Systematics and Phytogeography of Floral Diversity in Hindukush-Karakoram-Himalaya, Northern Pakistan

By

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Systematics and Phytogeography of Floral Diversity in Hindukush-Karakoram-Himalaya, Northern Pakistan

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In

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2024

بسم الله الرحمن الرحيم

In the name of Allah, the Most Merciful, the Most Kind

DEDICATED

To

My Brother

Hammad Qayyum

And

My father

Abdul Qayyum Raja (late)

Special Thanks

To

My Mother

For her endless love sacrifices and support

Certificate of Approval

This is to certify that the research work presented in this thesis, entitled " **Systematics and Phytogeography of Floral Diversity in Hindukush-Karakoram-Himalaya, Northern Pakistan**" was conducted by Ms. Iqra Qayyum under the supervision of Prof. Dr. Mushtaq Ahmad. No part of this thesis has been submitted anywhere else for any other degree. This thesis is submitted to the Department of Plant Sciences in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Field of Plant Sciences (Plant Systematics and Biodiversity), Department of Plant Sciences, Quaid-i-Azam University, Islamabad, Pakistan.

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Iqra Qayyum

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ABSTRACT

This study is the first attempt to provide full taxonomic information on plant species in the Hindukush-Karakoram-Himalaya region of northern Pakistan. This study is separated into two sections: pollen morphology and anatomical study. A total of 96 species from 28 different families were collected, identified, examined, and investigated for their morphological traits. Lamiaceae and Asteraceae were identified as dominating families. The pollen grains were acetolyzed, quantified, and characterized using scanning electron microscopy. A statistical analysis of the pollen properties of 86 herbaceous plants revealed major similarities and differences between the species. With 23species, the Lamiaceae family was the most dominant producing pollen in various shapes such as prolate-spheroidal, sub-prolate, oblate-spheroidal, and hexa-colporate, with micro-reticulate and reticulate exine ornamentation. Exine thickness was highest in *Vitex trifolia* 4.09 µm and lowest in *Stachys rigida* 1.02 µm. *Clinopodium vulgare* showed highest 55.95 µm polar diameter and equatorial diameter 54.35 µm in *Lambium album*. Asteraceae is the second leading family having 12 species. *Anaphalis nepelensis* showed highest exine thickness as 36.3 µm among all the asteraceaeous taxa. The exine sculpture of selected pollen was investigated and found to be micro-reticulate, echinate, psilate, reticulate, and granulate, with pollen grains shaped as oblate, per-oblate, spheroidal, and sub-spheroidal. The pollen size varies from small to large, as do the apertures, which range from monocolpate to tricolpate. The pollen grains would be statistically analyzed using IBM SPSS Statistics 20 software. Exine surfaces were studied to determine whether they were psilate, echinate, or reticulate. The pollen grains of Fabaceae, Violaceae, Rananculaceae, Geraniaceae, Brassicaceae, Onagraceae, Aspergaceae, Balsaminaceae, Boraginaceae, Amaranthaceae, and Solanaceae were tricolpate, hexa-colporate and pentaporus. The clarification of the leaf micromorphology of the selected 50 herbaceous plants reveals characteristics like the stomata's categories, trichome type, and epidermal cell size and shape. The leaf micromorphology of 50 herbaceous plants revealed foliar anatomical traits, such as changes in epidermal cell, trichome morphology, and stomatal type. *Stachys emodi* has the longest epidermal cell length, measuring 69.54 µm at the adaxial and 66.65 µm at the abaxial surface. The highest length of guard cell was recorded as 36.45 µm and width of stomata abaxial and 36.15 at adaxial in *Erigeron bonariensis* 34.55 µm in asteraceaeous taxa. In anatomical features diacytic, actinocytic, anomocytic, anisocytic and paracytic were studied. The systematics research, particularly palynological and anatomical studies, is fully described in this work. Asteraceae and Lamiaceae have paracytic, diacytic, anomocytic, and anisocytic stomata, while Boraginaceae, Rubiaceae, Balsaminaceae, and Onagraceae had

actinocytic and anomocytic stomata, as well as diacytic and staurocytic stomata. Anticlinal wall patterns were found to be undulating, curving, straight, and sinuate. The epidermal cell shape was found to be polygonal, pentagonal, tetragonal, and irregular. Micromorphological traits that have been recognized serve as a foundation for proper identification of herbaceous species and their systematic relevance.

1.1 Geographical Overview of HinduKush-Karakoram-Himalaya Regions

Mountains are important land ecosystems with unique landscapes that support a wide range of species. The Himalayas represent one of the most intricate and diverse mountain ecosystems on Earth, characterized by a harsh climate, distinct seasonal variations, and a rich array of plant species (Oommen & Shanker, 2005; Kala & Mathur, 2002). In northwestern Pakistan, the convergence of three of the world's tallest mountain ranges: the Hindu Kush, Karakoram, and Himalayas which creates a region renowned for its rich floral diversity and significant phyto-geographical importance. These mountain ranges, located between 34° 0' to 36° 50' N and 71° 12' to 75° 0' E, cover an area of 132,700 km², making them some of the largest in the world (Hashmi & Shafiullah, 2003).

The Karakoram Range stretches across the borders of India, China, and Pakistan, within the Gilgit-Baltistan area. Skardu Valley, in northern Pakistan's Baltistan region, is at 35° 18' north and 75° 37' east. The Deosai Plateau is located at 30°00 N 75°30 E between the boundary of the western Himalayas and the Karakorum. It has a height of 4,115 meters (14,500 feet) and is one of the highest plateaus in the world. It is about 30 km from Skardu and covers an area of 5,000 km². The main connection is the Karakoram Highway (KKH), which links Gilgit-Baltistan to the rest of the country and connects Pakistan with China.

1.2 Distinctive Features and Sub-regions

Gilgit-Baltistan is home to some of the highest mountain ranges in the world, including the Hindu Kush, Karakoram, and Himalayas. The region boasts 101 peaks that exceed 7,000 meters in height, with notable ones such as Nanga Parbat, Rakaposhi, and K-2. The region's unique plant life is shaped by its natural ecological zones (Rao & Marwat, 2003). Gilgit-Baltistan is in Pakistan's far north and is divided into seven districts: Gilgit, Ghizer, Skardu, Diamer, Ghanche, Astore, and Hunza-Nagar. The region, often known as the 'Axis of Asia,' is located between 35˚-37'N latitude and 72˚-75'E longitude, bordering Xinjiang territory in China. Gilgit-Baltistan is bounded by Chitral to the west, the Kalam, Kohistan, and Kaghan valleys to the south, Tajikistan adjacent, and the occupied areas of Ladakh and Kashmir to the east. It is where Southern, Central, and Southeast Asia meet. The region covers 72,496 km² and has a population of about 1.5 million, with a density of 10 people per km². Out of the total area, only 69,480 hectares (0.96%) are under cultivation, while approximately 60,000 hectares of arable land remain unused. The remainder consists of rangelands, mountains, forests, lakes, and rivers (IUCN, 2003). Each district has its own culture and language, with seven distinct language groups: Shina, Balti, Wakhi, Khowar, and Burushaski. Most of the region consists of rugged mountains, with just one percent allocated to agriculture. The remaining area is made up of mountains, rivers, and glaciers (66%), rangelands (23%), and forests (4%) (IUCN, 2002).

The Naran Valley in northeastern Pakistan is a significant site for plant geography research (Khan et al., 2011c). It is located on the western edge of the Himalayas, near the Hindu Kush range, where the arid climate of the western Eurasian mountains transitions to the wetter climate of the Sino-Japanese region (Kuhle, 2007; Qaiser and Abid, 2005; Khan et al., 2011b).Naran Valley is located 270 km north of Islamabad, the capital of Pakistan, with coordinates spanning between 34° 54.26′N to 35° 08.76′N latitude and 73° 38.90′E to 74° 01.30′E longitude. Its elevation varies from 2,450 to 4,100 meters above sea level. The valley is bordered by rugged mountain ridges on both sides of the Kunhar River, which flows from the northeast to the southwest and passes through the town of Naran. Originating from Lake Lulusar near Babusar Pass at an altitude of 3,455 meters, the Kunhar River runs through the valley, which lies at the westernmost edge of the Himalayas and marks the starting point of the Hindu Kush mountains, extending west of the Indus River. Naran Valley is made up of basement rocks such as amphibolites, limestone, dolomite, agate, and deformed granitoids. The valley has a dry, temperate environment with noticeable seasonal fluctuations. Although the average annual precipitation is relatively low at 900 to 1,000 mm, heavy snowfall occurs from November to April, with an average accumulation of 7 meters annually. Summers are cool and dry due to the high mountains blocking monsoon rains. Snowmelt from May to September is the main water source for plant growth and the Kunhar River. Most of the year, temperatures stay below 10°C, with the growing season from June to August when daytime temperatures range between 16°C and 20°C. Field data collection was carried out using stratified random sampling with quadrats (Khan *et al*., 2011c).

1.3 Biodiversity Hotspot in Northern Pakistan

These mountains offer vital habitats for high-altitude plants and animals, supporting a diverse range of life. Mountain ecosystems are home to diverse plants, trees, insects, reptiles, birds, and large mammals. Protecting and managing these resources is essential for maintaining the region's sustainability. Pakistan is home to approximately 5,700 species of flowering plants, with nearly 400 of these being endemic and around 1,000 vascular plant species found in the northern mountain regions. Despite the challenges of poor management and overexploitation of some valuable plant species, Gilgit-Baltistan remains rich in endemic floral species and is recognized as a key area for medicinal and aromatic plants. While the full range of the region's plant diversity hasn't been fully studied, it is thought to host some of Pakistan's most important and varied plant communities.

Similarly, Gilgit-Baltistan is home to a diverse range of medicinal and aromatic plants. Currently, these medicinal plants face several threats, including overexploitation, inadequate management, free grazing, and agricultural mechanization. The region is characterized by five distinct types of forests, corresponding to various ecological zones: Mountain Subtropical Scrub, Mountain Dry Temperate Coniferous, Mountain Dry Temperate Broadleaved, Sub-Alpine, and Northern Dry Scrub. Each zone's unique climate supports a diverse range of plant and animal species. However, some species, like the snow leopard, Marco Polo sheep, and brown bear, are endangered (Rao and Marwat, 2003). The total forested area in Gilgit-Baltistan is 281,600 hectares, with 64,512 hectares designated as Protected Forest and 217,088 hectares as Reserve Forest. Forests are mainly found in the Diamer, Gilgit, and Astore districts. Many remote and rugged mountainous valleys in the region have not been thoroughly studied due to their inaccessibility and complex geopolitical situation. Most existing botanical research is based on qualitative data for ethno-botanical studies or floras (Ahmad *et al*., 2009). There has been limited quantitative analysis of plant communities across different geo-climatic gradients to better understand local and regional vegetation and biodiversity patterns (Saima *et al*., 2009; Khan *et al*., 2011a).

1.4 Ethnobotany

Ethnobotany is the study of how people interact with plants and their ecosystems. It combines botany, ecology, and anthropology to explore how human actions affect plant environments and to document indigenous knowledge about plants (Bhatti *et al*., 2001).

1.5 Floral Diversity of Study Area

The floral vegetation of north-western region of Himalayan range comprises of trees, Shrubs, herbs and grasses. The most dominant families are Compositae followed by Brassicaceae, Rosaceae, Poaceae, Labiatae, Gentianaceae, and Scrophulariaceae, Polygonaceae, Balsiminaceae, Cyperaceae Papilionaceae, Umbelliferae, Primulaceae. Blooming of flowers occurs mostly in two seasons: monsoon and spring. Post monsoon is the best time for collection of plants as mostly plants are in flowering stage. This region is renowned for its rich biodiversity, thanks to its altitude variations, snowfall, and diverse climate. Anges. Alam J., (2010) reported endemic species from Gilgit Baltistan *Astragalus clarkeanus*, *Asperula oppositifolia* subsp. *baltistanica*, *Berberis pseudoumbellata* subsp. *gilgitica*, *Haplophyllum gilesii* and *Tanacetum baltistanicum* are also found as critically endangered (CR) while *Aconitum violaceum* var. weileri and *Rhodiola saxifragoides* are vulnerable (VU). The distribution of plant species across the Earth's surface is not random or uniform. Instead, it is geographically specific and influenced by environmental and climatic factors (Khan *et al*. 2020).

1.6 Overview of Systematics of Floral Diversity

Systematics exploration is of great importance to record the occurrence of plant species. Their taxonomic characterization enables one to describe the economic utilization of wild botanicals. To undertake such an investigation, it is important that the flora of the region should be well known. It would be possible to evaluate the vegetable wealth of the region only when all the plants are properly collected and preserved, accurately identified, and described for a system of classification. In Pakistan, systematics is now a well-recognized field and explored various eminent angiosperm species to characterize their taxonomic traits to identify them correctly but still many regions such as deserts lands are still unexplored systematically. Many taxonomic studies on higher land plants have been conducted in various regions of Northern Pakistan (KPK), Azad and Jammu Kashmir, Punjab, Baluchistan, and Sindh but most of the northern mountainous regions of Pakistan still unexplored. Among such regions, Naltar valley, Bunji Himalayan region, Kargah HinduKush, Bargo Nala Karakoram. With respect to the spectrum of taxonomic elaboration, dicot angiosperm species in these regions has been ignored for many reasons. The major reasons are the unavailability of research and academic institutes in these areas.

The study of systematic features representing flora has proved very helpful in taxonomy at different hierarchical levels. (Ahmed *et al*., 2014; Malik *et al*., 2015; Shaheen *et al*., 2014), however, most above-reported studies from these areas presents only checklist of plant species along with ethnomedicinal documentation without any focus on pollen, seed and anatomical micromorphological traits of flora. Biodiversity serves as a chief character for the appropriate functioning of an ecosystem. To find out the association among closely linked taxa systematic studies is very useful. Intricate taxa can be identified by taxonomic tools. A key role is played by the scanning and light microscopy morphotypes and microanatomical characters (Hussain *et al*., 2018). This project explores the diversity of angiospermic flora, the most important groups of land plants and summarize available taxonomic data at the family level. The work is a helpful source of reference not only for taxonomists but for all who are interested in the different aspects of plant diversity. It contains evidence from practically all disciplines linked to modern systematics. An updated floral inventory of angiospermic flora was provided, along with diagnostic traits, keys for identification, and literature references. This project provided information on the taxonomic characterization of flora by incorporating a multidisciplinary approach using morpho-anatomical and palynological data using light and scanning electron microscopy (LM and SEM). The study also examines the taxonomic relationships within the Dicot angiosperms by stress on medicinally important species.

1.7 Taxonomic Identification

Taxonomy, a vital discipline in biological science, involves the systematic study of identifying, describing, classifying, and naming organisms, especially at the species or other taxa levels. In the field of plant taxonomy, the focus is on activities aimed at organism identification and classification. To establish the relationships between organisms based on their nature and taxonomic characteristics, extensive and diverse plant data collections are essential. For novice taxonomists, morphological features have traditionally served as the primary evidence for general taxonomy and organism identification. These comprehensive approaches allow for a deeper understanding of the plant kingdom and its diverse species. Plant taxonomy has experienced rapid and progressive transformations, closely linked to the advancements in science and technology (Jalali *et al*., 2016). Historically, taxonomic research was primarily driven by a sense of curiosity surrounding biodiversity and the desire to explore and understand various species. This scientific field is dynamic, continuously evolving as taxonomists gather and analyze data. The significance of taxonomic research lies in its role as a guiding framework for prioritizing research, fulfilling the need for well-defined research strategies, communicating the value of taxonomic studies to researchers in related fields, and promoting the dissemination of taxonomic information to the public (Maulana *et al*., 2020).

1.8 Taxonomic Hierarchies and Pollen Traits

Pollen morphology such as the type and number of apertures, symmetry, polarity, shape, and size; is generally considered stable within a plant species. As a result, mature pollen grains are assumed to have a consistent morphology with minimal variation within a species, making them useful for taxonomic classification. However, various studies have shown that pollen traits, particularly pollen size, can vary depending on environmental conditions. 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 held 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 help identify and classify different plant types and influence 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 like scanning electron microscopy and transmission electron microscopy are useful for examining exine sculpturing in detail (Bozic, and Siber 2020).

In angiosperms, key trends at higher taxonomic levels include the number, position, and structure of pollen apertures, the exine structure and stratification, and sometimes the size and surface patterns ((El Aanachi *et al*., 2021; Bose *et al*., 2012). Researchers identified plants based on comparison between pollen microscopic characters of examine specimens to determined differences between them. 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 period (Edwards, 2018). Scanning electron microscopy (SEM) is the advanced form of microscopy that is used for characterization of pollen morphological features of plants (Hameed *et al*., 2020). This sophisticated form of microscopy enables detailed observations of pollen structures, contributing to our understanding of plant taxonomy and evolution. Pollen in an anther is a colony of closely associated male gametophytes that develop as a result of asexual reproduction; their genetic variation is controlled by the results of recombination of parent genes of the same species; it is the genesis of living creatures that is as complete as it is theoretically conceivable to be near to the ontological entire level where there is no death (Pozhidaev and Petrova, 2023). The diverse morphology of pollen makes palynology, a study of pollen; an appealing field for taxonomy, particularly for groups with a wide range of pollen surface features (Nazish *et al*., 2020). These features are crucial for identifying species within specific groups or taxa, aiding in the understanding of Angiosperm systematics and phylogeny (Khan *et al*., 2019). Pollen grains serve as a vital record of Earth's vegetation and have numerous applications. They provide valuable insights into plant evolution, including the origins and diversification of angiosperms (flowering plants), and offer perspectives on plant life during historical periods marked by significant environmental changes and extinction (Al-Hakimi and Latiff, 2015; Prieu *et al*., 2019).

Pollen grains are used to assess how climate impacts Earth's vegetation, and data on how different plant species respond to past climatic changes are valuable for informing conservation strategies. Additionally, pollen serves as a significant allergen, with periods of high pollen levels from allergenic plants like grass or ragweed being identifiable through airborne pollen analysis (Carter *et al*., 2018). Pollen is also an important tool in forensic science, helping to link individuals or objects to crime scenes. The study of pollen falls under the discipline of palynology, which illustrates the study of living and fossil spores, pollen, and other palynomorphs. In palynological research, pollen grains are typically categorized into groups based on their morphology.

Mbagwu *et al*. (2009) showed palynological analyses on five species of Asteraceae and found that the similarities and differences in pollen morphology are significant for biosystematics. In the taxonomy of Lamiaceae, palynology is crucial and provides valuable data for classifying genera and species within the family. Pollen morphology, including features like aperture number, shape, and tectum ornamentation, has been extensively studied in various members of the Lamiaceae family. These pollen characteristics have proven to be helpful in enhancing its taxonomic understanding and classification. Numerous botanists have conducted studies on the pollen morphological characteristics of Lamiaceous species (Firdous *et al*., 2015). Similarly, (Doaigey *et al*., 2018), reported that the ornamentation of sexine (the outer layer of the pollen wall) exhibits variability and could serve as a significant characteristic at the generic level. These findings have contributed to a better understanding of Lamiaceae taxonomy and provided valuable insights into the differentiation and classification of its species.

1.9 Taxonomic Hierarchies and Foliar Microanatomy

Within plant taxonomy, anatomical features play a crucial role, particularly in defining higher taxonomic ranks such as genera and families (Donaldson *et al*., 2017). Foliar anatomical features of plants are important tools which are used to overcome the problem of identification. The leaf epidermal anatomical feature of each plant species has unique epidermal features. Leaf epidermal anatomy is an essential tool for systematic studies of plants. Two types of characteristics are utilized by taxonomists for correct identification of plants: macro-morphological and micro-morphological characteristics. Macro-morphological characteristics are visually observed by researchers and apply the taxonomic hierarchy on plants for correct identification (Raza *et al*., 2022).

Initially observed characteristics are such as type of inflorescence, arrangement of leaves, stem surface and fragrance of plants. For correct identification of plants, it's essential to examine the micro-morphological characteristics. Taxonomists used 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. The 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). Furthermore, the comparative anatomy of leaves, incorporating attributes from cross-sectional leaf features in higher plants has demonstrated immense utility in differentiating between species (Atalay *et al*., 2016). 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). Foliar microanatomical characteristics offer valuable insights into specific plant families and their ecological adaptations. Various epidermal features, including the length and types of epidermal cells, stomatal complexes, and trichome morphotypes, have emerged as crucial factors in distinguishing dicot angiosperms (Mladenova *et al*., 2019).

Scanning Electron Microscope (SEM) has introduced a new perspective to the examination of morpho-structural traits on leaf surfaces. This advanced technique has enabled a detailed evaluation of leaf surfaces, particularly concerning trichome morphology. By utilizing the scanning visualization approach, taxonomic issues related to trichomes were effectively resolved. Through SEM analysis, it was observed that the leaf surfaces were adorned with diverse types of trichomes, and the features of the stomatal complexes held considerable importance in systematic classification (Arabameri *et al*., 2020).

Comparative anatomy of leaves including attributes from transverse sections has proven valuable in both identifying angiosperm species to understand their taxonomic associations (Begum *et al*., 2013). 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 undulation. Five plant species belonging to the 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). Tripathi and Mondal (2012) conducted comparative micro-morphological study of stomata of 45 genera of order Leguminales and recognized three types of stomata viz. paracytic, anisocytic and anomocytic. Ethnobotanical survey of family Brassicaceae was conducted in Leepa Valley, Muzaffarabad by (Ishtiaq *et al*., 2015). Tripathi and Mondal (2012) conducted comparative micro-morphological study of stomata of 45 genera of order Leguminales and recognized three types of stomata viz. paracytic, anisocytic and anomocytic. In conclusion, analyzing the form and composition of vascular bundles in leafstalks, the comparative analysis of leaf anatomy, and the observation of glandular trichome features play vital roles in the taxonomic investigation of plants. These distinctive characteristics are valuable tools for differentiating and delimiting species across various taxonomic levels.

1.10 Justification of Research Project

In contemporary research, the north-western region of Himalayan range is not yet fully explored due to its diverse and complex location. The indigenous plants are not check listed by any plant taxonomists before. So, it is very necessary to study on taxonomic level in this area. Mainly the present study will be focused on pollen grains which are major contributors of ecosystem function. The study of pollen grains is called Palynology. Pollen is a major component of taxonomic study. Palynological applications are used in many other fields of biology such as vegetation reconstruction, oil exploration, melissopalynology, forensic science and allergy research. Generally, Pollen morphology is important to understand the taxonomic and phylogenetic history of vegetation. Palynological studies offer valuable insights for distinguishing and identifying closely related or challenging taxa. This information has broad applications and aids in identifying related taxa and major plant groups throughout history. Palynological evidence is essential for resolving issues with problematic taxa and can also be used to reconstruct past environments and evolutionary processes. Advanced and more detailed pollen analyses could lead to the development of improved identification keys. These keys would provide a foundational tool for pollen research across various fields, including archaeology, botany, mellitology, geology (for dating purposes), immunology, and eco-botany.

The anatomical study of plants of north-western region of Himalayan range is essential for taxonomic study. In this research project we will investigate palyno-morphic and foliar epidermal, petiole and stem anatomy of plants of the area. Two major approaches will be used in this taxonomic study: qualitative & quantitative. In the quantitative study, micro morphological features will be examined. Microscopic characteristics such as stomata, trichomes, epidermal cells, subsidiary cells, glands and silica bodies will measure with light microscope (LM) ocular lens scale. For corrected identification of plants, it’s essential to examine the qualitative characteristics. Taxonomists used anatomical features such as epidermal cells, stomatal features, trichome and glands. Within the genus and species, peculiar characteristics are useful in delimitation of species.

Objectives of the Study

The aim of this research project is to explore the north-western region of Himalayan range of Pakistan based on taxonomic characterization.

1. Enlist a comprehensive floristic checklist of flora along distribution localities and their geographical coordinates.
2. Identification and preservation of selected flora using flora of Pakistan and herbarium techniques.
3. Taxonomic study based on morphological (qualitative & quantitative), anatomical (SEM) palynological (SEM) for identification and classification of plants
4. Description of detailed foliar epidermal anatomical features of plants.
5. Elucidation of differences based on morphology, leaf epidermal anatomy and palynology at species and generic level for correct identification.

The focus of the current research is limited to palynological and anatomical examinations of specific plant species in the Hindukush, Karakoram, and Himalayan regions of Northern Pakistan. Plant identification and microscopic analysis were carried out in the Plant Systematics and Biodiversity Lab at Quaid-i-Azam University, Islamabad. The research consisted of two key components: an investigation into pollen morphology and a detailed study of pollen surface patterns, both conducted utilizing light and scanning electron microscopy. Furthermore, foliar anatomical characteristics of the study area were examined using scanning electron microscopy. The research encompasses the creation of a pollen identification key and the documentation of flora in Northern Pakistan.

2.1 Sampling Sites

Plants were collected from different sites of Hindukush, Karakoram and Himalayan region of northern Pakistan. The species were collected from Bunji nala, Kargah, Nalter valley, Bargo nala, Bagrote valley, Haramosh, Chalt, Hoper, Banji, Satrangi lake and Naran Kaghan. This research work was conducted in Plant Systematics and Biodiversity Lab, Quaid-I-Azam University Islamabad.

2.2 Plant Collection and Preservation

The present research focused on the taxonomic investigation of selected flora from the Hindukush, Karakoram, and Himalayan regions in Northern Pakistan. A total of 93 plants, representing various families, were systematically collected from diverse areas within the Himalaya, Hindukush, and Karakoram. Subsequently, the collected plants were allowed to dry, with regular replacement of newspapers every two weeks until complete dryness was achieved. The dried specimens were then brought to the Plants Systematics and Biodiversity laboratory for identification.

Field trips were conducted during the flowering period spanning 2022-2023. Comprehensive data, including habitat details, field numbers, collection dates, flower colors, locality specifics, habits, phytography, and flowering periods, were meticulously recorded during these field excursions. The collected plants were carefully pressed in newspapers to facilitate the drying process, with periodic changes of newspapers until optimal dryness was attained. Flowers from the specimens were carefully stored in zipper bags for subsequent microscopic studies (Usma *et al*., 2022).

2.3 Field Data

Plant samples, including roots, stems, leaves, and flowers, were collected for study. A total of 93 species belonging to 28 families were gathered for taxonomic analysis. Key information such as growth form, habitat, flower color, voucher numbers, collection date, collector's name, flowering periods, and other distinguishing characteristics were documented. Plants belong to 28 different families.

2.4 Plant Identification

Plant identification is a fundamental step in research related to Plant Taxonomy and Systematics. The specific species were compared with specimens housed in the Herbarium of Pakistan (ISL), Department of Plant Sciences at Quaid-i-Azam University, Islamabad. Descriptions were referenced from sources such as Tropicos, Flora of Pakistan, and Flora of China. The plant species was verified using TPL (http://www.Theplantlist.org) and the International Plant Names Index (http://www.ipni.org).

2.5 Plant Preservation

Plants collected from the field were pressed using a plant press, with flowers placed between newspaper sheets. The dried specimens were subsequently treated with chemicals for preservation. For poisoning 5g of Mercuric chloride were put on the one liter of Ethyl alcohol (Groot, 2011). In this solution plant sample dipped, which were mounted on sheets of Herbarium and then acquiesced to Herbarium of Pakistan (ISI) Quaid-i-Azam University Islamabad.

2.6 Chemicals used for Research Work:

Different types of chemicals were used for poisoning of plant species and slides preparations. For plant species poisoning 99.8% Absolute Ethanol and 5 grams of Mercuric chloride (BDH) were used. For palynological purposes Acetic acid (100 %) (Merck) and Glycerin jelly were used.

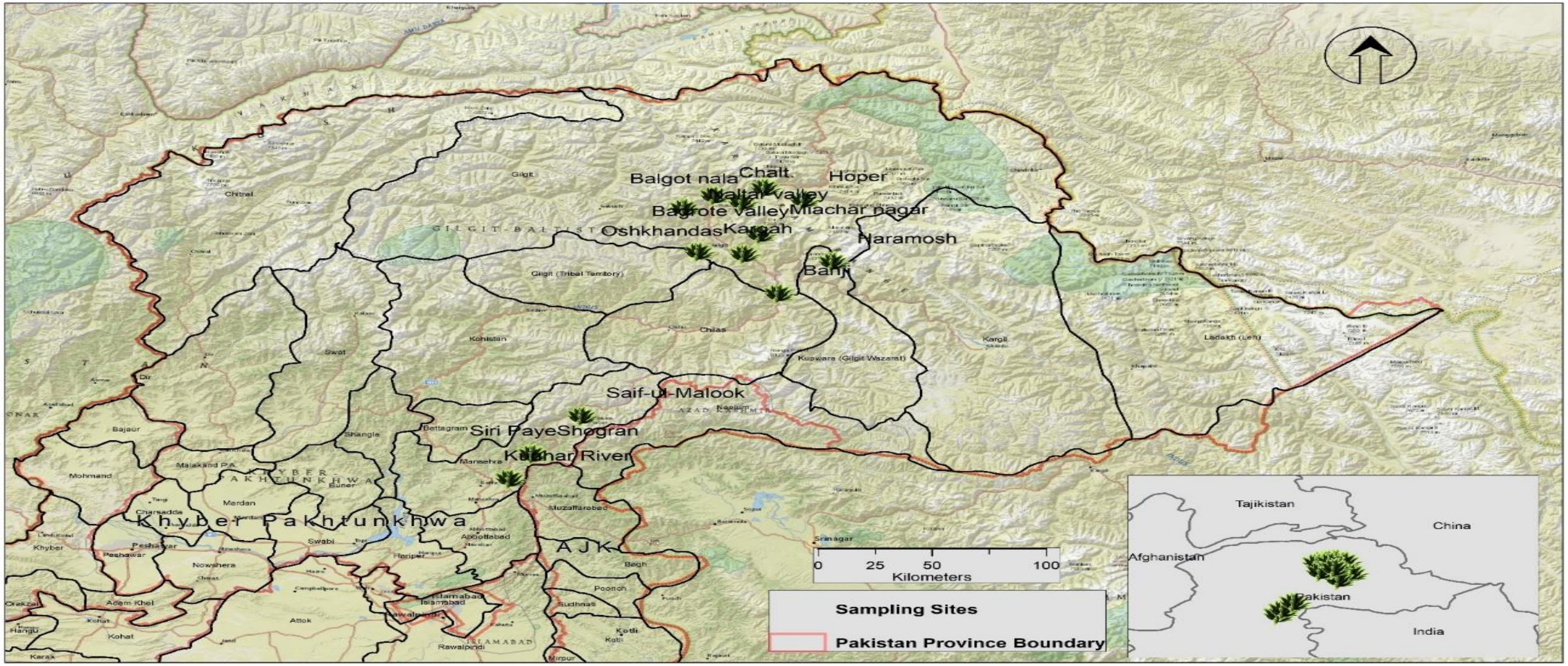

Figure 1: Map of the study area

Table 1. List of plants, family, voucher no., locality, collector and coordinates from different sites of HKH

S. no.	Scientific name	Family	Voucher number	Locality	Collected by	Collection date	Coordinates
1	*Achillea nobilis* L.	Asteraceae	133956ISL	Shogran	Iqra, Aroosa	July 2023	34°63 N 73°46 E
2	*Aconitum heterophyllum* Wall.ex Royle	Ranunculaceae	133957ISL	Haramosh	Marsha, Iqra	Aug 2022	35°84 N 74°89 E
3	*Acontholimon libanoticum* Boiss.	Plumginaceae	133958ISL	Nalter velly	Iqra, Aroosa	July 2023	36°16 N 74°17 E
4	*Actaea spicata L.*	Ranunculaceae	133959ISL	Haramosh	Marsha, Iqra	Aug 2022	35°84 N 74°89 E
5	*Anaphalis nepalensis* var.	Asteraceae	133960ISL	Bagrote valley	Iqra, Aroosa	Sep 2022	36°00 N 74°54 E
6	*Artemesia herba-alba* var.	Asteraceae	133961ISL	Bagrote valley	Iqra, Aroosa	Sep 2022	36°00 N 74°54 E
7	*Artimesia sentinifolia* Turcz. ex Krasch.,	Asteraceae	133962ISL	Naltar valley	Iqra, Aroosa	July 2023	36°16 N 74°17 E
8	*Aster alpinus* L.	Asteraceae	133963ISL	Banji	Iqra, Aroosa	Aug 2022	35°64 N 74°63 E
9	*Aster altaicus* Willd.	Asteraceae	133964ISL	Kargah	Iqra, Aroosa	Aug 2022	35°89 N 74°24 E
10	*Astraglus leguminosea* Linn.	Fabaceae	133965ISL	River Kunhar	Iqra, Aroosa	Aug 2023	34°48 N 73°35 E
11	*Astragalus breviscapus* B.Fedtsch.	Leguminosae	133966ISL	Haramosh	Marsha, Iqra	Aug 2022	35°84 N 74°89 E
12	*Astragalus graveolens* Benth.	Leguminosae	133967ISL	Haramosh	Marsha, Iqra	Aug 2022	35°84 N 74°89 E
13	*Astragalus rhizanthus* Benth.	Fabaceae	133968ISL	Banji	Iqra, Aroosa	Aug 2022	35°64 N 74°63 E
14	*Bistorta affinis* (D.Don) Greene	Polygonaceae	133969ISL	Miachar nagar	Iqra, Aroosa	July 2023	36°29 N 74°56 E
15	*Carum carvi* Linn.	Apiaceae	133970ISL	Banji	Iqra Aroosa	July 2023	35°64 N 74°63 E
16	*Chaerophyllum reflexum* Aitch.	Apiaceae	133971ISL	Miachar nagar	Iqra, Aroosa	July 2023	36°29 N 74°56 E
17	*Chenopodium foliosum* Asch	Amaranthaceae	133972ISL	Shogran	Iqra, Asim, aroosa	June 2023	34°60 N 73°30 E
18	*Cicer microphyllum* Benth.	Paploinaceae	133973ISL	Miachar nagar	Iqra, Asim, aroosa	July 2023	36°29 N 74°56 E
19	*Clematis grata* Wall.	Ranunculaceae	133974ISL	Miachar nagar	Iqra, Aroosa	July 2023	36°29 N 74°56 E

20	*Clinopodium vulgare* L.	Lamiaceae	133974ISL	Haramosh	Marsha, Iqra	Aug 2022	35°84 N 74°89 E
21	*Convolvulus arvensis* L.	*Convolvulaceae*	133975ISL	Banji	Iqra, Aroosa	July 2023	35°64 N 74°63 E
22	*Cynoglossum wallichii G.Don.*	Boraginaceae	133976ISL	Balgot nala	Iqra, Aroosa	Sep 2023	36°21 N 74°45 E
23	*Epilobium angustifolium* L.	Onagraceae	133977ISL	Kargah	Iqra, Aroosa	Aug 2022	35°89 N 74°24 E
24	*Erigeron alpinus* L.	Asteraceae	133978ISL	Banji	Iqra, Aroosa	July 2023	35°64 N 74°63 E
25	*Erigeron annuus* (L.)	Asteraceae	133979ISL	Nagar	Iqra, Aroosa	July 2023	36°78 N 74°29 E
26	*Erigeron bellidioides* (Buch. Ham. ex D.Don) Benth.	Asteraceae	133980ISL	Nagar	Iqra, Aroosa	July 2023	36°78 N 74°29 E
27	*Erigeron bonariensis* L.	Asteraceae	133981ISL	Banji	Iqra, Aroosa	July 2023	35°64 N 74°63 E
28	*Euphrasia pectinata* Ten	Orobanchaceae	133982ISL	Saif ul malook	Iqra, Aroosa	June 2023	34°87 N 73°69 E
29	*Fessia purpurea* (Griff.) Speta	Asparagaceae	133983ISL	Saif ul malook	Iqra, Aroosa	June 2023	34°87 N 73°69 E
30	*Festuca rubra* L.	Poaeceae	133984ISL	Chalt	Iqra, Aroosa	Aug 2023	36°24 N 74°31 E
31	*Galium verum* L.	*Rubiaceae*	133985ISL	Kargah	Iqra, Aroosa	July 2023	35°89 N 74°24 E
32	*Gentiana autumnalis* L.	Gentianaceae	133986ISL	Miachar nagar	Iqra, Asim	July 2023	36°29 N 74°56 E
33	*Geranium pratense* L.	Geraniaceae	133987ISL	Kargah	Aroosa, Asim	July 2023	35°89 N 74°24 E
34	*Heracleum maximum* W. Bartram	Apiaceae	133988ISL	Miachar nagar	Iqra, Asim	July 2023	36°29 N 74°56 E
35	*Hieracium murorum* L.	Asteraceae	133989ISL	Miachar nagar	Iqra, Asim	July 2023	36°29 N 74°56 E
36	*Impatience edgeworthii* Hook.f.	Balsaminaceae	133990ISL	Kargah	Iqra, Asim	July 2023	35°89 N 74°24 E
37	*Impatiens bicolor* Royle	Balsaminaceae	133991ISL	Saif ul malook	Iqra, Aroosa	June 2023	34°87 N 73°69 E
38	*Impatiens brachycentra*	Balsaminaceae	133992ISL	Chalt	Iqra, Aroosa	Aug 2023	36°24 N 74°31 E
39	*Iris ruthenica* Ker Gawl.	Iridaceae	133993ISL	Saif ul malook	Iqra, Aroosa	June 2023	34°87 N 73°69 E
40	*Isodon rugosus Wall. ex Benth*	Lamiaceae	133994ISL	Chalt	Iqra, Aroosa	Aug 2023	36°24 N 74°31 E
41	*Lactuca dissecta* D.Don	Asteraceae	133995ISL	Siri Paye	Iqra, Aroosa	June 2023	34°63 N 73°46 E
42	*Lamium album* L.	Lamiaceae	133996ISL	Balgot nala	Iqra, Aroosa	Sep 2023	36°21 N 74°45 E
43	*Lentopodium nivale* (Ten) Huet ex Hand.	Asteraceae	133997ISL	Balgot nala	Iqra, Aroosa	Sep 2023	36°21 N 74°45 E

44	*Limonium gilessi* (Hems). Rech.f. and Koeie	Plumbaginaceae	133998ISL	Balgot nala	Iqra, Aroosa	Sep 2023	36°21 N 74°45 E
45	*Medicago polymorpha* Linn.	Fabaceae	133999ISL	Kargah	Iqra, Aroosa	July 2023	35°89 N 74°24 E
46	*Melilotus indica* (L.) All.	Fabaceae	134000ISL	Bagrote valley	Iqra, Aroosa	July 2023	36°00 N 74°54 E
47	*Nepeta clarkei* Hook.f.	Lamiaceae	134002ISL	Haramosh	Marsha, Iqra	Aug 2022	35°84 N 74°89 E
48	*Nepeta connata Royle ex Benth*	Lamiaceae	134003ISL	Haramosh	Marsha, Iqra	Aug 2022	35°84 N 74°89 E
49	*Nepeta govaniana* (Wall. Ex Benth) Benth.	Lamiaceae	134004ISL	Bagrote valley	Iqra, Aroosa	July 2023	36°00 N 74°54 E
50	*Nepeta leucolaena* Benth. Ex Hook.f.	Lamiaceae	134005ISL	Satrangi lake	Iqra, Aroosa	Sep 2023	36°37 N 74°48 E
51	*Nepeta nervosa* Royle ex Benth.,	Lamiaceae	134006ISL	Bagrote valley	Iqra, Aroosa	July 2023	36°00 N 74°54 E
52	*Nepeta podostachys* Benth.	Lamiaceae	134007ISL	Bagrote valley	Iqra, Aroosa	July 2023	36°00 N 74°54 E
53	*Onosma hispidum* Wall. Ex G.Don	Boraginaceae	134008ISL	Miachar nagar	Iqra, Farhat	July 2023	36°29 N 74°56 E
54	*Oxytropis deflexa* (Pall.) DC.	Fabaceae	134009ISL	Miachar nagar	Iqra, Aroosa	July 2023	36°29 N 74°56 E
55	*Oxyria digyna* (L.) Hill	Polygonaceae	134010ISL	Miachar nagar	Iqra, Aroosa	July 2023	36°29 N 74°56 E
56	*Papaver nudicaule* Linn.	Papaveraceae	134011ISL	Miachar nagar	Iqra, Aroosa	July 2023	36°29 N 74°56 E
57	*Pedicularis pyramidata Pall. Ex steven*	Orobanchaceae	134012ISL	Saif ul malook	Iqra, Aroosa	June 2023	34°87 N 73°69 E
58	*Peroveskia abrotanoides* Kar.	Lamiaceae	134013ISL	Bagrote valley	Ilham, Aroosa	July 2023	36°00 N 74°54 E
59	*Persicaria capitata* (Buch-Ham.ex D.Don) H. Gross	Polygonaceae	134014ISL	Saif ul malook	Iqra, Aroosa	June 2023	34°87 N 73°69 E
60	*Polygonum biaristatum* Aitch. & Hemsl.	Polygonaceae	134015ISL	Siri Paye	Iqra, Aroosa	June 2023	34°63 N 73°46 E
61	*Potentilla arvensis* (L.)	Rosaceae	134016ISL	Satrangi lake	Iqra, Aroosa	Sep 2023	36°37 N 74°48 E
62	*Potentilla crantzii (Crantz) Fritsch.*	Rosaceae	134017ISL	Banji	Ilham, Aroosa	Aug 2022	35°64 N 74°63 E
63	*Primula macrophylla* D. Don	Primulaceae	134018ISL	Banji	Ilham, Aroosa	Aug 2022	35°64 N 74°63 E
64	*Prunella* vulgaris L.	Lamiaceae	134019ISL	Siri Paye	Iqra, Aroosa	June 2023	34°63 N 73°46 E
65	*Pulsatilla wallichiana (Royle)* Ulbr.	Ranunculaceae	134020ISL	Kargah	Iqra, Aroosa	Aug 2022	35°89 N 74°24 E

66	*Rumex nepalensis* Spreng.	Polygonaceae	134021ISL	River kunhar	Iqra, Aroosa	Aug 2022	34°48 N 73°35 E
67	*Salvia lanata* Roxb.	Lamiaceae	134022ISL	Nalter Valley	Iqra, Aroosa	July 2023	36°16 N 74°17 E
68	*Salvia nubicola* Wall.	Lamiaceae	134023ISL	Nalter Valley	Iqra, Aroosa	July 2023	36°16 N 74°17 E
69	*Salvia Plebeia* R. Br.	Lamiaceae	134024ISL	Bagrote valley	Iqra, Aroosa	July 2023	36°00 N 74°54 E
70	*Sambucus ebulus* L.	Adoxaceae	134025ISL	River Kunhar	Iqra, Aroosa	Aug 2022	34°48 N 73°35 E
71	*Scutellaria grossa* Wall.	Lamiaceae	134026ISL	Nagar	Iqra, Aroosa	July 2023	36°78 N 74°29 E
72	*Scutellaria linearis* Benth.	Lamiaceae	134027ISL	Nagar	Iqra, Aroosa	July 2023	36°78 N 74°29 E
73	*Sedum ewersii Ledeb.*	Crassulaceae	13402ISL	Nagar	Iqra, Aroosa	July 2023	36°78 N 74°29 E
74	*Silene gonosperma* (*Rupr.) Bocquet*	Caryophyllaceae	134098ISL	Kargah	Iqra, Aroosa	Aug 2022	35°89 N 74°24 E
75	*Silene kunawarensis Benth.*	Caryophyllaceae	134030ISL	Kargah	Iqra, Aroosa	Aug 2022	35°89 N 74°24 E
76	*Silene vulgaris* (Moench) Garcke	Caryophyllaceae	134031ISL	Haramosh	Marsha, Iqra	Aug 2022	35°84 N 74°89 E
77	*Sisymbrium officinale* (L.) Scop.	Brassicaceae	134032ISL	River Kunhar	Iqra, Ilham, Aroosa	Aug 2022	34°48 N 73°35 E
78	*Solidago virgaurea* L.	Asteraceae	134033ISL	Balgot nala	Iqra, Aroosa	Aug 2022	36°21 N 74°45 E
79	*Stachys annua* (L.) L.	Lamiaceae	134034ISL	Saif ul malook	Iqra, Aroosa	June 2023	34°87 N 73°69 E
80	*Stachys emodi* Hedge	Lamiaceae	134035ISL	Shogran	Iqra, Aroosa	June 2023	34°63 N 73°46 E
81	*Stachys palustris* L.	Lamiaceae	134036ISL	Balgot Nala	Iqra, Aroosa	Aug 2022	36°21 N 74°45 E
82	*Stachys rigida* Nutt.ex Benth	Lamiaceae	134037ISL	Kargah	Iqra, Aroosa	Aug 2022	35°89 N 74°24 E
83	*Swertia petiolate D. Don*	Gentianceae	134038ISL	Haramosh	Marsha, Iqra	Aug 2022	35°84 N 74°89 E
84	*Tamaricaria elegans* (Royle)	Tamaricaceae	134039ISL	Shogran	Iqra, Aroosa	June 2023	34°63 N 73°46 E
85	*Tanacetum artemisioides* Sch. Bip. ex Hook.fil	Asteraceae	134040ISL	Haramosh	Iqra, Ilham Aroosa	Aug 2022	35°84 N 74°89 E
86	*Tanacetum gracile* Hook. f & T. A	Asteraceae	134041ISL	Haramosh	Marsha, Iqra	Aug 2022	35°84 N 74°89 E
87	*Thalictrum pedunculatum Edgew*.	Ranunculaceae	134042ISL	Haramosh	Marsha, Iqra	Aug 2022	35°84 N 74°89 E
88	*Thymus linearis* Benth	Lamiaceae	134043ISL	Shogran	Iqra, Aroosa	Jube 2022	34°63 N 73°46 E
89	*Thymus vulgaris* L.	Lamiaceae	134044ISL	Siri Paye	Iqra, Aroosa	June 2023	34°63 N 73°46 E

90	*Trifolium repens* L.	Fabaceae	134045ISL	Balgot nala	Iqra, Aroosa	Aug 2022	36°21 N 74°45 E
91	*Viola canescens* Wall.	Violaceae	134046ISL	Shogran	Iqra, Aroosa	June 2023	34°63 N 73°46 E
92	*Viola odorata* L.	Violaceae	134047ISL	Shogran	Iqra, Aroosa	June 2023	34°63 N 73°46 E
93	*Vitex negundo* L.	Lamiaceae	134048ISL	Nagar	Iqra, Aroosa	July 2023	
94	*Vitex trifolia* L.	Lamiaceae	134049ISL	Satrangi lake	Iqra, Aroosa	Aug 2022	36°37 N 74°48 E

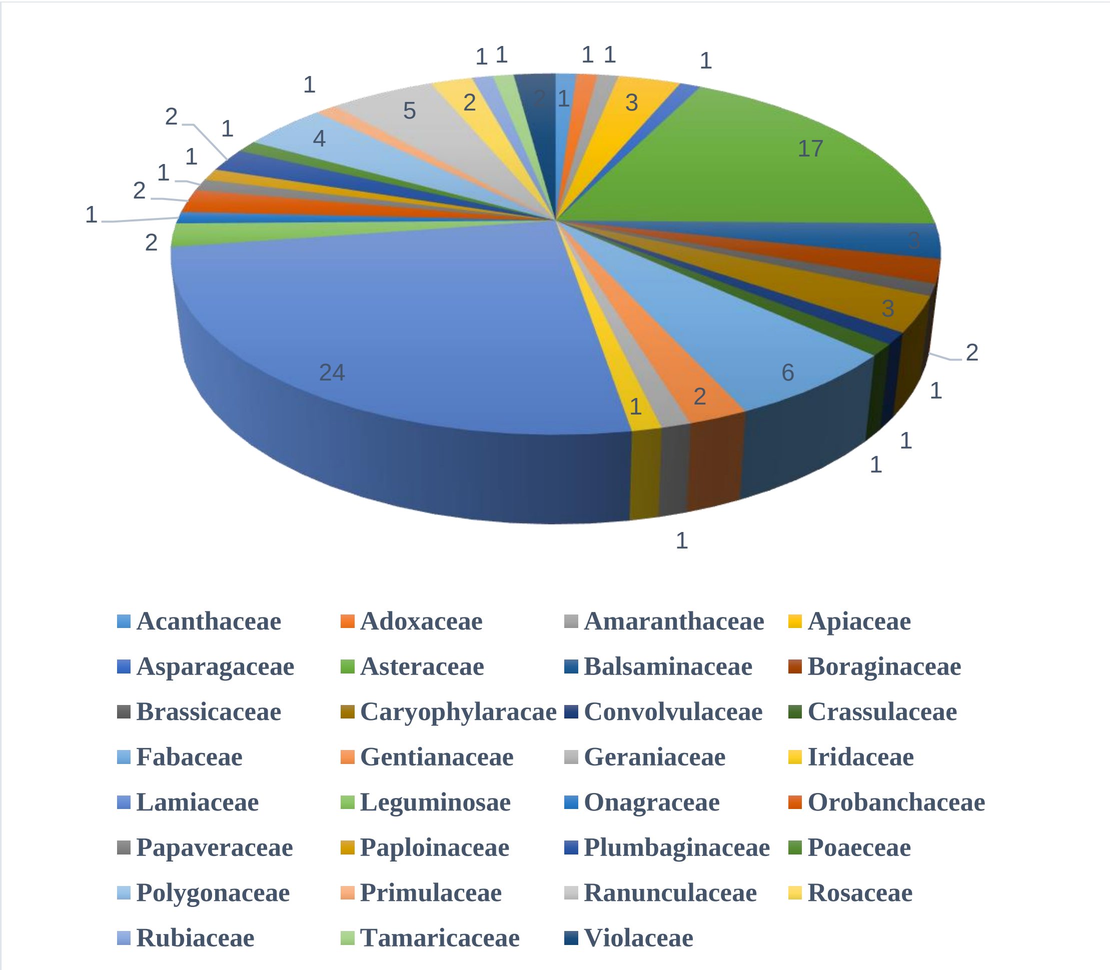

Figure 2: Graphical illustration of plant families

2.7 Anatomical Studies

Light microscopy (LM) will be carried out using the protocol of (Sadia *et al.*, 2019) with slight modification. The dried leaves samples will be put into the test tube along with lactic acid and nitric acid in ratio of 3:1 and boiled so that the leaves become transparent. The samples were again put into the petri dish and washed its surface to remove debris. After treatment with lactic acid both abaxial and adaxial sides will be carefully placed leaves with the help of needle on glass slide and covered with glass slip to avoid air bubble. With the help of LM both qualitative and quantitative characters like stomata size and type, stomatal pore size, number of trichomes, epidermal cell size, and shape will be measured, and photographs will be taken by using Leica D-20, Meiji Infinity camera at different resolutions.

Modern SEM machines are managed by highly advanced software that creates images of the surface of the tested specimens as well as maps of the constituent compositions on the specimens' surfaces. For scanning electron microscopy, the upper and lower epidermis of leaves will be mounted on stubs, sputtered with gold coating, and then introduced into SEM to acquire digital image. (Shaheen *et al.,* 2021).

The following characters were used to calculate stomatal indices: trichome type, anticlinal wall, number of stomata and epidermal cells, stomatal apparatus, stomatal pore, and epidermal cell length (L) and width (W). The qualitative and quantitative characteristics are sum up in Tables 2 and 3, respectively. Quantitative properties are expressed as minimum–maximum = mean standard± error (e.g., 57.5–115 = 85.5± 10.73). Five readings of each character were recorded for each of the adaxial and abaxial surfaces. The values of the minimum, maximum, mean, and standard error were determined by utilizing SPSS software to analyze the quantitative data. These results are very helpful in determining the species and type of various epidermal features. The length and width of the epidermal cells, stomata, stomatal pores, subsidiary cells, trichomes, and percentages of the stomatal complex are all included in these indices.

Plate 1: Junction of three mountainous ranges

Plate 2: Panoramic view of Bargo nala, Karakoram

Plate 3: Panoramic view of Banji Valley Gilgit

Plate 4: Panoramic view of Phandar Valley Gilgit

2.8 Microscopic Studies of Collected Plants

Flowers possessing well ripened anthers were separated. From anthers, ray florets and disk florets were separated with the help of needle. The process was conducted according to the Erdtman method (1969), One drop of acetic acids was put on the slide and then through a small metal made rod anthers were then crushed so that pollen can came out from anthers. For staining purpose glycerin jelly was prepared according to the method of Meo and Khan (2005). One drop of glycerin jelly was put on the slide and then covered with a cover slip. Slides were cleaned with tissue paper from sides, nail polish were exerted on it and then study through light microscopy.

2.9 Observation of Taxonomic Features Using Microscopic Techniques

Slides were examined under a microscope, and all pollen readings, including both qualitative and quantitative features, were recorded. Quantitative measurements such as equatorial diameter, polar diameter, colpi width, colpi length, spine width, spine length, number of spines between colpi, exine thickness, and counts of fertile and sterile pollen were noted, with five replicate readings for each parameter. Qualitative features, including colpi shape, spine shape, and pollen sculpturing, were also documented. The quantitative data were entered into an Excel spreadsheet (Microsoft Excel 2010) and analyzed using SPSS software to determine mean values, standard errors, and minimum-maximum ranges. Size of pollen were different from each other however shapes of some pollen were similar. Porate, colpate and tricolporate type of apertures were noted.

2.10 Pollen fertility Investigation

Fertile pollen grains were identified as those that stained properly, while unstained or broken grains were considered sterile. The number of fertile pollen grains on the slides was counted.

2.11 Palynomorph features

In palynomorph features, both qualitative and quantitative characteristics of the pollen were recorded.

2.12 Qualitative Characters

It entails the size and shape of pollen in both polar and equatorial views, as well as the number of colpi, pores, spines, and the overall ornamentation of the pollen.

Plate 5: Field plant collection

Plate 6: Preparation of herbarium sheets of dried plants specimens.

Plate 7: Microscopic observation and measurement of Pollen through Light Microscope

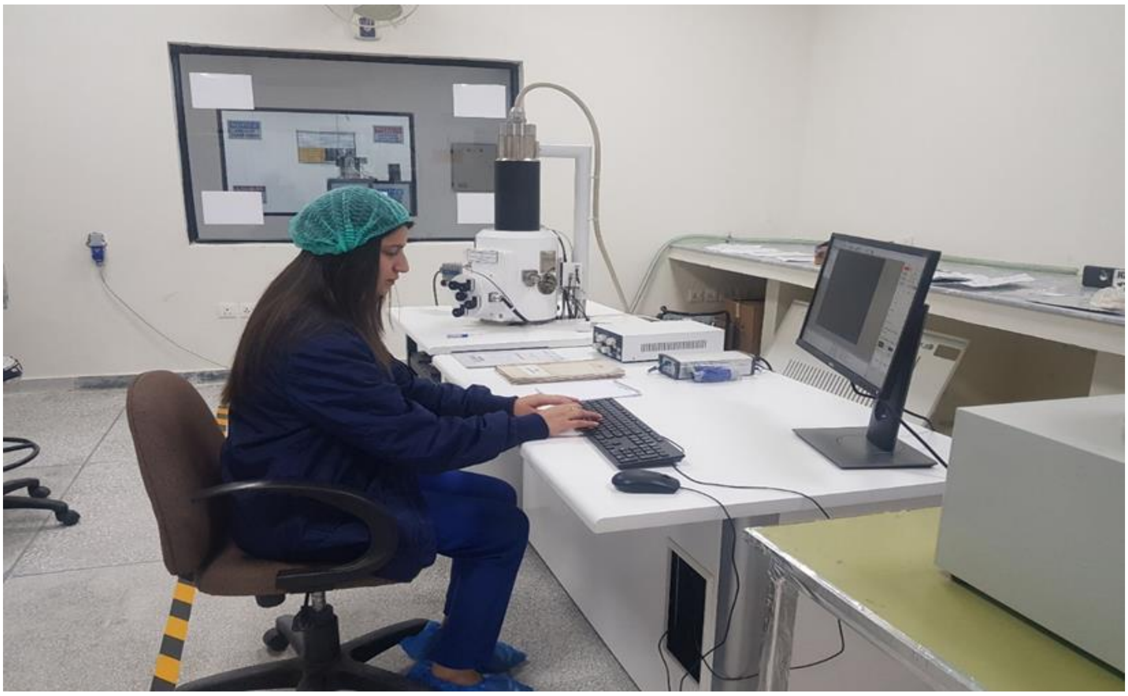

Plate 8: Microscopic visualization and photography of Pollen through Scanning electron microscope.

2.13 Quantitative Characters

It includes Polar diameter, equatorial distance, colpus length, colpus measurement, spine length, spine width, number of pores, no. of spines between colpi and exine thickness of pollen were noted.

2.14 Morphological Investigation

For morphological studies, plant specimens were dried using two methods: either by placing stem sections in the shade or by slicing the specimens to eliminate the inner parenchyma. The desiccated specimens were then affixed to herbarium sheets in accordance with established standard protocols (Groot, 2011). The preserved specimens will be assessed with a binocular light microscope and with the naked eye. The evaluation and analysis of both quantitative as well as qualitative features will be documented. Using accessible taxonomic data, morphological characters will be authenticated and confirmed. Voucher specimens will be stored at the Pakistan Herbarium, Quaid-i-Azam University, Islamabad, Pakistan.

2.15 Palynological Investigation

For pollen morphological investigation fresh and preserved polliniferous material will be following special technique of (Jones & Pearce 2015). Both quantitative and qualitative character of pollen observation will be re recorded using light microscope. Scanning electron microscope analysis of pollen will be performed using JOEL-JSM 5910. Photographs of pollen with Nikon Fx-35 microscope equipped with camera Model: 1-5 C-ME1. Pollen description will be conducted using the glossary of (Punt *et al*., 2007).

2.16 Statistical Study

Five consecutive readings for each pollen type were performed. Quantitative pollen data were measured following the method of (Dutra & Gasparino, 2018). Using the statistical software IBM SPSS Statistics 20, the mean, min, max, and standard deviation for each of the pollen grains were investigated. Values are presented in the table in the form of Mean (Mini-Max) ± SE. Using the method of Erdtman (1986) P/E ratio was determined for finding out the pollen shape using the below formula.

╟/ ╓= ╟≠╓ ╓× ٥ ٤ ٤

(PA= polar axis, ED = equatorial diameter of the same pollen)

[illegible]

Where, F= total number of fertile pollen S= total number of sterile pollens.

2.17 Morphological Attributes

Using binocular light microscope (Bausch and Lomb model W, New York) various morphological features of pollen grains were noted with the 10X, 20X and 40X. For each morphological parameter 5 readings were taken to find out the mean, maximum, minimum and standard error values. The morphological data was further found out by comparing with Flora of Pakistan, The Plant List, International Plant Name Index (www.ipni.org) was brought into use to verify the plant names (Usma *et al*., 2022).

3. Summary

Northern Pakistan boasts a diverse floristic landscape. Some indigenous and medicinal plants in the country are limited to these places. The current study was carried out in selected localities of the Hindukush-Karakoram-Himalaya region of northern Pakistan. These locations were examined for the first time in a systematic manner. This chapter is divided into sections that provide a graphical overview of plant species from various families collected in the Hindukush-Karakoram-Himalaya region of northern Pakistan. A quick summary of these sections includes:

Section 1: Pictorial overview of plants collected.

Section 2: Pollen morphological studied using SEM. Micromorphological qualitative (pollen shape, types, and exine peculiarities) and quantitative characteristics (P/E index ratio, pore size and number, exine thickness, colpi size, mesocolpium distance, pollen fertility and sterility, spine size etc).

Section 3: Foliar Anatomical findings using SEM. Qualitative and quantitative leaf epidermal anatomical characteristics include length

3.1 Field Pictorial Guide

During field surveys different photographs of plant species were captured. The floral pictorial guide assists taxonomists to visualize floral morphology of live plants in the correct identification (Plate 9 to 18).

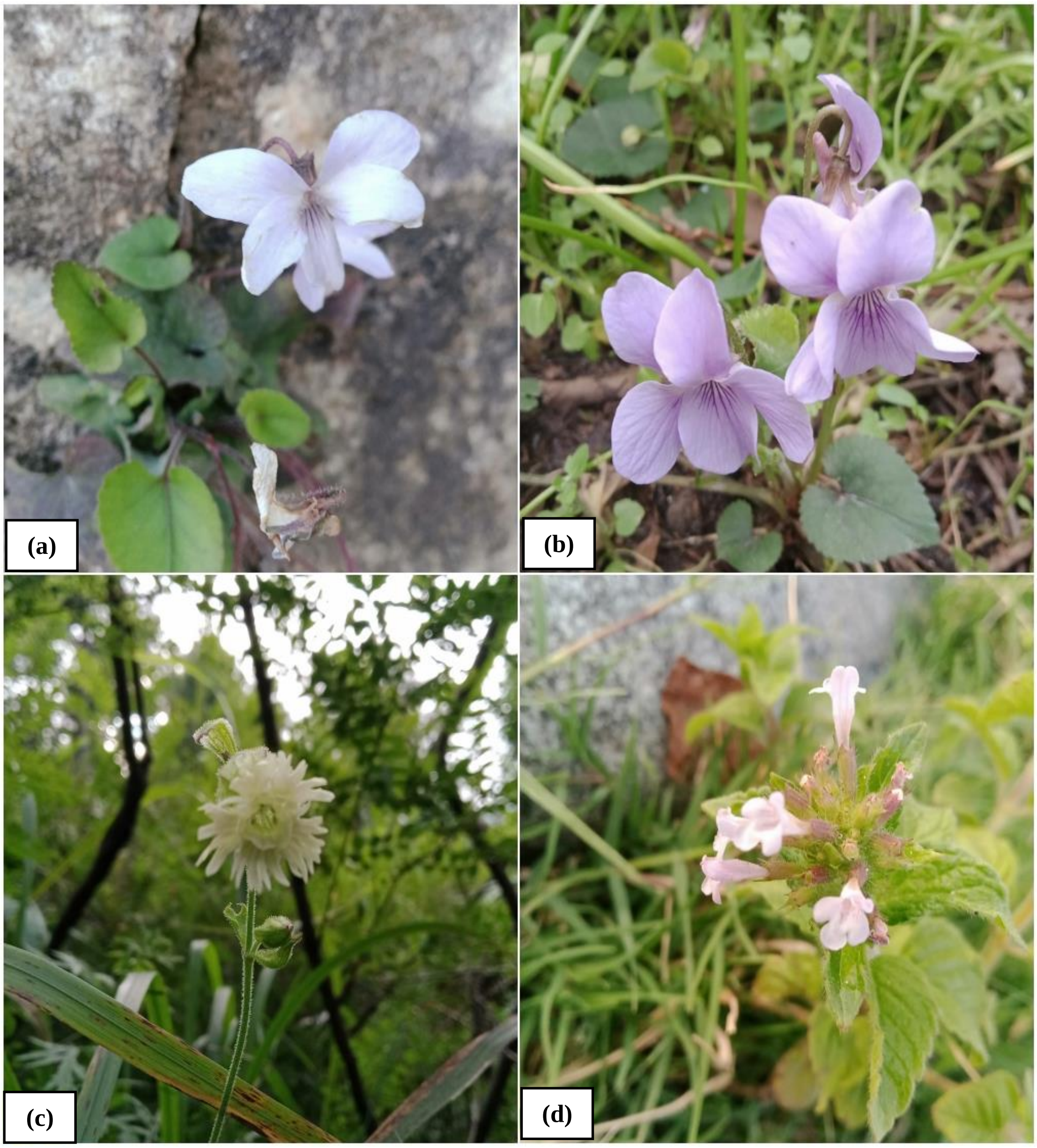

Plate 9: Field pictorial view of **(a)** *Viola canescens* Wall. **(b)** *Viola odorata* L. **(c)** *Silene vulgaris* (Moench) Gracke **(d)** *Clinopodium vulgare* L.

Plate 10: Field pictorial view of **(a)** *Convolvulus arvensis* L. **(b)** *Erigeron annuus* (L.). **(c)** *Pulsatilla wallichiana* (Royle) Ulbr. **(d)** *Silene gonosperma (Rupr.) Bocquet*

Plate 11: Field pictorial view of **(a)** *Tanacetum artemisioides* Sch. Bip. ex Hook.fil **(b)** *Hieracium murorum* L. **(c)** *Clematis grata* Wall. **(d)** *Aster alpinus* L.

Plate 12: Field pictorial view of **(a)** *Euphrasia pectinata* Ten **(b)** *Pedicularis pyramidata Pall. Ex steven* **(c)** *Nepeta leucolaena* Benth. Ex Hook.f. **(d)** *Anaphalis nepalensis* var.

Plate 13: Field pictorial view of **(a)** *Astragalus rhizanthus* Benth. **(b)** *Tamaricaria elegans* (Royle) **(c)** *Carum carvi* Linn. **(d)** *Trifolium repens* L.

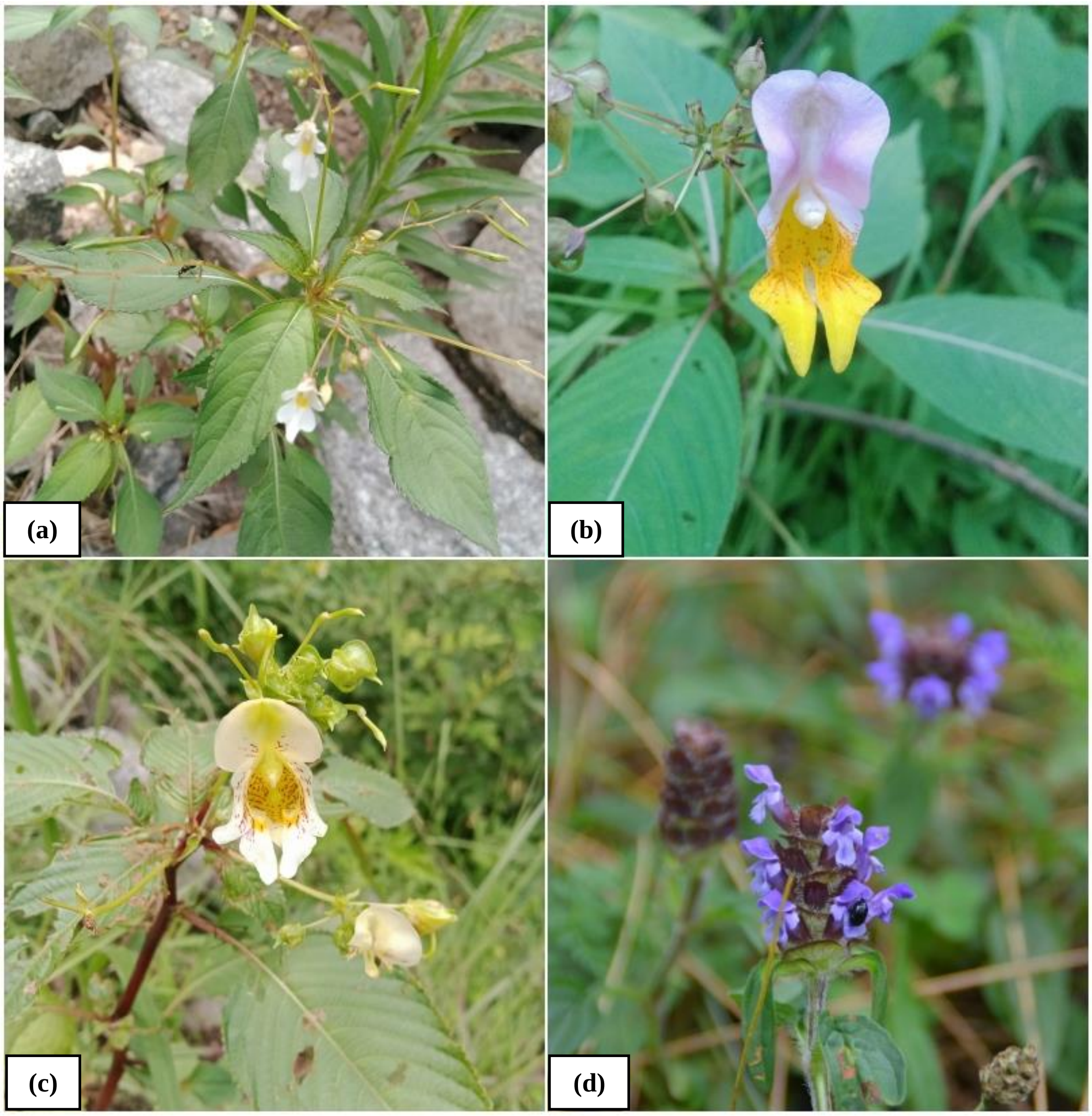

Plate 14: Field pictorial view of **(a)** *Impatiens brachycentra* **(b)** *Impatiens bicolor* Royle **(c)** *Impatience edgeworthii* Hook.f. **(d)** *Prunella* vulgaris L.

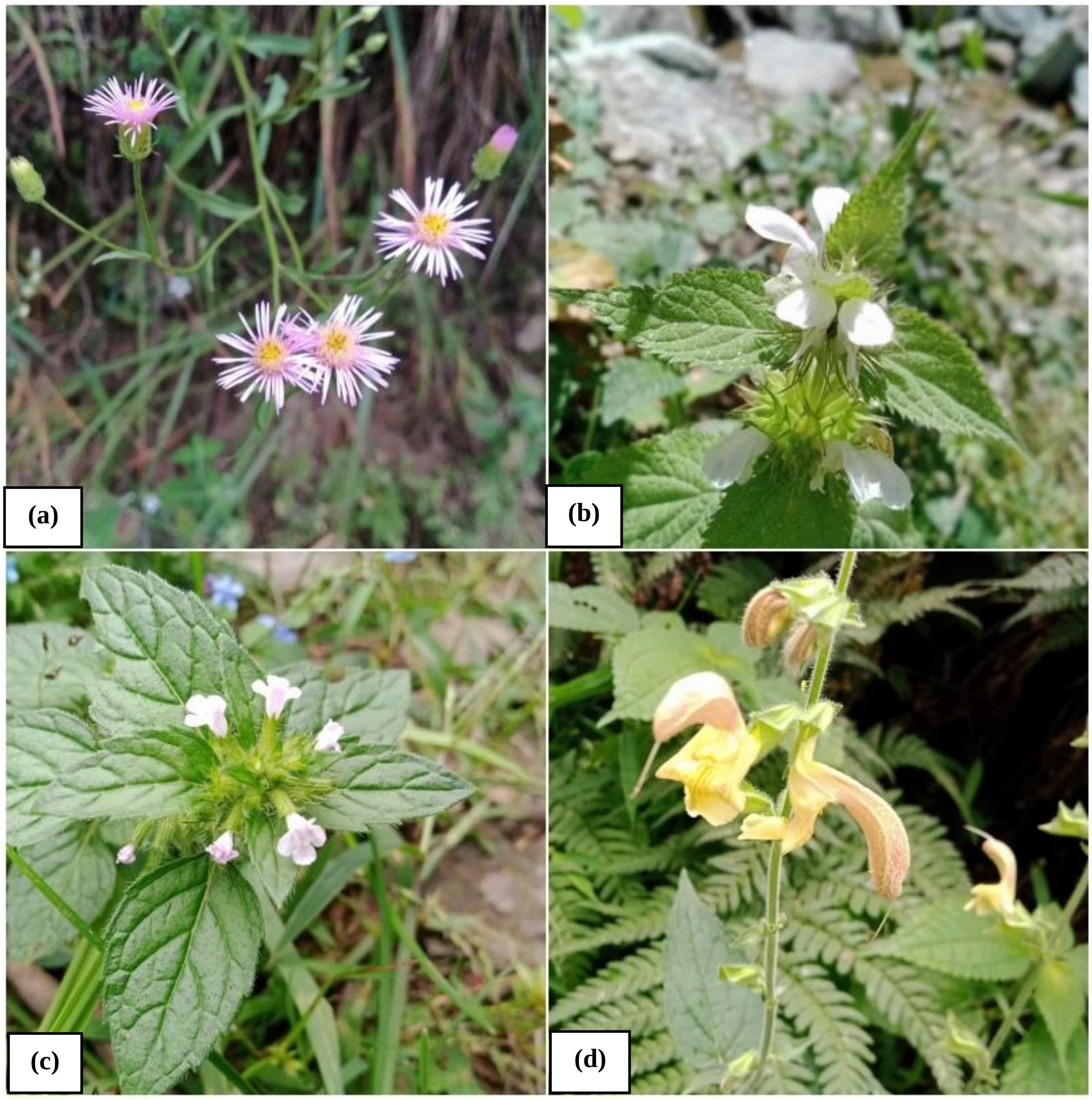

Plate 15: Field pictorial view of **(a)** *Erigeron bellidioides* (Buch. Ham. ex D.Don) Benth. **(b)***Lamium album* L. **(c)** *Clinopodium vulgare* L. **(d)** *Salvia nubicola* Wall.

Plate 16: Field pictorial view of **(a)** *Gentiana autumnalis* L. **(b)** *Sisymbrium officinale* (L.) Scop. **(c)** *Limonium gilessi* (Hems). Rech.f. and Koeie **(d)** *Aconitum heterophyllum* Wall.ex Royle

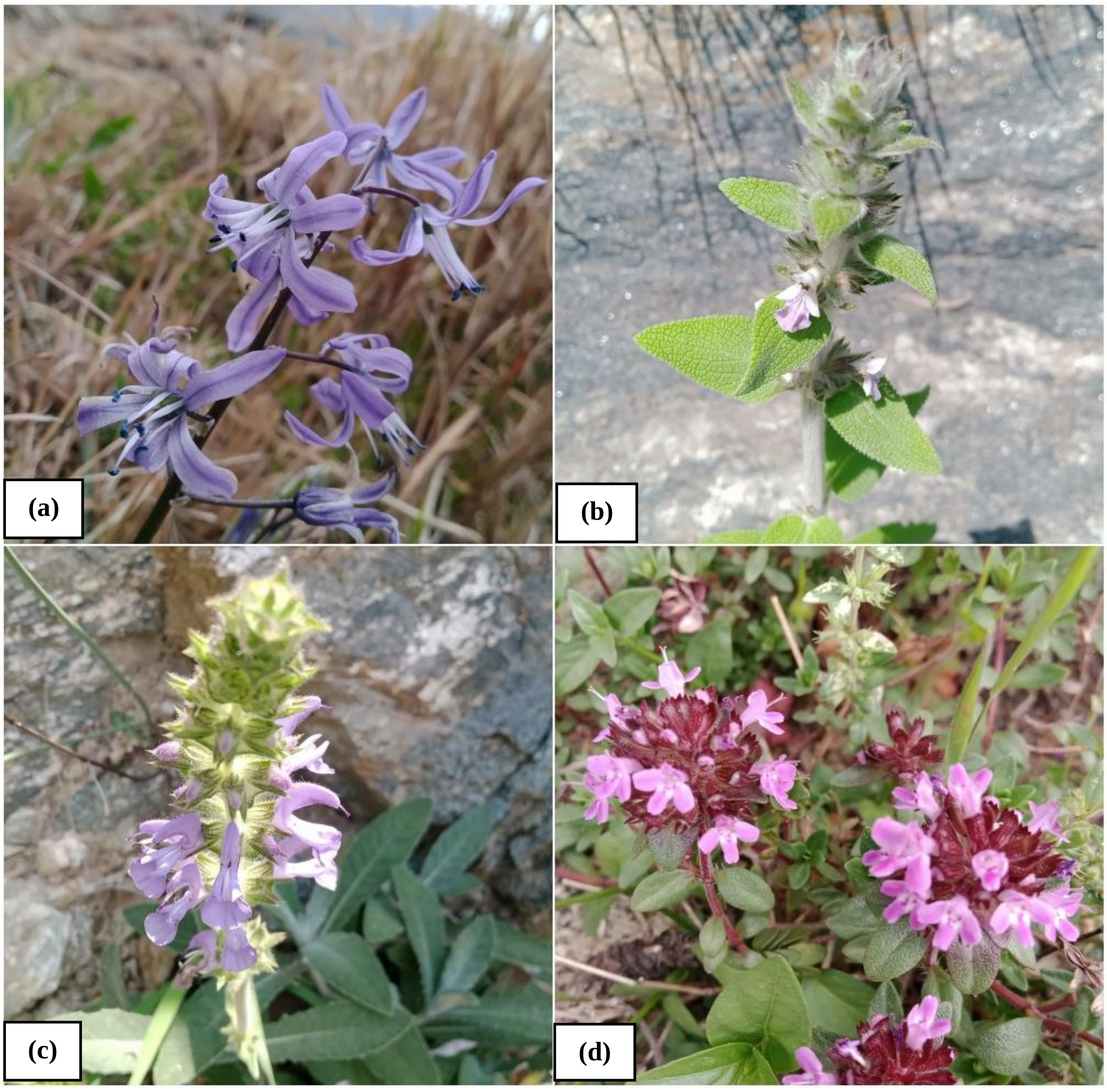

Plate 17: Field pictorial view of **(a)** *Fessia purpurea* (Griff.) Speta **(b)** *Stachys emodi* Hedge **(c)** *Salvia lanata* Roxb**. (d)** *Thymus linearis* Benth

Plate 18: Field pictorial view of **(a)** *Acontholimon libanoticum* Boiss**. (b)** *Isodon rugosus Wall. ex Benth* **(c)** *Persicaria capitata* (Buch-Ham.ex D.Don) H. Gross **(d)** *Vitex negundo* L.

3.2 Pollen Micromorphological Studies of Flora

The pollen morphology of 86 selected medicinal plants was examined showing differentiations in pollen shapes and size. The variation in exine thickness, equatorial diameter and polar axis, P/E ratio, pores, no. of spines, mesocolpium were examined. The quantitative and qualitative features of pollen grains were described in table 2 and 3. Pollen grains of the reported species were noted to be monad, polar, radially symmetrical, reticulate and peroblate. Pollen grains of the species varied in colpi, number of pores, spine length and spine width. Scanning micrographs of pollens were illustrated in plate 19 to 41.

a) Exine Thickness and Sculpturing

Exine is the outer covering of pollen grains. The exine texture is the most important feature for the recognition of a plant specimen. The thickness of the exine was measured and analyzed with the help of the (SPSS) software for different values. Exine ornamentation serves as a crucial pollen feature for delineating selected taxa of the Himalayas, displaying patterns such as psilate, regulate, reticulate, and echinate. Pollen grains vary in different species and are very useful for species identification in plant taxonomy. Reticulate, microreticulate, regulate, scabrate, granulate, pantaporate and echinated exine ornamentations were observed in the taxa of this study.

b) Aperture Pattern

The pollen grain apertures were observed to be monoporate, monocolpate, dicolpate, trizonocolporate, tricolpate, and tricolporate.

c) P/E ratio

The P / E ratio for each taxon was calculated using pollen morphology terminology of Punt *et al*. (2007). It was obtained by dividing the mean values of polar diameter by equatorial diameter.

d) Pollen diameter and equatorial diameter

The polar and equatorial diameters of pollen grains varied with each other and showed their respective sizes.

e) Mesocolpium

In this study, the maximum mesocolpium was recorded in *Impatiens brachycentra* 19.00 (19.0-20.25)0.25µm and the minimum in *Primula macrophylla* 4(2.14-6.12)±0.43 µm.

f) Symmetry, Size, and Shape

Pollen grains in current study were examined to be monad, radially symmetrical, and isopolar. The pollen morphology of the present examined species showed different pollen shapes. Prolate-spheroidal and oblate-spheroidal were observed in many species, followed by subprolate and suboblate. The pollen grains size was examined to be small, medium, and large, and in many species, it was recorded to be small.

g) Pollen shape

Different shapes of pollen were observed according to its size. In this study, oblate-spheroidal, sub-oblate-subprolate, prolate-spheroidal and spheroidal shapes were recorded.

3.2.1 Micromorphological features of Lamiaceaous Pollen

The pollen of selected Lamiaceaous taxa was visualized using scanning imaging analysis, revealing diverse sculpturing patterns and exine types. Pollen micro-morphological investigation of 23 species of Lamiaceae was examined under scanning electron microscope (SEM) to reveal the ultra-picture of pollen of this family. As illustrated in plate 19 to 24.

The pollen of the *Clinopodium vulgare* is iso-polar and exhibits a circular to obtuse shape, typically forming a monad unit. In our findings, the equatorial diameter was measured at 51.1 µm, and the polar diameter was 55.95 µm. The exine ornamentation was macro-reticulate, while the colpi had a length of 7.95 µm and a width of 4.95 µm. Additionally, the exine thickness was 3.5 µm. These detailed measurements and characteristics are essential for accurately identifying and classifying plant species based on their pollen morphology. Our research relates with Kremer *et al.*, (2021) that pollen were monads, iso-polar and outline is elliptical. The morphology of pollen, characterized by the ratio between the length of the polar axis and the equatorial axis (P/E ratio), is essential for species identification. In plant systematics, palynomorphological characteristics serve as a critical tool for the accurate identification and classification of species (Kaya *et al.*, 2019).

The *Isodon rugosus* Wall. ex Benth is iso-polar and hexa-colpate, with an elliptic shape in the equatorial view and a circular shape in the polar view. The exine ornamentation is characterized by a macroreticulate pattern. The equatorial diameter of the pollen is 23.8 µm, while the polar diameter is 36.65 µm. The exine thickness was recorded at 3.15 µm, and the mesocolpium, which is the area between the colpi, measures 10.15 µm. The P/E ratio, which reflects the relationship between the polar and equatorial diameters, was calculated to be 1.09. These detailed morphological and quantitative characteristics provide valuable insights into the pollen structure of *I. rugosus*, contributing to its taxonomic classification and identification. According to Hameed *et al*., (2020) pollens were isopolar, hexcolporate, semiangular to suborolate. These observations relate to our research.

The *Lambium album* was examined, revealing that the pollen is trihexacolpate with an elliptic shape in the equatorial view and a circular shape in the polar view. The exine ornamentation is psilatereticulate, characterized by a relatively smooth surface with a reticulate pattern. The exine thickness was observed to be 2.65 µm. The equatorial diameter of the pollen is 54.35 µm, while the polar diameter is 43.25 µm. The length of the colpi was measured at 7.95 µm, which is greater than the colpi width of 4.3 µm. Additionally, the mesocolpium, the region between the colpi, was measured at 9.1 µm. These detailed observations provide essential insights into the pollen structure of *Lambium* album, contributing to its accurate classification and identification within the taxonomic framework. According to Atalay *et al*., (2016) pollen of *Lambium* were medium sized, tricolpate, subprolate to oblate-spheroidal in shape. These observations slightly match our findings.

Measurements indicated that the polar diameter of the pollen grain of *Nepeta clarkei* was 20.2 µm, which is greater than the equatorial diameter of 16.9 µm. Additionally, the mean length and width of the colpi were 2.15 µm and 3.5 µm, respectively, while the mesocolpium measured 7.15 µm. The exine thickness was recorded at 2.75 µm. The study revealed that the pollen grains are isopolar and monad, exhibiting a reticulate and perforate exine ornamentation, this observation relates with (Celenk *et al*., 2008).

In this study, both qualitative and quantitative aspects of *Nepeta govaniana* pollen were examined, as these characteristics are crucial for species-level identification. The analysis revealed that the pollen is monad, isopolar, and exhibits a hexa- to multisyncolpate structure. The pollen shape varies from circular to rhombic and is characterized by scabrate and verrucate ornamentation. The exine thickness was measured at 2.06 µm, and the mesocolpium, the region between the colpi, was calculated to be 12.53 µm. The polar diameter of the pollen grains was 24.15 µm, which is greater than the equatorial diameter of 29.6 µm. These detailed morpho-palynological features are instrumental in the accurate identification and classification of *Nepeta govaniana*, providing valuable insights into its taxonomic characterization. While Jabeen *et al*., (2023) elaborated pollen with sinuate outline, acute apex and hexacolpate.

The analysis revealed that the pollen grains *Nepeta leucolaena*, are without spines and are characterized as isopolar, monad, and hexacolporate. Quantitative measurements showed that the equatorial diameter was 31.5 µm and the polar diameter was 31.55 µm. The exine thickness was measured at 1.75 µm, while the colpi length and width were 6.7 µm and 3.5 µm, respectively. Additionally, the mesocolpium, the area between the colpi, was calculated to be 9.05 µm. These detailed observations provide essential insights into the pollen morphology of *Nepeta leucolaena*, contributing to its taxonomic classification. Pollen shape was elliptic in the equatorial view and circular in the polar view, with scabrate exine ornamentation. These observations match with (Jabeen *et al*., 2023).

In *Nepeta nervosa*, the pollen grains are characterized as monad, isopolar, and hexacolpate. The shape of the pollen varies from circular to elliptic, and the exine ornamentation is scabrate, featuring a rough surface texture. The polar diameter of the pollen grains is 22.35 µm, which is smaller than the equatorial diameter of 32.45 µm. The exine thickness was measured at 2.44 µm. Additionally, the colpi, which are the grooves between the pollen apertures, have a length of 5.33 µm and a width of 5.45 µm, these observations differ from (Moon *et al*., 2008). These detail morpho-palynological characteristics are essential for understanding the pollen structure of *Nepeta nervosa* and contribute valuable information for its taxonomic classification.

The equatorial diameter of *Nepeta podostachys* was 21.5 µm, while the polar diameter was slightly larger at 22.65 µm. The exine thickness was measured at 1.45 µm. Additionally, the colpi, which are the grooves between the pollen apertures, had a length of 3.3 µm and a width of 1.75 µm. The mesocolpium, which is the area between the colpi, was recorded at 7.25 µm. These detailed measurements provide a comprehensive understanding of the pollen morphology in *Nepeta podostachys* and contribute to its taxonomic classification. The pollen grains were observed to be monad and isopolar. Both the equatorial and polar views of the pollen displayed a circular shape. The exine ornamentation was scabrate, characterized by a rough, textured surface. These observations relate to Ahmad *et al*., (2015).

The thickness of the exine was recorded at 2.15 µm. Additionally, the length of the colpi, which are the grooves between the pollen apertures, was measured at 11.5 µm, with a width of 4.15 µm. The mesocolpium, the area situated between the colpi, was found to be 11.55 µm. These detailed measurements and morphological features provide crucial information for the accurate classification and identification of *Perovskia abrotanoides*. The pollen grains were identified as monad and isopolar. The equatorial diameter of the pollen grains was 24.9 µm, while the polar diameter was 33.6 µm. The pollen exhibited a circular shape in both the equatorial and polar views. The exine ornamentation was described as psilate-scabrate, featuring a surface with a combination of smooth and rough textures. Bano *et al*., (2020), elaborated reticulate perforate to micro-reticulate type exine sculpturing.

In *Prunella vulgaris*, the pollen grains were observed to be monad and isopolar. The pollen grains exhibited a circular shape in both the equatorial and polar views. The exine ornamentation was characterized as psilate-scabrate, displaying a texture that combines smooth and slightly rough elements. Quantitative analysis provided the following measurements: the equatorial diameter of the pollen grains was 28.25 µm, while the polar diameter was 23.85 µm. The thickness of the exine was recorded at 2.65 µm. The colpi, which are the furrows between the pollen apertures, had a length of 5.15 µm and a width of 2.95 µm. The mesocolpium, the area situated between the colpi, was measured at 12.35 µm. According to Celenk *et al*., (2024) pollen were monads, isopolar, hexacolpate, radially symmetrical, and ellipsoidal in polar view. These detailed morphological and quantitative characteristics offer valuable insights into the pollen structure of Prunella vulgaris, aiding in its precise taxonomic identification and classification.

Quantitative measurements revealed that the equatorial diameter of *Salvia lanata*, was 28.25 µm, while the polar diameter was slightly larger at 30.35 µm. The thickness of the exine was measured at 1.75 µm. The colpi, which are the grooves between the pollen apertures, had a length of 3.25 µm and a width of 4.85 µm. The mesocolpium, the area situated between the colpi, was recorded at 10.75 µm. These detailed morphological and quantitative characteristics provide important information for the accurate classification and identification of *Salvia lanata*. In *S. lanata*, the pollen was identified as monad and isopolar. The pollen exhibited a circular shape in both the equatorial and polar views. The exine ornamentation was described as verucate, characterized by a surface covered with wart-like projections. According to Ozler *et al*., (2013) pollen grains were monad, the shape in equatorial is spheroidal to suboblate while circular to elliptic in polar view.

The equatorial diameter of *Salvia nubicule*, was 50.75 µm, while the polar diameter was slightly smaller at 42.45 µm. The thickness of the exine was recorded as 2.25 µm. The colpi, measured 13 µm in length and 13.5 µm in width. The mesocolpium, the region situated between the colpi, was measured at 12.55 µm. These detailed morphological and quantitative characteristics contribute valuable insights into the pollen structure of *Salvia nubicule*, aiding in its accurate taxonomic classification and identification. In *S. nubicule*, the pollen grains were identified as monad and isopolar. Both the equatorial and polar views of the pollen were circular in shape. The exine, or outer layer of the pollen grain, exhibited a microreticulate ornamentation, characterized by a fine network of reticulate patterns. While Ozler *et al*., (2011) described pollen as monad, subprolate to suboblate pollen shape and recticulate type of exine ornamentation. These results match our observations.

In *Salvia plebeia*, the pollen grains were identified as monad, hexacolpate and isopolar. The pollen exhibited a circular to elliptic truncate shape in both the equatorial and polar views. The exine, or outer layer of the pollen, displayed a microreticulate ornamentation, characterized by a fine network of interconnected ridges. The measurements revealed that the equatorial diameter of the pollen grains was 43.25 µm, while the polar diameter was slightly larger at 44.75 µm. The exine thickness was measured at 2.09 µm. The colpi, had a length of 6.75 µm and a width of 3.5 µm. The mesocolpium, the area between the colpi, was recorded at 12.65 µm. These detailed morphological and quantitative features provide crucial information for the accurate classification and identification of *S. plebeia*. According to Bahadur *et al*., (2022) pollens were small, prolate to subspheroidal. These findings slightly differ from our observations.

The pollen grain of *Scutellaria grossa*, was observed to be monad and isopolar. The shape of the pollen was elliptical in both the equatorial and polar views. The grain showed an equatorial diameter of 23.45 µm and a slightly larger polar diameter of 24.75 µm. The exine thickness was recorded as 1.75 µm. The colpi, which are the grooves that separate the pollen apertures, had a length of 3.15 µm and a width of 4.75 µm. The mesocolpium, which is the area situated between the colpi, was measured at 10.75 µm. These detailed morphological and quantitative characteristics offer valuable insights into the pollen structure of Scutellaria grossa, enhancing our understanding for its accurate taxonomic classification and identification The exine, which is the outer layer of the pollen grain, featured a microreticulate ornamentation, characterized by a delicate network of fine reticulate patterns. While oblate spheroidal, exine thickness is 0.94 µm was observed by (Yildirim *et al*., 2021).

The *Scutellaria linearis*, showed an equatorial diameter of 32.25 µm and a slightly larger polar diameter of 26 µm. The exine thickness was recorded as 1.55 µm. The colpi, which are the grooves that separate the pollen apertures, had a length of 4.3 µm and a width of 2.65 µm. The mesocolpium, which is the area situated between the colpi, was measured at 10.75 µm. These detailed morphological and quantitative characteristics offer valuable insights into the pollen structure of *S. linearis,* enhancing our understanding for its accurate taxonomic classification and identification. The pollen grains were observed to be monad, hexacolpate and isopolar. The shape of the pollen was circualr in both the equatorial and polar views. The exine, which is the outer layer of the pollen grain, featured a microreticulate ornamentation, characterized by a delicate network of fine reticulate patterns. These findings relate to (Yildirim *et al*., 2021).

Quantitative measurements of *Stachys annua* showed an equatorial diameter of 41.75 µm and a slightly larger polar diameter of 44 µm. The exine thickness was recorded as 2.5 µm. The colpi, which are the grooves that separate the pollen apertures, had a length of 3.15 µm and a width of 4.75 µm. The mesocolpium, which is the area situated between the colpi, was measured at 10.75 µm. The pollen was observed to be monad, tricolpate and isopolar. The shape of the pollen was circualr in both the equatorial and polar views. The exine, which is the outer layer of the pollen grain, featured a microreticulate ornamentation, characterized by a delicate network of fine reticulate patterns. It relates to the work of Totmaj and Salmaki, (2022).

The exine thickness of *Stachys emodi* was recorded as 2.05 µm. The colpi, which are the grooves that separate the pollen apertures, had a length of 5.75 µm and a width of 5.75µm, polar diameter of 38.4 µm and equatorial diameter of 41.5 µm. The mesocolpium, which is the area situated between the colpi, was measured at 11.15 µm. These detailed morphological and quantitative characteristics offer valuable insights into the pollen structure of *Stachys emodi*, enhancing our understanding for its accurate taxonomic classification and identification. In *S. emodi*, the pollen grains were observed to be monad, tricolpate, microreticulate, perforate exine sculpturing and isopolar. The shape of the pollen was circualr in both the equatorial and polar views. The exine, which is the outer layer of the pollen grain, featured a microreticulate ornamentation, characterized by a delicate network of fine reticulate patterns. While Ozal Guner, (2022) elaborate pollen as monad, radially symmetrical and isopolar. It matches with our findings

The measurements for the pollen grains of *Stachys palustris* showed an equatorial diameter of 36.15 µm and a slightly larger polar diameter of 30.15 µm. The exine thickness was recorded as 2.25 µm. The colpi, which are the grooves that separate the pollen apertures, had a length of 7.95 µm and a width of 4.45 µm. The mesocolpium, which is the area situated between the colpi, was measured at 10.35 µm. These detailed morphological and quantitative characteristics offer valuable insights into the pollen structure of *Stachys palustris*, enhancing our understanding for its accurate taxonomic classification and identification. In *S. palustris*, the pollen grains were observed to be monad, tricolpate and isopolar. The shape of the pollen was circualr in both the equatorial and polar views. The exine, which is the outer layer of the pollen grain, featured a microreticulate ornamentation, characterized by a delicate network of fine reticulate patterns. These results vary from Suleyman Dogu, (2021).

The equatorial diameter of *Thymus linearis* observed as 36.15 µm and a slightly larger polar diameter of 30.15 µm. The exine thickness was recorded as 2.25 µm. The colpi, which are the grooves that separate the pollen apertures, had a length of 3.95 µm and a width of 4.45 µm. The mesocolpium, which is the area situated between the colpi, was measured at 10.35 µm. The pollen was monad, hexacolpate and isopolar. The shape of the pollen was circualr in both the equatorial and polar views. The exine, which is the outer layer of the pollen grain, featured a striate ornamentation, perforate and psilate exine ornamentation characterized by a delicate network of fine reticulate patterns. Prolate pollen and reticulate type of exine ornamentation were described by Bano *et al*., (2020).

Quantitative measurements of *Thymus vulgaris* showed an equatorial diameter of 33.25 µm and a slightly larger polar diameter of 34.35 µm. The exine thickness was recorded as 1.75 µm. The colpi, which are the grooves that separate the pollen apertures, had a length of 4 µm and a width of 4.75 µm. The mesocolpium, which is the area situated between the colpi, was measured at 13.3 µm. The pollen grains were observed to be monad and isopolar. The shape of the pollen was circular in both the equatorial and polar views. The exine, which is the outer layer of the pollen grain, featured a microreticulate ornamentation, characterized by a delicate network of fine reticulate patterns. This research matches with the findings of Nath and Sonmez, (2023).

The equatorial diameter of *Vitex negundo* was 25.75 µm and a slightly larger polar diameter of 21.6 µm. The exine thickness was recorded as 1.65 µm. The colpi, which are the grooves that separate the pollen apertures, had a length of 4 µm and a width of 4.75 µm. The mesocolpium, which is the area situated between the colpi, was measured at 11.6 µm. The pollen was monad, tricolpate, circular to elliptic truncate and isopolar. The shape of the pollen was circular in both the equatorial and polar views. The exine, which is the outer layer of the pollen grain, featured a microreticulate ornamentation, characterized by a delicate network of fine reticulate patterns. Previously Khan *et al*., (2021) did this work and our findings showed similarities with them.

The equatorial diameter of *Vitex trifolia* measured as 20.9 µm and a slightly larger polar diameter of 30.75 µm. The exine thickness was recorded as 4 µm. The colpi, which are the grooves that separate the pollen apertures, had a length of 4.5 µm and a width of 5.3 µm. The mesocolpium, which is the area situated between the colpi, was measured at 16.75 µm. In *Vitex trifolia*, the pollen grains were observed to be monad and isopolar. The shape of the pollen was circualr in both the equatorial and polar views. The exine, which is the outer layer of the pollen grain, featured a microreticulate ornamentation, characterized by a delicate network of fine reticulate patterns. These findings partially match with (Chun-Xiao Yan, 2023).

3.2.2 Micromorphological features of Asteraceaeous Plants

Twelve astersceous species were analyzed for pollen micromorphology. The observed ranges are summarized and reported as mean values of 15 pollen grains per species as obtained from different parameters from 12 species measured using LM. The morpho-structural features measured in micrometers diameter of polar and equatorial axis, echinae size, colpi size, mesocolpium distance, thickness of exine, no. of echinae and P/E ratio were calculated. The summary of pollen morphometric traits is presented in Table and scanning imaging micrographs was shown in Plates 24 to 27.

The pollen morphological characteristics of *Achillea nobilis* were examined using Scanning Electron Microscopy (SEM) and Light Microscopy (LM). The pollen grains were monad and tricolporate, lacking spines. They exhibited a circular shape in the equatorial view and a triangular shape in the polar view, with perforate exine ornamentation. The equatorial diameter measured 59.3 µm, while the polar diameter was 48.05 µm. Pollen fertility was estimated at 90%, with a sterility rate of 10%. In a comparative study, Akyalçin *et al*. (2011) described Achillea nobilis pollen grains as ranging from oblate-spheroidal to prolate-spheroidal, noting variations in morphology and a high fertility rate. To date, the taxonomic significance of Achillea nobilis pollen morphology has not been thoroughly analyzed. Variations in pollen morphology and germination significantly influence the species' dispersal properties (Anely Nedelcheva, 2008).

The current research on *Anaphalis napelensis* describes its tricolporate pollen as having a triangular to circular shape, with exine ornamentation ranging from macroechinate to perforate. These findings align with those of Ahmad *et al*. (2013). The maximum equatorial diameter was recorded at 39.8 µm, and the maximum polar diameter at 36.3 µm, resulting in a P/E ratio of 0.91. Earlier research by Kaur and Singhal (2015) on the Moraceae family, which includes Anaphalis napelensis, highlighted pollen and cytomorphological diversity, consistent with our observations. The pollen size varies from small to large, enhancing its viability and contributing to the plant's high invasiveness. Pollen fertility was calculated at 83.33%. According to Khan *et al*. (2023), pollen fertility rates are useful indicators of a plant's ability to thrive in unfavorable conditions or outside its natural range (refer to Plate 0).

The study results indicate that the pollen type of *Artemisia sentinifolia* is monad and tricolporate, with no spines present. The pollen shape is circular to elliptic in the equatorial view and triangular in the polar view, consistent with the findings of Lin *et al*. (2005). The equatorial diameter was measured at 21.15 µm and the polar diameter at 25.45 µm, resulting in a P/E ratio of 1.2. Pollen fertility was observed to be 88%, with a sterility rate of 12%. Echinate exine ornamentation was noted, whereas Hussain *et al*. (2019) described the pollen as having granular exine sculpturing. The size and shape of pollen grains are critical traits that enhance pollen dispersal.

The *Aster alpinus* is tricolporate, with a circular to elliptic form in the equatorial view and a triangular appearance in the polar view. The equatorial diameter of 36.25 µm and a polar diameter of 45.85 µm, with a P/E ratio of 0.9. Pollen fertility was observed to be 81.81%, with a sterility rate of 18.19%. The exine ornamentation is echinate. Palynological studies on the Asteraceae family, such as those by Umber *et al*. (2022), also reported echinate to reticulate pollen surfaces. The pollen of Asteraceae is characterized by finite spines (Bahadur *et al*., 2022). Echinate pollen can disperse over longer distances by adhering to the bodies of pollinators, playing an important part in the invasion mechanisms of these plants.

The pollen of *Erigeron alpina* is tricolporate and circular to elliptic in shape, with perforate exine ornamentation. The equatorial diameter was measured at 24.45 µm, while the polar diameter was 21.65 µm, resulting in a polar to equatorial (P/E) ratio of 0.8. Tellería and Katinas (2009) have demonstrated that the P/E ratio is a character of systematic importance. Taxonomic studies of the genus Erigeron by Tulli Ann Kerstetter (1994) also described the plant's morphology. High pollen fertility, calculated at 85%, was observed in *Erigeron alpina*, with a sterility rate of 15%.

The pollen of *Erigeron bellidioides* was monad and tricolporate, with an elliptic shape in the equatorial view and a triangular shape in the polar view and lacked spines.

The exine ornamentation was densely echinate. The equatorial diameter was 25.5 µm, and the polar diameter was 22.8 µm, resulting in a P/E ratio of 0.8. Pollen fertility was observed to be 67.85%, with a sterility rate of 32.15%. Ullah *et al*. (2024) also reported that Erigeron bellidioides has tricolporate pollen with echinate sculpturing. Pollen morphological characters, such as surface sculpturing, size, shape, and outline, are useful for distinguishing taxa (Rashid *et al*., 2022).

In our study, the equatorial diameter of Erigeron bonariensis was 34.15 µm, and the polar diameter was 31.5 µm. We examined tricolporate pollen with a circular to elliptic shape and echinate exine sculpturing in E. bonariensis. Previous findings by Anar *et al*. (2022) observed that *Erigeron bonariensis* has suboblate pollen grains with a P/E ratio of 0.88. They also reported pollen fertility at 75% and sterility at 24%. According to Florentine *et al*. (2021), the diversity in pollen morphological characters observed using LM and SEM provides evidence of variations in pollen type, exine sculpturing, and pollen apertures.

Our study's findings on *Hieracium murorum* reveal that the pollen grains are monad and tricolporate, with a circular shape in the equatorial view and an elliptic shape in the polar view. The exine sculpturing was echinate and non-perforate. The equatorial diameter measured 32.95 µm, while the polar diameter was 37.5 µm. Environmental factors such as temperature, salinity, light intensity, and substrate humidity significantly affect pollen viability and sterility (Dafni and Firmage, 1995). These factors can influence the success of pollen grains in fertilization, thereby impacting the reproductive success and spread of species. Pollen grain size, exine ornamentation, and the number of pores among the most distinctive features that facilitate the spread of different species (Feulner *et al*., 2011).

Lactuca dissecta, commonly known as split-leaf lettuce, is an Asian species of plant belonging to the tribe Cichorieae within the family Asteraceae. Our study found that the equatorial and polar diameters of its pollen were 16.52 µm and 36.8 µm, respectively. The pollen grains are tricolporate, with a triangular to elliptic shape, and exhibit microechinate exine ornamentation. According to Roohi Abid and Muhammad Qaiser (2022), the pollen of Lactuca dissecta is isopolar, spheroidal to oblate-spheroidal, and elliptic to rarely circular, differing from our findings. This discrepancy highlights the importance of understanding pollen morphology in taxonomy, as it plays a crucial role in the accurate identification of Asteraceous flora at species, generic, and tribe levels.

Both qualitative and quantitative characteristics of *Leontopodium nivale* pollen were observed in our study, including equatorial and polar diameters, number of pores and colpi, exine sculpturing and thickness, pollen shape, and the P/E ratio. The pollen was monad and tricolporate. In the equatorial view, the shape was elliptic, while in the polar view it was circular, and in the general view, it appeared triangular. The exine sculpturing was echinate. Similar findings regarding pollen shape and exine sculpturing were reported by Lee *et al*. (2016

The pollen of *Solidago virgaurea* is tricolporate, with macroechinate exine ornamentation. The equatorial diameter was measured at 23.25 µm, and the polar diameter at 21.35 µm, resulting in a P/E ratio of 0.9. Pollen fertility was found to be 89.47%. In the equatorial view, the pollen grains of Solidago virgaurea are circular, while in the polar view, they exhibit a triangular obtuse shape. This is consistent with the research by Migdalek *et al*. (2014), who studied the pollen morphology of *S. virgaurea* and reported similar findings, including colporate apertures, a circular equatorial outline, and echinate ornamentation. These observations align with our research, reinforcing the importance of these palynological characteristics in understanding and identifying *Solidago virgaurea.*

The pollen morphology of *Tanacetum artemisioides* was examined using both Light Microscopy (LM) and Scanning Electron Microscopy (SEM). Our analysis revealed that the pollen grains are monad, tricolporate, and exhibit a shape ranging from circular to elliptic. We measured the polar diameter at 20.8 µm and the equatorial diameter at 24.4 µm, resulting in a P/E ratio of 0.8. The pollen fertility was found to be 93.75%. Pollen fertility is a crucial indicator of plant reproductive health and stability. This is consistent with the research by Migdalek *et al*. (2014)

3.2.3 Micromorphological features of Fabaceaeous Pollen

In fabaceous taxa the exine thickness ranged from 0.94-5.25 µm in *Trifolium pratense* and maximum in *Astragalus Legumimesea.* The polar diameter was measured as minimum 17.75 µm in *Astragalus Legumimesea*, 24.82 µm in *Trifolium pratense* and maximum in *Melilotus indica* as 28.9 µm. The equatorial diameter was recorded as 25.23 µm in *Trifolium pretense*, 27.3 µm in *Trifolium repens*, 21.54 µm in *Medicago polymorpha*, 27.22 µm in *Astragalus breviscapus*, 22.35 µm in *Astragalus graveolens*, 25.66 µm in *Astragalus rhizanthus*, 19.4 µm in *Astragalus Legumimesea* as minimum and 29.4 µm in *Melilotus indica*. The width of colpi measured as maximum 8.43 µm in *Astragalus breviscapus* followed by7.35 µm in *Trifolium repens*, 6.76 µm in *Trifolium pretense* and minimum 3.5 µm in *Astragalus rhizanthus*. P/E ratio was recorded was observed as 0.90 in *Medicago polymorpha* as minimum and maximum as 1.11 in *Astragalus rhizanthus*. Mesocolpium ranged from 5.9 - 16.8 µm. The pollen grain was tricolporate and small-medium in size. The shape was oblate-spheroidal to prolate spheroidal and per-oblate and exine ornamentation were reticulate scarbate and perforated as shown in plate 27 and 28. Paly-nomorphological features play significant role in the classification and identification of Fabaceous species from a taxonomic standpoint. Khan *et al*. (2019) investigated triangular, subprolate to prolate, radially symmetrical, and reticulate to faintly regulate sculpture patterns in *Medicago* species, which contradicted the current findings.

A similar investigation was carried out by Bagheri *et al*. (2019) on the 22 species of Astragalus section Hymenostegis. He discovered that the pollen had an oblate to spheroidal form, with pores that were tricolpate and microreticulate, which sculpted the exine. Studies on hololeuce species revealed that they are isopolar, radially symmetrical, and have prolate-spheroidal to subprolate or prolate shapes along with polar and equatorial axes (21.42–32.93 to 17.13–28.26 µm). Similar aperture conditions, like tricolporate, have been noted in several Fabaceous sections (Karaman Erkul *et al*., 2017).

3.2.4 Micromorphological features of Polygonaceae Taxa

Quantitative measurements revealed that the equatorial diameter of the pollen grains was 25.51 µm in *Rumex nepalensis*, 25.84 µm in *Oxyria digyna*, 27.25 µm in *Bistorta affinis*, 28.65 µm in *Polygonum biaristatum* and maximum 30.7 µm in *Persicaria capitate*, while the polar diameter was slightly larger at 30.25 µm in *Bistorta affinis* and minimum in *Oxyria digyna* as 24.66 µm. The exine thickness ranged from 1.56- 3.92 µm. Additionally, the colpi, which are the furrows or grooves separating the pollen apertures, had a length of 13.81 µm in *Rumex nepalensis*, 13.25 in *Persicaria* *capitate*, 11.46 in *Oxyria digyna*, 8.74 in *Polygonum biaristatum* and minimum in *Bistorta affinis* as 3.33 while width of colpi noted as 3.85 -7.52 µm in *P. capitata* and *O.digyna* respectively. The mesocolpium, the area between the colpi, was recorded at 14.2 µm maximum in *P. capitate* and lowest value was noted as 4.82 in *O.digyna*. The P/E ratio was observed between 0.95 -1.11. The pollen size was ranged from small to medium having tricolporate, tricolpate and hexacolporate colpus. The shape of pollen was Spheroidal, spherical, per-oblate having reticulate- semi tectate, psilate, granulate and regulate exine sculpturing.

Ronse De Craene *et al*. (2004) have seen a striking resemblance in the morphology of pollen. The three categories of apertures found in this investigation align with findings from previous studies conducted by Zhou *et al*. (2004) and Hong and Hedberg (1990). It is widely acknowledged that the tricolpate aperture is the ancestral form from which composite apertures originated, including pantoporate and tricolporate (Takhtajan 2009). The pollen grains exhibited a variety of exine ornamentation patterns, including granulate, microreticulate, striate reticulate, microechinate, and reticulate with pitted texture (as reported by Payel Paul and Monoranjan Chowdhury 2020) and were consistent with our findings

3.2.5 Micromorphological features of Rananculaceaeous Taxa

The polar diameter ranged from 23.33-51.74 µm in *Aconitum heterophyllum* and *Pulsatilla wallichiana* respectively, while equatorial diameter 22.16- 45.42 µm, colpi length 6.07-12.23 µm in *Actaea spicata* and *Clematis grata* respectively, and colpi width 4.72- 14.33µm. The exine thickness ranged from 1.63-4.0r0 µm. The highest P/E ratio was found in *A. spicata* (1.14) followed by *P. wallichiana* (1.13), *C. grata* (1.1), *A. heterophyllum* (1.05) and *Thalictrum pedunculatum* (1.03). While the lowest mesocolpium was observed in *C. grata* as 3.6 µm and highest in *A. spicata* 9 µm. The pollen grain size small to large, tricolporate, shape per- prolate, spheroidal and oblate-spheroidal and exine sculptures as regulate and tiny echinate or microreticulated. Perveen and Qaiser (2005) revealed that the pollen grains of the Ranunculaceae family feature ornamentations consisting of tectum striates and sharp ends. In contrast to these previous findings, our scanning electron microscopy results showed a microreticulate, echinate and regulate structure.

Menemen and Uzel (2016) have observed that many species in the Ranunculaceae family, which includes those in the Ranunculus genus, are taxonomically complicated because of their shared morphology. According to Ahmad *et al*. (2018), trizonocolpate, pantocolpate, and pantoporate pollen grains predominate among Ranunculus species. They proposed that many Ranunculaceae species share the pollen traits seen in the taxa of Ranunculus that were investigated. Furthermore, our investigation and the findings of Akbary *et al*. (2017) revealed that the pollen grains of R. sphaerospermus and R. trichophyllus are tricolpate with echinate ornamentation.

3.2.6 Micromorphological features of Caryophyllaceaeous Taxa

In the family caryophyllaceae, three members of genus *Silene* were observed. The polar diameter ranged from 14.16-30.42 µm in *Silene gonosperma* and *silene kunawarensis*, while equatorial diameter ranged from 12.33- 28.62 µm respectively. The width of colpi observed as 2.66 in *S. gonosperma*, 4.12 in S. vulgare and 8.12 in *S. kunawarensis*. Additionally, the length of the colpi was maximum in S. vulgare as 9.92 µm and minimum 3.00 µm in *S. gonosperma*. The P/E ratio observed as 1.03 in *S. vulgare*, 1.06 in *S. kunawarensis* and 1.14 in *S. gonosperma*. The maximum value of mesocolpium was observed in *S. kunawarensis* as 8.5 µm. the pollen grains under light microscopic analysis observed as tricolporata and pantaporate. The pollen was small to medium in size having spheroidal and per-oblate shape. Exine ornamentation was not psilate, infact it was observed as micro-echinate sculpturing.

The morphology of pollen from various phytogeographical regions in Pakistan belonging to the subfamily Caryophylloideae (Caryophyllaceae) has been assessed. The subfamily Caryophylloideae is known for its subspheroidal and prolate pollen grains. The no. of pores varies across the species in the subfamily, ranging from 5 in Silene apetala to 19–35 in Silene conoidea. Based on the quantity of pori, Sahreen *et al*. (2008a) also divided Caryophyllaceae species. According to Yildiz and Minareci (2008), the surface of pollen had thin walls, and the exine size of the species we studied had similar thin walls. The current findings on the subspheroidal and prolate pollen forms in Caryophyllaceae are consistent with another research (Perveen & Qaiser, 2006; Yildiz, 2001, 2006). Through many research on the morphology of Caryophyllaceae pollen, researchers have shown that the family's pollens range in size from 25 to 50 µm (Sahreen *et al*., 2008a, 2008b). Our findings concurred with those previously examined. In addition to the pantoporate pollen found in this study, other researchers have also found pantoporate pollen in the Caryophyllaceae family (Perveen & Qaiser, 2006; Yildiz, 2001, 2006).

Considerable diversity in pollen size and sculpting demonstrates strong taxonomic potential for species identification and characterization (Perveen & Qaiser 2006). According to Perveen and Qaiser (2006), one of the large families of angiosperms with a pantoporate pollen evolutionary pattern is the Caryophyllaceae family. Our results show that the subfamily's pollen morphology is quite close to that of earlier research.

3.2.7 Micromorphological features of Balsaminaceaeous Taxa

Balsaminaceae pollen grains measured 23.6 µm in *Impatiens brachycentra*, 25.73 µm in *Impatiens edgeworthii*, and up to 36.5 µm in Impatiens bicolor. Impatiens bicolor had a somewhat higher polar diameter (36.5 µm) than *Impatiens brachycentra*, which had a minimum of 23.4 µm. Exine thickness ranged between 1.63 and 3.10 µm. *Impatiens edgeworthii* has a colpi length of 8.72 µm, *Impatiens brachycentra* has a colpi length of 5.15 µm, and *Impatiens bicolor* has a colpi width of 3.42-8.1 µm. *Impatiens brachycentra* had the highest mesocolpium measurement of 19.6 µm, while *Impatiens bicolor* had the lowest at 12.55 µm. The P/E ratio ranged between 0.9 and 1.03. The pollen size varied from small to tricolporate colpi. Pollen forms included per-oblate, prolate-spheroidal, and oblate-spheroidal, with echinate, reticulate, and irregular reticulate exine sculpturing.

Palynological examination of these two Balsaminaceae species is first described in our study, and our findings generally reflect those reported by (Pechimuthu, Arumugam *et al*. 2020). Steven B. Janssens *et al*. (2019) evaluated the pollen wall structure of five African *Impatiens* species ranging in size from medium to big, which is consistent with our published results. (Janssens, Wilson *et al*. 2012) discovered that the ancestral pollen type in *Impatiens* is a triangular, tri-aperturate pollen grain with reticulate exine ornamentation, which later evolved into the main *Impatiens* pollen type: a 4-aperturate, rectangular pollen grain with reticulate exine ornamentation. Their results are like ours, but the aperture of pollen grains differs.

3.2.8 Micromorphology of Orobanchaceaeous Taxa

In Orobanchaceae The pollen grains in *Pedicularis pyramidata* had an equatorial diameter of 26.41 µm, while *Euphrasia pectinata* had a maximum of 31.9 µm. *Pedicularis pyramidata* had a slightly larger polar diameter of 27.54 µm, while *Euphrasia pectinata* had a minimum of 32.8 µm. The exine thickness varied between 1.0 and 1.04 µm. Colpi, the furrows or grooves separating the pollen apertures, were only present in *Euphrasia pectinata*, with a length of 2.5µm and a width of 4.7µm, respectively. Colpi were completely absent in *Pedicularis pyramidata*. *Euphrasia pectinata* was the only species to have a mesocolpium measuring 12.35 µm between its colpi. The P/E ratio ranged between 1.0 and 1.04. The pollen size varied from small to medium, with tricolporate colpi. The pollen had a per-oblate and prolate-spheroidal shape, with psilate and coarsely retipilate exine sculpturing.

(Mosyakin *et al*. 2023) found pollen grains to be (2-) 3 (-4)-colpate, rarely 3-colporate, and inaperturate (reported in Epifagus for the first time), suboblate to prolate (P/E = 0.77-1.56) in shape, medium and rarely small-sized, with polar axis = 14.63-34.58 µm and equatorial diameter = 14.63-30.59 µm. Our findings differ from these findings. The 3-colpate kind of apertures and a nanogemmate exine sculpture proposed by Zoya M. Tsymbalyuk *et al*. (2023) are like our results. Dyschoriste species have pollen grains that are medium to large, isopolar, prolate spheroidal, subprolate to prolate, circular, subcircular, and subtriangular amb, 3-colporate, and 13-20 pseudocolpate, and the exine is psilate-microechinate to perforate-microechinate. (Da Silva Monteiro, Buril *et al*. 2023) reported these data, which are also consistent with the outcomes that we analyzed.

3.2.9 Micromorphology of Rosaceaeous Taxa

Quantitative measurements in the Rosaceae family revealed that the equatorial diameter of the pollen grains was a minimum 23.56 µm in *Potentila reptans* and a maximum 26.58 µm in Potentilla crantzii, while the polar diameter was slightly larger at 24.50 µm in *Potentilla crantzii* and a minimum in *Potentila reptans*. The exine thickness varied between 0.9 and 1.0 µm. The colpi measured 8.9 µm in *Potentila reptans* and 4.25 µm in *Potentilla crantzii*, with widths ranging from 2.8-8.21 µm in each species. *Potentilla crantzii* had a maximum mesocolpium area of 9 µm, while *Potentilla reptans* had a minimum of 5 µm. The P/E ratio ranged between 0.95 and 1.0.

The pollen size varied from tiny to tricolporate colpi. The pollen's shape was per-oblate, with Echinate and regulate exine sculpturing.

(Wang, Huang *et al*. 2023)) studied the pollen morphology of 30 individuals from six Chaenomeles taxa using both light and scanning electron microscopy, and their results are consistent with ours.(Cerdan 2023) investigated pollen grains from 15 native Rosales species found in Brazil, and their findings are identical to what we reported in this family.

3.2.10 Micromorphology of Gentianaceaeous Taxa

In Gentianaceae, quantitative measurements revealed that the equatorial diameter of the pollen grains was a minimum 28.75 µm in *Gentiana autumnalis* and a maximum 45.32 µm in Swertia petiolate. The polar diameter was slightly larger at 42.02 µm in *Swertia petiolate* and a minimum in *Gentiana autumnalis*. The exine thickness varied from 1.60 to 3.25 µm. *Gentiana autumnalis* had colpi measuring 3.50 µm in length and 3.83 µm in breadth, but *Swertia petiolate* did not have any. *Swertia petiolate* has a mesocolpium of 7 µm between its colpi. The P/E ratio ranged between 0.85 and 1.02. The pollen size ranged from small to medium, and it contained tricolporate and pericolporate colpi. The pollen's shape was per-oblate, with Psilate-striate and regulate exine sculpturing.

The species' pollen grains varied morphologically in their pollen units (tetrads or monads), size (small, medium, and large), shape (oblate, suboblate, oblate spheroidal, spheroidal, prolate spheroidal, and prolate), polarity (heteropolar, isopolar, or subisopolar), symmetry (bilateral or radial), and number and type of aperture (3-colporate and 1-3porate) studied. (Wortley *et al*. 2012), and these results mostly relate to our work. The aperture morphology differed among colporate, hemicolporate, porate, and hemiporate, while the exine ornamentation varied between genera, including reticulate, gemmate-pilate, rugulate, gemmate-baculate, and rugulate-echinate. as reported by (Ferreira, Absy *et al*. 2013), which is also consistent with our findings.

3.2.11 Micromorphology of Plumbaginaceaeous Taxa

In the Plumbaginaceae family, pollen grains had an equatorial diameter of 19.06 µm in *Limonium gilesii* and a maximum of 54.50 µm in *Acontholimon libanoticum*. The polar diameter was slightly larger at 59.03 µm in *Acontholimon libanoticum* and a minimum of 20.92 µm in *Limonium gilesii*. The exine thickness varied from 2.04 to

5.75 µm. The colpi had a maximum length of 12.50 µm in *Acontholimon libanoticum* and a minimum of 5.42 µm in *Limonium gilesii*. The width of the colpi was 3.65 - 3.90 µm in *Limonium gilesii* and Acontholimon libanoticum. *Limonium gilesii* had a maximum mesocolpium of 7 µm, while *Acontholimon libanoticum* had a minimum of 11 µm. The pollen size varied from small to large, with tricolporate colpi. The pollen form ranged from oblate to per-oblate, with echinate and reticulate exine sculpturing.

Our findings on the pollen morphology of *Acontholimon libanoticum* are consistent with those of (Ateş, İğci *et al*. 2019). (Osman and El-Garf 2006) did very little work, and their results only slightly match ours, but the pollen morphology of this specie was also analyzed for the first time in our research, which distinguishes our results.

3.2.12 Micromorphology of Apiaceaeous Taxa

In the Apiaceae family, quantitative studies found that the equatorial diameter of the pollen grains was 24.86 µm, while the polar diameter was 27.38 µm in *Chaerophyllum reflexum*. The exine thickness measured 1.30 µm. In *Chaerophyllum reflexum*, the furrows or grooves that separate pollen apertures measured 3.74 µm in length and 4.82 µm in breadth. The mesocolpium, the region between the colpi, was measured at 9.8 µm. The P/E ratio was measured at 1.2 µm. The pollen was medium-sized, with tricolporate colpi. The pollen was per-oblate, with Psilate-echinate exine sculpturing. *Carum carvi* pollen has an equatorial diameter of 44.16 µm and a polar diameter of 46.91 µm, belonging to the Apiaceae family. The exine thickness was 4.00 µm. The colpi length and breadth measured 7.75-6.0 µm. The P/E ratio was assessed at 1.06 µm. The pollen was medium and contained tricolporate colpi. The pollen was per-oblate, with pilate-granulate sculpturing.

(Özkök, Sezer *et al*. 2022) analysis of pollen colpi, shape, polarity, and equatorial diameter is largely consistent with our findings. (Birjees, Ahmad *et al*. 2022) identified three types of exine ornamentation: regulate, striate, and cerebroid, which differ from our findings. The pollen morphology of eight species and the foliar epidermis of seven species of the Apiaceae family were studied using microscopic techniques. As a result, five species of pollen prolate and three species of perprolate were identified, each having three colpi. The exine ornamentation was identified as regulatory, striate, and cerebroid. Heracleum leucocarpum has the largest pollen, measuring 43.25 µm polar and 21.6 µm equatorial. Elaeosticta chitralica produced the smallest pollen, measuring 18.4 µm in diameter (Birjees, Ahmad *et al*. 2022). The P/E ratio ranged between 1.59 and 2.16. All of the investigated taxa had radially symmetrical, isopolar, and tricolporate pollen (Özkök, Sezer *et al*. 2022).

3.2.13 Micromorphology of Amaranthaceae Taxa

In the Amaranthaceae family, pollen grains in *Chenopodium foliosum* had an equatorial diameter of 18.75 µm and a polar diameter of 21.95 µm. The exine thickness measured 3.05 µm. In *Chenopodium foliosum*, the furrows or grooves that separate the pollen apertures measured 3.5 µm in length and 3.2 µm in breadth. The area between the colpi, known as the mesocolpium, measured 12.05 µm. The P/E ratio was measured at 1.1 µm. The pollen was tiny and contained tricolporate colpi. The pollen was spheroidal, with Micro-echinate scabrate exine sculpturing.

The pollen size, form, and exine sculpturing are consistent with the findings of (Majeed, Ahmad *et al*. 2023). Our findings are also consistent with those of (Al-Qahtani 2023), and they exhibit no differences from ours.

3.2.14 Micromorphology of Violaceaeous Taxa

The equatorial diameter of pollen grains in the Violaceae family ranged from 18.3 µm in *Viola canscens* to 18.8 µm in *Viola odorata*, while the polar diameter was somewhat higher at 24.2 µm in *Viola canscens* and 18.8 µm in *Viola odorata*. Exine thickness ranged between 0.7 and 1.3 µm. The colpi in *Viola odorata* had a maximum length of 12.5 µm and a minimum of 9.5 µm. The breadth of the colpi was 5.25-6.3 µm in both species. *Viola canscens* had a maximum mesocolpium area of 15.5 µm, while *Viola odorata* had the lowest at 7.8 µm. The P/E ratio ranged between 0.7 and 1.3. The pollen size varied from tiny to tricolporate colpi. The pollen's morphologies ranged from suboblate to subprolate, with micro-verrucate and verrucate perforate exine sculpturing.

There has been relatively little palynological investigation of the Violaceae family to date, which makes our work novel, however our results are slightly similar to those published by (Mark, Wortley *et al*. (2012). Pollen morphology is also highly similar, as noticed by (Kallajxhiu, Kapidani *et al*. 2021).

3.2.15 Micromorphology of Boraginaceaeous Taxa

The equatorial diameter of pollen grains in Boraginaceae was 26.42 µm, while *Onosma hispidum* had a polar diameter of 27.60 µm. The exine thickness measured 2.31 µm. In *Onosma hispidum*, the furrows or grooves that separate pollen apertures measured 8.74 µm in length and 5.80 µm wide. The mesocolpium, the area between the colpi, was measured at 7.3 µm. The P/E ratio was measured at 1.01 µm. The pollen was medium-sized, with tricolporate colpi. The pollen was per-oblate, with Psilate-echinate exine sculpturing.

Exine sculpturing differs from our results, as noted by SADIA, AHMAD *et al*. (2024)), but other features are similar. The quantitative and qualitative results presented by. Kumar, Sharma *et al*. (2020) closely reflect our work, making it significant from a taxonomic standpoint. Yousaf, Zafar *et al*. (2022) provide a palynological analysis of Boraginaceae that includes our findings.

3.2.16 Micromorphology of Papaveraceaeous Taxa

In Papaveraceae, pollen grains had an equatorial diameter of 22.97 µm and a polar diameter of 25.84 µm in *Papaver nudicaule*. The exine thickness measured 1.17 µm. In addition, the colpi was lacking. The P/E ratio was measured at 1.03 µm. The pollen was medium-sized, with tricolporate colpi. The pollen was per-oblate, with Echinate exine sculpturing.

Our analysis differs slightly from that of Ismael Mazuecos-Aguilera and Suárez-Santiago (2023) in terms of pollen morphology, size, and aperture. Pollen grains can be spheroidal, prolate spheroidal, or oblate spheroidal (P/E diameter ratio = 0.99-1.12, with a mean of 1.03 ± 0.03). The pollen aperture is tricolpate, whereas the exine sculpturing is microechinate. These findings are consistent with our data, as reported by Chatchai Ngernsaengsaruay *et al*. (2023).

3.2.17 Micromorphology of Crassulaceaeous Taxa

Pollen grains in the Crussalaceae family have an equatorial diameter of 45.32 µm and a polar diameter of 25.84 µm in *Sedum ewersii*. The exine thickness measured 1.60 µm. In addition, the colpi was lacking. The P/E ratio was measured at 0.92 µm. The pollen was medium-sized, with tricolporate colpi. The pollen was per-oblate, with Echinate exine sculpturing.

Pollen grains are frequently free, radially symmetrical, isopolar, sub-oblate to oblatespheroidal, or prolate-spheroidal to subprolate, and many are prolate and tricolporate. Muhammad Qaiser, Anjum Perveen *et al* (2015) findings in Crassulacae closely reflect our own. (Shahrestani and Faghir 2021) identified two types of exine sculpturing: regulate-striate and regulate-striate-perforate, which are supported by our findings.

3.2.18 Micromorphology of Rubiaceaeous Pollen

Rubiaceae pollen grains had an equatorial diameter of 19.66 µm and polar diameter of 19.41 µm in *Galium verum*. The exine thickness was 4.5 µm. In addition, the colpi was missing. The P/E ratio was measured at 0.98µm. The pollen was tiny and contained tricolporate colpi. The pollen was per-oblate with reticulate sculpturing.

Pollen grains were classified as medium (25-50 mm) or big (50-100 mm) in size, isopolar or apolar, 2-porate, 3-porate, or 3-colporate, and oblate spheroidal, suboblate, prolate spheroidal, or subprolate (Gonçalves-Esteves, Vieira *et al*. 2023). The exines were reticulate in most species (Silveira Júnior, Saba *et al*. 2012)

3.2.19 Micromorphology of Plantaginaceaeous Pollen

Pollen grains in the Plantaginaceae family have an equatorial diameter of 20.51µm and a polar diameter of 18.67µm in *Veronica alpina*. The exine thickness was 1.15 µm. In addition, the colpi length and width were 6.43–5.34 µm. The P/E ratio was measured at 0.91µm. The pollen was tiny and contained tricolporate colpi. The pollen was per-oblate with regulate sculpturing.

Pollen grains are tiny to medium in size, radially symmetrical, and spherical, having a prolate shape along the equatorial axis. They are pantoporate and tricolpate. The exine sculpture is reticulate, microreticulate, scabrate, verrucate, striate, and controlled. (Butt, Zahid *et al*. 2024). Scanning electron microscopy (SEM) was used to thoroughly investigate and document the Plantago genus. Pollen grains are tiny to medium-sized (P = 18.7–44.0 µm, E = 13.7–34.2 µm), prolatespheroidal to prolate (P/E = 1.05–1.54 µm), and shaped (Mohsenzadeh, Sheidai *et al*. 2020).

3.2.20 Micromorphology of Onagraceae Pollen

Onagraceae pollen grains have equatorial diameter of 16.74 µm and polar diameter of 19.25 µm in *Epilobum angustifolium*. The exine thickness was 1.69 µm. In addition, the colpi was missing. The P/E ratio was assessed at 1.14µm. The pollen was tiny and contained tricolporate colpi. The pollen was sheroidal, with Regulate sculpturing.

Palynological research have shown the following properties of the genus *Epilobium* as; their pollen grains are tetrad, angulaperturate, 3-zonoporate (occasionally 2,4 porate), suboblate, and oblate-spheroidal in shape, with baculate, baculate-rugulate, and rugulate ornamentation (Başer, Akay *et al*. 2021). Pollen grains were typically tetrads, radially symmetrical, isopolar, abundant, and yellow. Five species appeared oblate, while E. rechingeri and E. tetragonum were suboblate; the polar view was triangular, and the equatorial view was ellipsoid. (Omar and Sardar 2022).

3.2.21 Micromorphology of Poaeceaeous Pollen

Festuca rubra pollen grains have a polar diameter of 24.59µm and an equatorial diameter of 20.32µm, belonging to the Poaeceae family. The exine thickness was 1.12 µm. In addition, the colpi length and width were 10.98 -7.73 µm, respectively. The P/E ratio was determined at 1.21 µm. The pollen was tiny and had monoporate colpi. The pollen was per-oblate with regulate sculpturing.

Pollen was found in Dactyloctenium aegyptium (L.) Wild, whereas pollen in Lolium temulentum L. was spherical and irregular in shape. Polar and equatorial diameters also varied, indicating that Desmostachya bipinnata (L.) Stapf. can be distinguished from Sorghum bicolor (L.) Moench based on diameter variation (Harun, Shaheen *et al*. 2022). All the taxa studied had sub-spheroidal pollen, and exine ornamentation included microechinateareolate (11 species) and microechinate (1 species). Pollen apertures were classified as monoporate (11 spp.) or diporate (Cenchrus pennisetiformis), (Nazish and Althobaiti 2022).

3.2.22 Micromorphology of Geraniaceaeous Pollen

Geranium pratense pollen grains are 24.86 µm equatorial and 27.38 µm polar in size. The exine thickness measured 1.30 µm. The colpi length and width were 3.74 -

4.82 µm, respectively. The P/E ratio was determined at 1.2 µm. The pollen was tiny and tricolporate. The pollen was per-oblate, with regulate sculpturing.

Palynological research revealed that pollen grains were medium in size, spheroidal and subprolate, radially symmetrical, tricolporate, and reticulate-clavate in ornamentation (İlçim, Günenç *et al*. 2019). Pollen grains were monad, radially symmetric, and isopolar, with tricolporate apertures of the spheroid, prolate-spheroid, or sub-prolate type. Three pollen types were identified based on changes in exine sculpturing patterns: reticulate-clavate, striaterugulate, and reticulum cristatum with clavae (Wang, Ye *et al*. 2021).

3.2.23 Micromorphology of Primulaceaeous Pollen

Primulaceae pollen grains have an equatorial diameter of 28.27 µm and a polar diameter of 27.94 µm in *Primula macrophylla*. The exine thickness was 1.28 µm. In addition, the colpi length and width were 28.27 - 27.94 µm. The P/E ratio was determined at 0.98 µm. The pollen was medium and contained tricolporate colpi. The pollen was per-oblate with regulate sculpturing.

Pollen grains and monads in all analyzed species were isopolar, small to medium in size, prolate spheroidal, subprolate, or prolate in form, with (3)-4-colporate apertures, regular colpi or loxocolpi, and reticulate-granulate, granulate, rugulate-granulate, or microreticulate exines. (da Silva-Fourny, Hollunder *et al*. 2020). pollen grains are radially symmetric, isopolar, spheroidal-subprolate to prolate, amb angulaperturate or fossaperturate, and tricolpate or tricolporate (Shiha 2020).

3.2.24 Micromorphology of Asparagaceaeous Pollen

Asparagaceae pollen grains have an equatorial diameter of 47.7µm and a polar diameter of 34.4µm in *Fessia purpurea*. The exine thickness was 2.17 µm. In addition, the colpi length and width were 7.08-3.58 µm. The P/E ratio was assessed at 0.7 µm. The pollen was tiny and contained tricolporate colpi. The pollen was oblate, with perforated sculpturing.

Species' pollen types can vary from D-shaped to elliptical, triangular, and spindle-shaped, and all forms have been observed in various members of the taxonomic groups reviewed in this research. One of the study's most notable discoveries is that the taxa of the genus Muscari, Hyacinthella, and Bellevalia show no significant variation in pollen structures, particularly harmony (Citak, Uysal *et al*. 2022). Pollenkitt and harmomegathy studied pollen morphology and discovered that pollenkitt partially or totally coats the pollen surface, which could complicate the identification of exine sculpture (Chao, Tzeng *et al*. 2024).

3.2.25 Micromorphology of Iridaceaeous Pollen

Iridaceae pollen grains have an equatorial diameter of 28.7 µm and a polar diameter of 34.7 µm in *Iris ruthenica*. The exine thickness was 2.4 µm. The colpi length and width ranged from 0.67 to 5.08µm. The P/E ratio was assessed at 1.2 µm. The pollen was tiny and contained tricolporate colpi. The pollen was sub-prolate with micro-reticulate sculpturing.

Scanning electron microscopy was used to examine the pollen morphology of 14 Korean Iris species from two subgenera (Limniris and Pardanthopsis) and one closely related species (Sisyrinchium rosulatum). Pollen grains in all analyzed taxa were large (P¼ 35.9-86.7 lm, E¼ 37.3-72.9 lm), oblate (P/E ¼ 0.68) to prolate (P/E ¼ 1.99) in form, and monosulcate with a granulate-perforate aperture membrane (Choi, Ryu *et al*. 2022). The findings revealed that the pollen grains of Iris sintenisii are smaller than those of Iris germanica. The exine of Iris sintenisii is narrower than the exine of pollen grains from Iris germanica (Kallajxhiu, Kapidani *et al*. 2016).

3.2.26 Micromorphology of Adoxaceaeous Pollen

Sambucus ebulus pollen grains have a polar diameter of 19.9µm and an equatorial diameter of 21.45µm, belonging to the Adoxaceae family. The exine thickness was 3.15 µm. In addition, the colpi length and width were 7.3–9.85 µm. The P/E ratio was assessed at 0.9µm. The pollen was tiny and contained tricolporate colpi. The pollen had an oblate-spheroidal shape with reticulate sculpturing.

The exine ornamentation (microreticulate-heterobrochate), the length of the polar axis (tiny pollen), and the pollen shape (about 80% prolate-spheroidal and spheroidal pollen grains) 44 were the distinguishing features of the analyzed species' pollen grains (Wrońska-Pilarek, Jagodziński *et al*. 2020). The pollen grains of the examined species are 3¬colporate, ellipsoidal, spheroidal, or oblate spheroidal and medium in size. In equatorial view, the outline is elliptical or circular, whereas in polar perspective, it is three-lobed or triangular. Colpi are lengthy and have degree pointed ends (Цимбалюк and Безусько 2017).

3.2.27 Micromorphology of Brassicaceaeous Pollen

Pollen grains in the family Brassicaceae have an equatorial diameter of 24.5 µm and a polar diameter of 25.2 µm in *Sisymbrium officinale*. The exine thickness measured 5.05 µm. In addition, the colpi length and width was 2.95-5.65 µm respectively. The P/E ratio was measured at 1.0 µm. The pollen was small, with tricolporate colpi. The pollen was Prolate-spheroidal, with reticulate sculpturing.

Pollen grains in the genus Iberis are typically small to medium in size, radially symmetrical, isopolar, spheroidal, virtually tricolpate, and occasionally syncolpate or tetracolpate. The external sculpture is reticulate, while the structure is semitectate (Çilden and Özmen-Baysal 2024). Except for Matthiola longipetala, the pollen grains were small to medium-sized, tricolpate, and had an inconspicuous opening. The form varied between prolate-spheroidal and perprolate. The external ornamentation was microreticulate, reticulate, or macroreticulate (Erden and Menemen 2021).

3.2.28 Micromorphology of Tamaricaceaeous Pollen

Tamaricaria elegans pollen grains measure 25.05 µm equatorial and 17.2 µm polar. The exine thickness was 2.25 µm. In addition, the colpi length and width were 4.8–5.45 µm. The P/E ratio was assessed at 0.6 µm. The pollen was tiny and had bicolor colpi. The pollen was oblate-spheroidal in shape with fine to coarse reticulate sculpturing.

Pollen grains from eight species of Tamarix L. were gathered in central Iraq. They were inspected using a light microscope (LM) and a scanning electron microscope (SEM). They were tricolpate, isopolar, and radially symmetric. The pollen grains of the study specimen are medium-sized, class (AL Msary and AL Ani 2023). Except for some T. androssowii individuals, all of the species investigated had monad and tricolpate (Shagholi, Keshavarzi *et al*. 2020).

3.2.29 Discussion

Pollen grain morphology has emerged as a pivotal component in the multidisciplinary collaboration of plant systematics and evolution. By unraveling taxonomic puzzles at various levels family, generic, and specific this tool not only enriches our understanding of plant diversity but also contributes to the exploration of genetic resources and the evolutionary relationship of crops (Gabr, 2018). Many researchers have utilized the differences in the polar unit, shape, symmetry, aperture, and wall sculpture of pollen grains to distinguish between different taxa. Pollen varies in size, shape (equatorial diameter, polar diameter, exine thickness, colpi length, colpi width) and exine ornamentations. These results are the main findings for species identifications based on morphological characters. Light and scanning electron microscopy are the significant characters for the identification of the complex flora in the field of plant taxonomy, aeropalynology and melissopalynology. The current study encourages the taxonomists for the identification of taxa.

Scanning electron microscopy revealed a broad spectrum of variations among selected Himalayan species, underscoring the crucial role of pollen morphology in systematic plant studies. This detailed analysis not only enhances our understanding of plant diversity but also brightens the genetic resources essential for crop evolution. Our results show similarity to the previous reported knowledge from Margalla hills of Pakistan (Sufyan *et al*., 2018). The current study gives the details of palynological study of medicinally and economically important taxa in the study area. Pollen morphology plays an important role in the recent issues of plant taxonomy, systematics and their implications. The study revealed that indigenous plants have been used for the treatment of numerous respiratory, digestive, dermatological, rheumatic and renal diseases. So, it was necessary to identify local medicinal plants and conservation-based strategies in need of development for the protection of flora.

Here we describe in this section, the detailed micromorphology of (86) plant specimens belonging to 28 different families using scanning electron microscopy from Karakoram, Hindukush and Himalayan Northern Pakistan. Among them Lamiaceae (23 species) was the most dominating family having maximum number of species followed by Asteraceae(12 species), Fabaceae (8 species), Polygonaceae and Ranunculaceae (each with 5 species), Caryophyllaceae and Balsaminaceae (each with

3 species), Orobanchaceae, Rosaceae, Gentianaceae, Plumbaginaceae, Apiaceae and Violaceae (each with 2 species), , Plantaginaceae, Amaranthaceae, Boraginaceae, Papaveraceae, Crassulaceae, Rubiaceae, Onagraceae, Poaceae, Geraniaceae, Primulaceae, Asparagaceae, Iridaceae, Adoxaceae, Brassicaceae and Tamariaceae (one specie each).Pollen micromorphological characters of plant taxa analyzed here pollen shape, type, size, mesocolpium, colpus orientation, spines features, exine sculpturing, exine thickness P/E ratio pollen size and fertility determination.

Scanning electron microscopy has been utilized to answer taxonomic problems at the family, genus, species, and variety levels in systematics and evolution (Bahadur et al., 2019, 2020; Paul & Chowdhury, 2020). Moore and Webb (1978) discovered that the exine ornamentation and aperture features of pollen were important for their parent genus or species. This paper is part of a comprehensive microscopic and taxonomic analysis of previously published publications on the Lamiaceae family in Pakistan. (Gul *et al*., 2019a, 2019b). This study has the potential to demonstrate the utility of Lamiaceous pollen characteristics in phylogeny, correct identification, and categorization. Our current findings demonstrated that the pollen morphology of the study taxa shared some taxonomic traits and had certain major characters that distinguished the study species. Pollens were found to be monad, tricolpate, hexacolporate, radially/bilaterally symmetrical, small to medium-sized, oblate/subspheroidal, or subspheroidal in shape. Exine sculpture was found to be reticulate, microreticulate, and bireticulate, with colpus surface ornamentation verrucate, gemmate, scabrate, and psilate, revealing similarities withAmina *et al*., 2020).

There have been several morpho-taxonomic research carried out on Asteraceous taxa. Most of the genera possess zonocolporate pollen. The study has shown on the position as well as the shape of the colpus and most species of this family are tricolpus, isopolar, spheroidal and echinate ornamentation as noticed earlier by (Khan *et al*., 2021; Umber *et al*., 2022). On the exine sculptured pattern two diverse pollen were visualized: (1) dense acute end spinules (2) sparsely distributed spiules (Ismail and shehbaz, 2020). It has been shown that pollen morphological characters are valuable in the systematics of the Asteraceae (Shabestari *et al*., 2013. The pollen grains of *Lactuca dissecta* were trizonocolporate, echino-lophate, and circular in polar view. (Qureshi *et al*., 2002) studied the micro-morphological features of *Lactuca*, including exine thickness, equatorial diameter, polar diameter, colpi length, colpi width, and number of spines. In accordance with our study, the examination of pollen grains revealed consistent attributes, affirming the spheroidal shape, trizonocolporate nature, and echinate surface morphology.

Palynologically, Fabaceae is a europalynous family, with varied pollen characteristics (Erdtman *et al*., 1961) Lashin (2006) and Ozbek *et al*. (2014) investigated the shape of pollen grains from a few Fabaceae species. They highlighted the importance of aperture, pore length, colpi length, and lexine sculpturing in distinguishing taxa. Pollen grains are usually radially symmetrical, isopolar, and tricolporate. The current findings are consistent with (El-Sayed *et al*., 2010), who reported that pollen grains in Fabaceae are often triangular in polar view and elliptic in equation view.

For distinguishing and recognising questionable taxa, the distinctive characteristics of the pollen grains seen and examined in each of the investigated taxa were important. While Polygonum and Persicaria share several palynological traits, their categorization as different genera are justified by their unique distinctions in lumina, muri features, and pollen particle sizes (Payel Paul and Monoranjan Chowdhury 2020).

The Polygonaceae family, often known as knotweed, smartweed, and buckwheat, is distinguished by ochreate stipules and prominent nodes. The Polygonaceae family, which includes over 1,200 species across 48 genera, is widely distributed from tropical to arctic latitudes, with the greatest richness found in northern temperate zones (Freeman and Reveal 2005; Sanchez and Kron 2008). For a long time, the distinct morphological properties of Polygonaceae pollen have been employed to address taxonomic issues at several levels, including family, genus, species, and variety. These features are currently considered crucial in the interdisciplinary approach to plant systematics and evolution (Carlo and Paula 2004). Despite the fact that the pollen morphology of Polygonaceae has been thoroughly investigated worldwide, there is a noticeable scarcity of research from Southwestern and Southeast Asian countries, particularly on the subfamily Polygonoideae (Yasmin *et al*., 2010; Taheri and Assadi, 2012; Yurtseva *et al*., 2014). The Polygonaceae family has significant representation in the floral diversity of India's Himalayan and sub-Himalayan regions.

According to Nowicke & Skvarla (1979) the family Ranunculaceae is remarkably uniform with only exceptions to the spinulose and punctate, perforated tectum. Present studies also confirm the uniformity of pollen. However, considerable variation is observed in shape, apertural types, arrangement of apertures and tectal surface. In a palynological research of several species widespread in Turkey (Yıldız 1996, 2001a). Pollen grain features related to *Silene* species include tectate, semitectate, periporate, spinulate, spinulate-microperforate, and reticulate. Our tests revealed that *Silene* pollen grains were tectate, semitectate, polyporate, microechinate, and microperforate. The pollen grain characteristics obtained throughout the investigation, including the number of pores and various ornamentation factors, were substantially compatible with those previously determined. (Yıldız 2001 b). All taxa had spheroidal and poliporate pollen, with exine surface ornamentations ranging from microechinate-microperforate (punctate) to perforate.

Impatiens species are notoriously difficult to classify due to their tremendous diversity (Yu *et al*., 2009). In recent years, advanced scanning electron microscopy (SEM) techniques have been used to take clearer photographs of pollen and identify more characteristics (Ahmad *et al*., 2018; Song *et al*., 2024). The primary sexine ornamentation of balsams is reticulate sculpturing. This reticulate ornamentation pattern exhibits significant variation in lumina density, muri width and form, and lumina granule density. Microreticulate sculpturing is defined as "a reticulate ornamentation consisting of muri and lumina smaller than 1 µm" (Punt *et al*. 2007, Janssens *et al*. 2005), which showed similarities with our findings. The Impatiens pollen wall arrangement is quite consistent throughout the genus. As already observed by Vinckier *et al*. (2012), foot layer and endexine are slightly intermingled and therefore sometimes difficult to distinguish from each other. *Pedicularis,* a eurypalynous taxon, differed in several pollen characteristics, including form, number and type of aperture, and exine ornamentation. However, aperture types and exine were the most important pollen characteristics. Wang *et al*. (2003) identified five different forms of exine ornamentation in the genus Pedicularis: microfoveolate, microreticulate, microrugulate, microscabrate, and retipilate. Bano *et al*. (2012) reported microscabrate and psilate exine ornamentation while researching four endemic species of Pedicularis from the Alpine zone of the Deosai plateau Himalayan region, which is like the current findings. However, during Mill's recent treatment (2015), two species evaluated by Bano *et al*. (2012) were no longer considered endemic because they had been recorded from other places. Qaiser *et al*. (2014) discovered per-oblate and prolate-spheroidal pollen grains with coarsely reti-pilate exine ornamentation in E. foliosa, which closely resembled our findings.

Pollen grains in Roasaceae family members are monads, small to medium in size, with oblate to prolate shapes and simple striate-psilate tectal microperforations or striate-plicate with supratectal ridges and tectal microperforations, as mentioned by Song and Hong (2021), which is consistent with our observations. Gentianaceous taxa w ere monad, isopolar and radially symmetrical, medium to minutae in size, sub-prolate to prolate in pollen shape class, 3-zonocolpate to 3-zonocolporate, with usually long tapering colpi. The morphology of the pollen grains exhibited significant variation in exine ornamentation viz. striate, striato-reticulate and reticulate mentioned by Kumar *et al*., (2022) which have great resemblance with our species *G. autumnalis and S. petiolate.* The pollen of Apiaceae family was observed as 3 zonocolporate, striate regulate exine and per-porate in shape by Perveen and Qaiser (2006) while our results showed that *Carum carvi* has psilate- granulate sculpturing, tricolporate and per-oblate in shape.

Micrmorphological traits of amaranthaceae are diverse (radially symmetrical, generally apolar, pantoporate, polypantoporate, form spheroidal, tectum punctate scabrate, rarely spinulose; Perveen & Qasier, 2012; Hussain *et al*., 2018). Amaranthaceae pollen grains are pantopolyporate, with some genera, such *Chenopodium L*., having similar exine structure (Pinar & İnceoglu, 1999b). Chenopodium sp. exhibits scabrate, microechinate, and microechinate-scabrate exine sculpturing. Nazish *et al*. (2019) found spinules on the exine of C. album, which aligns with our findings. In Viola, the three-aperturate pollen morph is the ancestral condition, and the presence of four-, five-, or six-aperturate pollen grains is considered derived (Nadot *et al*. 2000), with the pollen aperture number increasing with ploidy level, most likely as a function of genome and cell size. The exine of V. kitaibeliana is microreticulate, with lumina smaller than 1 µm Scoppola and Magrini (2019). The size varies across species, and this study aligns with our findings.

According to Gazer *et al*., (2017) the pollen of Boraginaceous species was prolate, iso-polar, pseudo-colpate, and regulate. Kumar *et al*., (2020) observed specimen of H. indicum pollen grains were tricolpate, pentaporate and spinouse tectum which showed similarities with our results. According to (Pérez-Gutiérrez *et al*., 2015), Chelidonieae are a varied group in terms of pollen ornamentation, with up to five forms, the most common being microechinate-microreticulate. Chelidonieae, however, is far less varied than other Papaveraceae tribes, such as Fumarieae. Our findings revealed that *Papaver nudicaule* possesses micro-echinate ornamentation with tricolpate, per-oblate pollen.

Pollen grains in the Sedum species range from prolate-spheroidal to prolate. The polar axis measures 12.80 to 29.40 µm. In *S. rubens*, the grains are tricolporate, occasionally tetracolporate, with colpi varying from 11.3 up to 22.5 µm in length and 0.5 up to 4.5 µm in width at the equatorial region indicated by (Giuliani *et al*., 2018), which resembles our study in *S. ewersii*. Rubiaceae's main palynological investigations have defined the family as eurypollinic, making pollen morphology more useful in classifying and identifying its members. According to Dessein *et al*. (2005), morpho-palynological data in the Rubiaceae can indicate evolutionary relationships between taxa and be used to reject or support taxonomic decisions. Miro-echinate (Silveira *et al*., 2012) was used to observe the surface, which ranged in size from small to large in this investigation.

Perveen *et al*., (2004) observed the pollen of brassicaceous taxa as reticulate exine ornamentation, prolate- spheroidal shape with long sunken tricolpus. According to our analysis the pollen grain of *Sisybrium officinale* is tricolporate small to medium in size having with prolate- spheroidal shape and reticulate sculpturing. Amina *et al*., (2020) described *S. irio* grains have spheroidal shape and reticulate exine surface. Previously Azzazy 2011 reported the palynomorphs features with semi-tectate exine and micro-reticulate patterns. Elkordy and Faried, (2017) reported reticulate exine type and prolate type pollen in Tamaricaceae family. Previous work by Qaiser and Perveen (2004) described coarse to fine reticulate grains while our results showed that

Tamaricaria elegans have coarse reticulate exine surface with oblate spheroidal pollen shape which is like earlier studies. Palynology is a distinct method for dating and comparing sediments, as well as recognizing continuous and interrupted periods. This technique can construct a stratigraphic framework at the basin level, pinpoint the date of structural trap formations, and enable chronostratigraphic modeling in places with structural complexities to estimate missing sections (Aggarwal *et al*., 2019).

Table 2: Quantitative pollen attributes of selected Plant species.

Sr no.	Plant taxa	Family	Polar diameter	Equatorial diameter	Width of colpi	Length of colpi	Mesocolpium	Exine thickness	P/E Ratio	No. of spines	Spine length	Spine width
1.	*Clinopodium vulgare*	Lamiaceae	55.95(52.13-57.86)	51.1(49.98-53.17)	4.95(2.42-6.92)	7.65(5.75-9.83)	12.35(10.37-15.87)	3.5(1.12-5.31)	1.09	-	-	-
2.	*Isodon rugosus*	Lamiaceae	36.65(35.37-38.96)	23.8(21.57-25.37)	3.6(1.09-5.52)	5.6(3.91-7.66)	10.15(7.93-14.48)	3.15(1.18-5.16)	1.53	-	-	-
3.	*Lambium album*	Lamiaceae	43.25(41.47-45.83)	54.35(52.37-56.06)	4(2.91-6.94)	7.95(5.21-9.96)	9.1(7.12-12.59)	2.65(1.08-4.96)	0.79	-	-	-
4.	*Nepeta clarkei*	Lamiaceae	20.2(18.56-22.71)	16.9(13.36-18.11)	3.5(1.11-4.02)	2.15(0.91-4.12)	7.15(5.82-10.91)	2.25(1.09-4.06)	1.19	-	-	-
5.	*Nepeta govaniana*	Lamiaceae	24.15(22.86-26.31)	29.06(28.56-31.71)	3.15(2.01-5.02)	5.2(3.12-7.01)	12.53(9.36-15.81)	2.6(1.18-4.16)	0.83	-	-	-
6.	*Nepeta leucolaena*	Lamiaceae	31.55(28.63-33.12)	31.05(29.23-33.22)	3.5(1.82-4.99)	6.7(4.82-8.17)	9.05(7.52-11.81)	1.75(0.06-2.99)	1.01	-	-	-
7.	*Nepeta nervosa*	Lamiaceae	22.35(20.7-24.73)	32.45(30.83-34.82)	5.45(3.41-7.29)	5.33(3.18-7.11)	11.3(10.96-13.67)	2.44(1.18-5.01)	0.68	-	-	-

8.	*Nepeta podostachys*	Lamiaceae	22.65(20.7-24.99)	21.5(19.7-23.69)	1.75(0.01.3.13)	3.3(1.06-5.28)	7.25(6.12-9.41)	1.45(0.02-3.08)	1.05	-	-	-
9.	*Peroveskia abrotanoides*	Lamiaceae	33.6(30.84-35.18)	24.9(22.44-26.16)	4.15(2.31-6.45)	11.5(9.74-13.62)	11.55(8.36-13.87)	2.15(1.01-4.96)	1.34	-	-	-
10.	*Prunella vulgaris*	Lamiaceae	23.85(21.84-25.78)	28.25(28.24-30.18)	2.95(0.92-4.01)	5.15(3.85-7.02)	12.35(10.86-14.71)	2.65(1.08-3.06)	0.84	-	-	-
11.	*Salvia lanata*	Lamiaceae	30.35(28.64-33.18)	28.25(26.81-30.98)	3.1(1.02-5.92)	3.25(1.16-5.06)	10.75(8.56-12.94)	1.75(0.01-2.64)	1.07	-	-	-
12.	*Salvia nubicule*	Lamiaceae	42.25(40.24-44.08)	50.75(48.67-51.99)	13(11.95-13.15)	13.5(11.09-15.83)	12.55(9.36-16.67)	2.25(1.01-3.06)	0.83	-	-	-
13.	*Salvia Plebeia*	Lamiaceae	44.75(42.67-46.86)	43.25(41.37-45.06)	3.5(1.01-5.15)	6.75(4.12-8.99)	12.65(10.94-16.11)	2.09(1.08-4.16)	1.03	-	-	-
14.	*Scutellaria grossa*	Lamiaceae	24.75(23.56-26.71)	23.45(20.23-25.52)	3.15(1.21-4.95)	4.75(2.02-6.99)	12.15(10.36-14.67)	1.65(0.03-2.98)	1.05	-	-	-
15.	*Scutellaria linearis*	Lamiaceae	26(24.29-28.77)	32.25(30.23-36.22)	2.65(0.99-2=4.18)	4.3(2.34-6.19)	10.75(7.36-12.55)	1.55(0.05-2.74)	0.80	-	-	-
16.	*Stachys annua*	Lamiaceae	44(40.67-46.06)	41.75(39.97-44.26)	5(3.01-7.19)	7.25(5.31-9.14)	12.4(10.21-14.60)	2.5(1.07-3.06)	1.05	-	-	-
17.	*Stachys emodi*	Lamiaceae	38.4(36.78-40.56)	41.05(39.77-43.16)	4.25(2.11-6.89)	5.75	11.15(8.56-14.12)	2.05(1.02-3.12)	0.93	-	-	-
18.	*Stachys palustris*	Lamiaceae	30.15(28.84-32.18)	36.15(34.77-38.16)	3.25(1.12-4.99)	7.95(5.91-9.54)	10.35(7.18-12.99)	2.25(1.07-3.16)	0.83	-	-	-

19.	*Stachys rigida*	Lamiaceae	25.0(23.23-26.12)	24.4(23.7-25.99)	6.9(6.2-7.84)	4.99(2.12-6.01)	14.2(13.21-15.02)	1.02(0.02-3.03)	1.02	-	-	-
20.	*Thymus linearis*	Lamiaceae	25.8(23.58-27.10)	30.25(28.75-33.91)	7.25(5.94-9.12)	6.75(4.72-8.01)	9.95(7.81-11.94)	1.65(0.02-3.12)	0.85	-	-	-
21.	*Thymus vulgaris*	Lamiaceae	34.35(31.88-36.18)	33.25(30.81-35.98)	9.9(7.13-11.01)	4(3.02-6.59)	13.3(09.36-17.67)	1.75(0.01-2.88)	1,03	-	-	-
22.	*Vitex negundo*	Lamiaceae	21.6(19.61-23.55)	25.75(23.76-27.06)	1.75(0.01-3.12)	4(2.83-6.12)	11.6(8.36-13.77)	1.65(0.01-2.98)	0.83	-	-	-
23.	*Vitex trifolia*	Lamiaceae	30.75(28.88-33.64)	20.9(18.66-24.24)	3(1.32-5.11)	4.5(1.99-5.83)	16.7(13.36-18.57)	4(2.01-5.91)	1.47	-	-	-
24.	*Achillea nobilis*	Asteraceae	48.5(46.44-50.34)	59.3(57.84-61.64)	5.95(3.12-7.81)	9.35(7.62-11.01)	16.1(14.93-18.23)	1.8(0.01-3.01)	0.8	98	5.8	4.22
25.	*Lactuca dissecta*	Asteraceae	36.8(35.12-38.61)	16.52(14.34-18.67)	4.2(2.73-6.16)	6.3(4.78-6.62)	11.4(9.82-13.81)	1.75(0.05-2.99)	2.2	103	6.1	4.2
26.	*Anaphalis napelensis*	Asteraceae	36.3(35.88-38.64)	39.8(37.84-41.64)	4.95(2.81-6.19)	6.4(3.98-9.14)	13.1(10.99-17.98)	2.1(1.05-3.76)	0.91	124	4.5	3.95
27.	*Aster alpinus*	Asteraceae	45.85(43.34-87.42)	46.25(44.94-48.02)	5.25(3.12-7.21)	6.75(4.98-8.83)	11.8(9.64-14.11)	1.85(0.03-3.19)	0.9	95	7.5	4.4
28.	*Tanacetum artemisioides*	Asteraceae	20.8(19.34-22.93)	24.4(21.56-26.77)	3.46(1.31-5.45)	5.7(3.18-7.14)	11.8(10.01-13.35)	1.85(0.02-3.19)	0.8	109	7.2	4.2
29.	*Erigeron alpina*	Asteraceae	21.65(20.43-23.12)	24.45(22.34-27.11)	3.4(2.04-5.89)	4.45(2.63-6.45)	13.75(10.63-15.67)	1.77(0.01-3.29)	0.8	122	5.9	4.05

30.	*Erigeron bonariensis*	Asteraceae	31.05(28.66-34.34)	34.15(31.-37.98)	3.8(1.34-5.99)	6.3(4.1-8.49)	14.3(12.72-16.83)	1.65(0.15-2.89)	0.9	109	5.1	1.73
31.	*Erigeron bellidioides*	Asteraceae	22.8(20.34-25.12)	25.5(22.13-27.98)	4.4(2.13-6.96)	5.45(3.98-8.14)	13.31(11.01-16.34)	2.05(0.65-4.97)	0.8	125	4.5	3.3
32.	*Artimesia sentinifolia*	Asteraceae	25.45(23.64-27.08)	21.15(18.97-24.44)	3.5(1.76-4.9)	3.25(1.62-6.93)	12.8(10.36-14.67)	1.91(0.3-2.01)	1.2	120	4.5	4.1
33.	*Hieracium murorum*	Asteraceae	37.5(34.98-40.76)	32.95(30.21-35.11)	3.7(1.23-5.99)	6(4.13-8.75)	13.42(11.08-15.75)	3.8(1.76-5.12)	1.1	129	4.9	3.9
34.	*Solidago virgaurea*	Asteraceae	21.35(18.78-24.68)	23.25(21.08-27.64)	5.75(3.22-8.21)	10.65(8.12-14.08)	12.25(9.05-15.21)	1.65(0.05-3.89)	0.9	59.	5.5	4.1
35.	*Lentopsdium nivale*	Asteraceae	34.15(32.54-36.81)	23.35(20.11-26.76)	4.55(2.77-7.02)	10.45(8.35-13.89)	12.05(10.02-14.98)	2.01(0.96-4.75)	1.4	102	7.5	3.22
36.	*Trifolium pratense*	Fabaceae	24.82 (22.27-26.85) ±0.38	25.23 (23.60-26.60) ±0.54	6.76 (4.73-9.26) ±1.3	12.25 (8.64-14.30) ±1.6	12.8(10.12-14.64)	0.94 (0.48-1.86) ±0.36	0.98	-	-	-
37.	*Trifolium repens*	Fabaceae	19.2(17.7-20.2)0.43	27.3(26.7-28.0)0.23	7.35(6.7-8.0)0.23	5.3(4.7-6.0)0.25	17.5(17.0-18.2)0.22	2.8(2.25-3.25)0.17	1.1	-	-	-
38.	*Medicago polymorpha*	Fabaceae	19.50 (17.52-21.47) ±0.92	21.54 (16.65-25.78) ±1.8	A	A	5.9(3.82-7.96)	1.67 (1.30-1.73) ±0.63	0.90	-	-	-

39.	*Astragalus breviscapus*	Fabaceae	28.78 (27.21-29.62) ±0.73	27.22 (24.53-29.72) ±0.94	8.43 (7.73-9.34) ±0.96	11.90 (10.32-12.34) ±1.54	12.3(11.08-14.98)	2.63 (1.11-3.34) ±0.46	1.05	-	-	-
40.	*Astragalus graveolens*	Fabaceae	20.34 (17.45-23.83) ±1.24	22.35 (16.73-27.04) ±0.62	4.82 (4.85-6.74) ±0.83	4.79 (3.63-7.45) ±0.94	12(10.13-14.62)	1.86 (1.06-2.25) ±0.34	0.91	-	-	-
41.	*Astragalus rhizanthus*	Fabaceae	28.70 (28.70-29.50) ±0.5	25.66 (25.66-26.35) ±0.62	3.5 (3.25-3.75) ±0.46	4.52 (2.90-7.72) ±0.92	7(5.91-9.05)	2.29 (2.00-2.15) ±0.39	1.11	-	-	-
42.	*Astragalus Legumimesea*	Fabaceae	17.75(17.2-18.2)0.29	19.4(18.2-20.2)0.60	5.25(4.75-5.75)0.28	7.25(6.7-7.5)0.28	5.7(5.25-6.25)0.29	5.25(4.75-5.7)0.29	0.9	-	-	-
43.	*Melilotus indica*	Fabaceae	28.9(26.7-30.0)0.67	29.4(28.0-30.5)0.4	4.85(4.25-5.5)0.23	2.95(2.2-3.5)0.29	16.8(16.0-17.7)0.32	3.8(2.2-4.7)0.46	0.9	-	-	-
44.	*Bistorta affinis*	Polygonaceae	30.25 (29.75-30.75) ±0.28	27.25 (26.75-27.75) ±0.29	4.0 (3.75-4.25) ±0.14	3.33 (3.00-3.75) ±0.29	6(4.83-8.11)	3.35 (1.51-5.41) ±0.23	1.11	-	-	-
45.	*Polygonum biaristatum*	Polygonaceae	29.63 (28.44-30.40) ±0.62	28.65 (25.81-30.52) ±1.57	6.21 (3.63-9.73) ±1.3	8.74 (4.32-12.52) ±1.23	6.2(4.16-8.57)	3.92 (1.82-4.61) ±0.32	1.03	-	-	-

46.	*Oxyria digyna*	Polygonaceae	24.66 (17.71-28.81) ±1.34	25.84 (21.47-29.41) ±1.56	7.52 (4.21-10.92) ±1.64	11.46 (8.86-13.36) ±1.54	4.8(2.01-6.94)	1.56 (0.75-1.65) ±1.54	0.95	-	-	-
47.	*Rumex nepalensis*	Polygonaceae	28.45 (22.21-32.30) ±0.81	25.51 (19.72-27.81) ±1.42	6.3 (4.23-8.47) ±0.42	13.81 (11.45-17.30) ±1.2	9(7.97-11.01)	2.50 (0.98-3.20) ±0.32	1.11	-	-	-
48.	*Persicaria capitata*	Polygonaceae	30.8 (29.75-32.750) 0.514	30.7 (29.25-32.25) 0.60	3.85 (3.0-4.75) 0.30	13.25 (12.0-14.75) 0.51	14.2 (13.0-15.25) 0.41	2.45 (2.0-3.0) .18	1.0	-	-	-
49.	*Aconitum heterophyllum*	Ranunculaceae	23.33 (22.75-24.25) ±0.46	22.16 (21.75-22.80) ±0.30	5.38 (2.73-9.00) ±1.16	7.75 (7.30-8.25) ±0.23	8(7.01-9.06)	4.00 (3.70-4.35) ±0.26	1.05	-	-	-
50.	*Clematis grata Wall.*	Ranunculaceae	28.45 (26.60-29.10) ±0.92	25.43 (22.80-29.12) ±0.83	8.43 (4.92-12.41) ±2.5	12.23 (10.72-14.60) ±1.25	3.6(1.08-5.83)	1.93 (0.70-1.70) ±0.4	1.1	-	-	-
51.	*Pulsatilla wallichiana*	Ranunculaceae	51.74 (46.50-58.25) ±1.96	45.42 (35.75-54.82) ±2.86	14.33 (11.50-17.14) ±1.61	18.25 (10.76-26.46) ±2.54	7.5 (7.10-9.25)	1.63 (1.20-2.50) ±0.41	1.13	-	-	-

52.	*Actaea spicata*	Ranunculaceae	40.75 (38.20-42.40) ±0.72	35.63 (32.00-38.32) ±1.36	4.72 (3.66-6.32) ±0.61	6.07 (4.43-7.51) ±0.56	9 (7.30-10.15)	1.7 (0.92-2.61) ±0.45	1.14	-	-	-
53.	*Thalictrum pedunculatum*	Ranunculaceae	29.63 (28.44-30.40) ±0.62	28.65 (25.81-30.52) ±1.57	6.21 (3.63-9.73) ±1.3	8.74 (4.32-12.52) ±1.23	3.9(1.01-4.71)	3.92 (1.82-4.61) ±0.32	1.03	-	-	-
54.	*Silene vulgaris*	Caryophyllaceae	24.23 (19.94-28.10) ±0.10	23.90 (22.31-26.45) ±0.61	4.12 (1.62-6.30) ±0.72	9.92 (6.65-16.63) ±2.10	8 (6.30-10.05)	1.19 (0.67-1.72) ±0.32	1.03	-	-	-
55.	*Silene gonosperma*	Caryophyllaceae	14.16 (13.25-14.75) ±0.46	12.33 (12.00-12.75) ±0.22	2.66 (2.25-3.00) ±0.22	3.00 (2.75-3.25) ±0.14	4.59(2.81-6.04)	5.16 (4.75-5.50) ±0.22	1.14	-	-	-
56	*Silene kunawarensis*	Caryophyllaceae	30.42 (25.80-34.65) ±1.52	28.62 (21.41-33.70) ±1.80	8.12 (1.73-8.91) ±0.91	9.21 (5.34-16.54) ±1.30	8.5 (6.30-9.75)	1.40 (1.08-1.81) ±0.15	1.06	-	-	-
57..	*Impatiens edgeworthii*	Balsaminaceae	26.57 (25.84-27.64) ±0.87	25.73 (21.64-24.73) ±0.74	3.42 (1.93-3.65) ±0.53	8.72 (8.62-11.23) ±0.83	13.7(11.14-15.06)	1.63 (1.57-1.83) ±0.65	1.03	-	-	-

58.	*Impatiens bicolor*	Balsaminaceae	36.5 (34.7-38.2) 0.62	35.05 (32.7-36.7)0.6	5.30(4.75-5.75)5.3	4.40(3.75-4.75)0.41	12.55(7.25-20.25) 2.9	3.10(2.75-3.5)0.12	1.0	-	-	-
59.	*Impatiens brachycentra*	Balsaminaceae	23.4(22.7-24.2)0.27	23.6(22.7-24.6)0.38	8.1(7.7-8.5)0.12	5.15(4.5-5.75)0.23	19.6(19.0-20.25)0.25	2.8(2.25-3.25)0.16	0.9	-	-	-
60.	*Pedicularis pyramidata*	Orobanchaceae	27.54 (26.32-29.53) ±0.63	26.41 (24.52-27.64) ±0.67	A	A		1.46 (1.4-1.86) ±0.26	1.04	-	-	-
61.	*Euphrasia pectinata*	Orobanchaceae	32.8(32.0-33.75)0.32	31.9(31.7-33.7)0.34	4.7(4.25-5.25)0.16	2.5(2.0-3.0)0.16	12.35(11.7-13.0)0.23	2.4(2.0-3.0)0.18	1.0	-	-	-
62.	*Potentilla crantzii.*	Rosaceae	24.50 (23.25-26.00) ±1.02	26.58 (24.50-28.25) ±0.8	2.8 (2.25-3.25) ±0.30	4.25 (3.75-4.75) ±0.3	9(7.71-11.2)	6.08 (5.75-6.50) ±0.22	1.0	-	-	-
63.	*Potentila reptans*	Rosaceae	22.40 (19.60-24.45) ±0.76	23.56 (19.30-25.82) ±1.6	8.21 (6.45-11.35) ±0.82	8.9 (7.30-9.10) ±0.72	5(4.01-7.03)	1.87 (1.45-3.12) ±0.15	0.95	-	-	-
64.	*Gentiana autumnalis*	Gentianaceae	29.50 (28.75-30.25) ±0.75	28.75 (27.75-30.25) 9±1.32	3.83 (3.50-4.25) ±0.14	3.50 (3.25-3.75) ±0.25	7(5.51-8.99)	3.25 (3.75-3.50) ±0.41	1.02	-	-	-

65.	*Swertia petiolate*	Gentianaceae	42.02 (45.12-46.30) ±1.05	45.32 (31.75-59.230 ±2.20	A	A		1.60 (1.31-1.98) ±0.16	0.85	-	-	-
66.	*Acontholimon libanoticum*	Plumbaginaceae	59.03 (58.25-60.25) ±1.04	54.50 (53.50-55.25) ±0.62	3.90 (3.50-4.50) ±0.30	12.50 (10.75-14.75) ±1.18	11(9.85-13.62)	5.75 (5.25-6.25) ±0.29	1.08	-	-	-
67.	*Limonium gilesii*	Plumbaginaceae	20.92 (14.43-26.06) ±0.78	19.06 (17.15-21.13) ±0.45	3.65 (1.92-4.52) ±0.34	5.42 (3.02-7.54) ±0.94	7(5.12-8.99)	2.04 (1.43-2.76) ±0.86	1.09	-	-	-
68.	*Chaerophyllum reflexum*	Amaranthaceae	27.38 (19.64-31.50) ±1.24	24.86 (20.72-26.33) ±0.61	4.82 (3.2-7.2) ±0.73	3.74 (2.34-6.38) ±0.83	9.8(7.12-11.03)	1.30 (0.78-1.92) ±0.35	1.2	-	-	-
69.	*Chenopodium foliosum*	Amaranthaceae	21.95(19.7-23.0) 0.75	18.75(17.75-19.7) 0.35	3.2 (2.75-3.7)0.17	3.5(3.25-4.0)0.14	12.05(11.5-12.7)0.21	3.05(2.75-3.2)0.09	1.1	-	-	-
70.	*Viola canscens*	Violaceae	24.2(22.2-27.2)0.9	18.3(17.2-19.7)0.48	6.3(5.25-7.2)0.35	9.5(8.7-10.2)0.24	15.5(14.5-15.7)0.23	2.45(2.0-3.0)0.18	1.3	-	-	-
71.	*Viola odorata*	Violaceae	18.8(17.7-20.2)0.74	24.2(23.2-25.2)0.57	5.25(4.7-5.75)0.28	12.5(11.7-13.25)0.44	8.7(7.75-10.2)0.76	2.1(2.0-2.25)0.08	0.7	-	-	-

72.	*Onosma hispidum*	Boraginaceae	27.60 (16.80-.32.82) .±0.93	26.42 (25.74-28.01) ±0.25	5.80 (3.68-7.96) ±0.73	8.74 (6.37-9.67) ±0.64	7.3(6.01-8.16)	2.31 (0.91-3.41) ±0.17	1.01	-	-	-
73.	*Papaver nudicaule*	Papaveraceae	.25.84 (19.04-29.14) ±0.23	22.97 (19.13-24.90) ±0.61	A	A		1.17 (0.70-1.80) ±0.18	1.03	-	-	-
74.	*Sedum ewersii*	Crassulaceae	42.02 (45.12-46.30) ±1.05	45.32 (31.75-59.230 ±2.20	A	A		1.60 (1.31-1.98) ±0.16	0.92	-	-	-
75.	*Galium verum*	Rubiaceae	19.41 (18.25-20.25) ±0.60	19.66 (17.75-23.25) ±1.79	A	A		4.5 (4.25-4.75) ±0.14	0.98	-	-	-
76.	*Carum carvi*	Apiaceae	46.91 (46.25-47.75) ±0.77	44.16 (42.73-46.55) ±0.53	6.0 (5.31-6.69) ±0.6	7.75 (7.20-8.30) ±0.14	11(9.17-13.96)	4.00 (3.75-4.25) ±0.25	1.06	-	-	-
77.	*Veronica alpina*	Plantaginaceae	18.67 (14.80-22.70) ±0.81	20.51 (12.34-27.95) ±2.1	5.34 (2.91-8.37) ±1.63	6.43 (2.12-11.85) ±1.83	9(7.12-11.65)	1.15 (0.71-1.92) ±0.28	0.91	-	-	-

78.	*Epilobum angustifolium*	Onagraceae	19.25 (16.56-23.00) ±0.98	16.74 (15.56-19.75) ±0.85	A	A		1.69 (1.36-2.12) ±0.14	1.14	-	-	-
79.	*Festuca rubra*	Poaceae	24.59 (19.91-28.95) ±1.34	20.32 (19.45-23.40) ±0.94	7.73 (7.65-16.24) ±0.96	10.98 (7.76-16.35) ±1.96	8(6.86-10.85)	1.12 (0.73-1.71) ±0.18	1.21	-	-	-
80	*Geranium pratense.*	Geraniaceae	27.38 (19.64-31.50) ±1.24	24.86 (20.72-26.33) ±0.61	4.82 (3.2-7.2) ±0.73	3.74 (2.34-6.38) ±0.83	11(10.01-13.98)	1.30 (0.78-1.92) ±0.35	1.2	-	-	-
81..	*Primula macrophylla*	Primulaceae	27.94 (26.71-30.67) ±0.85	28.27 (25.27-29.74) ±0.85	8.79 (5.70-11.56) ±0.95	6.10 (4.13-7.35) ±0.8	4(2.14-6.12)	1.28 (1.15-2.32) ±0.83	0.98	-	-	-
82.	*Fessia purpurea*	Asparagaceae	34.4(32.7-35.7)0.89	47.7(47.0-48.5)0.43	3.58(3.25-4.0)0.22	7.08(6.75-7.25)0.22	11.67(10.7-12.7)0.58	2.17(2.00-2.25)0.08	0.7	-	-	-
83.	*Iris ruthenica*	Iridaceae	34.7(34.2-35.2)0.29	28.7(27.2-30.7)1.06	5.08(4.7-5.25)0.17	0.67(0.25-1.2)0.30	18.9(18.2-19.7)0.44	2.4(2.0-3.0)0.30	1.2	-	-	-
84.	*Sambucus ebulus*	Adoxaceae	19.9(19.5-20.5) 0.18	21.45(20.25-22.7)0.47	9.85(9.25-10.5)0.23	7.3(6.75-7.75)0.20	12.0(11.25-12.7)0.25	3.15(2.7-3.75)0.18	0.9	-	-	-

85.	*Sisymbrium officinale*	Brassicaceae	25.2(24.5-26.2) 0.30	24.5(23.25-26.50) 0.5	5.65(5.25-6.25) 0.23	2.95(2.25-3.50) 0.21	17.3(16.7-18.0) 0.23	5.05(4.50-5.50) 0.183	1.0	-	-	-
86.	*Tamaricaria elegans*	Tamaricaceae	17.2 (15.7-18.2) 0.42	25.05 (24.2-26.0) 0.34	5.45(4.5-6.5) .39	4.8 (4.25-5.25) 0.2	17.3(16.7-18.0) 0.23	2.25(2.0-2.75) 0.13	0.6	-	-	-

Table 3: Qualitative pollen attributes of selected Plant species.

S. no.	Taxa	Family	No. of apertures	Size of pollen	Shape of pollen	Exine sculpturing
1.	*Clinopodium vulgare*	Lamiaceae	Hexacolpate	Medium	Oblate- spheroidal	Macroreticulate
2.	*Isodon rugosus* Wall.ex Benth	Lamiaceae	Hexacolpate	Small- medium	Per prolate	Macroreticulate
3.	*Lambium album*	Lamiaceae	Tri-hexcolptae	Small- medium	Oblate- sphereoidal	Psilate-reticulate
4	*Nepeta clarkei*	Lamiaceae	Hexacolpate	Medium	Oblate spheroidal	Reticulate
5..	*Nepeta govaniana*	Lamiaceae	Hexa to multi syncolpate	Medium	Oblate spheroidal	Reticulate
6	*Nepeta leucolaena*	Lamiaceae	Hexacolporate	Medium	Spherical	Macroreticulate
7.	*Nepeta nervosa*	Lamiaceae	Hexacolpate	Small- medium	Sub prolate	Macroreticulate
8.	*Nepeta podostachys*	Lamiaceae	Tri-hexacolporate	Medium	Sub prolate	Microreticulate
9.	*Peroveskia abrotanoides*	Lamiaceae	Hexacolpate	Large	Oblate –prolate	Reticulate
10.	*Prunella vulgaris*	Lamiaceae	Tri to Hexacolpate	Medium	Sub oblate	Reticulate

11.	*Salvia lanata*	Lamiaceae	Hexacolpate	Large	Spherical	Reticulate
12.	*Salvia nubicola*	Lamiaceae	Hexacolpate	Large	Oblate spheroidal	Microreticulate
13.	*Salvia Plebeia*	Lamiaceae	Hexacolpate	Medium	Prolate	Macro-reticulate
14.	*Scutellaria grossa*	Lamiaceae	Tricolpate	Small	Prolate	Reticulate
15.	*Scutellaria linearis*	Lamiaceae	Hexacolpate	Medium	Sub prolate	Macroreticulate
16.	*Stachys annua*	Lamiaceae	Tricolpate	Small- medium	Sub oblate	Microreticulate
17.	*Stachys emodi*	Lamiaceae	Tricolpate	Small-medium	Sub oblate	Microreticulate
18.	*Stachys palustris*	Lamiaceae	Tricolpate	Small- medium	Sub prolate	Microreticulate
19.	*Stachys rigida*	Lamiaceae	Tricolpate	Small	Prolate-spheroidal	Reticulate-perforate
20.	*Thymus linearis*	Lamiaceae	Hexacolpat	Large	Prolate spheroidal	Reticulate striate
21.	*Thymus vulgaris*	Lamiaceae	Tricolpate	Large	Prolate spheroidal	Macro-reticulate
22.	*Vitex negundo L.*	Lamiaceae	Tricolpate	Medium	Sub prolate	Psilate
23.	*Vitex trifolia*	Lamiaceae	Tricolpate	Small	Sub prolate	Reticulate-verrucate
24.	*Achillea nobilis*	Asteraceace	Tricolporate	Large	Sub-oblate	Echinate

25.	*Anaphalis napelensis*	Asteraceace	Tricolporate	Medium	Oblate spheroidal	Macroechinate
26.	*Artimesia sentinifolia*	Asteraceace	Tricolporate	Medium	Sub-prolate	Echinate
27.	*Aster alpinus*	Asteraceace	Tricolporate	Medium	Oblate spheroidal	Echinate
28.	*Erigeron alpina*	Asteraceace	Tricolporate	Small	Sub-oblate	Macroechinate
29.	*Erigeron bellidioides*	Asteraceace	Tricolporate	Medium	Sub-obllate	Densely echinate
30.	*Erigeron bonariensis*	Asteraceace	Tricolporate	Medium	Oblate spheroidal	Echinate
31.	*Hieracium murorum*	Asteraceace	Tricolporate	Medium	Prolate	Echinate lophate
32.	*Lactuca dissecta D.Don*	Asteraceace	Tricolporate	Medium	Per-prolate	Macroechinate
33.	*Lentopsdium nivale*	Asteraceace	Tricolporate	Medium	Prolate	Echinate
34.	*Solidago virgaurea*	Asteraceace	Tricolporate	Small	Oblate spheroidal	Macromchinate
35.	*Tanacetum artemisioides*	Asteraceace	Tricolporate	Small	Sub-oblate	Macroechinate
36.	*Astragalus leguminesea*	Fabaceae	Tricolporate	Small	Oblate-spheroidal	Reticulate perforate

37.	*Trifolium pratense L.*	Fabaceae	Tricolporate	Small	Per-oblate	Reticulate
38.	*Melilotus indica*	Fabaceae	Tricolporate	Small	Oblate-spheroidal	Reticulate
39.	*Trifolium repens*	Fabaceae	Tricolporate	Small	Prolate-spheroidal	Reticulate-scabrate
40.	*Astragalus rhizanthus*	Fabaceae	Tricolporate	Medium	Per-oblate	Perforate
41.	*Astragalus graveolens*	Fabaceae	Tricolporate	Small	Spheroidal	Perforate
42.	*Astragalus breviscapus*	Fabaceae	Tricolporate	Medium	Per-oblate	Reticulate
43.	*Medicago polymorpha*	Fabaceae	Tricolporate	Small	Spheroidal	Perforate
44.	*Persicaria capitata*	Polygonaceae	Hexacolporate	Small	Spherical	Reticulate-semi tectate
45.	*Bistorta affinis*	Polygonaceae	Tricolporate	Medium	Per-oblate	Psilate-echinate
46.	*Polygonum biaristatum*	Polygonaceae	Tricolpate	Small	Per-oblate	Granulate
47.	*Rumex nepalensis*	Polygonaceae	Tricolpate	Medium	Per-oblate	Reticulate
48.	*Oxyria digyna*	Polygonaceae	Tricolporate	Small	Per-oblate	Regulate
49.	*Aconitum heterophyllum*	Ranunculaceae	Tricolporate	Small	Spheroidal	Regulate
50.	*Clematis grata* Wall.	Ranunculaceae	Tricolporate	Medium	Per-oblate	Regulate
51.	*Pulsatilla wallichiana*	Ranunculaceae	Tricolporate	Large	Per-oblate	Echinate

52.	*Actaea spicata*	Ranunculaceae	Tricolporate	Medium	Per-oblate	Reticulate
53.	*Thalictrum pedunculatum*	Ranunculaceae	Tricolporate	Small	Per-oblate	Regulate
54.	*Silene vulgaris*	Caryophyllaceae	Pantaporate	Medium	Spheroidal	Echinate
55.	*Silene gonosperma*	Caryophyllaceae	Pantaporate	Small	Per-oblate	Echinate
56.	*Silene kunawarensis*	Caryophyllaceae	Tricolporate	Medium	Per-oblate	Echinate
57.	*Impatience edgeworthii*	Balsaminaceae	Tricolpate	Small	Per-oblate	Echinate
58.	*Impatiens bicolor*	Balsaminaceae	Tricolpate	Small	Prolate-spheroidal	Reticulate
59.	*Impatiens brachycentra*	Balsaminaceae	Tricolpate	Small	Oblate-spheroidal	Irregular reticulate
60.	*Pedicularis pyramidata*	Orobanchaceae	Tricolpate	Medium	Per-oblate	Psilate
61.	*Euphrasia pectinate*	Orobanchaceae	Tricolpate	Small	Prolate-spheroidal	Coarsely retipilate
62.	*Potentilla crantzii*	Rosaceae	Tricolporate	Small	Per-oblate	Regulate
63.	*Potentila reptans*	Rosaceae	Tricolpate	Small	Per-oblate	Echinate
64.	*Gentiana autumnalis*	Gentianaceae	Tricolporate	Medium	Per-oblate	Psilate-striate
65.	*Swertia petiolate*	Gentianceae	Pericolporate	Small	Per-oblate	Regulate
66.	*Acontholimon libanoticum*	Plumbaginaceae	Tricolpate	Large	Oblate	Reticulate

67.	Limonium gilesii	Plumbaginaceae	Tricolpate	Small	Per-oblate	Reticulate
68.	*Chaerophyllum reflexum*	Apiaceae	Tricolpate	Medium	Per-oblate	Psilate-echinate
69.	*Chenopodium foliosum*	Amaranthaceae	Tricolpate	Small	Spheroidal	Micro-echinate scabrate
70.	*Viola canscens*	Violaceae	Tricolporate	Small	Sub-prolate	Micro-verrucate
71.	*Viola odorata*	Violaceae	Tricolporate	Small	Sub-oblate	Verrucate perforate
72.	*Onosma hispidum*	Boraginaceae	Tricolporate	Medium	Per-oblate	Psilate-echinate
73.	*Papaver nudicaule*	Papaveraceae	Tricolpate	Medium	Per-oblate	Echinate
74.	*Sedum ewersii*	Crassulaceae	Tricolporate	Medium	Per-oblate	Echinate
75.	*Galium verum*	*Rubiaceae*	Tricolporate	Small	Per-oblate	Reticulate
76.	*Carum carvi*	Apiaceae	Tricolpate	Medium	Per-oblate	Psilate-granulate
77.	*Veronica alpina*	Plantaginaceae.	Tricolporate	Small	Per-oblate	Regulate
78.	*Epilobum angustifolium*	Onagraceae	Tricolporate	Small	Spheroidal	Regulate
79.	*Festuca rubra*	Poaeceae	Monoporate	Small	Per-oblate	Regulate
80.	*Geranium pratense*	Geraniaceae	Tricolporate	Small	Per-oblate	Regulate

81.	*Primula macrophylla*	Primulaceae	Tricolporate	Medium	Per-oblate	Regulate
82.	*Fessia purpurea*	Asparagaceae	Tricolporate	Small	Oblate	Perforate
83.	*Iris ruthenica*	Iridaceae	Tricolporate	Small	Sub-prolate	Micro-reticulate
84.	*Sambucus ebulus*	Adoxaceae	Tricolporate	Small	Oblate-spheroidal	Reticulated
85.	*Sisymbrium officinale*	Brassicaceae	Tricolporate	Small	Prolate-spheroidal	Reticulate
86.	*Tamaricaria elegans*	Tamaricaceae	Bicolporate	Small	Oblate- spheroidal	Fine to coarse reticulate

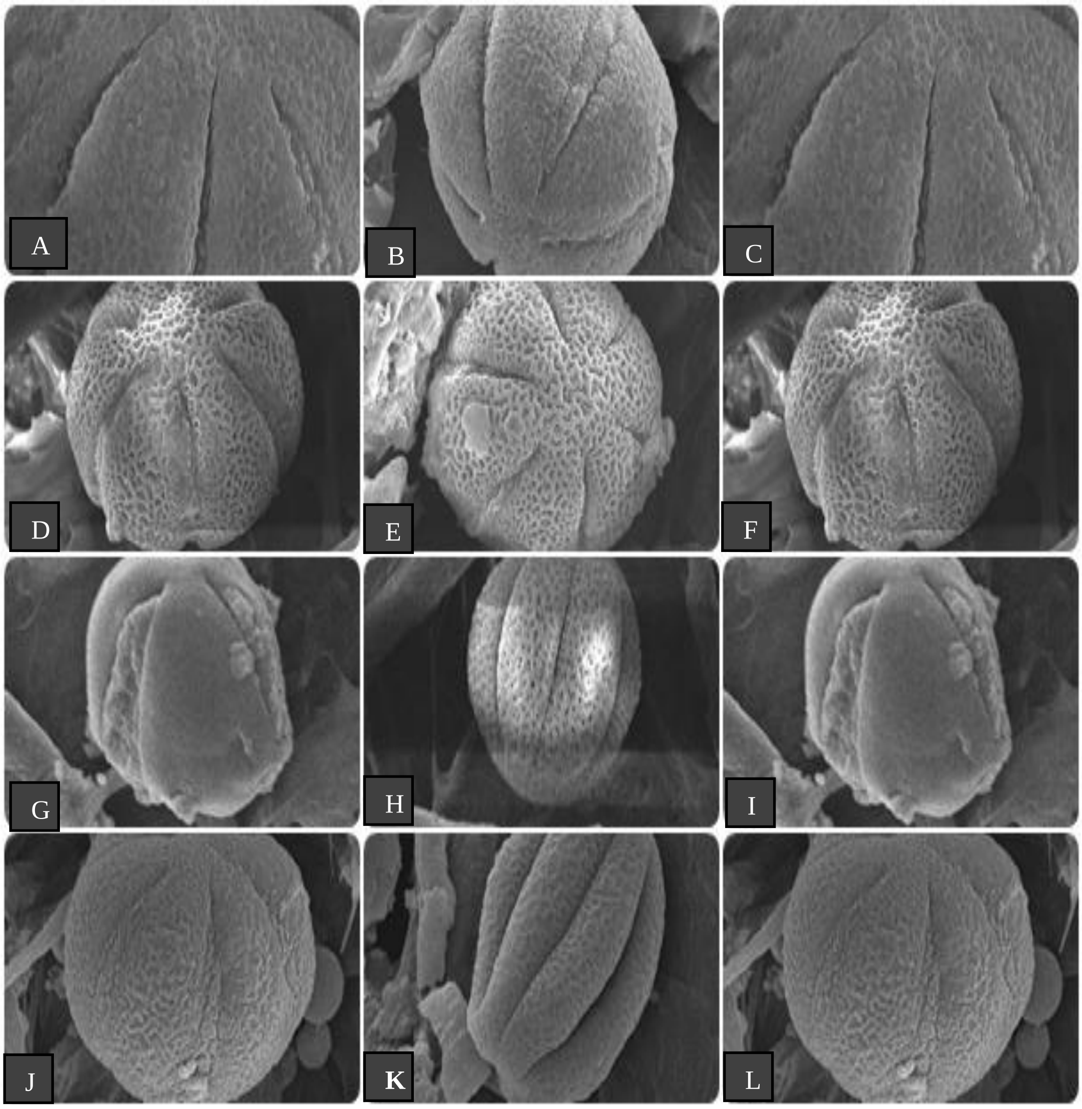

Plate 19: Scanning electron microscopy pollen micrographs. (A-C) *Chenopodium vulgare* (D-F) *Isodon rugosus* (G-I) *Lambium album* (J-L) *Nepeta clarkei*

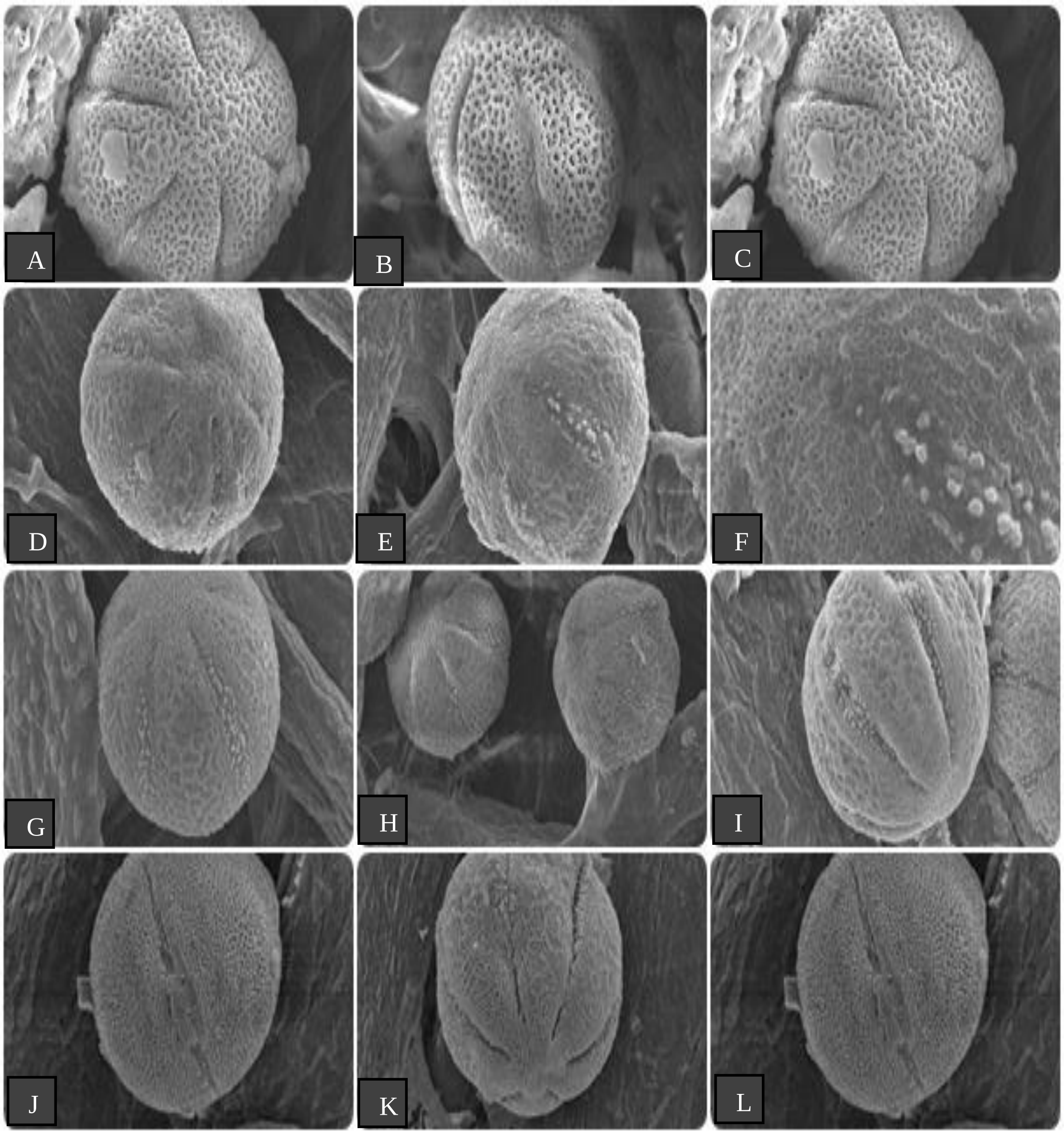

Plate 20: Scanning electron microscopy pollen micrographs. (A-C) *Nepeta govaniana* (D-F) *Nepeta leucolaena* (G-I) *Nepeta nervosa* (J-L) *Nepeta podostachys.*

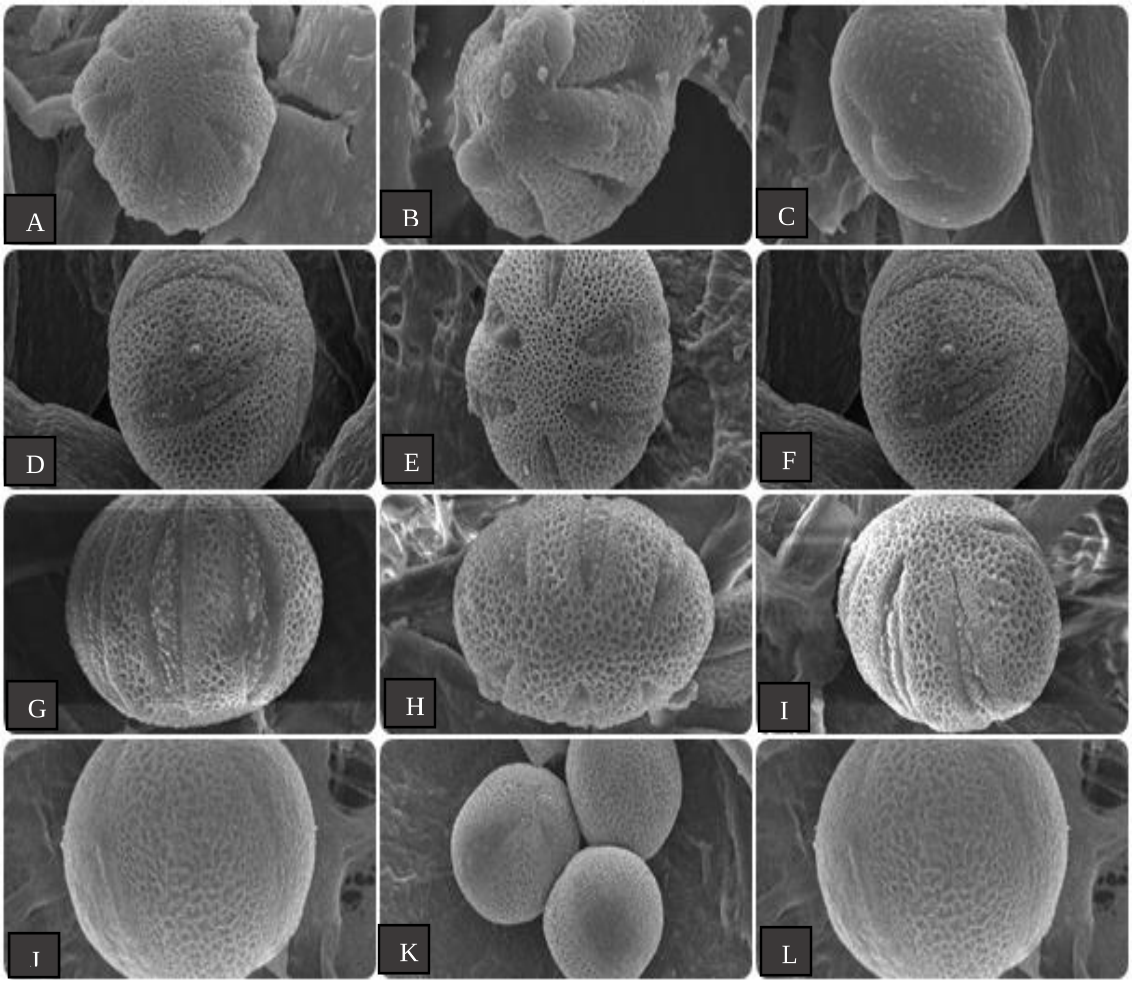

Plate 21: Scanning electron microscopy pollen micrographs. (A-C) *Peroveskia abrotanoides* (D-F), *Salvia lanata*,(G-I) *Salvia plebian*, (J-L) *Scutellaria grossa*

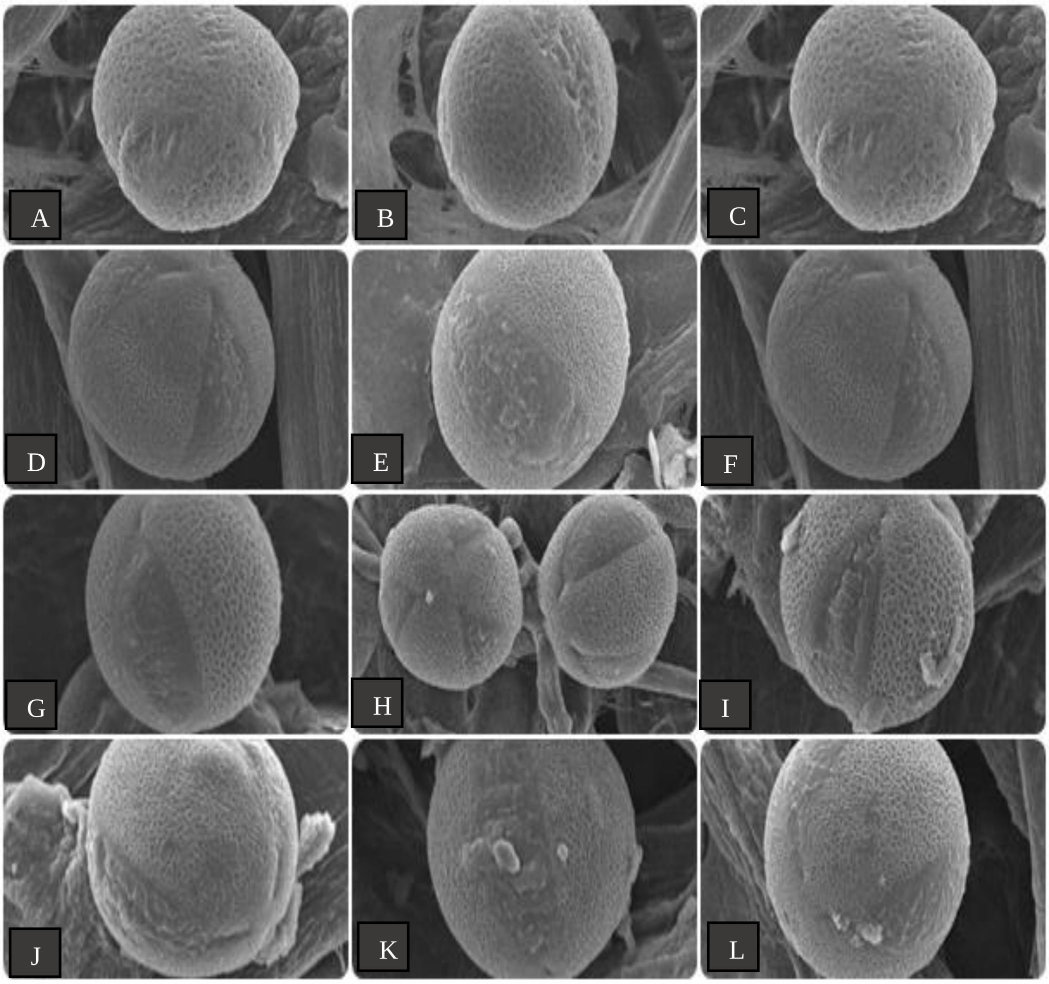

Plate 22: Scanning electron microscopy pollen micrographs. (A-C) *Scutellaria linearis* (D-F), *Stachys annua* (G-I), *Stachys emodi* (J-L), *Stachys palustris*

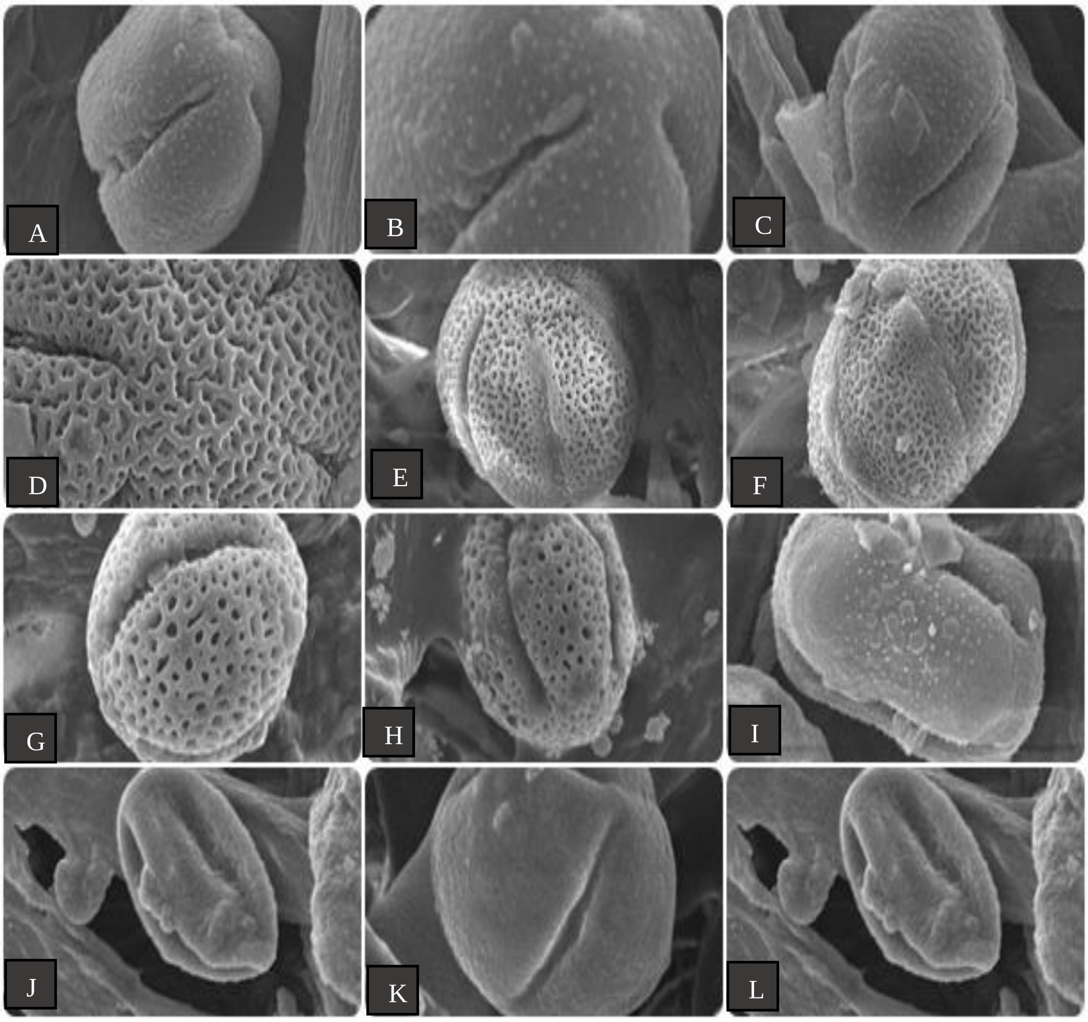

Plate 23: Scanning electron microscopy pollen micrographs. (A-C) *Stachys rigida* (D-F) *Thymus linearis* (G-I) *Thymus vulgaris* (J-L) *Vitex negundo*

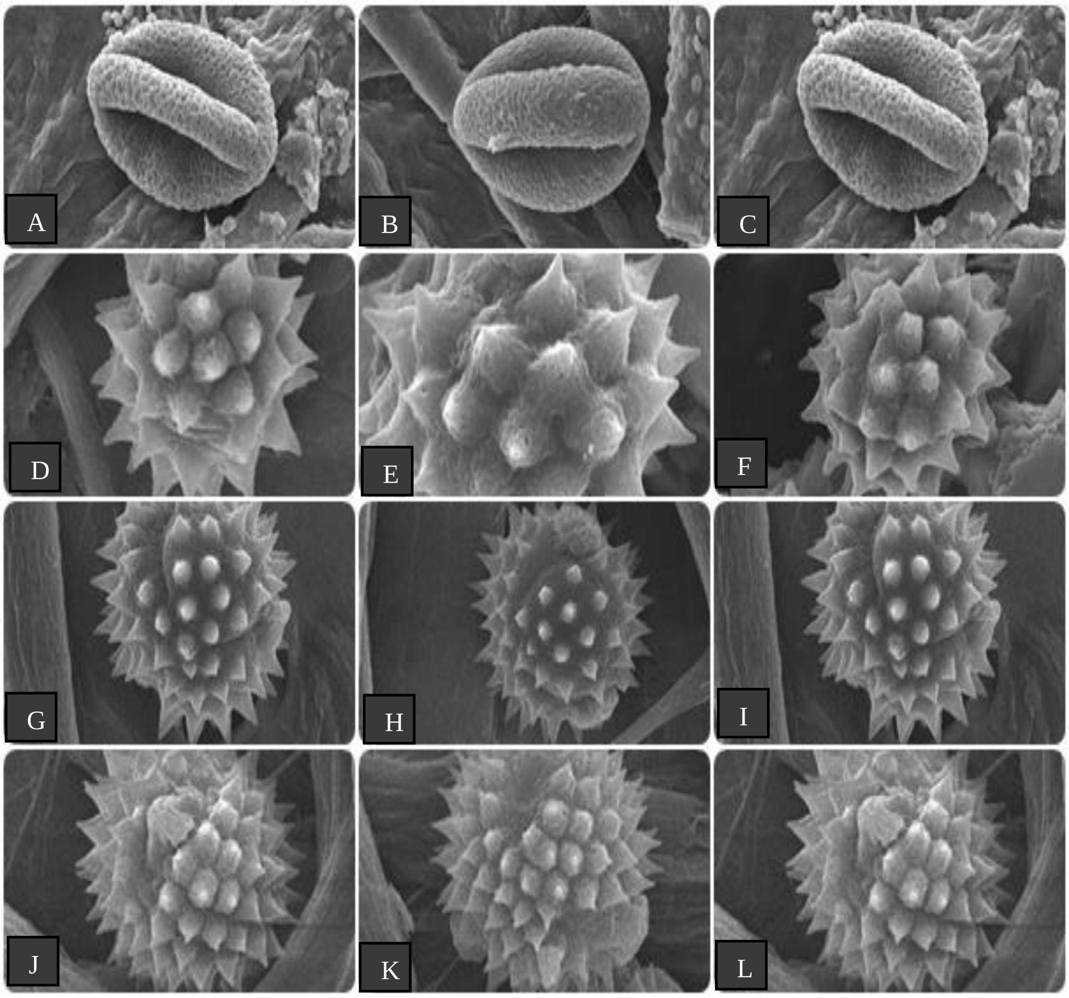

Plate 24: Scanning electron microscopy pollen micrographs. (A-C) *Vitex trifolia* (D-F) *Achillea nobilis* (G-I) *Anaphalis napelensis* (J-L) *Aster alpinus.*

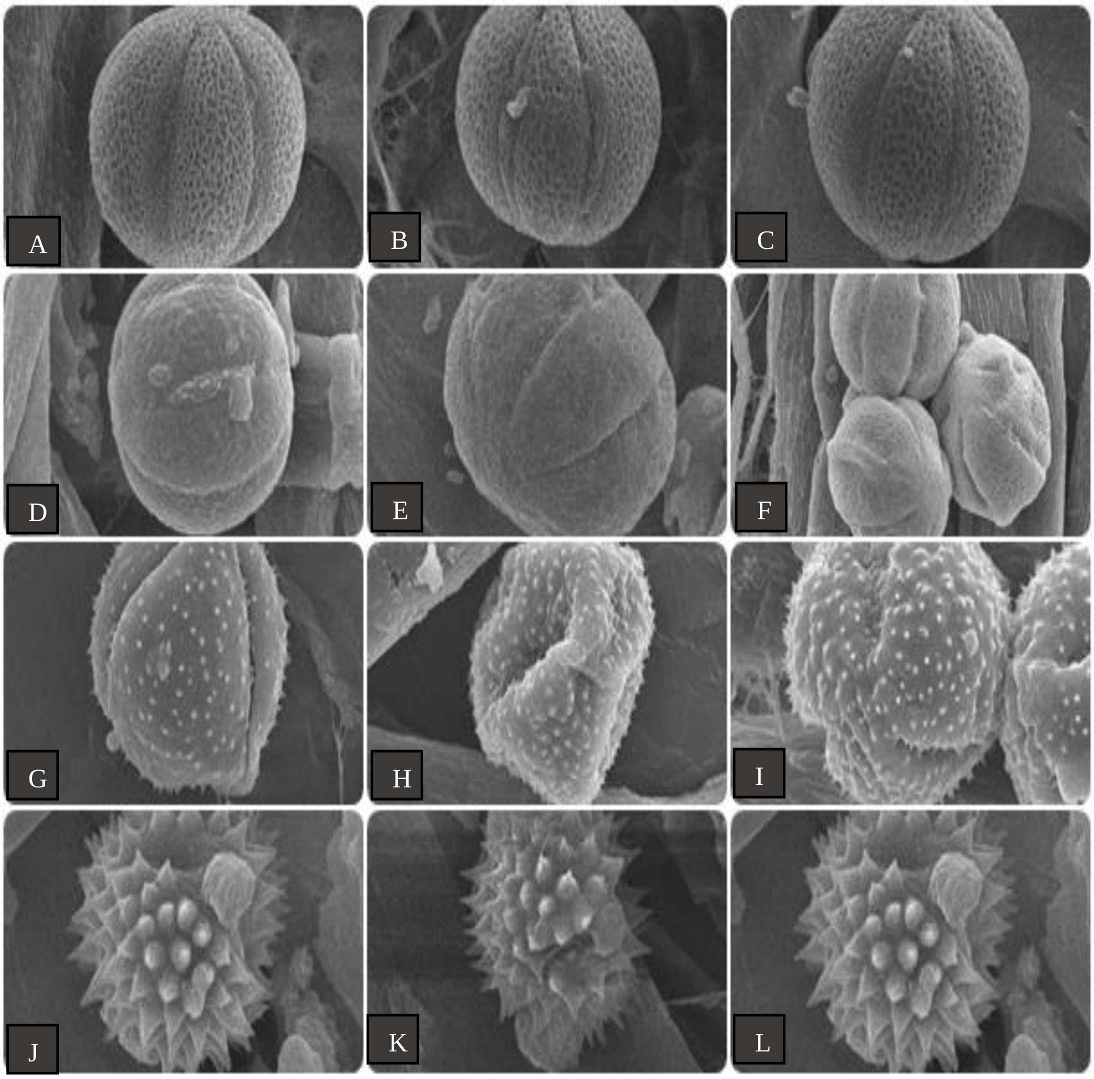

Plate 25: Scanning electron microscopy pollen micrographs. (A-C) *Prunella vulgaris* (D-F) *Salvia nubicola* (G-I) *Artemesia sentinifolia* (J-L) *Erigeron alpina.*

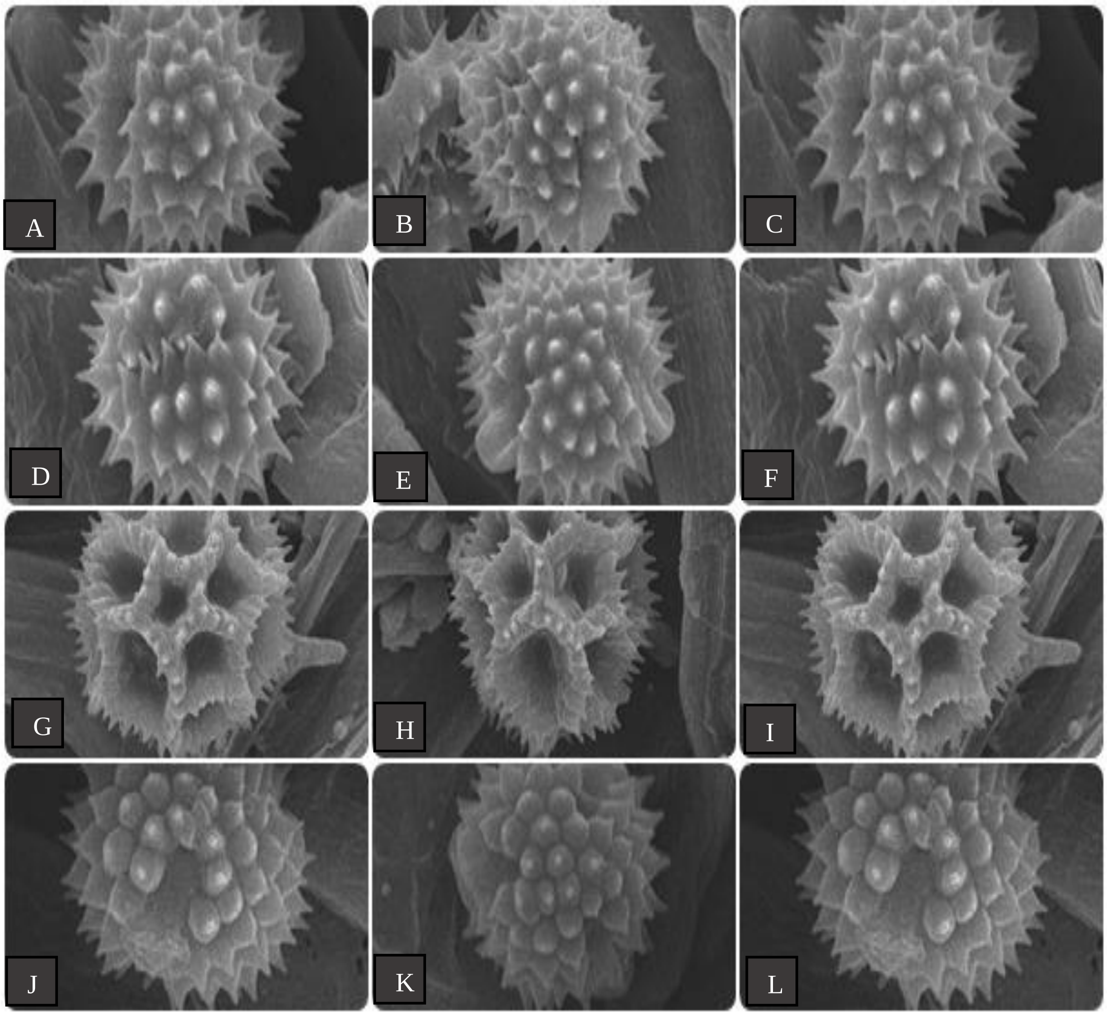

Plate 26: Scanning electron microscopy pollen micrographs. (A-C) *Erigeron bellidioides* (D-F) *Erigeron bonariensis* (G-I) *Hieracium murorum* (J-L) *Lactuca disecta.*

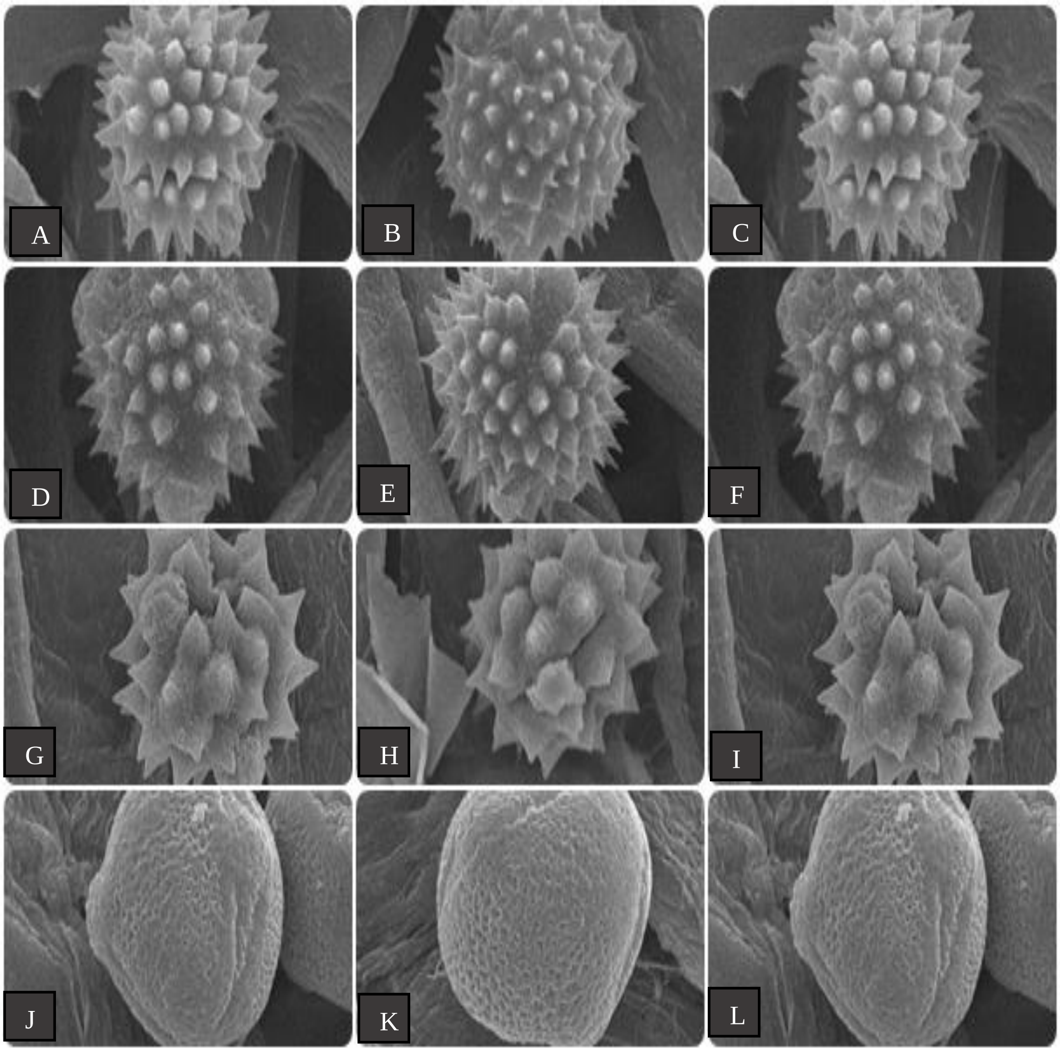

Plate 27: Scanning electron microscopy pollen micrographs. (A-C) *Lentopsdium nivale* (D-F) *Solidago virgaurea* (G-I) *Tanacetum artemisioides* (J-L) *Melilotus indica.*

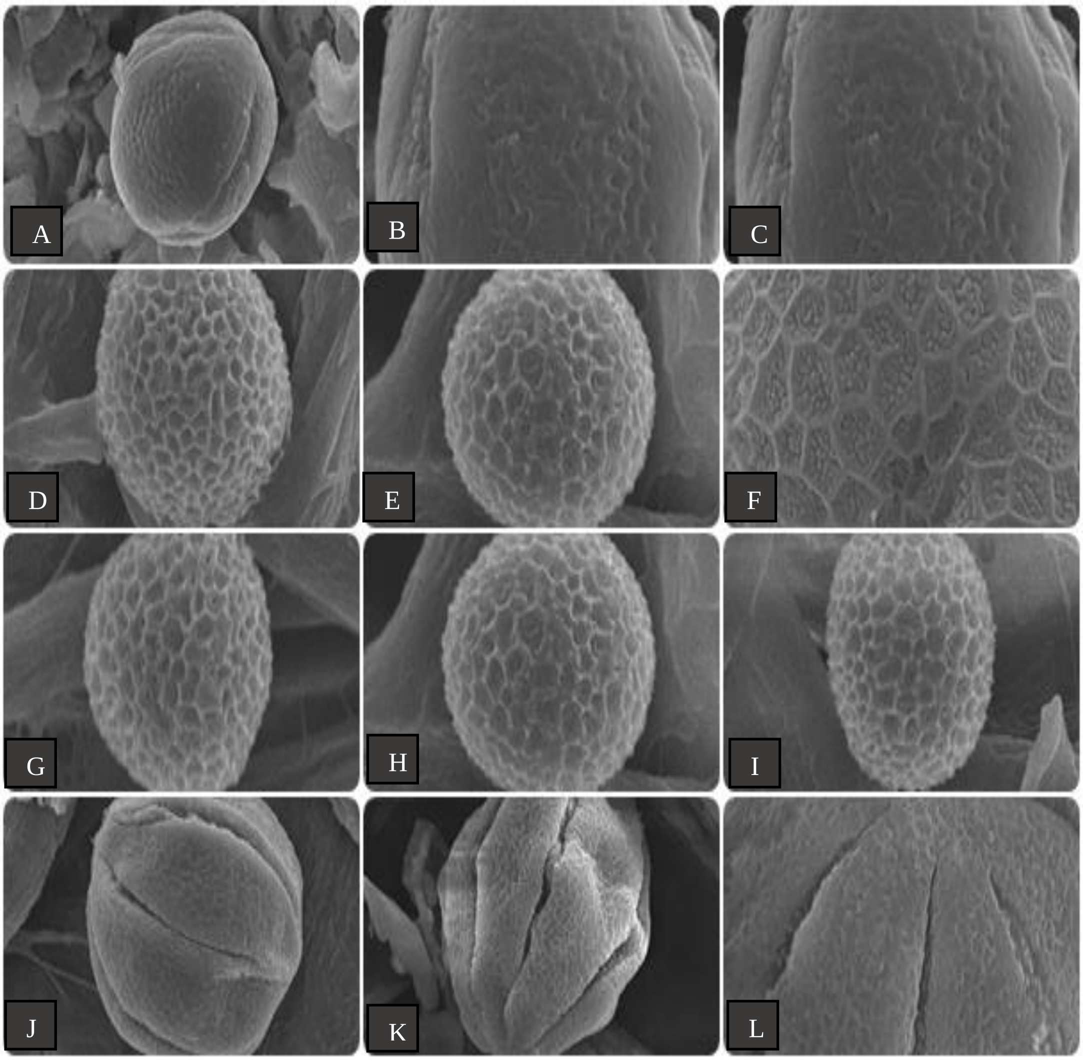

Plate 28: Scanning electron microscopy pollen micrographs. (A-C) *Trifolium repens* (D-F) *Impatiens bicolor* (G-I) *Impatiens brachycentra* (J-L) *Euphrasia pectinate*

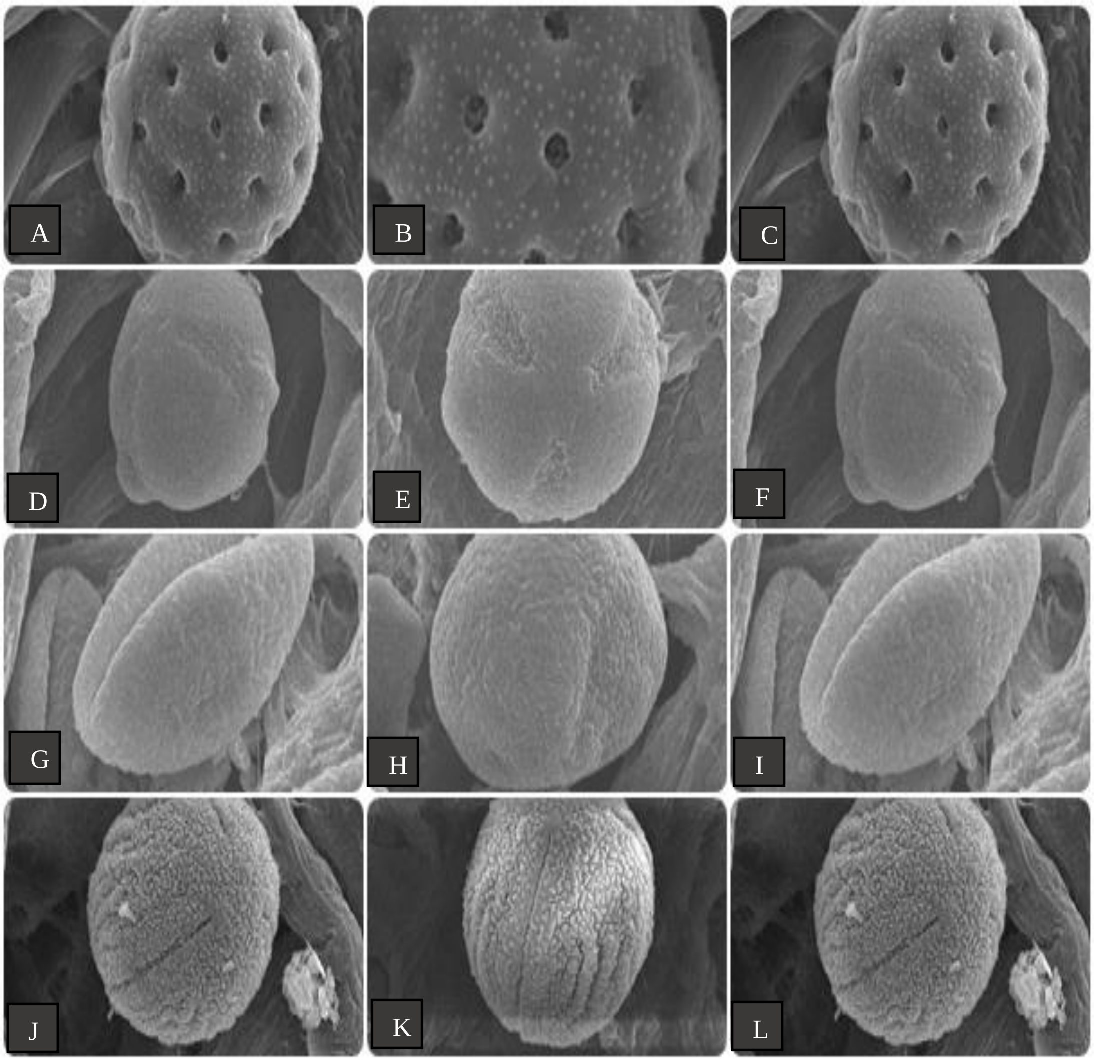

Plate 29: Scanning electron microscopy pollen micrographs. (A-C) *Chenopodium foliosum* (D-F) *Viola canscens* (G-I) *Viola odorata* (J-L) *Fessia purpurea*

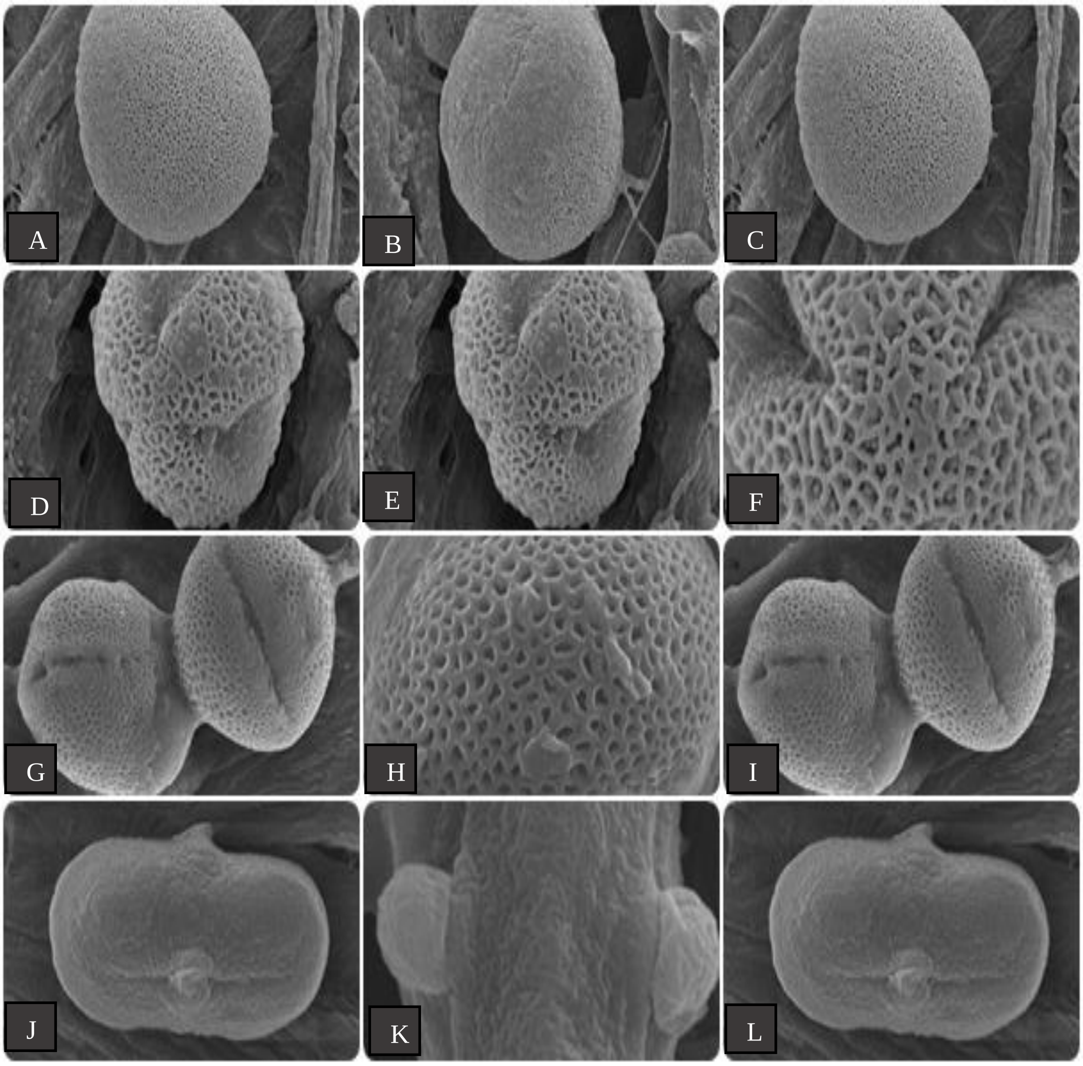

Plate 30: Scanning electron microscopy pollen micrographs. (A-C) *Iris ruthenica* (D-F) *Sambucus ebulus* (G-I) *Sisymbrium officinale* (J-L) *Tamaricaria elegans.*

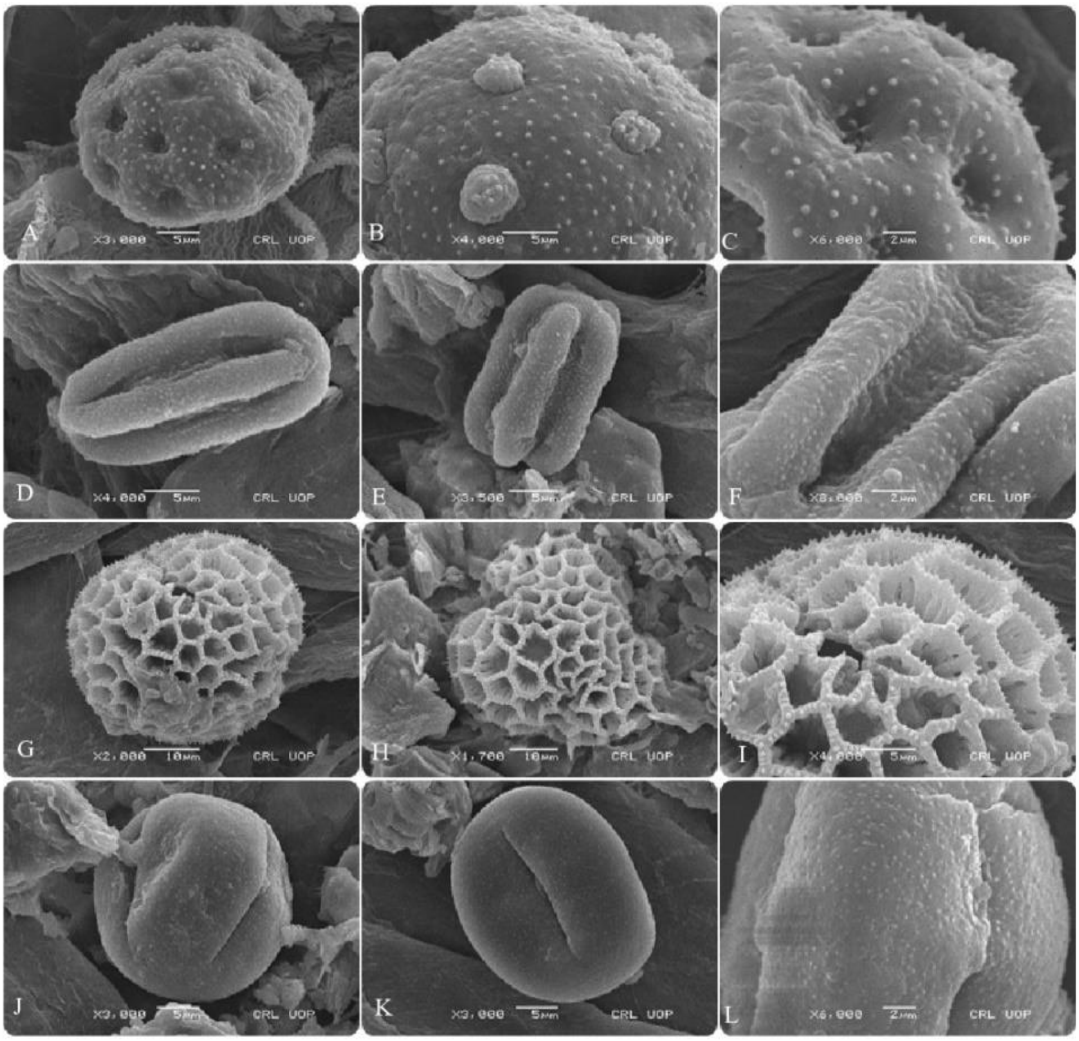

Plate 31: Scanning electron microscopy pollen micrographs. (A-C) *Chaerophyllum reflexum* Aitch. (D-F) *Onosma hispidum* Wall. Ex G.Don (G-I) *Acontholimon libanoticum* Boiss. (J-L) *Bistorta affinis* (D.Don) Greene

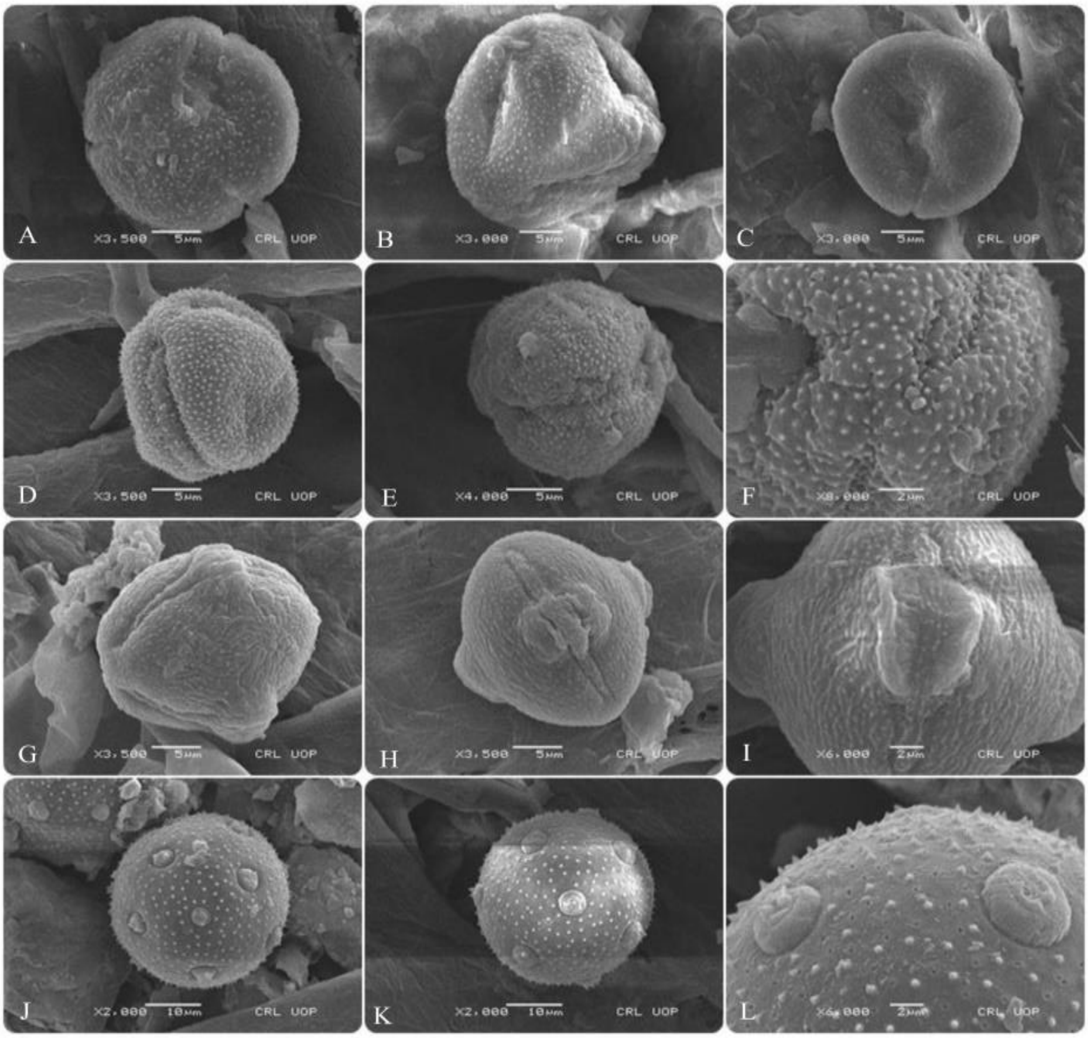

Plate 32: Scanning electron microscopy pollen micrographs. (A-C) *Polygonum biaristatum* Aitch. & Hemsl. (D-F) *Papaver nudicaule* Linn. (G-I) *Potentilla crantzii* (*Crantz) Fritsch*. (J-L) *Silene kunawarensis* Benth.

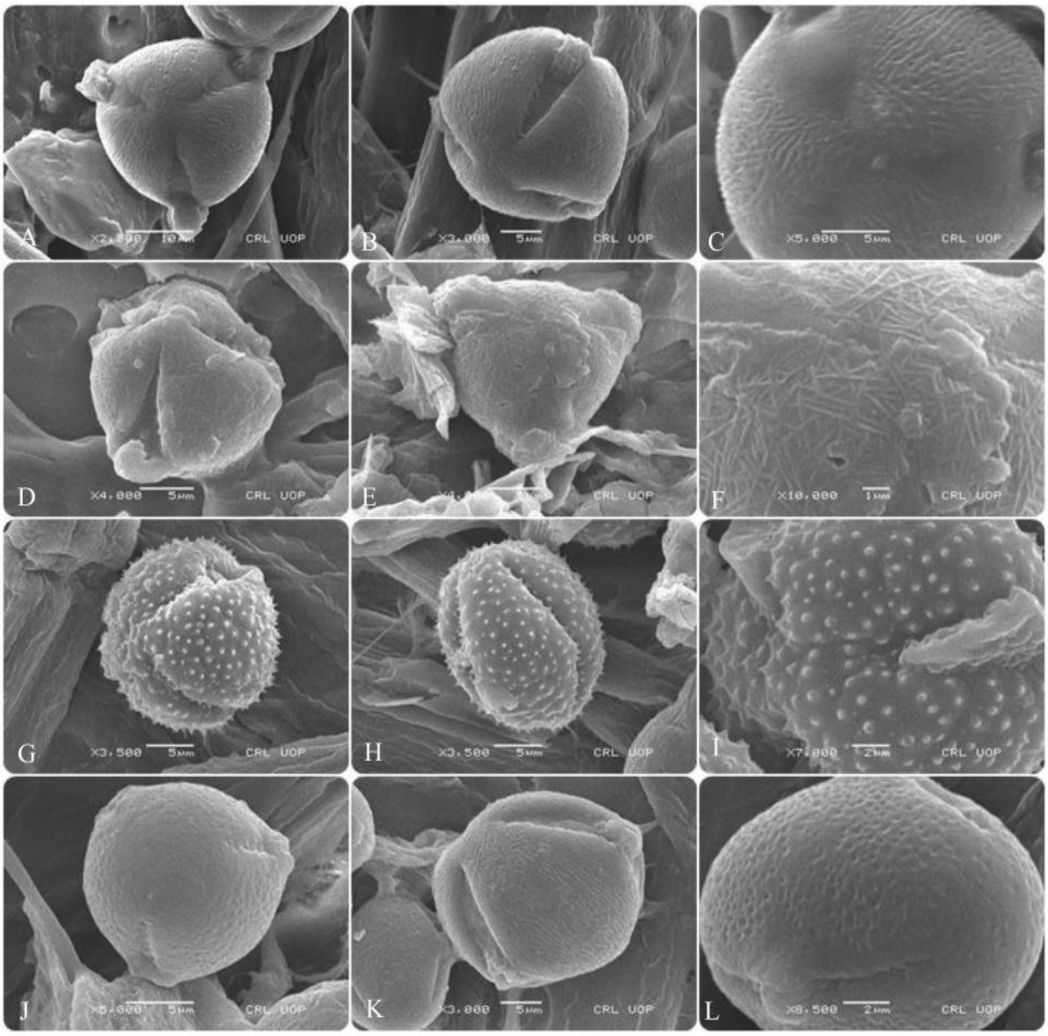

Plate 33: Scanning electron microscopy pollen micrographs. (A-C) *Gentiana autumnalis* L. (D-F) *Sedum ewersii Ledeb.* (G-I) *Potentila reptans* L (J-L) *Astragalus rhizanthus* Benth.

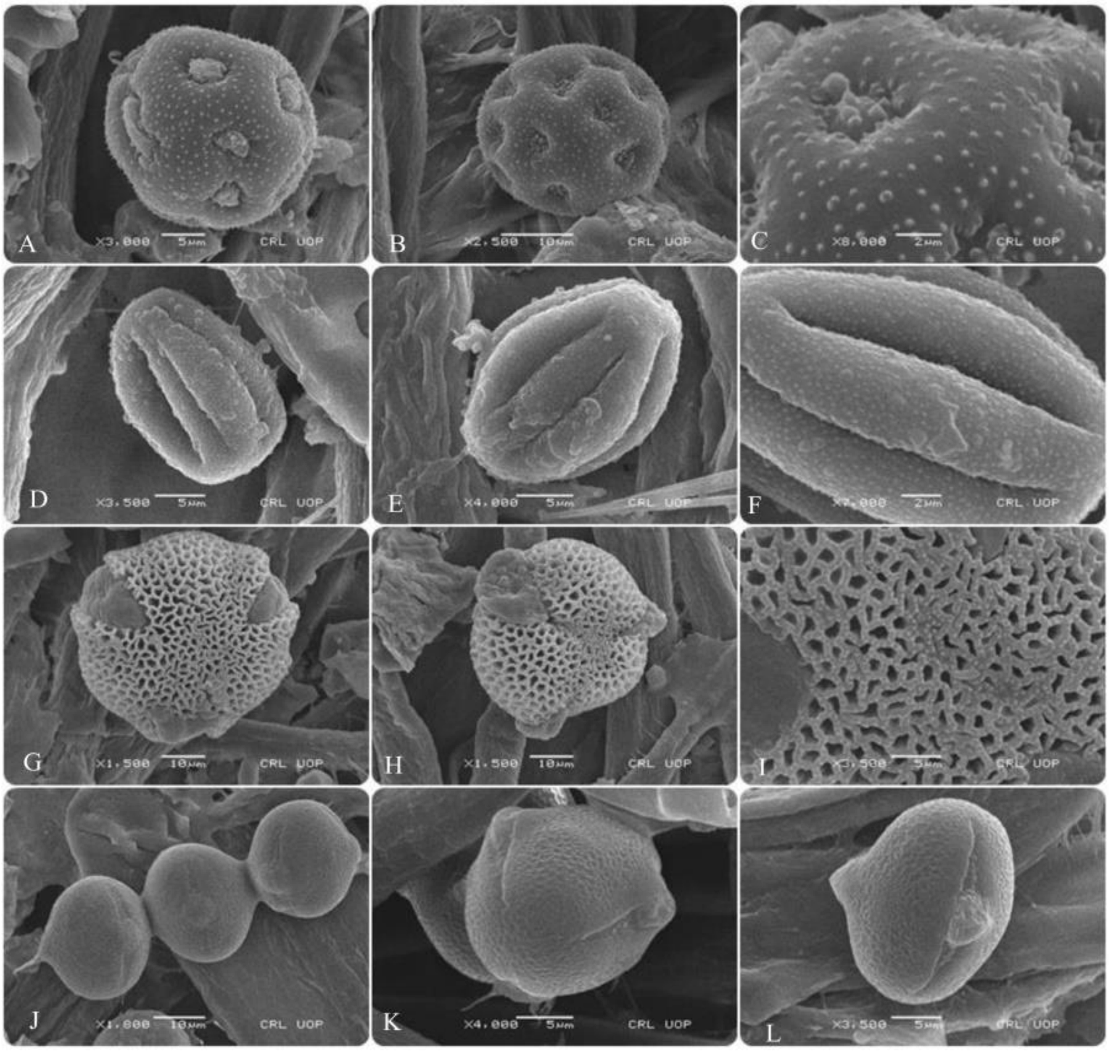

Plate 34: Scanning electron microscopy pollen micrographs. (A-C) *Pulsatilla wallichiana* (Royle) Ulbr. (D-F) *Galium verum* L. (G-I) Limonium gilesii (Hems) Rech.f. and Koeie (J-L) *Astragalus graveolens* Benth.

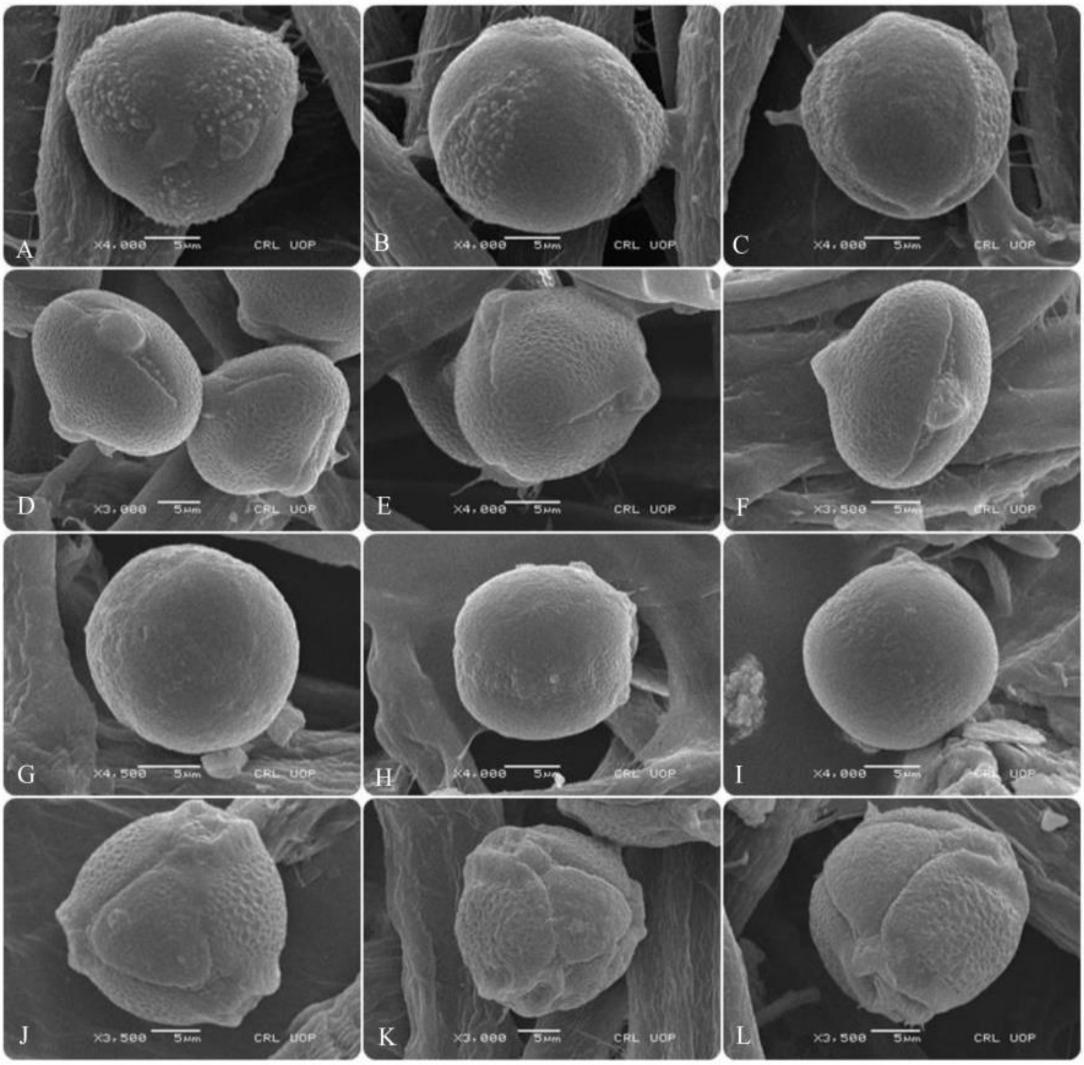

Plate 35: Scanning electron microscopy pollen micrographs. (A-C) *Carum carvi* Linn. (D-F) *Medicago polymorpha* Linn. (G-I) *Pedicularis pyramidata* Pall. Ex steven (J-L) *Thalictrum pedunculatum Edgew*.

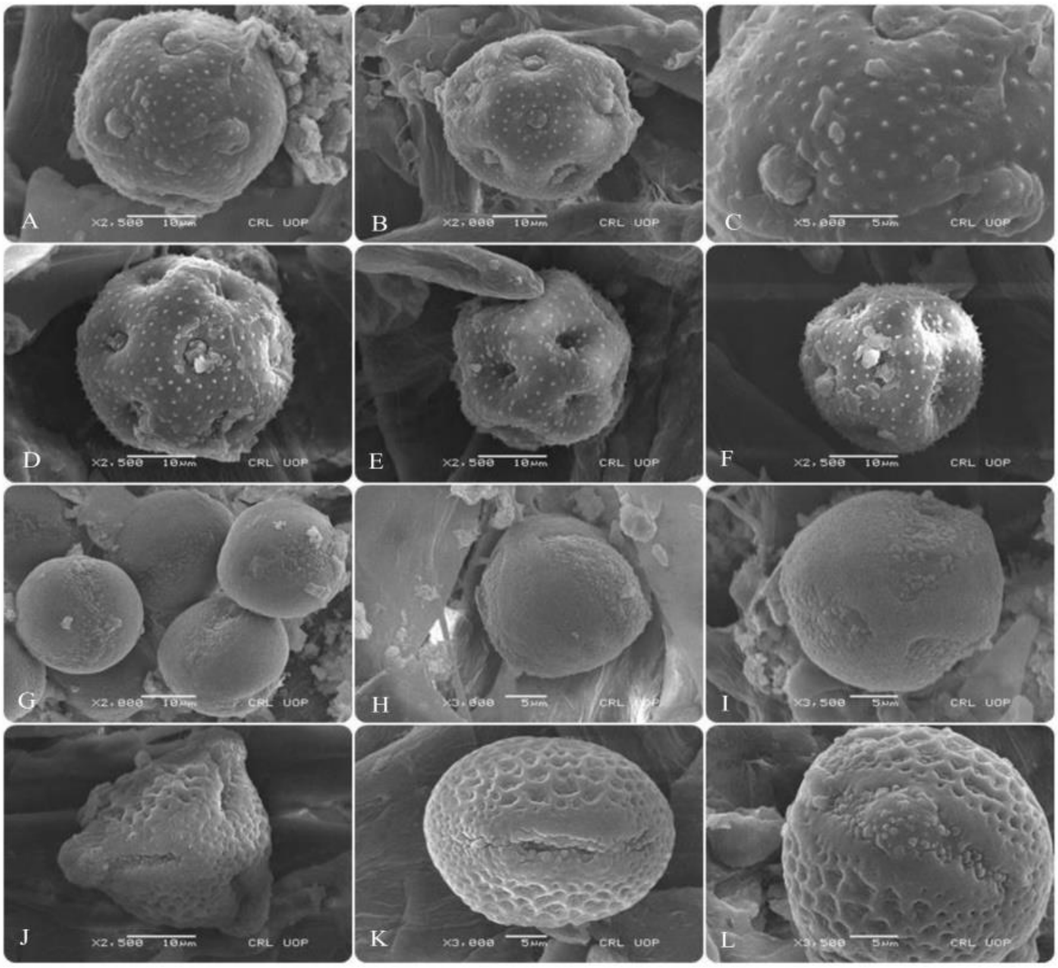

Plate 36: Scanning electron microscopy pollen micrographs. (A-C) *Silene vulgaris* (Monech Garcke) (D-F) *Silene gonosperma (Rupr.) Bocquet (G-I) Veronica alpina L (J-L) Trifolium pratense L.*

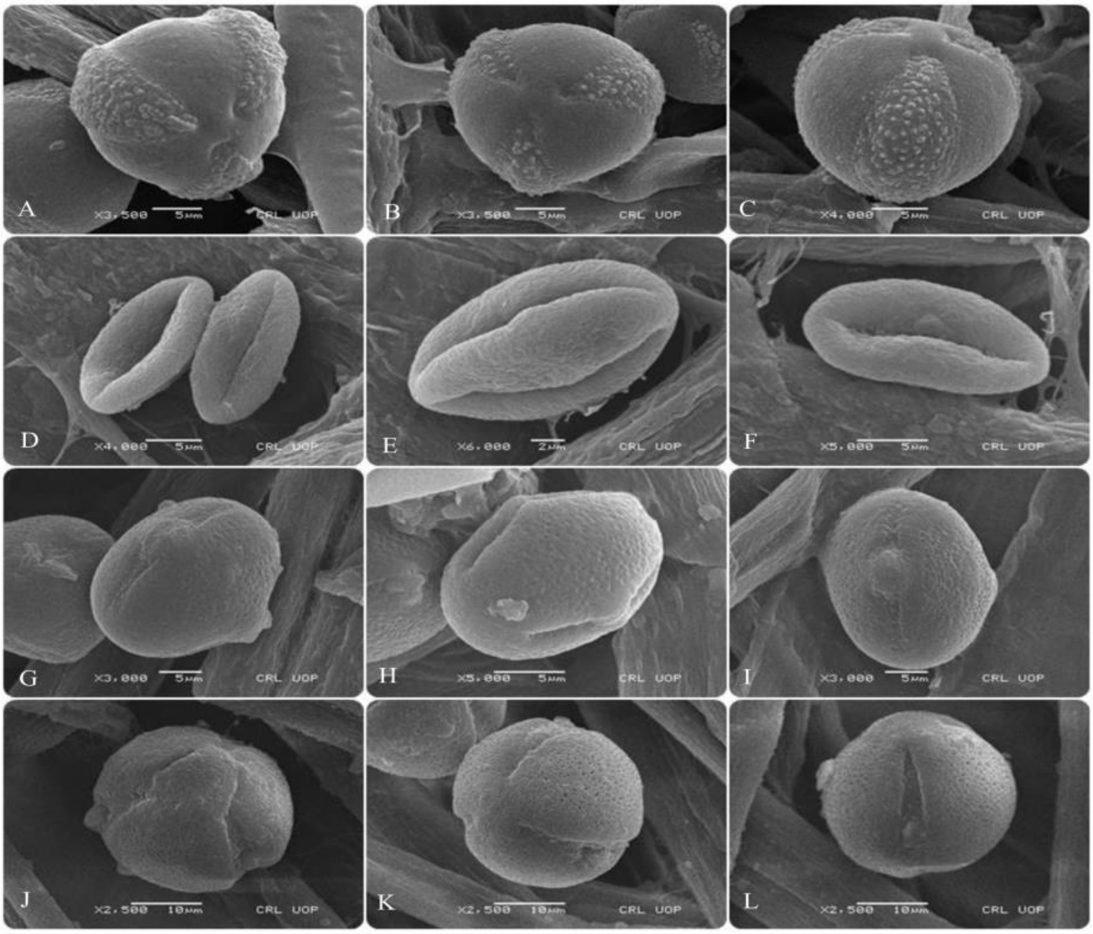

Plate 37: Scanning electron microscopy pollen micrographs. (A-C) *Aconitum heterophyllum* Wall.ex Royle (D-F) *Clematis grata* Wall. (G-I) *Astragalus graveolens* Benth. *(J-L) Primula macrophylla* D. Don

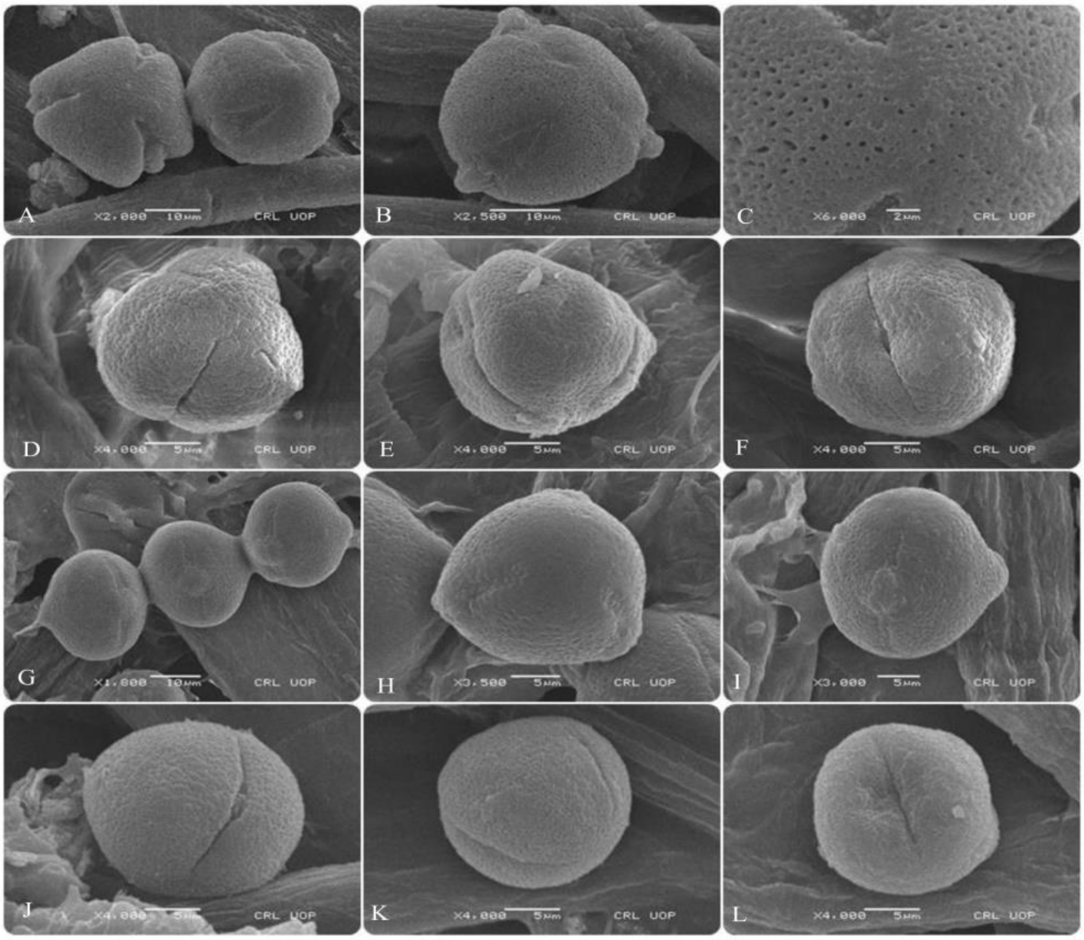

Plate 38: Scanning electron microscopy pollen micrographs. (A-C) *Swertia petiolate D. Don* (D-F) *Rumex nepalensis* Spreng. (G-I) *Astragalus breviscapus* B.Fedtsch. *(J-L) Oxyria digyna* (L.) Hill

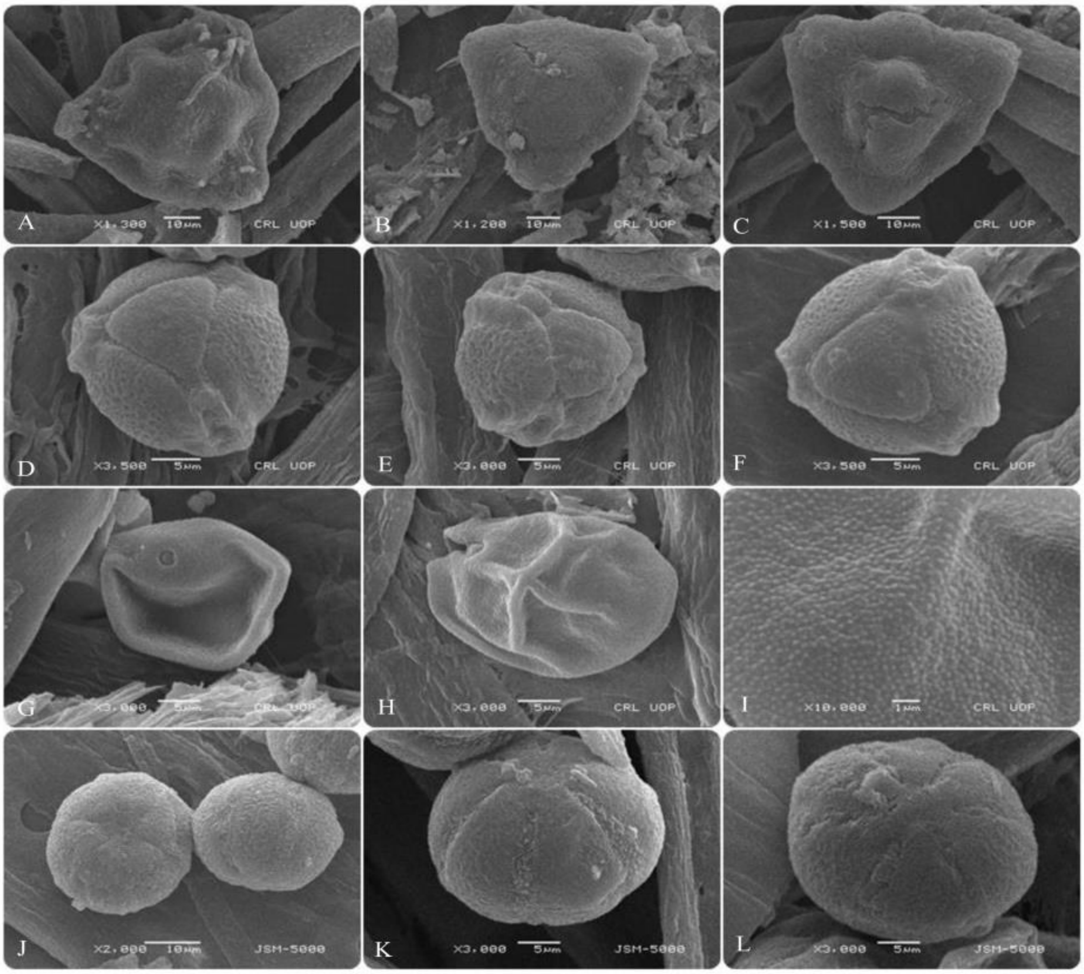

Plate 39: Scanning electron microscopy pollen micrographs. (A-C) *Epilobum angustifolium* L. (D-F) *Thalictrum pedunculatum Edgew.* (G-I) *Festuca rubra* L. *(J-L) Actaea spicata* L.

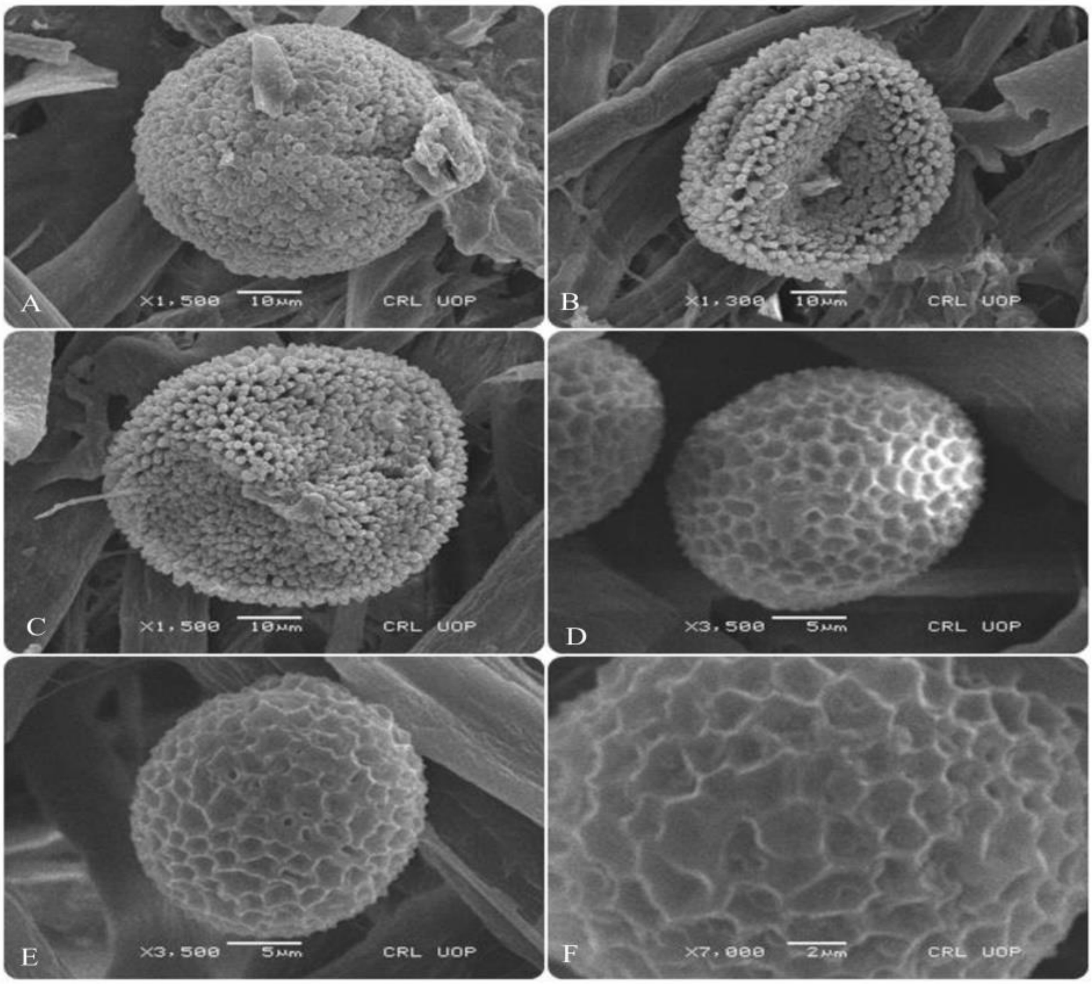

Plate 40: Scanning electron microscopy pollen micrographs. (A-C) *Geranium pratense* L. (D-F) *Impatience edgeworthii* Hook. f

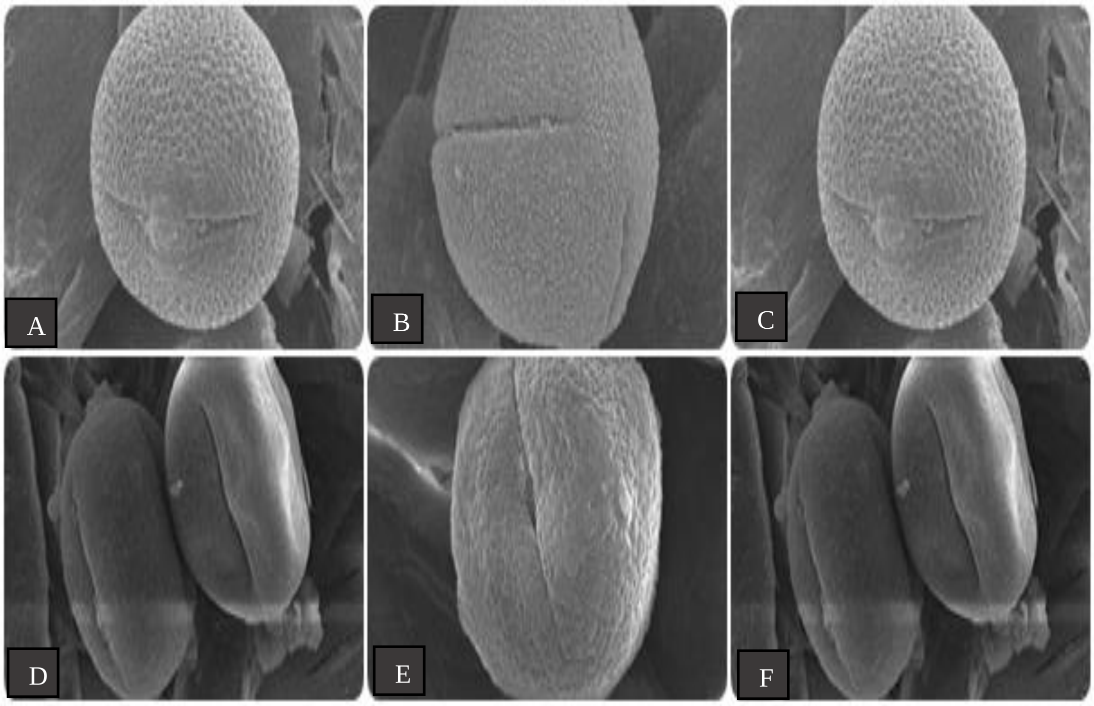

Plate 41: Scanning electron microscopy pollen micrographs. (A-C) *Astragalus leguminesea* (D-F) *Persicaria capitate.*

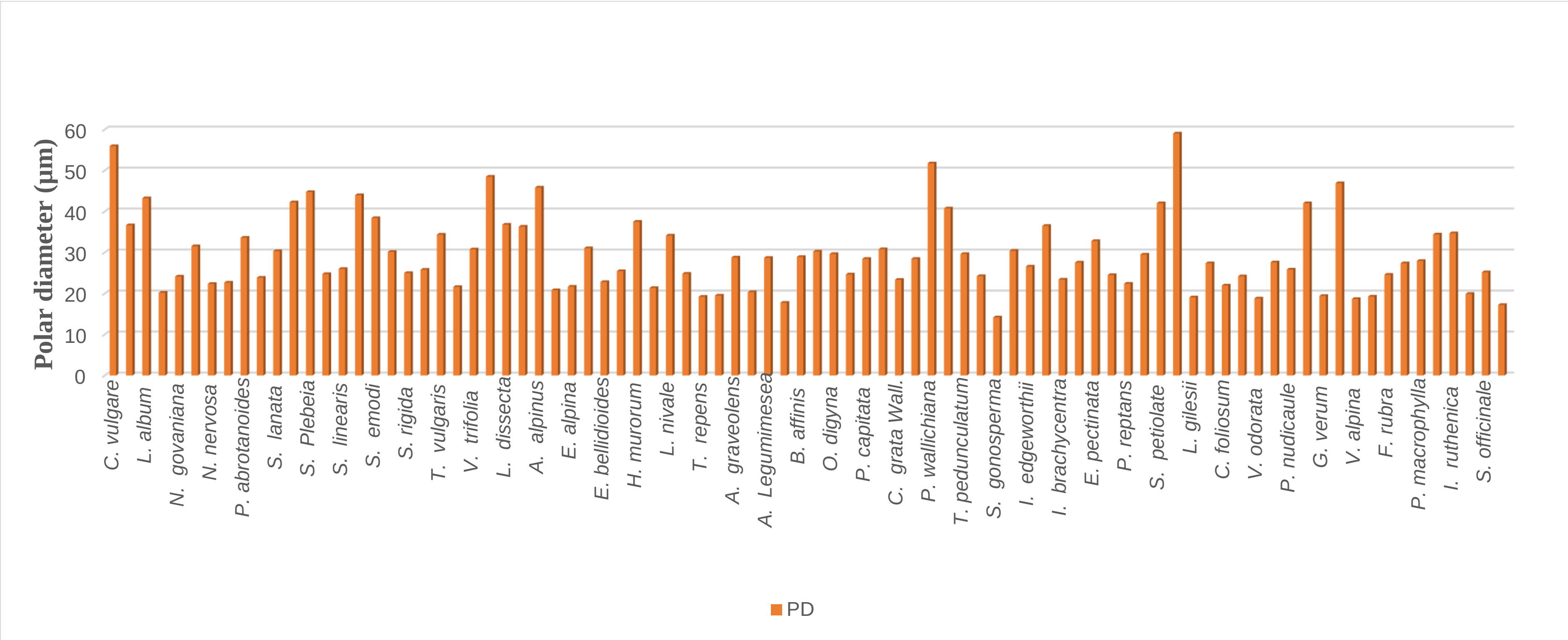

Figure 3: Variation in polar diameter of pollen among various Taxa

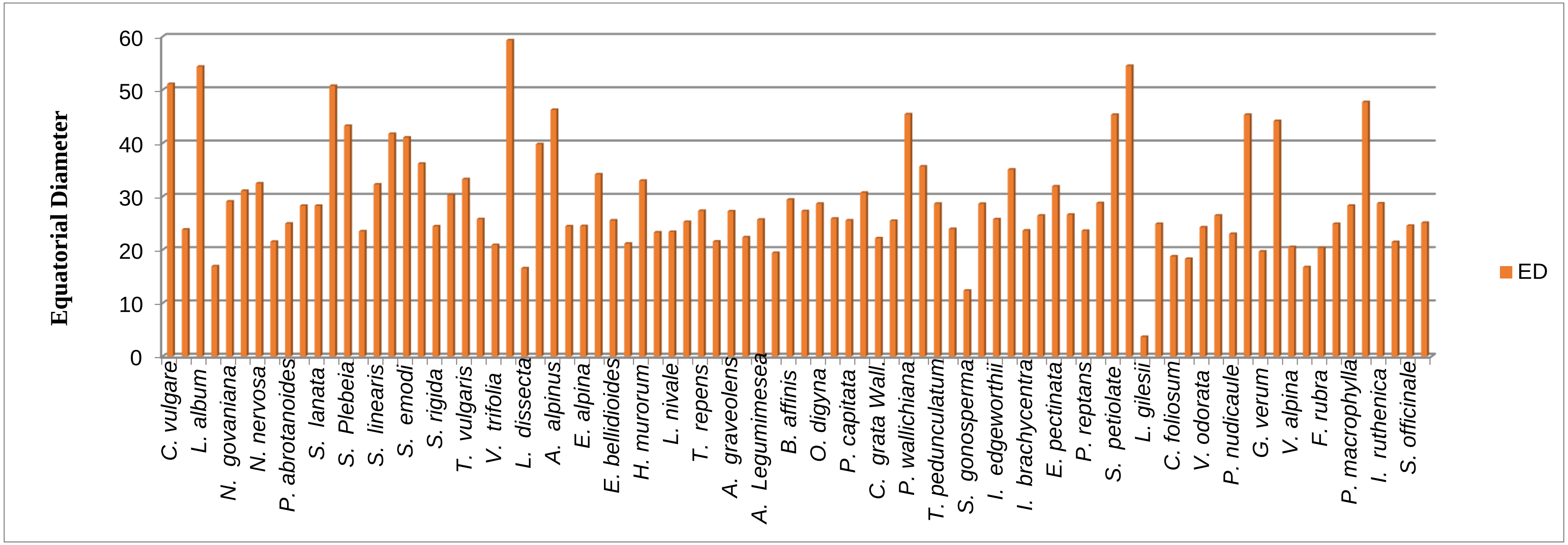

Figure 4: Variation in Equatorial diameter of pollen among various Taxa

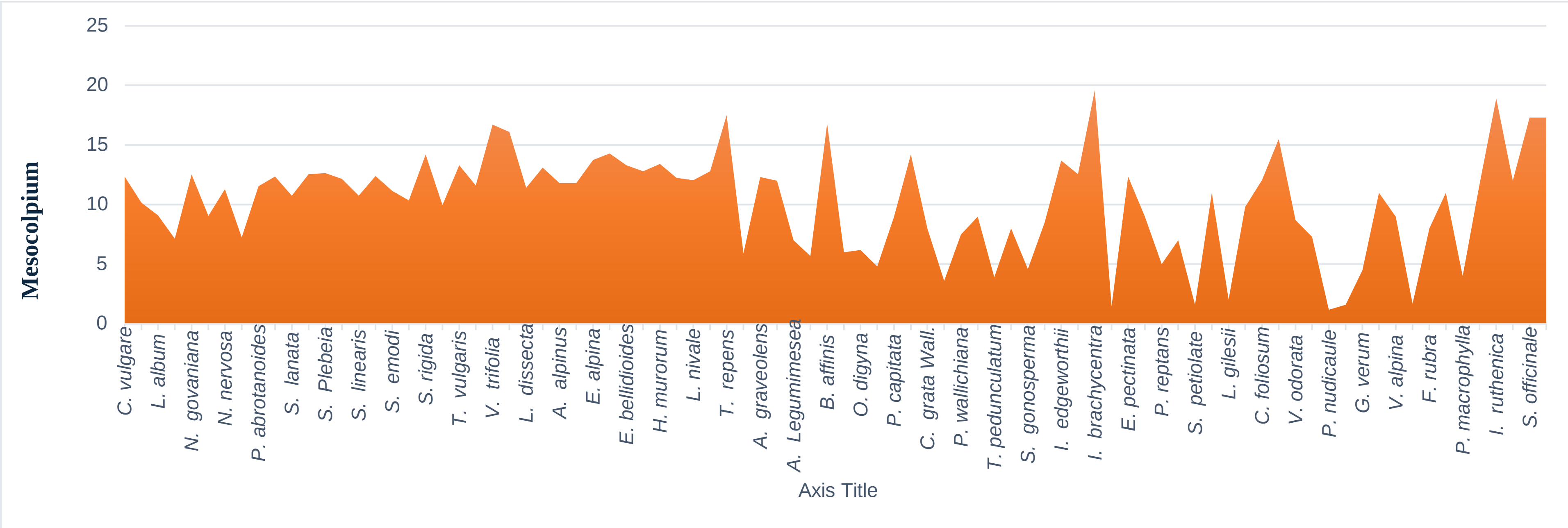

Figure 5: Variation in Mesocolpium of pollen among various Taxa

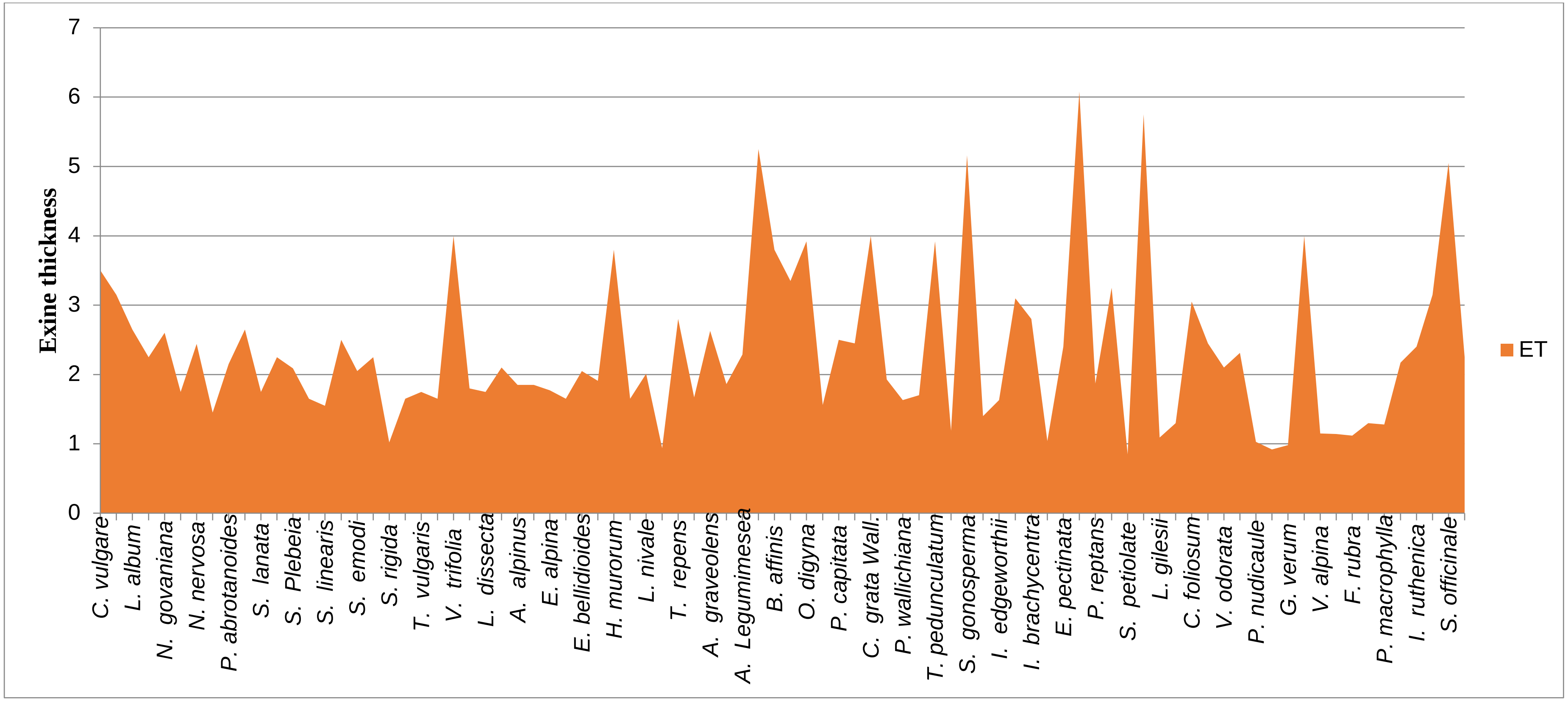

Figure 6: Variation in Exine thickness of pollen among various Taxa

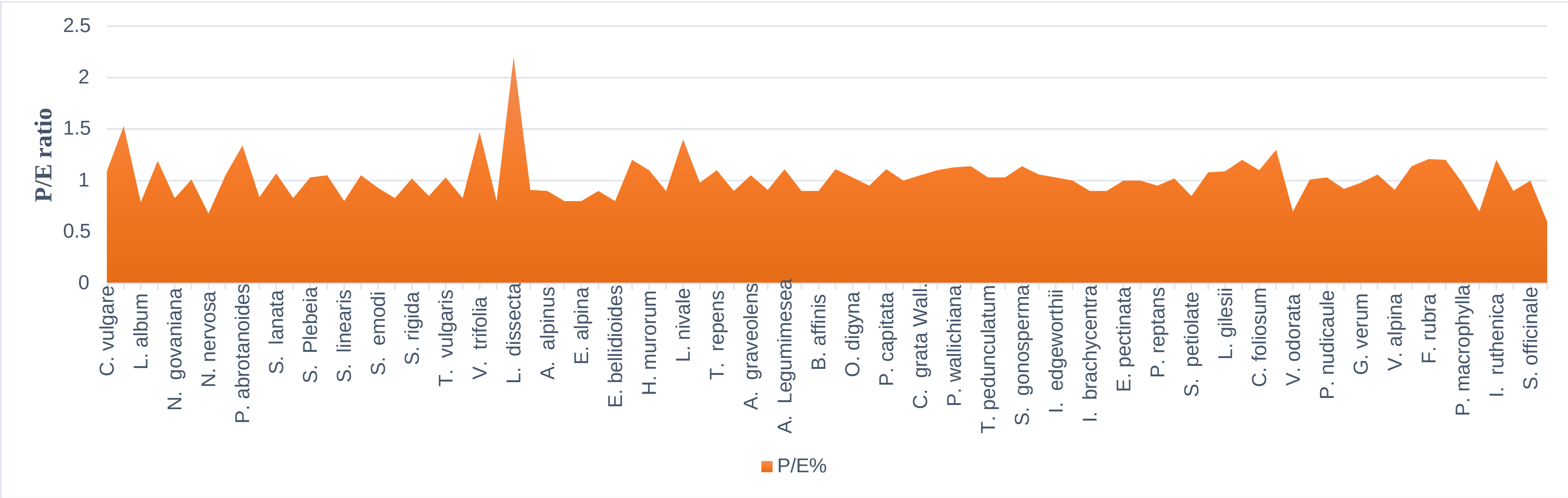

Figure 7: Variation in P/E ratio of pollen among various Taxa

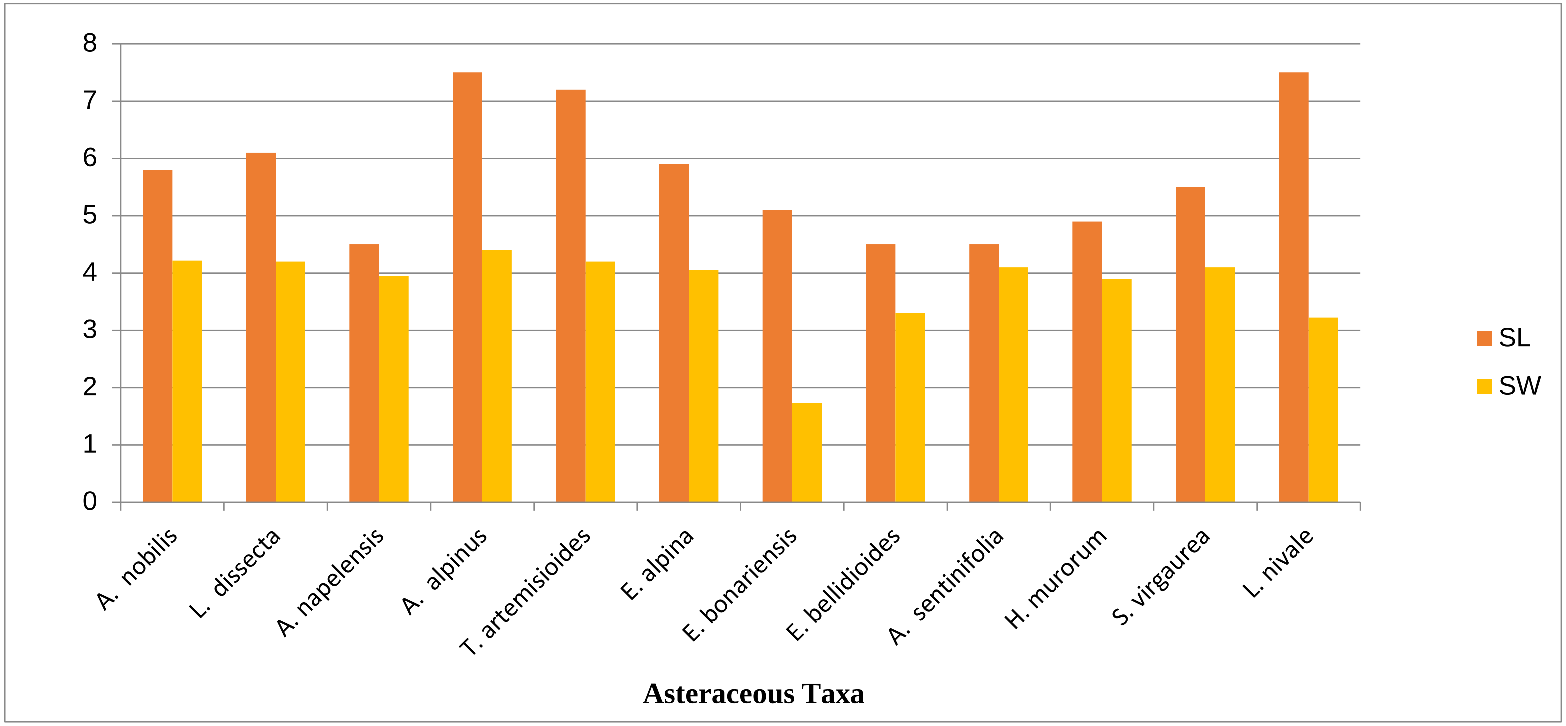

Figure 8: Variation in Spine Length and Spine width in asteraceous taxa

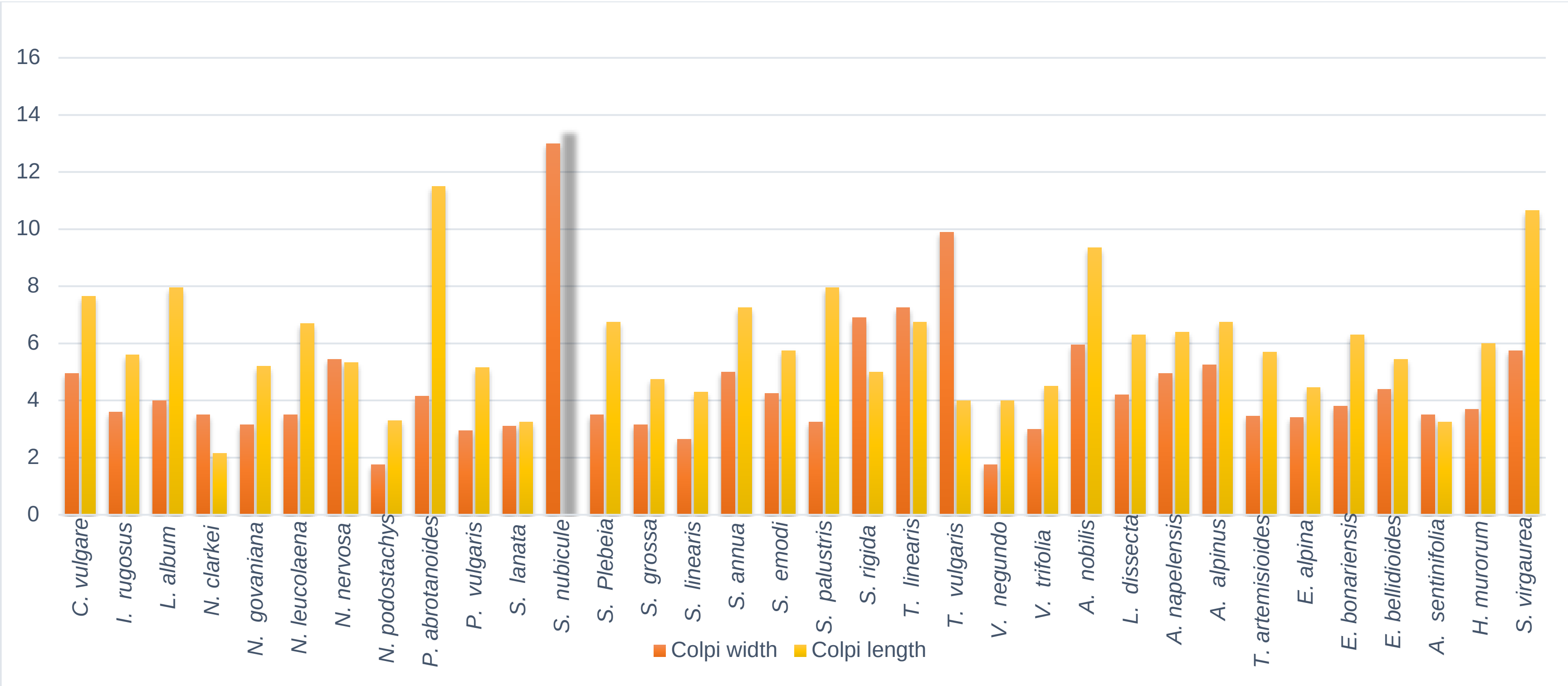

Figure 9: Variation in Colpi length and Colpi width of pollen among dominant families

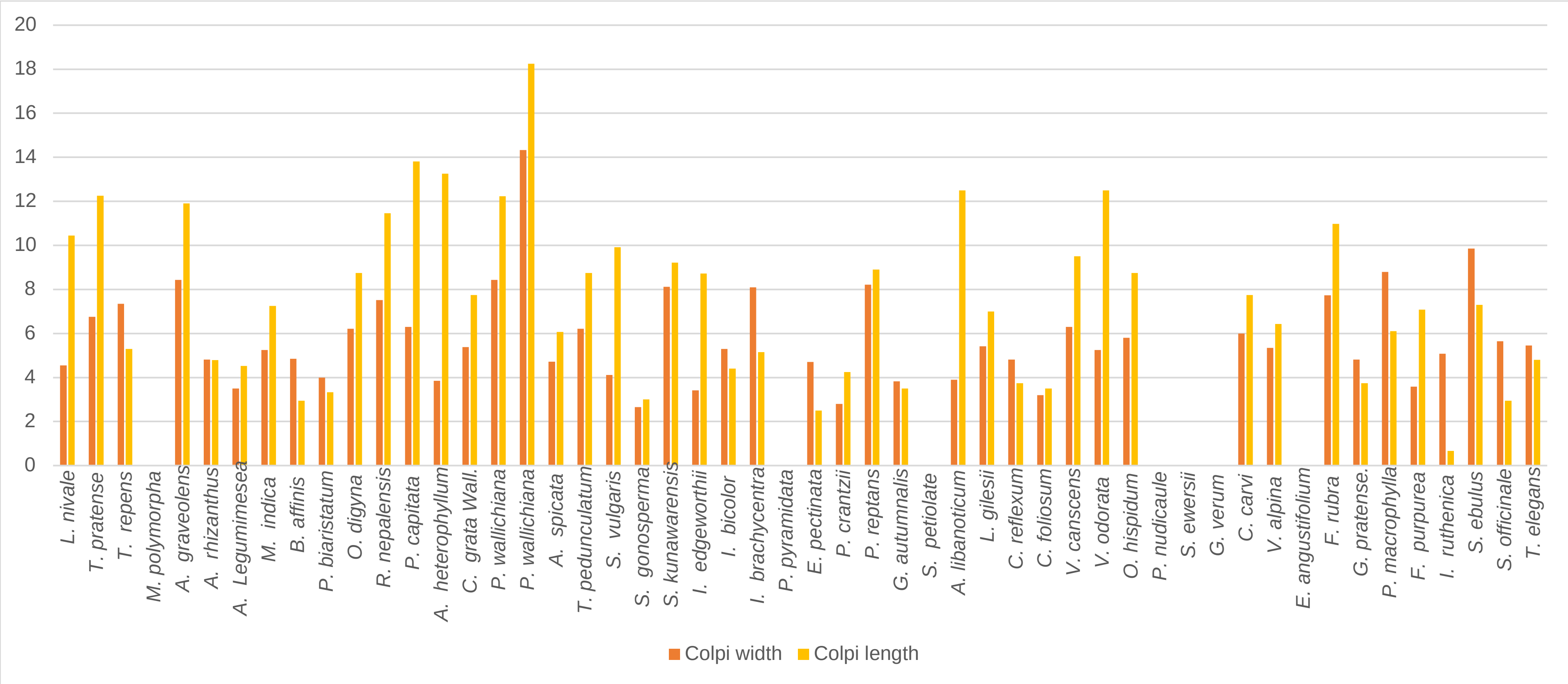

Figure 10: Variation in Colpi length and Colpi width of pollen among selected taxa

3.3. Foliar Anatomical Findings

This study consists of anatomical features based on scanning electron microscopy, and the results are shown in plate 42 to 54. The current study primarily offers an effective framework by critically studying the literature on investigated plant species from diverse zones of Pakistan. According to our study, the most dominant families were Asteraceae (15 species) and Lamiaceae (14 species).

In the present investigations, a total of 50 different plant species were analyzed, belonging to 16 different plant families, via microscopic techniques. The qualitative and quantitative attributes of foliar anatomy are presented in Tables 4 and 5.

3.3.1. Epidermal Morphology

Foliar epidermal morphology has diverse applications in the fields of plant systematics and taxonomy. The investigated plant taxa show a wide range of variations in shape, size of stomata, adaxial and abaxial surfaces, types of stomata, subsidiary cells, and trichomes.

3.3.2. Qualitative features

Substantial variations in the attributes of foliar anatomy of investigated plant taxa belonging to various plant families were seen on both epidermal surfaces such as adaxial and abaxial surfaces. A diverse range of features were perceived in epidermal cells in our study, including polygonal, irregular, tetragonal, pentagonal, regular, and wavy types (Table 3). Polygonal and irregular epidermal cell shapes were the most dominant shapes found in 13 species, followed by polygonal and regular, which were observed in 9 investigated plant species. Both peripedal and tetragonal cell shapes were present in three species whereas a wavy epidermal cell shape was found only in one species in the current study. Variations are also observed in the pattern of the anticlinal wall of the plant species, i.e., undulate, straight, curved, and sinuate. Undulate was the most dominant pattern of anticlinal wall observed in 18 investigated plant species i.e., *Acantholimon libanoticum, Achillea nobilis, Actaea spicata, Amorphophallus napalensis, Artemisia herba-alba, Artemisia sessilifolia, Carum carvi, Cynoglossum lanceolatum, Erigeron annuus, Hieracium murorum, Lactuca dissecta, Nepeta clarkei, Onosma hispida, Papaver nudicaule, Perovskia abrotanoides, Salvia lanata, Salvia Plebeia,* and *Thalictrum pedunculatum,* followed by a straight pattern, which is found in 14 plant species. Similarly, the sinuate and curved patterns of the anticlinal wall were present in 11 and 7 examined species, respectively.

3.3.3. Quantitative Attributes

3.3.4. Epidermal Cells of Selected Plant Specimens

A diverse range of variations in length and width of both surfaces were analyzed in the current investigation (Table 3). The highest length of epidermal cells was found on the upper surface (adaxial), whereas the lowest length was present on the lower surface (abaxial) of epidermal cells. In addition, the maximum width of epidermal cells was observed on the lower surface, and in contrast, the minimum width was found on the upper surface of epidermal cells. On the adaxial surface, the maximum length of epidermal cells was observed in *Stachys emodi* (69.54 ± 0.68), while the minimum length of epidermal cells was found in *Clematis grata* (24.75 ± 2.18). Similarly, the highest value of width on the adaxial surface was detected in *Silene vulgaris* (49.42 ±0.99), and the lowest value of width was observed in *Epilobium angustifolium* (12.65 ±1.11). Furthermore, on the abaxial surface, *Acantholimon libanoticum* represented the highest value of the length of epidermal cells (68.62 ± 2.19) while *Amorphophallus napalensis* had the lowest value of the length of the abaxial surface (22.95 ± 1.40). Similarly, the maximum width of lower epidermal cells was observed in *Artemesia herba-alba* (45.00 ± 0.60) while *Amorphophallus napalensis* (11.65 ±1.10) had the lowest value of epidermal cells.

3.3.5. Variation in Guard Cells

The guard cells were also observed in all investigated plant species, with noticeable variations in length and width of both the adaxial surface and the abaxial surface (Table 2). In the case of the adaxial surface, the highest length of guard cells was noticed in *Swertia petiolata* (41.95 ±0.74) while the lowest value of length in guard cells was observed in *Amorphophallus napalensis* (10.75 ± 0.41). *Galium verum* had the highest value of the width of the guard cells (20.25 ± 0.48) whereas the lowest width of the guard cells was observed in *Acantholimon libanoticum* (5.25 ± 0.49). Similarly, in the case of the abaxial surface, the maximum length of guard cells was observed in *Geranium pretense* (42.95 ± 0.70) while the lowest length of guard cells was found in *Artemesia herba-alba* (8.14 ± 0.39). *Clinopodium vulgare* had the highest value of the width of the guard cells (23.53 ± 0.67) whereas the lowest width of the guard cells was observed in *Lactuca dissecta* (5.23 ± 0.56).

3.3.6. Stomatal Complex Morphology

In current research, the stomata were found on both sides of the epidermis, but the lower surface had the most dominant number of stomata. The stomata are the special types of pores that are responsible for the exchange of gases. A single stomata is surrounded by two guard cells that have an important role in the opening and closing of the stomata.

3.3.7. Qualitative Features of Stomata

Various types of stomata were studied in the currently investigated plant species, i.e. Anisocytic, Anomocytic, Paracytic, Diacytic, and Staurocytic. The Anisocytic type of stomata was observed in 16 plant taxa including *Acantholimon libanoticum, Achillea nobilis, Actaea spicata, Aster alpinus, Aster altaicus, Carum carvi, Cynoglossum lanceolatum, Erigeron alpinus, Erigeron bonariensis, Hieracium murorum, Impatiens bicolor*, *Lactuca dissecta*, *Leontopodium nivale, Perovskia abrotanoides, Pulsatilla wallichiana*, and *Stachys annua*. The anomocytic type of stomata was found in 13 plant species i.e. *Amorphophallus napalensis*, *Artemisia herba-alba, Cynoglossum wallichii, Erigeron annuus, Erigeron bellidioides, Galium verum, Geranium pretense, Impatiens edgeworthii*, *Isodon rugosus, Onosma hispida, Salvia lanata, Salvia nudicaule,* and *Thalictrum pedunculatum*. The Paracytic stomatal type was present in 12 plant taxa, including *Artemisia sessilifolia, Clematis grata, Clinopodium vulgare, Epilobium angustifolium, Medicago polymorpha, Nepeta clarkei, Nepeta connata, Papaver nudicaule, Prunella vulgaris, Salvia Plebeia, Stachys palustris,* and *Tanacetum artemisioides*. The Diacytic type of stomata was observed in 8 plant species including *Persicaria bistorta, Potentilla crantzii, Silene vulgaris, Solidago virgaurea, Stachys emodi, Tanacetum gracile, Thymus linearis,* and *Thymus vulgaris*. The Staurocytic type of stomata was found only in a single plant species i.e. *Swertia petiolata*.

3.3.8. Quantitative features of stomata

In the current study, variations were also observed in both the length and width of stomata. In the case of the adaxial surface, the maximum length of stomata was observed in the *Geranium pretense* (40.00 ± 0.64) whereas the minimum value of the length of stomata was found in *Amorphophallus napalensis* (11.95 ± 0.52). Similarly, *Onosma hispida* had the highest value of width (33.05 ± 1.28) while the lowest value of width was observed in *Papaver nudicaule* (7.50 ± 0.36). Furthermore, on the abaxial surface, the maximum length of stomata was found in *Impatiens edgeworthii* (46.95 ± 1.05) whereas the minimum value of the length of stomata was observed in *Clinopodium vulgare* (11.15 ± 0.53). Similarly, *Nepeta connata* had the highest value of width (31.05 ± 1.39) while the lowest value of width was noticed in *Amorphophallus napalensis* (8.75 ± 1.04).

3.3.9. Trichomes Morphology

In a total of 50 plant species, the trichomes were noticed only in 16 examined plant species. In some plant taxa, the trichomes were only found on one side of the leaf, whereas in some species, the trichomes were observed on both sides of the leaf. Trichomes are epidermal attachments that may be unicellular, multicellular, glandular, and non-glandular, depending on the species. In some plant families, the trichomes are the diagnostic characters where we can easily identify the plant species due to specific types of trichomes.

In the current research, the trichomes also show variations in their shapes and sizes. The dominant shape of trichomes in the current study was conical, followed by cylindrical, glandular, capitate, and stellate.

3.3.10 Discussion

The current study has checked the qualitative and quantitative characteristics of 50 distinct plant species that are members of 16 different plant families using a taxonomy approach. Adaxial and abaxial epidermal cell appearance, stomata kinds, anticlinal wall patterns, and trichomes on both sides are examples of qualitative features. Quantitative features include both adaxial and abaxial epidermal cells' length and width, the size of stomatal length and width, guard cells' length and width, etc. This study gives vital information for the proper and exact identification of selected plant species via micromorphological characters by using microscopic techniques (Ullah *et al*., 2018). In addition to the foliar epidermal morphology, this study contrasts with previous micromorphological studies and provides important information regarding the trichome diversity and shape of the plant species under study (Gul *et al*., 2019). It was discovered that trichomes have unique ornamentation and come in a variety of forms, including glandular and non-glandular, unicellular, and multicellular (Ashfaq *et al*., 2019). Our findings unequivocally validate the usefulness of such features in indicating the systematic link between the species and defining the limit of taxonomically difficult taxa.

When paired with confirmation from previous studies, the findings of this work highlight the critical role that light microscopy plays in the understanding of foliar epidermal structure. The capacity of foliar epidermal features to distinguish species within a subfamily is what gives them systematic value. To distinguish between various species, plant taxonomists mainly depend on qualitative and quantitative micro-morphological epidermal traits. To facilitate accurate taxonomic identification and the separation of closely related groups, taxonomic keys for the species under study were developed based on these characteristics (Thadeo *et al*. 2014). In terms of accurate and precise species identifications in plant taxonomy, the most changeable aspect is the morphology of the leaf based on taxonomic levels (family, genus, and species). The majority of anatomical features, especially the leaf epidermis, are important for systematic processes even when environmental influences are taken into account (Inceer and Ozcan 2011). The anatomical structure of the taxa under consideration consists of adaxial and abaxial surfaces, such as anisocytic and anomocytic.. These traits align with the previous studies that Napp-Zinn and Eble (1978) reported.

According to our research, the most dominant families in this study area were Asteraceae (15 species) including *Achillea nobilis, Artemisia herba-alba, Artemisia sessilifolia, Aster alpinus, Aster altaicus, Erigeron alpinus, Erigeron annuus, Erigeron bellidioides, Erigeron bonariensis, Hieracium murorum, Lactuca dissecta, Leontopodium nivale, Solidago virgaurea, Tanacetum artemisioides,* and *Tanacetum gracile* and Lamiaceae (14 species) including *Clinopodium vulgare, Isodon rugosus, Nepeta clarkei, Nepeta connata, Perovskia abrotanoides, Prunella vulgaris, Salvia lanata, Salvia nudicaule, Salvia Plebeia, Stachys annua, Stachys emodi, Stachys palustris, Thymus linearis* and *Thymus vulgaris* followed by *Plumbaginaceae (Acantholimon libanoticum*), Ranunculaceae (*Actaea spicata, Clematis grata, Pulsatilla wallichiana,* and *Thalictrum pedunculatum*), Araceae (*Amorphophallus napalensis*), Apiaceae (*Carum carvi*), Boraginaceae (*Cynoglossum lanceolatum, Cynoglossum wallichii,* and *Onosma hispida*), *Onagraceae (Epilobium angustifolium*), *Rubiaceae (Galium verum*), *Geraniaceae (Geranium pretense*), *Balsaminaceae (Impatiens bicolor, Impatiens edgeworthii*), Fabaceae (*Medicago polymorpha*), *Papaveraceae (Papaver nudicaule*), Polygonaceae (*Persicaria bistorta*), Rosaceae (*Potentilla crantzii*), Caryophyllaceae (*Silene vulgaris*), and *Gentianaceae (Swertia petiolata*).

The present study examined irregular epidermal cells with undulate anticlinal walls and anomocytic stomata on the abaxial surface of species belonging to the Lamiaceae and Asteraceae families. This research was previously reported by Mabel *et al*. (2014), who found both glandular and non-glandular types of trichomes in their studies, which differs from the current findings, which only show the presence of non-glandular multicellular trichomes. While the current data show irregular and polygonal-shaped epidermal cells, Shahzad *et al*. (2021) report that the epidermal cell shape is rectangular with an undulate cell wall in *Artemisia sessilifolia, Artemisia herba-alba, Aster alpinus,* and *Aster altaicus* on both sides. This study analyzed both anisocytic and anomocytic stomata, which is comparable the earlier research conducted by Shahzad *et al*. In this work, multicellular and non-glandular trichomes were examined as well. The polygonal epidermal cells in *Erigeron alpinus, Erigeron annuus, Erigeron bellidioides,* and *Erigeron bonariensis* were surveyed in previous work by Mabel *et al*. (2014). These cells had wavy anticlinal wall patterns on their upper surface and irregular anticlinal wall patterns on their lower side. These results are fairly like the current findings, except for the lower surface's undulated anticlinal walls. The present investigation identified previously described multicellular non-glandular trichomes and anisocytic and anomocytic kinds of stomata. Gul *et al*. (2019) studied various species of Lamiaceae and observed irregular epidermal cells with undulating walls and anisocytic stomata in *Isodon rugosus, Salvia lanata, Salvia Plebeia,* and *Salvia nudicaule* which is quite similar to the present-day investigation. Multicellular non-glandular trichomes with bulbous bases were observed, as in the previous work. In *Nepeta clarkei*, and *Nepeta connata* the observed shape of epidermal cells was polygonal, possesses paracytic stomata, and straight anticlinal walls only on the abaxial side were perceived. These results show deviance from previous work in which differently shaped epidermal cells with diacytic stomata were witnessed. Gul *et al*., (2019) reported *Perovskia abrotanoides, Prunella vulgaris, Thymus linearis,* and *Thymus vulgaris* with tetracytic and anomocytic types of stomata on the abaxial surface, while our research explained polygonal and irregular epidermal cells with undulating and entire walls retaining anomocytic stomata. Hameed *et al*., (2020) studied the transverse section of *Prunella vulgaris* in which collenchyma, micro crystal, oil gland, parenchyma, palisade layer, prismatic crystal, and rosset crystal were examined, but there has been no surplus foliar anatomical work on *Prunella vulgaris*. Our work examined polygonal epidermal cells with straight anticlinal walls, and paracytic stomata were inspected on both surfaces.

Ramzan *et al*. (2019) formerly described the anatomical characteristics of *Carum carvi, Achillea nobilis,* and *Actaea spicata* and found stomata were absent on the adaxial surface and paracytic stomata on the abaxial surface of *Carum carvi*, which were correlated with current findings, and glandular, unicellular, with pointed tip trichomes were observed, which were absent in earlier work. However, polygonal and irregular epidermal cells were examined in the present research, which shows a significant deviation from previous work. Gostin *et al*. (2009) observed foliar cross-sections of *Medicago polymorpha* in which palisade and parenchyma cells were recorded, but regrettably, there is no epidermal anatomical study in previous literature. This study elaborates on irregular and polygonal epidermal cells having anomocytic and anisocytic stomata on adaxial and abaxial surfaces with glandular multicellular trichomes. In *Clematis grata*, irregular epidermal cells were observed with sinuous anticlinal walls having anomocytic stomata on both abaxial and adaxial surfaces and no trichomes, which shows similarity with the prior work of Salim *et al*., (2016).

Irregular and polygonal epidermal cells with wavy to straight anticlinal walls have paracytic stomata in *Acantholimon libanoticum*, while our study examined anisocytic stomata, which is not consistent with previous literature, and trichomes were absent in both current and recent research. Previously, brachyparacytic stomata were observed in *Amorphophallus napalensis* while in the present study, they are paracytic. Gaafar *et al*., (2019) observed wavy polygonal and irregular epidermal cells having only anisocytic stomata in *Clinopodium vulgare*, while our results showed anisocytic stomata and a wide elliptical shape of the stomatal pore. Al-Mousawi *et al*. (2019) inspected thick anticlinal-walled epidermal cells and anisocytic stomata in *Papaver nudicaule* while the present study showed polygonal epidermal cells with thin anticlinal walls and anomocytic stomata. *Silene vulgaris has been recorded to have an irregular* epidermal cell and an anticlinal wall deeply undulated (Ullah *et al*. 2018). *Silene vulgaris* a Caryophyllaceae member, grows in dry and exposed habitats. Some species are growing as weeds in different crops, i.e., *Silene conoidea* (Al-Hadeethi *et al*., 2023). In Geraniaceae *Geranium pretense* three different secretory trichomes were recorded in the aerial parts of the plant (Aedo *et al*., 2023). The undulate and straight anticlinal walls with polygonal epidermal cell shapes have been recorded in *Clematis grata, Cynoglossum lanceolatum, Cynoglossum wallichii, Epilobium angustifolium, Galium verum, Hieracium murorum, Impatiens bicolor, Impatiens edgeworthii, Lactuca dissecta*, and *Persicaria bistorta.*

Diversity in trichomes may help the erroneous description of plants, as it is an important taxonomic feature of leaves ingrained in various studies. From a taxonomic point of view, trichomes have a diverse physiological and ecological role in the establishment of plants within their habitat. A lot of work has been done on the trichome diversity of different families, but nothing has been reported on poisonous plant trichomes that might accumulate in plants. In these studies, different types of trichomes are observed in plants. Trichomes can help the plants defend themselves in a variety of ways. Glandular trichomes are a rich source of essential oils, many of which have poisonous properties and aid in the protection of plants against herbivores and pathogens. In some situations, poisonous chemicals produced by trichomes were shown to be transmitted via the stalk to distal plant tissues, improving their resistance against plant enemies.

Taxonomists mainly use the interdisciplinary discipline of systematics to enhance plant identification, categorization, and systematic placement. Epidermal leaf structure is the most incredible tool that taxonomists have at their disposal today for distinguishing and emphasizing closely related species. The study that is being presented is an important taxonomic tool because of the variations in the anatomical characteristics. This work has demonstrated that anatomical features can assist in reconciling complex and contradicting taxonomic concerns. To use correctly recognized taxa, the current research endeavors to introduce a few chosen species together with their micromorphological features. According to Hussain *et al*. (2019), the micro-morphological characteristics of leaves, in addition to their size and form, are useful diagnostic tools for identifying various taxonomic relationships. This research work demonstrates the excessive variation in morphological features of the flora.

The systematics of the plant species under investigation in Pakistan are thoroughly described in this study. Leaf epidermal anatomy is one type of systematic study (SEM). This is the first comprehensive examination of the studied area's flora that has been documented. Identification of different plant species has relied heavily on the application of a combination of SEM analysis and epidermal micromorphological study, with particular emphasis on trichome diversity. The form of the stomata, their distribution, the shape of the epidermal cells, trichomes, and the anticlinal wall are the major anatomical characteristics used in plant taxonomy to distinguish different species of plants. Microscopy is thought to be crucial for distinguishing between various plants and holds great potential for helping plant taxonomists accurately identify species. Research and documentation on plant taxa can save people from being poisoned by substances that could have healed them. Therefore, more study is required to validate conventional knowledge about these plants through appropriate experimentation, enabling the identification of the components of the plant’s taxa

Table 4: Micromorphological quantitative features of Foliar epidermis

S. No	Plant name	Ad×Ab	Length of epidermal cell Mean (Min-Max) ±SE(µm)	Width of epidermal cell Mean (Min-Max) ±SE(µm)	Length of guard cells Mean (Min-Max) ±SE(µm)	Width of guard cells Mean (Min-Max) ±SE(µm)	Length of stomata Mean (Min-Max) ±SE(µm)	Width of stomata Mean (Min-Max) ±SE(µm)
1.	*Acantholimon libanoticum* Boiss.	Ab	68.62(61.50-75.75) ±2.19	22.62(19.50-25.75) ±0.69	19.00(15.25-22.75) ±0.76	9.37(7.75-11.00) ±0.42	26.62(23.00-30.25) ±0.68	11.15(8.25-14.25) ±0.56
		Ad	67.87(57.00-78.75) ±3.76	30.62(28.25-33.00) ±0.99	24.25(22.50-26.00) ±0.58	5.25(3.75-6.75) ±0.49	25.25(20.00-30.50) ±1.95	16.00(13.25-18.75) ±0.87
2.	*Achillea nobilis* Roch. ex Nyman.	Ab	65.25(55.25-75.25) ±2.89	38.87(36.25-41.50) ±0.78	36.62(33.25-40.00) ±0.53	14.00(12.25-15.75) ±0.67	31.87(28.25-35.50) ±0.73	27.25(24.75-29.75) ±1.45
		Ad	53.75(49.50-58.00) ±1.12	37.62(25.25-50.00) ±3.56	29.62(24.25-35.00) ±1.20	13.46(10.25-17.00) ±0.34	28.55(23.75-32.50) ±0.86	30.85(26.65-35.75) ±1.35
3.	*Actaea spicata* L.	Ab	36.50(28.00-45.00) ±2.76	44.37(40.75-48.00) ±1.48	36.00(32.25-39.75) ±0.87	8.50(6.75-10.25) ±0.37	32.13(28.25-36.00) ±0.47	23.50(22.25-24.75) ±0.58
		Ad	35.30(30.25-40.50) ±1.65	30.75(25.25-35.25) ±1.46	24.95(20.25-28.75) ±0.63	8.90(6.50-10.25) ±0.77	19.25(17.25-20.75) ±0.65	22.75(19.75-25.25) ±0.48
4.	*Amorphophallus napalensis* (Wall.) Bogner & Mayo	Ab	22.95(18.25-25.75) ±1.40	11.65(8.25-14.00) ±1.10	10.14(9.75-12.00) ±0.27	8.65(7.75-9.75) ±0.41	13.50(10.50-16.50) ±1.11	8.75(5.75-11.75) ±1.04
		Ad	25.75(22.75-28.75) ±0.72	17.10(14.75-20.75) ±0.86	10.75(9.75-12.00) ±0.41	6.65(5.75-7.75) ±0.33	11.95(12.25-14.25) ±0.52	9.25(7.75-10.75) ±1.19
5.	*Artemesia herba-alba* Asso	Ab	52.45(48.75-55.75) ±0.88	45.00(32.75-40.25) ±0.60	8.14(7.75-10.00) ±0.39	7.65(6.75-8.75) ±0.33	12.15(11.25-14.25) ±0.49	11.75(8.75-14.75) ±1.19
		Ad	37.35(34.00-42.75) ±3.64	24.48(20.50-28.00) ±1.02	24.25(22.75-25.00) ±0.71	7.30(5.75-8.00) ±0.57	27.45(25.75-29.00) ±0.59	12.86(10.00-15.25) ±0.49
6.	*Artemisia sessilifolia* L.	Ab	48.70(42.25-55.25) ±1.40	37.46(27.75-44.75) ±0.54	24.15(20.75-25.75) ±0.72	8.43(6.75-9.25) ±0.41	21.25(18.25-24.00) ±0.80	16.35(14.75-18.75) ±0.56
		Ad	71.05(65.75-75.25) ±0.88	22.25(20.25-24.25) ±0.71	15.50(13.75-18.25) ±0.67	10.00(8.25-11.75) ±0.56	18.25(16.75-20.00) ±0.48	15.86(13.50-17.00) ±0.64

7.	*Aster alpinus* Gueldenst. ex Ledeb.	Ab	42.45(35.75-48.25) ±2.76	19.50(17.00-22.00) ±0.70	32.05(28.25-36.75) ±0.75	9.95(7.50-13.25) ±0.49	34.74(31.25-36.75) ±0.51	18.4(15.75-20.00) ±0.59
		Ad	35.3(32.75-39.25) ±1.10	16.25(13.75-18.75) ±1.8	27.25(25.00-30.50) ±0.65	10.75(8.25-12.00) ±0.71	27.95(23.25-31.50) ±0.95	17.55(15.00-20.25) ±0.70
8.	*Aster altaicus* Wild.	Ab	40.05(35.25-45.25) ±2.10	32.95(29.25-35.25) ±0.76	34.70(30.00-38.00) ±0.87	12.15(9.75-14.00) ±0.55	28.34(25.75-30.50) ±0.59	23.62(20.75-25.75) ±0.62
		Ad	50.86(45.25-55.00) ±1.03	35.05(32.25-40.75) ±0.60	34.35(30.75-38.25) ±0.70	10.26(7.75-12.75) ±0.82	32.05(30.00-34.25) ±0.91	27.16(23.75-30.75) ±0.64
9.	*Carum carvi* L.	Ab	46.65(41.75-51.25) ±0.68	21.75(19.25-23.75) ±0.0.71	21.45(18.25-24.75) ±0.79	7.60(6.75-9.00) ±0.58	23.74(20.25-26.25) ±0.82	22.45(19.25-25.75) ±0.98
		Ad	46.06(42.25-50.25) ±0.81	17.54(15.25-19.75) ±0.62	20.30(17.00-23.75) ±0.59	8.80(5.75-10.75) ±0.38	24.85(20.75-27.00) ±0.51	15.55(12.25-18.75) ±0.50
10.	*Clematis grata* Wall.	Ab	42.23(38.50-45.75) ±0.81	15.84(13.75-16.75) ±0.32	29.15(22.25-35.75) ±0.26	9.64(5.00-12.75) ±0.31	34.15(22.75-28.25) ±0.78	18.36(16.25-19.75) ±0.60
		Ad	24.75(18.75-30.25) ±2.18	18.65(17.25-20.75) ±0.49	20.35(17.25-23.25) ±0.78	10.70(9.75-11.75) ±0.58	24.65(21.25-28.75) ±0.71	13.65(11.25-15.75) ±0.39
11.	*Clinopodium vulgare* L.	Ab	65.52 (55.50-75.00) ±3.30	35.52(30.25-40.75) ±0.59	27.50(23.25-30.25) ±0.56	23.53(21.50-26.25) ±0.67	11.15(10.25-12.25) ±0.53	5.75(4.50-6.00) ±0.29
		Ad	66.52(60.25-72.50) ±2.32	28.40(25.25-32.00) ±1.3	21.1(18.00-24.00) ±0.71	16.35(12.75.20.50) ±0.71	15.52(13.25-18.00) ±0.69	4.00(3.50-4.25) ±0.13
12.	*Cynoglossum lanceolatum* Hochst. ex DC.	Ab	33.32(30.75-36.25) ±0.70	21.45(19.00-23.75) ±0.77	25.50(24.00-27.00) ±0.63	12.35(9.75.14.50) ±0.48	20.52(19.25-22.00) ±0.65	11.45(9.50-13.25) ±0.59
		Ad	32.55(28.75-37.25) ±0.69	22.55(20.75-23.25) ±0.56	28.95(25.75-30.25) ±0.62	8.06(6.25-11.25) ±0.56	26.55(23.75-28.25) ±0.64	15.45(13.50-17.50) ±0.59
13.	*Cynoglossum wallichii* D. Don	Ab	43.45(40.75-45.25) ±1.58	32.15(28.75-36.75) ±1.11	37.45(34.75-40.25) ±1.65	12.54(10.25-14.75) ±0.69	28.46(25.75-32.50) ±0.70	30.85(26.75-34.75) ±0.61
		Ad	38.85(34.75-42.75) ±0.81	30.80(25.75-35.75) ±1.28	27.05(25.25-29.75) ±0.69	8.15(6.75-9.25) ±0.46	30.95(26.25-34.25) ±0.58	22.45(20.25-24.75) ±0.40
14.	*Epilobium angustifolium* L.	Ab	29.35(22.25-35.75) ±1.47	22.45(19.50-25.75) ±0.66	29.15(26.25-32.75) ±1.42	9.32(7.75-10.75) ±0.38	20.15(17.75-22.75) ±1.08	19.65(16.25-21.75) ±0.67
		Ad	28.95(22.25-32.75) ±2.20	12.65(9.25-15.25) ±1.11	14.34(11.25-16.25) ±0.56	8.00 (6.50-9.50) ±0.76	21.23(17.25-25.25) ±0.65	15.60(12.25-17.75) ±1.21
15.	*Erigeron alpinus* L.	Ab	30.85(20.25-40.25) ±2.8	17.52(15.50-19.75) ±0.80	32.15(30.25-35.25) ±0.43	8.75(7.25-10.00) ±0.65	31.15(27.00-34.00) ±0.75	16.4(13.25-18.75) ±0.68

		Ad	37.83(34.50-40.75) ±1.41	21.35(18.25-23.25) ±0.90	19.00(17.00-20.50) ±0.79	8.95(7.25-10.50) ±0.59	18.35(16.25-20.25) ±0.75	21.20(19.00-23.00)±0.60
16.	*Erigeron annuus* (L.) Desf.	Ab	67.75(60.75-75.25) ±3.14	34.35(30.75-37.00) ±0.80	24.85(24.25-29.25) ±0.65	11.35(8.50-14.00) ±0.49	25.34(19.00-25.75) ±0.87	23.76(25.25-31.25) ±0.67
		Ad	69.45(64.25-74.00) ±1.8	24.60(17.25-30.75) ±2.1	23.76(25.25-30.00) ±1.7	13.67(9.50-15.00) ±0.56	23.43(19.00-26.25) ±0.76	24.64(21.75-28.25) ±0.81
17.	*Erigeron bellidioides* Griseb.	Ab	49.53(43.00-55.50) ±2.20	34.40(30.25-37.25) ±0.49	28.23(26.25-31.25) ±0.50	10.65(9.00-12.00) ±0.67	32.34(27.00-36.50) ±0.43	22.29(18.25-24.00) ±0.76
		Ad	35.43 (25.00-45.50) ±2.34	31.03(28.75-34.25) ±0.50	27.45(22.75-31.00) ±0.67	5.45(4.00-7.00) ±0.43	31.72(27.75-35.25) ±0.32	23.43(20.00-24.50) ±0.40
18.	*Erigeron bonariensis* L.	Ab	48.13(42.75-53.25) ±2.10	39.50(30.00-49.00) ±2.01	36.45(35.00-37.50) ±0.70	9.00(7.50-10.25) ±0.54	37.06(35.75-40.25) ±0.41	20.55(17.00-22.00) ±0.58
		Ad	53.04(48.25-59.00) ±1.20	41.45(35.25-48.00) ±0.75	36.15(32.75-39.00) ±1.54	8.73(6.50-10.50) ±0.70	25.50(21.00-29.75) ±1.45	29.45(27.25-31.75) ±0.65
19.	*Galium verum* L.	Ad	43.50(40.75-46.25) ±0.68	24.23(23.75-26.50) ±1.10	34.75(30.25-39.75) ±1.20	20.25(18.25-22.00) ±0.48	34.75(32.00-36.00) ±0.56	19.43(15.00-22.00) ±0.54
		Ab	36.15(33.75-39.75) ±0.90	17.65(11.00-22.75) ±1.40	29.53(27.50-30.75) ±0.70	10.35(8.25-11.75) ±0.65	30.6(27.00-32.00) ±0.76	16.04(14.50-18.00) ±0.87
20.	*Geranium pretense* L.	Ad	59.65(53.75-65.00) ±0.49	46.54(40.00-52.00) ±1.87	31.53(29.50-34.75) ±0.65	12.35(10.25-14.75) ±0.45	40.00(36.00-43.00) ±0.64	28.04(25.50-32.00) ±0.70
		Ab	58.75(50.25-66.25) ±0.61	35.65(31.75-39.75) ±1.20	42.95(40.25-45.75) ±0.70	14.45(12.25-15.75) ±0.54	36.65(33.25-38.00) ±0.44	37.55(33.75-40.25) ±0.55
21.	*Hieracium murorum* C.B. Clarke.	Ad	54.54(48.75-60.35) ±0.55	23.32(19.45-27.25) ±0.35	21.80(18.75-25.25) ±0.65	6.80(5.50-8.50) ±0.58	27.80(25.50-30.25) ±0.43	15.11(13.00-17.00) ±0.67
		Ab	56.65(52.75-60.65) ±1.64	25.14(21.00-28.75) ±0.45	19.45(16.25-23.65) ±0.54	8.50(7.25-9.75) ±0.75	31.35(29.25-32.75) ±0.32	16.95(14.00-18.75) ±0.38
22.	*Impatiens bicolor* Hook. f.	Ad	60.65(56.25-63.75) ±0.57	12.54(10.00-14.00) ±0.28	22.64(20.25-24.75) ±0.43	10.50(9.25-12.00) ±0.67	19.55(17.25-22.50) ±0.63	11.25(9.75-13.25) ±0.53
		Ab	32.45(28.75-36.50) ±0.60	14.15(13.75-16.25) ±0.43	12.15(10.00-13.00) ±0.63	9.32(7.75-10.25) ±0.52	17.15(15.75-20.25) ±0.53	14.35(11.25-16.00) ±0.44
23.	*Impatiens edgeworthii* Hook. f.	Ad	63.21(55.00-70.00) ±2.35	24.40(20.75-28.75) ±1.10	36.05(32.00-40.75) ±0.76	13.30(10.75-15.75) ±0.46	36.60(33.25-39.00) ±0.54	23.55(21.75-25.75) ±0.67
		Ab	51.85(48.25-54.55) ±0.54	33.45(30.25-37.00) ±0.47	32.55(28.25-36.75) ±0.78	11.40(9.00-14.25) ±0.72	46.95(44.75-48.75) ±1.05	23.35(19.00-26.75) ±0.54

24.	*Isodon rugosus* Wall. ex Benth.	Ad	38.65(36.75-39.50) ±0.44	29.25(27.25-30.25) ±1.09	32.55(26.25-38.75) ±0.56	17.40(5.00-10.25) ±0.64	33.65(29.25-36.00) ±0.76	18.35(16.00-20.75) ±0.64
		Ab	39.34(37.50-42.00) ±2.2	30.12(26.25-33.75) ±1.5	23.65(20.75-25.75) ±0.86	7.75(5.75-8.25) ±0.56	22.50(19.00-24.00) ±0.74	18.35(16.75-21.25) ±0.70
25.	*Lactuca dissecta* D. Don	Ad	27.45(22.00-32.00) ±1.60	18.65(14.50-21.75) ±0.75	15.86(13.50-17.50) ±0.57	6.21(5.5-7.00) ±0.59	16.34(13.00-18.00) ±0.53	12.53(10.00-14.75) ±0.69
		Ab	40.35(37.25-42.75) ±0.77	29.35(25.75-33.35) ±0.55	18.35(14.75-21.65) ±1.44	5.23(4.25-6.00) ±0.56	17.85(14.75-20.75) ±1.33	14.45(10.75-17.25) ±0.65
26.	*Leontopodium nivale* (Ten.) A. Heut ex Hand. Mazz.	Ad	33.63(30.75-36.75) ±0.79	24.25(21.25-27.00) ±1.13	20.35(16.75-23.65) ±1.47	8.23(7.25-9.00) ±0.59	16.85(12.75-19.75) ±1.38	16.45(13.75-19.25) ±0.61
		Ab	41.60(37.25-45.25) ±2.10	25.13(23.25-28.73) ±1.50	28.85(21.75-33.75) ±0.71	6.25(4.75-7.25) ±0.49	22.76(19.75-25.75) ±0.63	13.54(10.00-16.50) ±0.76
27.	*Medicago polymorpha* L.	Ad	59.91(51.75-65.25) ±1.71	27.84(22.75-32.75) ±1.36	20.00(13.75-27.00) ±0.67	8.90(7.25-10.50) ±0.48	31.55(28.25-33.00) ±0.69	14.45(12.00-17.50) ±0.66
		Ab	54.55(48.75-60.25) ±2.10	23.23(19.00-26.00) ±0.63	27.06(23.25-30.75) ±0.48	8.76(7.00-9.50) ±0.63	24.31(17.00-30.75) ±1.28	12.14(9.25-15.75) ±0.76
28.	*Nepeta clarkei* Hook.f.	Ad	51.75(45.50-56.25) ±2.00	34.40(30.25-38.25) ±0.80	28.50(26.25-31.00) ±0.65	15.55(11.25-20.75) ±0.70	32.95(28.25-36.50) ±0.65	30.45(27.75-34.75) ±1.70
		Ab	47.85(41.00-53.00) ±1.98	35.76(25.75-45.50) ±2.64	26.20(22.00-31.00) ±1.30	12.56(10.25-14.75) ±0.43	30.55(24.75-35.50) ±0.52	24.05(20.00-28.75) ±1.51
29.	*Nepeta connata* Royle ex Benth.	Ad	36.25(32.00-44.50) ±2.12	32.25(28.75-38.00) ±1.12	30.05(26.25-34.50) ±0.87	10.55(8.50-12.25) ±0.69	34.40(32.25-37.5) ±0.77	29.15(28.25-30.00) ±0.60
		Ab	60.65(53.75-66.00) ±0.50	47.54(40.00-54.00) ±1.88	32.53(29.51-34.75) ±0.66	13.35(10.25-16.75) ±0.44	40.6(36.00-44.00) ±0.63	31.05(27.65-35.75) ±1.39
30.	*Onosma hispida* Wall. ex Don.	Ab	51.95(45.50-58.00) ±1.13	33.86(26.25-50.00) ±3.58	31.20(28.25-35.00) ±1.23	15.46(12.25-17.00) ±0.38	28.55(25.75-32.50) ±0.90	29.04(26.50-32.00) ±0.71
		Ad	54.95(50.50-59.00) ±1.18	34.86(27.25-48.00) ±3.10	33.20(29.25-36.00) ±1.10	14.46(11.25-18.00) ±0.40	31.55(27.75-35.50) ±0.85	33.05(28.00-37.75) ±1.28
31.	*Papaver nudicaule* L.	Ad	46.45(40.75-55.75) ±0.62	35.00(30.75-40.00) ±0.29	22.35(19.75-25.00) ±0.58	6.32(3.75-8.00) ±0.39	25.35(22.75-28.50) ±0.49	7.50(6.00-9.00) ±0.36
		Ab	23.95(20.25-25.75) ±1.48	12.65(9.25-14.00) ±1.17	11.14(10.75-12.00) ±0.26	8.65(6.75-9.75) ±0.44	11.15(9.25-12.25) ±0.52	9.70(6.75-11.75) ±1.01
32.	*Perovskia abrotanoides* Karel.	Ad	24.75(20.75-28.75) ±0.78	18.10(16.75-20.75) ±0.81	11.14(10.75-12.00) ±0.46	6.65(4.75-7.75) ±0.38	12.15(11.25-14.25) ±0.55	8.70(6.75-10.75) ±1.11

		Ab	50.45(45.75-55.75) ±0.80	35.00(30.75-40.25) ±0.67	8.14(6.75-10.00) ±0.30	7.65(5.75-8.75) ±0.39	13.15(12.25-14.25) ±0.46	10.7(6.75-14.75) ±1.11
33.	*Persicaria bistorta* Samp.	Ad	36.35(31.00-42.75) ±2.60	24.48(18.50-29.00) ±1.09	22.25(19.75-25.00) ±0.78	7.30(6.75-8.00) ±0.50	26.45(23.75-29.00) ±0.54	12.86(9.00-16.25) ±0.41
		Ab	47.70(40.25-55.25) ±1.41	35.46(25.75-44.75) ±0.55	24.15(22.75-26.75) ±0.70	8.43(5.75-10.25) ±0.40	22.25(19.25-24.00) ±0.75	16.35(13.75-18.75) ±0.58
34.	*Potentilla crantzii* (Crantz) Fritsch	Ad	72.05(68.75-75.25) ±0.80	22.05(19.25-24.25) ±0.70	15.46(12.75-18.25) ±0.65	9.56(7.25-11.75) ±0.58	17.25(15.75-20.00) ±0.49	15.86(14.50-17.00) ±0.63
		Ab	42.45(36.75-48.25) ±2.74	20.50(18.00-22.00) ±0.75	33.05(29.25-36.75) ±0.76	11.95(8.50-13.25) ±0.47	33.74(30.25-36.75) ±0.58	18.40(17.75-20.00) ±0.59
35.	*Prunella vulgaris* L.	Ad	35.3(30.75-39.25) ±1.13	16.25(12.75-19.75) ±1.2	28.25(26.00-30.50) ±0.61	9.75(7.25-12.00) ±0.79	26.95(21.25-31.50) ±0.98	19.55(17.00-20.25) ±0.77
		Ab	40.05(34.25-45.25) ±2.11	31.95(27.25-35.25) ±0.72	34.70(31.00-38.00) ±0.83	12.15(10.75-14.00) ±0.54	30.34(27.75-33.50) ±0.53	23.62(22.75-25.75) ±0.66
36.	*Pulsatilla wallichiana* Ulbr.	Ab	47.86(40.25-55.00) ±1.06	36.05(31.25-40.75) ±0.66	35.35(31.75-38.25) ±0.74	9.26(6.75-12.75) ±0.83	34.05(32.00-37.25) ±0.92	25.16(21.75-30.75) ±0.65
		Ad	48.0(30.50-45.75) ±0.81	16.84(13.75-18.75) ±0.33	26.15(22.25-30.75) ±0.24	8.64(5.00-10.75) ±0.36	26.15(22.75-32.25) ±0.72	19.36(16.25-23.75) ±0.69
37.	*Salvia lanata* Roxb.	Ad	27.75(18.75-33.25) ±2.17	20.65(18.25-22.75) ±0.46	20.35(16.25-24.25) ±0.75	12.70(10.75-14.75) ±0.54	26.65(22.25-30.75) ±0.73	15.65(11.25-17.75) ±0.31
		Ab	64.52 (54.50-74.00) ±3.38	36.52(30.25-41.75) ±0.51	26.5(22.25-30.25) ±0.52	25.53(21.50-28.25) ±0.63	13.50(11.50-16.50) ±1.14	5.75(4.50-7.00) ±0.25
38.	*Salvia nudicaule* L.	Ad	68.52(65.25-72.50) ±2.11	30.40(25.25-35.00) ±1.10	21.1(17.00-24.00) ±0.79	15.35(12.75.19.50) ±0.78	15.52(12.25-18.00) ±0.67	4.45(3.50-5.25) ±0.16
		Ab	34.32(32.75-36.25) ±0.72	22.45(19.00-24.75) ±0.73	24.10(22.00-27.00) ±0.65	11.35(9.75.13.50) ±0.47	19.52(17.25-22.00) ±0.61	13.45(10.50-16.25) ±0.52
39.	*Salvia Plebeia* R. Br.	Ad	30.55(27.75-34.25) ±0.62	20.55(18.75-21.25) ±0.51	24.95(23.75-29.25) ±0.69	10.06(7.25-12.25) ±0.51	23.55(20.75-26.25) ±0.69	15.45(12.50-18.50) ±0.53
		Ab	41.45(37.75-46.25) ±1.53	32.15(27.75-37.75) ±1.14	36.45(32.75-39.25) ±1.68	14.54(11.25-16.75) ±0.61	31.46(27.75-34.50) ±0.72	33.85(28.75-38.75) ±0.69
40.	*Silene vulgaris* (Moench) Garcke	Ad	38.85(35.75-41.75) ±0.87	49.42(48.25-50.50) ±0.99	26.05(22.25-29.75) ±0.61	11.15(9.75-12.25) ±0.43	26.95(22.25-30.25) ±0.59	22.45(19.25-25.75) ±0.43
		Ab	58.04(55.25-60.00) ±1.33	31.80(24.75-38.75) ±1.21	31.15(25.75-37.00) ±1.57	14.53(10.50-18.00) ±0.81	33.50(29.00-36.00) ±1.50	26.43(22.25-30.73) ±0.87

41.	*Solidago virgaurea* L.	Ad	38.50(35.75-40.25) ±0.64	22.33(19.75-25.25) ±1.79	40.20(38.25-42.00) ±1.67	27.26(24.00-30.00) ±0.75	39.00(35.00-42.00) ±0.89	16.53(12.50-18.25) ±0.81
		Ab	33.15(25.75-40.75) ±0.91	15.65(11.50-20.75) ±1.78	25.53(20.50-30.75) ±0.89	9.35(5.25-12.75) ±0.51	25.6(22.75-28.00) ±0.92	16.23(14.00-19.00) ±0.90
42.	*Stachys annua* L.	Ad	58.65(50.75-75.00) ±0.50	38.54(30.00-45.50) ±1.64	41.45(37.25-45.75) ±0.75	15.55(13.25-17.75) ±0.53	39.85(36.75-43.00) ±1.16	37.55(34.75-40.50) ±0.67
		Ab	65.75(60.25-70.25) ±0.51	35.65(30.75-41.75) ±1.58	37.45(34.25-40.75) ±0.65	13.55(10.25-16.75) ±0.52	42.85(38.75-46.75) ±1.11	33.55(27.75-38.25) ±0.78
43.	*Stachys emodi* Hedge.	Ad	69.54(65.75-74.25) ±0.68	30.32(26.00-34.25) ±0.40	30.80(26.75-34.25) ±0.70	8.90(6.00-10.50) ±0.60	33.80(29.50-36.25) ±0.40	17.11(14.00-21.00) ±0.58
		Ab	66.65(60.75-72.65) ±1.29	36.14(33.00-39.75) ±0.61	26.45(22.25-29.00) ±0.47	7.20(6.00-8.75) ±0.50	24.35(20.25-29.75) ±0.51	15.95(12.25-18.75) ±0.36
44.	*Stachys palustris* L.	Ad	45.65(40.25-50.75) ±0.85	22.54(20.00-25.00) ±0.50	18.64(15.25-20.75) ±0.68	10.50(9.25-12.00) ±0.65	19.45(16.25-22.75) ±0.60	14.25(11.75-17.25) ±0.55
		Ab	41.15(37.75-45.75) ±0.95	20.65(15.00-25.75) ±1.45	29.53(28.50-30.75) ±0.74	11.35(8.25-14.75) ±0.62	27.6(24.00-32.00) ±0.71	18.04(14.50-22.00) ±0.81
45.	*Swertia petiolata* D. Don	Ad	56.65(48.75-65.00) ±0.42	49.54(40.00-58.00) ±1.84	29.53(25.50-34.75) ±0.63	14.35(10.25-18.75) ±0.47	37.50(32.00-43.00) ±0.61	31.50(25.50-38.00) ±0.77
		Ab	60.75(54.25-66.25) ±0.69	36.65(31.75-42.75) ±1.21	41.95(36.25-45.75) ±0.74	15.45(12.25-19.75) ±0.51	45.95(41.75-48.75) ±1.09	40.55(33.75-46.25) ±0.51
46.	*Tanacetum artemisioides* Sch. Bip. ex Hook.f.	Ad	56.54(52.75-60.35) ±0.51	25.32(19.45-32.25) ±0.39	20.80(15.75-25.25) ±0.69	7.80(5.50-10.50) ±0.52	26.80(21.50-30.25) ±0.48	16.50(13.00-20.00) ±0.61
		Ab	51.65(42.75-60.65) ±1.62	27.14(21.00-34.75) ±0.42	21.45(18.25-23.65) ±0.52	9.50(7.25-11.75) ±0.71	29.35(25.25-32.75) ±0.31	17.95(14.00-21.75) ±0.31
47.	*Tanacetum gracile* Hook. f. & Thomson	Ad	57.65(50.25-63.75) ±0.56	14.54(10.00-17.00) ±0.21	21.64(18.25-24.75) ±0.48	12.50(9.25-15.00) ±0.62	18.55(14.25-22.50) ±0.60	13.25(9.75-16.25) ±0.55
		Ab	30.45(25.75-36.50) ±0.67	16.15(13.75-18.25) ±0.47	11.50(9.00-13.00) ±0.67	11.32(7.75-14.25) ±0.59	17.15(13.75-20.25) ±0.57	14.35(11.25-17.00) ±0.49
48.	*Thalictrum pedunculatum* Edgew.	Ad	59.21(52.00-65.00) ±2.31	25.40(20.75-30.75) ±1.15	35.05(30.00-40.75) ±0.71	14.30(10.75-17.75) ±0.43	35.60(30.25-39.00) ±0.54	27.55(21.75-32.75) ±0.62
		Ab	48.85(41.25-54.50) ±0.58	35.45(30.25-41.00) ±0.41	32.55(26.25-36.75) ±0.73	11.40(9.00-13.25) ±0.79	35.65(31.25-38.00) ±0.49	23.35(19.00-27.75) ±0.51
49.	*Thymus linearis* Benth.	Ad	36.65(32.75-39.50) ±0.41	32.25(27.25-36.25) ±1.02	33.55(28.25-38.75) ±0.53	11.40(5.00-15.25) ±0.67	34.65(32.25-36.00) ±0.71	19.35(16.00-22.75) ±0.69

		Ab	38.50.(36.00-40.00) ±2.33	29.40(25.75-33.75) ±1.11	37.05(30.00-44.75) ±0.75	9.30(7.75-12.75) ±0.47	37.60(34.25-39.00) ±0.59	25.55(21.75-29.75) ±0.60
50.	*Thymus vulgaris* L.	Ad	51.85(47.25-54.50) ±0.59	38.45(30.25-46.00) ±0.42	29.55(22.25-36.75) ±0.73	12.40(9.00-15.25) ±0.70	35.00(33.25-38.00) ±0.40	22.35(19.00-25.75) ±0.55
		Ad	36.65(33.75-39.50) ±0.43	29.25(22.25-36.25) ±1.01	34.55(28.25-40.75) ±0.51	13.40(8.00-17.25) ±0.66	36.65(32.25-39.00) ±0.72	23.35(16.00-28.75) ±0.61

Table 5: Micromorphological qualitative features of Foliar epidermis.

S. No	Taxa	Family	Abaxial/Adaxial surfaces	Stomata (P/A)	Type of stomata	Epidermal cell shape	Anticlinal wall pattern
1.	*Acantholimon libanoticum* Boiss.	*Plumbaginaceae*	Abaxial	Present	Anisocytic	Polygonal	Undulate
2.	*Achillea nobilis* Roch. ex Nyman.	Asteraceae	Adaxial	Present	Anisocytic	Polygonal, Irregular	Undulate
3.	*Actaea spicata* L.	Ranunculaceae	Abaxial	Present	Anisocytic	Polygonal	Undulate
4.	*Amorphophallus napalensis* (Wall.) Bogner & Mayo	Araceae	Adaxial	Present	Anomocytic	Polygonal, Irregular	Undulate
5.	*Artemisia herba-alba* Asso	Asteraceae	Abaxial	Present	Anomocytic	Polygonal, Irregular	Undulate
6.	*Artemisia sessilifolia* L.	Asteraceae	Adaxial	Present	Paracytic	Polygonal, Irregular	Undulate
7.	*Aster alpinus* Gueldenst. ex Ledeb.	Asteraceae	Abaxial	Present	Anisocytic	Polygonal	Curved
8.	*Aster altaicus* Wild.	Asteraceae	Adaxial	Present	Anisocytic	Polygonal, Pentagonal	Straight
9.	*Carum carvi* L.	Apiaceae	Abaxial	Present	Anisocytic	Polygonal, Tetragonal	Undulate
10.	*Clematis grata* Wall.	Ranunculaceae	Adaxial	Present	Paracytic	Polygonal	Straight
11.	*Clinopodium vulgare* L.	Lamiaceae	Abaxial	Present	Paracytic	Polygonal	Sinuate
12.	*Cynoglossum lanceolatum* Hochst. ex DC.	Boraginaceae	Adaxial	Present	Anisocytic	Irregular	Undulate
13.	*Cynoglossum wallichii* D. Don	Boraginaceae	Abaxial	Present	Anomocytic	Polygonal, Irregular	Straight
14.	*Epilobium angustifolium* L.	*Onagraceae*	Adaxial	Present	Paracytic	Polygonal, Pentagonal	Straight

15.	*Erigeron alpinus* L.	Asteraceae	Abaxial	Present	Anisocytic	Polygonal, Tetragonal	Curved
16.	*Erigeron annuus* (L.) Desf.	Asteraceae	Adaxial	Present	Anomocytic	Polygonal	Undulate
17.	*Erigeron bellidioides* Griseb.	Asteraceae	Abaxial	Present	Anomocytic	Polygonal, regular	Sinuate
18.	*Erigeron bonariensis* L.	Asteraceae	Adaxial	Present	Anisocytic	Wavy	Curved
19.	*Galium verum* L.	*Rubiaceae*	Abaxial	Present	Anomocytic	Polygonal, Pentagonal	Straight
20.	*Geranium pretense* L.	*Geraniaceae*	Adaxial	Present	Anomocytic	Polygonal, Tetragonal	Sinuate
21.	*Hieracium murorum* C.B. Clarke.	Asteraceae	Adaxial	Present	Anisocytic	Polygonal	Undulate
22.	*Impatiens bicolor* Hook. f.	*Balsaminaceae*	Abaxial	Present	Anisocytic	Polygonal	Straight
23.	*Impatiens edgeworthii* Hook. f.	*Balsaminaceae*	Adaxial	Present	Anomocytic	Polygonal, Irregular	Straight
24.	*Isodon rugosus* Wall. ex Benth	Lamiaceae	Abaxial	Present	Anomocytic	Polygonal	Curved
25.	*Lactuca dissecta* D. Don	Asteraceae	Abaxial	Present	Anisocytic	Regular	Undulate
26.	*Leontopodium nivale* (Ten.) A. Heut ex Hand. Mazz.	Asteraceae	Abaxial	Present	Anisocytic	Polygonal	Straight
27.	*Medicago polymorpha* L.	Fabaceae	Adaxial	Present	Paracytic	Polygonal	Curved
28.	*Nepeta clarkei* Hook.f.	Lamiaceae	Abaxial	Present	Paracytic	Polygonal, Irregular	Undulate
29.	*Nepeta connata* Royle ex Benth.	Lamiaceae	Adaxial	Present	Paracytic	Polygonal	Sinuate
30.	*Onosma hispida* Wall. ex Don.	Boraginaceae	Abaxial	Present	Anomocytic	Regular	Undulate

31.	*Papaver nudicaule* L.	*Papaveraceae*	Adaxial	Present	Paracytic	Polygonal, Irregular	Undulate
32.	*Perovskia abrotanoides* Karel.	Lamiaceae	Abaxial	Present	Anisocytic,	Polygonal	Undulate
33.	*Persicaria bistorta* Samp.	Polygonaceae	Adaxial	Present	Diacytic	Polygonal, Regular	Straight
34.	*Potentilla crantzii* (Crantz) Fritsch	Rosaceae	Abaxial	Present	Diacytic	Polygonal, regular	Curved
35.	*Prunella vulgaris* L.	Lamiaceae	Abaxial	Present	Paracytic	Polygonal, regular	Straight
36.	*Pulsatilla wallichiana* Ulbr.	Ranunculaceae	Abaxial	Present	Anisocytic	Polygonal, regular	Straight
37.	*Salvia lanata* Roxb.	Lamiaceae	Abaxial	Present	Anomocytic	Polygonal, regular	Undulate
38.	*Salvia nudicaule* L.	Lamiaceae	Adaxial	Present	Anomocytic	Polygonal, regular	Sinuate
39.	*Salvia Plebeia* R. Br.	Lamiaceae	Abaxial	Present	Paracytic	Polygonal, regular	Undulate
40.	*Silene vulgaris* (Moench) Garcke	Caryophyllaceae	Abaxial	Present	Diacytic	Irregular	Sinuate
41.	*Solidago virgaurea* L.	Asteraceae	Adaxial	Present	Diacytic	Polygonal, regular	Sinuate
42.	*Stachys annua* L.	Lamiaceae	Abaxial	Present	Actinocytic	Polygonal, Irregular	Sinuate
43.	*Stachys emodi* Hedge.	Lamiaceae	Abaxial	Present	Diacytic	Polygonal, Irregular	Straight,
44.	*Stachys palustris* L.	Lamiaceae	Abaxial	Present	Paracytic	Polygonal, Irregular	Curved
45.	*Swertia petiolata* D. Don	*Gentianaceae*	Abaxial	Present	Staurocytic	Polygonal, Irregular	Straight
46.	*Tanacetum artemisioides* Sch. Bip. ex Hook.f.	Asteraceae	Adaxial	Present	Paracytic	Polygonal, Irregular	Sinuate

47.	*Tanacetum gracile* Hook. f. & Thomson	Asteraceae	Abaxial	Present	Diacytic	Polygonal	Sinuate
48.	*Thalictrum pedunculatum* Edgew.	Ranunculaceae	Abaxial	Present	Anomocytic	Polygonal, Regular	Undulate
49.	*Thymus linearis* Benth.	Lamiaceae	Abaxial	Present	Diacytic	Polygonal, regular	Sinuate
50.	*Thymus vulgaris* L.	Lamiaceae	Abaxial	Present	Diacytic	Polygonal, regular	Straight

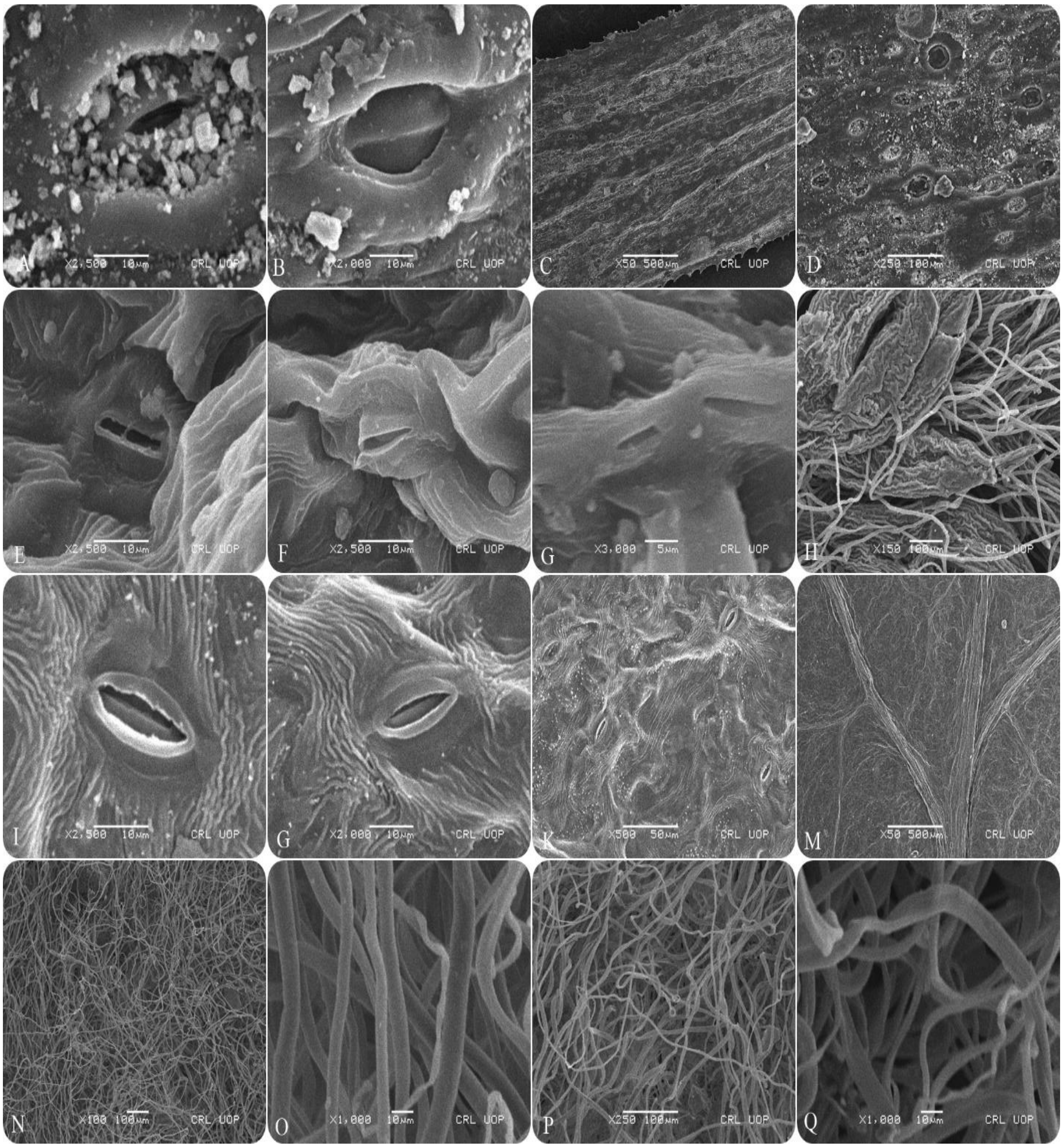

Plate 42: *Acantholimon libanoticum* (A-B) abaxial and (C-D) adaxial surface, *Achillea nobilis* (E-F) abaxial and (G-H) adaxial surface, *Actaea spicata* (I-K) abaxial and (L) adaxial surface, *Amorphophallus napalensis* (M-P) adaxial surface.

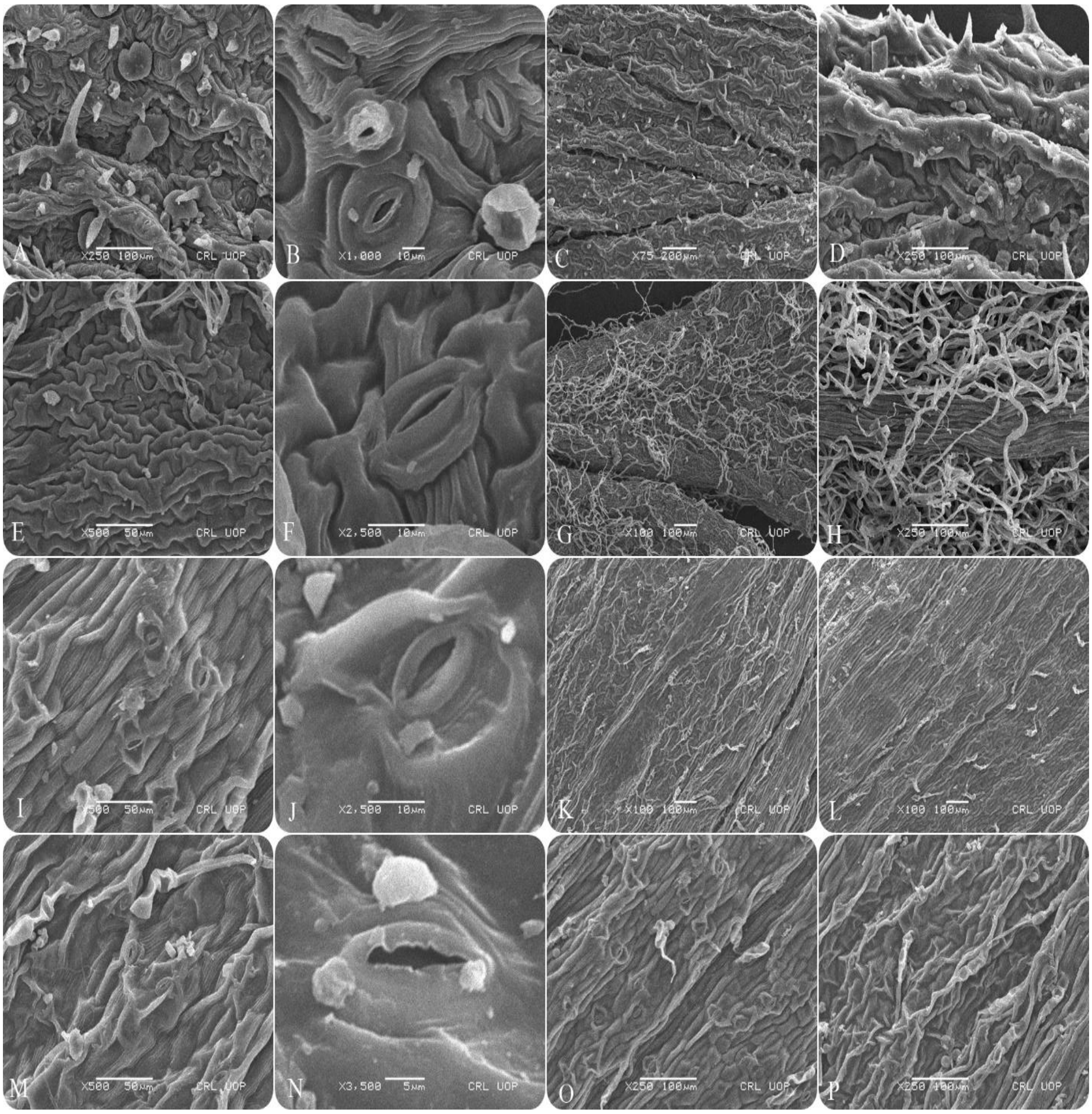

Plate 43: *Artemesia herba-alba* (A-B) abaxial and (C-D) adaxial surface, *Artemisia sessilifolia* (E-F) abaxial and (G-H) adaxial surface, *Aster alpinus* (I-K) abaxial and (L) adaxial surface, *Aster altaicus* (M-N) abaxial and (O-P) adaxial surface

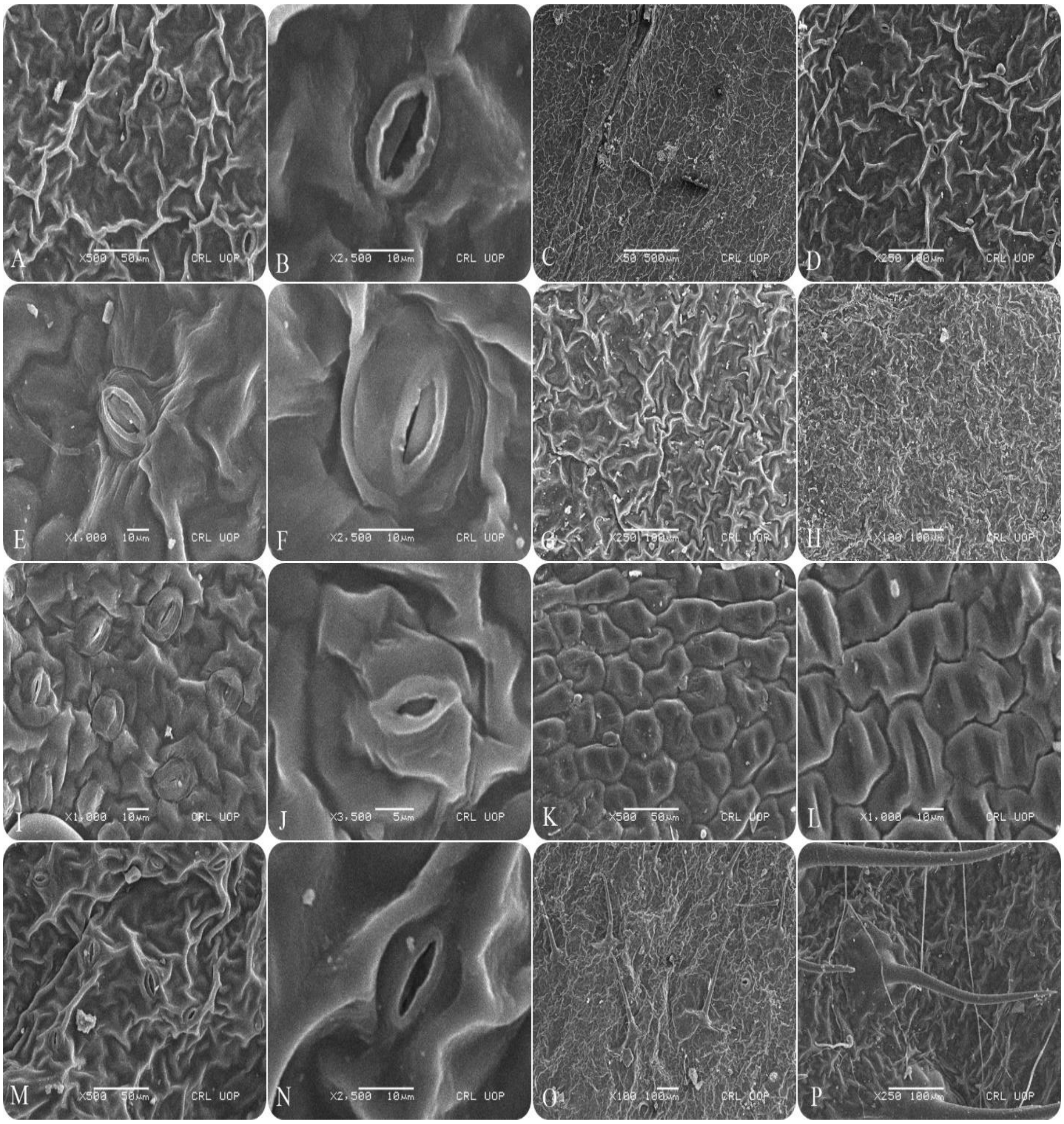

Plate 44: *Carum carvi* (A-B) abaxial and (C-D) adaxial surface, *Clematis grata* (E-F) abaxial and (G-H) adaxial surface, *Clinopodium vulgare* (I-J) abaxial and (K-L) adaxial surface, *Cynoglossum lanceolatum* (M-N) abaxial and (O-P) adaxial surface

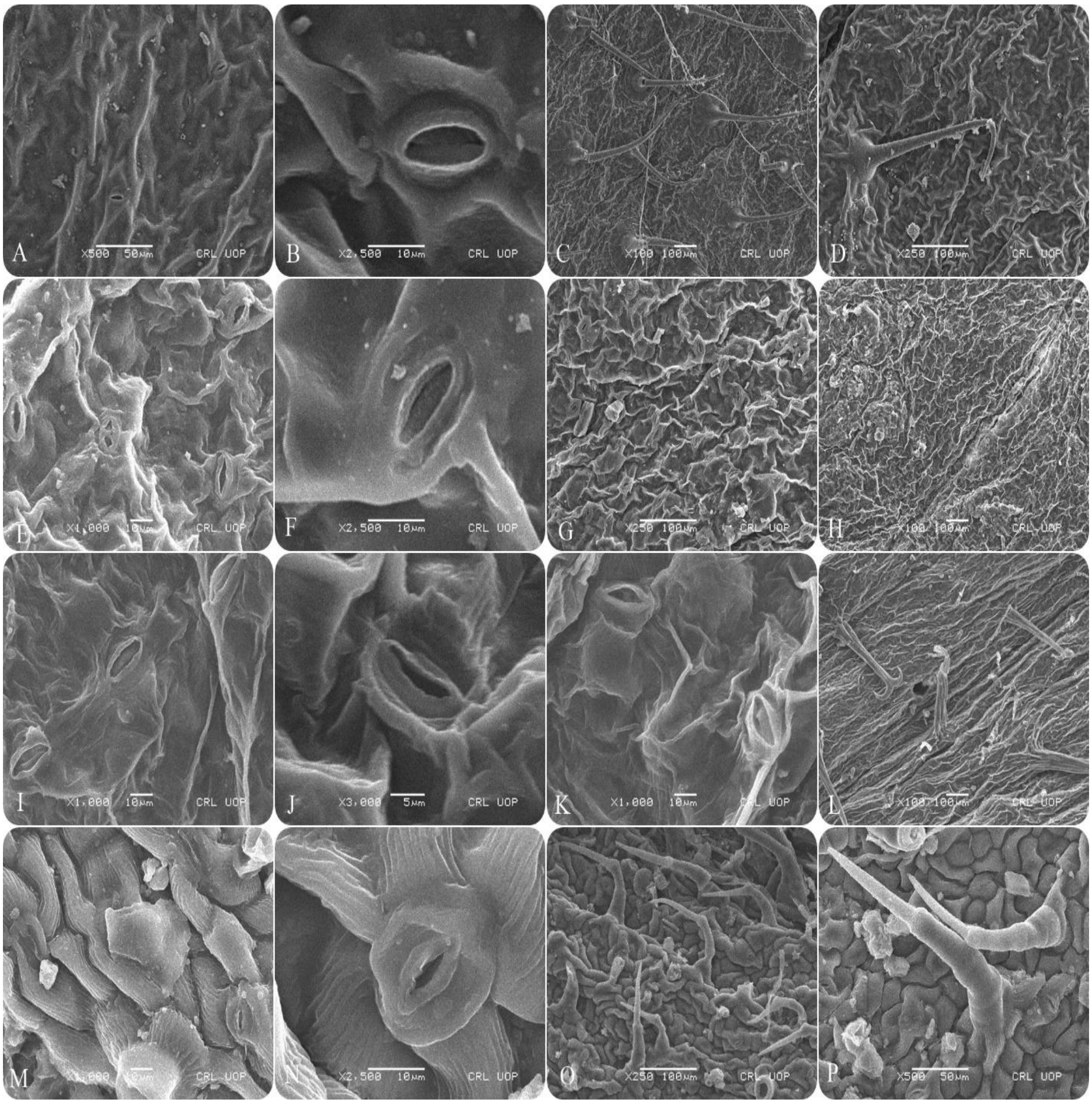

Plate 45: *Cynoglossum wallichii* (A-B) abaxial and (C-D) adaxial surface, *Epilobium angustifolium* (E-F) abaxial and (G-H) adaxial surface, *Erigeron alpinus* (I-J) abaxial and (K-L) adaxial surface, *Erigeron annuus* (M-N) abaxial and (O-P) adaxial surface.

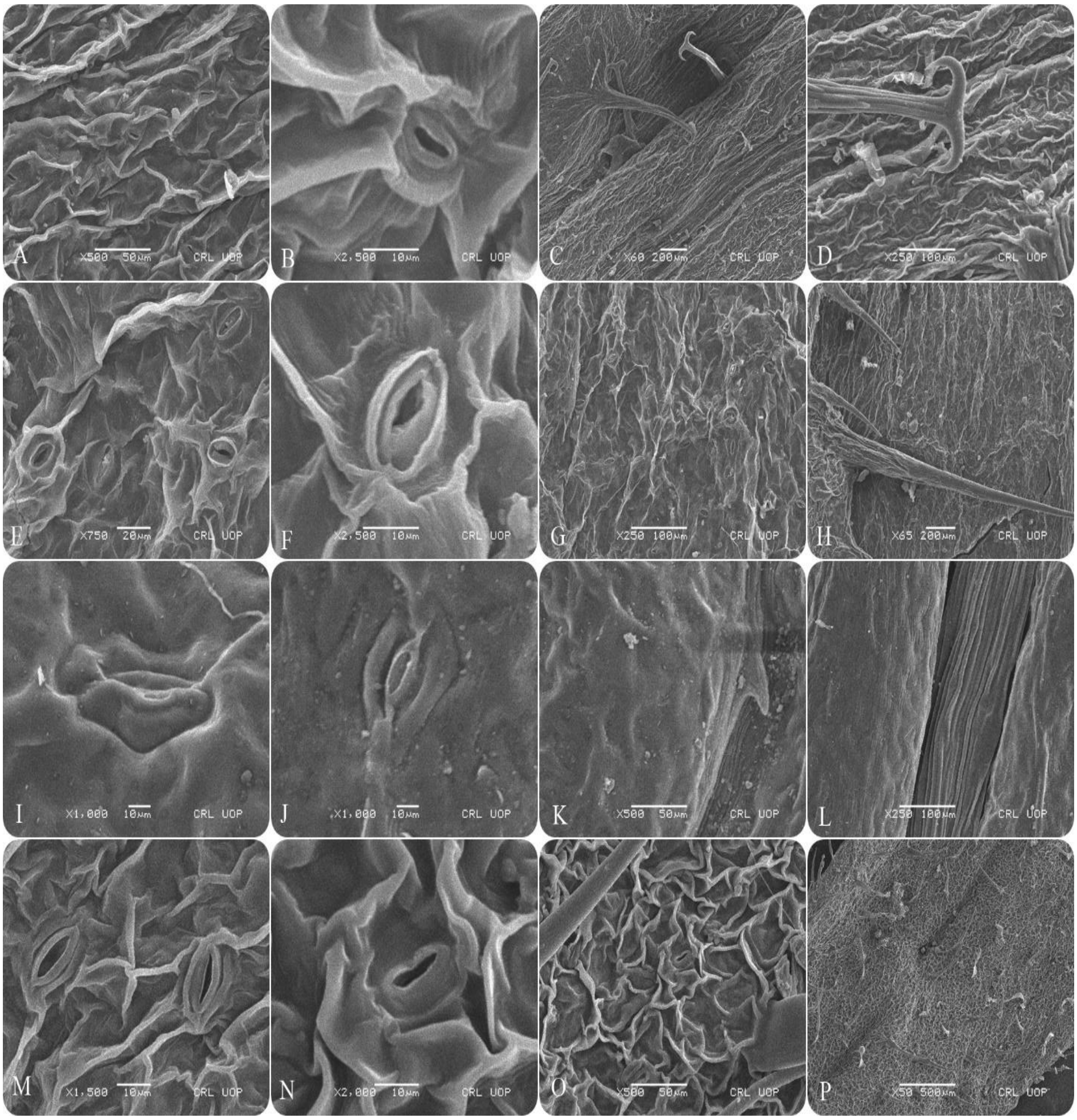

Plate 46: *Erigeron bellidioides* (A-B) abaxial and (C-D) adaxial surface, *Erigeron bonariensis* (E-F) abaxial and (G-H) adaxial surface, *Galium verum* (I-K) abaxial and (L) adaxial surface, *Geranium pretense* (M-O) abaxial and (P) adaxial surface.

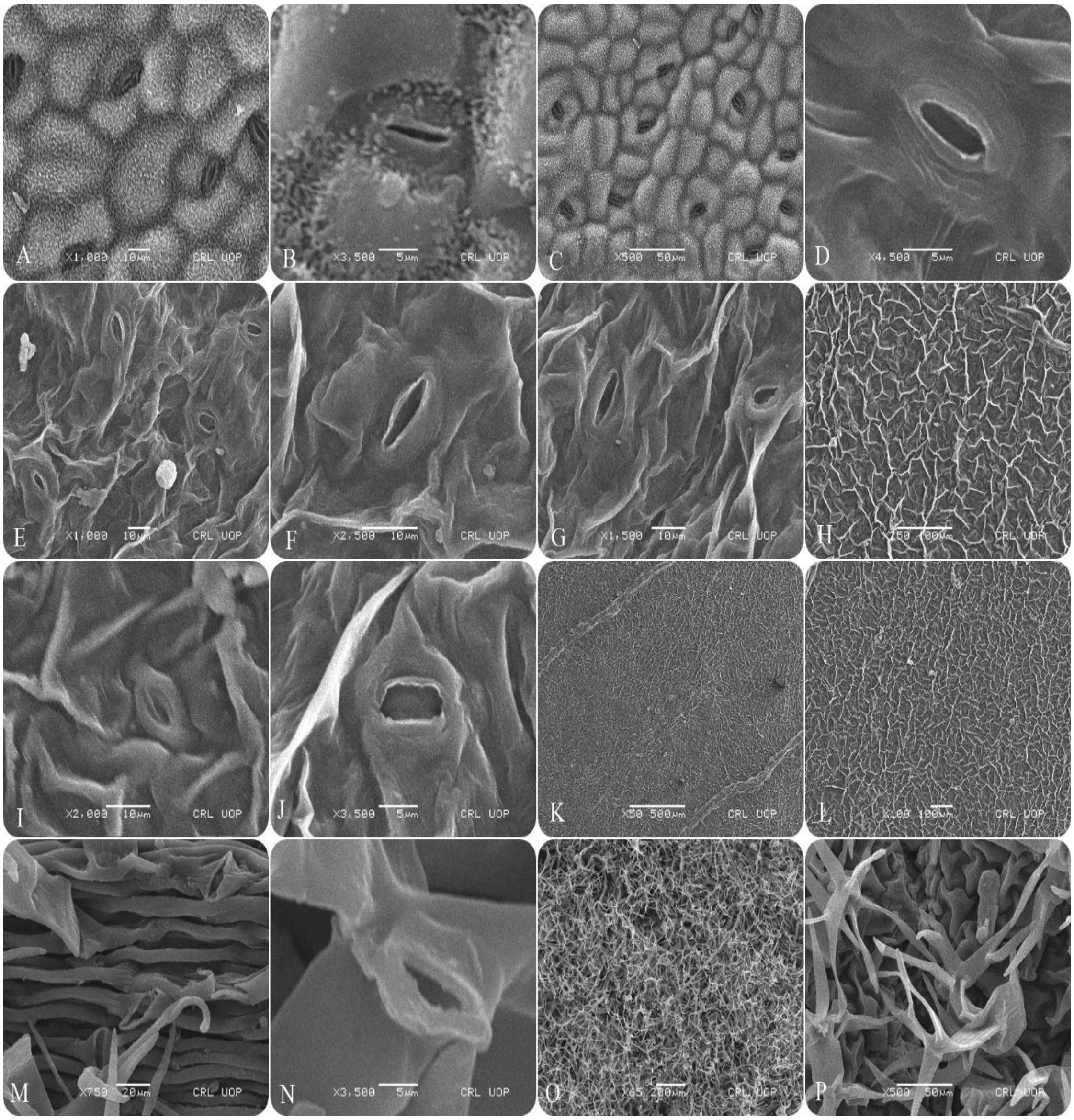

Plate 47: *Hieracium murorum* (A-B) abaxial and (C-D) adaxial surface, *Impatiens bicolor* (E-H) adaxial surface, *Impatiens edgeworthii* (I-K) abaxial and (L) adaxial surface, *Isodon rugosus* (M-O) abaxial and (P) adaxial surface.

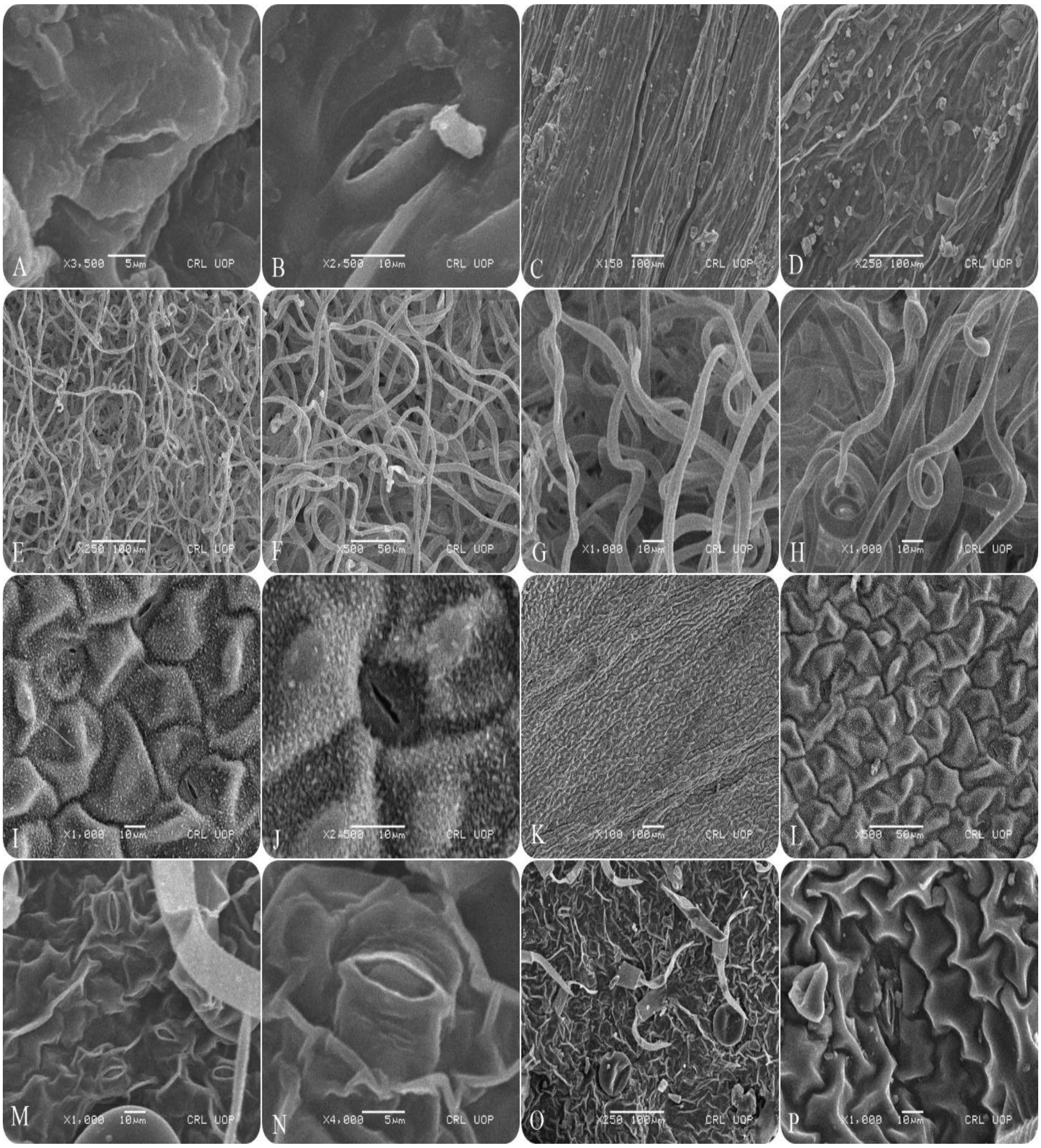

Plate 48: *Lactuca dissecta* (A-B) abaxial and (C-D) adaxial surface, *Leontopodium nivale* (E-F) abaxial and (G-H) adaxial surface, *Medicago polymorpha* (I-K) abaxial and (L) adaxial surface, *Nepeta clarkei* (M-O) abaxial and (P) adaxial surface.

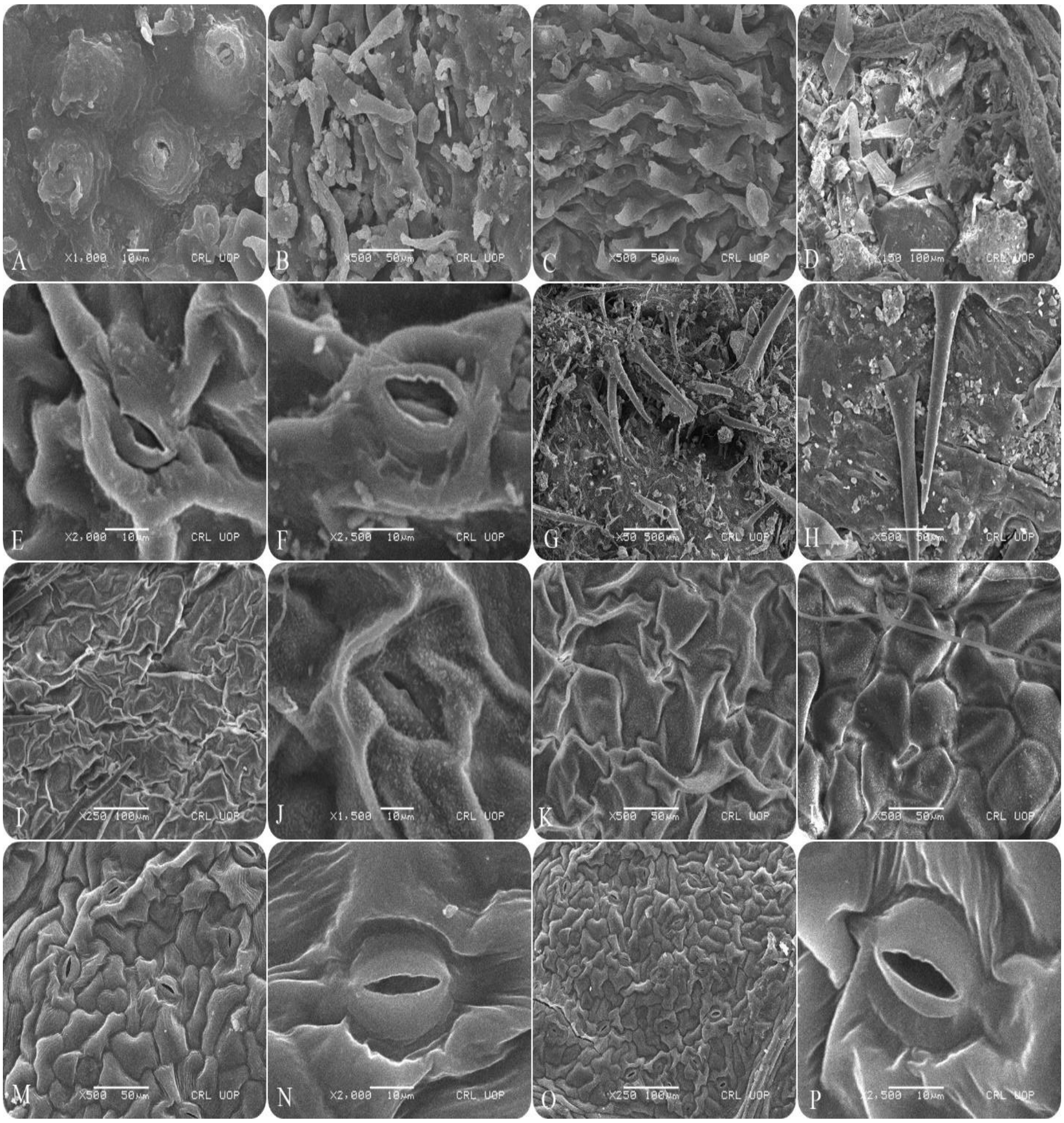

Plate 49: *Nepeta connata* (A-B) abaxial and (C-D) adaxial surface, *Onosma hispida* (E-F) abaxial and (G-H) adaxial surface, *Papaver nudicaule* (I-K) abaxial and (L) adaxial surface, *Perovskia abrotanoides* (M-P) abaxial surface.

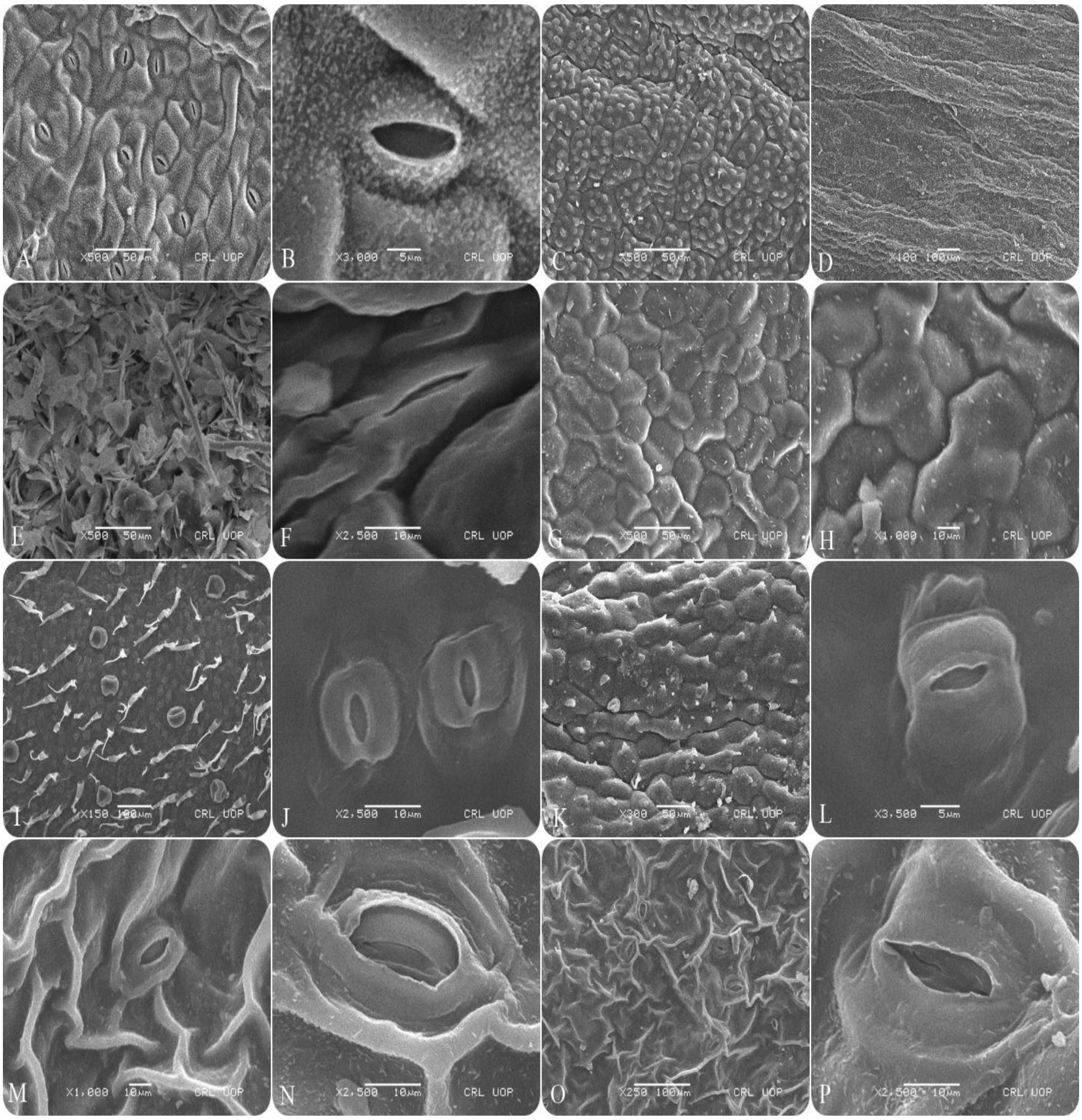

Plate 50: *Persicaria bistorta* (A-B) abaxial and (C-D) adaxial surface, *Potentilla crantzii* (E-F) abaxial and (G-H) adaxial surface, *Prunella vulgaris* (I-L) surface, *Pulsatilla wallichiana* (M-P) abaxial surface.

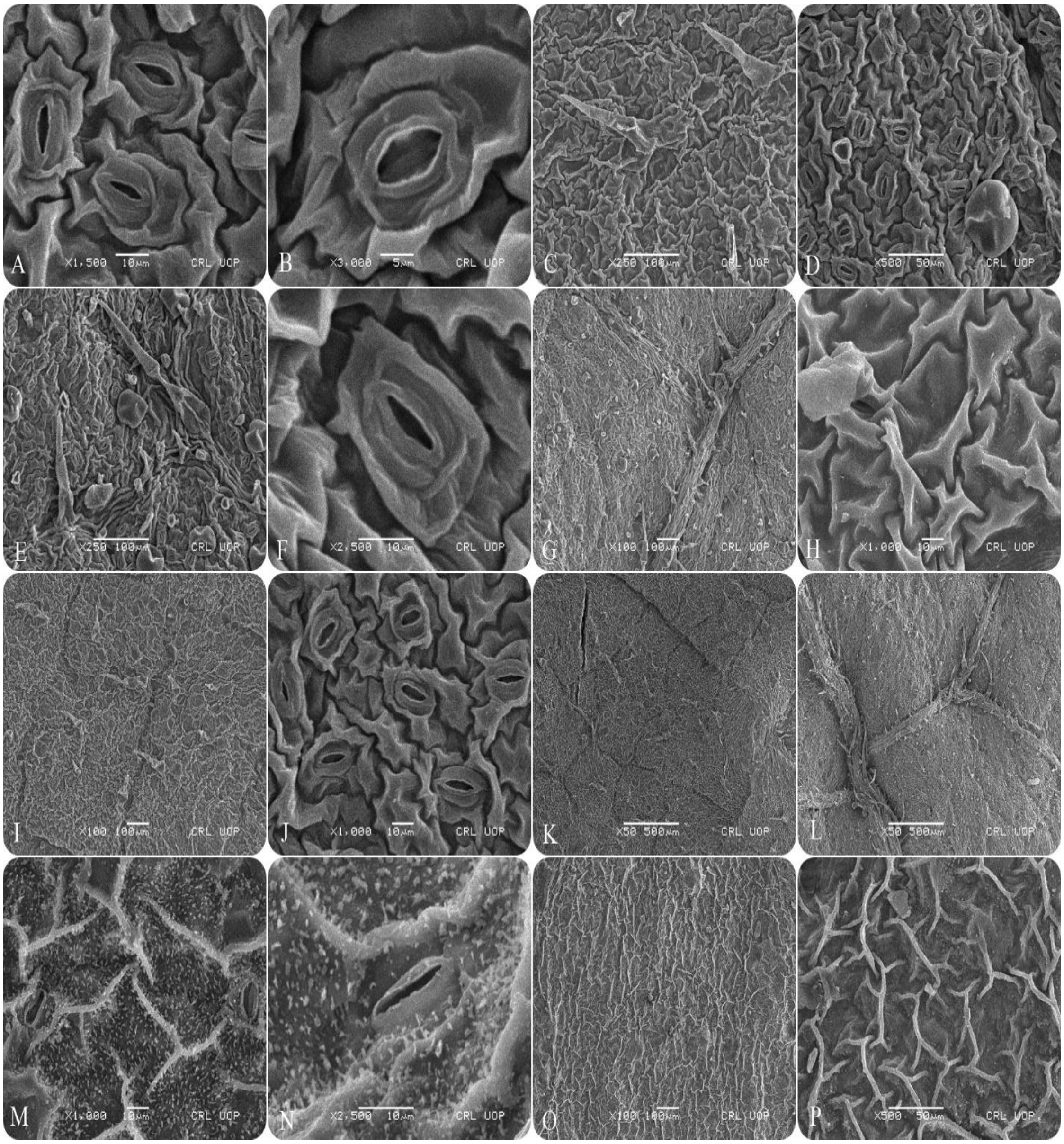

Plate 51: *Salvia lanata* (A-D) abaxial surface, *Salvia nudicaule* (E-F) abaxial and (G-H) adaxial surface, *Salvia Plebeia* (I-K) abaxial and (L) adaxial surface, *Silene vulgaris* (M-O) abaxial and (P) adaxial surface.

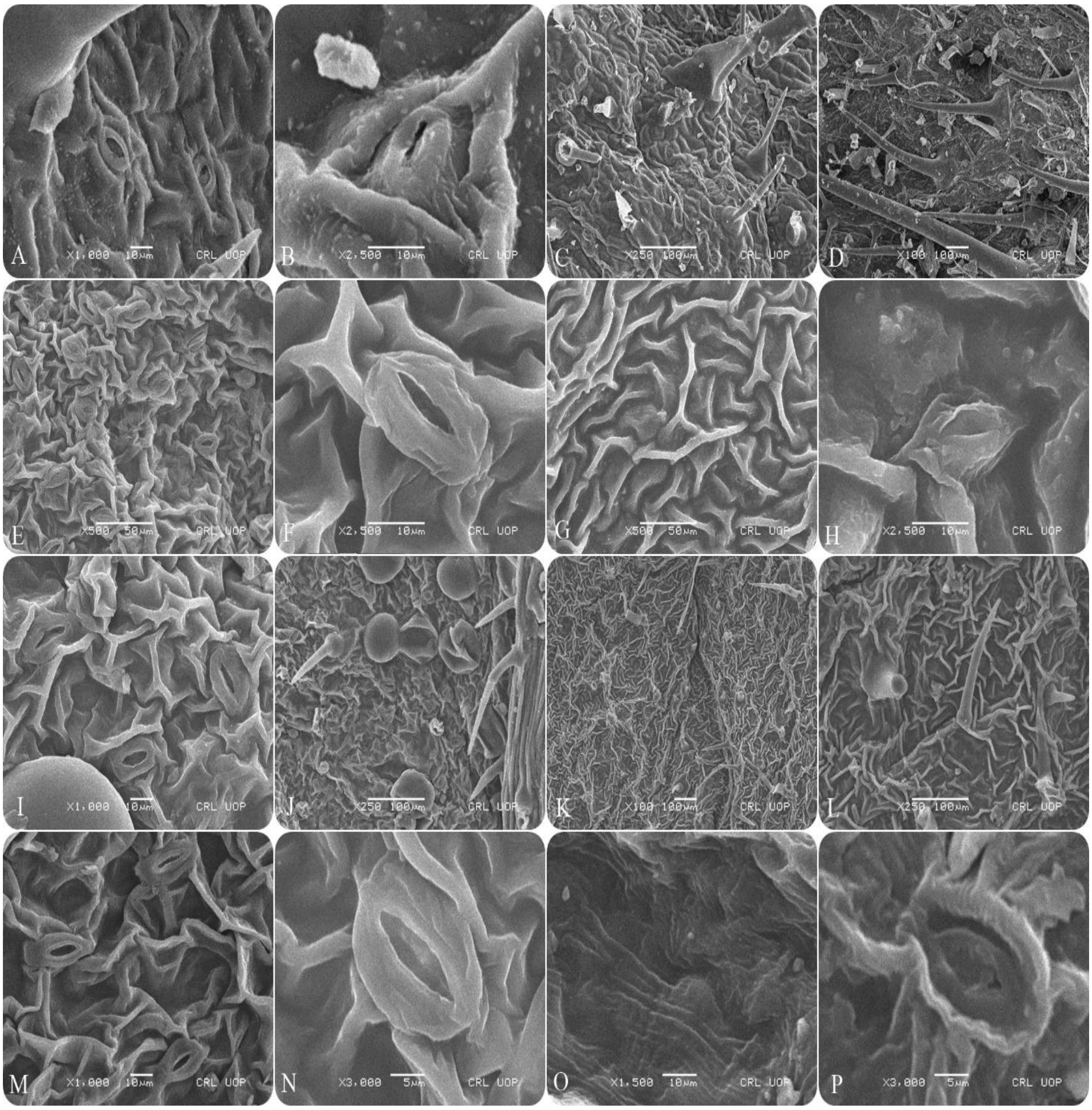

Plate 52: *Solidago virgaurea* (A-B) abaxial and (C-D) adaxial surface, *Stachys annua* (E-F) abaxial and (G-H) adaxial surface, *Stachys emodi* (I-K) abaxial and (L) adaxial surface, *Stachys palustris* (M-O) abaxial and (P) adaxial surface.

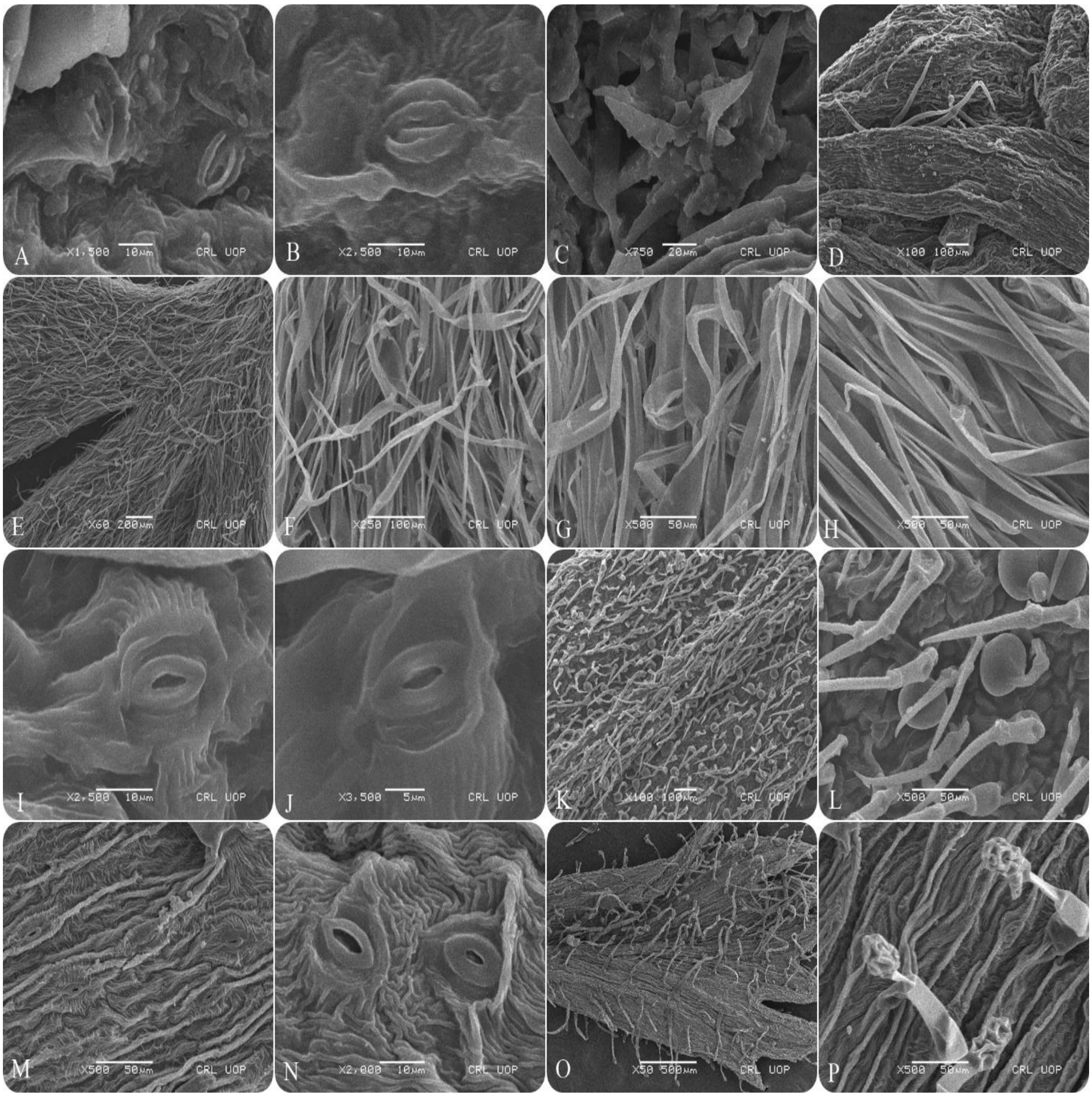

Plate 53: *Swertia petiolata* (A-B) abaxial and (C-D) adaxial surface, *Tanacetum artemisioides* (E-H) adaxial surface, *Tanacetum gracile* (I-K) abaxial and (L) adaxial surface, *Thalictrum pedunculatum* (M-O) abaxial and (P) adaxial surface.

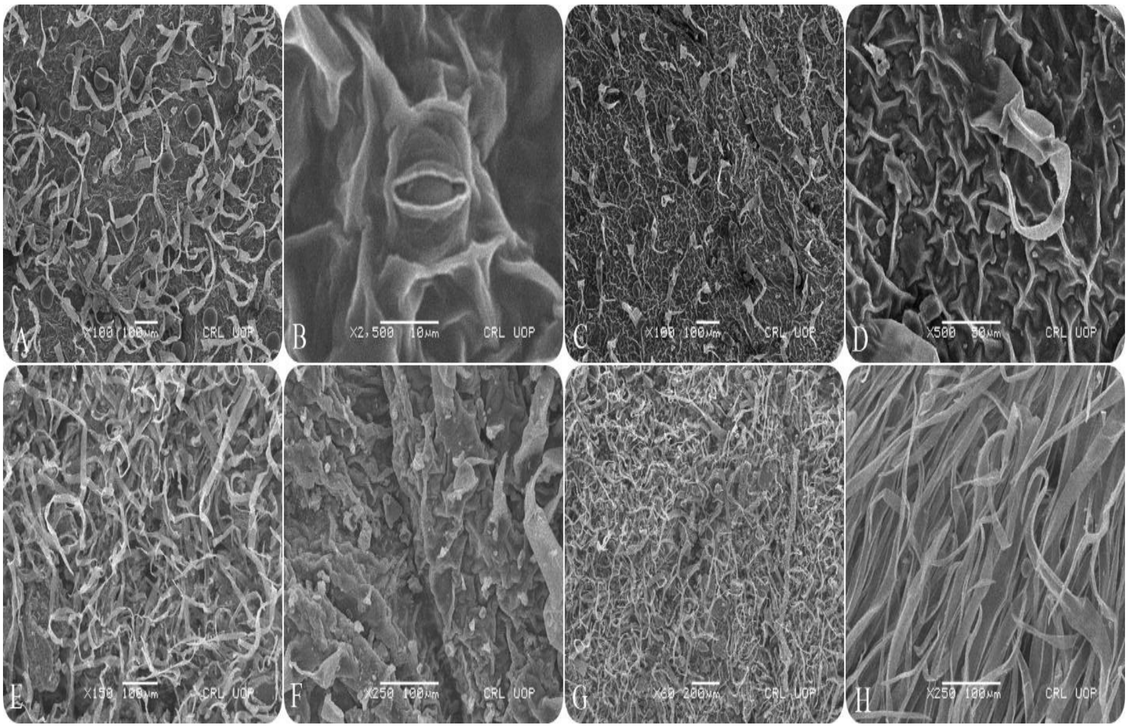

Plate 54: *Thymus linearis* (A-B) abaxial and (C-D) adaxial surface, *Thymus vulgaris* (E-H) adaxial surface.

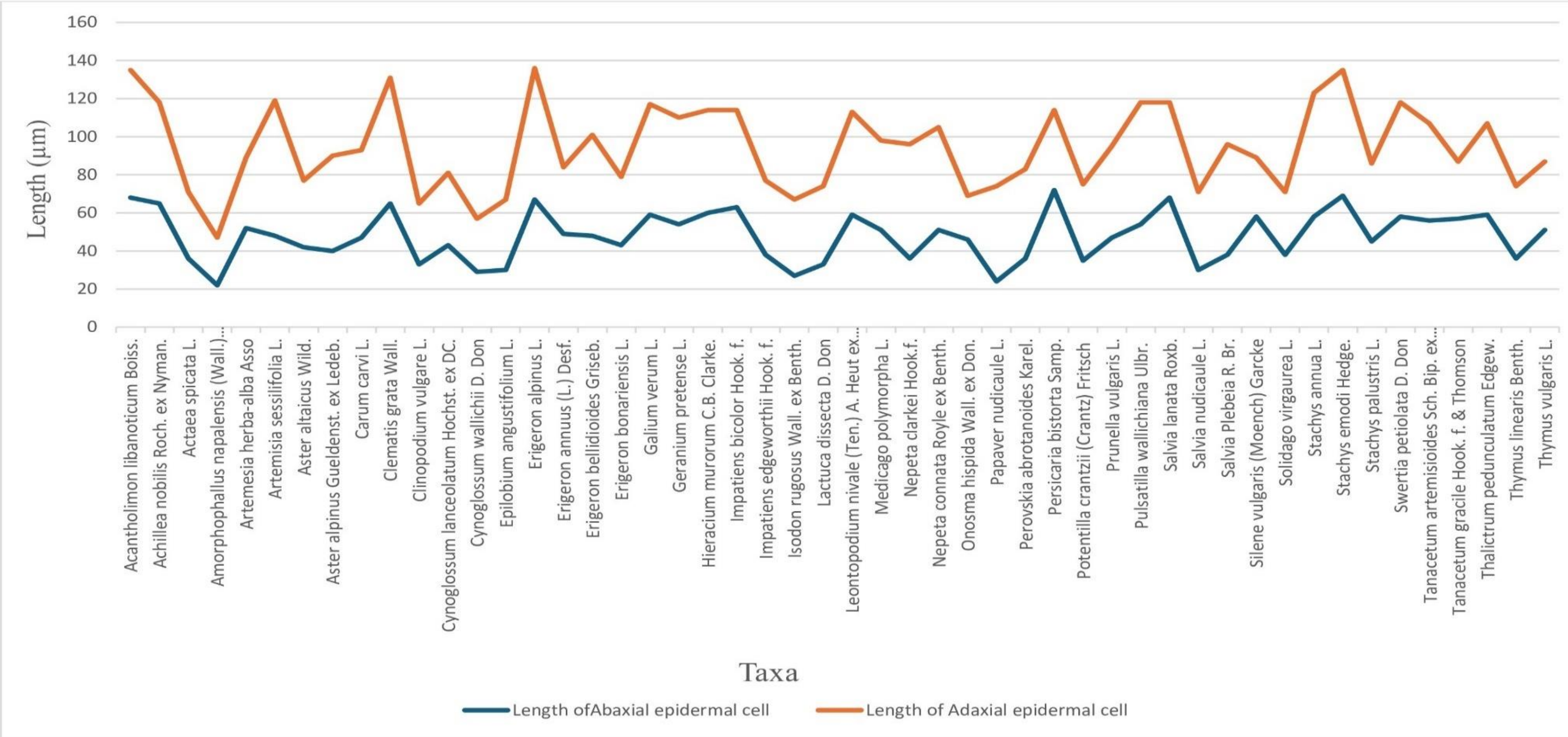

Figure 11: Variations in length of epidermal cells of the selected taxa of Himalayas

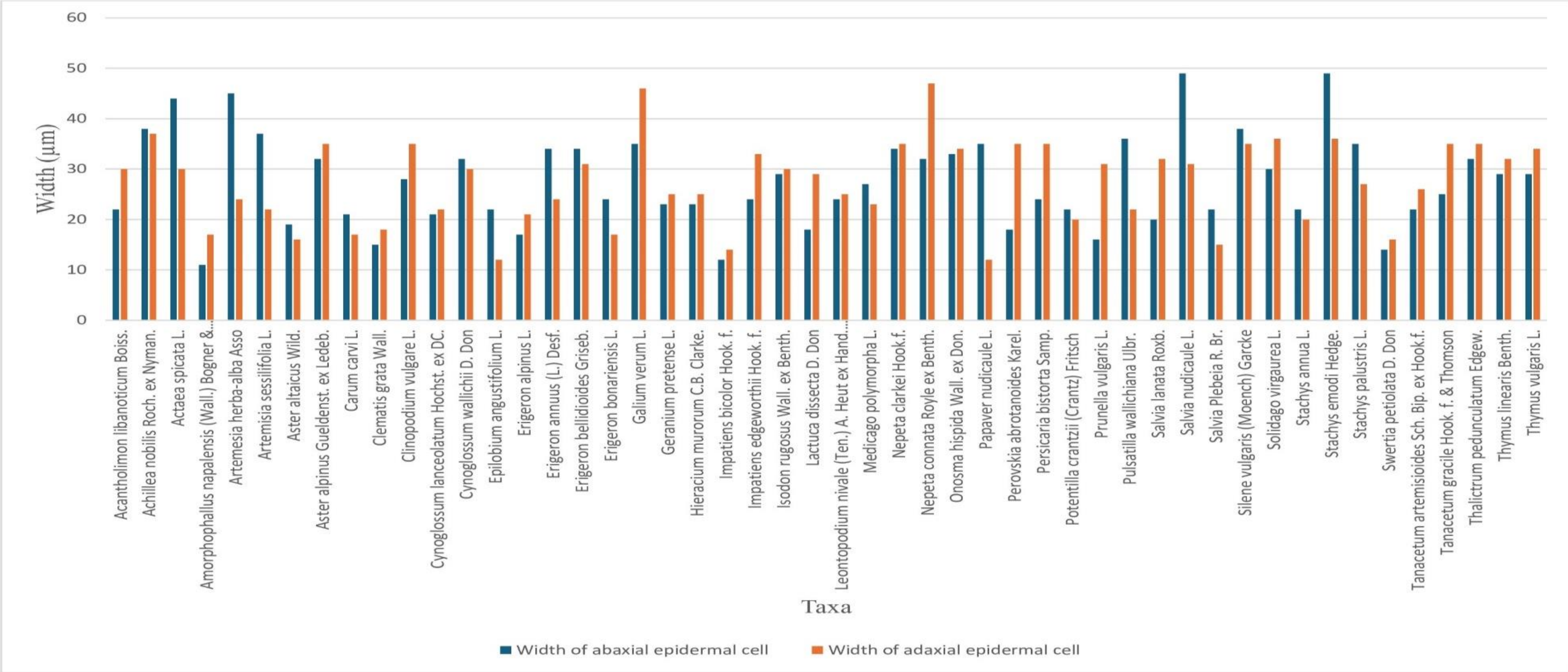

Figure 12: Variations in width of epidermal cells of the selected taxa of Himalayas

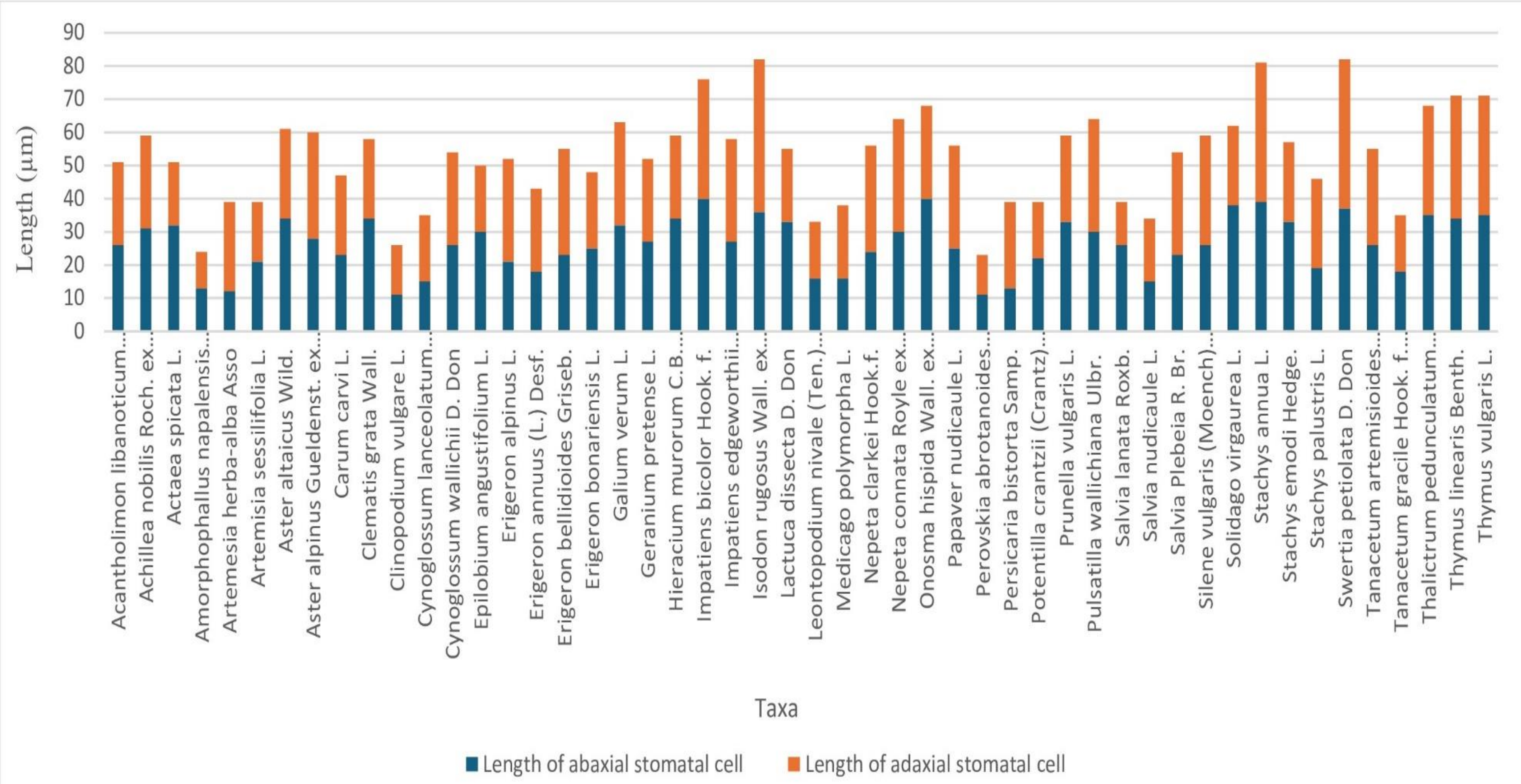

Figure 13: Variations in width of stomatal cells of the selected taxa of Himalayas

Conclusion

This study was done for the first time in northern Pakistan to assess selected taxa from various places in the Hindukush-Karakoram-Himalaya region. The study connects directly to plant ecology, aeropalynology, chemotaxonomy, molecular biology, and environmental sciences. In the current work, a systematic description (using LM and SEM) of selected taxa from the Hindukush-Karakoram-Himalaya area in Northern Pakistan was investigated. In the discipline of plant taxonomy, pollen morphology and foliar epidermal structure were shown to be useful tools for identifying and delimiting species and genera.

Palynology

The pollen characteristics of 86 herbaceous plants were investigated, and statistical analysis yielded considerable information about plant similarities and variations. Lamiaceae was the most dominant family, with 23 species producing pollen in various shapes such as prolate-spheroidal, sub-prolate, oblate-spheroidal, and hexa-colporate, with micro-reticulate and reticulate exine ornamentation. Exine thickness was highest in *Vitex trifolia* 4.09 µm and lowest in *Stachys rigida* 1.02 µm. *Clinopodium vulgare* showed highest 55.95 µm polar diameter and equatorial diameter 54.35 µm in *Lambium album*. Asteraceae is the second leading family having 12 species. *Anaphalis nepelensis* showed highest exine thickness as 36.3 µm among all the asteraceaeous taxa. The exine sculpture of selected pollen were examined to be micro-reticulate, echinate, psilate, reticulate and granulate while the shape of pollen grains oblate, per-oblate, spheroidal and sub spheroidal.

Anatomy

The leaf micromorphology of 50 herbaceous plants revealed foliar anatomical traits, such as changes in epidermal cell, trichome morphology, and stomatal type. *Stachys emodi* has the longest epidermal cell length, measuring 69.54 µm at the adaxial and 66.65 µm at the abaxial surface. The highest length of guard cell was recorded as 36.45 µm and width of stomata abaxial and 36.15 at adaxial in *Erigeron bonariensis* 34.55 µm in asteraceaeous taxa. In anatomical features diacytic, actinocytic, anomocytic, anisocytic and paracytic were studied. This research provides detailed information about systematics study including palynological and anatomical study.

Future Recommendations

- These northern Pakistan floras can be more accurately and correctly identified at the molecular level by using the systematics study.
- The regional flora must be compiled to improve the biodiversity study in northern Pakistan as soon as possible.
- To create an atlas of the study area, this systematics technique is helpful to taxonomists, botanists, and ecologists.
- Initiatives to raise community knowledge about the regulation and management of floral biodiversity should be initiated.
- It is important to implement conservation methods to improve socioeconomic conditions and support the long-term growth of herbal medicine in these areas.

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QUAID-I-AZAM UNIVERSITY
DEPARTMENT OF PLANT SCIENCES

Subject: **Publication of W – Category Ms. Iqra Qayyum (Ph.D. Scholar)**

This is in reference to circular regarding the publication requirement for Ph.D. scholars in Department of Plant Sciences, Faculty of Biological Sciences. It is certified that **Ms. Iqra Qayyum** has published impact factor research paper in W-Category as given below:

S. No.	Paper Title	Year	Impact Factor
1.	Iqra Qayyum, Mushtaq Ahmad, Zabta Khan Shinwari. Nizomova Maksuda, Usman Kulovna, Maria Hamayun, Sarwar Khawaja, Aroosa Habib Muhammad Idrees (2024). Palynological Investigation for Taxonomic Authentication of Medicinal Flora from the Hindukush Range of Northern Pakistan. *Pakistan journal of Botany*., 57(2)	2024	1.2

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PALYNOLOGICAL INVESTIGATION FOR TAXONOMIC AUTHENTICATION OF MEDICINAL FLORA FROM THE HINDUKUSH RANGE OF NORTHERN PAKISTAN

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Abstract

The current study sought to evaluate the morphological variations in pollen grains between 38 species of the Hindukush range of Northern Pakistan. A total of 38 taxa have been analyzed using microscopic techniques to examine the qualitative and quantitative characters of pollen. Pollen size, shape, ornamentation, polar diameter, equatorial diameter, exine thickness, colpi length, colpi width and mesocolpium were studied. Pollen grains of the most taxa studied were tricolporate and prolate. Majority of the pollen recorded have small-medium size and its shape were oblate, peroblate. The study declared that people living in the rural areas were primarily dependent on the medicinal plants. In this study 150 peoples were interviewed through random sampling technique. These medicinal plants were used for the treatment of different diseases i.e digestive, respiratory and dermatological problems in Gilgit. Under a Scanning electron microscope reticulate, echinate, psilate, and perforate have been examined. In addition to being a useful tool for specific delimitation, palynological studies can be used as a key for identifications of taxonomic characters on species, genus and family level. Exine ornamentations provide useful identifying traits to differentiate closely related species. Thus, it is evident that pollen morphological characteristics can both be helpful in distinguishing between taxa at a particular level.

Key words: Pollen, Medicinal plants, Taxonomic features, Microscopy, Identifications.

Introduction

Palynology is the scientific study of pollen and spores, practically applied in genetics, forensics and systematic studies (Noor *et al.,* 2017). Palynological studies serve as essential tools across a range of disciplines including melissopalynology, aeropalynology, criminology, paleobotany, allergy research, and stratigraphic correlation of coal and gas deposits in rock formations. The micrograph imaging of pollen using light and scanning electron microscopy are helpful for morphological descriptions and taxonomic implications (Umber *et al.,* 2022; Khan *et al.,* 2023) investigated that pollen morphological study aids in finding out the phylogenetics and systematics information's of angiosperms. Pollen morphological studies offer insights into genetic diversity and adaptive traits critical for crop evolution, aiding in the selection of cultivars with desired genetic traits for improved agricultural practices. The pollen morphological studies investigated via scanning electron microscope were very useful for taxonomic study due to its high resolution of images (Jones & Bryant, 2007; Alam *et al.,* 2023). The palynological features are used for intrageneric and intraspecific classification (Gentry, 1986). This study is conducted to play an important role in the modern taxonomy for identification and delimitation of species. (Sufyan *et al.,* 2018) recorded that pollen size, shape, and ornamentation are very important distinguishing attributes. A palynological study was conducted to elucidate the morphological characteristics of pollen, serving as a crucial tool for plant taxonomists in species delimitation. This investigation aids in identifying and resolving taxonomic challenges spanning from the species to genus level, unraveling intricate relationships within plant classifications (Singh *et al.,* 2020). Exine sculpture, polar diameter, equatorial diameter, P/E ratio, number of colpi and pores are the important features for species identifications. It has made its link directly with aerobiology, forestry, horticulture, archaeology, geology, molecular biology, plant ecology and agriculture.

In Himalayan highly medicinal plants were recorded within the high altitudes (Shinwari *et al*., 2006; Kala & Ratajc, 2012; Shaheen *et al.,* 2023; Tariq *et al*., 2024) Ethnobotanical knowledge has been collected from the local peoples to know about the local uses of plants. (Sivasankari *et al.,* 2014; Shinwari *et al*., 2009) investigated the importance of herbal medicine to be used by the indigenous communities and local peoples in many countries. Ethnobotanical research documents the rich knowledge of cultural interactions between people and plants. It delves into the integration of plants into religious and cultural traditions, unveiling how communities have historically utilized them for diverse purposes, offering profound insights into human-plant relationships across time and geography. (Balick & Cox, 1996; Shinwari *et al*., 2011; Manzoor *et al.,* 2023a; Mirzaman *et al.,* 2023; Gillani *et al.,* 2024a).