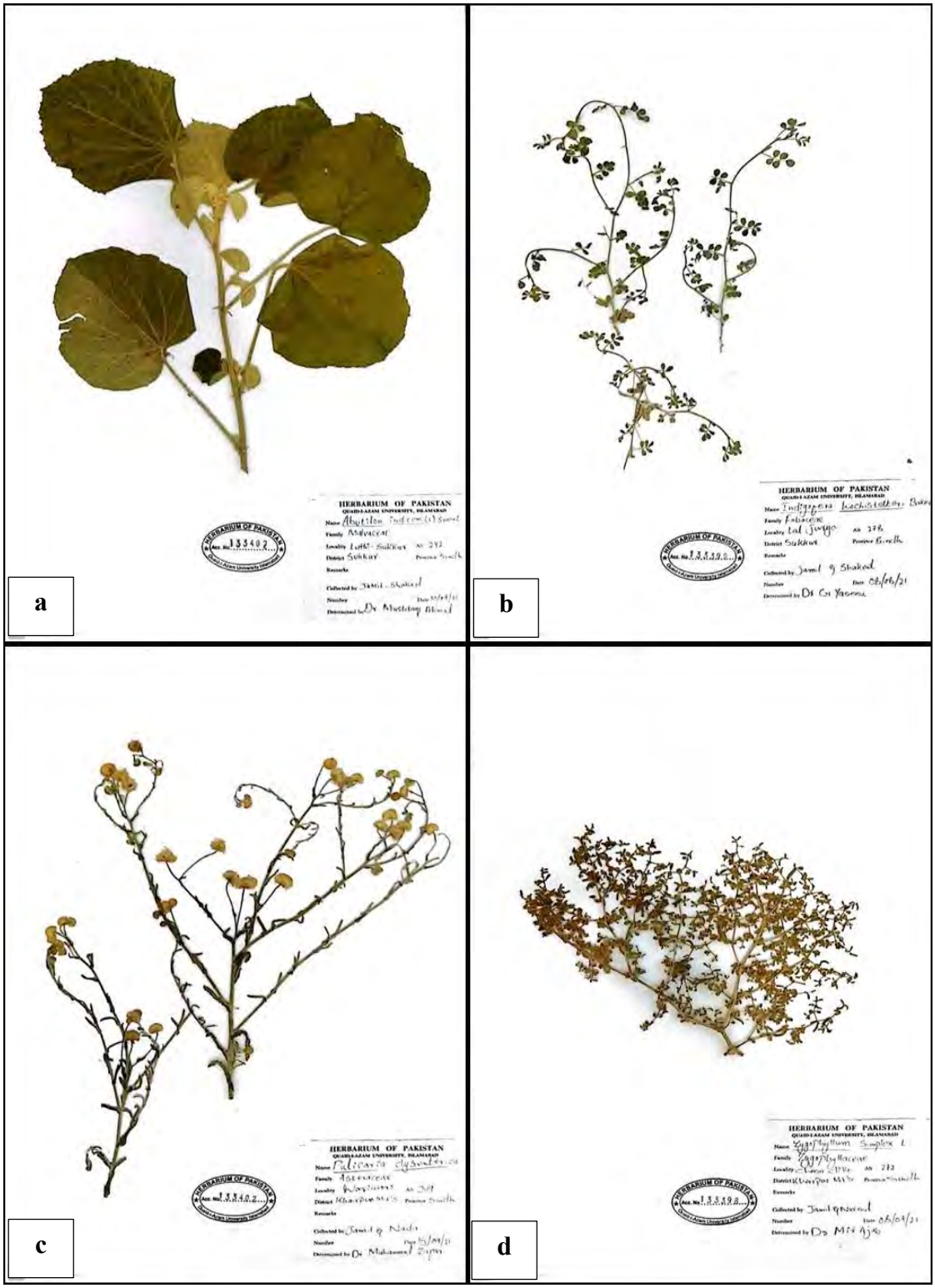

Plate 5. Mounted Herbarium Specimens: (a) *Abutilon indicum* (L.) Sweet (b) *Indigofera hochstetteri* Baker (c) *Pulicaria dysenterica* Gaertn (d) *Zygophyllum simplex* L.

2.6 Microscopic Micromorphological Studies

2.6.1 Pollen Morphometry

a) Acetolysis Technique (Light Microscopy)

Micro-morphological features of pollen grains were examined under Light Microscope (LM). The preparation of slide is followed to (Erdtman et al., 1963) acetolysis technique, which is popular method among palynologist all over the world. Anthers were collected from bloomed flowers, mostly in the stage of anthesis. Clean forceps are used to pick anthers from flowers and put it into glass slide. After that, 2 drops of acetic acid are put over anthers and crushed with glass rod. Within 2 to 3 minutes' pollen grains were released from anthers. Remaining debris were cleaned while pollen grains were attached to slide. Than Glycerin jelly for staining of pollen were used and Cover slip is placed over slip for long term preservation of slid. Prepared slides were studied on the Quantitative and Qualitative basis.

b) Scanning Electron Microscopy (SEM)

Exterior pollen grains sculptured elements were examined using scanning electron microscopy (SEM) micrographs. Anthers from bloomed flowers were separated and put on glass slide than one drop of acetic acid was fell over anthers and crushed with needle for 30 seconds, finally pollen were released. Rounded stub attached with glass to pick pollen grains from slide after 5 minutes and then stub was coated with gold-palladium. For gold coating of specimens, sputter device was used. Finally, these stubs install in SEM machine to take micrographs of Exine sculpturing (Majeed et al., 2022). Pollen characters were described using the terminologies of Punt et al., (2007) was followed for light microscopic observations and Halbritter et al., (2018) for scanning microscopic descriptions of pollen characters. The definitions of (Nilsson and Praglowski, 1992) were used for pollen shape classes (P/E index). According to (Rowley 1990). the pollen sizes were measured; very small < 10 µm, small 10-25 µm, medium 25–50 µm, large 50-100 µm, very large 100-200 µm and huge > 200 µm.

2.6.2 Foliar Epidermal Moprho-anatomy

In this method, preserved plant specimens were utilized to study foliar anatomical characters. 2-3 leaves were cut with razor blades and placed in test tubes. Boil for 1-3 minutes in a solution of 30% lactic acid and 70% nitric acid. After that, the

leaves were placed in petri dishes and rinsed to eliminate the chemicals. The leaf epidermis was peeled by using camel hair brushes and a pointed needle. In another petri dish bleach were taken along with peeled section of leaf. Around 2-4 drops of lactic acid were added to peeled section (epidermis) and let it merge for 2-4 minutes. After few minutes the peeled section was taken in glass slide again with a drop of lactic acid and cover slip. Nail paint was used to make glass slides permanent. After then, the clear slides were examined under a microscope (Raza et al., 2022).

2.7 Statistical Analysis

The statistical software (SPSS 16.0) used data to statistically measure the mean, maximum, minimum, and standard error values. About 15 to 20 readings were calculated for each parameter to statistically analyze the mean (minimum-maximum) SE (Zafar et al. 2019).

2.7.1 P/E Ratio

P/E ratio is determined based on equatorial diameter of same pollen as given by Butt et al. (2018).

$$\boldsymbol{P/E\ ratio = PD/ED}$$

Where P is the polar diameter and E is the equatorial diameter.

2.7.2 Stomatal Index

Stomata measurement was calculated under optical microscope in unit area for stomatal index. Stomatal index was measured using given formula.

$$\boldsymbol{S.I = S/E + S \times 100}$$

(S.I = Stomatal index; E= Epidermal cells per unit area; S= Stomata per unit area).

Plate 6. (a) Herbarium specimen's morphological study (b) Light microscopic observation and photography

CHAPTER: 3

Results & Discussion

3.1 Summary

The Takkar Wildlife Sanctuary has been bestowed with rich floristic diversity. Some endemic and medicinal plants of the country are restricted in this wild sanctuary area. The current project was confined to Districts Khairpur and Sukkur. These wild sanctuary areas were explored first time taxonomically. Previous work was fragmented but the present research is comprehensive and includes the taxonomic authentication using microscopic techniques of 56 wild sanctuary inhabited plants categorized into 23 families. The results are compiled and summarized in three separate sections.

Section 1: Floristic inventory of Takkar Wildlife Sanctuary plants and their field pictorial view.

Section 2: Qualitative and quantitative leaf epidermal microscopic anatomical characters including length width and shape of epidermal cells, subsidiary cells shape and size, morpho-structure of guard cells, anticlinal wall pattern, stomatal complex morphology, size of stomata, trichomes types and diameter.

Section 3: Microscopic pollen qualitative and quantitative attributes such as pollen shape, types and exine sculpturing. Quantitative features including polar and equatorial diameter, P/E ratio, aperture number and size, exine thickness, mesocolpium distance, spine size, and pollen fertility and sterility.

Section I
Floristic Checklist and Field Pictorial Guide of Takkar Wildlife Sanctuary

3.1 Floristic Inventory of Takkar Wildlife Sanctuary Plants and Field Pictorial Guide

This checklist was comprised of 56 wildlife sanctuary species belonging to 23 different families. The floristic checklist in the form of Table 1 includes botanical name, family, life form, voucher specimen, accession number, localities, and geographical coordinates.

The present research examined taxonomic attributes of 56 plant species belonging to various plant families, of which Fabaceae was dominant 16 species, followed by five (05) species of Convolvulaceae, Asteraceae (four species), Boraginaceae and Zygophyllaceae (three species each), Apocynaceae, Brassicaceae, Cleomaceae, Cucurbitaceae, Malvaceae and Solanaceae (two species each) and Aizoaceae, Amaranthaceae, Bignoniaceae, Gisekiaceae, Molluginaceae, Moringaceae, Plantaginaceae, Polygonaceae, Primulaceae, Scrophulariaceae, Thymelaeaceae and Verbenaceae with single species each (Figure 3).

During the field surveys, field photography including photographs of different plant parts of species was captured using Panasonic Digital Camera (ZS-20). The floristic pictorial guide assists to the taxonomist to examine the morphology of plants in depth leading towards accurate identification (Plate 7 to 33).

Table 1. Checklist of Takkar Wildlife Sanctuary plants with vouchering data, localities and geographical coordinates.

Sr. No.	Plant Species	Family	Locality	Latitude (N)	Longitude (E)	Accession No.
1	*Abutilon indicum* (L.) Sweet	Malvaceae	Sultan Bhambhiro	27°18′ 01.8″	68°54′ 58.3″	133397
2	*Acacia nilotica* (L.) Delile	Fabaceae	Lal Juryo Khan Shambani	27°18′ 55.0″	68°55′ 16.2″	133399
3	*Alhagi maurorum* Medik.	Fabaceae	Choon Diko,	27°18′57.44″	68°55′32.61″	133396
4	*Anagallis arvensis* L.	Primulaceae	Lal Juryo Khan Shambani	27°19′10.03″	68°55′50.83″	133395
5	*Anticharis glandulosa* Asch.	Scrophulariaceae	Dargah Sultan Badshah,	27°18′07.63″	68°55′17.76″	133398
6	*Arnebia hispidissima* DC.	Boraginaceae	Lal Juryo Khan Shambani	27°18′ 00.0″	68°54′ 56.1″	133402
7	*Bauhinia variegata* Linn.	Fabaceae	Zawar Mehar Ali Khaskheli	27°24′ 26.1″	68°52′ 02.6″	1333400
8	*Calotropis procera* (Aiton) Dryand.	Apocynaceae	Lal Juryo Khan Shambani	27°24′ 26.7″	68°51′ 59.2″	1333403
9	*Cirsium arvense* (L.) Scop.	Asteraceae	Lal Juryo Khan Shambani	27°16′ 59.8″	68°40′ 26.8″	1333401
10	*Citrullus colocynthhis* (L.) Schrad	Cucurbitaceae	Dargah Sultan Badshah	27°19′ 16.5″	68°55′ 13.1″	1333404
11	*Cleome brachycarpa* (Forssk.) Vahl ex DC.	Cleomaceae	Sultan Bhambhiro	27°23′ 54.1″	68°53′ 03.6″	1333410
12	*Cleome scaposa* DC.	Cleomaceae	Wariwaro	27°23′ 54.9″	68°53′ 04.0″	1333408
13	*Convolvulus arvensis* L.	Convolvulaceae	Mehrano Wildlife	27°23′ 34.2″	68°54′ 00.6″	1333405
14	*Corchorus depressus* (L.) Stocks	Malvaceae	Bangul Khan Chandio	27°24′ 26.1″	68°52′ 02.6″	1333407
15	*Corchorus tridens* L.	Malvaceae	Dargah Sultan Badshah	27°23′ 54.4″	68°53′ 03.6″	1333406
16	*Cressa cretica* L.	Convolvulaceae	Sultan Bhambhiro	27°19′ 16.5″	68°55′ 17.9″	1333409
17	*Crotalaria trifoliastrum* Willd.	Fabaceae	Lal Juryo Khan Shambani	27°24′ 19.6.″	68°52′ 38.0″	1333411
18	*Crotalaria burhia Benth.*	Fabaceae	Choon Diko,	27°24′ 52.3″	68°50′ 02.3″	1333419
19	*Cucumis melo ssp agrestis*	Cucurbitaceae	Lal Juryo Khan Shambani	27°18′57.44″	68°55′32.61″	1333420
20	*Cynoglossum lanceolatum* Forssk.	Boraginaceae	Dargah Sultan Badshah,	27°16′ 58.0″	68°40′ 48.3″	1333412
21	*Erythrina suberosa* Roxb.	Fabaceae	Lal Juryo Khan Shambani	27°17′ 00.1″	68°40′ 25.0″	1333413
22	*Evolvulus alsinoides* (L.) L.	Convolvulaceae	Zawar Mehar Ali Khaskheli	27°24′ 19.6.″	68°52′ 38.0″	1333414
23	*Farsetia jacquemontii* Hook.f. & Thomson	Brassicaceae	Lal Juryo Khan Shambani	27°24′ 33.6″	68°51′ 53.1″	1333416
24	*Farsetia stylosa* R.Br.	Brassicaceae	Lal Juryo Khan Shambani	27°24′ 27.4″	68°51′ 59.6″	1333415
25	*Gisekia pharnaceoides* L.	Gisekiaceae	Dargah Sultan Badshah	27°18′ 02.9″	68°54′ 55.0″	1333418

26	*Haloxylon stocksii* (Boiss.) Benth. & Hook. f.	Amaranthaceae	Sultan Bhambhiro	27°19′ 16.0″	68°55′ 15.0″	1333417
27	*Heliotropium bacciferum* Forssk.	Boraginaceae	Sultan Bhambhiro	27°18′ 52.9″	68°55′ 12.9″	1333421
28	*Indigofera cordifolia* Roth	Fabaceae	Wariwaro	27°16′ 57.8″	68°40′ 47.9″	1333422
29	*Indigofera hochstetteri* Baker	Fabaceae	Mehrano Wildlife	27°18′ 02.6″	68°54′ 54.8″	1333423
30	*Iphiona aucheri* (Boiss.) Anderb.	Asteraceae	Bangul Khan Chandio	27°18′ 02.9″	68°54′ 55.0″	1333427
31	*Ipomoea aquatic* Forssk.	Convolvulaceae	Dargah Sultan Badshah	27°18′ 54.8″	68°55′ 15.9″	1333425
32	*Lantana camara* L.	Verbenaceae	Wariwaro	27°18′ 51.8″	68°55′ 19.2″	1333424
33	*Melilotus albus* Medik.	Fabaceae	Mehrano Wildlife	27°18′10.07″	68°55′12.56″	1333426
34	*Merremia hederacea* (Burm. f.) Hallier f.	Convolvulaceae	Bangul Khan Chandio	27°23′ 33.1″	68°54′ 01.4″	1333430
35	*Mollugo cerviana* (L.) Ser.	Molluginaceae	Lal Juryo Khan Shambani	27°23′ 33.0″	68°53′ 36.4″	1333429
36	*Moringa oleifera* Lam.	Moringaceae	Lal Juryo Khan Shambani	27°11′15.49″	69°18′56.02″	1333428
37	*Oxystelma esculentum* (L. f.) Sm.	Apocynaceae	Dargah Sultan Badshah	27°24′ 19.6.″	68°52′ 38.0″	1333440
38	*Parkinsonia aculeata L.*	Fabaceae	Sultan Bhambhiro	27°17′03.5″	68°40′25.9″	1333435
39	*Pithecellobium dulce* (Roxb.) Benth.	Fabaceae	Mehrano Wildlife	27°16′ 58.0″	68°40′ 48.3″	1333439
40	*Pluchea lanceolata* (DC.) C.B.Clarke	Asteraceae	Sultan Bhambhiro	27°18′01.99″	68°40′ 46.5″	1333434
41	*Polygonum plebeium R.Br.*	Polygonaceae	Wariwaro	27°24′ 33.6″	68°51′ 53.1″	1333438
42	*Prosopis glandulosa* Torr.	Fabaceae	Mehrano Wildlife	27°′19 18.5″	68°55′ 19.7″	1333433
43	*Pulicaria dysenterica* Gaertn./boissieri	Asteraceae	Bangul Khan Chandio	27°24′ 17.7″	68°52′ 18.2″	1333437
44	*Schweinfurthia papilionacea* (L.) Boiss.	Plantaginaceae	Dargah Sultan Badshah	27°23′33.1″	68°54′01.4″	1333432
45	*Senna italica* Mill.	Fabaceae	Sultan Bhambhiro	27°20′0.866″	68°42′13.342″	1333436
46	*Sesbania bispinosa* (Jacq.) W.Wight	Fabaceae	Lal Juryo Khan Shambani	27°23′ 34.2″	68°54′ 00.6″	1333431
47	*Solanum americanum* Mill.	Solanaceae	Choon Diko,	27°27′ 02.8″	68°47′ 13.2″	1333446
48	*Tecomella undulata* (Sm.) Seem.	Bignoniaceae	Lal Juryo Khan Shambani	27°16′ 59.8″	68°40′ 26.8″	1333441
49	*Tephrosia purpurea* (L.) Pers.	Fabaceae	Dargah Sultan Badshah,	27°19′50.390″	68°41′53.050″	1333447

50	*Thymelaea passerina* (L.) Coss. & Germ.	Thymelaeaceae	Lal Juryo Khan Shambani	27°15′ 45.0″	68°53′ 40.1″	1333442
51	*Trianthema portulacastrum* L.	Aizoaceae	Zawar Mehar Ali Khaskheli	27°23′ 58.4″	68°53′ 07.7″	1333448
52	*Tribulus pentandrus* Forssk.	Zygophyllaceae	Sultan Bhambhiro	27°′19 18.5″	68°55′ 19.7″	1333443
53	*Trifolium resupinatum* L.	Fabaceae	Wariwaro	27°20′0.866″	68°42′13.342″	1333449
54	*Withania somnifera* (L.) Dunal	Solanaceae	Mehrano Wildlife	27°17′ 00.1″	68°40′ 25.0″	1333444
55	*Zygophyllum indicum* (Burm.f.) Christenh. & Byng	Zygophyllaceae	Bangul Khan Chandio	27°18′ 53.7″	68°55′ 14.0″	1333450
56	*Zygophyllum simplex* L.	Zygophyllaceae	Sultan Bhambhiro	27°18′ 55.0″	68°55′ 16.4″	1333445

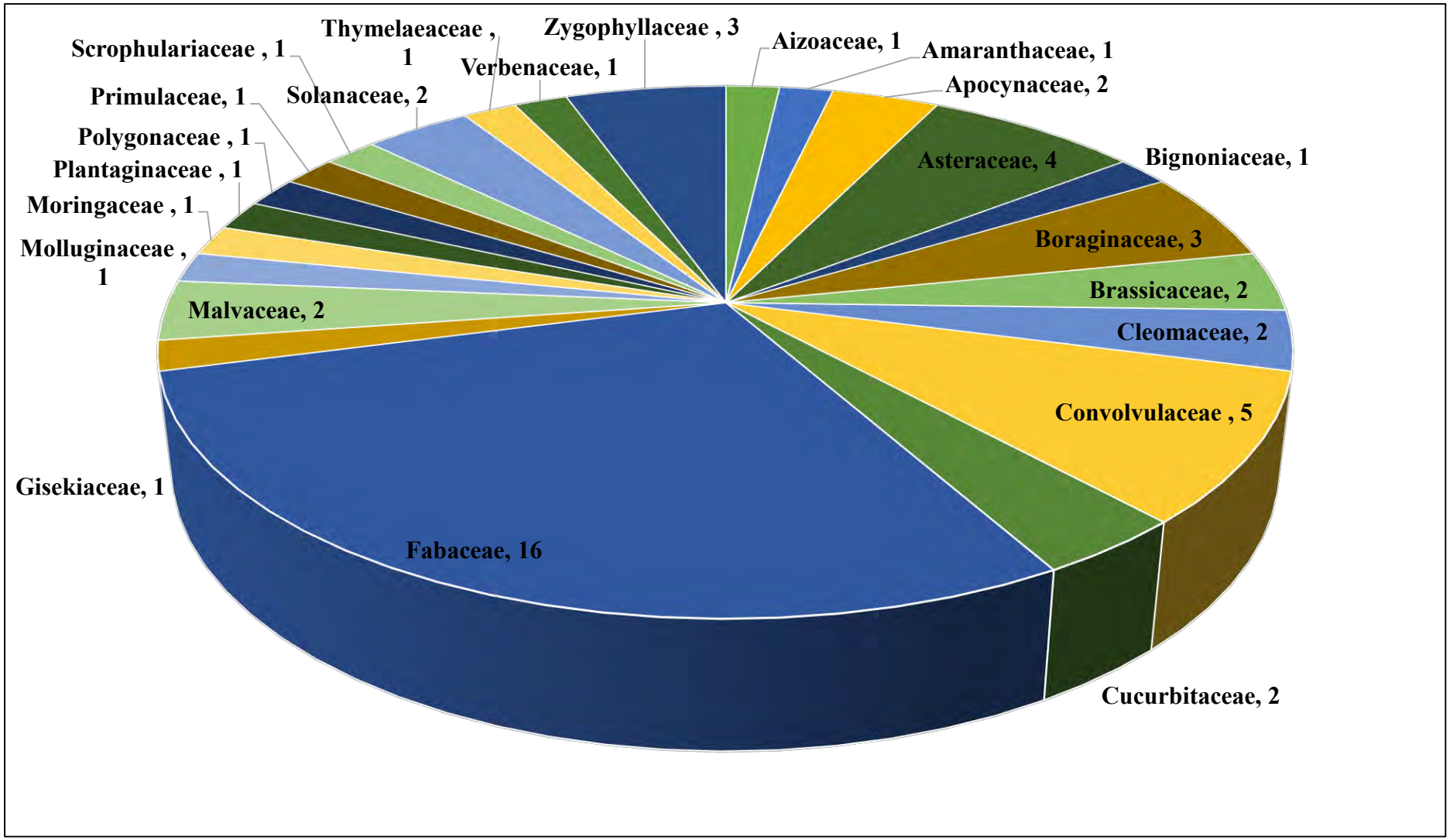

Figure 3. Graphical representation of collected plant species belonging to different families.

Plate 7. Field pictorial view of (a) *Abutilon indicum*; stellate pubescent, (b) *Acacia nilotica;* spike inflorescence

Plate 8. Field pictorial view of (a) *Alhagi maurorum;* Inflorescence lateral axillary racemes, (b) *Anagallis arvensis;* floral parts with bluish solitary flower

Plate 9. Field pictorial view of (a) *Anticharis glandulosa Asch.;* pubescent leaves with purplish flower, (b) *Arnebia hispidissima DC.;* Inflorescence a terminal scorpioid cyme

Plate 10. Field pictorial view of (a) *Bauhinia variegata;* pubescent raceme flower, (b) *Calotropis procera;* purplish flowers with darker tips

Plate 11. Field pictorial view of (a) *Cersium arvense;* Corolla purple staminate (b) *Citrullus colocynth;* corolla pale yellow with pubescent leaves

Plate 12. Field pictorial view of (a) *Cleome brachycarpa;* leaflets oblong to obovate, (b) *Cleome scaposa;* racemose inflorescence with ovate leaves

Plate 13. Field pictorial view of (a) *Cleome scaposa;* Inflorescence lateral axillary racemes, (b) *Convolvulus arvensis;* pubescent leaves with whitish flowers

Plate 14. Field pictorial view of (a) *Corchorus depressus ;* Inflorescence Cyme with elliptic leaves, (b) *Corchorus tridens L.;* linear-lanceolate leaves

Plate 15. Field pictorial view of (a) *Cressa cretica;* sessile leaflets, (b) *Crotalaria burhia;* raceme Inflorescence

Plate 16. Field pictorial view of (a) *Crotalaria trifoliastrum;* palmately trifoliolate leaves, (b) *Cucumis melo;* reniform leaves

Plate 17. Field pictorial view of (a) *Cynoglossum lanceolatum;* lanceolate leaves, (b) *Erythrina suberosa;* trifoliolate, glabrous leafs with showy flower

Plate 18. Field pictorial view of (a) *Evolvulus alsinoides;* vegetative branches (b) *Farsetia jacquemontii;* linear elongated leaves

Plate 19. Field pictorial view of (a) *Farsetia stylosa;* sissile linear leaves with purplish flowers, (b) *Gisekia pharnaceoides;* lanceolate leaves

Plate 20. Field pictorial view of (a) *Haloxylon stocksii;* axillary flower, (b) *Heliotropium bacciferum;* linear leaves with hairy surface.

Plate 21. Field pictorial view of (a) *Indigofera cordifolia;* cordate leaves and subsessile inflorescence, (b) *Indigofera hochstetteri*; raceme inflorescence

Plate 22. Field pictorial view of (a) *Ipomoea aquatic;* cymes inflorescence and triangular leaves, (b) *Lantana camara;* umbellate inflorescence, ovate leaves

Plate 23. Field pictorial view of (a) *Melilotus albus;* raceme inflorescence, (b) *Merremia hederacea*; cymose inflorescence

Plate 24. Field pictorial view of (a) *Moringa oleifera;* palmately trifoliolate leaves, (b) *Oxystelma esculentum;* racemose inflorescence

Plate 25. Field pictorial view of (a) *Parkinsonia aculeata;* axillary raceme inflorescence, (b) *Pithecellobium dulce;* elliptic leaves, sessile raceme inflorescence

Plate 26. Field pictorial view of (a) *Pluchea lanceolate;* corymb inflorescence, (b) *Polygonum plebeium;* axillary inflorescence and flashy dark green leafs

Plate 27. Field pictorial view of (a) *Prosopis glandulosa;* Inflorescence spikes, (b) *Pulicaria dysenterica;* racemose inflorescence

Plate 28. Field pictorial view of (a) *Schweinfurthia papilionacea;* lanceolate leaves, (b) *Senna italica;* opposite, glabrous leafs with pale green stem

Plate 29. Field pictorial view of (a) *Sesbania bispinosa;* raceme inflorescence, (b) *Solanum americanum;* dentate, glabrous leafs with white flower

Plate 30. Field pictorial view of (a) *Tecomella undulata;* opposite, linear-oblong leaves, orange-reddish flower (b) *Tephrosia purpurea;* raceme inflorescence, opposite leafs. elliptic-oblong

Plate 31. Field pictorial view of (a) *Thymelaea passerina;* axillary solitary inflorescence, (b) *Trianthema portulacastrum;* glabrous, obovate leafs

Plate 32. Field pictorial view of (a) *Tribulus pentandrus;* alternate, pubescent, lanceolate leaflets, (b) *Trifolium resupinatum;* white purplish flower, obovate.dentated leafs

Plate 33. Field pictorial view of (a) *Zygophyllum indicum;* leaves mostly in basal parts, whitish flowers (b) *Zygophyllum simplex;* succulent, sub-sessile leaves, pale yellow flower

Section II

Anatomical Characterization

(LM & SEM)

3.2 Foliar Epidermal Anatomy

3.2.1 Epidermal Anatomy of Leguminous Species

10 leguminous species belonging to seven genera were selected for anatomical examination with the help of light and scanning electron microscopy. The genera that were analyzed include *Acacia, Astragalus, Crotalaria, Dalbergia, Prosopis, Parkinsonia,* and *Tephrosia*. Significant variations in micromorphological foliar epidermal characters were examined (Table 2, 3 & 4). The scanning electron micrographs of Fabaceous taxa were illustrate in Plate 34, 35, 36, 37 and 38.

a) Foliar Epidermis

The shape of epidermal cells is polygonal or wavy with entire, slightly wavy, or sinuate walls. The shape of epidermal cells was the same on both abaxial and adaxial surfaces except in *Acacia modesta* and *Parkinsonia aculeata.* Where it was tetra to pentagonal in *Acacia modesta* while wavy in *Parkinsonia aculeata* on both sides. The pattern of anticlinal wall was entire, slightly wavy, sinuate, and deeply sinuate. The pattern of the wall was similar on both abaxial and adaxial surfaces. The length of epidermal cell ranges from (38.5± 6.35µm) in *Prosopis cineraria* to (17.5± 1.0µm) in *Astragalus homosus* on the abaxial surface. On the adaxial surface it varies from (47.5± 2.5µm) in *Dalbergia sisso* to (17.5± 1.76µm) in *Tephrosia purpurea* (Fig. 4). Subsidiary cells have also been found in all species with considerable variations. Three types of subsidiary cell arrangement were noted; margin sinuous, enclosing guard cells, followed by lobed margins enclosing guard cells, and lobed wavy margins, partly enclosing guard cell shapes. The largest subsidiary cell length (42±6.49 µm) along the adaxial side and the maximum length (40±4.67 µm) on the abaxial side were noted in *Dalbergia sisso*. The width of the largest subsidiary cell was noted in *Acacia jacquemontii* (22±3.5 µm) on the adaxial surface, while in *Dalbergia sisso* on the abaxial surface (13±1.2 µm), as mentioned in (Fig. 5).

b) Stomatal Complex

Fabaceous taxa examined were all amphistomatic except *Acacia modesta, Crotalaria burhia, Parkinsonia aculeata* and *Tephrosia purpurea* which are hypostomatic. Stomata of paracytic type were observed in all species except *Prosopis juliflora* where stomata were anisocytic. The stomatal length varies from (24.9±

0.06µm) in *Dalbergia sisso* to (8.2± 0.5µm) in *Prosopis juliflora* on the abaxial surface. On the adaxial surface, it ranges from (24± 0.6µm) in *Dalbergia sisso* to (8.8± 0.61µm) in *Prosopis juliflora* (Fig. 6). The stomatal index ranges between 41.2-4.28% on the abaxial surface and 31.4-8.5% on the adaxial surface. On the abaxial surface, it is highest in *Acacia nilotica* (41.2%) and lowest in *Dalbergia sissoo* (4.28%). Whereas on the adaxial surface, it is highest in *Dalbergia sissoo* (31.4%) and lowest in *Acacia nilotica* (8.5%) as illustrated in (Fig 7).

c) Trichomes

Unicellular, glandular trichomes are present on both surfaces in *Crotalaria burhia, Prosopis cineraria, Prosopis juliflora,* and *Tephrosia purpurea.* Trichomes are absent in the other six species. The length of trichomes ranges from (355± 44.3µm) in *Prosopis juliflora* to (67.5± 2.09µm) in *Crotalaria burhia* on the abaxial surface. On the adaxial surface, it ranges from (347± 67.6µm) in *Prosopis cineraria* to (75± 8.83µm) in *Crotalaria burhia.*

d) Taxonomic Identification Keys based on Foliar Anatomical Features

1 + Trichomes absent epidermal cell polygonal, entire anticlinal wall, stomata paracytic…...……..…..***Acacia jacquemontii***

- Trichomes absent, epidermal cell irregular……..…….. **2**

2 + Epidermal cell irregular, anticlinal wall entire, stomata paracytic, trichome absent……...***Acacia nilotica***

- Epidermal cell tetragonal, anticlinal wall entire and sinuate, stomata paracytic…….……..……..…. **3**

3 + Epidermal cell tetragonal to pentagonal with sinuate anticlinal wall, stomata paracytic abaxial, trichome absent…….…….....***Acacia modesta***

- Epidermal cell rectangular, anticlinal wall rounded ….....**4**

4 + Epidermal cell polygonal, anticlinal wall sinuate, stomata paracytic, trichome absent…….……..***Astragalus hamosus***

- Epidermal cell polygonal, anticlinal wall entire, trichomes present…….... **5**

5 + Epidermal cell polygonal isodiametric, abaxial paracytic stomata, trichome non-glandular unicellular……..…….***Crotalaria burhia***

- Epidermal cell polygonal, stomata paracytic, anticlinal wall wavy……..……. **6**

6 + Epidermal cell polygonal, anticlinal wall entire and slightly wavy, stomata

paracytic, trichomes absent……...…….***Dalbergia sissoo***

- Anticlinal wall entire, trichome present……..…… **7**

7 + Epidermal cell tetragonal, stomata paracytic, trichome unicellular non-glandular……..……...…***Prosopis cineraria***

- Epidermal cell polygonal, stomata paracytic…….. **8**

8 + Epidermal cell polygonal, anticlinal wall entire, trichomes unicellular……...……..…***Tephrosia purpurea***

- Stomata paracytic, anticlinal wall sinuate……..….....…….. **9**

9 + Epidermal cell wavy, stomata paracytic (abaxial), anticlinal wall sinuate, trichome absent……..……...…***Parkinsonia aculeata***

- Epidermal cell polygonal, stomata anisocyctic …….....…..... **10**

10 + Epidermal cell polygonal, stomata anisocytic, anticlinal wall entire, trichome unicellular glandular……..……..……....***Prosopis juliflora***

Table 2. Sampling and geography of of leguminous species from Takkar Wilife Sanctuary.

Leguminous species	Locality/District	Accession No.	Latitude (N)	Longitude (E)	Collector
Acacia jacquemontii Benth.	Choon Diko/ Khairpur	133395	27°21'14.3"N	68°47'20.6"E	Salman, Jamil
Acacia nilotica (L.) Delile	Lal Juryo Khan Shambani/Shukkar	133396	27°23′36.4″	68°53′36.5″	Jamil, Shoukat
Acacia modesta Wall.	Dargah Sultan Badshah/ Khairpur	133375	27°24′ 52.3″	68°50′ 02.3″	Jamil, Salman
Astragalus hamosus L.	Lal Juryo Khan Shambani/Shukkar	133398	27°23′38.1″	68°53′33.6″	Salman, Ghulam Yaseen
Crotalaria burhia Benth.	Zawar Mehar Ali Khaskheli/ Khairpur	133371	27°16′ 57.8″	68°40′ 47.9″	Jamil, Salman
Dalbergia sissoo DC.	Lal Juryo Khan Shambani	133390	27°23′38.1″	68°53′35.8″	Jamil
Prosopis cineraria (L.) Druce	Lal Juryo Khan Shambani/Shukkar	133367	27°23′37.9″	68°53′35.2″	Jamil, Shoukat
Prosopis juliflora (Sw.) DC.	Dargah Sultan Badshah/ Khairpur	133397	27°24′36.0″	68°51′35.7″	Jamil
Parkinsonia aculeata L.	Sultan Bhambhiro/ Shukkar	133378	27°18′ 02.6″	68°54′ 54.8″	Salman, Jamil
Tephrosia purpurea (L.) Pers.	Wariwaro/ Khairpur	133399	27°23′ 49.5″	68°53′ 17.3″	Jamil

Table 3. Foliar epidermal anatomy qualitative characters of leguminous species.

Leguminous species	Ad/ Ab	Shape of epidermal cells	Anticlinal walls	Stomata type	Trichomes
Acacia jacquemontii Benth.	**Ad**	Polygonal	Entire	Paracytic	Absent
	Ab	Polygonal	Entire	Paracytic	Absent
Acacia nilotica (L.) Delile	**Ad**	Polygonal	Entire	Paracytic	Absent
	Ab	Polygonal	Entire	Paracytic	Absent
Acacia modesta Wall	**Ad**	Tetragonal to Pentagonal	Entire	Absent	Absent
	Ab	Tetragonal to Pentagonal	Entire	Paracytic	Absent
Astragalus hamosus L.	**Ad**	Polygonal	Sinuate and deeply sinuate	Paracytic	Absent
	Ab	Polygonal	Sinuate and deeply sinuate	Paracytic	Absent
Crotalaria burhia Benth.	**Ad**	Polygonal	Entire	Absent	Unicellular
	Ab	Polygonal	Entire	Paracytic	Unicellular
Dalbergia sissoo DC.	**Ad**	Polygonal	Entire and Slightly wavy	Paracytic	Absent
	Ab	Polygonal	Entire and Slightly wavy	Paracytic	Absent
Prosopis cineraria (L.) Druce	**Ad**	Tetragonal	Entire	Paracytic	Unicellular
	Ab	Tetragonal	Entire	Paracytic	Unicellular
Prosopis juliflora (Sw.) DC.	**Ad**	Polygonal	Entire	Anisocytic	Glandular
	Ab	Polygonal	Entire	Anisocytic	Glandular
Parkinsonia aculeata L.	**Ad**	Wavy	Sinuate	Absent	Absent
	Ab	Wavy	Sinuate	Paracytic	Absent
Tephrosia purpurea (L.) Pers.	**Ad**	Polygonal	Entire	Absent	Unicellular
	Ab	Polygonal	Entire	Paracytic	Unicellular

Keywords: Ad = Adaxial, Ab = Abaxial

Table 4. Quantitative analysis for stomatal index of selected leguminous species.

Leguminous species	Ad /Ab	Stomata P/A	Av. No. of Tri. per unit area	Av. No. of Ep. cells per unit area	Av. No. of St. per unit area	Stomatal Index (%) S/(S+E)× 100
Acacia jacquemontii Benth.	**Ad**	P	-	193	23	10.73
	Ab	P	-	247	52	17.5
Acacia nilotica (L.) Delile	**Ad**	P	3	92	8	8.18
	Ab	P	-	69	22	91.2
Acacia modesta Wall	**Ad**	A	-	45	-	-
	Ab	P	-	46	11	19.16
Astragalus hamosus L.	**Ad**	P	-	88	15	14.86
	Ab	P	2	30	26	21.9
Crotalaria burhia Benth.	**Ad**	A	3	200	-	-
	Ab	P	17	81	39	32.39
Dalbergia sissoo DC.	**Ad**	P	7.6	61	28	31.4
	Ab	P	5	80	3	4.28
Prosopis cineraria (L.) Druce	**Ad**	P	3	145	17	10.49
	Ab	P		106	70	40.04
Prosopis juliflora (Sw.) DC.	**Ad**	A	-	191	-	-
	Ab	P	-	94	29	24.07
Parkinsonia aculeata L.	**Ad**	P	-	57	21	27.15
	Ab	P	-	94	59	38.75
Tephrosia purpurea (L.) Pers.	**Ad**	A	7	151	-	-
	Ab	P	-	92	30	24.55

Keywords: (Ad) = Adaxial, (Ab) = Abaxial, (P) = Present, (A) = Absent, (S) = Stomata, (E) = Epidermal cells, (%) = Percentage, (Av.) = Average, (No) = Number

Table 5. Quantitative measurements of foliar epidermal anatomical features of selected leguminous species.

Leguminous species	Ad/ Ab	Epidermal cells (µm)		Subsidiary cells (µm)		Stomata (µm)		Guard cells (µm)		Stomatal pore (µm)		Trichome (µm)	
		Min-Max (Mean±SE)											
		L	W	L	W	L	W	L	W	L	W	L	W
Acacia jacquemontii Benth.	**Ad**	25-35 (27.5±1.9)	17.5-25 (21.5±1.3)	15-35 (22.5±3.53)	15-35 (22.5± 3.5)	15-20 (16.5±1)	10-12.5 (11±0.61)	12.5-17.5 (14±1)	2.5-5 (4±0.61)	10-12.5 (11±0.61)	1.25-2.5 (2.05±0.27)	-	-
	Ab	12.5-25 (19±2.17)	10-17.5 (13.5±1.3)	20-27.5 (24.5±1.22)	10-15 (12±0.93)	15-17.5 (17±0.5)	10-15 (12±0.93)	12.5-15 (13.5±0.61)	2.5-5 (3±0.5)	10-12.5 (11±0.61)	1.25-2.50 (1.7±0.22)	-	-
Acacia nilotica (L.) Delile	**Ad**	22.5-37.5 (31±2.9)	10-25 (18±2.89)	12.5-15 (14.1±0.5)	5-5.5 (5.25±0.1)	10-15 (12±0.9)	6-8.7 (7.2±0.49)	10-15 (12±0.9)	2.5-3.25 (2.8±0.14)	6.75-10 (7.8±0.5)	0.25-1 (0.6 ±0.12)	117.5-275 (223±28.5)	10-12.5 (11.2±0.6)
	Ab	17.5-50 (31.5±5.4)	10-17.5 (14±1.5)	15-17.5 (16.1±0.57)	5-5.5 (5.15±0.1)	14.7-17.5 (15.9±0.6)	6.7-10 (8.3±0.6)	14.7-17.5 (15.9±0.6)	2.5-3 (2.7±0.1)	7.5-12.5 (9.5±0.9)	0.25-1 (0.7±0.14)	-	-
Acacia modesta Wall	**Ad**	27.5-50 (36±3.84)	17.5-22.5 (19.5±0.9)	-	-	-	-	-	-	-	-	-	-
	Ab	17.5-27.5 (22±2.0)	10-15 (12.5±0.8)	15-22.5 (19±1.27)	4.25-7.50 (5.6±0.57)	15-20 (17±0.93)	15-20 (17±0.93)	12.5-17.5 (14.5±0.93)	2.75-3.25 (2.9± 0.09)	7.5-12.5 (10±0.79)	0.75-1.25 (1±0.11)	-	-
Astragalus hamosus L.	**Ad**	25-32.5 (29±1.27)	10-15 (12.8±0.8)	15-20 (17.5±1.11)	5-7.5 (6.25±0.5)	12.5-13 (12.6± 0.1)	9.25-10 (9.8±0.14)	10-13 (12.1±0.53)	2.5-3.75 (3.35±0.2)	9.25-10.5 (9.9±0.2)	0.04-0.25 (0.14±0.04)	-	-
	Ab	15-20 (17.5±1.1)	12.25-13.75 (13.1±0.8)	15-17.5 (16.5±0.61)	6.25-7.75 (7.15±0.3)	10-15 (13±0.93)	6.25-8 (7.2±0.3)	10-12.5 (11.5±0.61)	2.5-3.5 (2.9±0.2)	5-10 (7.45± 0.8)	0.04-0.25 (0.10±0.03)	-	-
Crotalaria burhia Benth.	**Ad**	17.5-30 (25±2.09)	12.5-25 (20.5±2.1)	-	-	-	-	-	-	-	-	50-100 (75± 8.83)	7.5-11.25 (9.25±0.6)

	Ab	17.5-37.5 (27±3.39)	12.5-25 (20.5±2.2)	15-22.5 (20±1.36)	5-7.5 (6.4±0.4)	15-22.5 (19±1.27)	7-8.25 (7.6±0.20)	12.5-20 (16.5±1.27)	2.50-3.25 (2.85±0.2)	10-15 (12±0.93)	0.5-1 (0.75±0.11)	62.5-75 (67.5±2.09)	7.5-12.5 (10.05±0.8)
Dalbergia sissoo DC.	**Ad**	37.5-50 (47.5±2.5)	25-37.5 (27.5±2.5)	25-62.5 (42±6.49)	10-17.5 (14±1.5)	22.5-25 (24±0.6)	17.5-22.5 (20.5±0.9)	22.5-25 (24±0.6)	6.25-7.5 (7.05±0.3)	12.5-17.5 (14±1)	3.75-5 (4.5±0.3)	-	-
	Ab	12.5-50 (30±6.37)	20-25 (23.5±1)	25-50 (40±4.67)	10-17.5 (13±1.2)	24.7-25 (24.9±0.06)	17.25-17.5 (17.4±0.05)	24.7-25 (24.9±0.06)	7.25-7.5 (7.45±0.05)	15-17.5 (16.9±0.5)	2.5-5 (3.9±0.59)	-	-
Prosopis cineraria (L.) Druce	**Ad**	22.5-37.5 (28±2.6)	12.5-20 (16±1.27)	15-22.5 (19±1.5)	5-7.5 (6.5±0.6)	12.5-17.5 (15.5±0.8)	7.5-8 (7.65± 0.1)	12.5-17.5 (15.05± 0.79)	2.5-3 (2.85± 0.1)	10-15 (12.5±0.8)	1.25-2.5 (1.85±0.2)	225-525 (347±67.6)	12.5-15 (13.5±0.6)
	Ab	25-62.5 (38.5±6.35)	12.5-27.5 (21±3.02)	15-25 (18±1.8)	5-7.5 (6.5±0.6)	12.5-17.5 (14.5±0.9)	5-10 (7.5±0.79)	12.5-17.5 (14.5±0.9)	2.5-3.25 (2.8±0.15)	10-12.5 (11.5±0.6)	1-1.5 (1.25±0.1)	150-550 (335±79.7)	5-17.5 (12.5±2.1)
Prosopis juliflora (Sw.) DC.	**Ad**	23-47 (35.5±3.09)	10-22.5 (14±2.17)	10-15 (12.5±1.11)	5-6.25 (5.35± 0.3)	7.7-10.2 (8.8±0.58)	5.7-7.3 (6.5±0.59)	7.2-10.1 (8.6±0.66)	2.8-3.4 (3.1±0.23)	5.3-6.2 (5.9±0.76)	0.56-2.2 (1.7±0.32)	180-320 (252±45.8)	15-30 (19±2.80)
	Ab	24.5-52 (36.3±3.27)	11.3-26 (16±2.31)	9.7-16.3 (12.7±0.87)	5.4-7.3 (6.1±0.82)	7.4-9.3 (8.2±0.54)	5.3-7.2 (6.4±0.39)	7-10.3 (8.8±0.58)	2.4-3.3 (2.7± 0.21)	5-7.3 (6.4±0.41)	1-1.5 (1.3±0.09)	225-450 (355±44.3)	25-50 (38.5±4.1)
Parkinsonia aculeata L.	**Ad**	10-30 (21.5±3.5)	7.5-17.5 (12.5±1.7)	-	-	-	-	-	-	-	-	-	-
	Ab	15-37 (24±3.9)	7.5-15 (12±1.2)	12.5-25 (19.5±2.42)	5-7.5 (6.5±0.6)	15-22.5 (18.5±1.5)	7.5-10 (8.5±0.6)	12.5-20 (16±1.5)	3.75-5 (4.5±0.27)	7.5-15 (11.5±1.3)	1.5-2.5 (2.05±0.2)	-	-
Tephrosia purpurea (L.) Pers.	**Ad**	12.5-22.5 (17.5±1.76)	12.5-17.5 (14±1)	-	-	-	-	-	-	-	-	95-142.5 (111±8.38)	10-15 (11.5±1)
	Ab	22.5-45 (35±4.13)	12.5-22.5 (17.5±1.7)	12.5-22.5 (17.5±1.76)	5-10 (8±0.93)	10-17.5 (14±1.5)	7.5-10 (8.5±0.61)	10-17.5 (14±1.5)	2.75-3.25 (2.9±0.09)	7.5-12.5 (10.5±0.9)	1-1.75 (1.35±0.12)	-	-

Keywords: (L) = Length, (W) = Width, (Ad) =Adaxial, (Ab) = Abaxial, (Min) = Minimum, (Max) = Maximum, (SE) = Standard error, (µm) = Micrometer

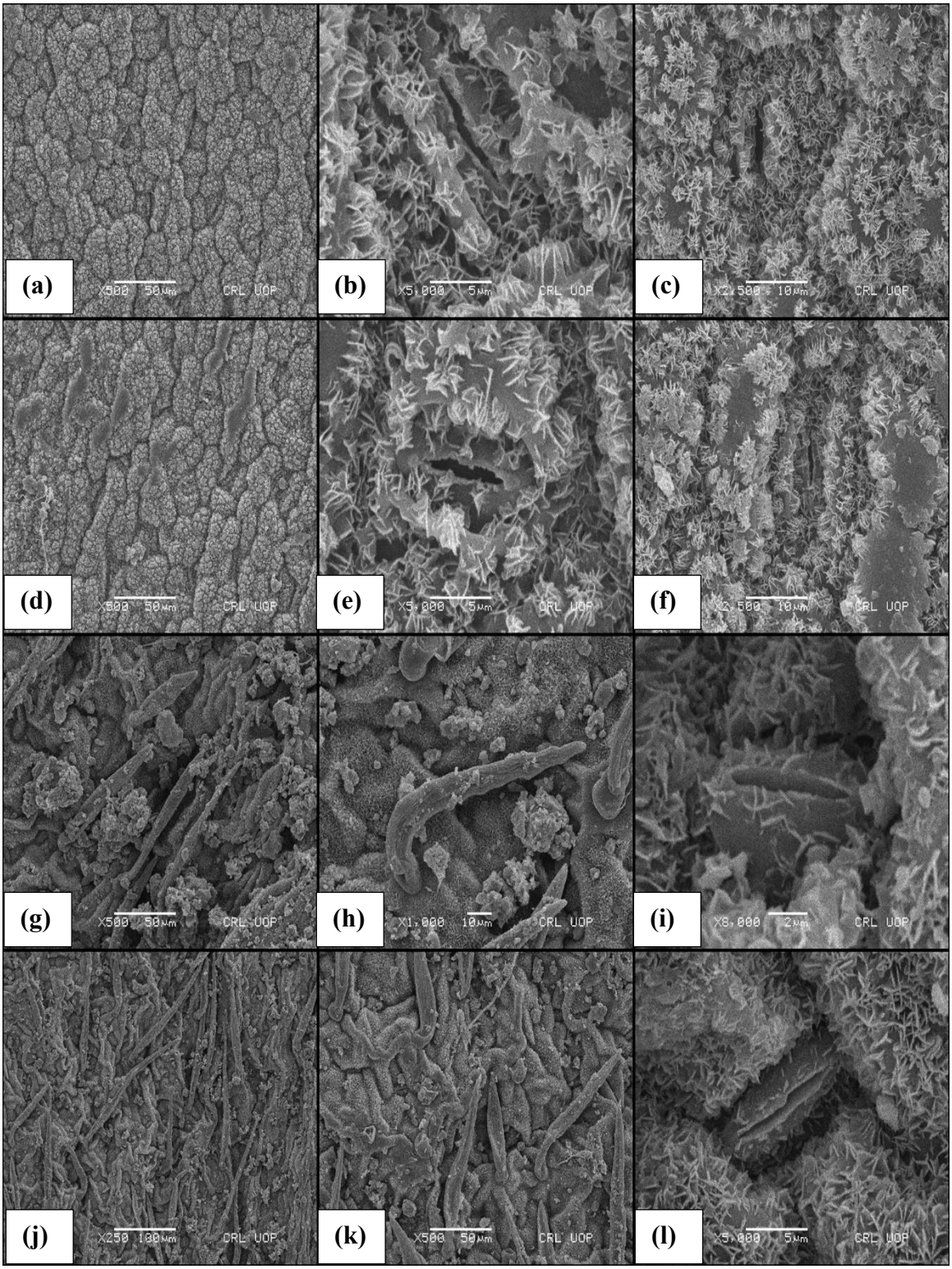

Plate 34. SEM anatomical photographs of leguminous species: *Acacia jacquemontii* Benth. (a-c) Adaxial surface (d-f) Abaxial surface; *Acacia nilotica* (L.) Delile (g-i) Adaxial surface (j-l) Abaxial surface

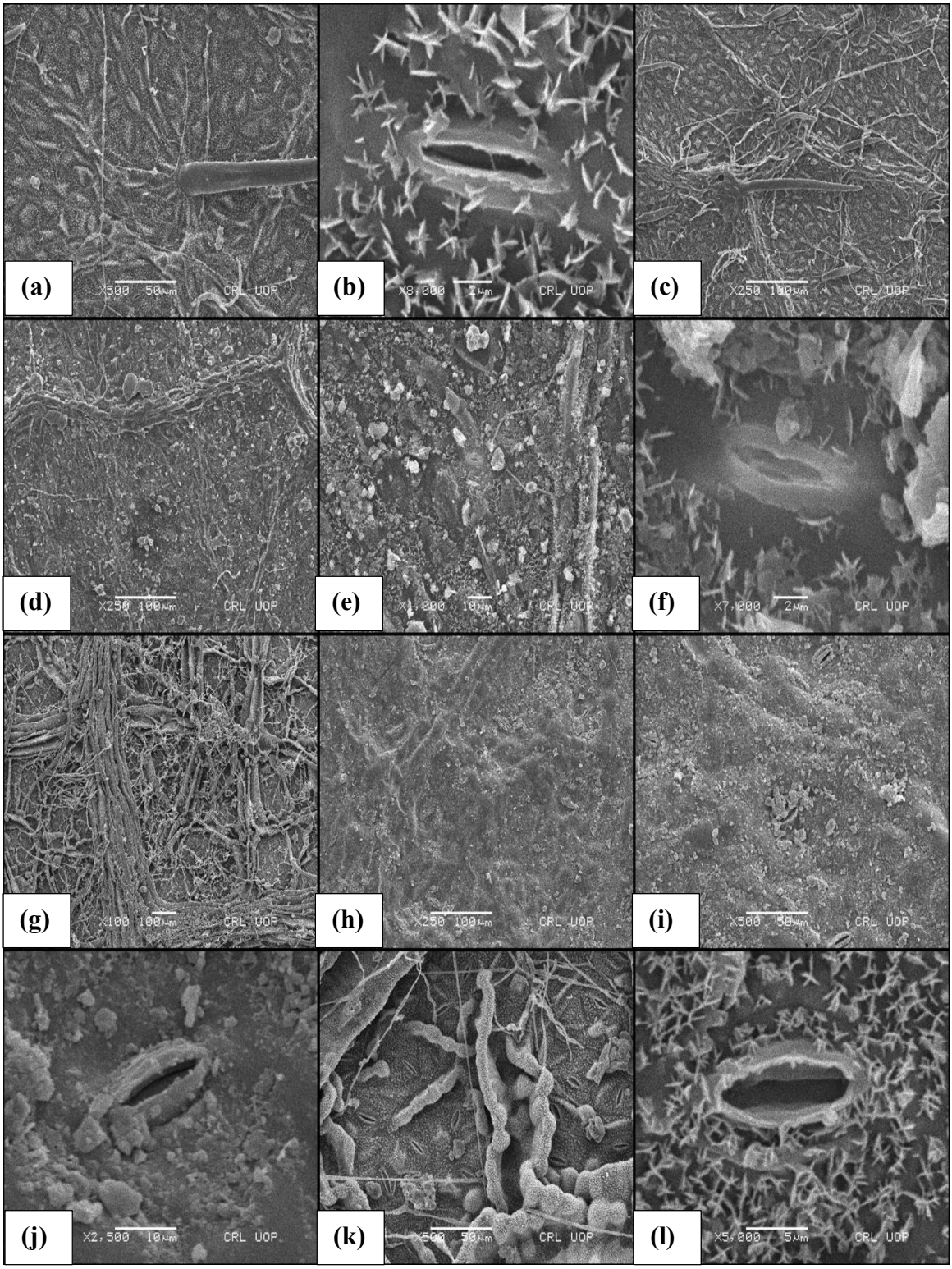

Plate 35. SEM anatomical photographs of leguminous species: *Acacia modesta* Wall. (a-c) Adaxial surface (d-f) Abaxial surface; *Astragalus hamosus* L. (g-i) Adaxial surface (j-l) Abaxial surface

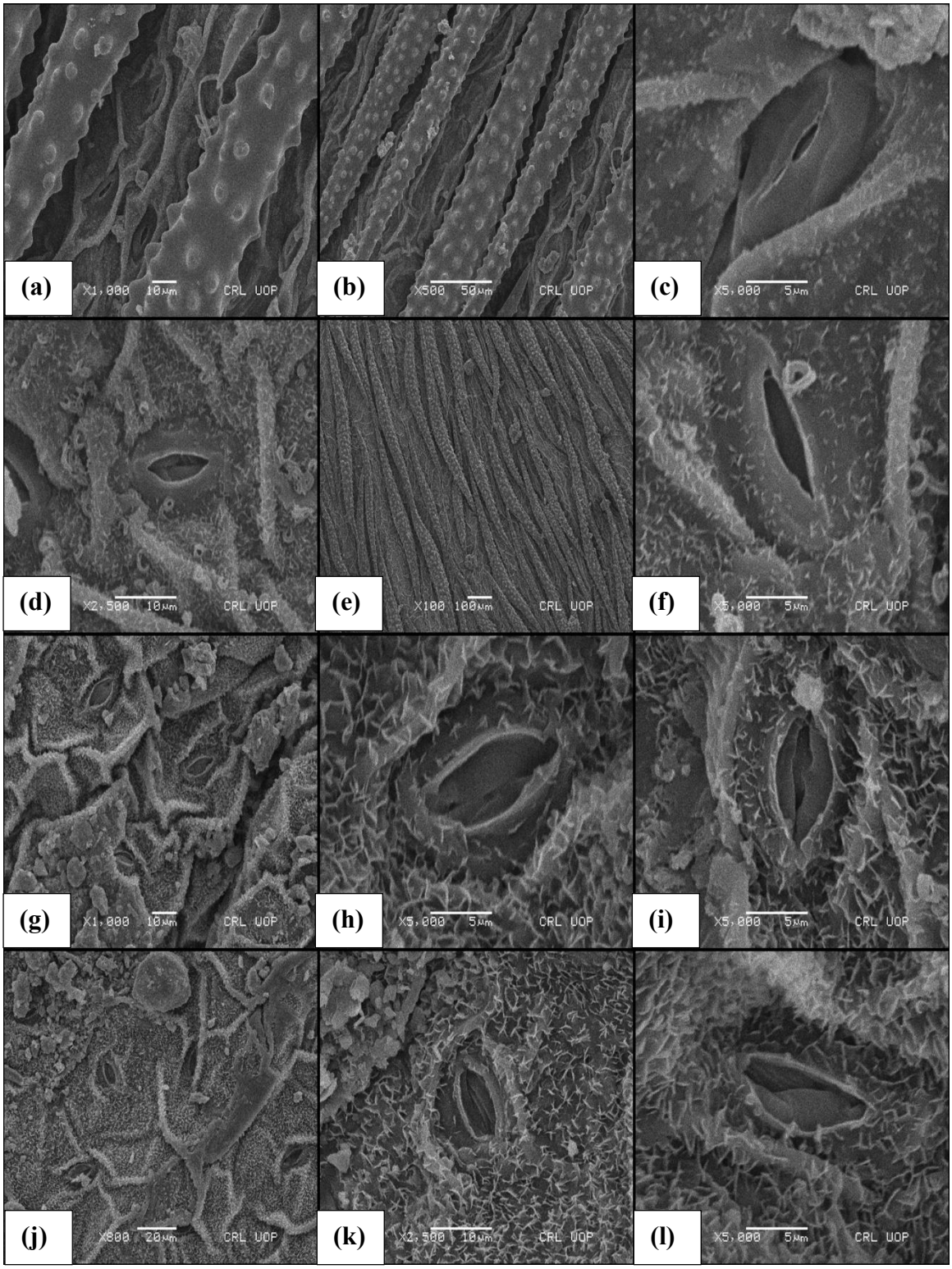

Plate 36. SEM anatomical photographs of leguminous species: *Crotalaria burhia* Benth. (a-c) Adaxial surface (d-f) Abaxial surface; *Dalbergia sissoo* DC. (g-i) Adaxial surface (j-l) Abaxial surface

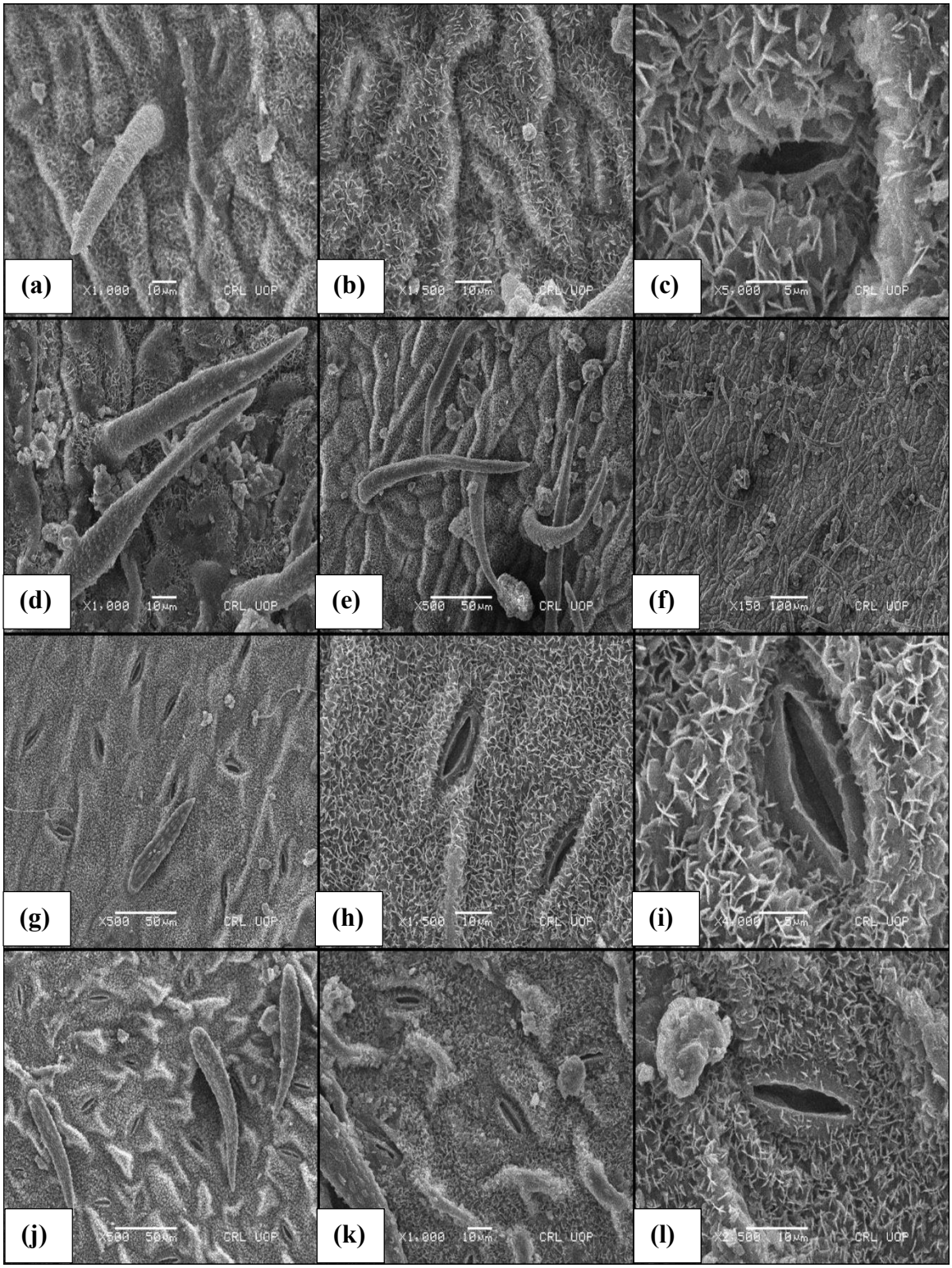

Plate 37. SEM anatomical photographs of leguminous species: *Parkinsonia aculeata* L. (a-c) Adaxial surface (d-f) Abaxial surface; *Prosopis cineraria* (L.) Druce (g-i) Adaxial surface (j-l) Abaxial surface

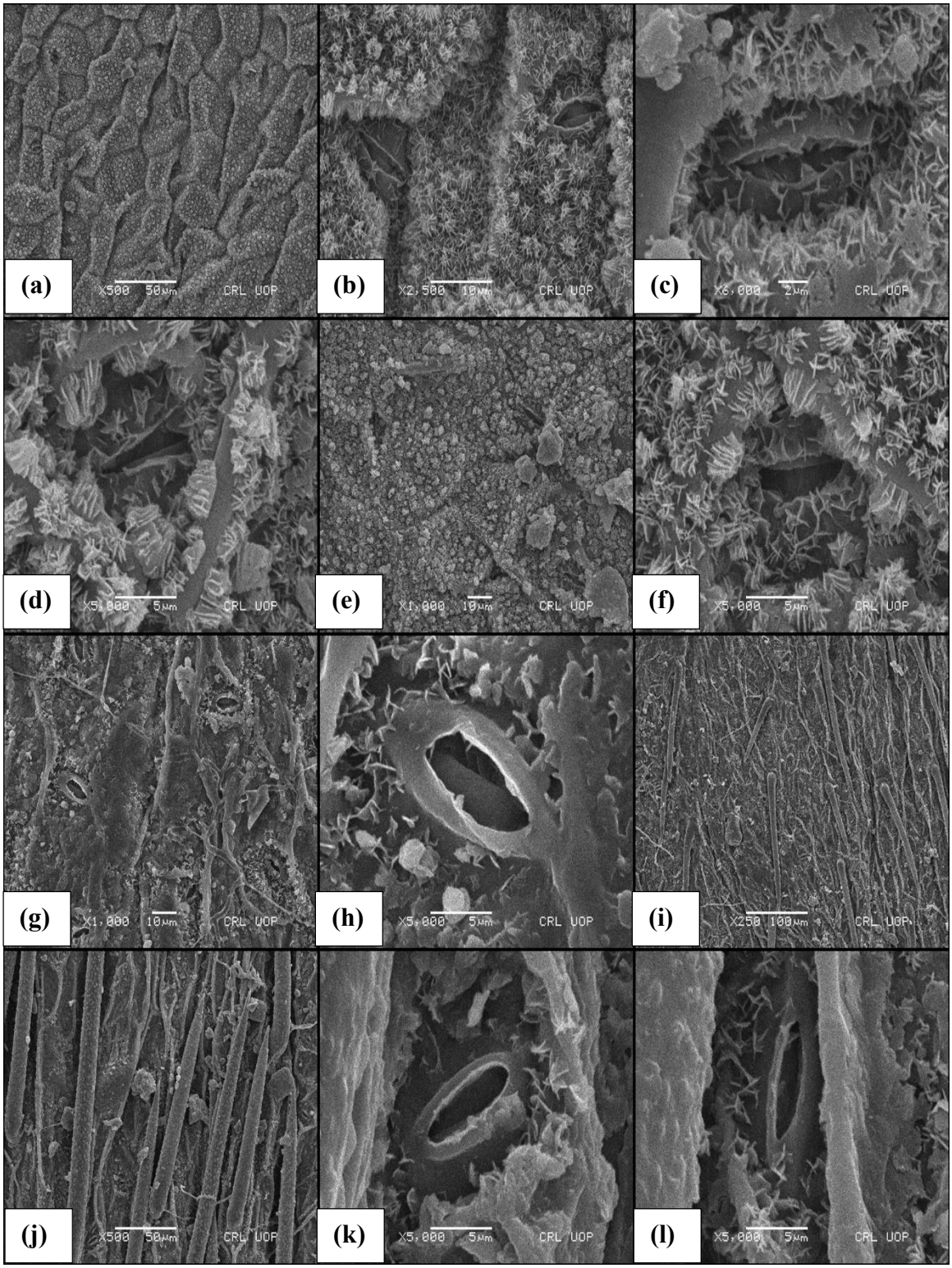

Plate 38. SEM anatomical photographs of leguminous species: *Prosopis juliflora* (Sw.) DC. (a-c) Adaxial surface (d-f) Abaxial surface; *Tephrosia purpurea* (L.) Pers. (g-i) Adaxial surface (j-l) Abaxial surface

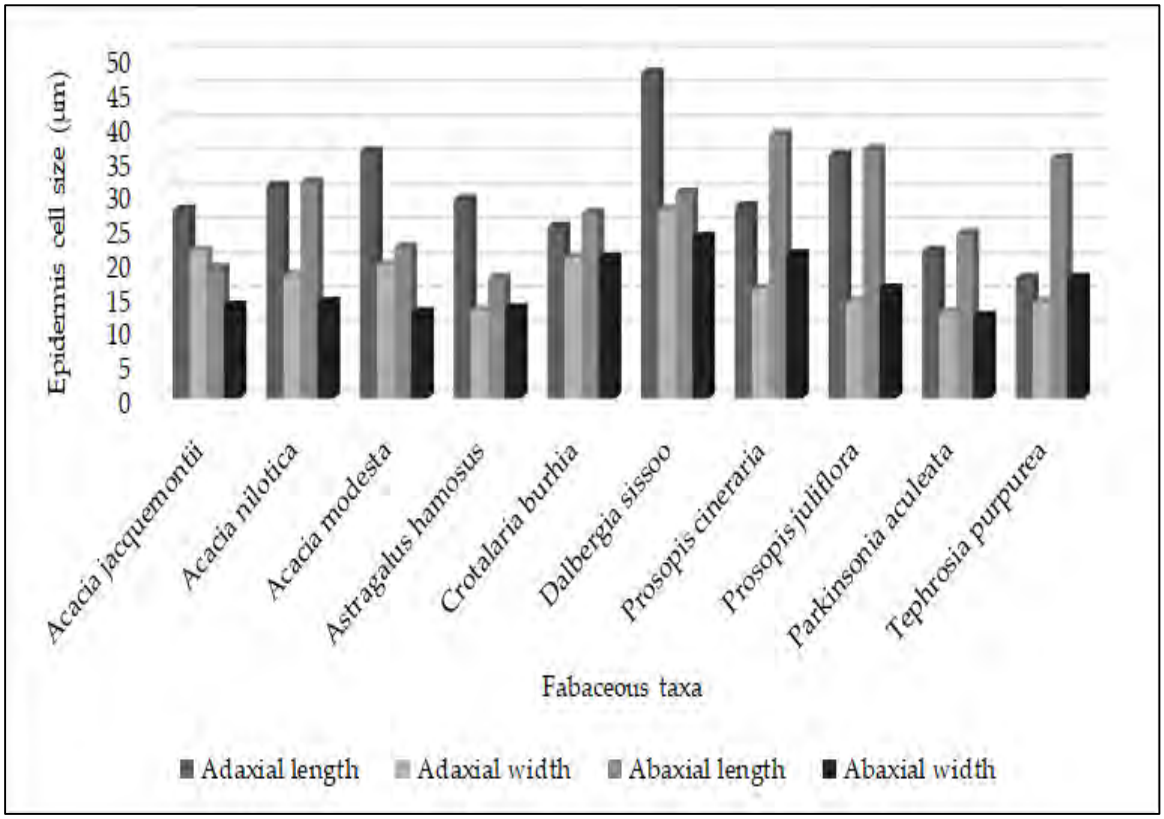

Figure 4. Epidermal cell size along adaxial and abaxial surface in leguminous species

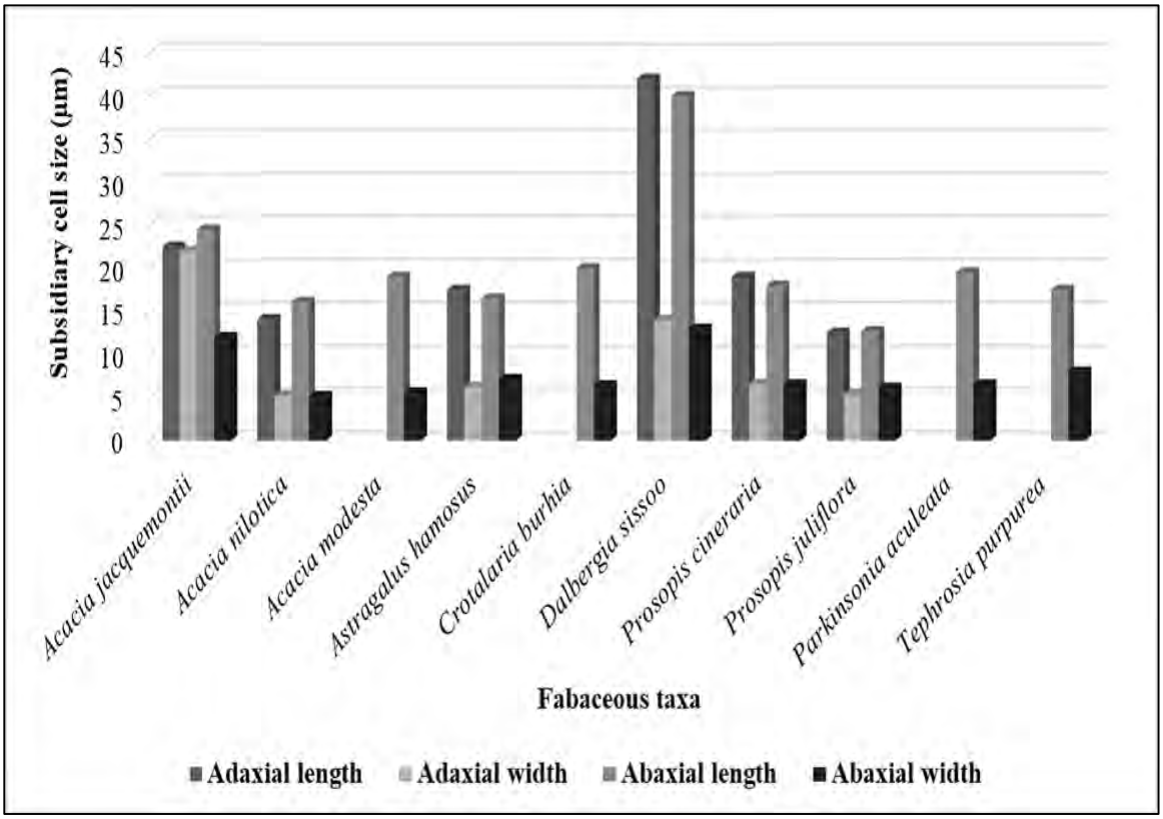

Figure 5. Subsidiary cell size variations along among leguminous species.

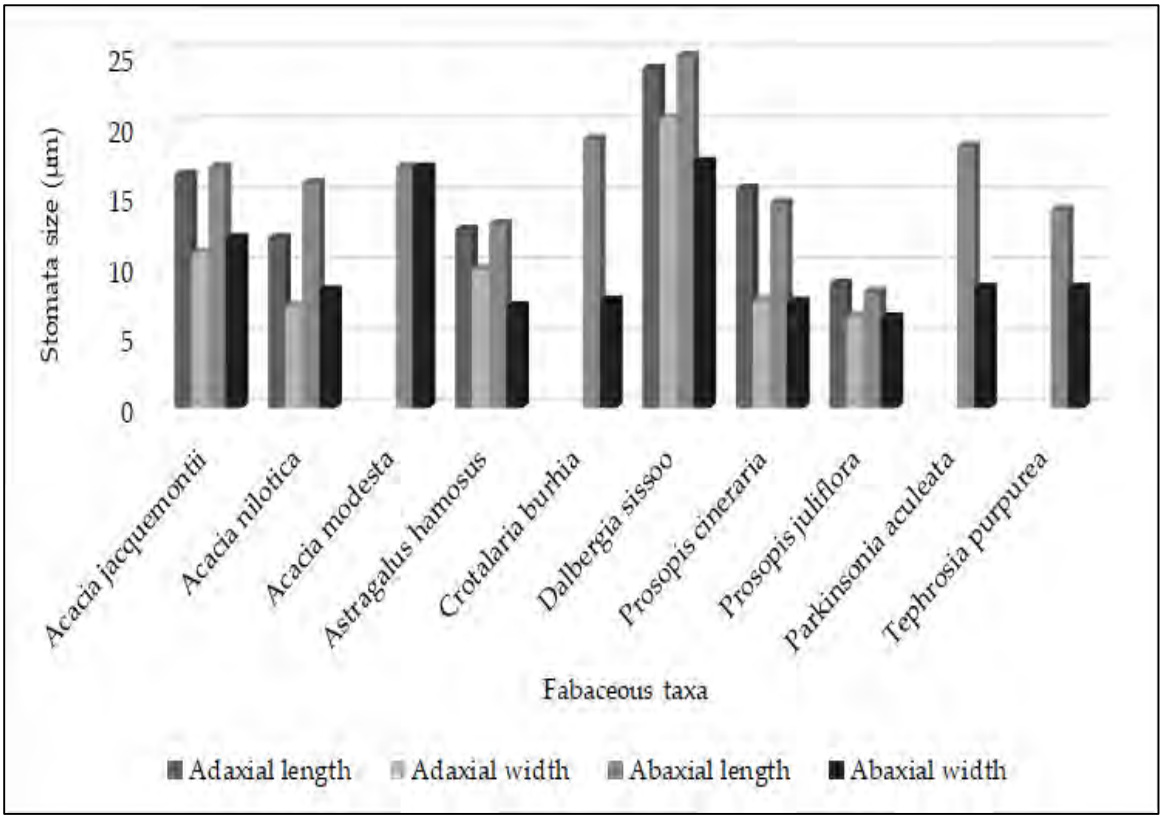

Figure 6. Mean stomatal size variations among leguminous species.

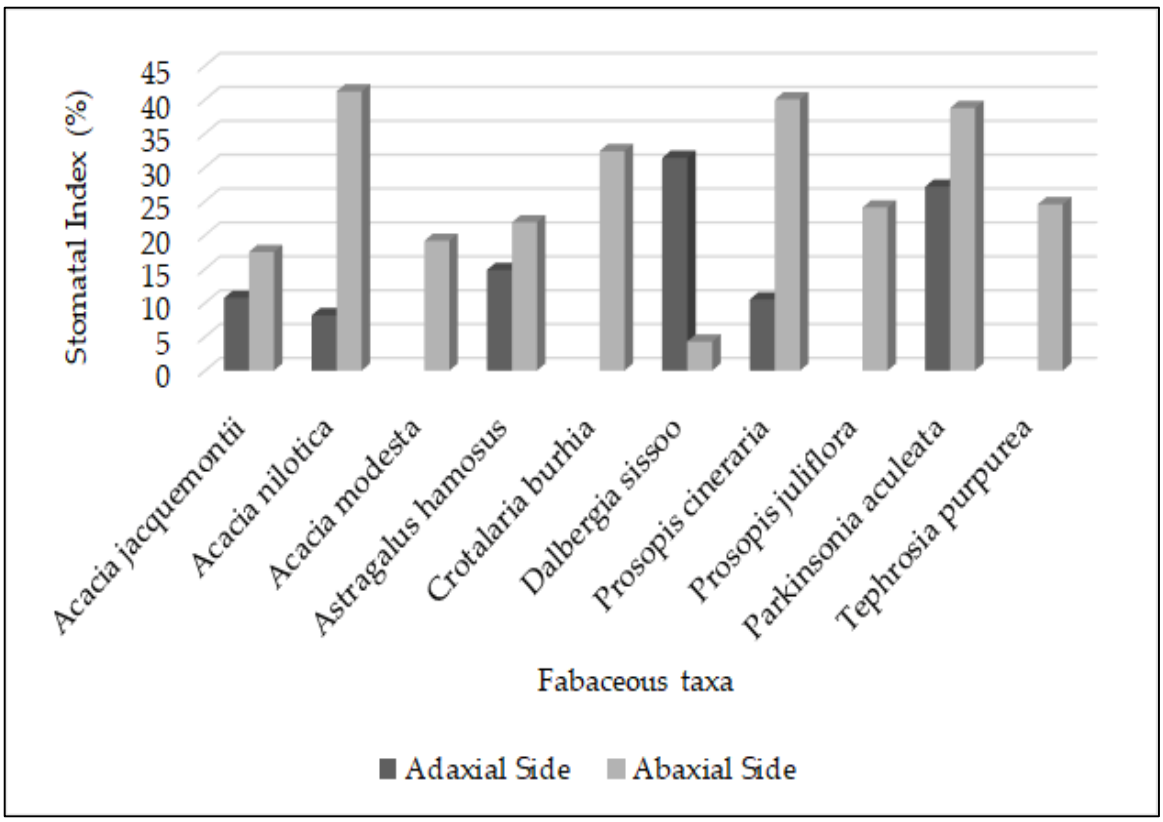

Figure 7. Stomatal index along adaxial and abaxial surface among leguminous species

4. Discussion

The present study was based on a microscope visualization tool to observe the microstructural characteristics of the leguminous species from the different localities of the Takkar Wildlife sanctuary. The micromorphological features are useful for the identification of plant species at various taxonomic levels. In the current research, the plant species were examined on the basis of epidermal cell size and shape, stomatal presence and absence along with stomatal type and size and presence and absence of trichomes and their size and type.

In the taxonomy of angiosperms, the use of leaf epidermal features is expanding and has been used for many years. The use of leaf epidermal traits in systematic botany is becoming more frequent, as is the use of other markers like DNA sequences and chemical compositions (Hameed *et al.*, 2020). Foliar epidermal characters are valuable tools for anatomical studies. Although considerable work has been conducted on wood anatomy and gross morphology for identification purposes but without foliar epidermal morphology identification criteria would be incomplete (Endress *et al.*, 2000; Zafar *et al.*, 2019). One of the significant features of taxonomic classification is anatomical leaf study that is of boundless position from taxonomical assessment. That is why most families have research on the basis of anatomical leaf study (Shaheen *et al.*, 2010; Birjees *et al.*, 2022). Countless stress has been laid on leaf epidermal micro-morphology for the purpose of classification (Metcalfe and Chalk, 1979). Although there exists a lot of literature on angiospermic families from a taxonomic viewpoint (Sahreen *et al.*, 2010).

Leaf epidermis is an important taxonomic feature and taxonomic analysis of many families is done with the help of leaf epidermis (Shaheen *et al.*, 2009; Sadia *et al.*, 2020). The use of microscopic imaging tools can be quite useful in examining foliar epidermal micromorphology and quantifying the idea that glandular trichome density reduces with increasing aridity. The impact of the microenvironment on plants can be seen at the morpho-structural level of trichomes as well as the stomata (Belmonte *et al.*, 2022). The majority of morphological and anatomical adaptations made by wildlife sanctuary habitats include thinner cuticles, smaller leaves, fewer stomata per unit leaf area, higher succulent, and wax deposition (Abd Elhalim *et al.*, 2016). Foliar epidermal micromorphology is particularly important, and earlier reports highlight its importance in the identification of diverse plant groups (Mamoona *et al.*, 2011; Esfandani -

Bozchaloyi and Zaman, 2018; Attar *et al.*, 2019; Bano *et al.*, 2019; Kandemir *et al.*, 2019; Shah *et al.*, 2019; Ullah *et al.*, 2019). The anatomical properties of the Fabaceous species and their significance for the taxonomic classification have been presented by some earlier studies (Rashid *et al.*, 2019; Yousaf *et al.*, 2022). (Çİldİr *et al.*, 2017) analyzed the leaf anatomical and micromorphological implications of *Lathyrus* species using light and scanning microscopy. Variations were observed in the epidermal cell shape of the selected plant species of Fabaceae. Polygonal, tetragonal, pentagonal, and wavy-shaped epidermal cells were reported in the present study. Duarte and Wolf (Duarte and Wolf, 2005) reported polygonal epidermal cells in *Acacia* species which is in accordance with the present study. Variations were also recorded in epidermal cell size with the largest epidermal cell size reported in *Prosopis cineraria* with epidermal cell length (38.5± 6.35µm) and the smallest in *Astragalus homosus* (17.5± 1.11µm) on abaxial surface. While the abaxial surface largest and smallest epidermal cell (47.5± 2.5µm) (17.5± 1.76µm) in *Dalbergia sissoo* and *Tephrosia purpurea,* respectively. In Fabaceous taxa: *Acacia nilotica* and *Acacia modesta* observed epidermal cell shape is polygonal and tetragonal to pentagonal which was not accordance with the (Saini *et al.*, 2008). Epidermal cell shape in *Dalbergia sissoo* is polygonal and irregular which was accordance with the previous findings of (Shaheen *et al.*, 2013).

The stomatal frequency are very most importantly use in taxonomy (Krishnamurthy and Kannabiran, 1970). The foliar anatomical remaining persistent no change of environmental stress according to (Davis and Heywood, 1963). In *Acacia nilotica* the straight anticlinal wall and paracytic stomata are observed and anticlinal wall straight are also observed by (Sahreen *et al.*, 2010). In *Acacia nilotica* paracytic type of stomata were observed while (Baretta-Kuipers, 1981) observed both paracytic and anomocytic type of stomata. Stomatal frequency, size, and distribution are regarded as important tools in phylogeny and taxonomy (Albert and Sharma, 2013). (Gill *et al.*, 1982) studied 21 species of Fabaceae and reported paracytic type stomata. In the order of Legume family, paracytic, anisocytic and anomocytic stomata were examined and (Bano *et al.*, 2019) discovered stomatal complex on both the adaxial and abaxial side of *Astragalus*. The *Astragalus homosus* was also found to have amphistomatic and polygonal epidermal cells with deeply sinuate anticlinal walls in the current study.

The majority of Fabaceae members have paracytic stomata as their primary stomata type, according to previous studies (JU, 2020) whereas *Crotalaria* species have

stomata that are paracytic, anisocytic, diacytic, or have one subsidiary cell (Ekeke and Agogbua, 2020). Paracytic stomata were reported in all the species except *Prosopis juliflora.* (Martínez Quesada, 1997) reported anisocytic stomata in *Prosopis juliflora* that does not coincide with the present study. Epidermal cells shape observed irregular in *Prosopis juliflora* were coincide with the findings of (Shaheen *et al.*, 2020). In order to assess the efficacy of the features defining the botanical identity (Robertson *et al.*, 2010) proposed microscopic standards to distinguish the leaves of *Prosopis cineraria* with petiole micromorphological sectioning.

The research on the epidermal cells of *Tephrosia* species reveal that the abundance of epidermal cells varies from the leaf of one species to another within genera and that the size of stomata is significant taxonomic character. However, *Tephrosia purpurea* stomata complex type was paracytic, which conflicts with the observations made by (Saeed *et al.*, 2019). The stomatal index varied accordingly to the number of epidermal cells and stomata on both leaf surfaces. The maximum stomatal index was observed in *Acacia nilotica* (41.2%) on abaxial side while the along adaxial surface (31.4%) was observed for *Dalbergia sisso*. (Mamoona *et al.*, 2011) confirmed the presence of stomata on adaxial and abaxial sides. (Nazish *et al.*, 2022) reported a significant decrease in stomata number per unit leaf area when they grow in more arid land habit.

Presence of trichomes is an additional astonishing character in leaf epidermal micromorphology which have significance role in classification of various taxa. Trichomes are an important taxonomic tool and can be used to delimit taxa. Unicellular trichomes were observed in *Crotalaria burhia* while glandular trichomes were seen in *Prosopis juliflora* and *Tephrosia purpurea.* (Bijauliya *et al.*, 2017) reported simple uniseriate trichomes that coincides with our study.

Our findings indicate that plants flourishing in Wildlife sanctuary conditions may improve their leaf functions by changing morphological and histochemical traits, which are significant adaptive capabilities to external conditions of low soil moisture and highly intense light. It is suggested that functional traits are frequently linked to anatomical adaptability.

3.2.2 Foliar Anatomy of Wild Species of Takkar Wildlife Sanctuary

Leaf epidermal anatomical characteristics can be used for a variety of purposes, including plant identification, plant classification, and plant ecology. In plant identification, leaf epidermal anatomical characteristics can be used to identify and distinguish between different plant species. For example, the shape and size of epidermal cells, the thickness of cell walls, the presence or absence of stomata, and the presence or absence of trichomes can all be used to help identify a particular plant species. In plant classification, leaf epidermal anatomical characteristics can be used to group plant species into different families or genera based on their similarities and differences. This can be useful for understanding the evolutionary relationships between different plant species.

In the present research, both qualitative and quantitative data were observed. Foliar epidermal anatomical features observed under light microscopy (LM) are types of epidermal cells, stomatal types, and subsidiary cells, various types of trichomes, presence or absence of stomata. And all these features were also studied quantitatively (Table 2, 3, 4, 5,6 7 & 8). The detailed anatomical characters of wild plant species were given below.

a) *Abutilon indicum* (L.) Sweet

Leaves are amphistomatic

Adaxial surface: Epidermal cells shapes was polygonal with 3-5 lobs per cell. While the type of stomata was Diacytic with 92 average number of epidermal cells. And Rounded anticlinal walls pattern. Stellate type trichomes, in these types of trichomes 6-8 arms with multicellular arms. The length and width of epidermal cells are (25.6-8.25 = 45.5±09.63) µm and (11.3-28 = 21±1.2) µm respectively. Whereas length and width of stomata observed (23.72-29.2 = 25.3±0.71) µm (14-23.73 = 18.2±1.21) µm respectively. And stomatal index recorded (8.09 %).

Abaxial surface: Epidermal cells shapes wavy with 3-7 lobs per cell. Stomatal type observed diacytic whereas stomatal index (9.37 %). anticlinal walls pattern of epidermal cell is Rounded. Average Number of Epidermal cell were 73 while length was (13.5-24.5 = 17.5±) µm and width (11-19 = 14.6±2.6) µm. The stomatal length was (24.7-26 = 35.6±0.64) µm while width (16.3-21 = 17.75±0.36) µm.

b) *Anagallis arvensis* L.

Leaves are amphistomatic

Adaxial surface: Pentagonal shaped epidermal cells with Sinuous anticlinal walls pattern. The average number of epidermal cells per unit are is 97. The length and width of epidermal cell are 32.5-27.5 = 21±3.6 µm and 11.3-21 = 15±1.26 µm respectively. Anomocytic type of stomata are examined. The observed length and width of stomata is 13.5-19.8 = 17.5±0.4 µm and 7.17-3 = 8.75±0.2 µm respectively. The noted guard cells length is 8.6.5-17.5= 15±0.79 µm and width is 6.5-3.8 = 2.85±0.1 µm. The stomatal pore length observed 9.17-15.8 = 12.5±0.8 µm and width is 2.23-2.5 = 1.85±0.2 µm. Subsidiary cell measured length and width is 16.3-22.5 = 19±1.5 µm and 5.27-7.5 = 6.6±0.6 µm respectively. Stomatal index is 12.07%.

Abaxial surface: Epidermal cells Wavy shaped with average number of epidermal cells per unit area is 72. Anticlinal wall pattern of epidermal cell is Sinuous. The noted length of epidermal cells is 26-52.3 = 29.4±6.45 µm and width is 11.4-24.17 = 22±3.05 µm. Anomocytic type of stomata were observed. The observed length and width of stomata is 13.5-18.5 = 13.5±0.11 µm and 4.17-11 = 8.5±0.89 µm respectively. The noted guard cells length is 6.35-17.5= 14.5±0.9 µm and width is 2.17-3.25= 2.8±0.15 µm. The stomatal pore length observed are 10.6-12.5 = 11.5±0.6 µm and width is 1.5-1.5 = 1.25±0.1 µm. Subsidiary cell measured length and width is 15.52-24.6 = 18±1.8 µm and 7.4-7.5 = 6.5±0.6 µm respectively. Stomatal index is 8.97 %.

c) *Anticharis glandulosa* Asch.

Leaves are amphistomatic

Adaxial surface: Wavy shaped epidermal cells with Sinuous anticlinal walls pattern. The average number of epidermal cells per unit are is 42. The length and width of epidermal cell are 14.8-20.3 = 17.8±1.04 µm and 8.7-13.3 = 10.56±0.84 µm respectively. Anomocytic type of stomata were observed while recorded length and width of stomata is 10.3-12.8 = 11.86±0.46µm and 6.9-9.8 = 8.22±0.56 µm respectively. The noted guard cells length is 9.16-18 = 16.8±0.76µm and width is 6.17-10.7= 8.88±0.64 µm. The stomatal pore length observed are 6.9-8.9 = 9.22±0.35 µm and width is 2.12-3.3 = 2.42±0.13 µm. Stomatal index is 12.9 %. Subsidiary cell

measured length and width is 14.9-11.7= 10.98±0.31 µm and 6.6-7.9 = 3.34±0.25 µm respectively. Multicellular with glandular tip trichome type was observed whereas length examined is 32.4-42.5 = 44.7±6.66 µm and width is 17.5-15 = 13.5±0.6 µm.

Abaxial surface: Examined epidermal cells were Wavy shaped while average number of epidermal cells recorded 66. Anticlinal wall pattern of epidermal cell is Sinuous. The observed length of epidermal cells is 20.5-15.6 = 13.5±1.09 µm and width is 6.59-8.9 = 7.34±0.4µm. Anomocytic type of stomata are observed. The observed length and width of stomata is 9.17-10.9 = 10.1±0.22 µm and 6.8-8.3 = 7.48±0.3 µm respectively. The noted guard cells length is 8.16-18 = 16.8±0.76 µm and width is 4.75-6 = 2.25±0.23 µm. The stomatal pore length observed are 8.6-12.5 = 11.5±0.6 µm and width is 1.51-1.5 = 1.25±0.1 µm. Stomatal index is 18.25%. Subsidiary cell measured length and width is 18.52-24.6 = 18±1.8µm and 7.4-7.5 = 6.5±0.6 µm respectively.

d) *Arnebia hispidissima* DC.

Leaves are Amphistomatic

Adaxial surface: Wavy shaped epidermal cells with Smooth & angular anticlinal walls pattern. The average number of epidermal cells per unit area is 27. The length and width of epidermal cell are 29.5-41.5 = 39.8±2.6 µm and 16.4-12.5 = 13±1.3 µm respectively. Diacytic type of stomata were examined. The observed length and width of stomata is 24.5-35.5 = 27.5±0.18 µm and 16-13.5 = 18.5±0.12 µm respectively. Stomatal index is 23.27 %. The noted guard cells length is 6.35-2.45= 29.5±0.9 µm and width is 3.9-10.6 = 8±0.5 µm. The stomatal pore length observed are 7.3-25 = 22±0.9 µm and width is 1.14-1.25 = 1.2±0.06 µm. Subsidiary cell measured length and width is 33.5-47.5 = 62±9.02 µm and 11.5-17.8 = 14.5±0.9 µm respectively. Unicellular glandular trichome type observed with length examined is 89.5-165 = 127±13.19 µm and width is 11-24 = 19.5±3.07 µm. Stomatal index is 23.27 %.

Abaxial surface: Epidermal cells were polygonal shaped with average number of epidermal cells per unit area 73. Anticlinal wall pattern of epidermal cell is Smooth & angular. The observed length of epidermal cells is 23.7-32.5 = 23.5±1.44 µm and width is 10.5-33 = 19±2.29 µm. Diacytic type of stomata were observed. The observed length and width of stomata is 23.5-24 = 31.5±0.9 µm and 18.5-21 = 16±0.4 µm respectively. The noted guard cells length is 16.5-23.7= 28.5±0.6 µm and width is 9.18-12.5=

11.5±0.6 µm. The stomatal pore length observed are 9.6-17.5 = 16.5±0.6 µm and width is 2.25-1.75 = 1.4±0.09 µm. Stomatal index is 13.05 %. Subsidiary cell measured length and width is 33.7-51.6 = 42.4±3.09 µm and 17.5-15.3 = 13.5±0.6 µm respectively.

e) *Calotropis procera* (Aiton) Dryand.

Leaves are amphistomatic

Adaxial surface: Pentagonal shaped epidermal cells with Straight anticlinal walls pattern. The average number of epidermal cells per unit are is 96. The length and width of epidermal cell are 26.2-11 = 13.1±0.29 µm and 15.5-29.5 = 21.9±5.56 µm respectively. Paracytic type of stomata were observed. The observed length and width of stomata is 12.27-13.68 = 18.5±0.9 µm and 8.5-13.5 = 10.6±1.29µm respectively. The noted guard cells length is 7.82-9.90= 9.7±0.06 µm and width is 3.25-4.20= 3.9±0.06 µm. The stomatal pore length observed 8.5-15.5 = 11.7±1.34 µm and width is 2.14-18.5 = 16.8±0.8 µm. Subsidiary cell length measured length and width is 46.8-65 = 51.5±3.92 µm and 26.9-37.5= 32.95+2.19 µm respectively. Stomatal index is 13.2%.

Abaxial surface: Pentagonal Epidermal cells with average number of epidermal cells per unit area is 72. Anticlinal wall pattern of epidermal cell is Straight. The observed length of epidermal cells is 22.2-16.7 = 12.5±1.17 µm and width is 9.5-6.23 = 5.6±2.49 µm. Paracytic type of stomata were observed. The observed length and width of stomata is 13.73-30.4 = 28±0.66 µm and 6.15-13.5 = 10.86±0.56 µm respectively. Stomatal index is 41.9%. The noted guard cells length is 7.32-9.00= 8.7±0.09 µm and width is 3.54-4.41= 3.6±0.09 µm. The stomatal pore length observed are 3.14-18.5 = 16.8±0.8 µm and width is 1.75-7.5 = 6.2±0.55 µm. Subsidiary cell length measured length and width is 52.5-75 = 64±4.3µm and 31.5-37.8 = 41.5±2.57µm respectively.

f) *Citrullus colocynthis* (L.) Schrad

Leaves are hypostomatic

Adaxial surface: Polygonal shaped epidermal cells with smooth anticlinal walls. The average number of epidermal cells per unit are is 91. The length and width of epidermal cell are 21.5-26.5 = 20.8±1.5 µm and 12.5-13.5 = 13.8±0.41 µm respectively. Multicellular glandular trichrome type was observed with length examined is 60-90 = 76±11.4 µm and width is 30-35 = 32.6±2.5 µm.

Abaxial surface: Polygonal Epidermal cells shapes were examined with average number of epidermal cells per unit area is 39. Anticlinal wall pattern of epidermal cell is Smooth & rounded. The observed length of epidermal cells is 27.5-24.5 = 26.8±0.73 µm and width is 12.3-16 = 14.58±0.26 µm. Anomocytic type of stomata were observed however the observed length and width of stomata is 13-11.8 = 17.46±0.39 µm and 8.4-6.5 = 6.64±0.08 µm respectively. The noted guard cells length is 9.3-12.5 = 16±0.82 µm and width is 4.19-9.13= 9.38±0.64 µm. The stomatal pore length observed are 6.15-8.5 = 8.06±0.4 µm and width is 3.16-2.5 = 2.28±0.19 µm. Subsidiary cell length measured length and width is 19.13-8.19 = 8.44±0.08 µm and 16.19-3.5 = 3.22±0.19 µm respectively. Stomatal index is 36 %.

g) *Cleome brachycarpa* (Forssk.) Vahl ex DC.

Leaves are amphistomatic

Adaxial surface: Hexagonal shaped epidermal cells with Sinuous anticlinal walls pattern. The average number of epidermal cells per unit are is 86. The length and width of epidermal cell observed 26.5-28.2 = 23.36±0.19 µm and 13.6-11.9 = 10.36±0.18 µm respectively. Anomocytic type of stomata were examined. Stomatal index is 8.51 %. The observed length and width of stomata is 13.6-11.5 = 15.42±0.06 µm and 9.13-8.35 = 8.42±0.03 µm respectively. The noted guard cells length is 9.7-15.9 = 18.5±0.06 µm and width is 4.17-6.42 = 9.86±0.06 µm. The stomatal pore length observed 5.9-8.5 = 10.24±0.1 µm and width is 2.13.-7.5 = 2.44±0.04 µm. Subsidiary cell measured length and width is 19.34-9.17 = 9.32±0.09 µm and 4.3-4.5 = 4.38±0.04 µm respectively.

Abaxial surface: Epidermal cells were polygonal shaped with average number of epidermal cells is 105. Anticlinal wall pattern of epidermal cell is Irregularly thickened. The observed length of epidermal cells is 48.75-63.50 = 55.55±2.94 µm and width is 24.50-49.50 = 35.30±4.32 µm. Diacytic type of stomata were observed. The observed length and width of stomata is 25.75-31 = 28.80±0.89 µm and 13.75-17.25 = 15.25±0.61 µm respectively. The noted guard cells length is 4.75-6 = 2.25±0.23 µm and width is 7.13-14.9 = 15.6±0.18 µm. The stomatal pore length observed are 3.1-10.5= 10.32±0.09 µm and width is 2.3-2.5 = 2.44±0.04 µm. Subsidiary cell length measured length and width is 25.50-31.75 = 28.55±1.04 µm and 7.25-10.50 = 8.35±0.56 µm respectively. Stomatal index is 19.50 %.

h) *Cleome scaposa* DC.

Leaves are amphistomatic

Adaxial surface: Polygonal shaped epidermal cells with Sinuous anticlinal walls pattern. The average number of epidermal cells per unit are is 46. The length and width of epidermal cell are 26-25 = 21.5±1.23 µm and 18.5-45 = 22.5±1.6 µm respectively. Anomocytic type of stomata were examined. The observed length and width of stomata is 12.6-13.5 = 11±0.61 µm and 18-17.5 = 17±0.12 µm respectively. The noted guard cells length is 9.5-17.5 = 14±1 µm and width is 2.18-5.43 = 4±0.61 µm. The stomatal pore length observed 6.4-9.5 = 11±0.61 µm and width is 1.22-2.1 = 2.05±0.27µm. Subsidiary cells measured length and width is 15.32-34.61= 22.5±3.53 µm and 11.42-23.7 = 17.5±3.5 µm respectively. Shaggy multicellular trichrome type was observed with length examined is 32-47.8=62.7±6.19 µm and width is 11.27-31=59.3±5.15µm. Stomatal index is 28 %.

Abaxial surface: Hexagonal epidermal cells with average number of epidermal cells per unit area is 81. Anticlinal wall pattern of epidermal cell is Sinuous. The observed length of epidermal cells is 15.5-25 = 19±2.32 µm and width is 11.7-17.5 = 13.5±1.8 µm. Anomocytic type of stomata were observed. The observed length and width of stomata is 18-17.5 = 17±0.12 µm and 12.5-15 = 12±0.93 µm respectively. The noted guard cells length is 8.5-15.6= 13.5±0.61 µm and width is 2.5-5.18 = 3±0.5 µm. The stomatal pore length observed 5.1-7.14 = 11±0.61 µm and width is 1.25-2.50 = 1.7±0.22 µm. Subsidiary cells measured length and width is 18.6-27.5 = 24.5±1.22 µm and 11.23-14.13 = 12±0.93µm respectively. Shaggy trichome multicellular type was observed with length examined is 35-87.5 = 59.5±7.3 µm and width is 12.5-15 = 13.5±0.6µm. Stomatal index is 7.29 %.

i) *Convolvulus arvensis* L

Leaves are hypostomatic

Adaxial surface: Irregular/wavy shaped epidermal cells with Straight anticlinal walls patterns. The average number of epidermal cells per unit are is 95. The length and width of epidermal cell are 12.4-13.7 = 12.2±0.78µm and 7.3-7.9 = 6.44±0.28 µm

respectively. Moniliform trichrome type was observed whereas length examined is 50-60 = 54±4.18 µm and width is 10-19 = 16±3.67µm.

Abaxial surface: Elongated to hexagonal epidermal cells shapes were examined with average number of epidermal cells per unit area is 87. Anticlinal wall pattern of epidermal cell is Sinuous. The observed length of epidermal cells is 22.4-13.7 = 12.2±0.78 µm and width is 7.3-7.9 = 6.44±0.28 µm. Paracytic type of stomata were observed. The observed length and width of stomata is 16.5-14.5 = 12.1±0.51 µm and 6.12-11.5 = 6.8±0.67 µm respectively. The noted guard cells length is 4.5-11.1 = 10.5±0.63 µm and width is 2.5-8.5 = 8±0.5µm. The stomatal pore length observed are 5.7-9.5 = 8.56±0.65 µm and width is 2.13-2.26= 2.48±0.14 µm. Subsidiary cell measured length and width is 26.6-10.12 = 10.3±0.13 µm and 15.13-6.22 = 5.66±0.33 µm respectively. Stomatal index is 11.42 %.

j) *Corchorus depressus* (L.) Stocks

Leaves are amphistomatic

Adaxial surface: Hexagonal shaped epidermal cells with undulate anticlinal walls pattern. The average number of epidermal cells per unit are is 67. The length and width of epidermal cell are 24.23-40.8 = 32±2.79 µm and 13.5-2.5 = 18.5±2.32 µm respectively. Diacytic type of stomata were examined. The observed length and width of stomata is 7.45-12.5 = 10.5±0.9 µm and 4.17-6.24 = 5.45±0.32 µm respectively. The noted guard cells length is 8.6-19.2= 18.9±0.1µm and width is 3.5-13.3 = 12±0.12 µm. The stomatal pore length observed are 5.38-6.2 = 5.9±0.13 µm and width is 2.13-2.8 = 2.5±0.1 µm. Stomatal index is 16.66 %. Subsidiary cell measured length and width is 18.16-8.12 = 8.08±0.23 µm and 4.47-4.16 = 4.3±0.1µm respectively. Trichrome multicellular glandular type was observed with length examined is 50-90=68.5±1.68 µm and width is 7.5-20=14±3.3µm.

Abaxial surface: Polygonal Epidermal cells shape were examined with average number of epidermal cells per unit area is 29. Anticlinal wall pattern of epidermal cell is slightly undulate or straight. The observed length of epidermal cells is 23.7-27.6 = 23.8±0.85 µm and width is 10.18-15.5 = 11.7±1.41 µm. Diacytic type of stomata are observed. The observed length and width of stomata is 10.18-17.5 = 14±1.7 µm and 5.19-7.15 = 6.25±0.18 µm respectively. The noted guard cells length is 8.6-19.2=

18.9±0.1 µm and width is 3.5-13.3 = 12±0.12 µm. The stomatal pore length observed are 5.38-6.2 = 5.9±0.13 µm and width is 2.13-2.8 = 2.5±0.1 µm. Subsidiary cell measured length and width is 18.16-8.12 = 8.08±0.23 µm and 4.47-4.16 = 4.3±0.1 µm respectively. Stomatal index is 22.22 %.

k) *Corchorus tridens* L.

Leaves are hypostomatic

Adaxial surface: Hexagonal shaped epidermal cells with Rounded anticlinal walls pattern. The average number of epidermal cells per unit are is 56. The length and width of epidermal cell are 26.7-21.6 = 27.06±0.54 µm and 15.7-16.6 = 14.86±0.18 µm respectively.

Abaxial surface: Polygonal epidermal cells shapes with average number of epidermal cells per unit area is 29. Anticlinal wall pattern of epidermal cell is Sinuous. The observed length of epidermal cells is 36.8-16.3 = 15.66±0.17 µm and width is 11.19-12.8 = 11.1±0.24µm. Paracytic type of stomata are observed. The observed length and width of stomata is 14.8-8.8 = 8.18±0.17 µm and 5.14-6.8 = 6.54±0.12 µm respectively. The noted guard cells length is 11.8-12.1 = 11±0.11 µm and width is 7.8-8.7 = 8.24±0.16 µm. The stomatal pore length observed are 5.9-6.6 = 6.22±0.12 µm and width is 2.9-3.2 = 3.02±0.05 µm. Stomatal index is 12.22 %. Subsidiary cell measured length and width is 28.12-8.9 = 8.58±0.12 µm and 16.18-6.16 = 6.84±0.1 µm respectively.

l) *Cucumis melo ssp agrestis*

Leaves are amphistomatic

Adaxial surface: Hexagonal shaped epidermal cells with Straight & Undulate anticlinal walls pattern. The average number of epidermal cells per unit are is 69. The length and width of epidermal cell are 34.6-10.2 = 11.94±0.7 µm and 17.15-5.23 = 8.8±0.23 µm respectively. Anomocytic type of stomata were examined. Stomatal index is 8.74 %. The observed length and width of stomata is 13.18-12.9 = 11.1±0.37 µm and 5.36-6.9 = 5.42±0.25 µm respectively. The noted guard cells length is 14-15.3 = 14.7±0.2 µm and width is 7.8-88 = 8.38±0.17 µm. The stomatal pore length observed

are 4.18-5.3 = 5.08±0.09 µm and width is 2.5-3.2 = 3.04±0.06 µm. Subsidiary cell measured length and width is 23.6-9.12 = 9.86±0.08 µm and 13.28-3.5 = 3.18±0.08 µm respectively. Unicellular glandular trichome type was observed whereas length examined is 80-94 = 86±2.75 µm and width is 4-8 = 6.1±0.71µm.

Abaxial surface: Hexagonal epidermal cells shapes with average number of epidermal cells per unit area is 48. Anticlinal wall pattern of epidermal cell is Straight & Undulate. The observed length of epidermal cells is 19.9-12 = 12.4±0.38 µm and width is 5.17-7.8 = 5.6±0.24 µm. Anomocytic type of stomata were observed. The observed length and width of stomata is 13.7-12.8 = 11.76±0.33 µm and 8.19-8.45 = 8.2±0.18 µm respectively. The noted guard cells length is 14-15.3 = 14.7±0.2 µm and width is 4.75-6 = 2.25±0.23 µm. The stomatal pore length observed were 10.25-13.75 = 12±0.70 µm and width is 3.8-88 = 8.38±0.17 µm. Subsidiary cell measured length and width is 23.6-9.12 = 9.86±0.08 µm and 13.28-3.5 = 3.18±0.08 µm respectively. Unicellular Trichrome type was observed whereas length examined is 62-74 = 66.8±2.26 µm and width is 4.5-6 = 5.16±0.26 µm. Stomatal index is 13.33%.

m) *Cynoglossum lanceolatum* Forssk.

Leaves are hypostomatic

Adaxial surface: Polygonal shaped epidermal cells with irregularly thickened anticlinal walls pattern. The average number of epidermal cells per unit are is 95. The length and width of epidermal cell are 34.17-34.5 = 28.5±5.2 µm and 11.5-17.5 = 15.5±0.8 µm respectively.

Abaxial surface: Polygonal epidermal cells shape with average number of epidermal cells per unit area is 63. Anticlinal wall pattern of epidermal cell is undulate. The observed length of epidermal cells is 24-37.5 = 25±2.1 µm and width is 11.25-20 = 16±1.5 µm. Anomocytic type of stomata are observed. The observed length and width of stomata is 12.7-37.5 = 33±2.29 µm and 6.16-21.5 = 20±1.11 µm respectively. Stomatal index is 20.25 %. The noted guard cells length is 6.18-37.5 = 33±2.3 µm and width is 4.5-12.5 = 10±1.1 µm. The stomatal pore length observed are 4.27-7.17 = 17±0.9 µm and width is 1.29-2.5 = 1.5±0.2 µm. Subsidiary cells measured length and width is 52.17-63.5 = 61±4.2 µm and 17.5-25 = 20.5±1.2 µm respectively. multicellular

trichrome type was observed with length examined is 55.75-158.50 = 108.30±16.68 µm and width is 23.50-58.25 = 37.85±6.26 µm.

n) *Evolvulus alsinoides* (L.) L.

Leaves are hypostomatic

Adaxial surface: Irregular shaped epidermal cells with Sinuous anticlinal walls pattern. The average number of epidermal cells per unit are is 66. The length and width of epidermal cells were 23.17-13.5 = 13.2±0.12 µm and 17.32-8.17 = 5.34±0.12 µm respectively. Multicellular trichrome type was observed whereas length examined is 83-96 = 91.4±2.13 µm and width is 8.5-12 = 10.6±0.7 µm.

Abaxial surface: Wavy epidermal cells shape with average number of epidermal cells per unit area is 49. Anticlinal wall pattern of epidermal cell is Beaded. The observed length of epidermal cells is 27.17-5.2 = 5.02±0.08 µm and width is 15.19-3.19 = 3.06±0.06 µm. Anomocytic type of stomata were observed. The observed length and width of stomata is 11.23-12.17 = 11.42±0.38 µm and 5.43.-5.19 = 5±0.05 µm respectively. The noted guard cells length is 4.18-16.5=19.8±0.25µm and width is 2.75-6 = 2.25±0.23 µm. The stomatal pore length observed were 5.17-7.5 = 6.92±0.25 µm and width is 2.12-2.5 = 2.34±0.06 µm. Subsidiary cells measured length and width is 22.5-10.5 = 10±0.17 µm and 16.8-6.5 = 4.06±0.12 µm respectively. Stomatal index is 15.51%.

o) *Farsetia stylosa* R.Br.

Leaves are Amphistomatic

Adaxial surface: Irregular shaped epidermal cells with Irregularly thickened anticlinal walls pattern. The average number of epidermal cells per unit are is 110. The length and width of epidermal cell is 26.5-18.55= 55.5±10.73 µm and 17.5-31.7 = 22±2.1 µm respectively. Anomocytic type of stomata were examined. The observed length and width of stomata is 14.71-28.17 = 26.2±0.81 µm and 7.13-21.75 = 19.2±1.31 µm respectively. The noted guard cells length is 7.4-6.17 = 7.5±0.83 µm and width is 4.12-4.6 = 4.4±0.04 µm. Stomatal index is 9.09 %. The stomatal pore length observed were 5.3-15 = 13.2±0.91 µm and width is 2.75-6.5 = 5.5±0.36 µm. Subsidiary cell measured length 46.7-35 = 57.5±25 µm and width is 17.5-37.5 = 27.5±3.25 µm respectively.

unicellular trichrome type was observed however length examined is 25-47.5 = 33.5±3.92µm and width is 12.5-32.5 = 21.5±6.96 µm.

Abaxial surface: Wavy epidermal cells shape with average number of epidermal cells per unit area is 76. Anticlinal wall pattern of epidermal cell is Sinuous irregular. The observed length of epidermal cells is 29.5-25.5 = 18.4±7 µm and width is 13.17-21.6 = 15.5±1.6 µm. Anomocytic type of stomata were observed. Stomatal index is 7.37 %. The observed length and width of stomata is 14.17-26.21 = 25.7±0.74 µm and 7.5-19.6 = 18.85±0.46 µm respectively. The noted guard cells length is 7.4-6.17 = 7.5±0.83 µm and width is 4.12-4.6 = 4.4±0.04µm. The stomatal pore length observed is 5.17-11.23 = 12.2±0.67 µm and width is 3.21-7.5 = 6.5±0.43 µm. Subsidiary cell measured length and width is 43.8-52.5 = 54.5±2.54 µm and 17.5-23.5 = 22.5±1.76 µm respectively. Unicellular trichome type was observed whereas length examined is 47.5-97.5 = 73.5±7.7µm and width is 12-42.5 = 29±4 µm.

p) *Gisekia pharnaceoides* L.

Leaves are amphistomatic

Adaxial surface: Hexagonal shaped epidermal cells with Straight Undulate anticlinal walls pattern. The average number of epidermal cells per unit are is 113. The length and width of epidermal cell is 323.6-37.5 = 28±2.6 µm and 15.9-19.17 = 16±1.27µm respectively. Paracytic type of stomata were examined. The observed length and width of stomata is 13.5-16.19 = 15.5±0.8 µm and 7.24-8.12 = 7.65±0.1 µm respectively. The noted guard cells length is 7.5-8.00 = 7.6±0.18 µm and width is 3.32-4.7 = 3.8±0.09 µm. The stomatal pore length observed is 4.9-15 = 12.5±0.8 µm and width is 1.22-2.5 = 1.85±0.2 µm. Subsidiary cells measured length and width is 37.9-22.5 = 19±1.5µm and 15.25-9.5 = 6.6±0.6 µm respectively. Shaggy trichome type was observed however length examined is 22.5-52.5 = 34.7±6.76µm and width is 12.5-15 = 13.5±0.6 µm. Stomatal index is 9.02%.

Abaxial surface: Hexagonal epidermal cells shape with average number of epidermal cells per unit area is 71. Anticlinal wall pattern of epidermal cell is rounded. The observed length of epidermal cells is 26.29-52.5 = 38.5±6.35 µm and width is 12.5-27.5 = 21±3.02 µm. Paracytic type of stomata are observed. Stomatal index is 8.97 %. The observed length and width of stomata is 13.18-17.19 = 14.5±0.9 µm and 6.13-10.45

= 7.5±0.79 µm respectively. The noted guard cells length is 9.7-7.15 = 15±0.79 µm and width is 2.3-3.25 = 2.8±0.15 µm. The stomatal pore length observed are 3.31-12.5 = 11.5±0.6 µm and width is 1.9-1.5 = 1.25±0.1 µm. Subsidiary cell measured length and width is 19.7-23.7 = 18±1.8µm and 9.16-7.5 = 6.5±0.6 µm respectively. Shaggy trichome type was observed and length examined is 26.7-5.19=29±7.21 µm and width is 12.8-36.12±7.39 µm.

q) *Heliotropium bacciferum* Forssk.

Leaves are amphistomatic

Adaxial surface: Polygonal shaped epidermal cells with Beaded anticlinal walls pattern. The average number of epidermal cells per unit are is 73. The length and width of epidermal cell are 28.26-20.3 = 17.8±1.04 µm and 12.7-13.3 = 10.56±0.84 µm respectively. Anisocytic type of stomata were examined. The observed length and width of stomata is 14.3-12.8 = 11.86±0.46 µm and 6.39-9.18 = 8.22±0.56 µm respectively. The noted guard cells length is 11.6-13.2 = 16.8±0.76 µm and width is 6.7-10.7 = 8.88±0.64 µm. The stomatal pore length observed is 2.9-10.9 = 9.22±0.55 µm and width is 1.12-3.3 = 2.42±0.3 µm. Subsidiary cell measured length and width is 19.9-11.7 = 10.98±0.31 µm and 14.16-3.19 = 3.34±0.25 µm respectively. Unicellular trichome type were observed whereas length examined is 32.8-36.12±7.39 µm and width is 7.49-21.12±18.21 µm. Stomatal index is 11.9 %.

Abaxial surface: Polygonal epidermal cells shape with average number of epidermal cells per unit area is 63. Anticlinal wall pattern of epidermal cell is Angular Undulate. The observed length of epidermal cells is 23.8-15.6 = 13.5±1.09 µm and width is 16.19-8.19 = 7.34±0.4 µm. Anisocytic type of stomata were observed. Stomatal index is 20.25 %. The observed length and width of stomata is 13.7-16.9 = 10.1±0.22 µm and 6.8-8.13 = 7.48±0.3 µm respectively. The noted guard cells length is 11.6-18.7 = 16±0.88 µm and width is 4.12-4.6 = 4.4±0.04 µm. The stomatal pore length observed is 4.7-7.9 = 6.16±0.61 µm and width is 2.75-6.5 = 5.5±0.36 µm. Subsidiary cell measured length and width is 27.8-9.2 = 8.34±0.25 µm and 17.5-37.5 = 27.5±3.25 µm respectively. Stomatal index is 20.25 %.

r) *Iphiona aucheri* (Boiss.) Anderb.

Leaves are hypostomatic

Adaxial surface: Wavy shaped epidermal cells with undulate anticlinal walls pattern. The average number of epidermal cells per unit are is 58. The length and width of epidermal cell are 23.16-32.9 = 27.5±1.9 µm and 16.12-22.6 = 21.5±1.6 µm respectively.

Abaxial surface: Wavy epidermal cells shape with average number of cells per unit area is 73. Anticlinal wall pattern of epidermal cell is Irregular Undulate. The observed length of epidermal cells is 27.5-26.7 = 19±2.7 µm and width is 10.7-17.5 = 12.5±1.3 µm. Anisocytic type of stomata are observed. The observed length and width of stomata is 17.35-17.19 = 17±0.5 µm and 9.41-15.17 = 12±0.93 µm respectively. The noted guard cells length is 7.7-21 = 19.8±0.25µm and width is 3.38-95 = 8.82±0.21 µm. The stomatal pore length observed is 5.3-7.5 = 6.92±0.25 µm and width is 1.23-2.5 = 2.34±0.06 µm. Subsidiary cell measured length and width is 19.3-9.5 = 10±0.17 µm and 13.8-4.5 = 4.06±0.12 µm respectively. Multicellular glandular trichome type was observed with length examined is 31.26-27.38±16.68 µm and width is 6.39.14.38±21.34 µm. Stomatal index is 8.43 %.

s) *Ipomoea aquatic* Forssk.

Leaves are hypostomatic

Adaxial surface: Hexagonal epidermal cells shaped with Straight & Undulate anticlinal walls pattern. The average number of epidermal cells per unit are is 57. The length and width of epidermal cell are 41.8-57.5 = 50.8±1.1 µm and 41.8-57.5 = 50.8±11.1µm respectively.

Abaxial surface: Hexagonal epidermal cells shape with average number of cells per unit are is 79. Anticlinal wall pattern of epidermal cell is Straight & Undulate. The observed length of epidermal cells is 29-28.5 = 21.5±1.64 µm and width is 12.18-25.32 = 17±2.29 µm. Anisocytic type of stomata were observed. Stomatal index is 15.05 %. Observed length and width of stomata is 13.42-31.16 = 28.5±0.6 µm and 9.12-19.13 = 19±0.6 µm respectively. The noted guard cells length is 13.42-31.16 = 28.5±0.6 µm and width is 9.12-19.13 = 19±0.6 µm. The stomatal pore length observed is 6.16-17.5

= 16.5±0.6 µm and width is 2.9-1.35 = 1.4±0.09 µm. Subsidiary cells measured length and width is 36.33-41.8= 42.4±3.09 µm and 12.5-15.18 = 13.5±0.6 µm respectively.

t) *Lantana camara* L.

Leaves are amphistomatic

Adaxial surface: Irregular epidermal cells with Sinuous anticlinal walls pattern. The average number of epidermal cells per unit are is 99. The length and width of epidermal cells were 18.2-14.8 = 13.1±0.25 µm and 16.65-27.5 = 21.9±5.66 µm respectively. Anomocytic type of stomata were examined. The observed length and width of stomata is 13.15-14.25 = 12.5±0.7 µm and 7.18-11.5 = 9.6±1.19 µm respectively. The noted guard cells length is 7.51-9.90 = 9.7±0.06 µm and width is 4.75-6 = 5.25±0.23 µm. The stomatal pore length observed is 13.75-17.25 = 15.40±0.72 µm and width is 3.13-4.20 = 3.9±0.06 µm. Subsidiary cells measured length 43.5-65.17= 51.5±3.92 and width is 25-37.5 = 32.95+2.19 µm respectively. Conical unicellular trichome type was observed while length examined is 87-5-150 = 122.7±6.25 µm and width is 22.5-62.5=38.5±6.96 µm. Stomatal index is 13.23%.

Abaxial surface: Wavy epidermal cells with average number of cells is 81. Anticlinal wall pattern of epidermal cell is Sinuous. The observed length of epidermal cells is 27.2-14.7 = 12.5±1.13 µm and width is 17.12-6.25 = 5.6±2.69 µm. Anomocytic type of stomata were observed. The observed length and width of stomata is 16.36-30.9 = 28±0.62 µm and 9.5-12.18 = 10.85±0.55 µm respectively. The noted guard cells length is 6.13-9.00 = 4.7±0.09µm and width is 3.16-4.00 = 3.6±0.09 µm. The stomatal pore length observed is 9.137-18.5= 16.8±0.8 µm and width is 3.25-5.75 =4.90±0.47 µm. Stomatal index is 41.93 %. Subsidiary cell measured length and width is 4.13-7.7 = 6.2±0.55 µm and 7.25-10.50 = 8.35±0.56 µm respectively. Conical Unicellular trichome type were observed and length examined is 80-152 = 117.5±19.66µm and width is 15-47.5 = 33.5±3.92 µm.

u) *Merremia hederacea* (Burm. f.) Hallier f.

Leaves are hypostomatic

Adaxial surface: Hexagonal epidermal cells with Straight anticlinal walls pattern. The average number of epidermal cells per unit are is 63. The length and width of epidermal

cell are 22.12-23.17 = 21.8±1.2 µm and 13.5-11.5 = 10.8±0.41 µm respectively. unicellular trichome type was observed with length examined is 60-90 = 76±11.4 µm and width is 13.6-35 = 32.6±2.5 µm.

Abaxial surface: Hexagonal epidermal cells with average number of cells is 105. Anticlinal wall pattern of epidermal cell is Straight. The observed length of epidermal cells is 27.9-28.5 = 27.8±0.83 µm and width is 9.13-11.8 = 10.58±0.25 µm. Diacytic type of stomata were observed. The observed length and width of stomata is 14.25-12.8 = 10.46±0.29 µm and 7.4-6.5 = 6.44±0.05 µm respectively. The noted guard cells length is 411.5-14.5 = 16±0.82 µm and width is 8.5-10.3 = 9.38±0.64 µm. The stomatal pore length observed is 5.5-8.5 = 8.06±0.4 µm and width is 2.7-2.5 = 2.28±0.19 µm. Subsidiary cells measured length and width is 28.3-8.5 = 8.44±0.08 µm and 13.19-3.5 = 3.22±0.19 µm respectively. Stomatal index is 16.8%.

v) *Mollugo cerviana* (L.) Ser.

Leaves are amphistomatic

Adaxial surface: Cylindrical epidermal cells, the average number of cells per unit are is 56. The length and width of epidermal cell is 23.21.8-26= 25.36±0.18 µm and 11.7-11.6 = 10.36±0.18 µm respectively. Gramineous type of stomata were examined. Stomatal index is 8.51 %. The observed length and width of stomata is 16.7-19.2 = 12.42±0.03 µm and 8.3-8.27 = 8.42±0.03 µm respectively. The noted guard cells length is 12.7-13.9 = 18.5±0.06 µm and width is 9.7-7.9 = 9.86±0.06 µm. The stomatal pore length observed is 7.3-4.5 = 10.24±0.1 µm and width is 2.3-2.5 = 2.44±0.04 µm. Subsidiary cell measured length and width is 19.4-9.5 = 9.32±0.09 µm and 9.3-4.15 = 4.38±0.04 µm respectively. Stomatal index is 8.51 %.

Abaxial surface: Cylindrical epidermal cells with average number of cells per unit area is 66. The observed length of epidermal cells is 18.9-19.23 = 18.8±0.12 µm and width is 9.5-9.7 = 9.58±0.03 µm. Gramineous type of stomata were observed. The observed length and width of stomata is 13.9-16.15 = 15.22±0.11 µm and 8.14-9.11 = 8.74±0.06 µm respectively. The noted guard cells length is 12.7-13.9 = 18.5±0.06 µm and width is 8.19-9.23 = 15.6±0.18 µm. The stomatal pore length is 7.12-10.5 = 10.32±0.09 µm and width is 2.13-2.5 = 2.44±0.04 µm. Subsidiary cells measured length and width is

16.4-11.17= 11.5±0.05 µm and 5.14-5.23 = 5.5±0.03µm respectively. Stomatal index is 31.57 %.

w) *Moringa oleifera* Lam.

Leaves are amphistomatic

Adaxial surface: Polygonal epidermal cells, the average number of cells per unit are is 14. The length and width of epidermal cell is 24.13-32.9 = 27.5±1.9 µm and 17.12-22.6 = 21.5±1.3 µm respectively. Anomocytic type of stomata were examined. The observed length and width of stomata is 16.25-21.6 = 16.5±1 µm and 11.6-12.63 = 11±0.61 µm respectively. The noted guard cells length is 8.6.5-11.5 = 14±1 µm and width is 2.23-5.4 = 4±0.61 µm. The stomatal pore length observed is 2.23-5.4 = 4±0.61 µm and width is 2.5-2.16 = 2.05±0.27 µm. Subsidiary cell measured length and width is 18.13-35.9= 22.5±3.53 µm and 11.34-23.12= 17.5±3.5 µm respectively. Stomatal index is 28%.

Abaxial surface: Wavy epidermal cells with average number of cells per unit area is 66. The observed length of epidermal cells is 16.5-26.7 = 19±2.17 µm and width is 10.7-17.5 = 13.5±1.3 µm. Anisocytic type of stomata were observed. The observed length and width of stomata is 16.35-17.19 = 17±0.5 µm and 9.48-15.17 = 12±0.93 µm respectively. The noted guard cells length is 9.4-12.6 =13.5±0.61 µm and width is 2.5-5 = 3±0.5 µm. The stomatal pore length is 8.13-11.5 = 11±0.61 µm and width is 1.25-2.50 = 1.7±0.22 µm. Subsidiary cells measured length and width is 1.25-2.50 = 1.7±0.22 µm and 11.13-15.13 = 12±0.93µm respectively. Stomatal index is 7.29 %.

x) *Oxystelma esculentum* (L. f.) Sm.

Leaves are hypostomatic

Adaxial surface: Hexagonal epidermal cells with undulate anticlinal walls pattern. The average number of epidermal cells per unit are is 95. The length and width of epidermal cells is 23.32-13.36= 12.2±0.75 µm and 16.13-7.18 = 6.54±0.28 µm respectively. Cylindrical Unicellular trichome type observed while length examined is 41.8-60.32 = 54±4.18 µm and width is 9.45-19.31 = 16±3.67 µm.

Abaxial surface: Polygonal epidermal cells with average number of cells is 95. Anticlinal wall pattern of epidermal cell is slightly undulate. The observed length of epidermal cells is 27.43-18.12= 17.9±0.65 µm and width is 15.4-11.17 = 8.28±1.92 µm.

Anisocytic type of stomata were observed. Stomatal index is 11.42 %. The observed length and width of stomata is 11.5-12.5 = 12.1±0.41 µm and 6.18-7.5 = 6.8±0.67 µm respectively. The noted guard cells length is 9.12-11.1 = 10.5±0.6 µm and width is 7.13-8.5 = 8±0.5 µm. The stomatal pore length observed 8.19-9.5 = 8.56±0.65 µm and width is 2.31-2.7 = 2.48±0.14 µm. Subsidiary cells measured length and width is 24.32-10.15= 10.3±0.13 µm and 15.13-6.2 = 5.66±0.33 µm respectively.

y) *Pithecellobium dulce (Roxb.) Benth.*

Leaves are amphistomatic

Adaxial surface: Polygonal shaped epidermal cells with irregular anticlinal walls pattern. The average number of epidermal cells per unit are is 68. The length and width of epidermal cells: 23.6-41.32 = 32±2.89 µm and 11.62-12.5 = 18.5±2.3 µm respectively. Paracytic type of stomata were examined. Stomatal index is 16.13%. The observed length and width of stomata is 17.5-12.5 = 10.5±0.9 µm and 6.17-6.25 = 5.45±0.32 µm respectively. The noted guard cells length is 8.13-11.5 = 10.5±0.9 µm and width is 2.12-3.6 = 2.65±0.1 µm. The stomatal pore length observed 5.17-7.5 = 6±0.6 µm and width is 1.71-1.25 = 1.05±0.09 µm. Subsidiary cells measured length and width is 21.32-25.21 = 23.5±1 µm and 12.7-12.5 = 11.5±0.6 µm respectively.

Abaxial surface: Hexagonal epidermal cells with average number of cells per unit area is 95. Anticlinal wall pattern of epidermal cell is slightly undulate. The observed length of epidermal cells: 22.43-27.23= 24.8±0.86 µm and width is 13.21-15.19= 12.7±1.21 µm. Paracytic type of stomata are observed. The observed length and width of stomata is 9.42-11.15 = 14±1.5 µm and 8.32-7.12 = 6.25±0.5 µm respectively. The noted guard cells length is 7.4-13.5 = 14±1.5 µm and width is 2.5-3 = 2.7±0.1 µm. The stomatal pore length observed is 5.19-10 = 7±1.2 µm and width is 5.19-10 = 7±1.2 µm. Subsidiary cells measured length and width is 34.23-26.15 = 20±2.6 µm and 18.5-11.42 = 8.5±0.6 µm respectively. Stomatal index is 8.65 %.

z) *Pluchea lanceolata* (DC.) C.B. Clarke

Leaves are Amphistomatic

Adaxial surface: Hexagonal epidermal cells with undulate anticlinal walls pattern. The average number of epidermal cells per unit are is 91. The length and width of epidermal

cell are 26.14-28.6= 27.06±0.64 µm and 16.23-17.18= 15.86±0.28 µm respectively. Anisocytic type of stomata were examined. Stomatal index is 8.33 %. The observed length and width of stomata is 15.25-28.75=26.60±0.63 µm and 7.32-19.50=18.30±0.39 µm respectively. The noted guard cells length is 7.4-13.5 = 14±1.5 µm and width is 2.5-3 = 2.7±0.11 µm. The stomatal pore length observed: 5.19-6.12 = 5.9±0.13 µm and width is 2.3-2.8 = 2.5±0.1 µm. Subsidiary cells measured length and width is 21.5-8.16 = 8.08±0.23 µm and 16.18-4.6 = 4.3±0.1 µm respectively. Trichome Multicellular glandular type was observed and length examined is 41-18.75 = 86.70±21.24 µm and width is 21.50-53.75 = 38.15±4.45µm.

Abaxial surface: Wavy epidermal cells shape with average number of epidermal cells is 59. Anticlinal wall pattern of epidermal cell is Sinuous. The observed length of epidermal cells is 28.32-21.8= 15.66±0.18 µm and width is 10.53-12.42= 11.1±0.34µm. Anisocytic type of stomata were observed. The observed length and width of stomata is 12.18-8.8 = 8.28±0.17 µm and 6.14-6.8 = 6.54±0.07 µm respectively. The noted guard cells length is 8.13.5-13.3 = 12±0.12 µm and width is 3.18-12.1 = 11±0.11 µm. The stomatal pore length: 4.9-6.6 = 6.22±0.12 µm and width is 2.13-3.2 = 3.02±0.05 µm. Subsidiary cells measured length and width is 22.23-18.9 = 8.58±0.12 µm and 16.15-7.91 = 6.84±0.1µm respectively. Stomatal index is 21.22 %.

aa) *Polygonum plebeium R.Br.*

Leaves are Amphistomatic

Adaxial surface: Wavy epidermal cells with beaded anticlinal walls pattern. The average number of epidermal cells per unit are is 69. The length and width of epidermal cell is 22.16-11.21 = 9.94±0.1 µm and 17.13-5.32 = 4.8±0.13 µm respectively. Anomocytic type of stomata were examined. Stomatal index is 8.32%. The observed length and width of stomata is 17.20-34.75=31.25±1.33 µm and 8.75-14.75=13.05±0.52 µm respectively. The noted guard cells length is 11.7-15.3= 14.7±0.2 µm and width is 4.18-88 = 8.38±0.17 µm. The stomatal pore length observed: 6.18-5.4 = 5.08±0.09 µm and width is 2.12-3.12 = 3.04±0.06 µm. Subsidiary cells measured length and width is 19.6-11.51 = 9.86±0.08 µm and 13.6-3.46 = 3.18±0.08µm respectively.

Abaxial surface: Polygonal Epidermal cells shape with average number of cells per unit are is 6. Anticlinal wall pattern of epidermal cell is Sinuous. The observed length of epidermal cells is 26.7-12.21 = 11.4±0.38 µm and width is 15.43-6.8 = 5.6±0.21 µm. Anomocytic type of stomata were observed. The observed length and width of stomata is 17.00-32.75=31.25±1.33 µm and 9.75-14.75=13.05±0.52 µm respectively. The noted guard cells length is 6.17-6.4 = 6.08±0.11 µm and width is 3.19-3.4 = 3.16±0.09 µm. The stomatal pore length observed: 4.7-3.1 = 4.96±0.07 µm and width is 1.9-2.8 = 2.34±0.15 µm. Subsidiary cells measured length and width is 27-8.8 = 8.06±0.22 µm and 14.54-4.8 = 4.54±0.09 µm respectively. Stomatal index is 13.18 %.

bb)*Pulicaria dysenterica* Gaertn./boissieri

Leaves are hypostomatic

Adaxial surface: Hexagonal epidermal cells with undulate anticlinal walls pattern. The average number of epidermal cells per unit are is 121. The length and width of epidermal cells is 29.18-36.21 = 28.5±5.2 µm and 17.19-17.14 = 14.5±0.9 µm respectively. Conical Multicellular trichome types were observed while length examined is 19.28-9.75=8.35±0.46µm and width is 7.42-6.72=7.31±0.41 µm.

Abaxial surface: Wavy epidermal cells with average number of epidermal cells is 93. Anticlinal wall pattern of epidermal cell is slightly undulate. The observed length of epidermal cells is 17.6-37.3 = 25±2.1 µm and width is 12.23-20.35 = 16±1.5 µm Anomocytic type of stomata are observed. The observed length and width of stomata is 13.75-12.25=9.30±0.80 µm and 5.50-7.25=5.90±0.47 µm respectively. The noted guard cells length is 12.5-31.5 = 33±2.3 µm and width is 3.15-12.5 = 10±1.1 µm. The stomatal pore length observed: 7.14-20 = 17±0.9 µm and width is 2.17-2.5 = 1.5±0.2 µm. Subsidiary cell measured length and width is 52.5-72.5 = 61±4.2 µm and 17.5-25 = 20.5±1.2 µm respectively. Stomatal index is 13.25 %.

cc) *Schweinfurthia papilionacea* (L.) Boiss.

Leaves are amphistomatic

Adaxial surface: Polygonal shaped epidermal cells with undulate anticlinal walls pattern. The average number of epidermal cells per unit are is 66. The length and width of epidermal cell is 43.25-60.75=48.75±3.18 µm and 23.25-45.75=36.35±4.08 µm

respectively. Paracytic type of stomata are examined. Stomatal index is 7.07 %. The observed length and width of stomata is 13.25-39.75=36.35±1.32µm and 7.75-10.50=9.15±0.47 µm respectively. The noted guard cells length is 5.13-18.21 = 7.6±0.18 µm and width is 3.23-4 = 3.8±0.09 µm. The stomatal pore length observed is 6.75-8.25=7.60±0.26 µm and width is 3.11-5.50=4.70±0.28 µm. Subsidiary cells measured length and width is 36.75-10.50=8.00±0.65 µm and 24.50-5.75=5.15±0.23 µm respectively. Multicellular cylindrical trichome type were observed while length examined is 84-96 = 91.4±2.13 µm and width is 8.21-12.17 = 10.6±0.7 µm.

Abaxial surface: Hexagonal epidermal cells with average number of cells per unit area is 49. Anticlinal wall pattern of epidermal cell is Irregularly thickened. The observed length of epidermal cells is 26.25-39.75=30.20±2.53 µm and width is 14.23-28.25=18.95±2.55 µm. Paracytic type of stomata were observed. The observed length and width of stomata is 14.32-34.00=32.85±0.62 µm and 5.52-8.05=6.44±0.44 µm respectively. The noted guard cells length is 14.75-16.50=15.45±0.39 µm and width is 4.75-5.50=5.25±0.13 µm. The stomatal pore length observed is 6-7.5 = 6.92±0.25 µm and width is 2.2-2.5 = 2.34±0.06 µm. Subsidiary cells measured length and width is 37.25-11.00=8.85±0.68 µm and 14.50-5.50=5.05±0.18 µm respectively. Multicellular cylindrical trichome type were observed whereas length examined is 81.36-10.2 = 94.2±3.29 µm and width is 9.87-15.28 = 12.2±1.01 µm. Stomatal index is 15.51 %.

dd)*Solanum americanum* Mill.

Leaves are amphistomatic

Adaxial surface: Polygonal shaped epidermal cells with Irregular anticlinal walls pattern. The average number of epidermal cells per unit are is 91. The length and width of epidermal cells is 35.50-66.00=52.60±3.61 µm and 24.75-43.25=35.70±2.44 µm respectively. Diacytic type of stomata were examined. The observed length and width of stomata is 17.25-32.00=30.35±0.86 µm and 8.75-16.75=14.35±1.00µm respectively. Stomatal index is 9.09 %. The noted guard cells length is 14.75-16.50=15.45±0.39 µm and width is 4.75-5.50=5.25±0.13 µm. The stomatal pore length observed: 6.32-7.5 = 6.92±0.25 µm and width is 2.12-2.5 = 2.34±0.06 µm. Subsidiary cells measured length and width is 35.75-40.50=37.85±0.84 µm and 17.75-11.75=9.45±0.70 µm respectively. Multicellular trichome type were observed while length examined is 25-47.5 = 33.5±3.92 µm and width is 12.5-32.5 = 21.5±6.96 µm.

Abaxial surface: Polygonal epidermal cells with average number of epidermal cells per unit area is 76. Anticlinal wall pattern of epidermal cell is Sinuous. The observed length of epidermal cells is 38.5-74.2=56.80±23.65 µm and width is 32.75-56.00=48.85±2.92 µm. Diacytic type of stomata were observed. The observed length and width of stomata is 17.25-52.75=35.90±1.32 µm and 11.21-16.75=15.25±0.44 µm respectively. The noted guard cells length is 9.36-8.31 = 7.6±0.18 µm and width is 3.50-4 = 3.8±0.09 µm. The stomatal pore length observed is 9.25-32.25=30.90±0.52 µm and width is 3.25-16.75=13.60±0.81 µm. Subsidiary cells measured length and width is 31.75-39.75=35.50±1.53 µm and 7.25-10.75=8.60±0.61 µm respectively. multicellular trichome type were observed while length examined is 47.5-97.5 = 73.5±7.7 µm and width is 12-42.5 = 29±4.08 µm. Stomatal index is 7.37 %.

ee) *Tecomella undulata* (Sm.) Seem.

Leaves are Amphistomatic

Adaxial surface: Irregular epidermal cells with undulate anticlinal walls pattern. The average number of epidermal cells per unit area is 91. The length and width of epidermal cells is 34.38-81.00=57.40±7.14 µm and 23.25-56.25=37.85±6.24 µm respectively. Diacytic type of stomata were examined. The observed length and width of stomata is 17.50-29.00=27.40±0.82 µm and 9.75-14.25=13.00±0.40 µm respectively. Stomatal index is 9.02 %. The noted guard cells length is 8.75-12.25=10.15±0.86 µm and width is 4.25-7.25=6.30±0.39 µm. The stomatal pore length observed is 7.16-9.75=8.35±0.46 µm and width is 4.75-6.00=5.500±0.23µm. Subsidiary cells measured length and width is 26.75-31.75=29.60±0.85 µm and 15.25-7.26=6.30±0.39 µm respectively.

Abaxial surface: Hexagonal epidermal cells with average number of cells per unit area is 105. Anticlinal wall pattern of epidermal cell is buttressed. The observed length of epidermal cells is 44.50-71.00=57.00±5.00 µm and width is 19.50-57.00=35.50±6.34 µm. Diacytic type of stomata were observed. The observed length and width of stomata is 18.50-29.00=27.40±0.82 µm and 11.75-14.25=13.00±0.40 µm respectively. The noted guard cells length is 16.75-12.25=10.15±0.86 µm and width is 4.25-7.25=6.30±0.39 µm. The stomatal pore length observed: 7.16-9.75=8.35±0.46 µm and width is 4.75-6.00=5.500±0.23 µm. Subsidiary cells measured length and width is

26.75-31.75=29.60±0.85 µm and 15.25-7.26=6.30±0.39 µm respectively. Stomatal index is 8.97 %.

ff) *Thymelaea passerina* (L.) Coss. & Germ.

Leaves are Amphistomatic

Adaxial surface: Hexagonal epidermal cells with Sinuous anticlinal walls pattern. The average number of epidermal cells per unit area is 73. The length and width of epidermal cells is 34.75-53.50=44.40±3.82 µm and 24.25-38.50=29.45±2.80 µm respectively. Diacytic type of stomata were examined. The observed length and width of stomata is 10.3-12.8 = 11.86±0.46 µm and 6.19-9.8 = 8.22±0.56 µm respectively. The noted guard cells length is 8.25-10.75=8.75±0.65 µm and width is 4.50-7.25=5.90±0.56 µm. The stomatal pore length observed: 6.75-8.25=7.60±0.26 µm and width is 4.13-5.50=4.70±0.28 µm. Subsidiary cells measured length and width is 28.75-34.50=31.10±0.95 µm and 17.75-10.50=9.25±0.57 µm respectively. Papillate unicellular trichome type were observed and length examined is 14.5-97.5 = 73.5±7.7µm and width is 4.15-42.5 = 29±4.08 µm. Stomatal index is 11.9%.

Abaxial surface: Hexagonal epidermal cells with average number of epidermal cells is 63. Anticlinal wall pattern of epidermal cell is straight. The observed length of epidermal cells is 48. 43.25-73.75=56.50±5.29 µm and width is 28.25-54.25=37.70±4.99 µm. Diacytic type of stomata were observed. Stomatal index is 20.25 %. The observed length and width of stomata is 9.7-10.9 = 10.1±0.22 µm and 6.8-8.3 = 7.48±0.3 µm respectively. The noted guard cells length is 7.75-11.75=9.60±0.65 µm and width is 4.75-7.25=6.15±0.42 µm. The stomatal pore length observed: 3.75-31.00=29.45±0.94 µm and width is 2.17-14.24=12.80±0.45 µm. Subsidiary cells measured length and width is 23.50-34.00=28.40±1.99 µm and 14.50-27.25=25.60±0.48 µm respectively.

gg) *Trianthema portulacastrum* L.

Leaves are hypostomatic

Adaxial surface: Hexagonal epidermal cells with Buttressed anticlinal walls pattern. The average number of epidermal cells per unit area is 73. The length and width of epidermal cells is 29.26-46.00=35.35±3.36 µm and 14.50-29.25=21.50±2.80 µm

respectively. Multicellular glandular trichome types were observed with length examined is 87.5-175 = 127±17.16 µm and width is 10.28-25.7 = 16.5±3.02 µm.

Abaxial surface: Hexagonal epidermal cells with average number of epidermal cells is 79. Anticlinal wall pattern of epidermal cell is Buttressed. The observed length of epidermal cells is 28.25-41.00=34.65±2.16 µm and width is 20.50-27.00=24.40±1.09 µm. Anisocytic type of stomata were observed. The observed length and width of stomata is 16.25-26.00=24.35±0.46 µm and 9.25-12.75=10.70±0.74 µm respectively. The noted guard cells length is 13.75-14.00-11.25±0.80µm and width is 8.75-6.50=5.45±0.28 µm. The stomatal pore length observed 10.25-7.75=6.30±0.43 µm and width is 4.25-5.25=4.65±0.16 µm. Subsidiary cells measured length and width is 35-51 = 42.4±3.09 µm and 12.5-15 = 13.5±0.6 µm respectively. Stomatal index is 15.05 %.

hh) *Tribulus pentandrus* Forssk.

Leaves are Amphistomatic

Adaxial surface: Polygonal shaped epidermal cells with straight. Anticlinal walls pattern. The average number of epidermal cells per unit area is 59. The length and width of epidermal cell is 29.25-44.00=34.05±2.57 µm and 17.00-24.00=19.95±1.13 µm respectively. Anisocytic type of stomata were examined. Stomatal index is 13.23 %. The observed length and width of stomata is 10.25-14.75 = 12.5±0.7 µm and 7.15-12.5 = 9.6±1.19 µm respectively. The noted guard cells length is 9.75-10.75=8.50±0.85 µm and width is 4.75-7.00=5.60±0.37µm. The stomatal pore length observed is 8.26-25 = 22.9±1.16 µm and width is 3.5-15 = 11.7±1.34 µm. Subsidiary cells measured length and width is 42.5-65 = 51.5±3.92 µm and 6. 25-37.5 = 32.95+2.19 µm respectively. unicellular cylindrical trichome types were observed while length examined is 87-5-150 = 122.7±6.25 µm and width is 22.5-62.5=38.5±6.96 µm.

Abaxial surface: Hexagonal epidermal cells with average number of epidermal cells observed in ocular lenses is 81. Anticlinal wall pattern of epidermal cell is Undulate straight. The observed length of epidermal cells is 48. 44.21-59.75=52.60±2.86 µm and width is 24.25-44.75=34.65±3.57 µm. Anisocytic type of stomata are observed. The observed length and width of stomata is 16.76-30.42 = 28±0.62 µm and 9.5-12.5 = 10.85±0.55 µm respectively. The noted guard cells length is 9.75-5.50=7.20±0.46 µm and width is 4.50-5.50=5.10±0.20 µm. The stomatal pore length observed is 9.7-18.5 =

16.8±0.8 µm and width is 3.75-7.5 = 6.2±0.55 µm. Subsidiary cells measured length and width is 52.5-75 = 64±4.03 µm and 32.5-47.5 = 41.5±2.57 µm respectively. Conical unicellular trichome type were observed whereas length examined is 76.18-12.52 = 117.5±19.66 µm and width is 17.31-47.5 = 33.5±3.92 µm. Stomatal index is 41.93%.

ii) *Withania somnifera* (L.) Dunal

Leaves are hypostomatic

Adaxial surface: Irregular shaped epidermal cells with straight anticlinal walls pattern. The average number of epidermal cells per unit area is 91. The length and width of epidermal cell are 41.00-70.75=54.10±4.95 µm and 24.25-32.00=28.70±1.43 µm respectively. Radiate trichome type were observed with length examined is 32.46-83.21 = 76±11.4 µm and width is 14.21-35.52 = 32.6±2.5 µm.

Abaxial surface: Hexagonal epidermal cells shape with average number of epidermal cells is 56. Anticlinal wall pattern of epidermal cell is straight. The observed length of epidermal cells is 38.50-58.25=50.00±3.43 µm and width is 32.50-34.00=28.40±1.99 µm. Anisocytic type of stomata were observed. Stomatal index is 21.26 %. The observed length and width of stomata is 18.75-32.25=28.65±1.16 µm and 10.75-21.25=19.00±1.15 µm respectively. The noted guard cells length is 16.25-20.50=17.95±0.81 µm and width is 4.19-8.14=6.10±0.67 µm. The stomatal pore length observed: 15.25-28.75=26.60±0.63 µm and width is 7.27-19.50=18.30±0.39 µm. Subsidiary cells measured length and width is 28.3-8.5 = 8.44±0.08 µm and 13.31-3.5 = 3.22±0.19 µm respectively.

jj) *Zygophyllum indicum* (Burm.f.) Christenh. & Byng

Leaves are Amphistomatic

Adaxial surface: Irregular shaped epidermal cells with Straight Sinuous anticlinal walls pattern. The average number of epidermal cells per unit area is 91. The length and width of epidermal cell are 29.23-46.00=35.35±3.36 µm and 14.50-29.25= 21.05±2.80 µm respectively. Anomocytic type of stomata were examined. The observed length and width of stomata is 12.23-12.5 = 12.42±0.03 µm and 8.13-8.51 = 8.42±0.03 µm respectively. The noted guard cells length is 11.26-18.9 = 18.5±0.06 µm and width is 3.67-10 = 9.86±0.06 µm. The stomatal pore length observed is 9.23-10.5 = 10.24±0.1

µm and width is 2.23-2.45 = 2.44±0.04 µm. Subsidiary cell measured length and width is 29-9.5 = 9.32±0.09 µm and 14.31-4.65 = 4.38±0.04 µm respectively. Stomatal index is 8.51 %.

Abaxial surface: Irregular shaped epidermal cells were examined with average number of epidermal cells per unit area is 105. Anticlinal wall pattern of epidermal cell is Straight Sinuous. The observed length of epidermal cells is 28.25-41.00=34.65±2.16 µm and width is 20.50-27.00=24.40±1.09 µm. Anomocytic type of stomata were observed. Stomatal index is 31.57%. The observed length and width of stomata is 14.9-15.5 = 15.22±0.11 µm and 7.25-8.9 = 8.74±0.06 µm respectively. The noted guard cells length is 13.65-20.8 = 20±0.26 µm and width is 5.17-16 = 15.6±0.18 µm. The stomatal pore length observed: 11.46-10.5 = 10.32±0.09 µm and width is 2.23-2.5 = 2.44±0.04 µm. Subsidiary cells measured length and width is 27.4-11.7 = 11.5±0.05 µm and 15.74-5.6 = 5.5±0.03 µm respectively.

Table 6. Qualitative foliar anatomical features of selected plant species of Takkar Wildlife Sanctuary.

No.	Taxo	Ab/Ad	Epidermal Cell Shape	Lobes per Cell	Anticlinal walls	Type of Stomata	Trichome type
1	*Abutilon indicum* (L.) Sweet	Ad	Polygonal	3-5	Rounded	Diacytic	Stellate
		Ab	Wavy	3-7	Rounded	Diacytic	-
2	*Anagallis arvensis* L.	Ad	Polygonal	4-8	Sinous	Anomocytic	-
		Ab	Wavy	5-9	Sinous	Anomocytic	-
3	*Anticharis glandulosa* Asch.	Ad	Wavy	4-9	Sinous	Anomocytic	Multicellular with glandular tip
		Ab	Wavy	4-10	Sinous	Anomocytic	-
4	*Arnebia hispidissima* DC.	Ad	Wavy	5-11	Straight	Diacytic	Unicellular
		Ab	Polygonal	4-8	Straight	Diacytic	-
5	*Calotropis procera* (Aiton) Dryand.	Ad	pentagonal	3-4	Straight	Paracytic	-
		Ab	pentagonal	3-4	Straight	Paracytic	-
6	*Citrullus colocynthis (L.) Schrad*	Ad	Hexagonal	3-4	smooth	A	Multicellular
		Ab	Polygonal	3-4	Smooth & rounded	Anomocytic	Multicellular
7	*Cleome brachycarpa* (Forssk.) Vahl ex DC.	Ad	Hexagonal	3-6	Sinous	Anomocytic	_
		Ab	Polygonal	3-7	Irregularly thickened	Diacytic	_
8	*Cleome scaposa* DC.	Ad	Polygonal	4-7	Sinous	Anomocytic	Shaggy
		Ab	Hexagonal	3-6	Sinous	Anomocytic	Shaggy

9	*Convolvulus arvensis* L.	Ad	Irregular	3-6	Straight	A	Moniliform
		Ab	Elongated to hexagonal	3-7	Sinous	Paracytic	-
10	*Corchorus depressus* (L.) Stocks	Ad	Hexagonal	2-4	Undulate	Diacytic	multicellular glandular
		Ab	Polygonal	2-4	Straight	Diacytic	-
11	*Corchorus tridens* L.	Ad	Hexagonal	2-4	Rounded	A	_
		Ab	Polygonal	2-5	Sinous	Paracytic	-
12	*Cucumis melo ssp agrestis*	Ad	Hexagonal	2-4	Straight & Undulate	Anomocytic	Unicellular
		Ab	Hexagonal	2-5	Straight & Undulate	Anomocytic	Unicellular
13	*Cynoglossum lanceolatum* Forssk.	Ad	Polygonal	3-6	Irregularly thickened	A	-
		Ab	Regular	3-7	Undulate	Anomocytic	Multicellular
14	*Evolvulus alsinoides* (L.) L.	Ad	Irregular	2-6	Sinous	A	Multicellular
		Ab	Wavy	3-8	Beaded	Anomocytic	-
15	*Farsetia stylosa* R.Br.	Ad	Irregular	3-6	Irregularly thickened	Anomocytic	Unicellular
		Ab	Wavy	3-6	Sinous irregular	Anomocytic	Unicellular
16	*Gisekia pharnaceoides* L.	Ad	Hexagonal	3-7	Straight Undulate	Paracytic	Shaggy
		Ab	Hexagonal	3-6	Rounded	Paracytic	Shaggy
17	*Heliotropium bacciferum* Forssk.	Ad	Polygonal	3-6	Beaded	Anisocytic	Unicellular
		Ab	Polygonal	3-7	Angular Undulate	Anisocytic	_

18	*Iphiona aucheri* (Boiss.) Anderb.	Ad	Wavy	4-6	Irregular Undulate	A	Multicellular
		Ab	Wavy	4-5	Irregular Undulate	Anisocytic	Multicellular
19	*Ipomoea aquatic* Forssk.	Ad	Hexagonal	3-7	Straight & Undulate	A	_
		Ab	Hexagonal	3-8	Straight & Undulate	Anisocytic	_
20	*Lantana camara* L.	Ad	Irregular	3-6	Sinous	Anomocytic	Conical
		Ab	Wavy	3-7	Sinous	Anomocytic	Conical
21	*Merremia hederacea* (Burm. f.) Hallier f.	Ad	Hexagonal	2-4	Straight	A	Unicellular
		Ab	Hexagonal	3-6	Straight	Diacytic	_
22	*Mollugo cerviana* (L.) Ser.	Ad	cylindrical	3-5	Straight	Gramineous	_
		Ab	cylindrical	3-9	Straight	Gramineous	_
23	*Moringa oleifera* Lam.	Ad	Polygonal	3-6	Beaded	Anomocytic	Cylindrical
		Ab	Wavy	3-7	Undulate	Anisocytic	Cylindrical
24	*Oxystelma esculentum* (L. f.) Sm.	Ad	Hexagonal	3-6	Undulate	A	Cylindrical Unicellular
		Ab	Polygonal	4-7	Undulate	Anisocytic	-
25	*Pithecellobium dulce* (Roxb.) Benth.	Ad	Polygonal	3-8	irregular	Paracytic	-
		Ab	Hexagonal	3-9	Straight Undulate	Paracytic	-
26	*Pluchea lanceolata* (DC.) C.B.Clarke	Ad	Hexagonal	3-6	Undulate	Anisocytic	Multicellular
		Ab	wavy	3-7	Sinous	Anisocytic	_
27	*Polygonum plebeium R.Br.*	Ad	Wavy	3-7	Beaded	Anomocytic	_
		Ab	Polygonal	2-6	Sinous	Anomocytic	_

28	*Pulicaria dysenterica* Gaertn./boissieri	Ad	Hexagonal	2-4	Undulate	_	Conical Multicellular
		Ab	wavy	2-5	Undulate	Anomocytic	-
29	*Schweinfurthia papilionacea* (L.) Boiss.	Ad	Polygonal	3-6	Undulate	Paracytic	Multicellular cylindrical
		Ab	Hexagonal	3-5	Irregularly thickened	Paracytic	Multicellular cylindrical
30	*Solanum americanum* Mill.	Ad	Polygonal	3-8	Irregular	Diacytic	Multicellular
		Ab	Polygonal	3-7	Sinous	Diacytic	Multicellular
31	*Tecomella undulata* (Sm.) Seem.	Ad	Irregular	3-8	Undulate	Diacytic	_
		Ab	Hexagonal	3-7	Buttressed	Diacytic	_
32	*Thymelaea passerina* (L.) Coss. & Germ.	Ad	Hexagonal	3-5	Sinous	Diacytic	Papillate unicellular
		Ab	Hexagonal	3-6	straight	Diacytic	_
33	*Trianthema portulacastrum* L.	Ad	Hexagonal	3-5	Buttressed	-	Multicellular glandular
		Ab	Hexagonal	2-4	Buttressed	Anisocytic	-
34	*Tribulus pentandrus* Forssk.	Ad	Polygonal	2-4	straight	Anisocytic	Conical unicellular
		Ab	Hexagonal	3-6	Undulate straight	Anisocytic	Conical unicellular
35	*Withania somnifera* (L.) Dunal	Ad	Irregular	2-4	straight	Anisocytic	Radiate
		Ab	Hexagonal	3-6	straight	Anisocytic	_
36	*Zygophyllum indicum (Burm.f.) Christenh. & Byng*	Ad	Irregular	3-6	Straight Sinous	Anomocytic	-
		Ab	Polygonal	3-7	Straight Sinous	Anomocytic	-

Table 7. Quantitative Analysis of Adaxial and Abaxial surfaces of epidermal cells, stomata and trichomes of various taxa of Takkar Wildlife Sanctuary

Taxa	Ad × Ab	L × W	Average No. of Epidermal cell	Epidermal cell (Min-Max = Mean + SE)	No. of Stomata (Avg)	Stomata (Min-Max = Mean + SE)	SI (%)	Trichome Number Per unit area	Trichome (Min-Max = Mean + SE)	TI (%)
Abutilon indicum (L.) Sweet	Ad	L	92	25.6-8.25 = 45.5±09.63	13	23.72-29.2 = 25.3±0.71	8.09	3	22-37.5 = 34.5±3.82	2.65
		W		11.3-28 = 21±1.2		14-23.73 = 18.2±1.21			11.5-22.5 = 21.5±6.96	
	Ab	L	73	13.5-24.5 = 17.5±5	6	24.7-26 = 21.6±0.64	9.37	5	A	
		W		11-19 = 14.6±2.6		16.3-21 = 13.75±0.36				
Anagallis arvensis L.	Ad	L	97	32.5-27.5 = 21±3.6	13	13.5-19.8 = 17.5±0.4	12.07	6		A
		W		11.3-21 = 15±1.26		7.17-3 = 8.75±0.2				
	Ab	L	72	26-52.3 = 29.4±6.45	7	13.5-18.5 = 13.5±0.11	8.97	A	A	A
		W		11.4-24.17 = 22±3.05		4.17-11 = 8.5±0.89				
Anticharis glandulosa Asch.	Ad	L	42	14.8-20.3 = 17.8±1.04	5	10.3-12.8 = 11.86±0.46	12.9	A	32.4-42.5 = 44.7±6.66	3.42
		W		8.7-13.3 = 10.56±0.84		6.9-9.8 = 8.22±0.56			17.5-15 = 13.5±0.6	
	Ab	L	66	20.5-15.6 = 13.5±1.09	16	9.17-10.9 = 10.1±0.22	18.25	A	A	A
		W		6.59-8.9 = 7.34±0.4		6.8-8.3 = 7.48±0.3				
Arnebia hispidissima DC.	Ad	L	27	29.5-41.5 = 39.8±2.6	11	24.5-35.5 = 27.5±0.18	23.27	3	89.5-165 = 127±13.19	8.57
		W		16.4-12.5 = 13±1.3		16-13.5 = 18.5±0.12			11-24 = 19.5±3.07	
	Ab	L	73	23.7-32.5 = 23.5±1.44	14	23.5-24 = 31.5±0.9	13.05	2		A
		W		10.5-33 = 19±2.29		18.5-21 = 16±0.4				
Calotropis procera (Aiton) Dryand.	Ad	L	96	26.2-11 = 23.1±0.29	9	12.27-13.68 = 18.5±0.9	13.23	8	87-5-150 =122.7±6.25	11.94
		W		15.5-29.5 = 17.9±5.56		8.5-13.5 = 10.6±1.29			22.5-62.5=38.5±6.96	
	Ab	L	72	22.2-16.7 = 12.5±1.17	13	13.73-30.4 = 28±0.66	41.93	11	80-152 = 117.5±19.66	37.93
		W		9.5-6.23 = 5.6±2.49		6.15-13.5 = 10.86±0.56			25-47.5 = 33.5±3.92	

Citrullus colocynthis (L.) Schrad	Ad	L	37	21.5-26.5 = 20.8±1.5	A	A	A	7	60-90 = 76±11.4	15.9
		W		12.5-13.5 = 13.8±0.41					30-35 = 32.6±2.5	
	Ab	L	39	27.5-24.5 = 26.8±0.73	9	13-11.8 = 17.46±0.39	36	3	A	A
		W		12.3-16 = 14.58±0.26		8.4-6.5 = 6.64±0.08				
Cleome brachycarpa (Forssk.) Vahl ex DC.	Ad	L	86	26.5-28.2 = 23.36±0.19	8	13.6-11.5 = 15.42±0.06	8.51	A	A	A
		W		13.6-11.9 = 10.36±0.18		9.13-8.35 = 8.42±0.03				
	Ab	L	26	18.9-19.16 = 18.8±0.19	12	14.9-15.5 = 15.22±0.11	31.57	A	A	A
		W		10.5-9.18 = 9.48±0.03		9.5-8.9 = 8.74±0.19				
Cleome scaposa DC.	Ad	L	46	26-25 = 21.5±1.23	14	16.8-20 = 16.5±1.57	28	3	32-47.8=62.7±6.19	2.59
		W		18.5-45 = 22.5±1.6		12.6-13.5 = 11±0.61			11.27-31=59.3±5.15	
	Ab	L	81	15.5-25 = 19±2.32	7	18-17.5 = 17±0.12	7.29	4	35-87.5 = 59.5±7.3	4.3
		W		11.7-17.5 = 13.5±1.8		12.5-15 = 12±0.93			12.5-15 = 13.5±0.6	
Convolvulus arvensis L.	Ad	L	95	22.4-13.7 = 12.2±0.78	A	A	A	6	50-60 = 54±4.18	5.94
		W		7.3-7.9 = 6.44±0.28					10-19 = 16±3.67	
	Ab	L	87	19.3-18.5 = 19.9±0.75	4	16.5-14.5 = 12.1±0.51	11.42	A	A	A
		W		12.5-10.5 = 8.28±1.83		6.12-11.5 = 6.8±0.67				
Corchorus depressus (L.) Stocks	Ad	L	67	24.23-40.8 = 32±2.79	13	7.45-12.5 = 10.5±0.9	16.66	4	50-90=68.5±1.68	5.2
		W		13.5-2.5 = 18.5±2.32		4.17-6.24 = 5.45±0.32			7.5-20=14±3.3	
	Ab	L	95	23.7-27.6 = 23.8±0.85	9	10.18-17.5 = 14±1.7	8.65	A		A
		W		10.18-15.5 = 11.7±1.41		5.19-7.15 = 6.25±0.18				
Corchorus tridens L.	Ad	L	56	26.7-21.6 = 27.06±0.54	5	A	A	A	A	A
		W		15.7-16.6 = 14.86±0.18		A				
	Ab	L	29	36.8-16.3 = 15.66±0.17	8	14.8-8.8 = 8.18±0.17	12.22	A	A	A
		W		11.19-12.8 = 11.1±0.24		5.14-6.8 = 6.54±0.12				
Cucumis melo ssp agrestis	Ad	L	69	34.6-10.2 = 11.94±0.7	6	13.18-12.9 = 11.1±0.37	8.74	3	80-94 = 86±2.75	4.16

		W		17.15-5.23 = 8.8±0.23		5.36-6.9 = 5.42±0.25			4-8 = 6.1±0.71	
	Ab	L	48	19.9-12 = 12.4±0.38	12	13.7-12.8 = 11.76±0.33	13.33	9	62-74 = 66.8±2.26	27.27
		W		5.17-7.8 = 5.6±0.24		8.19-8.45 = 8.2±0.18			4.5-6 = 5.16±0.26	
Cynoglossum lanceolatum Forssk.	Ad	L	95	34.17-34.5 = 28.5±5.2	A	A	A	A	A	A
		W		11.5-17.5 = 15.5±0.8						
	Ab	L	63	24-37.5 = 25±2.1	16	12.7-37.5 = 33±2.29	20.25	4	55.75-158.50 = 108.30±16.68	23.14
		W		11.25-20 = 16.7±1.5		6.16-21.5 = 20±1.11			23.50-58.25 = 37.85±6.26	

Keywords: Ad=Adaxial, Ab=Abaxial, L=Length, W=Width, M=Mean, SE=Standard Error, Max=Maximum, Min=Minimum, SI=Stomatal Index, TI=Trichome Index; Avg=Average; A=Absent

Table 8. Quantitative Analysis of Adaxial and Abaxial surfaces of epidermal cells, stomata and trichomes of plant species of Takkar Wildlife Sanctuary.

Taxa	Ad × Ab	L × W	Average No. of Epidermal cell	Epidermal cell (Min-Max = Mean + SE)	No. of Stomata (Avg)	Stomata (Min-Max = Mean + SE)	SI (%)	Trichome Number Per unit area	Trichome (Min-Max = Mean + SE)	TI (%)
Evolvulus alsinoides (L.) L.	Ad	L	66	23.17-13.5 = 13.2±0.12	A	A	A	2	83-96 = 91.4±2.13	2.94
		W		17.32-8.17 = 5.34±0.12					8.5-12 = 10.6±0.7	
	Ab	L	49	27.17-5.2 = 15.02±0.08	9	11.23-12.17 = 11.42±0.3	15.51	4	84-102 = 94.2±3.29	7.54
		W		15.19-3.19 = 3.06±0.06		5.43.-5.19 = 5±0.05			9-15 = 12.2±1.01	
Farsetia stylosa R.Br.	Ad	L	110	26.5-18.55= 55.5±10.73	11	14.71-28.17 = 26.2±0.81	9.09	3	25-47.5 = 33.5±3.92	2.65
		W		17.5-31.7 = 22±2.1		7.13-21.75 = 19.2±1.31			12.5-32.5 = 21.5±6.96	
	Ab	L	76	29.5-25.5 = 18.4±7	6	14.17-26.21 = 25.7±0.74	7.37	5	47.5-97.5 = 73.5±7.7	6.17
		W		13.17-21.6 = 15.5±1.6		7.5-19.6 = 18.85±0.46			12-42.5 = 29±4	
Gisekia pharnaceoides L.	Ad	L	113	23.6-37.5 = 28±2.6	13	13.5-16.19 = 15.5±0.8	9.02	6	22.5-52.5 = 34.7±6.76	4.37
		W		15.9-19.17 = 16±1.27		7.24-8.12 = 7.65±0.1			12.5-15 = 13.5±0.6	
	Ab	L	71	26.29-52.5 = 38.5±6.35	7	13.18-17.19 = 14.5±0.9	8.97	5	26.7-5.19=29±7.21	3.42
		W		12.5-27.5 = 21±3.02		6.13-10.45 = 7.5±0.79			12.8-36.12±7.39	
Heliotropium bacciferum Forssk.	Ad	L	73	28.26-20.3 = 17.8±1.04	5	14.3-12.8 = 11.86±0.46	11.9	3	32.8-36.12±7.39	3.52
		W		12.7-13.3 = 10.56±0.84		6.39-9.18 = 8.22±0.56			7.49-21.12±18.21	
	Ab	L	63	23.8-15.6 = 13.5±1.09	16	13.7-16.9 = 10.1±0.22	20.25	A	A	A
		W		16.19-8.19 = 7.34±0.4		6.8-8.13 = 7.48±0.3				
Iphiona aucheri (Boiss.) Anderb.	Ad	L	58	23.16-32.9 = 27.5±1.9		A		A	A	A
		W		16.12-22.6 = 21.5±1.6		A			A	
	Ab	L	94	27.5-26.7 = 19±2.7		17.35-17.19 = 17±0.5	8.43		31.26-27.38±16.68	
		W		10.7-17.5 = 12.5±1.3		9.41-15.17 = 12±0.93			6.39.14.38±21.34	

Ipomoea aquatic Forssk.	Ad	L	57	41.8-57.5 = 50.8±1.1		A			A	8.57
		W		41.8-57.5 = 50.8±1.1		A			A	
	Ab	L	79	29-28.5 = 21.5±1.64	14	13.42-31.16 = 28.5±0.6	15.05	2	35-100 = 70.5±14.1	2.46
		W		12.18-25.32 = 17±2.29		9.12-19.13 = 19±0.6			7.5-12.5=10.5±0.9	
Lantana camara L.	Ad	L	99	18.2-14.8 = 13.1±0.25	9	13.15-14.25 = 12.5±0.7	13.23	8	87-5-150 = 122.7±6.25	11.94
		W		16.65-27.5 = 21.9±5.66		7.18-11.5 = 9.6±1.19			22.5-62.5=38.5±6.96	
	Ab	L	81	27.2-14.7 = 12.5±1.13	13	16.36-30.9 = 28±0.62	41.93	11	80-152 = 117.5±19.66	37.93
		W		17.12-6.25 = 5.6±2.69		9.5-12.18 = 10.85±0.55			15-47.5 = 33.5±3.92	
Merremia hederacea (Burm. f.) Hallier f.	Ad	L	63	22.12-23.17 = 21.8±1.2	A	A	A	7	60-90 = 76±11.4	15.9
		W		13.5-11.5 = 10.8±0.41					13.6-35 = 32.6±2.5	
	Ab	L	105	27.9-28.5 = 27.8±0.83	9	14.25-12.8 = 10.46±0.29	16.8	3	75-100 = 90±10.6	15.78
		W		9.13-11.8 = 10.58±0.25		7.4-6.5 = 6.44±0.05			30-38 = 34.8±3.42	
Mollugo cerviana (L.) Ser.	Ad	L	86	23.21.8-26= 25.36±0.18	8	16.7-19.2 = 12.42±0.03	8.51	A	A	A
		W		11.7-11.6 = 10.36±0.18		8.3-8.27 = 8.42±0.03				
	Ab	L	66	18.9-19.23 = 18.8±0.12	12	13.9-16.15 = 15.22±0.11	31.57	A	A	A
		W		9.5-9.7 = 9.58±0.03		8.14-9.11 = 8.74±0.06				
Moringa oleifera Lam.	Ad	L	36	24.13-32.9 = 27.5±1.9	14	16.25-21.6 = 16.5±1	28	A	A	A
		W		17.12-22.6 = 21.5±1.3		11.6-12.63 = 11±0.61				
	Ab	L	89	16.5-26.7 = 19±2.17	7	16.35-17.19 = 17±0.5	7.29	4	35-87.5 = 59.5±7.3	4.3
		W		10.7-17.5 = 13.5±1.3		9.48-15.17 = 12±0.93			12.5-15 = 13.5±0.6	
Oxystelma esculentum (L. f.) Sm.	Ad	L	95	23.32-13.36= 12.2±0.75	A	A	A	6	41.8-60.32 = 54±4.18	5.94
		W		16.13-7.18 = 6.54±0.28					9.45-19.31 = 16±3.67	
	Ab	L	31	27.43-18.12= 17.9±0.65	4	11.5-12.5 = 12.1±0.41	11.42	A	A	A
		W		15.4-11.17 = 8.28±1.92		6.18-7.5 = 6.8±0.67				

Pithecellobium dulce (Roxb.) Benth.	Ad	L	68	23.6-41.32 = 32±2.89	13	17.5-12.5 = 10.5±0.9	16.13	A	A	A
		W		11.62-12.5 = 18.5±2.3		6.17-6.25 = 5.45±0.32				
	Ab	L	95	22.43-27.23= 24.8±0.86	9	9.42-11.15 = 14±1.5	8.65	A	A	A
		W		13.21-15.19= 12.7±1.21		8.32-7.12 = 6.25±0.5				
Pluchea lanceolata (DC.) C.B.Clarke	Ad	L	55	26.14-28.6= 27.06±0.64	5	15.25-28.75=26.60±0.63	8.33	A	41-18.75 = 86.7±21.24	A
		W		16.23-17.1= 15.86±0.28		7.32-19.50=18.30±0.39			21.5-53.7 = 38.15±4.4	
	Ab	L	59	28.32-21.8= 15.66±0.18	8	12.18-8.8 = 8.28±0.17	21.22	A	A	A
		W		10.53-12.42= 11.1±0.34		6.14-6.8 = 6.54±0.07				
Polygonum plebeium R.Br.	Ad	L	69	22.16-11.21 = 9.94±0.1	6	17.20-34.75=17.25±1.33	8.32	A		A
		w		17.13-5.32 = 4.8±0.13		8.75-14.75=9.05±0.52				
	Ab	L	64	26.7-12.21 = 11.4±0.38	12	17.00-32.75=31.25±1.33	13.18	A		
		W		15.43-6.8 = 5.6±0.21		9.75-14.75=13.05±0.52				
Pulicaria dysenterica Gaertn./boissieri	Ad	L	121	29.18-36.21 = 28.5±5.2	A		A	A	19.28-9.75=8.35±0.46	A
		W		17.19-17.14 = 14.5±0.9					7.42-6.72=7.31±0.41	
	Ab	L	93	17.6-37.3 = 25±2.1	16	13.75-12.25=9.30±0.80	13.25	A		A
		W		12.23-20.35 = 16±1.5		5.50-7.25=5.90±0.47				

Keywords: Ad=Adaxial, Ab=Abaxial, L=Length, W=Width, M=Mean, SE=Standard Error, Max=Maximum, Min=Minimum, SI=Stomatal Index, TI=Trichome Index; Avg=Average; A=Absent

Table 9. Quantitative Analysis of Adaxial and Abaxial surfaces of epidermal cells, stomata and trichomes of plant species of Takkar Wildlife Sanctuary.

Taxa	Ad × Ab	L × W	Average No. of Epidermal cell	Epidermal cell (Min-Max = Mean + SE)	No. of Stomata (Avg)	Stomata (Min-Max = Mean + SE)	SI (%)	Trichome Number Per unit area	Trichome (Min-Max = Mean + SE)	TI (%)
Schweinfurthia papilionacea (L.) Boiss.	Ad	L	66	43.25-60.75=48.75±3.18	A	33.25 39.75=16.35±1.32	7.29	2	84-96 = 91.4±2.13	2.94
		W		23.25-45.75=36.35±4.08		7.75-10.50=9.15±0.47			8-12 = 10.6±0.7	
	Ab	L	49	26.25-39.75=30.20±2.53	9	30.50-34.00=32.85±0.62	15.51	4	84-102 = 94.2±3.29	7.54
		W		14.00-28.25=18.95±2.55		5.52-8.05=6.44±0.44			9-15 = 12.2±1.01	
Solanum americanum Mill.	Ad	L	110	45.50-66.00=52.60±3.61	11	27.25-32.00=13.35±0.86	9.09	3	25-47.5 = 33.5±3.92	2.65
		W		29.75-43.25=35.70±2.44		10.75-16.75=9.35±1.00			12.5-32.5 = 21.5±6.96	
	Ab	L	76	38.5-74.2=56.80±23.65	6	29.25-52.75=35.90±4.32	7.37	5	47.5-97.5 = 73.5±7.7	6.17
		W		40.75-56.00=48.85±2.92		14.25-16.75=15.25±0.44			12-42.5 = 29±4	
Tecomella undulata (Sm.) Seem.	Ad	L	131	39.00-81.00=57.40±7.14	13	24.50-29.00=27.40±0.82	9.02	6	22.5-52.5 = 34.7±6.76	4.37
		W		23.25-56.25=37.85±6.24		11.75-14.25=13.00±0.40			12.5-15 = 13.5±0.6	
	Ab	L	71	44.50-71.00=57.00±5.00	7	24.50-29.00=27.40±0.82	8.97	A	A	A
		W		19.50-57.00=35.50±6.34		11.75-14.25=13.00±0.40				
Thymelaea passerina (L.) Coss. & Germ.	Ad	L	37	34.75-53.50=44.40±3.82	5	10.3-12.8 = 11.86±0.46	11.9	A	A	A
		W		24.25-38.50=29.45±2.80		6.9-9.8 = 8.22±0.56				
	Ab	L	63	43.25-73.75=56.50±5.29	16	9.7-10.9 = 10.1±0.22	20.25	A	A	A
		W		28.25-54.25=37.70±4.99		6.8-8.3 = 7.48±0.3				
Trianthema portulacastrum L.	Ad	L	32	29.00-46.00=35.35±3.36	12	26.75-32.25=29.85±0.91	27.27	3	87.5-175 = 127±17.16	8.57

		W		14.50-29.25=21.50±2.80		14.75-19.75=17.40±0.99			10-25 = 16.5±3.02	
	Ab	L	79	28.25-41.00=34.65±2.16	14	23.25-26.00=24.35±0.46	15.05	2	35-100 = 70.5±14.1	2.46
		W		20.50-27.00=24.40±1.09		9.25-12.75=10.70±0.74			7.5-12.5=10.5±0.9	
Tribulus pentandrus Forssk.	Ad	L	59	29.25-44.00=34.05±2.57	9	10.25-14.75 = 12.5±0.7	13.23	8	87-5-150 = 122.7±6.25	11.94
		W		17.00-24.00=19.95±1.13		7.5-12.5 = 9.6±1.19			22.5-62.5=38.5±6.96	
	Ab	L	18	44.00-59.75=52.60±2.86	13	26.76-30 = 28±0.62	41.93	11	80-152 = 117.5±19.66	37.93
		W		24.25-44.75=34.65±3.57		9.5-12.5 = 10.85±0.55			25-47.5 = 33.5±3.92	
Withania somnifera (L.) Dunal	Ad	L	37	41.00-70.75=54.10±4.95	A	A	A	7	60-90 = 76±11.4	15.9
		W		24.25-32.00=28.70±1.43					30-35 = 32.6±2.5	
	Ab	L	16	38.50-58.25=50.00±3.43	9	25.75-32.25=28.65±1.16	36	3	75-100 = 90±10.6	15.78
		W		32.50-34.00=28.40±1.99		14.75-21.25=19.00±1.15			30-38 = 34.8±3.42	
Zygophyllum indicum (Burm.f.) Christenh. & Byng	Ad	L	86	29.-46.00=35.35±3.36	8	12.3-12.5 = 12.42±0.03	8.51	A	A	A
		W		14.50-29.25=21.05±2.80		8.3-8.5 = 8.42±0.03				
	Ab	L	26	28.2-41.00=34.65±2.16	12	14.9-15.5 = 15.22±0.11	31.57	A	A	A
		W		20.50-27.00=24.40±1.09		8.5-8.9 = 8.74±0.06				
				29-46.00=35.35±3.36						
		W		14.50-29.25=21.05±2.80		10-12.5 = 11±0.61				
	Ab	L	89	28.25-41=34.65±2.16	7	15-17.5 = 17±0.5	7.29	4	35-87.5 = 59.5±7.3	4.3
		W		20.50-27.00=24.40±1.09		10-15 = 12±0.93			12.5-15 = 13.5±0.6	

Keywords: Ad=Adaxial, Ab=Abaxial, L=Length, W=Width, M=Mean, SE=Standard Error, Max=Maximum, Min=Minimum, SI=Stomatal Index, TI=Trichome Index; Avg=Average; A=Absent

Table 10. Quantitative Analysis of stomatal pore, guard cell and Subsidiary cell of various taxa of Takkar Wildlife Sanctuary

Taxa	Ad × Ab	L×W	Stomatal pore (Min-Max = Mean + SE)	Guard cell (Min-Max = Mean + SE)	Subsidiary cell (Min-Max = Mean + SE)
Abutilon indicum (L.) Sweet	Ad	L	9.36-15 = 13.2±0.91	7.24-7.7 = 7.5±0.83	43.7-61.8 = 57.5±25
		W	3.35-6.5 = 5.5±0.36	4.37-4.6 = 4.4±0.04	17.3-37.5 = 27.5±3.25
	Ab	L	7-14.25 = 12.2±0.67	7.12-8.00= 7.6±0.18	34.12-62.5= 54.5±2.54
		W	3.15-7.5 = 6.5±0.43	6.30-4 = 3.8±0.09	17.7-27.3 = 22.5±1.76
Anagallis arvensis L.	Ad	L	9.17-15.8 = 12.5±0.8	8.6-17.5= 3.2±0.79	16.3-22.5 = 19±1.5
		W	2.23-2.5 = 1.85±0.2	6.5-3.8 = 2.85±0.1	5.27-7.5 = 6.6±0.6
	Ab	L	8.6-12.5 = 11.5±0.6	6.35-17.5= 14.5±0.9	18.52-24.6 = 18±1.8
		W	1.51-1.5 = 1.25±0.1	2.17-3.25= 2.8±0.15	7.4-7.5 = 6.5±0.6
Anticharis glandulosa Asch.	Ad	L	6.9-8.9 = 9.22±0.35	8.16-18 = 16.8±0.76	14.9-11.7= 10.98±0.31
		W	2.12-3.3 = 2.42±0.13	6.17-10.7= 8.8±0.64	6.6-7.9 = 3.34±0.25
	Ab	L	4.7-7.9 = 6.16±0.61	13.6-18.7 = 16±0.88	7.8-9.2 = 8.34±0.25
		w	1.71-1.45 = 2.15±0.4	3.2-3.65= 2.1 ±0.25	4.14-7.31 = 4.51±0.7
Arnebia hispidissima DC.	Ad	L	7.3-25 = 22±0.9	6.35-2.45= 29.5±0.9	33.5-47.5 = 62±9.02
		W	1.14-1.25 = 1.2±0.06	3.9-10.6 = 8±0.5	11.5-17.8 = 14.5±0.9
	Ab	L	9.6-17.5 = 16.5±0.6	16.5-23.7= 28.5±0.6	33.7-51.6 = 42.4±3.09
		W	2.25-1.75 = 1.4±0.09	9.18-12.5= 11.5±0.6	17.5-15.3 = 13.5±0.6
Calotropis procera (Aiton) Dryand.	Ad	L	12.16-25 = 22.9±1.16	7.82-9.90= 9.7±0.06	46.8-65 = 51.5±3.92
		W	8.5-15.5 = 11.7±1.34	3.25-4.20= 3.9±0.06	26.9-37.5= 32.95+2.19
	Ab	L	3.14-18.5 = 16.8±0.8	7.32-9.00= 8.7±0.09	52.5-75 = 64±4.3
		W	1.75-7.5 = 6.2±0.55	3.54-4.41= 3.6±0.09	31.5-37.8 = 41.5±2.57
Citrullus colocynthis (L.) Schrad	Ad	L	A	A	8.3-8.5 = 8.42±0.08
		W	A	A	3.4-3.6 = 3.48±0.08

	Ab	L	6.15-8.5 = 8.06±0.4	9.3-12.5 = 16±0.82	A
		W	3.16-2.5 = 2.28±0.19	4.19-9.13= 9.3±0.64	A
Cleome brachycarpa (Forssk.) Vahl ex DC.	Ad	L	5.9-8.5 = 10.24±0.1	9.7-15.9 = 18.5±0.06	19.34-9.17 = 9.32±0.09
		W	2.13.-7.5 = 2.44±0.04	4.17-6.42 = 9.86±0.06	4.3-4.5 = 4.38±0.04
	Ab	L	3.1-10.5= 10.32±0.09	11.5-20.8 = 20±0.26	23.32-11.7= 11.5±0.05
		W	2.3-2.5 = 2.44±0.04	7.13-14.9 = 15.6±0.18	15.62-7.16 = 5.5±0.03
Cleome scaposa DC.	Ad	L	6.4-9.5 = 11±0.61	9.5-17.5 = 14±1	15.32-34.61= 22.5±3.53
		W	1.22-2.1 = 2.05±0.27	2.18-5.43 = 4±0.61	11.42-23.7 = 17.5±3.5
	Ab	L	5.1-7.14 = 11±0.61	8.5-15.6= 13.5±0.61	18.6-27.5 = 24.5±1.22
		W	1.25-2.50 = 1.7±0.22	2.5-5.18 = 3±0.5	11.23-14.13 = 12±0.93
Convolvulus arvensis L.	Ad	L	A	A	13.18-10.6= 10.32±0.25
		W	A	A	7.18-6.27 = 6.28±0.31
	Ab	L	5.7-9.5 = 8.56±0.65	4.5-11.1 = 10.5±0.63	26.6-10.12 = 10.3±0.13
		W	2.13-2.26= 2.48±0.14	2.5-8.5 = 8±0.5	15.13-6.22 = 5.66±0.33
Corchorus depressus (L.) Stocks	Ad	L	5.7-7.19 = 6.73±0.6	7.5-12.5 = 10.5±0.9	21.32-23.7 = 23.5±1
		W	2.7-1.25 = 1.05±0.09	2.5-3 = 2.65±0.1	9.6-12.17 = 11.5±0.6
	Ab	L	5.34-9.6 = 7±1.2	10-17.5 = 14±1.5	14.19-23.5 = 20±2.6
		W	3.7-1.25 = 1.05±0.09	2.5-3 = 2.7±0.1	5.43-10.12 = 8.5±0.6
Corchorus tridens L.	Ad	L	A	A	A
		W	A	A	A
	Ab	L	5.9-6.6 = 6.22±0.12	11.8-12.1 = 11±0.11	28.12-8.9 = 8.58±0.12
		W	2.9-3.2 = 3.02±0.05	7.8-8.7 = 8.24±0.16	16.18-6.16 = 6.84±0.1
Cucumis melo ssp agrestis	Ad	L	4.18-5.3 = 5.08±0.09	14-15.3 = 14.7±0.2	23.6-9.12 = 9.86±0.08
		W	2.5-3.2 = 3.04±0.06	7.8-88 = 8.38±0.17	13.28-3.5 = 3.18±0.08
	Ab	L	4.17-5.1 = 4.96±0.07	5.7-6.4 = 6.08±0.11	7-8.13 = 8.06±0.22

		W	1.22-2.8 = 2.34±0.15	2.9-3.4 = 3.16±0.09	14.17-4.8 = 4.54±0.09
Cynoglossum lanceolatum Forssk.	Ad	L	A	A	A
		W	A	A	A
	Ab	L	4.27-7.17 = 17±0.9	6.18-37.5 = 9.5±2.3	52.17-63.5 = 61±4.2
		W	1.29-2.5 = 1.5±0.2	4.5-12.5 =6.9±1.1	17.5-25 = 20.5±1.2

Keywords: Ad=Adaxial, Ab=Abaxial, L=Length, W=Width, M=Mean, SE=Standard Error, Max=Maximum, Min=Minimum, A=Absent

Table 11. Quantitative Analysis of stomatal pore, guard cell and Subsidiary cells of various taxa of Takkar Wildlife Sanctuary

Taxa	Ad × Ab	L×W	Stomatal pore (Min-Max = Mean + SE)	Guard cell (Min-Max = Mean + SE)	Subsidiary cell (Min-Max = Mean + SE)
Evolvulus alsinoides (L.) L.	Ad	L	A	A	A
		W	A	A	A
	Ab	L	5.17-7.5 = 6.92±0.25	4.18-16.5=19.8±0.25	22.5-10.5 = 10±0.17
		W	2.12-2.5 = 2.34±0.06	2.12-9.5 =8.82±0.21	16.8-6.5 = 4.06±0.12
Farsetia stylosa R.Br.	Ad	L	5.3-15 = 13.2±0.91	7.4-6.17 = 7.5±0.83	46.7-35 = 57.5±25
		W	2.75-6.5 = 5.5±0.36	4.12-4.6 = 4.4±0.04	17.5-37.5 = 27.5±3.25
	Ab	L	5.17-11.23 = 12.2±0.67	7.5-8.00 = 7.6±0.18	43.8-52.5 = 54.5±2.54
		W	3.21-7.5 = 6.5±0.43	3.32-4.7 = 3.8±0.09	17.5-23.5 = 22.5±1.76
Gisekia pharnaceoides L.	Ad	L	4.9-15 = 12.5±0.8	9.7-7.15 = 12±0.79	37.9-22.5 = 19±1.5
		W	1.22-2.5 = 1.85±0.2	2.5-3.8 = 2.5±0.1	15.25-9.5 = 6.6±0.6
	Ab	L	3.31-12.5 = 11.5±0.6	9.7-17.5 = 14.5±0.9	19.7-23.7 = 18±1.8
		W	1.9-1.5 = 1.25±0.1	2.3-3.25 = 2.8±0.15	9.16-7.5 = 6.5±0.6
Heliotropium bacciferum Forssk.	Ad	L	2.9-10.9 = 9.22±0.55	11.6-13.2 = 12.8±0.76	19.9-11.7 = 10.98±0.31
		W	1.12-3.3 = 2.42±0.3	6.7-10.7 = 8.88±0.64	14.16-3.19 = 3.34±0.25
	Ab	L	4.7-7.9 = 6.16±0.61	11.6-18.7 = 16±0.88	27.8-9.2 = 8.34±0.25
		W	2.75-6.5 = 5.5±0.36	4.12-4.6 = 4.4±0.04	17.5-37.5 = 27.5±3.25
Iphiona aucheri (Boiss.) Anderb.	Ad	L	A	A	A
		W	A	A	A

	Ab	L	5.3-7.5 = 6.92±0.25	7.7-21 = 12.8±0.25	19.3-9.5 = 10±0.17
		W	1.23-2.5 = 2.34±0.06	3.38-95 = 8.81±0.21	13.8-4.5 = 4.06±0.12
Ipomoea aquatic Forssk.	Ad	L	A	A	A
		W	A	A	A
	Ab	L	6.16-17.5 = 16.5±0.6	9.13-15.8 = 21.5±0.6	36.33-41.8= 42.4±3.09
		W	2.9-1.35 = 1.4±0.09	9.13-12.5 = 11.5±0.6	12.5-15.18 = 13.5±0.6
Lantana camara L.	Ad	L	7.26-21.3= 22.9±1.16	7.51-9.90 = 9.7±0.06	43.5-65.17= 51.5±3.92
		W	3.5-15.7 = 11.7±1.34	3.13-4.20 = 3.9±0.06	25-37.5 = 32.95+2.19
	Ab	L	9.137-18.5= 16.8±0.8	6.13-9.00 = 4.7±0.09	51.17-71.9 = 64±4.3
		W	4.13-7.7 = 6.2±0.55	3.16-4.00 = 3.6±0.09	31.5-43.5 = 41.5±2.57
Merremia hederacea (Burm. f.)	Ad	L	A	A	9.13-8.17 = 8.42±0.08
Hallier f.		W	A	A	3.14-3.16 = 3.48±0.08
	Ab	L	5.5-8.5 = 8.06±0.4	11.5-14.5 = 16±0.82	28.3-8.5 = 8.44±0.08
		W	2.7-2.5 = 2.28±0.19	8.5-10.3 = 9.38±0.64	13.19-3.5 = 3.22±0.19
Mollugo cerviana (L.) Ser.	Ad	L	7.3-4.5 = 10.24±0.1	12.7-13.9 = 13.5±0.06	19.4-9.5 = 9.32±0.09
		W	2.3-2.5 = 2.44±0.04	9.7-7.9 = 7.86±0.06	9.3-4.15 = 4.38±0.04
	Ab	L	7.12-10.5 = 10.32±0.09	12.3-10.8 = 20±0.26	16.4-11.17= 11.5±0.05
		W	2.13-2.5 = 2.44±0.04	8.19-9.23 = 15.6±0.18	5.14-5.23 = 5.5±0.03
Moringa oleifera Lam.	Ad	L	6.17-12.5 = 11±0.61	8.6.5-11.5 = 14±1	18.13-35.9= 22.5±3.53
		W	2.5-2.16 = 2.05±0.27	2.23-5.4 = 4±0.61	11.34-23.12= 17.5±3.5
	Ab	L	8.13-11.5 = 11±0.61	9.4-12.6 =13.5±0.61	29.8-27.5 = 24.5±1.22
		W	1.25-2.50 = 1.7±0.22	2.5-5 = 3±0.5	11.13-15.13 = 12±0.93
Oxystelma esculentum (L. f.) Sm.	Ad	L	A	A	11.23-10.6 = 10.32±0.25
		W	A	A	7.14-6.7 = 6.28±0.31
	Ab	L	8.19-9.5 = 8.56±0.65	9.12-11.1 = ±0.63	24.32-10.15= 10.3±0.13

		W	2.31-2.7 = 2.48±0.14	7.13-8.5 = 8±0.5	15.13-6.2 = 5.66±0.33
Pithecellobium dulce (Roxb.) Benth.	Ad	L	5.17-7.5 = 6.28 ±0.6	8.13-11.5 = 10.5±0.9	21.32-25.21 = 23.5±1
		W	1.71-1.25 = 1.05±0.09	2.12-3.6 = 2.65±0.1	12.7-12.5 = 11.5±0.6
	Ab	L	7.29-10 = 7.34 ±1.12	7.4-13.5 = 14±1.5	34.23-26.15 = 20±2.6
		W	5.19-10 = 4.39 ±1.23	2.5-3 = 2.7±0.11	18.5-11.42 = 8.5±0.6
Pluchea lanceolata (DC.) C.B.Clarke	Ad	L	5.19-6.12 = 5.9±0.13	13.6-15.2 = 18.9±0.1	21.5-8.16 = 8.08±0.23
		W	2.3-2.8 = 2.5±0.1	8.13.5-13.3 = 12±0.12	16.18-4.6 = 4.3±0.1
	Ab	L	4.9-6.6 = 6.22±0.12	3.18-12.1 = 11±0.11	22.23-18.9 = 8.58±0.12
		W	2.13-3.2 = 3.02±0.05	6.8-8.7 = 8.24±0.16	16.15-7.91 = 6.84±0.1
Polygonum plebeium R.Br.	Ad	L	6.18-5.4 = 5.08±0.09	11.7-15.3= 14.7±0.2	19.6-11.51 = 9.86±0.08
		W	2.12-3.12 = 3.04±0.06	4.18-88 = 8.38±0.17	13.6-3.46 = 3.18±0.08
	Ab	L	4.7-3.1 = 4.96±0.07	6.17-6.4 = 6.08±0.11	27-8.8 = 8.06±0.22
		W	1.9-2.8 = 2.34±0.15	3.19-3.4 = 3.16±0.09	14.54-4.8 = 4.54±0.09
Pulicaria dysenterica Gaertn./boissieri	Ad	L	A	A	37.5-62.5 = 49.5±4.43
		W	A	A	29.53-41.8 = 41±4.2
	Ab	L	7.14-20 = 17±0.9	12.5-31.5 = 13.4±2.3	52.5-72.5 = 61±4.2
		W	2.17-2.5 = 1.5±0.2	3.15-12.5 = 8.3 ±1.1	17.5-25 = 20.5±1.2

Keywords: Ad=Adaxial, Ab=Abaxial, L=Length, W=Width, M=Mean, SE=Standard Error, Max=Maximum, Min=Minimum, A=Absent

Table 8. Quantitative Analysis of stomatal pore, guard cell and Subsidiary cell of various taxa of Takkar Wildlife Sanctuary

Taxa	Ad × Ab	L×W	Stomatal pore (Min-Max = Mean + SE)	Guard cell (Min-Max = Mean + SE)	Subsidiary cell (Min-Max = Mean + SE)
Schweinfurthia papilionacea (L.) Boiss.	Ad	L	A	A	6.75-10.50=8.00±0.65
		W	A	A	4.50-5.75=5.15±0.23
	Ab	L	6-7.5 = 6.92±0.25	14.75-16.50=15.45±0.39	7.25-11.00=8.85±0.68
		W	2.2-2.5 = 2.34±0.06	4.75-5.50=5.25±0.13	4.50-5.50=5.05±0.18
Solanum americanum Mill.	Ad	L	27.00-34.75=31.25±1.33	7.20-7.7 = 7.5±0.83	35.75-40.50=37.85±0.84
		W	11.75-14.75=13.05±0.52	4.30-4.6 = 4.4±0.04	7.75-11.75=9.45±0.70
	Ab	L	29.25-32.25=30.90±0.52	7-8.00 = 7.6±0.18	31.75-39.75=35.50±1.53
		W	12.25-16.75=13.60±0.81	3.50-4 = 3.8±0.09	7.25-10.75=8.60±0.61
Tecomella undulata (Sm.) Seem.	Ad	L	7.00-9.75=8.35±0.46	7.75-12.25=10.15±0.86	26.75-31.75=29.60±0.85
		W	4.75-6.00=5.50±0.23	5.25-7.25=6.30±0.39	5.25-7.26=6.30±0.39 l
	Ab	L	7.75-12.5=9.30±0.80	7.75-16.75=13.75±1.62	6.75-8.50=7.55±0.34
		W	4.35-7.25=5.90±0.47	5.25-7.25=6.35±0.34	3.50-5.75=4.80±0.39
Thymelaea passerina (L.) Coss. & Germ.	Ad	L	6.75-8.25=7.60±0.26	7.25-10.75=8.75±0.65	28.75-34.50=31.10±0.95
		W	4.00-5.50=4.70±0.28	4.50-7.25=5.90±0.56	7.75-10.50=9.25±0.57
	Ab	L	25.75-31.00=29.45±0.94	7.75-11.75=9.60±0.65	23.50-34.00=28.40±1.99
		W	12.00-14.24=12.80±0.45	4.75-7.25=6.15±0.42	24.50-27.25=25.60±0.48
Trianthema portulacastrum L.	Ad	L	5.25-8.50=7.20±0.53	7.00-11.50=8.45±0.80	37.5-87.5 = 62±9.02
		W	4.50-6.00=5.10±0.28	4.50-6.00=5.20±0.32	12.5-17.5 = 14.5±0.9
	Ab	L	5.25-7.75=6.30±0.43	9.75-14.00-11.25±0.80	35-51 = 42.4±3.09
		W	4.25-5.25=4.65±0.16	4.75-6.50=5.45±0.28	12.5-15 = 13.5±0.6
Tribulus pentandrus Forssk.	Ad	L	20.26-25 = 22.9±1.16	5.75-10.75=8.50±0.85	42.5-65 = 51.5±3.92
		W	7.5-15 = 11.7±1.34	4.75-7.00=5.60±0.37	25-37.5 = 32.95+2.19
	Ab	L	14.7-18.5 = 16.8±0.8	5.75-8.50=7.20±0.46	52.5-75 = 64±4.3

		W	4.75-7.5 = 6.2±0.55	4.50-5.50=5.10±0.20	32.5-47.5 = 41.5±2.57
Withania somnifera (L.) Dunal	Ad	L	A	A	8.3-8.5 = 8.42±0.08
		W	A	A	3.4-3.6 = 3.48±0.08
	Ab	L	25.25-28.75=26.60±0.63	16.25-20.50=17.95±0.81	8.3-8.5 = 8.44±0.08
		W	17.00-19.50=18.30±0.39	4.00-8.00=6.10±0.67	3-3.5 = 3.22±0.19
Zygophyllum indicum (Burm.f.) Christenh. & Byng	Ad	L	9.23-10.5 = 10.24±0.1	18.6-18.9 = 18.5±0.06	9-9.5 = 9.32±0.09
		W	2.3-2.5 = 2.44±0.04	9.7-10 = 9.86±0.06	4.3-4.5 = 4.38±0.04
	Ab	L	10-10.5 = 10.32±0.09	19.5-20.8 = 20±0.26	11.4-11.7 = 11.5±0.05
		W	2.3-2.5 = 2.44±0.04	9.17-16 = 15.6±0.18	5.4-5.6 = 5.5±0.03

Keywords : Ad=Adaxial, Ab=Abaxial, L=Length, W=Width, M=Mean, SE=Standard Error, Max=Maximum, Min=Minimum, A=Absent

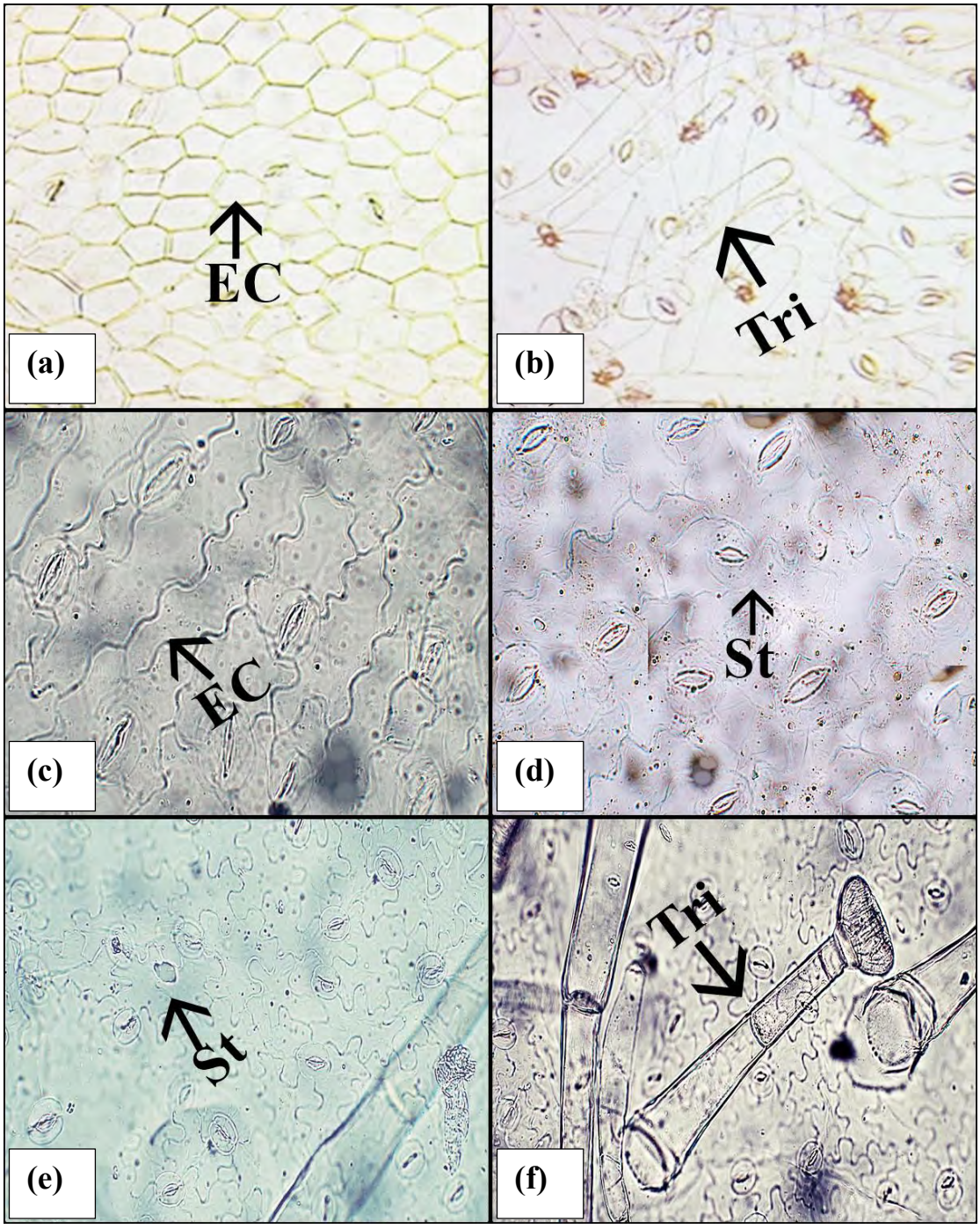

Plate 39. Light Micrographs (LM) illustrated stomata, shape of cells and wall pattern and trichomes of plant species; *Abutilon indicum* (a) Adaxial surface (b) Abaxial surface; *Anagallis arvensis* (c) Abaxial surface (d) Adaxial surface; *Anticharis glandulosa* (e) Abaxial surface (f) Adaxial surface

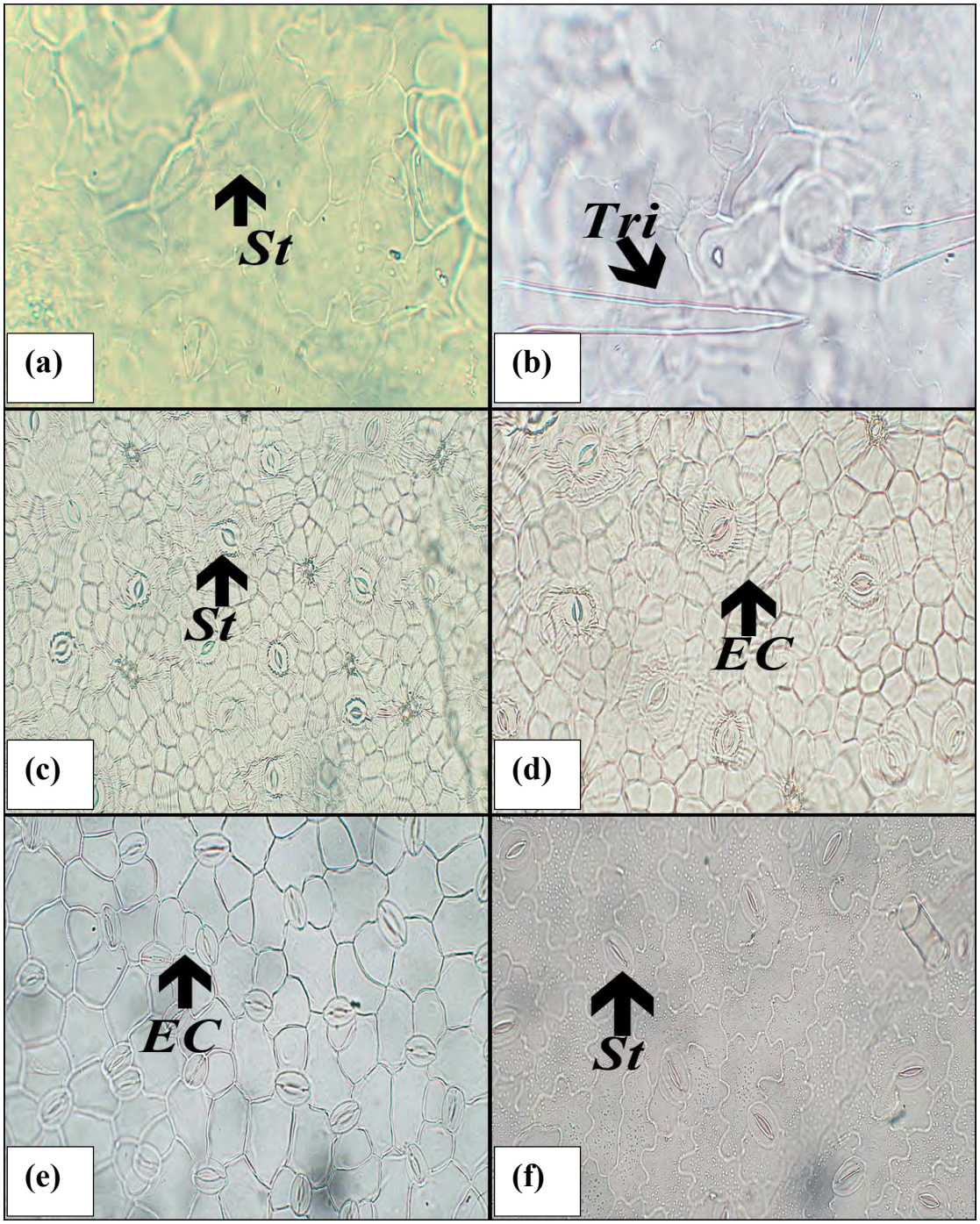

Plate 40. Light Micrographs (LM) illustrated stomata, shape of cells and wall pattern and trichomes of plant species; *Arnebia hispidissima* (a) Abaxial surface (b) Adaxial surface; *Calotropis procera* (c) Abaxial surface (d) Adaxial surface; *Citrullus colocynthis* (e) Abaxial surface (f) Adaxial surface

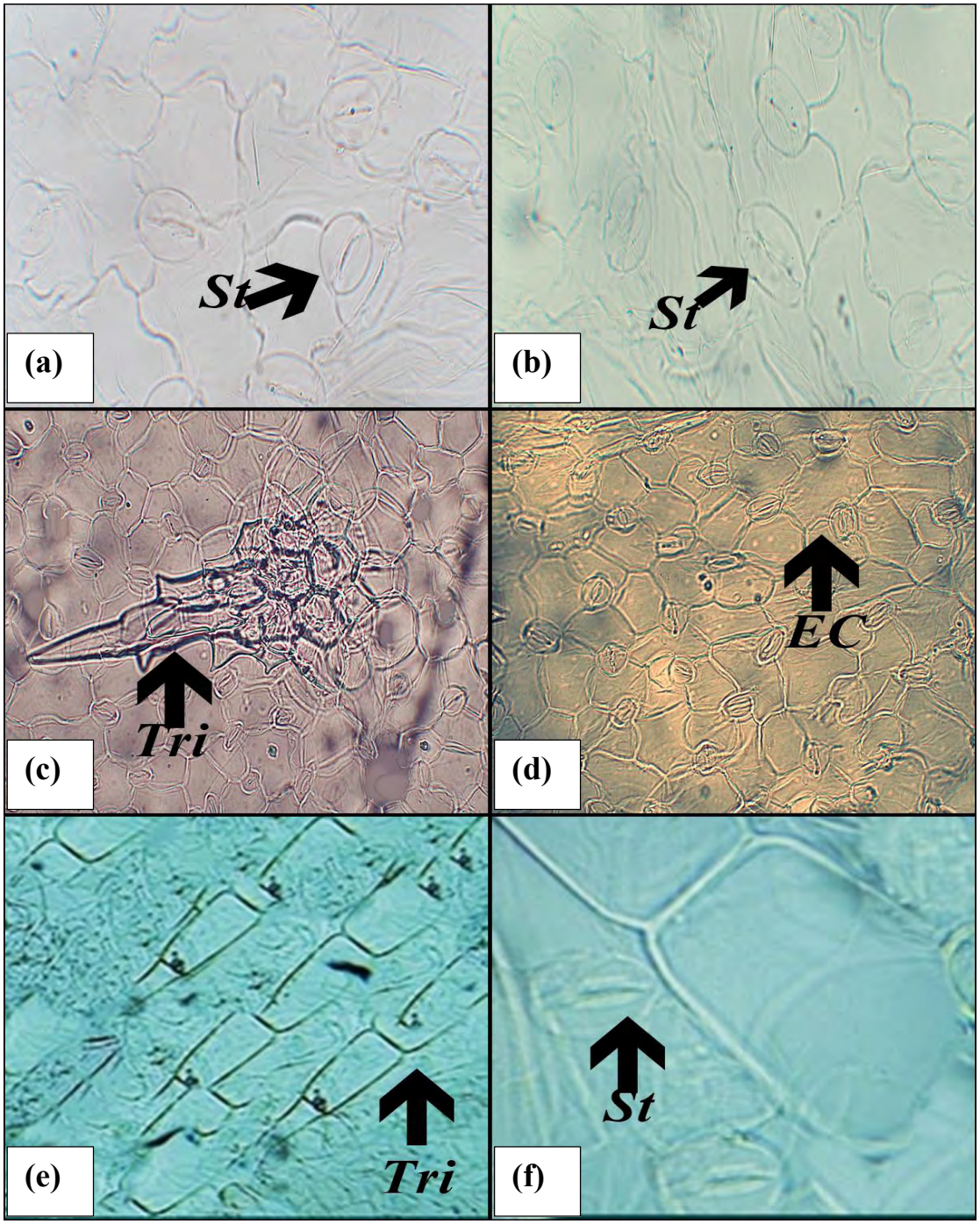

Plate 41. Light Micrographs (LM) illustrated stomata, shape of cells and wall pattern and trichomes of plant species; *Cleome brachycarpa* (a) Abaxial surface (b) Adaxial surface; *Cleome scaposa* (c) Abaxial surface (d) Adaxial surface; *Convolvulus arvensis* (e) Abaxial surface (f) Adaxial surface

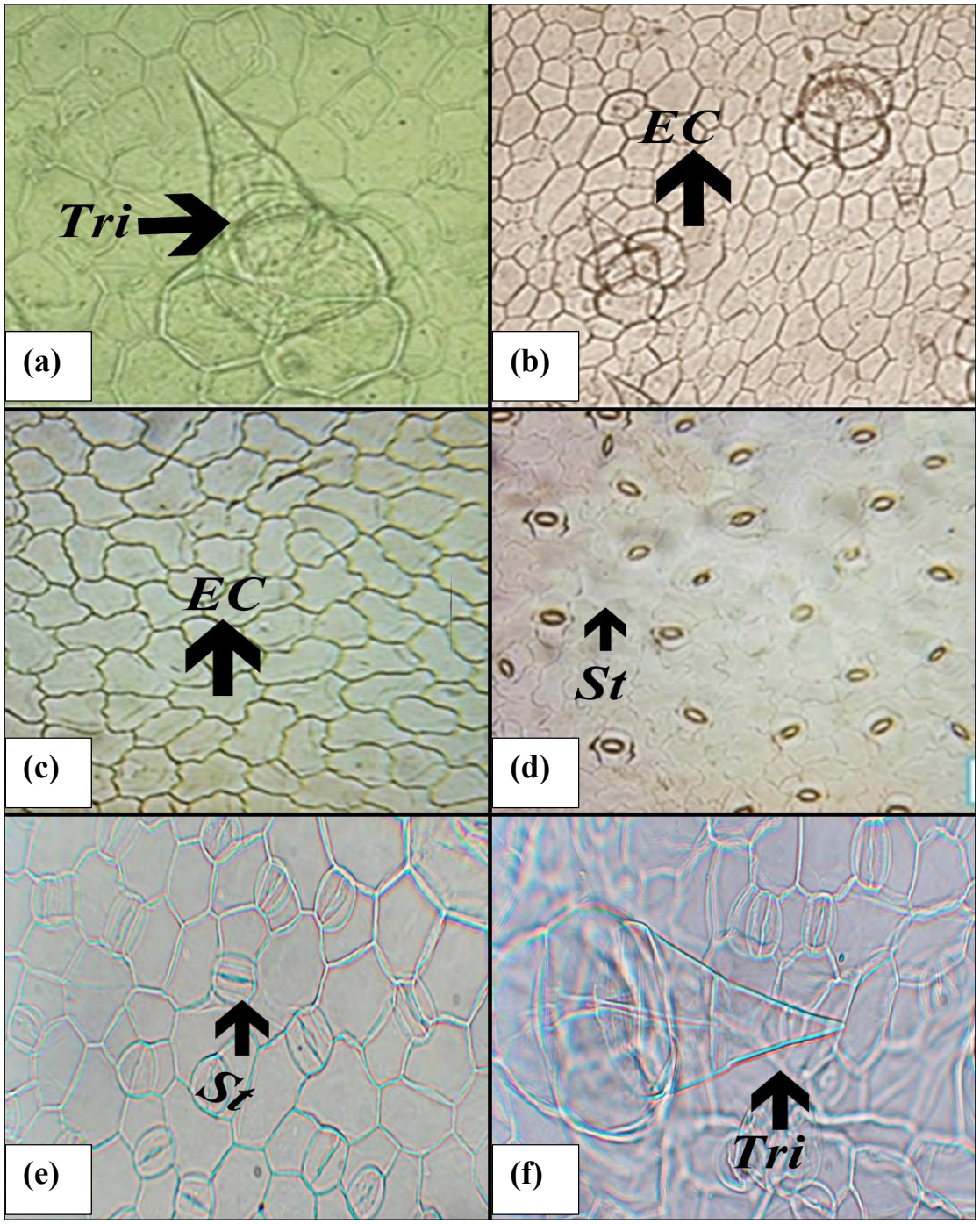

Plate 42. Light Micrographs (LM) illustrated stomata, shape of cells and wall pattern and trichomes of plant species; *Corchorus depressus* (a) Abaxial surface (b) Adaxial surface; *Corchorus tridens* (c) Abaxial surface (d) Adaxial surface; *Cucumis melo ssp* (e) Abaxial surface (f) Adaxial surface

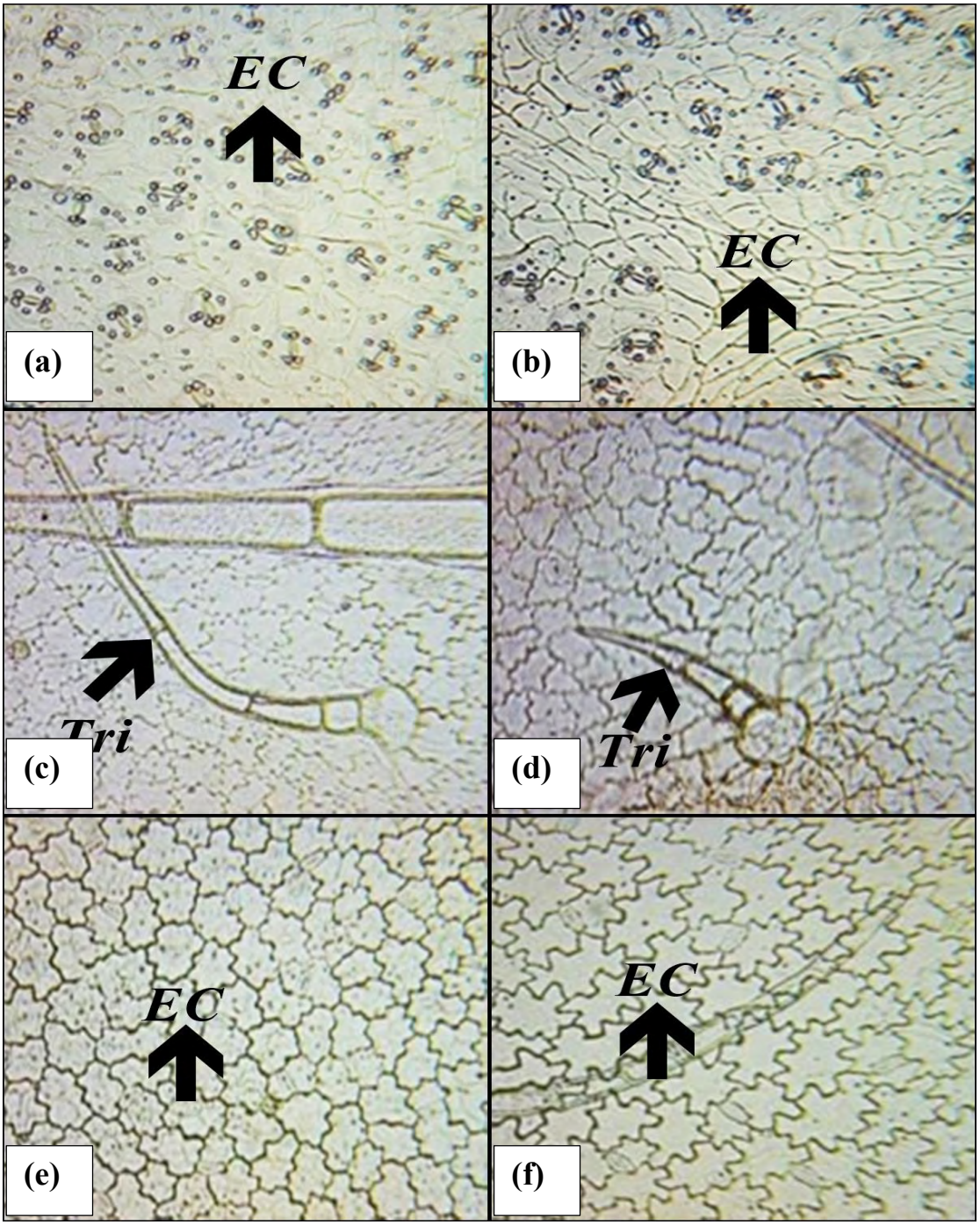

Plate 43. Light Micrographs (LM) illustrated stomata, shape of cells and wall pattern and trichomes of plant species; *Cynoglossum lanceolatum* (a) Abaxial surface (b) Adaxial surface; *Evolvulus alsinoid* (c) Abaxial surface (d) Adaxial surface; *Farsetia stylosa* (e) Abaxial surface (f) Adaxial surface

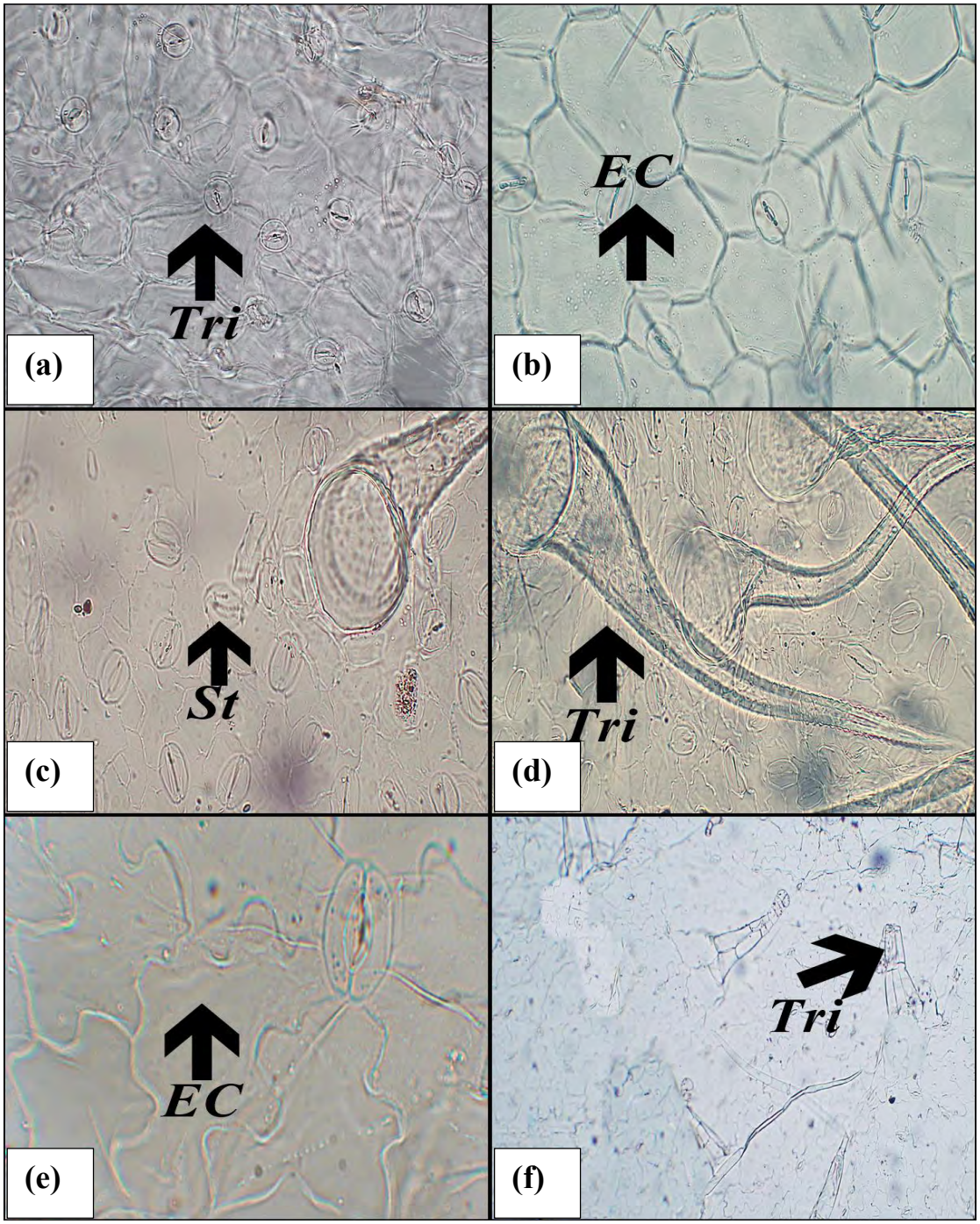

Plate 44. Light Micrographs (LM) illustrated stomata, shape of cells and wall pattern and trichomes of plant species; *Gisekia pharnaceoides* (a) Abaxial surface (b) Adaxial surface; *Heliotropium bacciferum* (c) Abaxial surface (d) Adaxial surface; *Iphiona aucheri* (e) Abaxial surface (f) Adaxial surface

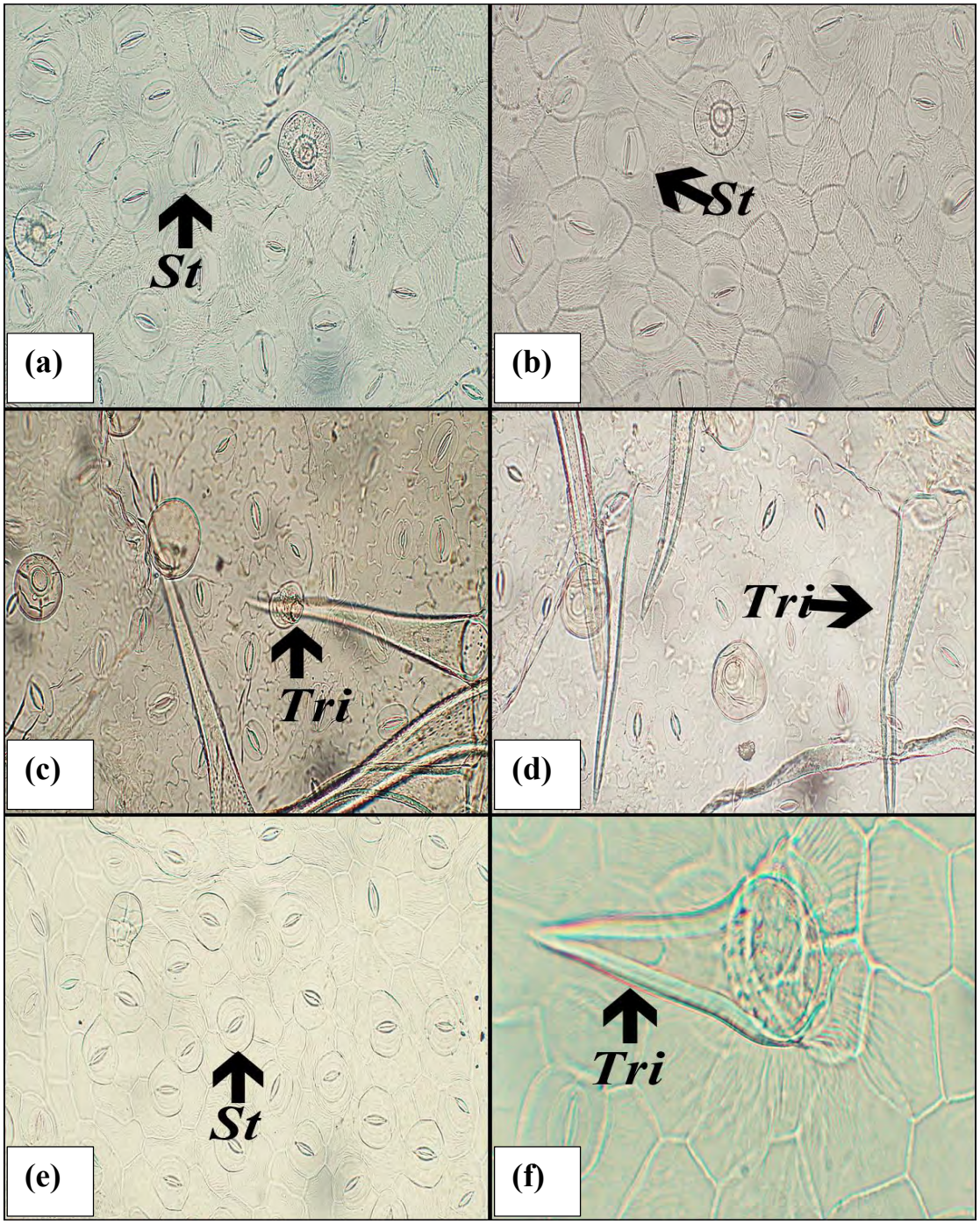

Plate 45. Light Micrographs (LM) illustrated stomata, shape of cells and wall pattern and trichomes of plant species; *Ipomoea aquatic* (a) Abaxial surface (b) Adaxial surface; *Lantana camara* (c) Abaxial surface (d) Adaxial surface; *Merremia hederacea* (e) Abaxial surface (f) Adaxial surface

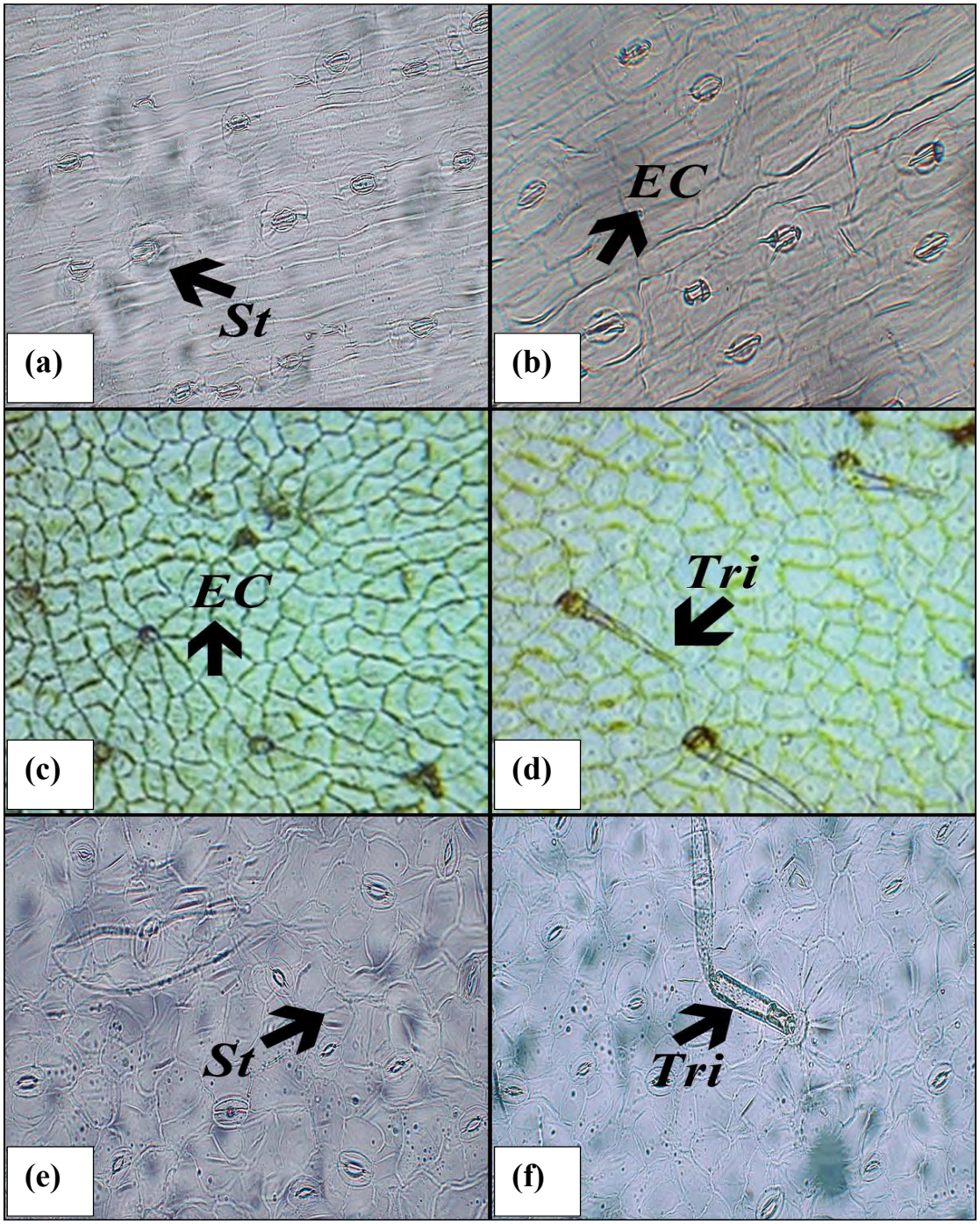

Plate 46. Light Micrographs (LM) illustrated stomata, shape of cells and wall pattern and trichomes of plant species; *Mollugo cerviana* (a) Abaxial surface (b) Adaxial surface; *Moringa oleifera* (c) Abaxial surface (d) Adaxial surface; *Oxystelma esculentum* (e) Abaxial surface (f) Adaxial surface

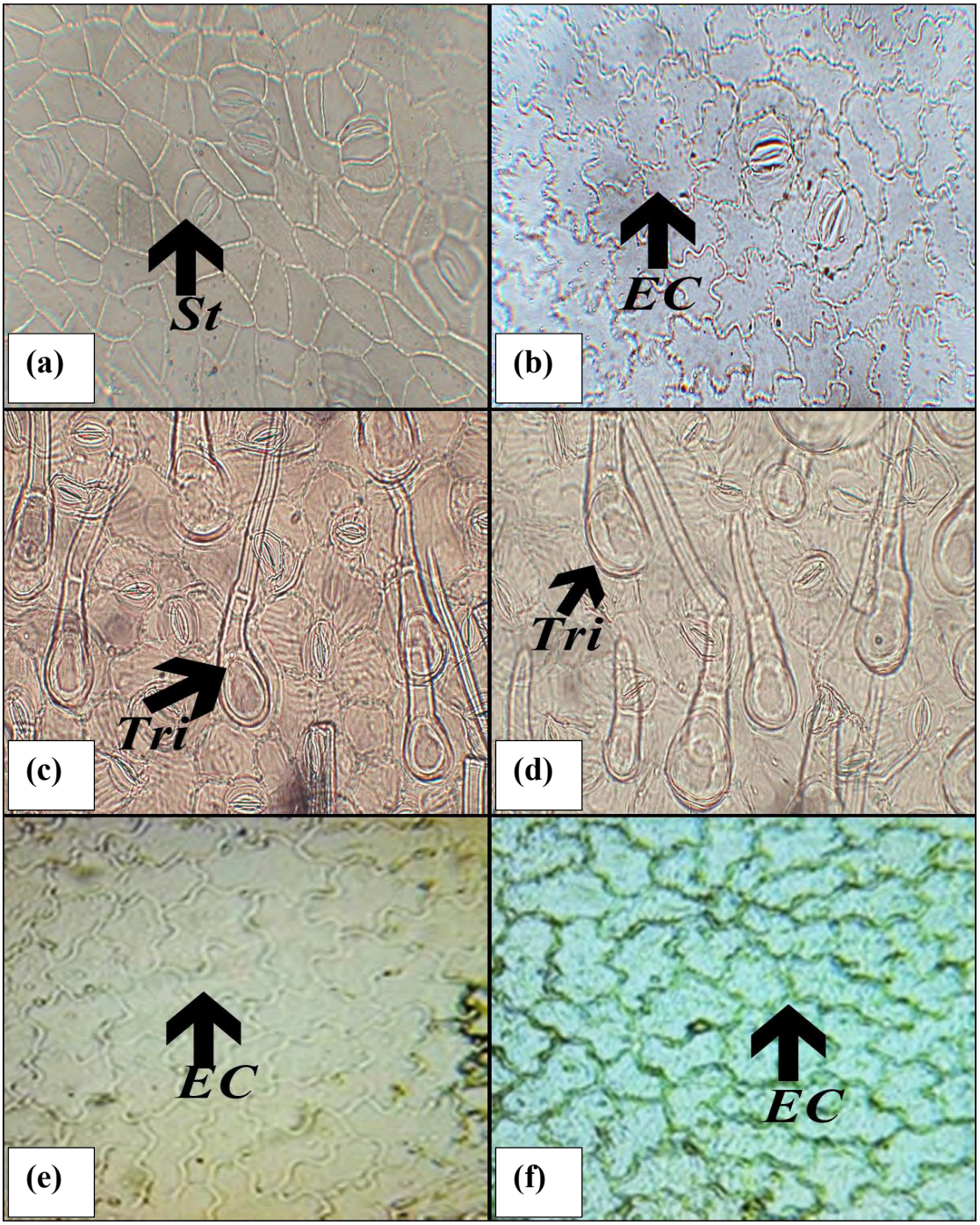

Plate 47. Light Micrographs (LM) illustrated stomata, shape of cells and wall pattern and trichomes of plant species *Pithecellobium dulce* (a) Abaxial surface (b) Adaxial surface; *Pluchea lanceolata* (c) Abaxial surface (d) Adaxial surface; *Polygonum plebeium* (e) Abaxial surface (f) Adaxial surface

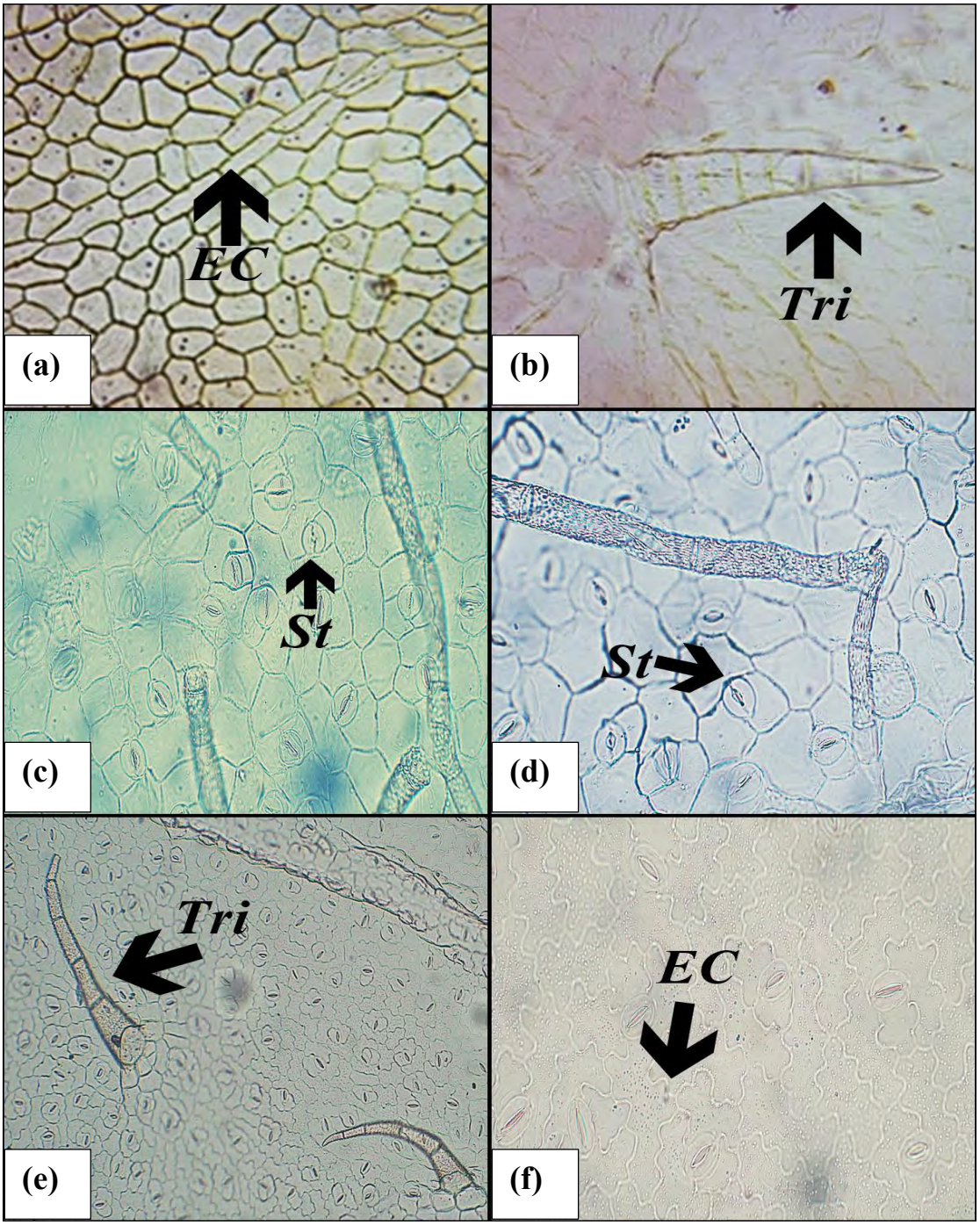

Plate 48. Light Micrographs (LM) illustrated stomata, shape of cells and wall pattern and trichomes of plant species; *Pulicaria dysenterica* (a) Abaxial surface (b) Adaxial surface; *Schweinfurthia papilionacea* (c) Abaxial surface (d) Adaxial surface; *Solanum americanum* (e) Abaxial surface (f) Adaxial surface

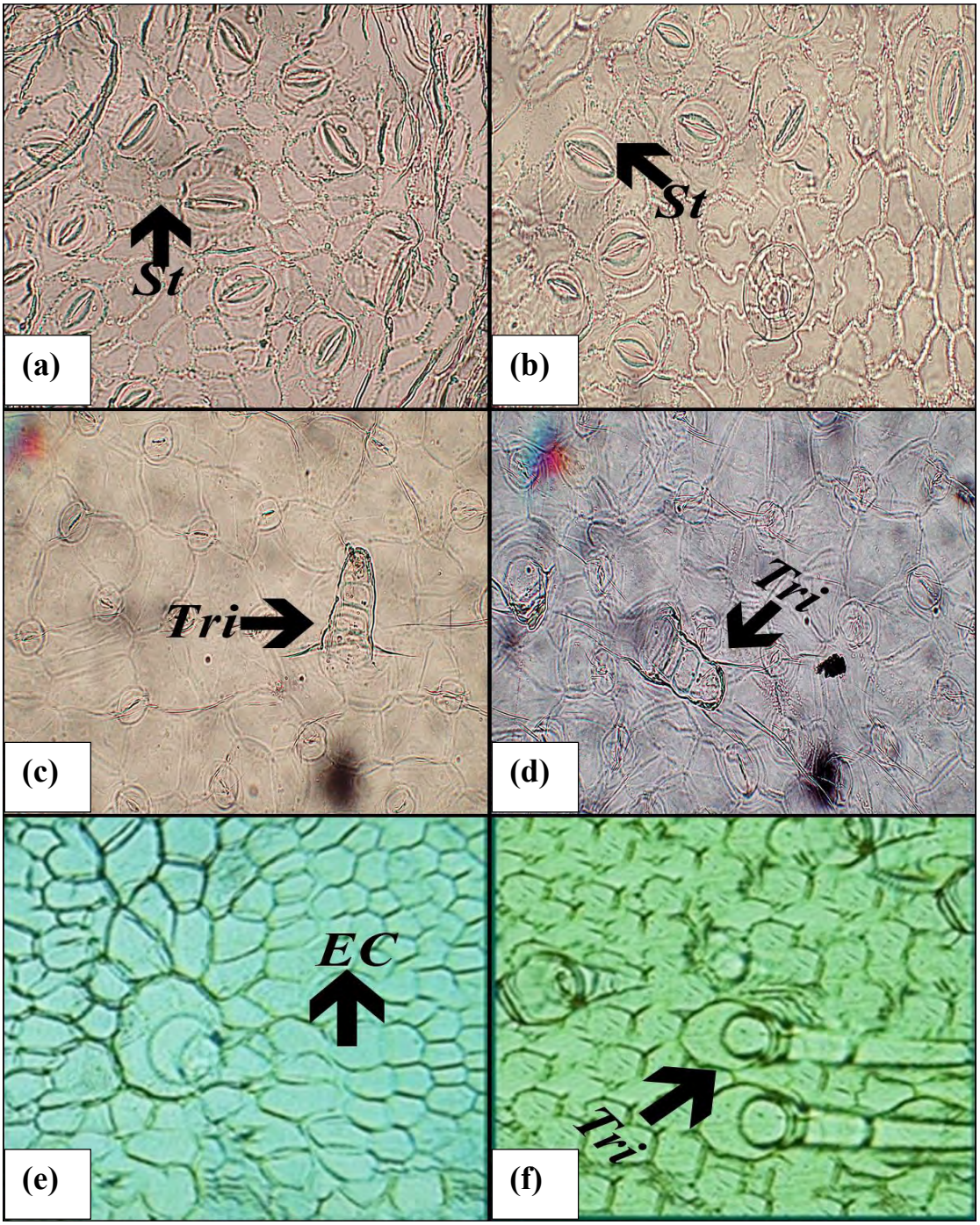

Plate 49. Light Micrographs (LM) illustrated stomata, shape of cells and wall pattern and trichomes of plant species; *Tecomella undulata* (a) Abaxial surface (b) Adaxial surface; *Thymelaea passerina* (c) Abaxial surface (d) Adaxial surface; *Trianthema portulacastrum* (e) Abaxial surface (f) Adaxial surface

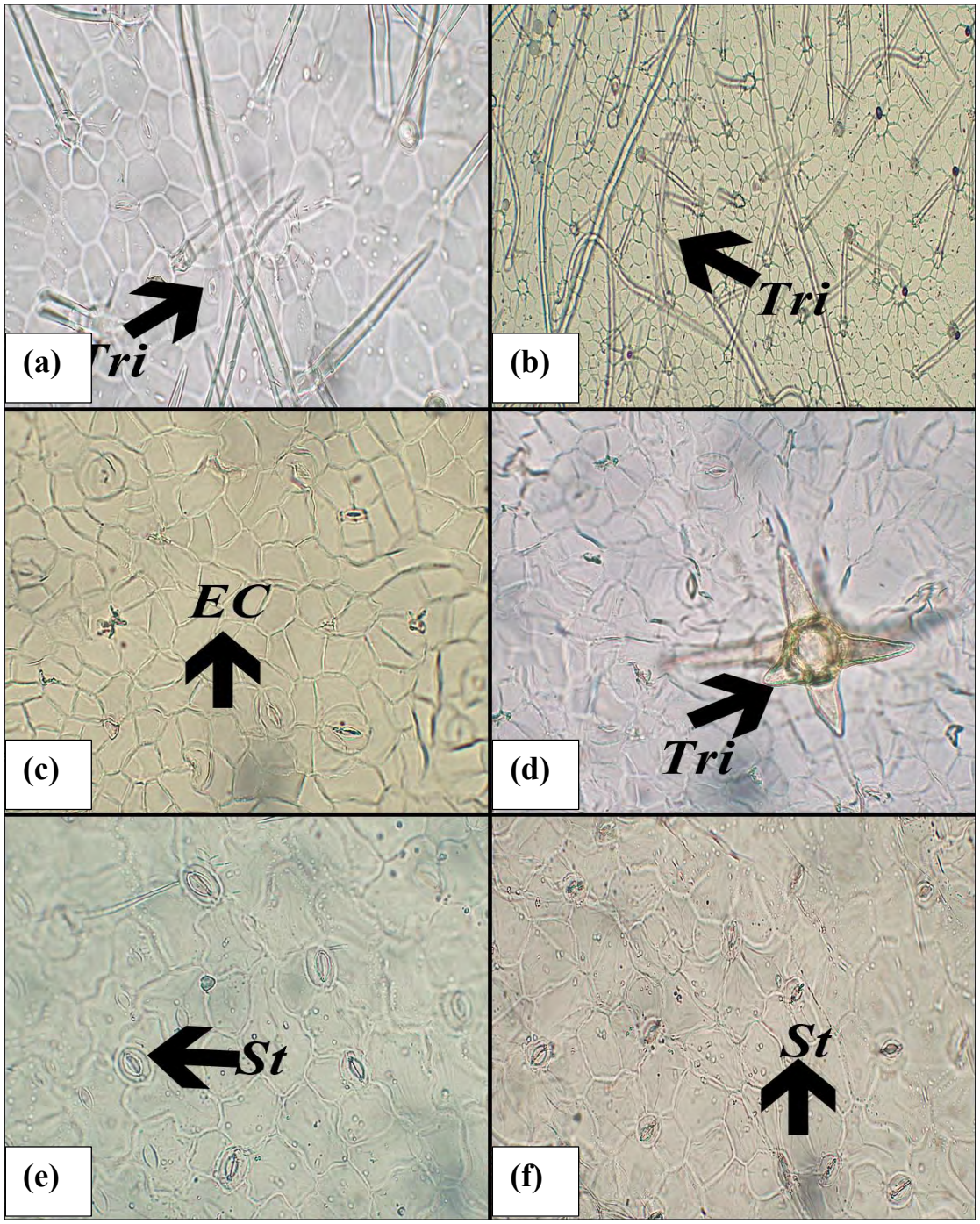

Plate 50. Light Micrographs (LM) illustrated stomata, shape of cells and wall pattern and trichomes of plant species; *Tribulus pentandrus* (a) Abaxial surface (b) Adaxial surface; *Withania somnifera* (c) Abaxial surface (d) Adaxial surface; *Zygophyllum indicum* (e) Abaxial surface (f) Adaxial surface

Section III

Pollen Micromorphology

(LM & SEM)

3.3.1 Pollen Morphology of Leguminous Species

Numerical findings of this research presented below. Morphometric study encompasses the shape and size of Pollen grains. Species were also studied on the basis of qualitatively. Results were mentioned detailed wise in Table 9 and 10. Fifteen species of fabaceae were studied palynologically. In quantitative findings, polar and equatorial diameters, exine thickness, Mesocolpium, colpi length and width were studied through light microscopy (LM) whereas Scanning Electron Microscopy (SEM) has been used to study qualitative features (Plates 51, 52, 53 & 54).

a) General Pollen Descriptions

Pollen grains structure defined on the basis of light microscopy by various palynologists in past viz. Erdtman (1969), Walker (1976) and Canright (1953). Various palynologists categorized Pollen grains on the basis of their sizes. In this regard, Erdtman Gunnar (1969) gave six classes on the basis of grain sizes, such as very small pollen grains less the < 10µm, while small grains ranges under 10 – 25µm, medium grains 25 – 50µm, large grains 50 – 100µm, very large grains 100 - 200µm and Gigantic grains greater than 200µm. In this research study, nine species of fabaceae have small grains while three have very small grains and one species have medium size grain.

b) Pollen shape

For pollen shape determination, polar and equatorial axis ratio is calculated. Largest polar axis found in *Trifolium resupinatum* (25.1 µm) whereas smallest polar axis in *AlhaGi maurorum* (6.06) Largest equatorial axis recoded in *Bauhinia variegate* (21.44 µm) whereas smallest in *Alhagi maurorum* (5.38 µm) as illustrated in Figure 8. Nine species have Prolate-spheroidal pollen shape in equatorial view such as. *Acacia nilotica, Alhagi maurorum, Bauhinia variegata, Indigofera cordifolia, Indigofera hochstetteri, Melilotus albus, Senna italica,*

Sesbania bispinosa, Tephrosia purpurea, and two species have sub-prolate shape in equatorial view *Prosopis glandulosa, Trifolium resupinatum,* while two species have oblate-spheroidal shape: *Crotalaria medicaginea*, *Erythrina suberosa.* Prolate and spheroidal shape were observed in *Crotalaria burhia* and *Parkinsonia aculeata* respectively.

In polar view, five species have semi-circular shape; *Bauhinia variegata Indigofera cordifolia, Melilotus albus, Prosopis glandulosa, Trifolium resupinatum* wheresas four species have triangular grains namely: *Erythrina suberosa, Indigofera hochstetteri, Parkinsonia aculeate, Sesbania bispinosa.* Semi-angular grains in polar view were observed in three species viz. *Alhagi maurorum, Crotalaria burhia, Tephrosia purpurea* whereas elliptic, semi triangular circular were observed respectively in *Acacia nilotica, Crotalaria medicaginea, Senna italic.* Lowest P/E ratio has observed in *Crotalaria medicaginea* (0.91) higher P/E ratio was recoded in *Crotalaria burhia Benth.* (1.38) as mentioned in Figure 9.

c) Pollen Types

Tricolporate pollen types were observed predominantly in *Alhagi maurorum, Crotalaria medicaginea, Crotalaria burhia, Indigofera hochstetteri, Melilotus albus, Parkinsonia aculeate, Prosopis glandulosa, Senna italic, Tephrosia purpurea, Trifolium resupinatum* while three species contain tricolpate pollen types: *Bauhinia variegate, Indigofera cordifolia, and Sesbania bispinosa* followed by polyads and trizonocolporate were respectively in *Acacia nilotica* and *Erythrina suberosa*.

d) Pollen apertures

Erdtman and Straka (1961) gave NPC-classification system. In this system Number, Position and character (NPC) of pollen grains aperture were examined. The NPC system utilized in the field of plant systematics as a diagnostic tool. Every species has peculiar patterns on pollen walls which are utilized by Palynologists to trace the

family and genus of pollen grains. In present research we observed various patterns on aperture pollen grains. The orientations were Slightly Sunken, slightly budged, Budged, Sunken in studied taxa. In numerical findings, largest colpi length was recorded (6.31 µm) in *Crotalaria medicaginea* whereas *smallest in Trifolium resupinatum* (1.34 µm) and largest width of colpi was observed in *Bauhinia variegate* (5.426 µm) and smallest in *Senna italic* (1.43 µm) as shown in Figure 10.

e) Exine sculpture and mesocolpium

Exine of pollen grains is made up of sporopollenin which is resistant to harsh chemicals and microbial and enzymatic treatments. The exine sculpture was scabrate in *A. nilotica* and Reticulate-Scabrate was observed in three species viz. *Crotalaria burhia, Erythrina suberosa* and *Trifolium resupinatum.* Other pollen wall patterns observed in SEM micrographs were psilate- scabrate, psilate-perforate, psilate-reticculate in *Indigofera hochstetteri, Prosopis glandulosa* and *Sesbania bispinosa* respectively. In five species we observed Reticulate, Reticulate-Verrucate and Psilate were respectively in *Bauhinia variegate, Parkinsonia aculeate, Crotalaria medicaginea, Melilotus albus* and *Indigofera hochstetteri* whereas *Senna italica* and *Tephrosia purpurea* have respectively Verrucate, Perforate-Reticulate. Thinnest exine was recoded (0.756 µm) in *Erythrina suberosa Whereas* Thickness observed was (5.24 µm) as illustrated in Figure 11. Mesocolpium distance between two colpi measured was (2.082 µm) which is lowest in *Tephrosia purpurea* and highest mesocolpium distance was (11.8 µm) in *Bauhinia variegata* (Figure 12).

f) Taxonomic Identification Keys based on Fabaceous Pollen

1 + Small sized, Polyad, Aperture absent, Scabrate…….*A. nilotica*

- Triangular convex, aperture bulged……..…2

2 + Trizonocolporate, reticulate scabrate exine……..…*E. suberosa*

- Tricolpate type pollen……..…….3

3 + Semi circular, reticulate, slightly sunken aperture…….*B. veriegata*

- Tricolpate, slightly bulged aperture…….…….4

4 + Prolate-spheroidal, psilate sculptured…….…….*I. cardifolia*

- Triangular, sunken aperture condition…….…….5

5 + Prolate-spheroidal, psilate reticulate ornamentation…….….*S. bispinosa*

- Tricolporate, very small grains……..……..…..……..6

6 + Semi-angular, psilate, sunken aperture……..*A. maurorum*

- Semi-triangular, oblate-spheroidal……...…7

7 + Reticulate-verrucate exine, slightly bulged aperture…….*C. medicaginea*

- Semi-angular, very small sized grains……..……8

8 + Reticulate scabrate exine, bulged aperture……*C. burhia*

- Slightly sunken aperture, triangular polar view……..……..9

9 + Psilate-scabrate surface, prolate-spheroidal…….…*I. hochstetteri*

- Very small pollen, semi-circular……10

10 + Bulged aperture, reticulate verrucate sculpturing……..*M. albus*

- Triangular polar view, bulged aperture……..……11

11 + Spheroidal grains, reticulate peculiarities…….*P. aculeate*

- Small grains, sub-prolate……....12

12 + Slightly bulged aperture, psilate perforate exine…….*P. glandulosa*

- Prolate-spheroidal, slightly bulged aperture…….……..13

13 + Verrucate sculpture, small, circular…….*S. italica*

- Semi-angular, bulged condition aperture…….……..…14

14 + Perforate-reticulate, prolate-spheroidal……*T. purpurea*

- Semi-circular polar shape, bulged aperture……15

15 + Reticulate-Scabrate exine, sub-prolate……..…*T. resupinatum*

Table 8. Qualitative features of Legnuminuous Pollen.

S. No.	Taxa	Size	Polar view	Equatorial View	Pollen Type	Exine sculpturing	Aperture orientation
1	*Acacia nilotica* (L.) Delile	Small	Elliptic	Prolate-spheroidal	Polyads	Scabrate	Slightly sunken
2	*Alhagi maurorum* Medik.	Very small	Semi Angular	Prolate-spheroidal	Tricolporate	Psilate	Sunken
3	*Bauhinia variegata* Linn.	Small	Semi Circular	Prolate-spheroidal	Tricolpate	Reticulate	Slightly Sunken
4	*Crotalaria medicaginea* Lam.	Very small	Semi Triangular	Oblate-spheroidal	Tricolporate	Reticulate-Verrucate	Slightly budged
5	*Crotalaria burhia Benth.*	Very small	Semi Angular	Prolate	Tricolporate	Reticulate-Scabrate	Budged
6	*Erythrina suberosa* Roxb.	Small	Triangular (Convex)	Oblate-spheroidal	Trizonocolporate	Reticulate-Scabrate	Bulged
7	*Indigofera cordifolia* Roth	Small	Semi Circular	Prolate-spheroidal	Tricolpate	Psilate	Slightly Bulged
8	*Indigofera hochstetteri* Baker	Small	Triangular	Prolate-spheroidal	Tricolporate	Psilate - Scabrate	Slightly Sunken
9	*Melilotus albus* Medik.	Very Small	Semi Circular	Prolate-spheroidal	Tricolporate	Reticulate-Verrucate	Bulged
10	*Parkinsonia aculeata L.*	Very Small	Triangular	Spheroidal	Tricolporate	Reticulate	Bulged
11	*Prosopis glandulosa* Torr.	Small	Semi Circular	Sub-prolate	Tricolporate	Psilate-Perforate	Slightly Bulged
12	*Senna italica* Mill.	Small	Circular	Prolate-spheroidal	Tricolporate	Verrucate	Slightly Bulged
13	*Sesbania bispinosa* (Jacq.) W.Wight	Small	Triangular	Prolate-spheroidal	Tricolpate	Psilate-Reticculate	Sunken
14	*Tephrosia purpurea (L.) Pers.*	Small	Semi Angular	Prolate-spheroidal	Tricolporate	Perforate-Reticulate	Bulged
15	*Trifolium resupinatum* L.	Medium	Semi Circular	Sub-prolate	Tricolporate	Reticulate-Scabrate	Bulged

Table 9. Quantitative features of Leguminuous pollen (n =20).

S. No.	Plant taxa	P/E ratio	Exine thickness (µm)	PD in (µm) Max-Min = M±SE	ED in (µm) Max-Min = M±SE	L of Colpi (µm) Max-Min = M±SE	W of Colpi (µm) Max-Min = M±SE	Mesocolpium Max-Min = M±SE
1	*Acacia nilotica* (L.) Delile	1.14	1.866 ± 0.37	18.58 ± 0.61	16.24 ± 0.72	3.026 ± 0.47	2.968 ± 0.81	2.696 ± 0.32
2	*Alhagi maurorum* Medik.	1.12	1.32 ± 0.94	6.06 ± 0.32	5.38 ± 0.27	3.21 ± 0.89	2.43 ± 0.61	5.05 ± 0.28
3	*Bauhinia variegata* Linn.	1.06	2.182 ± 0.23	21.44 ± 0.31	20.006 ± 0.21	5.778 ± 0.34	5.426 ± 0.64	11.8 ± 0.37
4	*Crotalaria medicaginea* Lam.	0.91	1.052 ± 0.79	8.82 ± 0.39	9.624 ± 0.82	6.31 ± 0.59	1.94 ± 0.37	4.074 ± 0.46
5	*Crotalaria burhia Benth.*	1.38	1.65 ± 0.43	9.784 ± 0.59	7.066 ± 0.34	3.196 ± 0.65	2.564 ± 0.92	3.842 ± 0.34
6	*Erythrina suberosa* Roxb.	0.93	0.756 ± 0.53	13.3 ± 0.61	14.318 ± 0.36	3.29 ± 0.29	3.22 ± 0.74	6.574 ± 0.38
7	*Indigofera cordifolia* Roth	1.09	1.746 ± 0.62	14.398 ± 0.78	13.16 ± 0.39	2.734 ± 0.26	2.576 ± 0.82	5.42 ± 0.59
8	*Indigofera hochstetteri* Baker	1.11	1.702 ± 0.74	15.3± 0.12	13.7± 0.82	2.8± 0.11	1.72± 0.17	5.9± 0.72
9	*Melilotus albus* Medik.	1.04	0.842 ± 0.81	8.012 ± 0.38	7.638 ± 0.29	3.012 ± 0.91	2.638 ± 0.63	7.534± 0.49
10	*Parkinsonia aculeata L.*	1.00	1.574 ± 0.59	10.866 ± 0.96	10.824 ± 0.81	2.54 ± 0.43	2.116 ± 0.39	5.362 ± 0.91
11	*Prosopis glandulosa* Torr.	1.16	1.528 ± 0.73	12.558 ± 0.38	10.8 ± 0.42	1.95 ± 0.59	1.872 ± 0.72	3.08 ± 0.31
12	*Senna italica* Mill.	1.01	2.52 ± 0.68	11.08 ± 0.37	10.88 ± 0.16	2.63 ± 0.23	1.43 ± 0.59	7.45 ± 1.23
13	*Sesbania bispinosa* (Jacq.) W.Wight	1.02	1.108 ± 0.41	11.474 ± 0.29	11.184 ± 0.52	3.29 ± 0.74	3.22 ± 0.91	6.574 ± 0.34
14	*Tephrosia purpurea (L.) Pers.*	1.06	2.16 ± 0.42	11.936 ± 0.71	11.15 ± 0.49	2.59 ± 0.52	1.974 ± 0.73	2.082 ± 0.82
15	*Trifolium resupinatum* L.	1.27	5.24 ± 0.81	25.1 ± 0.58	19.74 ± 0.31	1.34 ± 0.52	2.08 ± 0.71	3.74 ± 0.38

Keywords: P = Polar diameter; E = Equatorial diameter; Max = Maximum; Min = Minimum; M = Mean; SE = Standard Error; µm = Micrometer

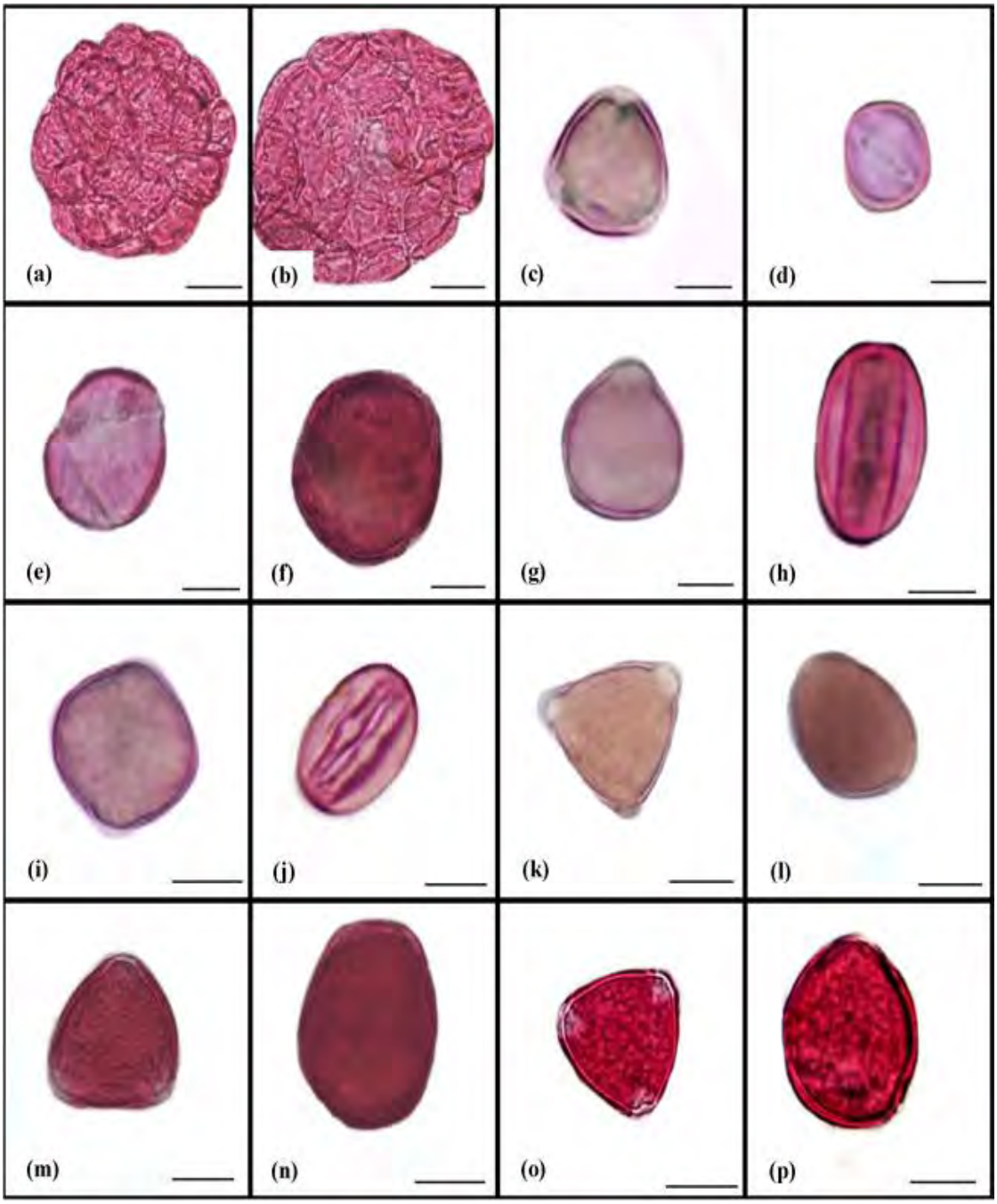

Plate 51. Light microscopic photographs showing polar and equatorial view; scale bar = 10 µm (a-b) *Acacia nilotica* (L.) Delile (c-d) *Alhagi maurorum* Medik. (e-f) *Bauhinia variegata* Linn. (g-h) *Crotalaria medicaginea* Lam. (i-j) *Crotalaria burhia* Benth. (k-l) *Erythrina suberosa* Roxb. (m-n) *Indigofera cordifolia* Roth (o-p) *Indigofera hochstetteri* Baker

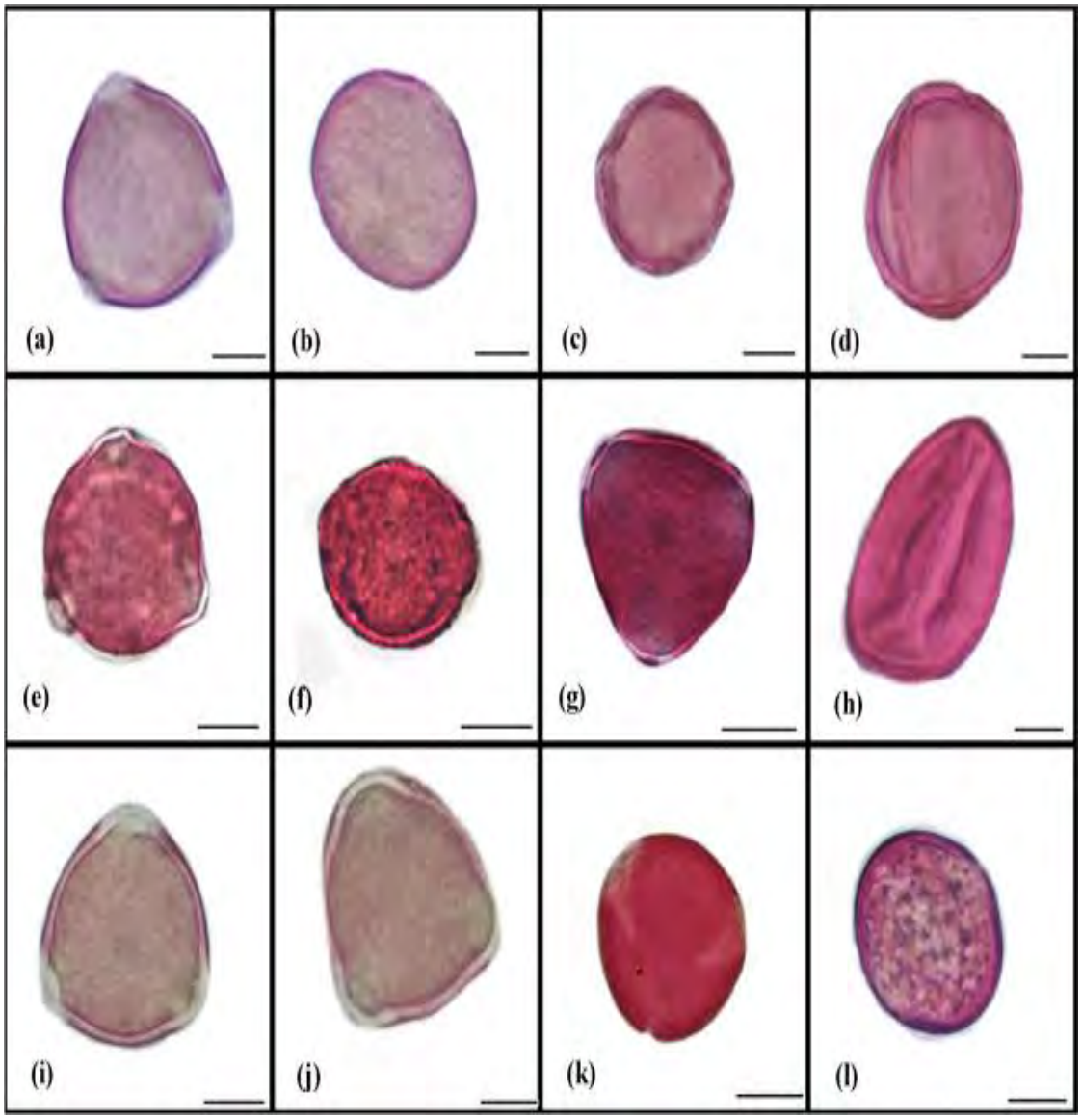

Plate 52. Light microscopic photographs showing polar and equatorial view; scale bar = 10 µm (a-b) *Melilotus albus* Medik. (c-d) *Prosopis glandulosa* Torr. (e-f) *Senna italica* Mill. (g-h) *Sesbania bispinosa* (Jacq.) W. Wight (i-j) *Tephrosia purpurea* (L.) Pers. (k-l) *Trifolium resupinatum* L.

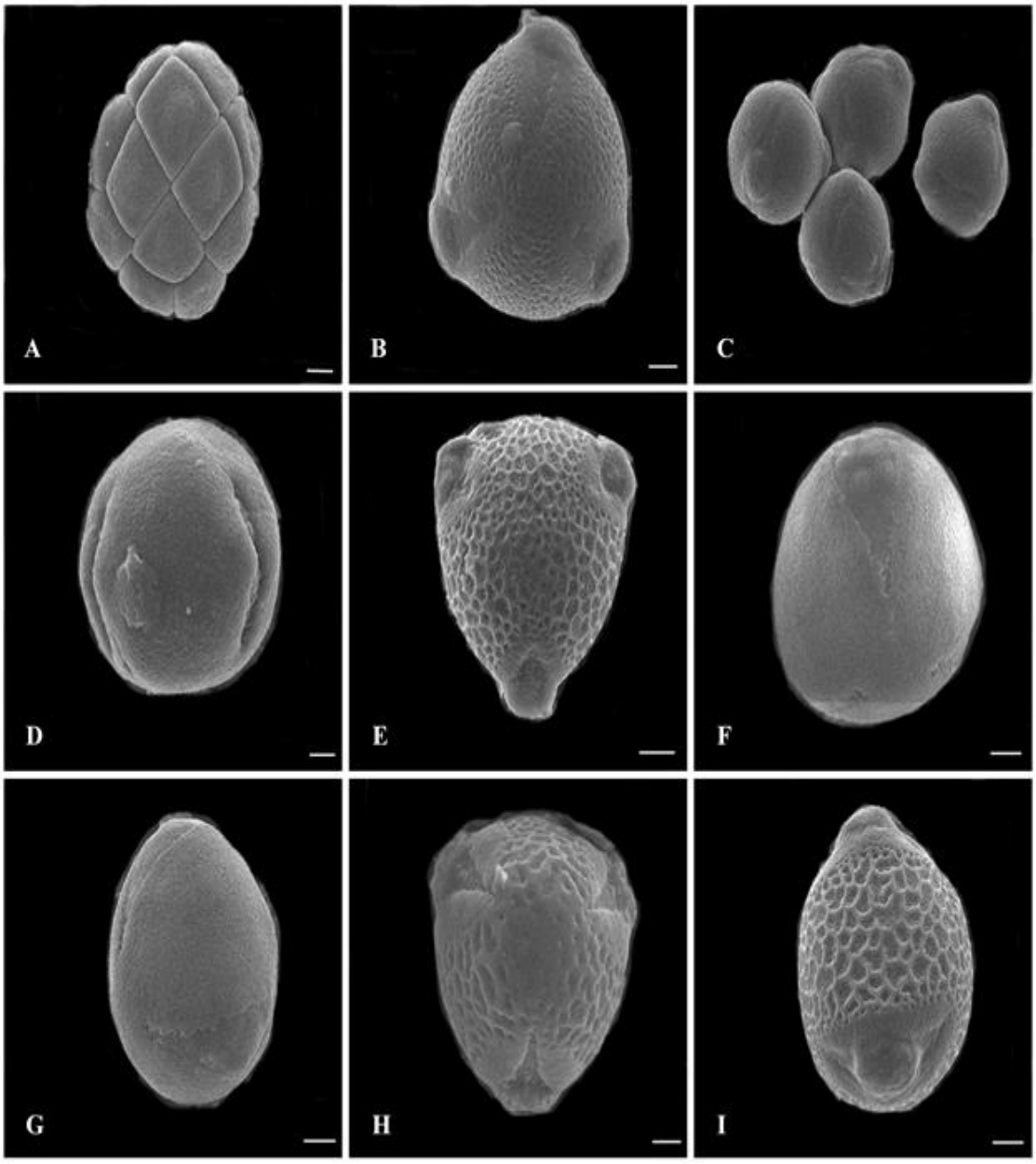

Plate 53. Scanning microscopic photographs (A) *Acacia nilotica*; scale bar = 10 µm (B) *Alhagi maurorum;* scale bar = 5 µm (C) *Bauhinia variegata;* scale bar = 10 µm (D) *Crotalaria medicaginea;* scale bar = 5 µm (E) *Crotalaria burhia;* scale bar = 10 µm (F) *Erythrina suberosa;* scale bar = 5 µm (G) *Indigofera cordifolia;* scale bar = 5 µm (H) *Indigofera hochstetteri*; scale bar = 5 µm (I) *Parkinsonia aculeata;* scale bar = 10 µm.

Figure 54. Scanning microscopic photographs (J) *Parkinsonia aculeata;* scale bar = 10 µm (K) *Prosopis glandulosa;* scale bar = 5 µm (L) *Senna italica;* scale bar = 5 µm (M) *Sesbania bispinosa;* scale bar = 10 µm (N) *Tephrosia purpurea;* scale bar = 5 µm (O) *Trifolium resupinatum;* scale bar = 5 µm.

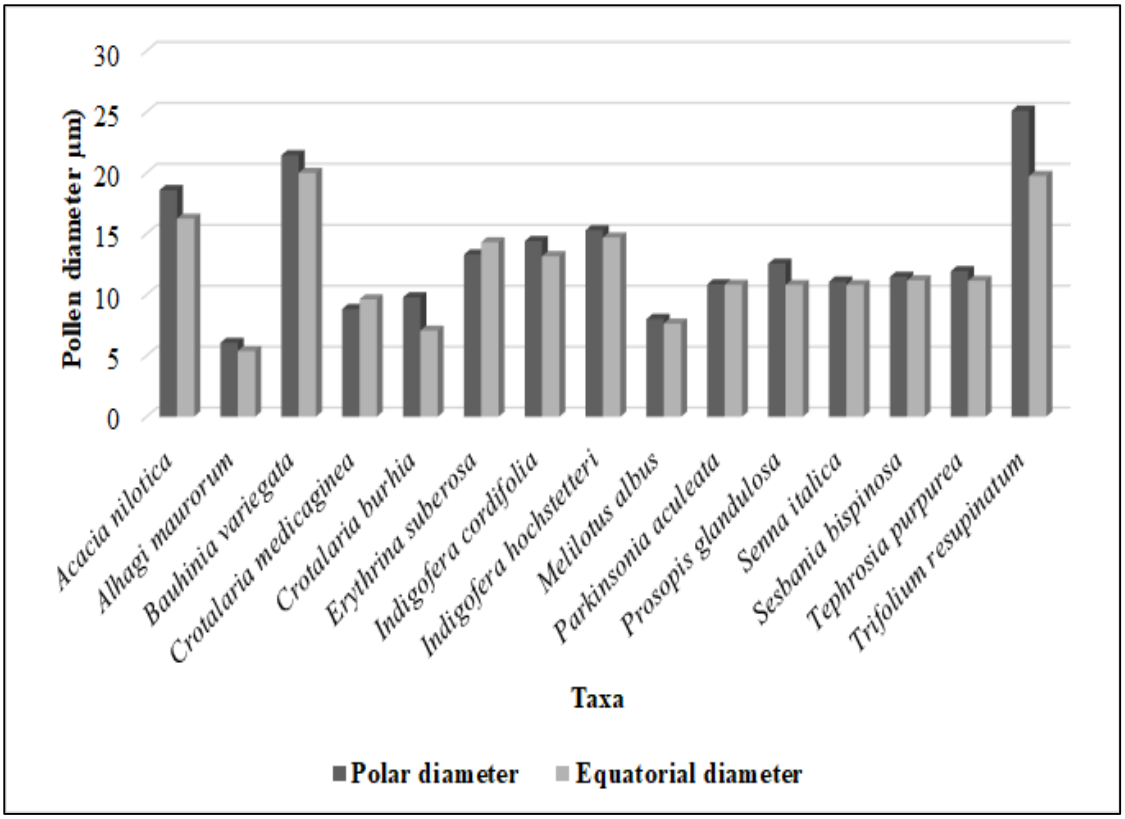

Figure 8. Variations in pollen diameter among leguminous taxa.

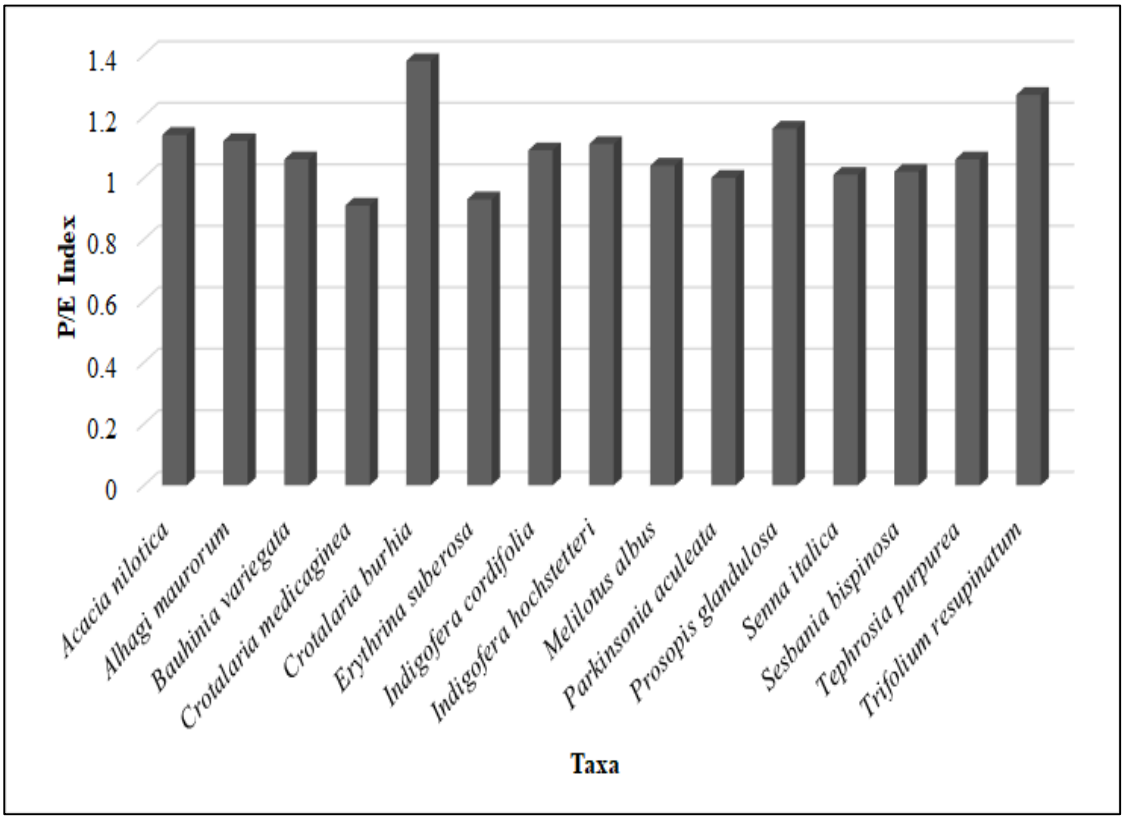

Figure 9. P/E index variations among selected leguminous taxa.

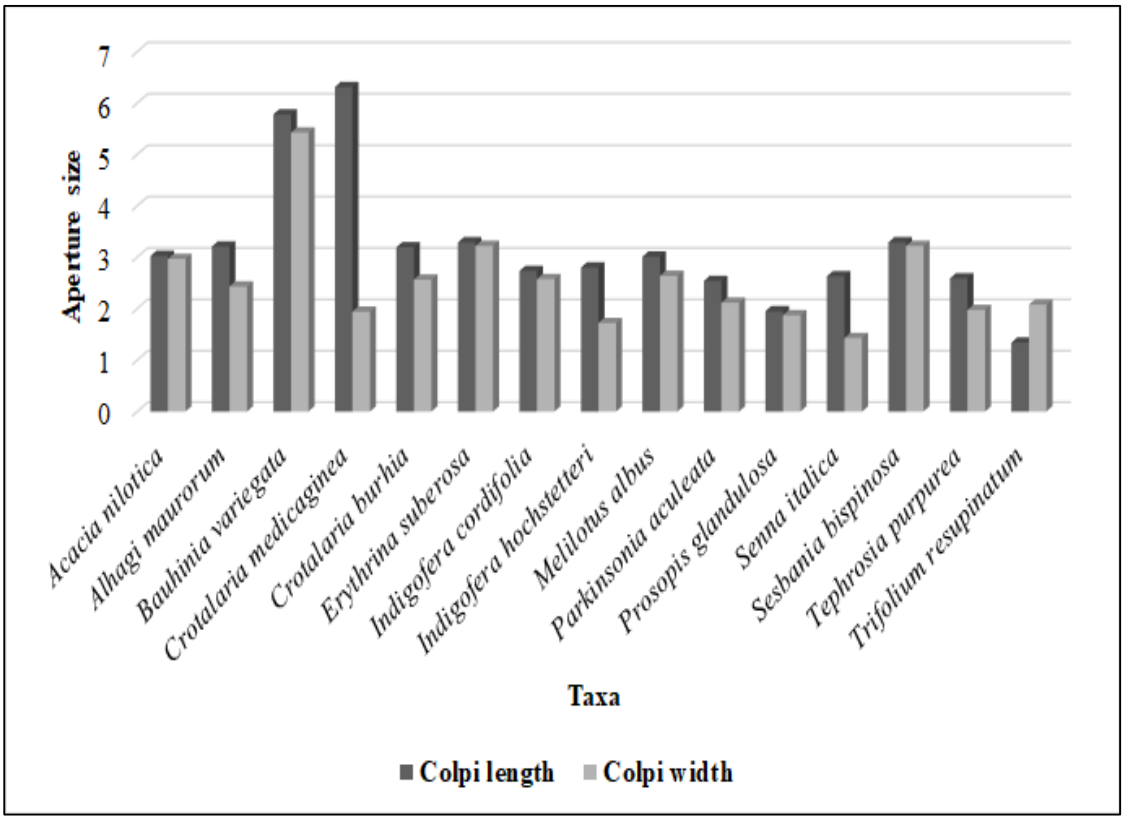

Figure 10. Average data variations of colpi size leguminous taxa.

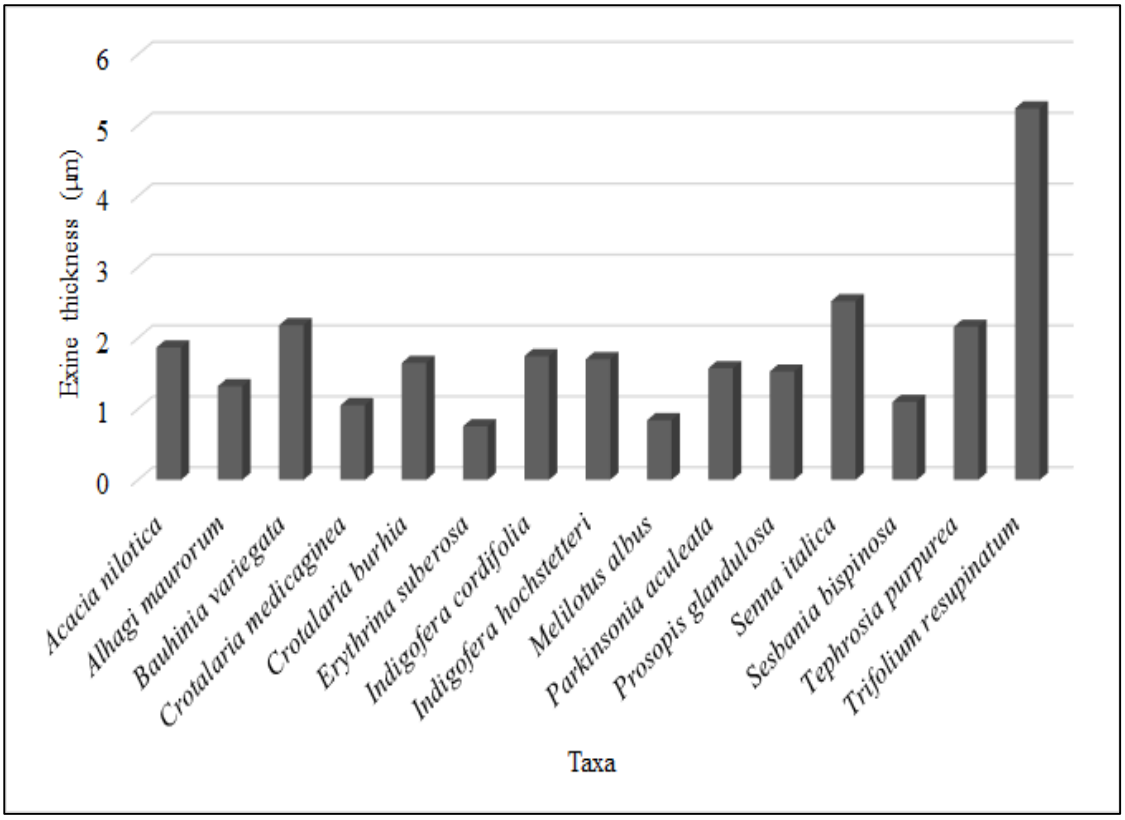

Figure 11. Mean exine thickness variations in studied leguminous taxa.

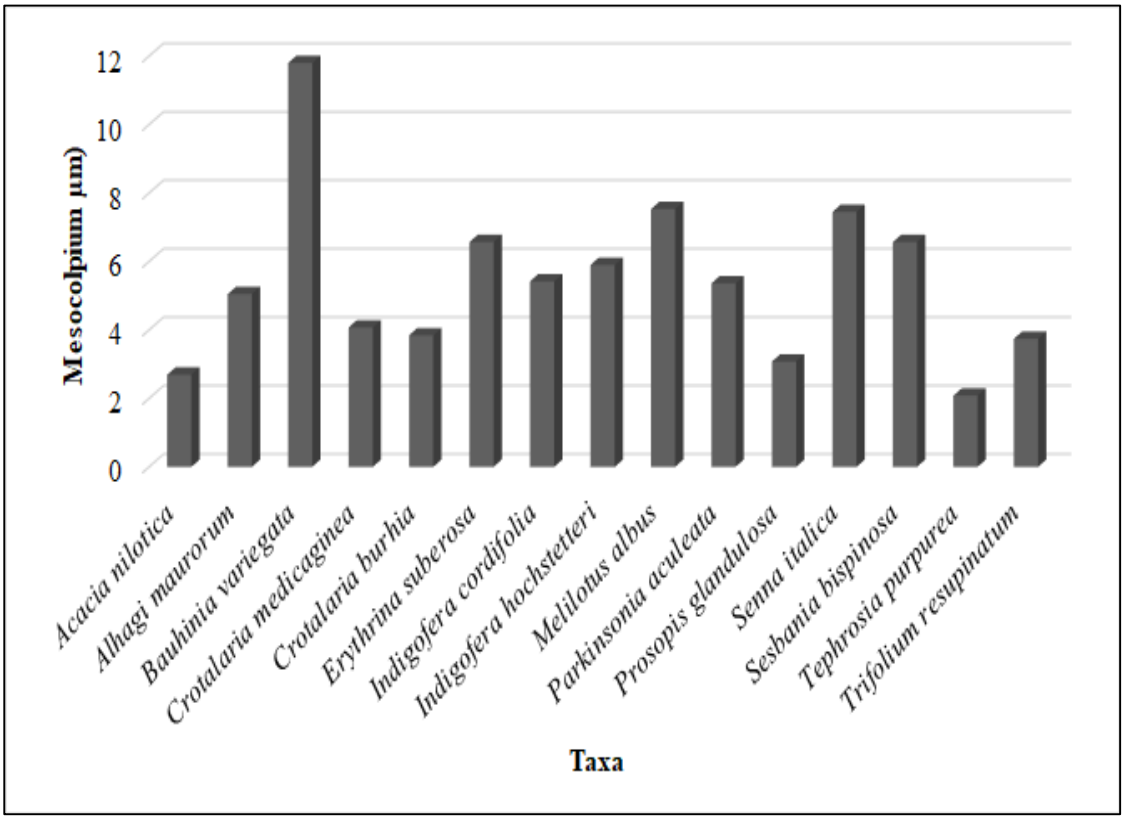

Figure 12. Average mesocolpium distance variations among leguminous taxa.

g. Discussion

Shape of Pollen grains is essential in taxonomic studies (Sufyan et al., 2018). comparative study of fabaceae plants indicates some significant taxonomic features reliable for micro-morphological study. Qalitative and quantitative results were given in the table no. 2 and 3. Many pecularities has been examined in the species of Fabaceae, examined feature such as exine sculpturing, aprture ornamentation, polarity, size, equatorial shape, P/E ration distinctive in all taxa which can be useful in taxonomic stuides.

In this palynological study, we observed Elliptic shape in polar view while in equatorial view Prolate-spheroidal and small size pollen in *Acacia nilotica* (L.) Delile. In previous study, the shape of pollen was rounded and Colporate (Shahzeb U. Khan et al., 2019). *Alhagi maurorum* Medik. has very small size of pollen grains, Semi Angular in polar shape and Prolate-spheroidal in equatorial view. The study published by (Perveen & Qaiser, 1998) results were different in numerical data but qualitative features are more or less similar. P/E ratio 1.12 calculated in our study was (1.12) whereas in previous study P/E ratio reported (1.04)

In *Bauhinia variegata* Linn., we observed semi Circular in polar view, Prolate-spheroidal in equatorial view, the type of pollen observed Tricolpate through LM. SEM micrographs results shows Exine sculpturing was Reticulate and Aperture orientation was Slightly Sunken. As we compare our study with previous research with (Maw et al., 2006) the results were circular in polar view, Prolate in equatorial view, Tricolpate pollen, Exine thickness 1.5-2.0 µm. Another study published from Iraq by (Al-timen et al., n.d.) he recorded mesocolpium 16.5 µm. The qualitative features of *Crotalaria medicaginea* were recorded in our research, size of pollen grain was Very small, Semi Triangular shape in polar view and Oblate-spheroidal in equatorial view. Pollen type recoded was Tricolporate. Sculpturing of exine was Reticulate-Verrucate with Slightly budged aperture. Quantitative data recorded was: Polar axis, equatorial axis, P/E ratio, length and width of Colpi, Mesocolpium. In previous research publication of (Bot, n.d.) has reported ethno-medicinal values of some species of genus *Crotalaria.* In this present research two species were under observation and both pollen grains size was Very small. Through (LM) we found polar and equatorial view were respectively semi

Angular and Prolate. Type of pollen grains were Tricolporate. SEM micrographs results show that Sculpturing of exine was Reticulate-Scabrate with Budged aperture.

Erythrina suberosa Roxb. Is tree present in wild as well in gardens as ornamental. This tree is leafless during the flowering season from February to mid-April. Flowers were very attractive birds and insects. In current study size of pollen was Small, Tricolporate type pollen with Triangular (Convex) view in polar and Oblate-spheroidal in equatorial view. Micrographs of SEM shows Reticulate-Scabrate with Bulged aperture. As we compare with previous findings of research published in 2013 (Hanif et al., 2013) more or less same qualitative feature were observed as give here 3-colporate with sub-triangular and small to medium grains size. Reticulate, exine sculpturing. In *Indigofera cordifolia* Roth Small size pollen. Semi Circular in polar view while in equatorial view Prolate-spheroidal shape observed. Tricolpate pollen type, exine sculpturing shows Psilate (smooth) with Slightly Bulged aperture orientation. As previous study of genus *Indigofera* of Taiwan shows more or less same qualitative features such as circular pollen in polar view and prolate in equatorial view. Some contradictions in previous results were in pollen type they reported colporate in mostly species of *Indigofera* (Wu & Huang, 1995) . A species *Indigofera hochstetteri* Baker was also shows some similarities with previous study(X. L. Zhao et al., 2016). The SEM micrographs shows Psilate - Scabrate exine whereas in previous research shows smooth (psilate-scabrate) to perforate, fossulate. Previous research studies by Anjum Perveen & Mohammad Qaiser (1998) (Perveen & Qaiser, 1998) Sidanand V Kambhar (2017) has only quantitative data analysis of various species of genus *Indigofera* (Arts, 2017).

Irum Khan (2019) (I. Khan et al., 2020) found the pollen grains *Melilotus albus* Medik were prolate, triangular, sub-prolate, and trizonocolporate with reticulate sculpturing however in present research we observed Semi Circular in polar view while in equatorial view the shape was Prolate-spheroidal, type of pollen: Tricolporate. The SEM micrographs shows Reticulate-Verrucate with Bulged orientation of aperture. *Melilotus albus* is a biennial herb, upright with white flowers. Mostly found in agricultural lands. This species has ability to adopt various ecological conditions. In view of conservation, according to the International Union for

Conservation of Nature (IUCN) this species is in category of Least Concern (LC) because it is invasive in nature (Hassemer et al., 2015).

In current research study qualitative features of *Parkinsonia aculeata L.* pollen grains were Very Small in size, polar view shape was Triangular and equatorial view shape was Spheroidal. The type of pollen: Tricolporate and Micrographs of SEM shows Reticulate exine sculpturing with Bulged orientation of aperture. If compared with previous findings of Rakshanda Aftab and Anjum Perveen (2006) (Aftab & Perveen, 2006) some dissimilarities found in that equatorial shape, non-angular in polar view but the pollen type and exine sculpturing is some as in our research. Another research study by Farhat Ullah (2021) the shape in polar view was circular, shape in equatorial: prolate which is opposite to our study whereas exine sculpturing some as current research (Ullah et al., 2022). In this comparative analysis obvious differences were observed in qualitative features of *Prosopis glandulosa* Torr. Compared with the former research of Shahzeb Ullah Khan (2020) (Shahzeb Ullah Khan et al., 2021). In this study, the shape of pollen was Prolate in equatorial view while type of pollen was Tricolporate. The SEM results shows exine reticulate with sunken aperture (Shahzeb Ullah Khan et al., 2021). In our present research findings, polar view shape is Semi Circular, in equatorial view shape is Sub-prolate and exine sculpturing was Psilate-Perforate with Slightly Bulged aperture. The type of pollen grains was same as in previous study: Tricolporate.

Pollen grains of *Senna italica* Mill. Was small size, circular in polar view while Prolate-spheroidal in equatorial view. Tricolporate pollen type and Verrucate exine sculpturing with Slightly Bulged orientation of aperture. Although some similarities were observed such as Circular shape in polar view and prolate, tricolporate, SEM results shows same exine sculpturing as in present research. S. M. El Naggar_ (2009) (El Naggar & Sallam, 2009) (Yousaf et al., 2022). In current research, size of pollen grains of *Sesbania bispinosa* (Jacq.) W. Wight were Small and shape in polar view is Triangular whereas in equatorial view the shape was Triangular with Psilate-Reticculate exine sculpturing. As compared with the previous findings of ghosh & Mundal (2016) (Ghosh & Mandal, 2016) was more or less similar as given here: Triangular, obtuse convax , prolate, elliptical reticulate (Waheed et al., 2021).

In view of present findings *Tephrosia purpurea* (L.) Pers. Have Prolate-spheroidal shape in equatorial view while in polar view the shape is semi angular. The type of pollen was Tricolporate. SEM micrographs shows Perforate-Reticulate with bulged aperture whereas the previous results show Areolate granulate sculpturing and micro reticulate mesocolpium (Antonio-Domingues et al., 2019) while another study the shape of equatorial view is Prolate spheroidal with psilate exine sculpturing elkordia et al 2022 Previously research finding of Lashin (2006) exine sculpturing *Trifolium resupinatum* L. was micro reticulate while in our research SEM results show Reticulate-Scabrate with Bulged aperture. The type of pollen was tricolporate with prolate in polar view (I. Khan et al., 2020). In current research, we observed sub-prolate in view in polar and tricolporate. More or less same qualitative feature were observed in this taxa as compared with previous findings. In this camparative study, we analyzed various literature published on palynological studies. Many similarities and differences were observed in qualitative results. More extensive research is reqired to understand the palynological aspect of Fabaceae family.

3.3.2 Palynological findings of flora in Takkar Wildlife Sanctuary

This section described the pollen morphometric features of 17 species in detailed as summarized in Table 10 and 11.

a) *Abutilon indicum* (L.) Sweet

Pollen grain large sized, Circular in polar view, Globose in equatorial, Zonoporate pollen type. Spine apex is blunt (acute) and base is bulbous. Minute perforations between spines. Rugose pattern and granules. Polar and equatorial diameter was found to be 103.5(10.8-110.50) ± 0.57 µm and 109.25(107.75-111.25) ±0.69 µm, respectively. Exine thickness was calculated 8.55(8.25-8.75) ±0.09 µm. P/E ratio measured was 1.0. Maximum and minimum calculated mesocolpium is 76.05(72.25-80.50) ±1.80. Recorded fertility is 68% while Sterility is 9% (Plate 55 a-c).

b) *Anticharis glandulosa* Asch.

Pollen grains were medium in size, tricolporate pollen type. Exine sculpturing is psilate. Shape of pollen in polar view was circular and sub-prolate in equatorial view. Polar and equatorial diameter was found to be 35.05(29.75-38.75) ±1.66 µm and 34.80(27.75-38.50) ±1.96 µm, respectively. Exine thickness was calculated 2.55(2.25-2.75) ±0.12 µm. P/E ratio measured was 1.0. Maximum and minimum calculated mesocolpium is 41–1.75 = 1.40 ± 0.06. Recorded fertility is 83% while Sterility is 3% (Plate 55 d-f).

c) ***Citrullus colocynthis* (L.) Schrad**

Pollen grain small sized, Sub-oblate to oblate in equatorial view while in polar view shape triangular (convex). Coarsely reticulate exine sculpturing observed in SEM micrographs. Polar and equatorial diameter was found to be 113.10(110.50-115.25) ±0.83 µm and 110.15(108.75-111.25) ±0.4 µm, respectively. Exine thickness was calculated 3.20(2.75-3.75) ±0.16 µm. P/E ratio measured was 1.02. Calculated mesocolpium is 87.05(80.25-109.50) ±5.64. Recorded fertility is 76% while Sterility is 8% (Plate 55 g-i).

d) *Cleome brachycarpa* (Forssk.) Vahl ex DC.

Pollen grain medium sized, Prolate shape in equatorial view whereas triangular in polar view. tricolporate pollen type. Reticulate exine sculpturing observed in SEM micrographs. Polar and equatorial diameter was found to be 33.55(32.0-37.75) ±1.06 µm and 32.10(28.75-34.75) ±1.17 µm, respectively. Exine thickness was calculated 0.95(0.75-1.25) ±0.09 µm. P/E ratio measured was 1.04. Calculated mesocolpium is 26.25(23.75-30.50) ±1.21. Recorded fertility is 85% while Sterility is 3% (Plate 56 a-c).

e) *Corchorus tridens* L.

Pollen grain medium sized, Sub-Prolate shape in equatorial view while in polar view shape is rounded, tricolporate grain type, observed SEM micrographs shows reticulate exine ornamentation. Polar and equatorial diameter was found to be 30.3(27.75-32.0) ±0.73 µm and 29.3(28.0-30.25) ±0.40 µm, respectively. Exine thickness was calculated 2.95(2.75-3.25) ±0.09 µm. P/E ratio measured was 1.03. Calculated mesocolpium is 23.61(71.25-72.75) ±2.21 µm. Recorded fertility is 89% while Sterility is 16% (Plate 56 d-f).

f) *Cressa cretica* L.

Pollen grain large sized, Prolate-spheroidal in equatorial view while in polar view shaped was Elliptical. Tricolpate pollen types were observed. Micrographs of SEM showed Psilate exine sculpturing. Polar and equatorial diameter was found to be 28.55(28.25-28.75) ±0.09 µm and 20.25(19.75-20.50) ±0.13 µm, respectively. Exine thickness was calculated 0.40(0.25-0.50) ±0.06 µm. P/E ratio measured was 1.40. Calculated mesocolpium is 32.6(41.0-41.0) ±0.17. Recorded fertility is 86% while Sterility is 3% (Plate 56 g-i).

g) *Farsetia jacquemontii* Hook.f. & Thomson

Pollen grain small sized, oblate-spheroidal shape in equatorial view while in polar view the shape of grain is circular. Tricolpate type pollen, reticulate exine ornamentation observed in SEM micrographs. Polar and equatorial diameter was found to be 54.75(53.0-55.50) ±0.45 µm and 52.0(49.75-53.0) ±0.58 µm, respectively. Exine thickness was calculated 2.15(2.0-2.25) ±0.61 µm. P/E ratio measured was 1.05.

Calculated mesocolpium is 48.75(48.50-49.0_±0.07 µm. Recorded fertility is 93% while Sterility is 5%. (Plate 57 a-c).

h) *Farsetia stylosa* R.Br.

Pollen grain medium sized, monad, Sub-oblate in equatorial view while circular in polar view, tricolporate type pollen, observed exine sculpturing is psilate. Polar and equatorial diameter was found to be 28.55(27.25-29.75) ±0.47 µm and 24.90(24.50-25.25) ±0.15 µm, respectively. Exine thickness was calculated 1.80(1.25-2.25) ±0.16 µm. P/E ratio measured was 1.16. Recorded fertility is 77% while Sterility is 5% (Plate 57 d-f).

i) *Gisekia pharnaceoides* L.

Pollen grain medium-large sized, Apiculate in equatorial view while in polar view Trilobate shape, Tricolpate pollen type, observed exine sculpturing is Spinulate and punctate. Polar and equatorial diameter was found to be 43.90 (49.50-50.25) ±0.15 µm and 49.1 (48.75-49.25) ±0.10 µm, respectively. Exine thickness was calculated 3.0 (2.75-3.25) ±0.07 µm. P/E ratio measured was 1.03. Calculated mesocolpium is 41.70 (41.0-42.25) ±0.21. Recorded fertility is 79% while Sterility is 3% (Plate 55 g-i).

j) *Haloxylon stocksii* (Boiss.) Benth. & Hook. f.

Pollen grain small sized, monad, Prolate-spheroidal shape in equatorial view while Spherical in polar view, Periporate type pollen. micro-echinate perforate sculpturing has been observed with scabrate surface. Polar and equatorial diameter was found to be 47.3 (45.75-48.0) ±0.40 µm and 48.25 (46.25-49.75) ±0.68µm, respectively. Exine thickness was calculated 2.40(2.0-2.75) ±0.15 µm. P/E ratio measured was 1.03. Calculated mesocolpium is 30.0 (29.50-30.75) ±0.22. Recorded fertility is 67% while Sterility is 2%. Scabrate Pollen surface, Exine sculpturing: densely micro-echinate perforate (Plate 58 a-c).

k) *Heliotropium bacciferum* Forssk.

Pollen grain medium-large sized, Prolate shape in equatorial view whereas Elliptical in polar view, Pollen grains were Zonoporate type, Sub-psilate sculpturing has been observed in SEM micrographs. Polar and equatorial diameter was found to be 53.6(45.50-57.0) ±2.13 µm and 53.0(47.25-57.25) ±1.63 µm, respectively. Exine

thickness was calculated 42.6(42.0-43.0) ±0.20 µm. P/E ratio measured was 1.03. Calculated mesocolpium is 42.6(42.0-43.0) ±0.20. Recorded fertility is 89% while Sterility is 3% (Plate 58 d-f).

l) ***Ipomoea aquatic*** **Forssk.**

Pollen grain medium-large sized, spheroidal shape in equatorial view and Isopolar. Pantoporate pollen types. Coarsely reticulate sculpturing has been observed. Polar and equatorial diameter was found to be 49.35(48.25-50.75) ±0.42 µm and 46.30(45.25-48.75) ±0.63 µm, respectively. Exine thickness was calculated 2.10 (2.0-2.25) ±0.06 µm. P/E ratio measured was 1.03. Calculated mesocolpium is 32.95 (32.75-33.25) ±0.09. Recorded fertility is 72% while Sterility is 3% (Plate 55 g-i).

m) ***Lantana camara*** **L.**

Pollen grain medium-large sized, monad, oblate-spheroidal shape was observed in equatorial view and, circular shaped in polar view. Pollen type is Colporate. Psilate, sculpturing was observed in micrographs of SEM. Polar and equatorial diameter was found to be 26.95(26.25-27.25) ±0.18 µm and 27.80(27.25-28.25) ±0.16 µm, respectively. Exine thickness was calculated 2.75(2.25-3.0) ±0.13 µm. P/E ratio measured was 0.96. Calculated mesocolpium is 21.50(20.50-22.0) ±0.28 Recorded fertility is 92 % while Sterility is 4 % (Plate 59 a-c).

n) ***Polygonum plebeium R.Br.***

Pollen grain Medium-large sized, monad, Prolate- spheroidal shape in equatorial view while spherical in polar view. Pollen grains type: colporate. Perforated exine sculpturing was observed. Polar and equatorial diameter was found to be 67.45(92.0-107.75)0.32 µm and 47.19(88.50-109.50) ±3.37 µm, respectively. Exine thickness was calculated 2.55(2.0-3.0) ±0.18 µm. P/E ratio measured was 1.03. Calculated mesocolpium is 87.05(80.25-109.50) ±5.64. Recorded fertility is 76% while Sterility is 8% (Plate 59 d-f).

o) ***Thymelaea passerina*** **(L.) Coss. & Germ.**

Pollen grain Medium sized, monad, spheroidal shape in equatorial view whereas in polar view shape is circular, Porate: pollen grain type. psilate, and lophoreticulate sculpturing has been observed. Polar and equatorial diameter was found to be

67.45(92.0-107.75)0.32 µm and 47.19(88.50-109.50) ±3.37µm, respectively. Exine thickness was calculated 1–1.50 = 1.20 ± 0.06 µm. P/E ratio measured was 1.01. Calculated mesocolpium is 36.1(59.25-78.25) ±3.60. Recorded fertility is 60% while Sterility is 3% (Plate 59 g-i).

p) *Zygophyllum indicum* (Burm.f.) Christenh. & Byng

Pollen grain medium sized, monad, oblate-spheroidal, tricolporate psilate, and lophoreticulate sculpturing has been observed. Polar and equatorial diameter was found to be 97.25–120.50 = 109.58 ± 2.10 µm and 91.75–116.50 = 106.20 ± 2.27 µm, respectively. Length of colpi was measured 1–1.75 = 1.40 ± 0.06 µm and width was 1–1.50 = 1.20 ± 0.06 µm. Exine thickness was calculated 1–1.50 = 1.20 ± 0.06 µm. P/E ratio measured was 1.03. Calculated mesocolpium is 87.05(80.25-109.50) ±5.64. Recorded fertility is 76% while Sterility is 8% (Plate 60 a-c).

q) *Zygophyllum simplex* L.

Pollen grain medium sized, monad, oblate-spheroidal, tricolporate psilate, and lophoreticulate sculpturing has been observed. Polar and equatorial diameter was found to be 97.25–120.50 = 109.58 ± 2.10 µm and 91.75–116.50 = 106.20 ± 2.27 µm, respectively. Length of colpi was measured 1–1.75 = 1.40 ± 0.06 µm and width was 1–1.50 = 1.20 ± 0.06 µm. Exine thickness was calculated 1–1.50 = 1.20 ± 0.06 µm. P/E ratio measured was 1.03. Calculated mesocolpium is 87.05(80.25-109.50) ±5.64. Recorded fertility is 76% while Sterility is 8% (Plate 55 d-f).

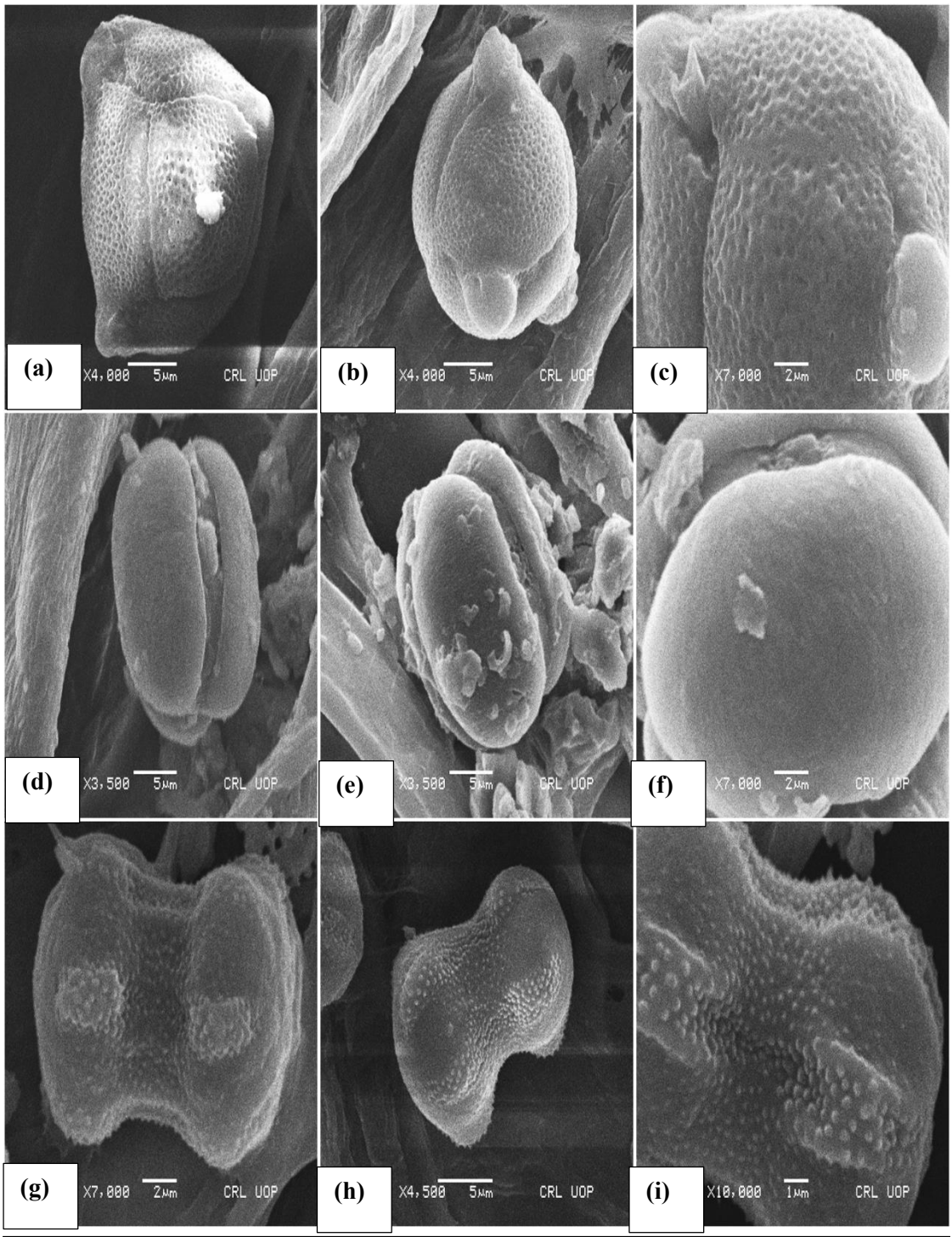

Plate 55. SEM micrographs of pollen grains, pollen surface pattern and exine peculiarities. (**a-c)** *Anagallis arvensis* scale bar 5 µm & 2 µm, **(c-d)** *Anticharis glandulosa* scale bar 5 µm & 2 µm, (**e-f)** *Arnebia hispidissima* scale bar 5 µm, 2 µm & 1 µm.

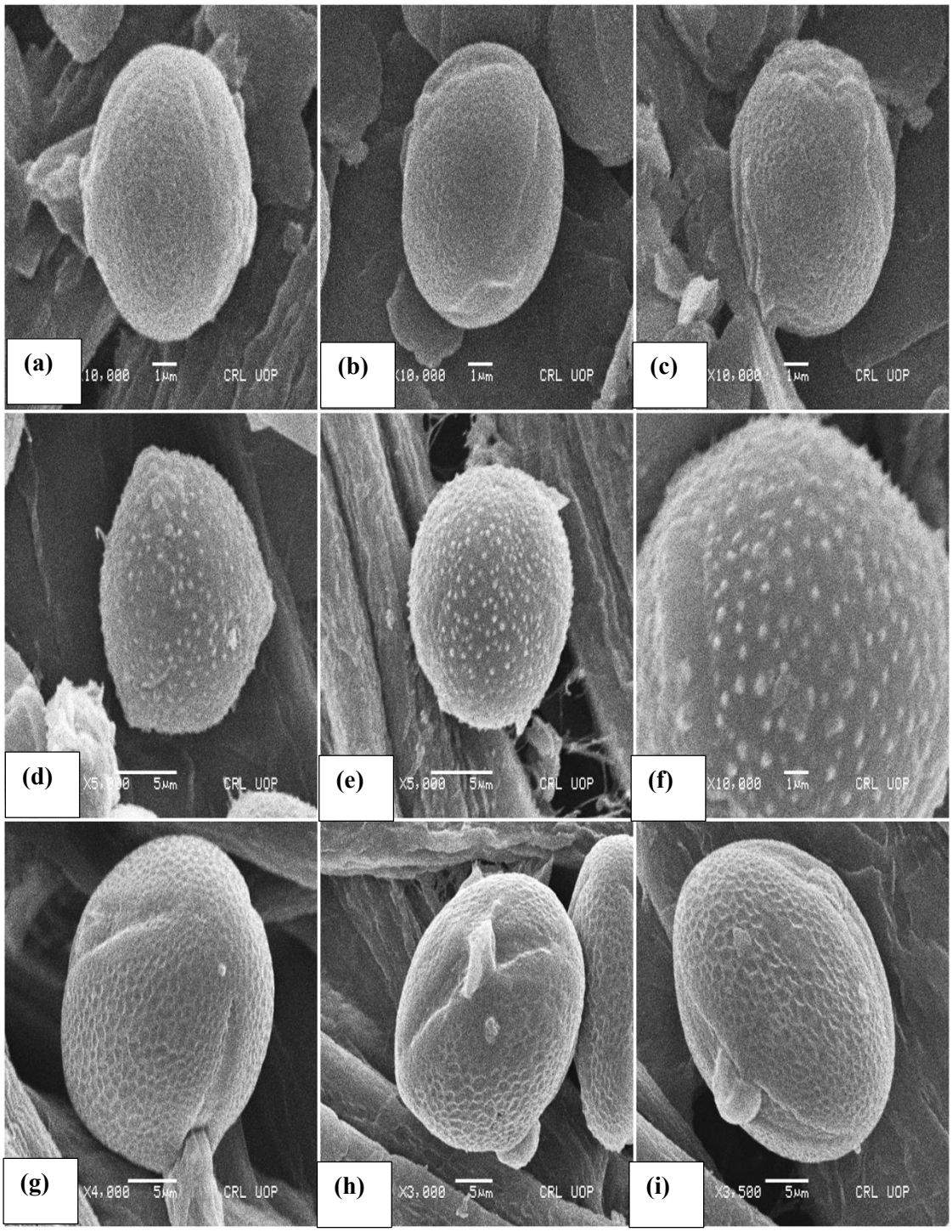

Plate 56. SEM micrographs of pollen grains, pollen surface pattern and exine peculiarities. (**a-c)** *Citrullus colocynthis* scale bar 1 µm, **(c-d)** *Cleome brachycarpa* scale bar 5 µm & 1 µm, (**e-f)** *Corchorus tridens* scale bar 5 µm.

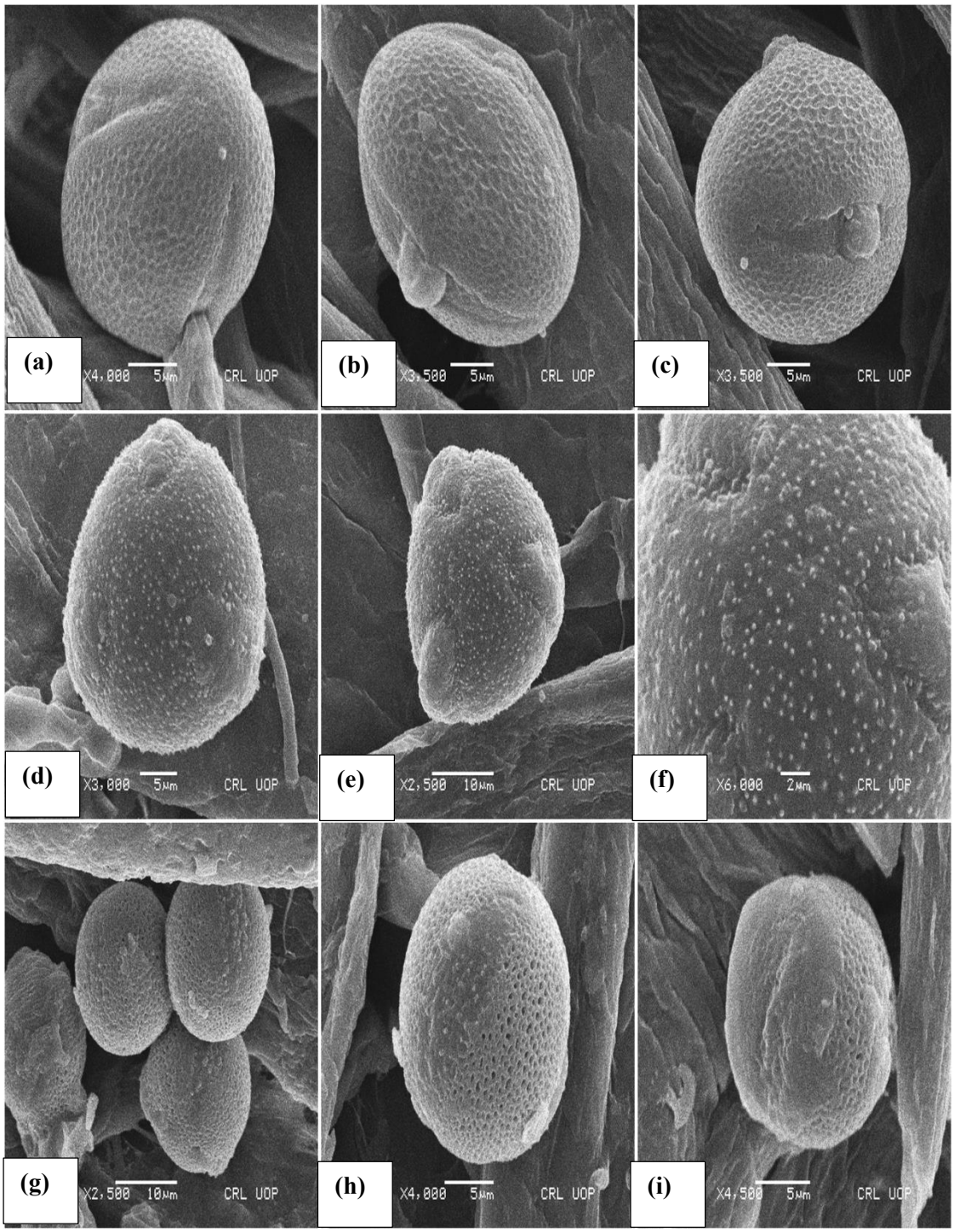

Plate 57. SEM micrographs of pollen grains, pollen surface pattern and exine peculiarities. (**a-c)** *Cressa cretica* scale bar 5 µm, **(c-d)** *Farsetia jacquemontii* scale bar 10 µm, 5 µm & 1 µm, (**e-f)** *Farsetia stylosa* scale bar 10 µm & 5 µm.

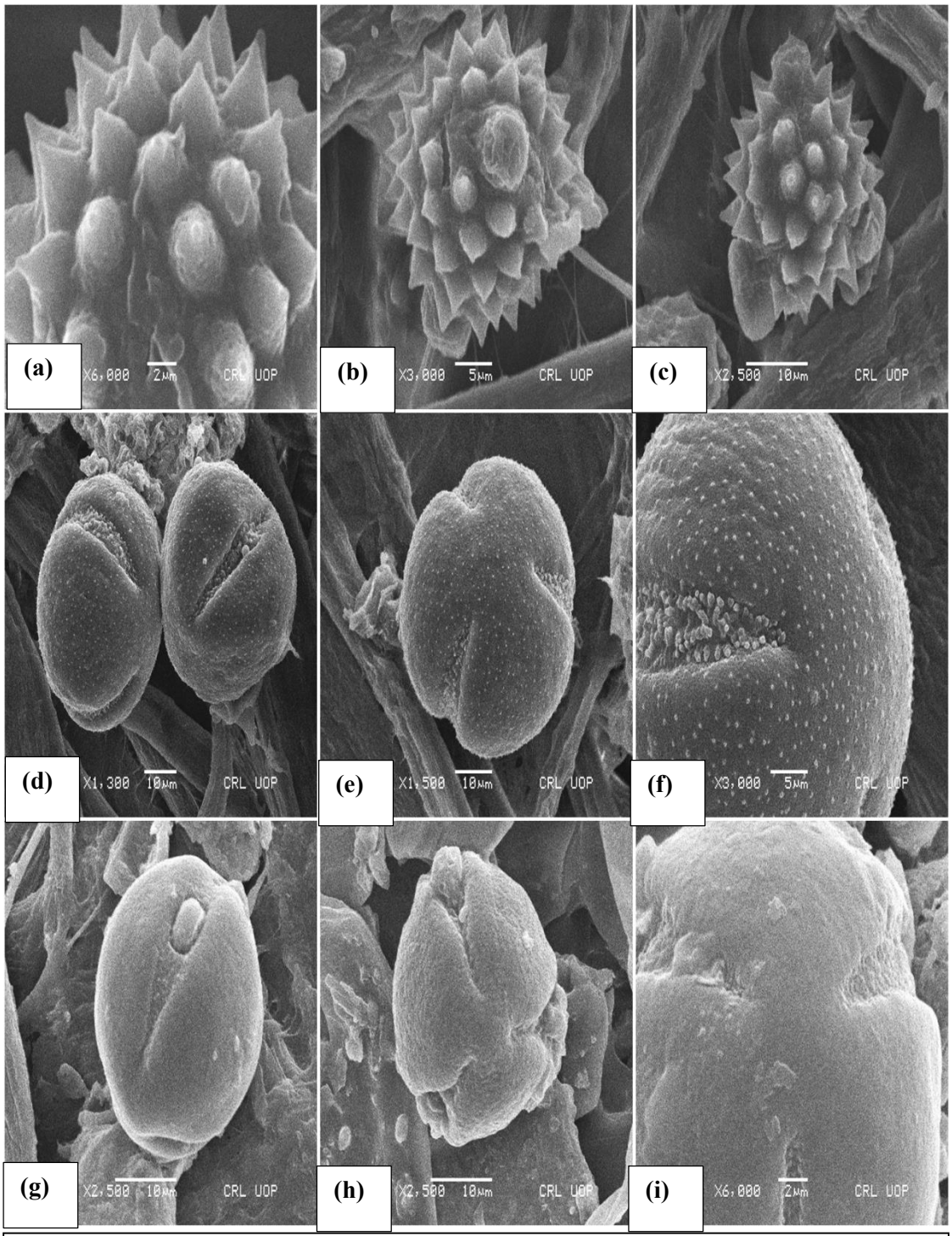

Plate 58. SEM micrographs of pollen grains, pollen surface pattern and exine peculiarities. (**a-c)** *Iphiona aucheri* scale bar 10 µm, 5 µm & 2 µm, **(c-d)** *Gisekia pharnaceoides* scale bar 10 µm, 5 µm & 1 µm, (**e-f)** *Heliotropium bacciferum* scale bar 2 µm & 10 µm.

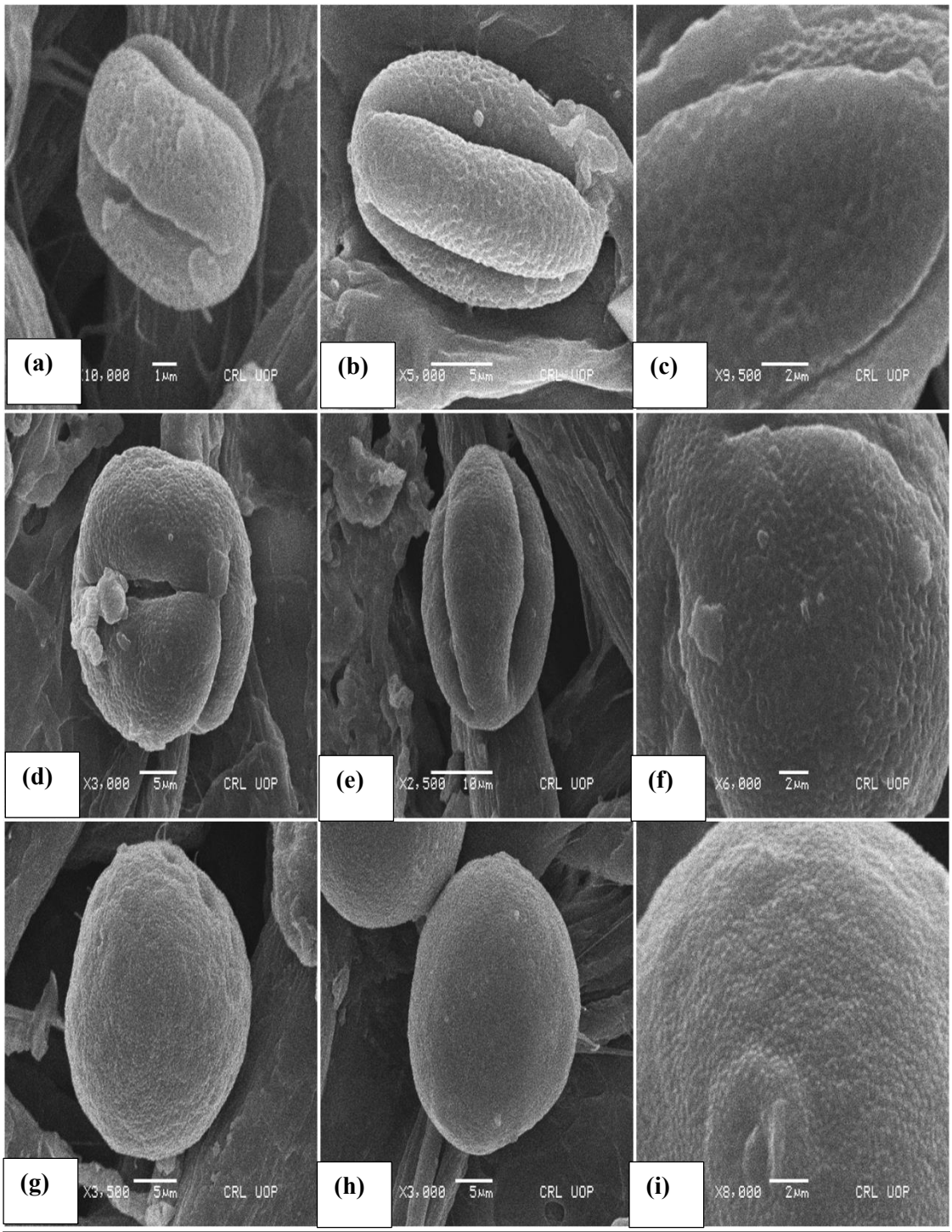

Plate 59. SEM micrographs of pollen grains, pollen surface pattern and exine peculiarities. (**a-c)** *Ipomoea aquatic* scale bar 1 µm, 5 µm & 2 µm, **(c-d)** *Lantana camara* scale bar 10 µm, 5 µm & 2 µm, (**e-f)** *Thymelaea passerina* scale bar 2 µm & 10 µm.

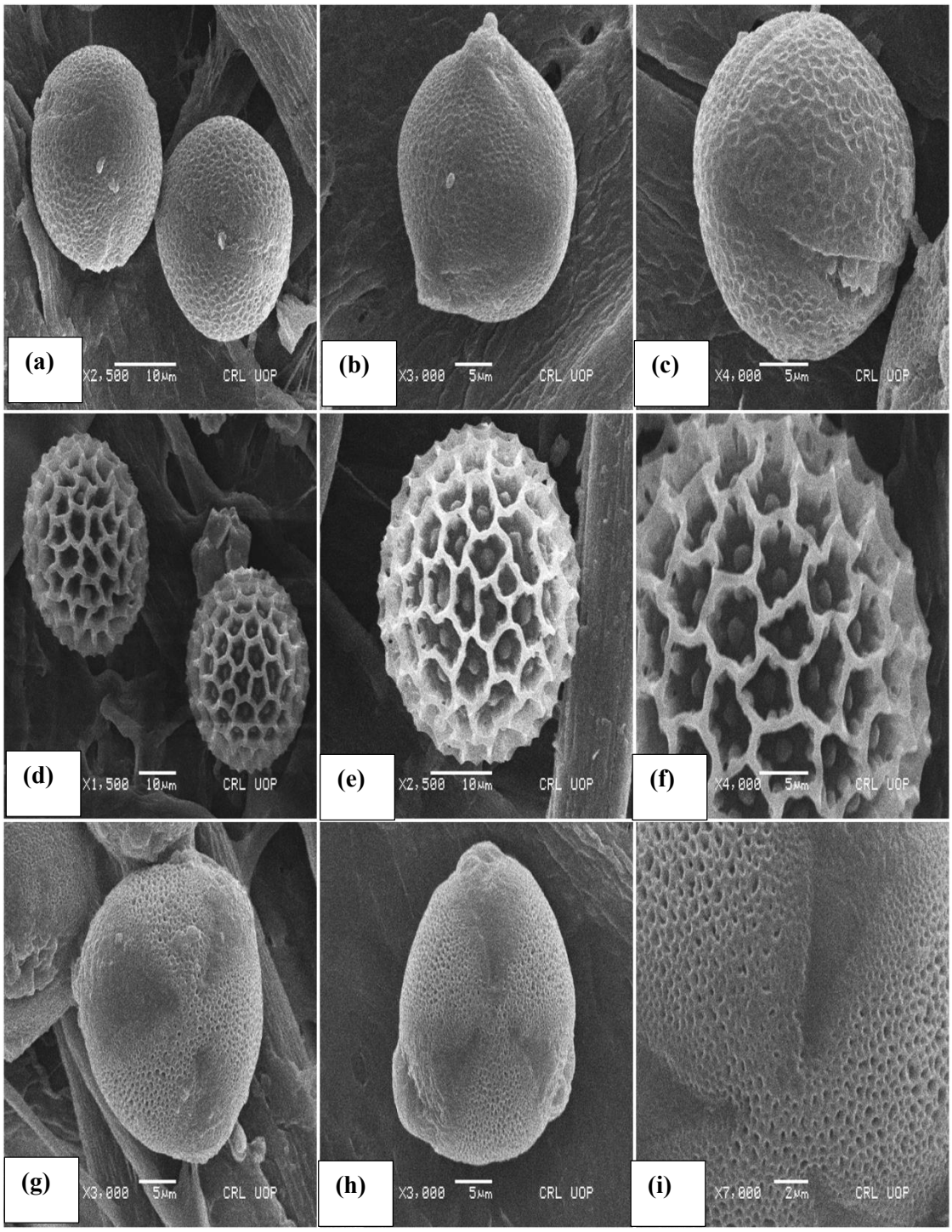

Plate 60. SEM micrographs of pollen grains, pollen surface pattern and exine peculiarities. (**a-c)** *Ipomoea aquatic* scale bar 1 µm, 5 µm & 2 µm, **(c-d)** *Tribulus pentandrus* scale bar 10 µm & 5 µm & 2 µm, (**e-f)** *Zygophyllum simplex* scale bar 5 µm & 2 µm.

Table 10. List of qualitative features of pollen of Plant species from Takkar Wildlife Sanctuary.

Sr. No	Plant name	Family	Shape in equatorial view	Shape in polar view	Pollen size	Exine surface	Pollen type	Aperture orientation	Fastigium cavity
1.	*Abutilon indicum* (L.) Sweet	Malvaceae	Globose	Spherical	large	Rugose	Zonoporate	Deeply sunken	-
2.	*Anticharis glandulosa* Asch.	Scrophulariaceae	Sub-oblate	Circular	Medium	Psilate	Tricolporate	-	-
3.	*Citrullus colocynthis (L.) Schrad*	Cucurbitaceae	Sub-oblate to oblate	Triangular (Convex)	small	Coarsely reticulate	Porate	Pore circular	-
4.	*Cleome brachycarpa* (Forssk.) Vahl ex DC.	Cleomaceae	Prolate	Triangular	Medium	Reticulate	Tricolporate	Sunken / spinulose	+
5.	*Corchorus tridens* L.	Malvaceae	Sub-Prolate	Round	Medium	Reticulate	Tricolporate	-	-
6.	*Cressa cretica* L.	Convolvulaceae Juss.	Prolate-spheroidal	Elliptical	Large	Psilate	Tricolpate	-	-
7.	*Farsetia jacquemontii* Hook.f. & Thomson	Brassicaceae	Oblate-spheroidal	circular	small	Reticulate	Tricolpate	Slightly bulged	-
8.	*Farsetia stylosa* R.Br.	Brassicaceae	Sub-oblate	Circular	Medium	Psilate	Tricolporate	-	-
9.	*Gisekia pharnaceoides* L.	Gisekiaceae	Apiculate	Trilobate	Medium-Large	Spinulate, finely punctate	Tricolpate	Sunken	-
10.	*Haloxylon stocksii* (Boiss.) Benth. & Hook. f.	Amaranthaceae	Prolate-spheroidal	Spherical	Small	densely micro-echinate perforate	Periporate	Slightly Sunken	-
11.	*Heliotropium bacciferum* Forssk.	Boraginaceae	Prolate	Elliptical	Medium-Large	Sub-Psilate	Zonoporate	Sunken	+
12.	*Ipomoea aquatic* Forssk.	Convolvulaceae Juss.	spheroidal	Isopolar	Medium-Large	Coarsely reticulate	pantoporate	Deeply bulged	-
13.	*Lantana camara* L.	Verbenaceae	Oblate-spheroidal	Triangular	Medium	psilate	Tricolpate	Bulged	-
14.	*Polygonum plebeium R.Br.*	Polygonaceae Juss.	Prolate-spheroidal	Spherical	Medium-large	perforate	Calporat	Deeply bulged	+
15.	*Thymelaea passerina* (L.) Coss. & Germ.	Thymelaeaceae	Spheroidal	Circular	medium	Irregular	Porate	Echinate, reticulum	-
16.	*Zygophyllum indicum (Burm.f.) Christenh. & Byng*	Zygophyllaceae	Prolate-spheroidal	Spherical	Large	Echinate	Polyporate	-	-
17.	*Zygophyllum simplex* L	Zygophyllaceae	Spherical	Spherical	Large - Very large	Echinate	Polyporate	-	-

Table 11. Quantitative pollen data measurement of Takkar Wildlife Sanctuary flora.

Sr. No	Plant name	Polar Diameter Mean (Min-Max) S.E µm	Equatorial Diameter Mean (Min-Max) S.E µm	P/E ratio	Exine thickness Mean (Min-Max) S.E µm	Mesocolpium Mean (Min-Max) S.E µm	Fertility %	Sterility %
1.	*Abutilon indicum* (L.) Sweet	103.5(10.8-110.50)± 0.57	109.25(107.75-111.25)±0.69	1.0	8.55(8.25-8.75)±0.09	76.05(72.25-80.50)±1.80	68%	9%
2.	*Anticharis glandulosa* Asch.	35.05(29.75-38.75)±1.66	34.80(27.75-38.50)±1.96	1.0	2.55(2.25-2.75)±0.12	41–1.75 = 1.40 ± 0.06	83%	3%
3.	*Citrullus colocynth his (L.) Schrad*	113.10(110.5-115.2)±0.83	110.15(108.75-111.25)±0.45	1.02	3.20(2.75-3.75)±0.16	87.05(80.25-109.50)±5.64	76%	8%
4.	*Cleome brachycarpa* (Forssk.) Vahl ex DC.	33.55(32.0-37.75)±1.06	32.10(28.75-34.75)±1.17	1.04	0.95(0.75-1.25)±0.09	26.25(23.75-30.50)±1.21	85%	3%
5.	*Corchorus tridens* L.	30.3(27.75-32.0)±0.73	29.3(28.0-30.25)±0.40	1.03	2.95(2.75-3.25)±0.09	23.61(71.25-72.75)±2.21	89%	16%
6.	*Cressa cretica* L.	28.55(28.25-28.75)±0.09	20.25(19.75-20.50)±0.13	1.40	0.40(0.25-0.50)±0.06	32.6(41.0-41.0)±0.17	86%	3%
7.	*Farsetia jacquemontii* Hook.f. & Thomson	54.75(53.0-55.50)±0.45	52.0(49.75-53.0)±0.58	1.05	2.15(2.0-2.25)±0.61	48.75(48.50-49.0_±0.07	93%	5%
8.	*Farsetia stylosa* R.Br.	28.55(27.25-29.75)±0.47	24.90(24.50-25.25)±0.15	1.16	1.80(1.25-2.25)±0.16	-	77%	5%
9.	*Gisekia pharnaceoides* L.	49.90(49.50-50.25)±0.15	49.1(48.75-49.25)±0.10	1.01	3.0(2.75-3.25)±0.07	41.70(41.0-42.25)±0.21	79%	3%
10.	*Haloxylon stocksii* (Boiss.) Benth. & Hook. f.	47.3(45.75-48.0)±0.40	48.25(46.25-49.75)±0.68	0.98	2.40(2.0-2.75)±0.15	30.0(29.50-30.75)±0.22	67%	2%
11.	*Heliotropium bacciferum* Forssk.	53.6(45.50-57.0)±2.13	53.0(47.25-57.25)±1.63	1.01	3.70(2.25-4.75)±0.47	42.6(42.0-43.0)±0.20	89%	3%
12.	*Ipomoea aquatic* Forssk.	49.35(48.25-50.75)±0.42	46.30(45.25-48.75)±0.63	1.06	2.10(2.0-2.25)±0.06	32.95(32.75-33.25)±0.09	72%	3%
13.	*Lantana camara* L.	26.95(26.25-27.25)±0.18	27.80(27.25-28.25)±0.16	0.96	2.75(2.25-3.0)±0.13	21.50(20.50-22.0)±0.28	92%	4%
14.	*Polygonum plebeium R.Br.*	67.45(92.0-107.75)0.32	47.19(88.50-109.50)±3.37	1.01	2.55(2.0-3.0)±0.18	36.1(59.25-78.25)±3.60	60%	3%
15.	*Thymelaea passerina* (L.) Coss. & Germ.	138.6(134.75-149.5)±2.75	76.60(40.50-91.0)±9.47	1.80	3.25(3.0-3.50)±0.11	-	83%	6%
16.	*Zygophyllum indicum (Burm.f.) Christenh. & Byng*	97.10(95.50-98.0)±0.43	89.80(89.0-90.50)±0.25	1.08	2.60(2.25-3.0)±0.15	73.65(70.25-82.75)±2.31	75%	4%
17.	*Zygophyllum simplex* L	102.85(92.0-111.25)±3.26	102.80(94.75-114.5)±3.43	1.0	3.55(3.0-4.50)±0.26	-	69%	4%

Abbreviations: +, Present; -, Absence

Abbreviation: -, Absent; %, Percentage; S.E, Standard Error; Min, minimum; Max, Maximum

Conclusion & Future Recommendations

4. Conclusion

This is the first documentation to explore the taxonomic diversity using LM and SEM of 56 plant species belonging to 23 families and 50 genera from Takkar Wildlife Sanctuary. It is concluded from this study that pollen morphological and foliar anatomical characters are very significant to aid in the accurate identification of plant species.

4.2 Palynology

The pollen attributes of the 32 plant species were helpful to compare the micromorphological illustration and statistical data analysis shows elaborative documentation in depth to visualize the exine sculpturing patterns. Leguminosae was the most dominating family representing 15 pollen inventories describing various types of stratified exine walls such as reticulate-scabrate, psilate–scabrate, psilate-perforate, psilate-reticulate, reticulate and reticulate-verrucate. Exine thickness was calculated maximum for *Trifolium resupinatum* was (5.24 µm). The taxonomic key was constructed based upon pollen micromorphological features to signify the sculptural characters-state of pollen flora of Takkar Wildlife Sanctuary.

4.1 Leaf Epidermal Anatomy

The leaf microanatomical of 46 selected species growing in the arid Takkar Wildlife Sanctuary reveals that epidermal anatomical characteristics, such as epidermal cells diverse shapes, trichome microanatomy, and variations in stomatal types were important taxonomic traits to correctly identify the species at generic level. Leguminous species as a dominant group was differentiated based on their diversification of epidermal cell types e.g., irregular, isodiametric, polygonal, undulated and wavy. The largest epidermal cells were examined in *Dalbergia sisso* (47.5 µm) on adaxial side and *Prosopis cineraria* (38.5 µm) on abaxial surface. It is concluded that leaf scanning bioimaging microscopic characters are very useful to identify plants of Takkar Wildlife Sanctuary.

5. Future Perspectives

- Molecular systematics studies with modern analytical tools should be performed to explain the classification of plants species in evolutionary hierarchy.
- Advanced molecular biological and spectroscopic and chromatographic techniques should be used for the proper identification of medicinal plants as an herbal drug formulation source to the pharmaceutical industry.
- Exploration of Wildlife Sanctuary flora diversity and their potential in drug development leads to the cultivation, and conservation should be practiced.
- A floral catalog of Wildlife Sanctuary plants will be developed should be helpful to the researchers of allied multidisciplinary areas for socio-economic uplift of community.

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Thesis Outcome

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LEAF MICROMORPHOLOGICAL TRAITS OF LEGUMES FROM TAKKAR WILDLIFE SANCTUARY

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Abstract

This study elucidates the micro-morphology of leaf among wildlife sanctuary inhabited leguminous species adapted to arid environment. The foliar structures that enable its survival in arid conditions are little recognized. The comparative anatomical attributes of 10 leguminous species were analyzed using bio imaging microscopic techniques. Both surfaces of the leaves exhibited differences in their leaf anatomical traits including type of stomata, epidermis, anticlinal wall, and diversity of trichomes. The epidermal cells shape was reported as polygonal, tetragonal to pentagonal and wavy. The largest epidermal cells were examined in *Dalbergia sisso* (47.5 µm) on adaxial side and *Prosopis cineraria* (38.5 µm) on abaxial surface. Largest stomatal complex was recorded for *Dalbergia sisso* (24.9 µm) on abaxial, while the smallest (8.28 µm) for *Prosopis juliflora* on adaxial side. Unicellular trichomes were observed on both surfaces of *Crotalaria burhia* while glandular trichomes were located in the coastal zone of *Prosopis juliflora*. The easy and quick identification of micromorphological markers of leguminous species reflect their adaptations to aridity in a wildlife sanctuary habitats. The current findings of the foliar micromorphological traits are of special interest for plant taxonomists for the correct identification of leguminous species.

Key words: Foliar traits; Paracytic stomata; Microscopic peculiarities; Wildlife Sanctuary.

Introduction

Fabaceae comprises 730 genera and 19,325 species (Soares *et al*., 2021). Family Fabaceae is also referred to as the bean, pea, or legume family. The Fabaceae is the third largest terrestrial plant family after the Asteraceae and Orchidaceae. The family is widely scattered in tropical regions and is thought to be worldwide due to the large number of species diversity (Barrett *et al*., 2021; Anjum *et al*., 2022). The Fabaceae plants are very diverse; it primarily consists of annual and perennial herbaceous plants, shrubs, and trees that are easily identified by their fruit or legume (Group *et al*., 2016). Plants in the family are also distinguished by the complex stipulate leaves (Shaheen *et al*., 2020). They are abundant in Pakistan's temperate, sub-temperate, grassland and timber grassland habitats, as well as subtropical regions. Plants of the Fabaceae are widely distributed in dry grassland areas. Despite systematic differences, the Fabaceae origin appear to be monophyletic (Uzma *et al*., 2012).

The introduction of microscopy has introduced a new dimension to the morphological features that are available for systematic implications (Chen *et al*., 2020; Majeed *et al.,* 2023). The diversity of trichomes was analyzed using imaging techniques, and their taxonomic relevance was discussed (Melo *et al*., 2010). Using the SEM technique, several trichome types were found to cover the leaf surface, with stomatal complex features having a substantial taxonomic value (Jabeen *et al.,* 2022; Manzoor *et al.,* 2023). The foliar epidermal structure provides significant relevant details to distinguish between the angiosperm groups. Various epidermal aspects, like stomata, hairs, and the length and shape of epidermal cells, have become key identification features for categorizing species within the dicot angiosperm families (Hong *et al*., 2011).

Two methods of identifying plants are employed in the field of plant taxonomy. Macromorphological traits such as inflorescence types, phyllotaxy, stems, aroma, and fruit observation are used to first observe plants. Second, plants are studied on a micromorphological scale to better understand their surface characteristics (Esfandani-Bozchaloyi and Zaman, 2018). Anatomical attributes are very helpful in identifying relationships between different orders and taxa, and their aspects have gained significance in evolutionary relationships. In a variety of plant groups, comparative foliar anatomy has proven to be taxonomically and diagnostically significant. Anatomical microstructure were examined using a variety of botanical techniques for their histological description (Majeed *et al*., 2022).

Micromorphological studies provide an important role in identifying and categorizing plant species within certain Angiosperm land plants (Abbas *et al*., 2022). The characteristics of leaf epidermal anatomy contribute significantly to the resolution of taxonomic issues. Many authors have described the use of epidermal morphology in their taxonomic research and botanical reviews. Furthermore (Ayodele & Olowokudejo, 2006) are the scientists who have successfully used aspects of leaf epidermal structure to address taxonomic issues. (Ahmed *et al*., 2016) the leaf is the non-reproductive organ that is most frequently utilized in plant taxonomy, and according to (Alege & Shaibu, 2015), the leaf epidermis is the second-most significant characteristic after cytology for resolving taxonomic and evolutionary issues. The epidermis of the leaves acts as a dynamic barrier between the internal environment of the plant and the outside