Phytodiversity using Microscopic Characterization in Potohar Plateau-Pakistan

BY

ANWER USMA

Department of Plant Sciences

Quaid-i-Azam University Islamabad, Pakistan

2023

Phytodiversity using Microscopic Characterization in Potohar Plateau-Pakistan

DOCTOR OF PHILOSOPHY IN PLANT SCIENCES

(PLANT SYSTEMATICS AND BIODIVERSITY)

BY

ANWER USMA

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Quaid-i-Azam University Islamabad, Pakistan

2023

IN the name of ALLAH, the Most Beneficient, the Most merciful.

Verify, it is ALLAH who causes the seed grain and the stone fruit to split and sprout. He brings forth the living from the dead and the dead from the living. Such is ALLAH. Then how are you deluded away from the Truth 6:95

"And he to whom wisdom is granted receiveth indeed a benefit overflowing"

(Al-Baqara)

"He who treads the path in search of knowledge, ALLAH would make that path easy, leading to paradise for him"

Sahih Muslim Vol.4; Hadith No.6518

DEDICATED

TO

MY AFFECTIONATE FATHER

AND

BELOVED MOTHER

AND

LOVING BROTHERS

Whom

Inspiration is a source of

Strength, guidance and

Achievement for me

CERTIFICATE OF APPROVAL

This is to certify that research work presented in this thesis, entitled **"Phytodiversity using Microscopic Characterization in Potohar Plateau-Pakistan"** was conducted by **Miss Anwer Usma** 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, Quaid-i-Azam University, Islamabad, Pakistan in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the field of Plant Sciences (Plant Systematics and Biodiversity), Department of Plant Sciences, Quaid-i-Azam University, Islamabad, Pakistan.

Student name: **Miss Anwer Usma** Signature: ______________

Examination committee

External Examiner 1

Prof. Dr. Fayyaz-ul-Hassan Sahi
Faculty of Crop & Food Sciences
Pir Mehr Ali Shah Arid Agriculture University,
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External Examiner 2

Dr. Shaikh Saeed
Associate Professor
Environmental Sciences Program
Fatima Jinnah Women University
The Mall
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Signature ______________

Supervisor
Prof. Dr. Mushtaq Ahmad
Department of Plant Sciences
Quaid-i-Azam University, Islamabad

Signature ______________

Chairman
Prof. Dr. Mushtaq Ahmad
Department of Plant Sciences
Quaid-i-Azam University,
Islamabad

Signature ______________

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FOREIGN EXAMINERS

1) **Prof. Dr. Athar Tariq**

California Department of Food and Agriculture

20th Capital Avenue

Suite 109, Sacramanto

CA-95814,

USA

E-mail: atariq@cdfa.ca.gov

2) **Prof. Dr. Geoffrey M. Gadd**

Department of Biological Sciences

University of Dundee

Dundee, DD1 4HN

Scotland, U.K.

E-mail: g.m.gadd@dundee.ac.uk

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Islamabad, Pakistan
Department of Plant Sciences

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ANWER USMA

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S. No.	Paper Title	Year	Impact Factor
1.	Usma, Anwer, Mushtaq Ahmad, Muhammad Zafar, Shazia Sultana, Fazal Ullah, Saddam Saqib, Asma Ayaz, and Wajid Zaman. "Palynological Study of Weed Flora from Potohar Plateau." *Agronomy* 12, no. 10 (2022): 2500.	2022	3.9
2.	Usma, Anwer, Mushtaq Ahmad, Mohamed Fawzy Ramadan, Amir Muhammad Khan, Muhammad Zafar, Mohammed Hamza, Shazia Sultana, and Ghulam Yaseen. "Micro-morphological diversity of pollen among Asteraceous taxa from Potohar Plateau-Pakistan." *Microscopy Research and Technique* 85, no. 7 (2022): 2467-2485.	2022	2.76

Prof. Dr. Mushtaq Ahmad
Supervisor

Professor
Department of Plant Sciences
Quaid-i-Azam University, Islamabad

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Abstract

This Project is the systematics exploration of floral diversity of Potohar Plateau-Pakistan using quantitative and qualitative micro-morphological characterization. Floral diversity of the study area is first time documented systematically with comprehensive qualitative and quantitative micromorpholgical analysis. Field trips were conducted in different areas of Potohar Plateau including Attock, Chakwal, Mianwali, Soon sakesar, Miani Village, Uchali Lake, Kabbaki Lake, Kalla Chitta Hills, Rawalpindi and Islamabad. The plants were collected, identified, pressed, dried, preserved and deposited in the Herbarium of Pakistan (ISL), Quaid-i-Azam University Islamabad. The highest number of species belongs to family Asteraceae (29 species), Fabaceae (22 species),Amaranthaceae (17 species), Poaceae (15 species) and remaining species belongs to different families. The first section is confined to Palyno-morphological characters studied by Light Microscope (LM) and Scanning Electron Microscope (SEM) . The Pollen micro-morphological variations observed during this study include pollen shape and size, Polar and equatorial diameter, pore size,P/E ration, apertures, Length and width of spines and exine thickness. Similarly remarkable variations regarding pollen exine sculpturing was reported among various families from reticulate,microechinate, scabrate, verrucate, microechinate-aerolate types. The Second section is confined to Seeds morphological characters studied by Light Microscope (LM) and Scanning Electron Microscope (SEM). The Seeds micro-morphological variations observed during this study include Length and width of seed, L/W ratio, color, shape, anticlinal wall pattern, periclinal wall thickness, anticlinal wall protuberance, periclinal wall elevation, surface sculpturing.

Total 103 plant species were studied for palynological description via light microscopy (LM) and scanning electron microscopy (SEM). In family Asteraceae largest pollen size was found in *Bidens pilosa* (97.5um), while the lowest pollen size was observed in *Carthamus lanatus* (12.5um). In family Amaranthaceae largest pollen was found in *Amaranthus gracizens* (81um), while the lowest pollen size was observed *Digeria muricata* (11.50um). In Fabaceae largest pollen is observed in *Lespedeza juncea* (38um), while lowest size in *Prosopis cineraria* (14.3um) Based on systematics exploration of various macro and micro characters (LM and SEM), the diagnostic palynological characters includes exine sculpturing, shape of pollen, number of colpi and spines.

Seed micromorphology was studied in 40 species belong to two families Asteraceae and Fabaceae. Seed shape in asteraceous and fabaceous species observed was Linear, Linear fusiform, curved-ring shaped, oblanceolate, obovoid, cylindrical, Pointed and Linear lanceolate. The highest seed length observed in Ageratum conyzoides that is 7.56 While lowest in Erigeron Canadensis 1.6. The Highest seed width observed in Parthenium hysterophorus 3.9, While lowest in Erigeron bonariensis 0.5. Taxonomic keys based on palynological and seed morphological characters were developed for identification of different species belongs to different families.

The taxonomic keys developed on the basis of Palynology and seed morphology were useful for classification and delimitation of selected taxa within families. This study further recommends to work on these plants with respect to their conservation status and write monograph on these plants of Potohar-Plateau based on Palyno-morphological and seeds morphological characters in addition to advanced systematics tools and features. The study further recommends correlating this data with phylogenetic information in order to use at global perspective for systematic of different families.

CHAPTER: 1
Introduction

1.1 Floral Diversity in-Potohar-Plateau Pakistan

The flora of Pakistan exhibits its diversified climatic zones distribution ranging from temperate to tropical and arid to semi-arid. Heterogeneous climatic conditions with wide ranges of ecological zones. Atmospheric temperature, humidity and precipitation differ intensely in various altitudinal regions. In the south-western locales of this land, the elevation is quite low resulting into high temperature accompanied by low precipitation, such varied climatic condition results with the arid and semi-arid ecology. In ecological terms, there exist five kind of rangelands including the alpine pastures, the semi-alpine pastures, the temperate rangelands, and the arid rangelands (Hua et al., 2015).

The Potohar Plateau part of largest province Punjab selected for present project includes (9) cities Attock, Chakwal, Mianwali, Soon sakasar, Miani Village, Uchali Lake, Kabbaki Lake, Kalla Chitta Hills, Rawalpindi and Islamabad. North Punjab, usually known and termed as the Potohar -Plateau ,stretches towards the south of northern hills,bordered in the west by Indus River and by Jhelum River in the east (Majeed et al., 2010). In the north Punjab region, Scrub vegetation ranges are located between Indus and Jhelum rivers in Attock, Rawalpindi, Jhelum and Chakwal Districts counting Islamabad. Acacia modesta is the leading species;in addition to that Amaranthus gracizens and dodonea viscosa are also found profoundly (Hussain, 2009). There is a variety of Plants and trees blooming in the area is reliant on rainfallas well as ground water,and the region is undergoing an undulated orography (Hashmi et al., 2012). The prevalent species of Plant families in this region belongs to Asteraceae, Amaranthaceae, Fabaceae, Poaceae, Brassicaceae, Asphodelaceae, Nyctaginaceae, Capparaceae, Chenopodiaceae, Tiliaceae, Menispermaceae, Verbenaceae, Cucurbitaceae, Euphorbiaceae at the same time, contingent upon their medicinal value (Bibi et al., 2014). Alongside the roads, field and canals, *Dalbergia sisso* is widely planted (Bajwa et al., 2003). Grass species which are native to Potohar region and the most abundantly found are *Aristida mutabilis,Cenchrus ciliaris, Cynodon dactylon, Dichanthium annulatum, Cenchrus biflorus, Dactylolactenium scindicum, Eleusine indica* (Hameed et al., 2008). Dominant species found in the area are *Zizyphus nummularia, Acacia modesta, Melia azedarach, Albizia lebbeck, Dodonea viscosa*, *Cassia fistula* and *Dalbergia sisso* (Qureshi et al., 2014; Qureshi et al 2018). *Lanta* *camara, Xanthium strumarium and Prosopis juliflora* were recorded as the chief non-native species in this region (Malik and Husain, 2006). Other species of plants include *Ajuga bracteosa, Rumex dentatus, Solanum nigrum, Chenopodium murale, Cleome brachycarpa, Capparis decidua, Atriplex stocksii , Corchorus depressus , Celosia argentea.*

Salt range of Pakistan is blessed with rich floral diversity (Ahmad and Waseem, 2004). There are some natural resources existing in Salt Range. The climate of this Range is dry subtropical while the vegetation of is partially evergreen. Vegetation of this locality is classified into three main types which are (i) Thorny-ever green tropical, (ii) semi ever green sub-tropical and (iii) degraded scrubs. *Dodonea viscosa, Olea cuspidate* and *Acacia modesta* that are typically present at hill swatches at an leviation of 750 m or higher are made up of the semi ever green sub-tropical (Ahmad et al., 2012).Plant species of dry-tropical thorny ever green forests includes *Capparis decidua, Maytenus royleanus, Salvadora oleoides* and *Acacia nilotica* while the plants that are under intense compression with inhibited growth constitute degraded scrublands (Ahmad et al., 2010). Salt accepting species are also found in some areas together with saline soil like *Fagonia indica* and *Withania coagulans*. The plants which are found in saline soil are *Salsola foetida*, *Amaranthus gracigenzs* and the grasses in the same saline soil include *Cynodon dactylon* (Ahmad et al., 2009). *Nerium oleander* is also reported to exist in this region (Ahmad et al., 2012). There is a great deal of diversity of grasses in the salt range with sixty two species (62) species of eleven (11) tribes involving the substantial volume of greenswards in northern Punjab, Pakistan (Ahmad et al., 2009). Pond borders and banks of streams have *Saccharum spontaneum* which is an exceptional soil binder. *Acacia nilotica, Eucalyptus camaldulensis* and *Zizyphus mauritiana* are other common trees of this locale while bushes that are also reported in this area include *Cannabis sativa, Calotropis procera, Lantana camara, Prosopis cineraria*. Furthermore, *Aerva javanica, Anagalis arvensis, Amaranthus hybridus, Abutilon indicum, Cenchrus ciliaris, Cynodon dactylon, Eragrostis poides* in consort with *Saccharum bengalense* have been reported to sprout here (Sarwar et al., 2017). Nearly sixty edible species of grass have already been documented within the study zone and the most frequently arising species among them are *Cynodon dactylon. Aristida mutabilis, Heteropogan contortus* (Sarwar et al., 2017).

1.2 Introduction to Potohar-Plateau Parts of Pakistan

Potohar -Plateau is characterized by low annual precipitation (0-800mm) and severe lack of available water. The Potohar Plateau is divided into three different zones i.e Arid, semi-arid and hyper-arid. In total one third land area of the world comprises of arid land. There are three major types of climate exists in Potohar-Plateau i.e Tropical, Mediterranean and continental. Distribution patterns of rainfall in both summer and winter season is different. Rainfall effects the Potohar-plateau in many ways and depending on edaphic characteristics the potential for soil erosion is quite different. Diurnal fluctuations of temperature also effect the growth of plant in Potohar-Plateau. Plant growth also affect the atmospheric humidity which is generally low. As a result of diurnal temperature changes, rocks disintegrate mechanically, root systems of the plant break up root particles subsequently soil in the Potohar-Plateau formed. In Potohar-plateau water holding capacity depends on the soil texture, structure and depth of the soil. In the area weathering of minerals and leaching of nutrients are slowed down due to decrease rainfall (Dregne, 2011). Vegetative growth in the Potohar regions are (i) Succulent perennials, (ii) non-succulent perennials, (iii) ephemeral annuals. Xerophytic plants of Potohar-plateau have a layer of cutin, extensive root system and different anatomical characteristics that help the plant to survive in this environment. Vegetation of Potohar-Plateau is quite different and classified as desert, semi desert, low rainfall wood land savanna, and in ever green scrub. In desert annual rain fall is less than 100mm, in semi desert 100 to 300mm in land savanna (300-600mm) and more than 500mm in ever green scrub (Jiapaer et al., 2011).

Potohar-Plateau of North Punjab spreads from 32 °10 °34 °9 °N latitude and 71° 10°73° 55° E longitude encompassing the district Attock (Jang, Hazro, Fateh jang, Hasan Abdal, Pindi Gheb), the district Rawalpindi (Kotli Sattian, Gujar Khan, Kahuta, Taxila, Kallar Sayyedan), Jhelum district (Dina, Sohawa, Pind Dadan Khan) and the district of Chakwal (Choa Saidan Shah, Kallar Kahar, Talagang, Lawa).

1.3. Dominant Vegetation of Potohar Region

The Potohar region is very rich in Grass flora, which is economically very important for livestock and wildlife feed, shelters for many birds and mammals, construction work, hay production, and civilian medicinal purposes (Ahmad et al., 2010). Chaudhry et al. (2001) Reported 41 species from the Chumbi Surla Wildlife Sanctuary, Ahmad et al. (2010) enlisted 60 grasses from Soone Valley and Nawaz et al. (2012) reported 33 species from the Salt Range.

The predominant grasses are *Heteropogon contortus* and *Cynodon dactylon* along the hills, and the salt patches are dominated by *Ochthochloa compressa* and *Aeluropus lagopoides. Chrysopogon serrulates, Cymbopogon jwarancusa* and *Pennisetum orientalis* are moderately high and predominant. *Aristida adscensionis*, Bromus spp. are high altitude predominant. The genus Lorium. (Nawaz et al., 2012; Hameed et al., 2012) also exist in the dominant vegetation of this region.

Other dicotyledonous plants that dominate the region are Phulai (*Acacia modesta*), Zaitoon (*Olea ferruginea*), and baikhar (*Justicia adhatoda)*. Many alien invaders such as Chatak Chandni (*Parthenium hysterophorus*), Sanatha (*Dodonaea viscosa)*, Panch phalli (*Lantana camara*) and Masqat (*Prosopis glandulos*) are endemic on the low hills (Hameed et al., 2012).

Studies of vegetation response to climate change focus on mountainous areas of recent times. Slight elevations can change the overall vegetation structure, species distribution pattern, and species composition along with physiological and other climatic factors (Parmesan, 2006).

Altitude changes are directly related to atmospheric pressure and temperature decline, but other factors such as soil nutrient and water availability, growth phase, radioactivity, and wind speed may also affect (Charrier et al., 2015). In general, grasses are more likely to adapt to extreme environments, so a wide range of species are expected to be resistant to different habitat types (Vitasse et al., 2009).

Species distributional pattern, species composition and community structure significantly altered with altitudinal gradient as reported by a number of researchers all over the world (Li et al., 2011; Abbasvand et al., 2014). Similar finding has been recorded in the Potohar region, particularly at higher altitudes. Variability in climatic and physiographic conditions are exceptionally high in the region, such as high mountain peaks of Tret, Daleh and Sakesar, sandy desert in Khushab district, heavily salt affected foothills near Lillah and Pind Dadan Khan, vast valleys like Vanhar, Soone and Soan, protected areas like Chinji, ChunbiSurla, Kala Chitta hills, Lehri Jindi and Domeli Diljabba, drier hills of Kala bagh, cooler Murree foothills, etc. (Mahmood et al., 2012). These variation is strong enough to impose a drastic change in distributional pattern and ecology of inhabitant grass species. (Bijlsma & Loeschcke et al., 2005). Species colonizing lower altitudes were different from those of higher altitudes in their structure, distributional range and contribution towards community structure (Lenoir et al., 2008).

High altitude species like *Lolium persicum*, *L. perenne*, *Themeda anathera*, *Arthraxon lancifolius*, *Apluda mutica*, *Rostraria cristata*, *Koeleria cristata* and K. macrantha restrict to limited areas. Vegetation of the Potohar region is constantly under threat due to anthropogenic activities like firewood collection, mining activities, construction work, overexploitation of medicinal/ economic plant resources, deforestation for agricultural purposes, habitat fragmentation, grazing and browsing of livestock (Wilson et al., 2005).

As Consequence, quite a few species are endangered, and facing extinction at local and international level (Nawaz et al., 2012). Moreover, species like *H. contortus*, *A. adscens*, *D. scindicum* in addition to *C. serrulatus* and *C. jwarancusa* dominated the vegetation community, all these species are well adapted to xeric conditions (Nawaz et al., 2012).

Environmental conditions abruptly changed at the highest altitude regarding temperature, atmospheric pressure, amount of annual rainfall and nutrient availability (Adler & Levine, 2007). Lower altitudes of the Potohar region generally shared similar climatic conditions with few exceptions. This might be a strong reason for close association of two or three dominant species at almost all altitudinal ranges, where a sudden change in climates and vegetation observed. *Chrysopogon serrulatus*, *C. jwarancusa* and *C. dactylon* dominated the vegetation component all over the Potohar region, all showed significant association among themselves (Patterson, 1980). *Saccharums pontanium,* a species of aquatic habitat, is Chang et al (2012) as reported by, it has been shown to be associated with *Imperata cylindrica* or *Cynodon dactylon,* which share a similar habitat.

1.4 Pollen Morphology of Important Families of Potohar Region (Asteraceae, Amaranthaceae, Fabaceae, Poaceae, Weeds)

Palynology play a significant role in the formation of natural groups and help in the evaluation of taxonomic relationship among various taxa. The study of Pollen morphology, an effective support to phylogeny and plant taxonomy has been recognized by numerous researchers (Bahadur et al., 2018; Bano et al., 2019; Nazish et al., 2019; Ullah et al., 2019). Likewise, Mbagwu and Edeoga (2006) use pollen characters to establish possible evidence of connection among particular groups of Angiosperms. The morphology of pollen grains is important for documentation and classification of plants, validation and confirmation (Arora and Modi, 2008).

(A) Asteraceae

Family Asteraceae consist of 1530 genus and approximately 23000 species which are distributed within 3 subfamilies and 17 tribes (Hayat and Khan,2009). It is the largest family of angiosperms and cosmopolitan in distribution. In Pakistan this family comprises of 650 species distributed in 15 tribes (Ahmad et al 2013). Members of this family are mostly herbs rarely trees and shrubs. (Skvarla et al, 1977) worked on the unique architecture of exine of this family and also studied the advance phylogeny and taxonomy of family Asteraceae.

Taxonomists use many disciplines to improve identification, classification and systematics position of plants with in taxa. But the most significant tool for identification and classification of closely related plant taxa is the study of their pollen grains. In Pakistan many work has been done on basic and applied palynology, while there is plenty of information published on pollen and spores morphology worldwide. The family Asteraceae is eurypalynous family (Meo et al.,2004) and having zonocolporate pollens found in most of its genera. The pollens are tricolporate; exine sculpturing is echinate with different variations in number and size of colpi (Qureshi et al 2009). The pollen grains of tribe Astereae, Helianthae and Inuleae has spinulose exine sculpturing while Vernonieae possess spinulose- lophate type of exine sculpturing. Some work has been done on fertility of pollens as it plays vital role in fruit and seed production in flowering plants (Rigamoto et al 2002). In family Asteraceae pollen fertility is high in both diploids and tetraploids (Blackmore et al 2009). Depending upon the climatic conditions fertility of pollens is based. In warm environment some species of genus Tradescantia pollen fertility may be higher than in cold, wet days (Ahmad et al.,2013). Due to the cosmopolitan distribution and predominance this family occupies highest rank among the angiosperm families.

Pollen morphology of family Asteraceae was done for the first time in Pakistan by (Perveen and Qaiser, 1999). (Coutinho et al., 2021) studied different aspects of pollen of different tribes and genus of family Asteraceae. However, at present there is no separate documentation on the pollen morphology of species belonging to family Asteraceae from Potohar region of Pakistan. The aim of this study is to provide detailed information of pollens and their exine structure based on both qualitative and quantitative characters by using Light and Scanning electron microscopy. These characters are helpful in identification of complicated species of the family. This study also aims to determine the pollen fertility of selected species of family Asteraceae which are economically important and this will help to identify the freely reproducing species for conservation purposes.

(B) Amaranthaceae

Amaranthaceae is a flowering plants family as the word amaranthus is derived from the "anthos" which is a Greek word means everlasting flower (Rastogi & Shukla, 2013). Amaranthaceae is large, diverse and cosmopolitan family. In past, some researchers included chenopodiaceae in the wider circumscription of Amaranthaceae and some authors have represented monophyly in their molecular studies in these families (Cuénoud et al., 2002; Judd, Campbell, Kellogg, Stevens, & Donoghue, 2008). The previous morphological and phylogenetic research revealed that Amaranthaceae and Chenopodiaceae had long been considered a single evolutionary lineage and were closely related families (Wang, Zhou, Bai, & Zhao, 2018). The AGP IV system in 2016 placed the family Amaranthaceae in order Caryophyllales and includes the plant species previously treated as family Chenopodiaceae. The family Amaranthaceae is estimated to contain a distribution of 180 genera and 2,500 species worldwide (Chase et al., 2016; Iamonico & Mosyakin, 2018; Kanwal & Abid, 2017; Safiallah, Hamdi, Grigore, & Jalili, 2017). The centers of diversity of Amaranthaceae are tropical and warm temperate regions. That is, Central and South America, South Africa, and Australia (Müller & Borsch, 2005). Majority of its species are halophytes and adapted to saline, xerophytic and xerohalophytic communities because they have the ability to grow and survive in high temperature, high irradiance, drought, and salinity (Dehghani & Akhani, 2009; Hedge et al., 1997; Zhigila, Yuguda, Akawu, & Oladele, 2014). In Pakistan, the plant species belong to this family are dominated by herbs and shrubs and dominantly distributed in salt ranges. The halophytes represent about 19% flora of Pakistan. The highest number of halophytic plant species (90) present in Pakistan is included in the family Chenopodiaceae (Khan & Qaiser, 2006).Palynological investigation is a beneficial tool in the taxonomic and phylogenetic identification of many plant families (Bahadur et al., 2018; Clark, Brown, & Mayes, 1980; Khan et al., 2018).

The application of light microscopy (LM) and scanning electron microscopy (SEM) has proven invaluable for observations of the surface morphology of plant materials. The use of SEM for the micro-morphological analysis of pollen grains has become a vital research method (Yang et al., 2017). Ullah et al. (2018) investigated the pollen morphology of subfamily Caryophylloideae and its taxonomic significance using LM and SEM. The micromorphological characters of *Marrubium trachyticum* Boiss. (Lamiaceae) using SEM and LM have been reported (Akçin & Camili, 2018). Butt et al. (2018) also utilized LM and SEM for morpho-palynological study of Cyperaceae. The use of LM and SEM is of special interest for the taxonomist to examine various taxonomic features (Khan, Ahmad, Zafar, & Ullah, 2017). Various authors have studied pollen morphology of family Amaranthaceae and Chenopodiaceae worldwide using LM and SEM (Dehghani & Akhani, 2009; Olvera, Fuentes-Soriano, & Hernández, 2006; Punsalpaamuu, Schluetz, Gegeensuvd, & Saindovdon, 2012; Talebi, Noori, & Nasiri, 2016). Moquin-Tandon was the first researcher who carried out the palynological study of Chenopodiaceae (Moquin-Tandon, 1849). Borsch (1998) studied the pollen types in Amaranthaceae using scanning electron microscope and revealed new characters such as ektexinous bodies on the membrane of an aperture. Olvera et al. (2006) studied the pollen morphology and systematics of Atripliceae from herbarium specimens and showed that the quantitative morphology of pollens provides insight for conflicts based on macro-morphology. The pollen characters including pollen diameter, pore diameter, pore number, exine thickness, operculum diameter and operculum spinules of subfamily Suaedoideae in Iran have been reported by Dehghani and Akhani (2009). Talebi et al. (2016) also conducted a palynological study on some Amaranthus taxa from Iran using light and scanning electron microscope and their results showed circular and poly pentaporate pollens with scabrate surface sculpturing. The comprehensive study on the pollen characters of some plants of Chenopodiaceae has been carried out by Punsalpaamuu et al. (2012) in Mongolia. Their study reported poly pantaporate pollen grains having exine without perforations. A palynological investigation of 13 Alternanthera species distributed in Mexico has been studied by Sánchez-del Pino, Fuentes-Soriano, Solis-Fernández, Pool, and Alfaro (2016) who indicated the pollen morphological characters (Pollen ornamentation, number of nanospines on pore membrane and metareticula form) as a beneficial tool to discriminate three types of pollens (Spheroidal, de decahedrical, dimorphic) within Alternanthera. The pollen grains morphology and biometry of 17 taxa belonging to Amaranthaceae family have been studied by Angelini et al. (2014) who reported spheroidal and radially symmetrical pollen grains with echinae and perforations on the surface.

The family Amaranthaceae is one of the rich families of the Potohar Plateau of Pakistan as it includes a higher number of halophytes present in salt range areas of Potohar Plateau. The pollen morphology of its members possesses rich diversity (i.e., radially symmetrical, usually apolar, pantoporate, polypantoporate, shape spheroidal, tectum punctate scabrate, rarely spinulose; Perveen & Qasier, 2012; Hussain et al., 2018). Pollen grains of Amaranthaceae are pantopolyporate and some genera of the family such as *Chenopodium* L. have similar exine structure (Pinar & İnceoglu, 1999b). Perveen and Qasier (2012), studied the pollen morphology of 40 Amaranthaceae taxa belonging to 14 genera, which was based on exine and surface ornamentation. Shinwari, Shinwari, and Khan (2004) described two major types of pollens (periporate and fenestrate) in 7 genera and 18 species of Amaranthaceae using light microscopy.

The few researchers in Pakistan have conducted a study on the pollen morphology of family Amaranthaceae and Chenopodiaceae which were treated as separate families but now family Chenopodiaceae is merged into the family Amaranthaceae. The current study has been carried out keeping in view the use of LM and SEM in the significance of pollen studies of Amaranthaceae and its aid in the identification of halophytic flora. The aim of current research work is to evaluate the palyno-morpholoical characters, pollen types, shape and sculpturing and relationship within the different genera of the family using light and scanning electron microscopy

(C) Fabaceae

Fabaceae Family comprises 730 genera and 19,325 species (Lewis et al. 2005). It is the largest family in terms of the number of endemic species in Brazil (Forzza et al. 2010), with 228 genera and 2896 species (Flora do Brasil 2020). Along with Quillajaceae D. Don, Polygalaceae Hoffmanns. & Link e Surianaceae Arn., the family forms the Fabales (APG IV 2016). Regarding the number of species, Fabaceae represents the third largest family of angiosperms, surpassed only by the families Asteraceae and Orchidaceae (Legume Phylogeny Working Group (LPWG) 2017). Due to the high number of species, the family is considered cosmopolitan, dispersed mainly in tropical regions (Lewis 1987; Judd et al. 2009).

Regardless of the systematic disparity within the family, Fabaceae appears to be a monophyletic group, despite the subfamily Caesalpinioideae being considered a paraphyletic group (LPWG 2013). To make the Caesalpinioideae more homogeneous, Lewis et al. (2005) divided and organized the genera into four tribes (Caesalpinieae, Cassieae, Cercideae, Detarieae). Currently, a new classification for Fabaceae is proposed by the LPWG (2017), which brings a new arrangement of the subfamilies based on morphological and molecular data. In this new classification, the Cercideae, Detarieae, Duparquetia and Dialiineae tribes, and the large clade formed by Mimosoideae–Caesalpinieae–Cassieae that constituted the subfamily Caesalpinioideae, are now recognized as subfamilies, together with Papilionoideae. Therefore, Fabaceae now consists of six subfamilies: Cercidoideae, Detarioideae, Duparquetioideae, Detarioideae, Caesalpinioideae and Papilionoideae (LPWG 2017).

(D) Poaceae

Grasses constitute a natural homogenous assemblage of kingdom Plantae belonging to the family Poaceae (Gramineae). Undeniably, Grasses are one of the most captivating families of flowering plants, with their variable life forms and indeed they plays their momentous part for all the living creature on planet Earth (Mitra and Mukherjee, 2005). With 610 genera and about 10,000 species, grasses are one to the largest and most treasured groups of plants (Cope, 1982). After Asteraceae, Leguminosae, Orchidaceae and Rubiaceae, the 5th largest family of Kingdom Plantae is the grass family, which is mainly known as Poaceae or Gramineae (Tzevlev and Michaelova, 1989). The family Gramineae can be distinguished by other families in terms of its characteristic morphological features which includes ligulate leaves, sheathing and flowers in spikelets, palea, glumes, lemma and caryopsis. The grasses are not closely related to other monocots. Size of grasses varies from minute unobtrusive herbs which are less than one inch to the giant sized bamboos that length up to 130 feet tall. It is very difficult to count the clear-cut number of grass species; however, according to Tzvelev, Poaceae, the number estimates up to of 11,000 species (Osborne, 2010).

The worth of Poaceae family have been acknowledged since time age-old to the modern day cereal crops which are the cultivars of their wild fore-fathers. The grass family mirrors extreme adaptation in response to their alternating atmospheres, capability to share their space with grazing animals and humans. Members of Poaceae have infinite diversity with distinctive forms of living. They propagate, replicate and complete their life in one short cycle. The most important reproductive phenomenon is seed production. The body of plant is just a limited thin leaf; single or double stems but the most significant feature is spike inflorescence which is the main reason of maximum seed production. Manifestly, grasses are the living creatures which are successful as they survive in hard conditions and grow when conditions become right. As grasses reproduce quickly, due to their short life cycle, therefore they belongs to group of most successful telluric life forms on the earth (Gandhi et al., 2016).

Poaceae is very diverse and one of the most morphological intricate angiosperm families (Lawrence, 1964). This family represents 9,000 species belonging to 651 genera (Khine, 2011). According to Clayton and Renvoize (1986), the total number of grasses in the world is approximately 10,000 sp. 651 genera. Grasses survive and lives in all conceivable habitats and every climatic condition (Mitra and Mukherjee, 2005). Habitats of grasses can be assumed as the highpoint vegetation which can be the semi-arid grasslands of the America as well as the pampas of Asia and the prairies of Africa (Ahmad et al., 2009).

Agrostology is the study of grasses. The grass family is of interest to humans. The cultural significance of cereal grasses times to the period when man was emerging from wild beast stage (Gould, 1968). In Pakistan, in terms of species and genera, Poaceae is one of the leading families of angiosperms (Cope, 1982). As a major portion of diet, most people on earth depends on grasses. Members of the family constitutes approximately 20% of the earth's land, therefore they are considered as ecological dominants of planet Earth (Samreen et al., 2015).

The life form of grasses can be annual or biennial or perennial. Annual means they complete their life in one season, and biennial plants complete their life in two seasons and perennial are those grasses which lives long and they took more than two years to fulfill their life season. C3 and C4 grasses are alienated into two physiological groups on the basis of leaf anatomy. Kranz anatomy is exhibited by C4 type grasses. C4 grasses has radiate mesophyll, but in Poaceae family C4 photosynthesis exhibits numerous independent pedigrees (Gandhi et al., 2016).

(E) Weeds

Weeds are considered plants that complete with the growth and development of crops. The growth of weeds in agricultural field can limit the production of staple crops and hence causes serious damage to their production (Chaudhri, 1992). According to weeds are those unwanted plants that can grow in irrelevant regions of the agricultural field. They grow in cultivated and wild habitats and cause damage to associated growing plants. Weeds belonging to the family Fabaceae can get essential nutrients from the soil and compete with crops to get this nutrition faster than the other plants(Rahmatullah et al., 2009). These plants obtained nitrogen from their surroundings and converted it into nitrogen-rich compounds to enhance the growth of essential microorganisms, increasing soil fertility(Mehsud et al., 2013). Many researchers work on the weed flora of the world specifically recorded 50 parasitic weeds from Pakistan.

The floral diversity of specific regions has great significance and their natural habitats had often been interpreted by weeds species due to the struggle for survival. Study of pollen grains plays an important role while studying plant taxonomy and biodiversity, as it helps in identifying plant species of particular area (Amarger, 2001).. To identify plant species, many taxonomists use different disciplines of plant systematics like morphology, anatomical studies, and palynological studies to find the exact position of plants within taxa. But the studies of pollen characters are considered the most important tool for classifying and identifying morphologically similar plants(Rashid & Rasul 2011). Previously much research has been done on pollen grains in Pakistan and worldwide.

Weeds play an important role in creating ecological balance in a crop system through supporting different life forms (Zafar et al., 2006. Throughout the world major vegetation of weeds belongs to families like Asteraceae, Poaceae, Amaranthaceae and Fabaceae. Growth of weeds is mostly dependent on the climatic condition of the area (Meo et al., 2005). Meo et al., (2004). Weeds are mostly found growing along the water passages, harvesting costs and fire hazards. In some previously reported studies the most commonly grown weeds of cotton crops are *Cynodon dactylon, Amaranthus viridis, Phyla nodiflora and Phragmites australis*. Common weeds of wheat crops are *Phragmites* sp., *Cynodon* sp., *Ranunculus* spp and *Polypogon* sp.,. Likewise, *Achyranthes aspera* is a common weed of sugarcane crop and Plantago lanceolata is important weed of chickpea fields. The correct identification of species is determinant for developing any weed management program according to its different ecological aspects. The taxonomic studies are preliminary research towards the use of identification and classification of weeds of the study area, which could be in the same way useful for weed scientists as well as for botanists. Thus, the morpho-palynological characters of weeds observed through by using microscopic techniques.

1.5 Seeds Morphology

Seed micromorphology provides several characters to support the significance of seed morphology in inferring phylogenetic as well as evolutionary relationships and species identification (Attar, Keshvari, Ghahreman, Zarre, & Aghabeigi, 2007; Johnson, Huish, & Porter, 2004). The diversity in seed shape, size, and color can help distinguish taxa (Ninkaew, Pornpongrungrueng, Balslev, & Chantaranothai, 2017). In previous studies seed morphology and anatomical features were considered rather conservative, thus supporting their taxonomic importance (Werker, 1997). Seed attributes have been revealed to be a useful tool for the delimitation of species at family (Speta, 1998) and grouping at the generic level (Jessop, 1975). Seed ultrastructural features particularly the seed surface and cell shape are considered to be a valuable distinguishing character at intraspecific and intrageneric levels (Kubitzki, Rohwer, & Bittrich, 2013). Seed size was reported to be directly related to the number of nutritional reserves that can be allocated to initial seedling development (Veloso et al., 2017).

(A)Asteraceous Seeds Morphology

Cypsela morphology is one of the most effective taxonomic feature that has an important role in solving different taxonomic problems related to inter- and intra-generic associations among different plant species of Asteraceae (Abid & Qaiser, 2015). Different morphological features (size, beak absence/presence, pappus branching and surface structure) are the main investigating characters of Asteraceous taxa (Karaismailoglu, 2015). Therefore, these micromorphological features of cypsela in

Asteracea could be important diagnostic features for solving different taxonomic relationships within the family. (Ghimire, Suh, Lee, Heo, & Jeong, 2018).

Cypsela morphology has been extensively used as a distinctive taxonomic tool by many researchers for the identification of groups and genera in tribe Anthemideae (Asteraceae) (Cassini, 1823). Likewise, similar study has been conducted on the seed coat and fruit wall of different species of tribes Mutisieae, Cichoreae, and Cynareae (Lavialle, 1912). Extensive work on the Cypsela morphology of several tribes (Compositae) has been conducted from various regions of the world by many researchers (Pak, Park, & Whang, 2001). Variation has been also found in characteristic features of cypselae in Asteraceae for example in the tribe Cynareae, the form of the cells of the testal epidermis and the types of thickenings of their walls provide taxonomically useful information (Kadereit & Jeffrey, 2007).

Apart from this, some work has been conducted on Cypsela morphology representing the family Asteraceae such as Inuleae (Abid & Qaiser, 2002), Anthemideae (Abid & Qaiser, 2009), Senecioneae (Abid & Ali, 2010) and Mutiseae (Abid & Alam, 2011) from Pakistan (Kashmir). In spite of this, limited data exist on the Cypsela morphology of some genera of tribe Lactuceae. For instance, (Abou-El-Naga, 1997) examined the taxonomic significance of 40 carpopodium species of tribe Cichoreae, while (Haque & Godward, 1984) examined the detailed carpopodia of family Asteraceae (2 subfamilies, 10 tribes, 18 genera, and 40 species). The results of their study showed that the subfamily Lactucoideae possess narrower, smoother carpopodia containing limited cells being originated via sideways fusion of unconnected segments. Additionally, LM and SEM has been used to conduct Cypsela seed surface sculpturing and wall anatomical studies of 14 species (genus Lactuca L.) (Zhu et al., 2006) to access their inter- and intra-generic relations among each other. Based on the literature survey, extensive work has been done on the Cypsela morphology of different tribes of Compositeae (including Cichoreae) nationally and internationally but no detailed information is available on the Cypsela morphology of the species discussed here particularly from Pakistan. The aims of the current study are, therefore, to provide a detailed explanation of the Cypsela morphology and to decide the level to which these micromorphological data can be efficiently used as a taxonomic character to delimit various genera of tribe Cichoreae.

(B) Fabaceaous Seeds Morphology

Seed characters, mainly outer surface features disclosed by means of scanning electron microscopy (SEM), have been widely employed in solving various problems in systematics and phylogenetic relationship of species (Segarra & Mateu, 2001). The significance of investigating ultrastructural pattern of the seed coat under SEM has been well known for reviewing phenetic linkages and classification of species (Koul, Nagpal, & Raina, 2000; Yoshizaki, 2003). SEM involves high magnification with fine details of ultrastructure that would allow the detection of qualitative variations not possible to observe under optical microscopy (Belhadj et al., 2007). SEM has brought revolutionary trends in study of microscopic organisms with many advantages side by side. The use of SEM was employed to examine the seed borne fungi by Alves and Pozza (2009). Rashid et al. (2018) also reported the use of SEM for systematic studies in tribe *Vicieae* (Papilionoideae). Souza and Marcos-Filho (2001) gave a comprehensive view of the modulatory role played by mature seed coat in Fabaceae and reported that seed cot structures differ among species and varieties. Erkul, Celep, and Aytaç (2014) examined seeds of 13 *Oxytropis* DC. species from Turkey using Light and SEM to evaluate the taxonomic relevance of macromorphological and micromorphological seed characters. The study recorded variation in seed size, shape, surface sculpturing pattern, hilum position, and weight. Kirkbride, Gunn, Weitzman, and Dallwitz (2000) developed a CD-ROM that includes an interactive key for the identification of seeds in the 686 legume genera. The characteristics of seeds in the legume family provide an accurate means for their identification. Recently, SEM has been widely used in investigating micromorphological characters of fruit and seed coats (Kaya, Ünal, Özgökçe, Doğan, & Martin, 2011). According to literature, brief information is available on seed morphological characters in tribes of subfamily Papilionoideae (Bortoluzzi, Carvalho-Okano, Garcia, & Tozzi, 2004), so the aim of present study was the use of SEM techniques to search for seed characters constructive in identification of studied taxa.

1.6 Significance of Pollen and Seeds Using LM and SEM

Although light microscopy continues to be a central element of life science, light microscopy is often regarded as an old technology. Although light microscopy is actually 400 years old, this technology is still evolving and the potential of biological science is not yet fully revealed. The purpose of a light microscope is to provide a magnified image of an illuminated or luminescent sample in the visible spectrum range or adjacent UV or near infrared spectral range. Optical magnification is achieved by passing light through the lens. Since the 1880s, light microscopes have been able to reach the theoretical limit of optical resolution. Unfortunately, many users of biological science are not yet aware of the importance of this technology and continue to receive poor quality images instead. (Dawe et al., 2006).

SEM can provide information Surface topography, crystals Structure, chemical composition And the electrical operation of the top surface A sample of about 1 jar. various Special stages (eg hot, cold, or Designed to allow on-site mechanical testing) Can be installed to enable performance under a variety of conditions Check the status. For example, cathode fluorescence At (light emission) temperature There are many that are close to absolute zero Images stronger than room temperature Light emitted from a cold sample Much quieter Other benefits of SEM. SEM has very profound benefits Most of the samples because of the field Surfaces that are in focus at the same time anything Surface roughness. Optical microscopes operating at high magnification have a very shallow depth of field, so image quality relies heavily on smooth surfaces. The final resolution is 1nm, which can achieve a much higher magnification (up to 1,000,000x). The maximum magnification that can be used with an optical microscope is about 1000 times. An opportunity to learn more than just the surface terrain. Crystal structure, chemical composition and electrical properties. By switching between different imaging methods, you can ensure that the information is cross-correlated (Parry, 2000).

1.7 Background Justification of The Study

Potohar region all over the world blessed with unique type of biodiversity including medicinal plants and have a different type of climatic conditions. In potohar regions of Pakistan most of the unique biodiversity exist and distributed across diverse type of landscape and habitats. Due to extreme temperature ranges the vegetation is the area is totally sparse but have a potential of medicinal flora. These medicinal plants resources are needed to be explored and correctly identified for promoting the public health. In potohar region, conservation methodologies are required intensely to preserve the medicinal plant resources. Due to the rich cultural heritage and diversity of medicinal plants in potohar regions of Punjab Pakistan, the proposed project confined to document floral diversity and systematic studies of Plants belonging to different families to solve the taxonomic issues of the Potohar region.

Lesser work on taxonomic studies carried out systematically in this region. This study aims to identify the plants with the help of basic taxonomic tools including morphology, Pollen Morphology and seeds morphology. Without these studies, these valuable plants would have either remained restricted to certain area or may have even extinct without being known to science. The main purpose of the study is to explore the indigenous knowledge of local communities of North Punjab regarding the use of plants which were never surveyed prior to this investigation. The medicinal plants are known to local people. There is a dare need to conserve the wild medicinal plant resources and their associated knowledge. So, this project is an attempt to create awareness among the people about the medicinal values, Palynology and Seeds morphology of these plants of Potohar region, so that this heritage may be wisely used and conserved and perpetuated through judicious management in health sector.

1.8 Objectives of The Present Project

The objectives of the research project are as follows

- Preparation of a detailed checklist of floral diversity of Potohar-Plateau regions of Nothern Punjab, Pakistan.
- The number of dominant families including (Asteraceae, Amaranthaceae, Fabaceae, Poaceae) from the Potohar Region characterized using detailed Pollen Morphology and Seeds Morphology.
- Developing a field guide consisting of unique floral pictorial for future studies regarding important flora of Potohar-Plateau

- Application of field photography of Plant species and Morpho-Palynology and Seeds Morphology via LM and SEM for correct identification.
- Construct Taxonomic Keys to Compare different taxonomic characters of the selected plant species to compare the results of LM and SEM.

Plate 1: Panoramic View of collection site at QAU, Islamabad

Plate 2: Panoramic View of collection site at Chakwal (Thoha Bahadur)

Plate 3: Collection area of grasses in Kallar kahar (Chakwal)

Plate 4: Collection area of Grasses in soon Sakaser

CHAPTER: 2

Materials and Methods

2.1 Research Work Outline

This section summarizes the methodology of the research Project. It briefly describes the selection of the study area, sampling technique and experimentation protocols. It also gives source of sample data, method of data collection and analysis. The main objective of the study is to examine the Taxonomic Characterization of Floral Diversity of Potohar- Plateau. The Laboratory analysis of the selected plants was performed in Plant systematics & Biodiversity Laboratory of Quaid-i-Azam University Islamabad. The study mainly focuses on the Morphology of Plants, Palynological, and Seed morphological perspectives.

Figure 1: Flow sheet showing research outline

2.2 Study Area

Potohar-Plateau in Punjab province,Pakistan that drives name due to extensive rock salt deposits(Ahmad et.,al, 2007). Potohar Plateau of North Punjab ranges over the administrative districts of Mianwali,Chakwal,Khushab,and Attock. The Potohar-Plateau of North Punjab is located between 32° 40° 30° North and 72° 47° 35° East. Potohar Plateau of North Punjab is situated in the subtropical region with height ranging from 250 to 1520m (Chaudhary et.,al, 1969). Potohar Plateau of North Punjab extends from the Jhelum river in the Barkala ridges and Tilla jogian which runs southwards and cross the Indus river near Kalabagh (Ahmad and Waseem,2006).

The Potohar-Plateau contains two distinctive hill tracts present in the east to south west direction separated by about 5 miles distance. The mountains of Potohar-Plateau running parallel to each other intervened by spurs,ridges, and hills with various lakes and valleys of the various phytogeographic and agroclimatic authorities. The three prominent lakes include Uchali lake, Kallar kahar and Khabikki lake. The Potohar-Plateau in the northern part of the Punjab Province includes great mines of Khewra, that yield great supplies of salt.

2.3 Climate of the Study Area

Potohar-Plateau of North Punjab has low annual precipitation of about 50cm. Rainfall is mostly confined to the months of june,July and August. The hills of Soon Sakesar in the salt range receive maximum rainfall due to their height. The study areas are warm temperate in nature. Extreme temperature is noticed between winter and summer. The average maximum temperature is 40 c(July) and the average minimum temperature is 10 C(January). Hot dry winds are common and drought continues for a long time in the area. The long winter season exists with frost (Ahmad et al., 2007).

2.4 Schematic Sketch of Present Study

The overall design for current research study is presented in given Figure 2.1

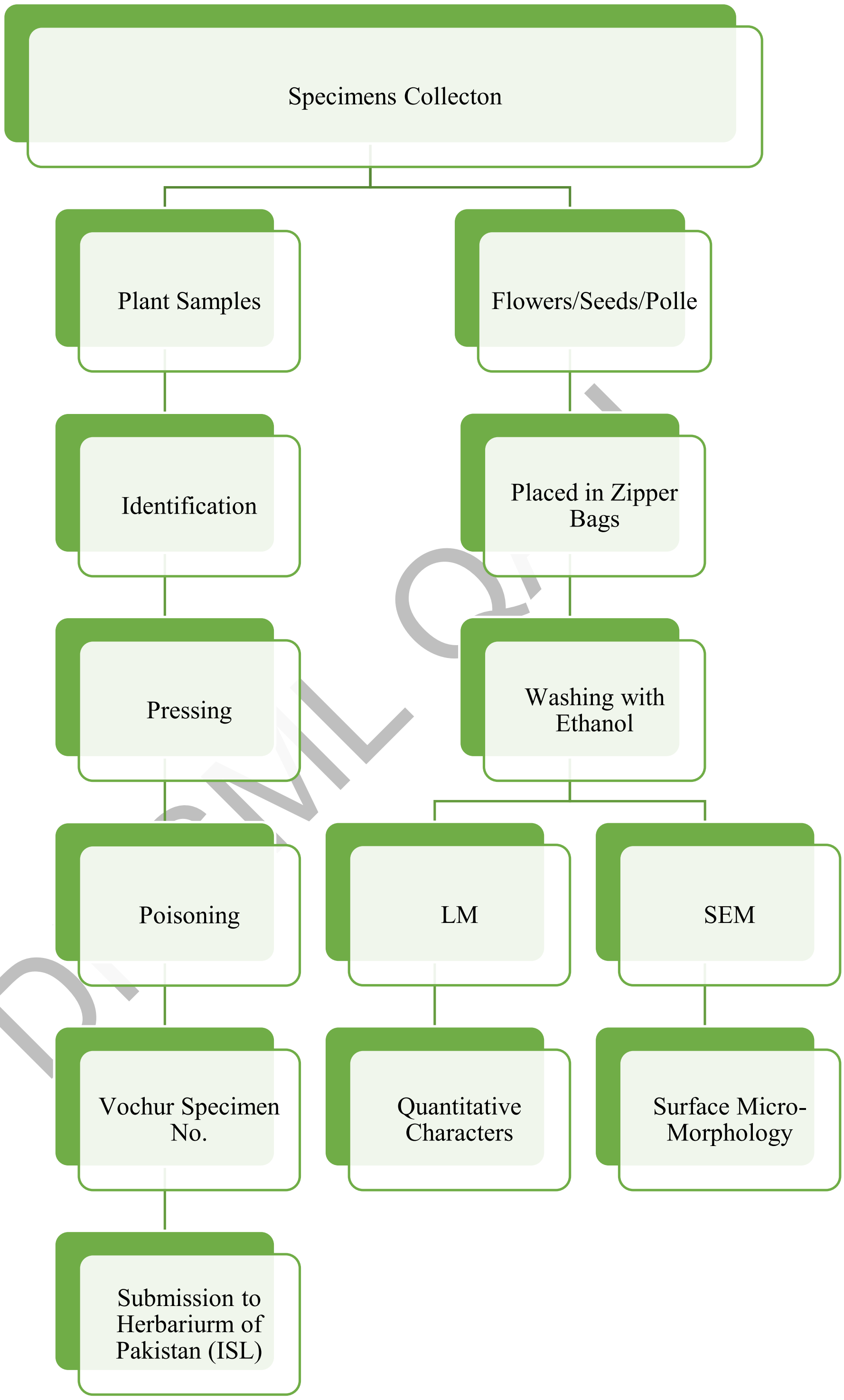

Figure 2: Schematic Sketch of present project

2.5 Field survey and Plants Collection

The Study was confined to the Plant Morphology, Palynology and seed Documentation of Floral Diversity in Potohar Plateau Pakistan. The Study Sites of Potohar Plateau includes Attock, Chakwal, Mianwali, Soon sakasar, Miani Village, Uchali Lake, Kabbaki Lake, Kalla Chitta Hills, Rawalpindi and Islamabad (Map). A number of trips to the fields were carried out during various blossoming seasons in the years (2020-2022). Plants with floral parts were collected, pressed, dried and placed in blotting papers and newspapers. Field Data was recorded in the field notebook regarding date of collection, field number, locality, habit, Habitat, Phytography, Flower color and Flowering Period. The particulars of source and collection with GPS data of the collected plant species are presented in Table 1.

2.6 Herbarium Preparation and Plant Identification

The collected plants were pressed, dried, poisoned, labelled and mounted on herbarium sheets and deposit in Herbarium of Pakistan (ISL), Quaid-i-Azam University Islamabad for future reference. In case of any ambiguities voucher specimens were compared with type specimens available at Herbarium of Pakistan (ISL), QAU Islamabad. Voucher specimens of all the documented species were properly processed and submitted to Herbarium of Pakistan (ISL), QAU Islamabad. The collected plants were identified based on their different morphological characteristics and cross verified with the samples already record documented in the herbarium and consulting Flora of Pakistan given by Ali and Qaiser, (1993-2010).

2.7 Systematics Studies of Floral Diversity of Potohar-Plateau

2.7.1 Palynological Studies (LM & SEM)

Palynological studies were carried out by adopting following procedures.

a) Pollen Material

The pollen material used in this research study was obtained from fresh collection containing flowers collected from various regions of Potohar-Plateau Pakistan. The details and origin of studied plant species have been presented in Table 2.1. In order to separate the pollen grains from anthers, stereo microscope was used.

b) Glycerin Jelly Preparation

Preparation of glycerin jelly for palynological studies was carried out by using the methodology of Meo and Khan (2005). For glycerin jelly preparation about 30 gm of gelatin was boiled in 50 ml of distilled water. After boiling for ½ an hour, 40 gm of glycerin and few drops of phenol crystals were added to the mixture. For pink color 0.1 % safranin was added and then mixture was stabilized at room temperature for later use.

c) Light Microscopic (LM) analysis of Pollen

Mature flowers were used for pollen morphological studies. The anthers were acetolyzed with 99.9% pure acetic acid then cursed to release pollen from anthers and debris was removed. Then drop of glycerin jelly was put on acetolysed pollen and slides were covered with cover slips and after these slides were permanently sealed with transparent nail paint. Tagging tape was used for giving slide number or name (Khan et al., 2020). Prepared slides were observed under light microscope (Meiji Techno MT4300H) and microphotography was carried out using Leica microscope fitted camera Meiji Infinity 1. Both qualitative and quantitative features were studied (Ahmad et al., 2013; Bahadur et al., 2018; Khan et al., 2021).Terminologies for pollen morphology were described according to Barthlott (1984), Erdtman (1960) and Ronald (2000).

d) Scanning Electron Microscopic Analysis (SEM) of Pollen

For SEM studies mature anthers were placed in the middle of clean glass slide, 1-2 drops of acetic acid were added and left for a minute. Anthers were then crushed to release the pollen from anthers, debris was removed and extracted pollen were transferred to stubs. Coating with gold was done in sputtering chamber using SPI-MODEL^{TM}. After gold coating, stubs were placed in Jeol Vacuum –evaporator for 15 minutes and observed under Scanning Electron Microscope (Model JEOL JSM- 5910) (Butt et al., 2018; Hussain et al., 2019). Pollen exine ornamentation was studied following the terminally of Bahadur et al., (2018).

e) Pollen Fertility and Sterility Estimation

Estimation of pollen fertility and sterility percentage was calculated by using formula adapted by Ullah et al., (2018).

$$Percentage\ of\ fertility = Fertility\ /F + S\ X\ 100$$

$$Percentage\ of\ Sterlity = Sterility/S + F\ X\ 100$$

Where F represents fertile pollen numbers and S represents sterile pollen numbers on slide.

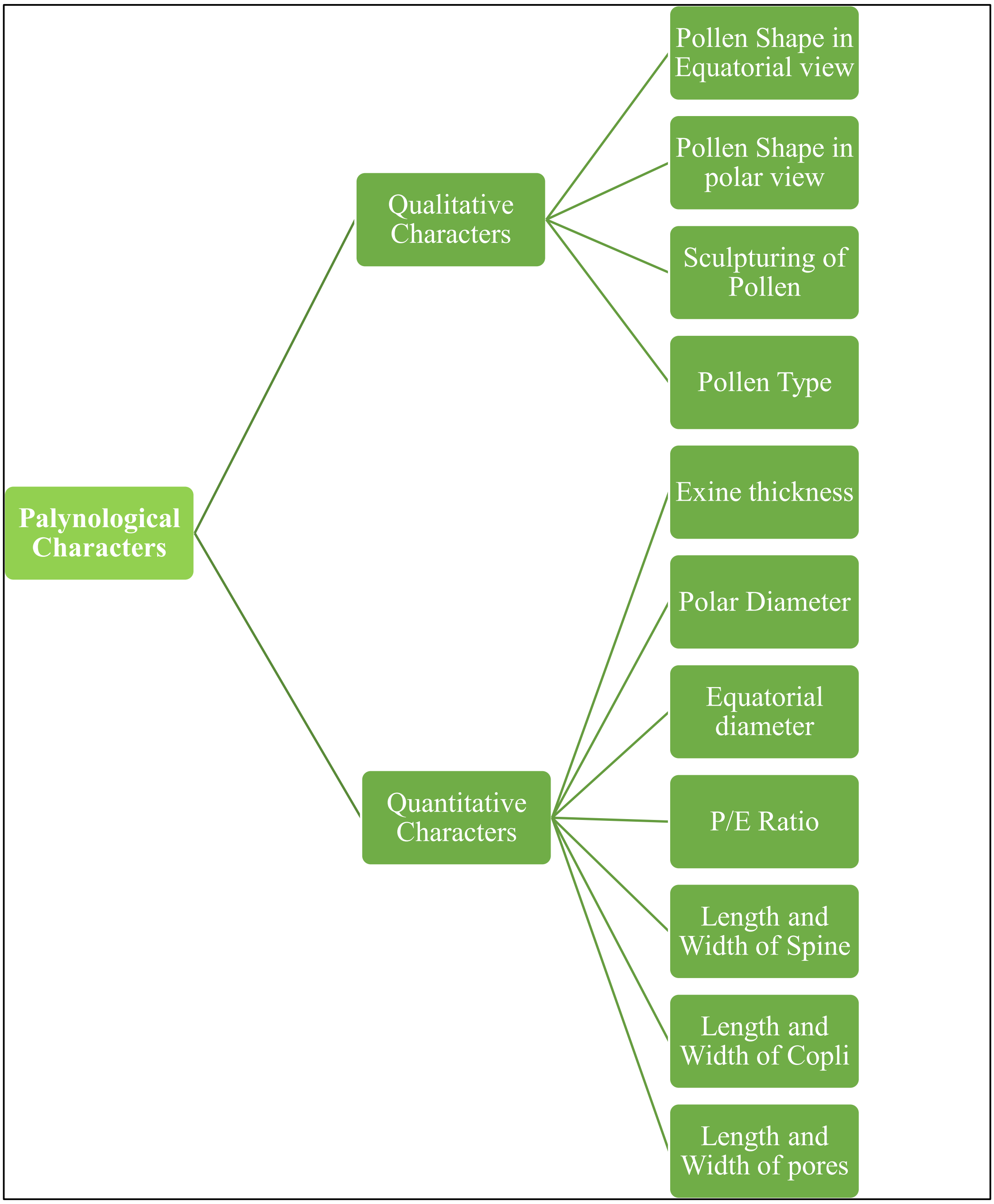

Figure 3: Schematic Representation of Pollen Parameters Characterization

2.7.2 Seed Morphological Studies

a) Taxon Sampling

In order to obtain seeds, mature seeds of plants were removed from fruits collected during field visits in fruiting season.

b) Light Microscopic Studies of Seed Morphology

Mature seeds of plants were washed through different grades of ethanol (60-80%) for 1 to 3 minutes to remove the debris on their surface. External color, Shape, Size (length & width), Hilum were observed using Binocular Dissecting microscope, placed in plant anatomy Lab Department of Plant sciences Quaid-i-Azam University, Islamabad, Pakistan.

c) Scanning Electron Microscopic Studies of Seed Morphology

For SEM studies seeds were immersed in absolute ethanol and left for a minute to completely dry. This step was carried out for detailed study of invasive seed morphology. Then seeds were mounted on stubs in different positions and gold coating was performed in sputtering chamber using SPI-MODEL$^{TM.}$ In all cases seeds of at least 10 samples of each species were analyzed, characterized and photographed with a Scan Electron Microscope (Model JEOL JSM- 5910). The seed characters observed were length of main axis, position of hilum, surface sculpture.

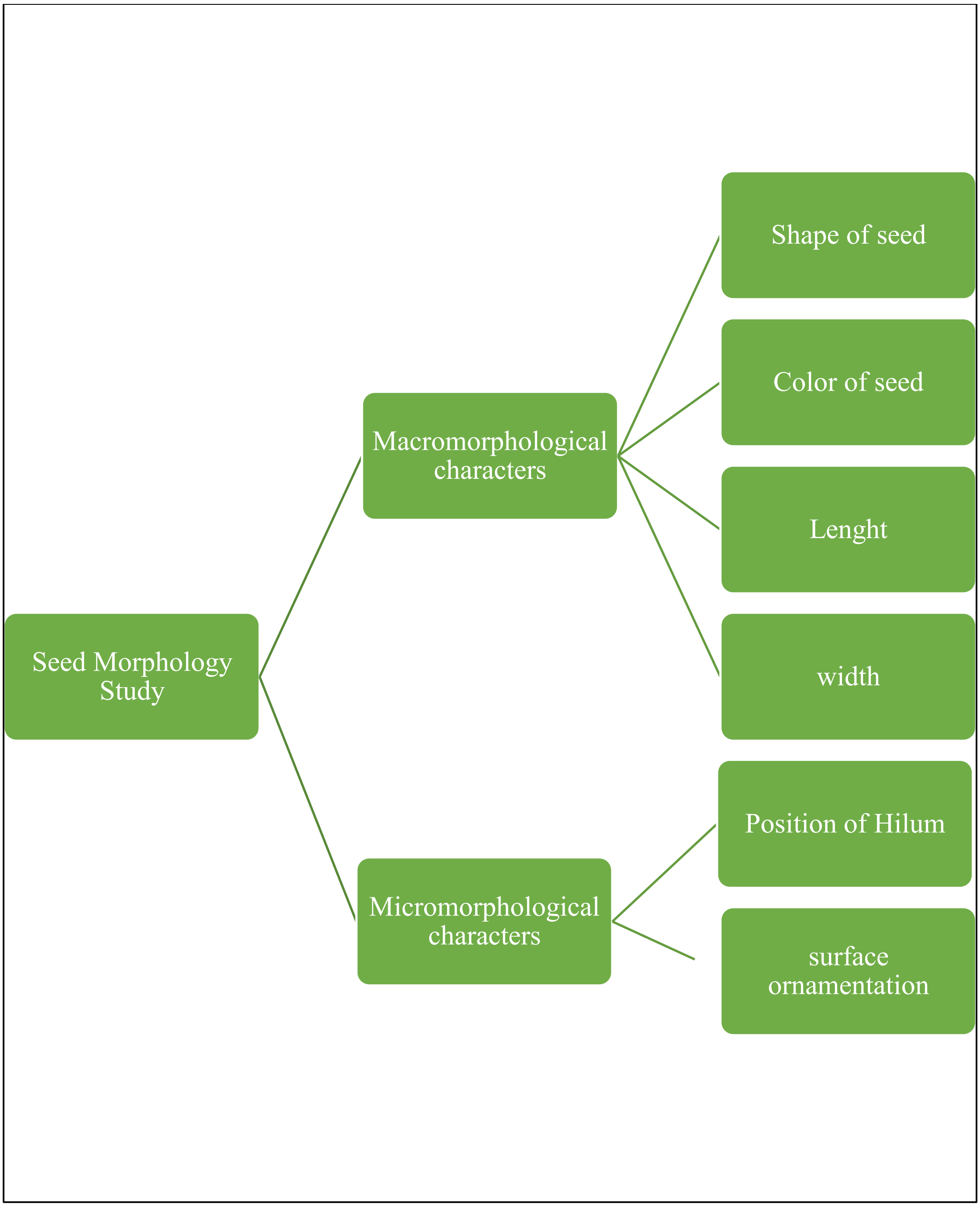

Figure 4: Parameters studied for seed morphological characters.

Plate 5: Panoramic view of Kallar Kahar

Plate 6: View of agricultural fields of Miani village

Plate 7: Diversity of plants near Uchali Lake

Plate 8: Pictorial view of Khabeki Lake

Plate 9: Wild flora near Numl Lake

Plate 10: Pictorial view of Vegetation on Kala Chitta Hills

Plate 11: Paranomic view of Soan Sakaser Valley

Plate 12: Diversity of plants of Khewra Salt Range

Plate 13: Plant collection during field surveys

Plate 14: Experimental work in laboratory to study pollen morphology

Plate 15: Quantitative data analysis of pollen using Microscope

Plate 16: Qualitative data analysis by studying morphological characters of plants

Plate 17: Light microscopic study of pollen grains

Plate 18: Morphological study of plants using stereo microscope

Plate 19: Preservation of plant specimen

Plate 20: Mounting of plants on herbarium sheets

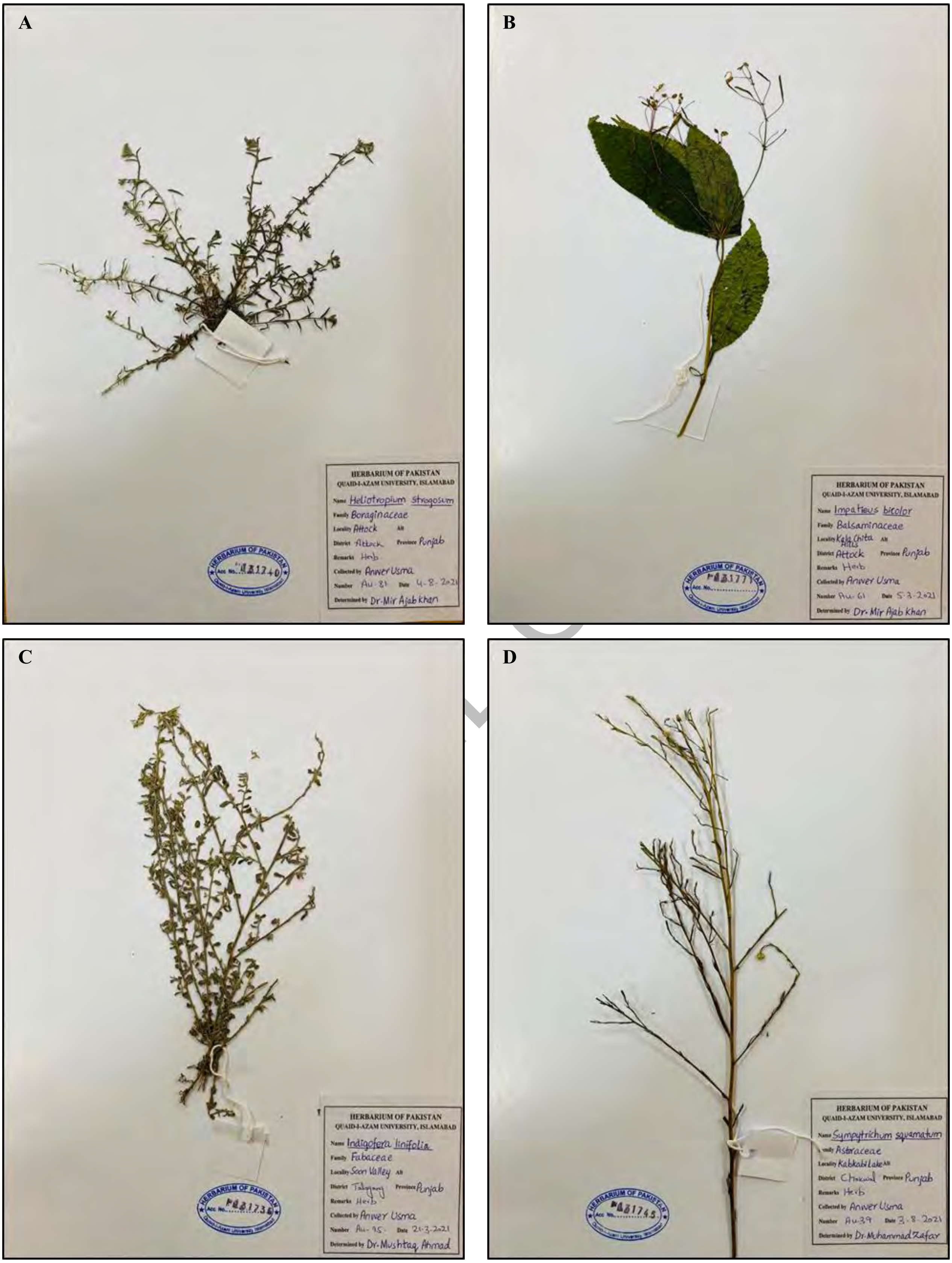

Plate 21: Herbarium specimen photographs of (A) *Heliotropium strigosum*, (B) *Impatiens bicolor*, (C) *Indigofera linifolia*, (D) *Symphyotrichum squamatum*

Plate 22: Herbarium specimen photographs of (A) *Dactyloctenium scindicum*, (B) *Croton bonplandianum*, (C) *Chrozophora plicata*, (D) *Cleome brachycarpa*

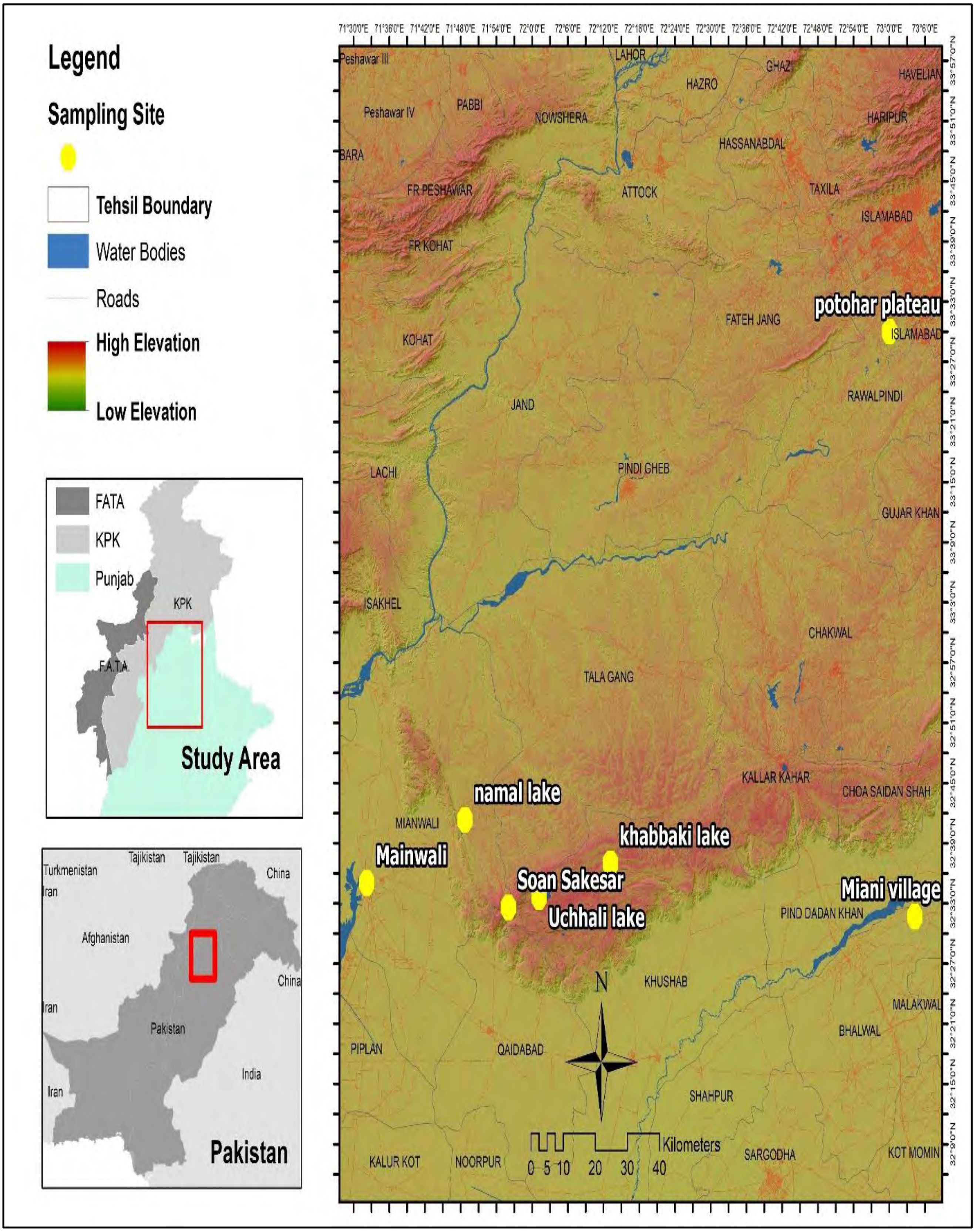

Figure 5: Map of study area showing collection sites.

Table 1: Check List of Floral Diversity of Potohar-Plateau with Collection Site.

Sr.No	Plant Taxa	Family	Locality	Voucher No	Accession No
1.	*Ageratum conyzoides (L.) L.*	Asteraceae	Khallar Kahar	AU-51	ACC-131695
2.	*Artemisia annua L.*	Asteraceae	Kalla chitta hills	AU-67	ACC-131696
3.	*Aster squamatus (Spreng.) Hieron.*	Asteraceae	Rawalpindi	AU-63	ACC-131697
4.	*Bidens bipinnata L.*	Asteraceae	Attock	AU-81	ACC-131698
5.	*Bidens pilosa L.*	Asteraceae	Attock	AU-23	ACC-131699
6.	*Calendula arvensis M.Bieb.*	Asteraceae	Uchali lake	AU-97	ACC-131700
7.	*Calendula officinalis L.*	Asteraceae	Soon sa Qaisar	AU-53	ACC-131701
8.	*Carthamus lanatus L.*	Asteraceae	Islamabad	AU-95	ACC-131702
9.	*Carthamus oxyacantha M.Bieb.*	Asteraceae	Numl Lake	AU-35	ACC-131703
10.	*Cirsium arvense (L.) Scop.*	Asteraceae	Soon Valley	AU-29	ACC-131704
11.	*Cousinia prolifera Jaub. & Spach*	Asteraceae	Chakwal	AU-25	ACC-131705
12.	*Eclipta prostrata (L.) L.*	Asteraceae	Moosa Khail Mianwali	AU-41	ACC-131706
13.	*Erigeron bonariensis L.*	Asteraceae	Islamabad	AU-91	ACC-131707
14.	*Erigeron canadensis L.*	Asteraceae	Islamabad	AU-39	ACC-131708
15.	*Ixeris polycephala Cass.*	Asteraceae	Kalla chita Hills	Au-51	ACC-131709
16.	*Lactuca sativa L.*	Asteraceae	Margalla Hills	Au-53	ACC-131710
17.	*Lactuca serriola L.*	Asteraceae	Soon Valley	Au-57	ACC-131711
18.	*Launea naudicaulis Hook.f.*	Asteraceae	Khallar kahar	Au-61	ACC-131712
19.	*Launea procumbens Roxb.*	Asteraceae	Margalla Hills	Au-65	ACC-131713
20.	*Parthenium hysterophorus L.*	Asteraceae	Islamabad	AU-13	ACC-131714
21.	*Silybum marianum (L.) Gaertn.*	Asteraceae	Islamabad	AU-107	ACC-131715
22.	*Sonchus arvensis L.*	Asteraceae	Mianwali	Au-67	ACC-131716
23.	*Sonchus asper (L.) Hill.*	Asteraceae	Margalla Hills	Au-71	ACC-131717
24.	*Sonchus oleraceous (L.) L.*	Asteraceae	Soon Valley	Au-79	ACC-131718
25.	*Sphagneticola trilobata (L.) Pruski*	Asteraceae	Chakwal	AU-15	ACC-131719
26.	*Taraxacum offinale (L.) Weber ex F.H.Wigg.*	Asteraceae	Chakwal	Au-81	ACC-131720
27.	*Taraxacum platycarpum Dahlst.*	Asteraceae	Soon valley	Au-85	ACC-131721

28.	*Verbesina helianthoides Michx.*	Asteraceae	Mianwali	AU-109	ACC-131722
29.	*Zinnia elegans L.*	Asteraceae	Salt range Chakwal	AU-118	ACC-131723
30.	*Achyranthus aspera L*	Amaranthaceae	Islamabad	Au-135	ACC-131724
31.	*Aerva javanica Hill*	Amaranthaceae	Salt Range, Chakwal	Au-37	ACC-131725
32.	*Amaranthus gracizens Linn*	Amaranthaceae	Salt Range, Chakwal	Au-95	ACC-131726
33.	*Amaranthus hybridus L.*	Amaranthaceae	Salt Range Chakwal	Au-91	ACC-131727
34.	*Amaranthus spinosus L.*	Amaranthaceae	Salt Range Chakwal	Au-137	ACC-131728
35.	*Amaranthus viridis L*	Amaranthaceae	Salt Range Chakwal	Au-39	ACC-131729
36.	*Atriplex stocksii (Forssk.) Stapf.*	Amaranthaceae	Salt Range, Chakwal	Au-179	ACC-131730
37.	*Celosia argentia L*	Amaranthaceae	Salt Range, Chakwal	Au-55	ACC-131731
38.	*Chenopodium album (L.) Stapf.*	Amaranthaceae	Islamabad	Au-66	ACC-131732
39.	*Chenopodium murale (L.) P.Beauv.*	Amaranthaceae	Chakwal	Au-83	ACC-131733
40.	*Chenopodium ambrosioides L.*	Amaranthaceae	Islamabad	Au-61	ACC-131734
41.	*Digeria muricata L*	Amaranthaceae	Rawalpindi	Au-59	ACC-131735
42.	*Kochia indica L*	Amaranthaceae	Salt Range, Chakwal	Au-231	ACC-131736
43.	*Kochia lonifolia Linn*	Amaranthaceae	Salt Range, Chakwal	Au-107	ACC-131737
44.	*Pupalia lappaceae L*	Amaranthaceae	Salt Range, Chakwal	Au-91	ACC-131738
45.	*Salsola lubricate L*	Amaranthaceae	Miani Village Chakwal	Au-65	ACC-131739
46.	*Sauda fruitcosa L*	Amaranthaceae	Salt Range, Chakwal	Au-111	ACC-131740
47.	*Acacia nilotica L*	Fabaceae	Islamabad	Au-211	ACC-131741
48.	*Accacia modesta L*	Fabaceae	Kabekhi Lake	AU-212	ACC-131742
49.	*Arachis hypagae L*	Fabaceae	Numl Lake	AU-205	ACC-131743
50.	*Astragalus psilocentros L*	Fabaceae	Soon valley	AU-206	ACC-131744
51.	*Astragalus scoripiurus L*	Fabaceae	Mianwali	AU-207	ACC-131745
52.	*Cassia fistula L*	Fabaceae	Salt range Chakwal	AU-168	ACC-131746
53.	*Cassia italic L.(Pers)*	Fabaceae	Islamabad	AU-169	ACC-131747
54.	*Cassia occidentalis Linn*	Fabaceae	Salt Range, Chakwal	AU-51	ACC-131748
55.	*Crotolaria burhia (Jones) schult*	Fabaceae	Salt Range, Chakwal	AU-53	ACC-131749
56.	*Dilbergia sisso Jaub. & Spach*	Fabaceae	Salt Range Chakwal	AU-61	ACC-131750
57.	*Lathyrus aphaca L*	Fabaceae	Salt Range Chakwal	AU-251	ACC-131751
58.	*Lespedeza juncea L*	Fabaceae	Salt Range Chakwal	AU-253	ACC-131752
59.	*Leucaena leucocephalla L*	Fabaceae	Salt Range, Chakwal	AU-191	ACC-131753
60.	*Melilotus indicus L*	Fabaceae	Kalla-Chitta Hills	AU-193	ACC-131754
61.	*Pigomia pinnata L*	Fabaceae	Qau, Islamabad	AU-45	ACC-131755

62.	*Prosopis cineraria L*	Fabaceae	Mianwali	AU-47	ACC-131756
63.	*Prosopis juliflora Linn*	Fabaceae	Mianwali	AU-59	ACC-131757
64.	*Pueraria tuberosa L*	Fabaceae	Soon Valley	AU-241	ACC-131758
65.	*Rhynchosia capitata L*	Fabaceae	Chakwal	AU-117	ACC-131759
66.	*Sophora mollis (Jones) schult*	Fabaceae	Chakwal	AU-119	ACC-131760
67.	*Tephrosia purpurea (Jones) schult*	Fabaceae	Salt Range, Chakwal	AU-207	ACC-131761
68.	*Vicia angustifolia (Jones) schult*	Fabaceae	Khallar Kahar	AU-09	ACC-131762
69.	*Brachiaria brizantha L*	Poaceae	Margalla Hills	Au-11	ACC-131763
70.	*Cenchrus biflorus L*	Poaceae	Soon Valley	Au-15	ACC-131764
71.	*Cenchrus ciliaris L*	Poaceae	Khallar kahar	Au-17	ACC-131765
72.	*Cenchrus pennisetiformis L*	Poaceae	Margalla Hills	Au-21	ACC-131766
73.	*Cymbopogon jwarancusa L*	Poaceae	Islamabad	Au-19	ACC-131767
74.	*Cynodon dactylon L*	Poaceae	Islamabad	Au-12	ACC-131768
75.	*Dactyloctenium aegyptium L*	Poaceae	Mianwali	Au-23	ACC-131769
76.	*Dichanthium annulatum L*	Poaceae	Margalla Hills	Au-25	ACC-131770
77.	*Eleusine indica Linn*	Poaceae	Soon Valley	Au-27	ACC-131771
78.	*Pennisetum glaucum L*	Poaceae	Chakwal	Au-29	ACC-131772
79.	*Pennisetum typhoides L*	Poaceae	Chakwal	Au-31	ACC-131773
80.	*Poa annua (L.) P.Beauv.*	Poaceae	Soon valley	Au-33	ACC-131774
81.	*Saccharum spontaneum L.*	Poaceae	Mianwali	Au-51	ACC-131775
82.	*Steria viridis (L.) P.Beauv.*	Poaceae	Salt range Chakwal	Au-9	ACC-131776
83.	*Zea mays L.*	Poaceae	Islamabad	Au-7	ACC-131777
84.	*Anagallis arvensis L*	Primroses	Salt Range Chakwal	AU-107	ACC-131778
85.	*Asphodelus tenuifolius Cav.*	Asphodelacea	Miani Village Talagang	AU-113	ACC-131779
86.	*Boerhivia procumbense L*	Nyctaginaceae	Khewra mines	AU-115	ACC-131780
87.	*Brachychiton acerifolius (A.Cunn. ex G.Don)*	Malvaceae	Uchali Lake	AU-99	ACC-131781
88.	*Broussonetia papyrifera (L.) L'Hér. ex Vent.*	Moraceae	Uchali Lake	AU-77	ACC-131782
89.	*Bryophyllum pinnatum (Lam.) Oken*	Crassulaceae	Rawalpindi	AU-65	ACC-131783
90.	*Capparis decidua (Forssk.)edgeW.*	Capparaceae	Musa khel Mianwali	AU-39	ACC-131784
91.	*Chorchorus depressus L*	Tiliaceae	Miani Village	AU-55	ACC-131785
92.	*Cissampelos pareira L.*	Menispermaceae	Kabkbi Lake	AU-110	ACC-131786
93.	*Citharexylum spinosum L.*	Verbenaceae	Islamabad	AU-205	ACC-131787

94.	*Cleome brachycarpa (Forssk.) Vahl ex DC*	Capparaceae	Salt Range	AU-209	ACC-131788
95.	*Cleome viscosa L.*	Capparceae	Attock	AU-211	ACC-131789
96.	*Commelina benghalensis L.*	Commelinaceae	Salt Range	AU-215	ACC-131790
97.	*Convolvulus arvensis L.*	Convolvulaceae	Islamabad	AU-217	ACC-131791
98.	*Cucumis melo sub agerestis L.*	Cucurbitaceae	Miani village Talagang	AU-31	ACC-131792
99.	*Datura innoxia Mill.*	Solanaceae	Miani village Talagang	AU-45	ACC-131793
100.	*Euphorbia granulata L.*	Euphorbiaceae	Miani village Talagang	AU-53	ACC-131794
101.	*Oxalis corniculata L.*	Oxalidaceae	Thoha Bahadur Chakwal	AU-69	ACC-131795
102.	*Solanum surattense Mill*	Solanaceae	Miani Village Chakwal	AU-51	ACC-131796
103.	*Trianthema portulastrum L*	Aizoaceae	Salt Range Chakwal	AU-57	ACC-131797

CHAPTER: 3

Results & Discussion

Summary

The Floral Diversity of Potohar Plateau, Pakistan has been bestowed with rich floristic diversity. The current research was conducted in the selected areas of Potohar Plateau i.e. Attock, Chakwal, Mianwali, Soon Sakasar, Miani Village, Uchali Lake, Kabbaki Lake, Kalla Chitta Hills, Numl Lake. These areas were explored first time systematically. Previous work was fragmented but the present research project is comprehensive and includes the Taxonomic study of 103 Plants belonging to Fifteen Families. Dominant families of my research project include Asteraceae, Amaranthaceae, Fabaceae and Poaceae. The results are compiled and presented separately in two sections.

Section 1: Qualitative and Quantitative pollen micro-morphological characters. Qualitative Characters include Pollen type, Pollen shape, Exine sculpturing, Orientation of Pores while Quntitative characters include Polar Diameter, Equatorial Diameter, Colpi Length, Colpi Width, Length and Width of Pores, P/E ratio and Exine thickness, Pollen fertility and sterility, Length and Width of Spines.

Section 2: Micromorphological seed features such as shape, color, size, surface texture, apex, hilum position, Anticlinal wall, Periclinal wall, cell outline, cell arrangement, Projections.

SECTION 1:
Palynology (LM & SEM)

3.2 Pollen Micro-morphological Studies of Floral Diversity of Potohar Plateau

Here we describe in this section, the detailed Pollen micro-morphology of 103 Plants belonging to Fifteen Families using scanning electron microscopy and Light microscopy. Among them, Dominant families include Asteraceae (29 Species), Amaranthaceae (17 Species), Fabaceae (22 Species), Poaceae (15 Species) and remaining species belonging to different families including Cucubitaceae, Capparaceae, Brasicaceae, Solanaceae, Menispermaceae, Euphorbiaceae, Chenopodiaceae, Tiliaceae (each with one and two species).

Pollen micro-morphological characters of Plants analyzed here include Pollen type, shape, size, Sculpturing, apertural membrane, Spines, Lacunar shape, Echini shape, Echini arrangement, Polar Diameter, Equatorial Diameter, P/E ratio, Exine thickness, Length and width of Spines, Length and width of Colpi, Length and Width of Pores. It also includes Pollen fertility and sterility percentages.

In this section include five parts

3.1.1 Asteraceous Pollen Micro-Morphology

3.1.2 Amaranthaceous Pollen Micro-Morphology

3.1.3 Fabaceous Pollen Micro-Morphology

3.1.4 Poaceous Pollen Micro-Morphology

3.1.5 Weeds Pollen Micro- Morphology

Table 2: Qualitative data of pollen of family Asteraceae members from Potohar region of Pakistan

Sr. No	Taxa	Shape	Polar View	Pollen Type	Polar shape/ Orientation	Pollen ornamentation	Echini arrangement	Lacunae sculpturing	Lacunar shape	Echini Shape	Inter-lacunar Gap
1.	*Ageratum conyzoides*	Oblate-spheroidal	Circular	Tricolporate	Elliptical/sunken	Echinate	Regular	Absent	Absent	-	Absent
2.	*Artemisia absinthimum*	Prolate-spheroidal	Angular	Trizonocolporate	Elliptical/sunken	Echinate	Regular	Absent	Absent	-	Absent
3.	*Aster squamatus*	Prolate-spheroidal	Triangular	Tricolporate	Elliptical/slightly sunken	Echinate	Rather regular	Absent	Absent	-	Absent
4.	*Bidens bipinnata*	Prolate-spheroidal	Triangular	Tricolporate	Rounded/elliptical sunken	Echino-lophate perforate	Regular	Fenestrated perforate	Pentagonal	-	Slightly narrow
5.	*Bidens pilosa*	Spheroidal	Circular	Tricolporate	Rounded/elliptical sunken	Echino-lophate perforate	Regular	Fenestrated perforate	Hexagonal	-	Narrow
6.	*Calendula arvensis*	Oblate-spheroidal	Circular	Tricolporate	Rounded/sunken	Echinate	Regular	Absent	Absent	-	Absent
7.	*Calendula officinalis*	Oblate-spheroidal	Semi angular	Trizonocolporate	Elliptical/sunken	Echinate	Rather Regular	Absent	Absent	-	Absent
8.	*Carthamus oxyacantha*	Sub-oblate	Triangular	Tricolporate	Elliptical/sunken	Coarsely regulate echinate perforated	Rather regular	Perforate	Pentagonal	-	Narrow
9.	*Carthamus lanatus*	Oblate-spheroidal	Triangular	Trizonocolporate	Rounded sunken	Echino-lophate perforate	Rather regular	Fenestrated perforate	Pentagonal to hexagonal	-	Narrow
10.	*Causinia prolifera*	Sub-Oblate	Circular	Tricolporate	Rounded sunken	Micro-reticulate echinate	Regular	Absent	Absent	-	Absent
11.	*Cirsium arvense*	Oblate-spheroidal	Circular	Tricolporate	Rounded/sunken	Echinate with broad spines	Regular	Fenestrates perforate	Tetragonal to pentagonal	-	Slightly Narrow

12.	*Eclipta prostrata*	Prolate-spheroidal	Triangular	Tricolporate	Rounded elliptical/sunken	Echino-lophate	Regular	Fenestrated	Pentagonal	-	Slightly narrow
13.	*Erigeron bonariensis*	Prolate-spheroidal	Circular	Tetrazonocolporate	Rounded	Echinate	Regular	Fenestrated	Hexagonal	-	Narrow
14.	*Erigeron Canadensis*	Prolate-spheroidal	Circular	Tricolporate	Rounded/slightly sunken	Echinate	Rather regular	Absent	Absent	-	Absent
15.	*Ixeris polycephala*	Oblate-spheroidal	Circular	Tricolporate	Rounded/ Sunken	Echinate	Regular	Absent	Pentagonal	Spines short with narrow bases and surrounded by lacunas	Absent
16.	*Lactuca sativa*	Prolate-spheroidal	Circular	Tri-tetra Zonocolporate	Rounded	Echinate	Regular	Fenestrated perforate	Tetragonal	Spines long with narrow bases and pointed tips	Narrow
17.	*Lactuca serriola*	Oblate-spheroidal	Circular to rectangular	Tetracolporate	Ellipitical/ Slightly sunken	Echinate	Regular	Absent	Absent	Spines short with broad bases and around the lacunar	Slightly narrow
18.	*Launea naudicaulis*	Spheroidal	Semi Angular	Tetracolporate	Rounded/ sunken	Echinate	Regular	Perforate	Hexagonal	Short with narrow bases and mucronate tips	Narrow
19.	*Launea procumbens*	Oblate-spheroidal	Circular	Tricolporate	Ellipitical/ Slightly sunken	Micro-reticulate Echinate	Regular	Absent	Pentagonal	Long spines with broad bases	Narrow

										and sharp narrow pointed tips	
20.	*Parthenium hysterophorus*	Oblate-spheroidal	Rounded triangular	Tetracolporate	Rounded/sunken	Echino-lophate	Rather-regular	Fenestrated perforate	Tetragonal-pentagonal		Slightly narrow
21.	*Silybum marianum*	Prolate-spheroidal	Circular	Tricolporate	Absent	Microechinate	Regular	Absent	Absent		Absent
22.	*Sonchus arvensis*	Prolate-spheroidal	Cicular	Tetracolporate	Ellipitical/ Slightly sunken	Echinate perforate-tectate	Regular	Perforate	Pentagonal	Short spine with very broad bases and small narrow tips	Slightly narrow
23.	*Sonchus asper*	Sub-oblate	Triangular	Tricolporate	Rounded/ Sunken	Psilate	Regular	Fenestrated perforate	Pentagonal	Spines with broad bases and surrounded by lacunas	Absent
24.	*Sonchus oleraceous*	Oblate-spheroidal	Circular	Tetracolporate	Ellipitical/ Sunken	Echino-lophate perforate	Regular	Perforate	Hexagonal	Absent	Narrow
25.	*Sphagneticola trilobata*	Oblate-spheroidal	Circular	Trizonocolporate	Elliptical/sunken	Echinate-perforate	Regular	Fenestrated perforate	Pentagonal		Narrow
26.	*Taraxacum offinale*	Prolate-spheroidal	Irregular	Trizonocolporate	Rounded /sunken	Echino-lophate perforate	Regular	Absent	Pentagonal to Hexagonal	Short spines with broad bases	Slightly Narrow
27.	*Taraxacum platycarpum*	Sub-oblate	Circular	Tricolporate	Rounded/ Sunken	Echinate	Regular	Absent	Pentagonal	Spine have broad bases and sharp pointed mucronate	Narrow

									tips	
28.	*Verbisinia eleusoides*	Prolate spheroidal	Hexagonal rounded	Tricolporate	Rounded/sunken	Echino-lophate	Regular	Fenestrated	Pentagonal	-	Narrow
29.	*Zinnia elegans*	Prolate spheroidal	Circular	Tricolporate	Rounded/elliptic al	Echinate with pointed spines	Regular	Fenestrated	Hexagonal	-	Slightly narrow

Table 3: Quantitative data of pollen of family Asteraceae members from Potohar region of Pakistan

Plant name	Exine thickness Mean (Min-Max) S.E µm*	Polar Diameter Mean (Min-Max) S.E µm	Equatorial Diameter Mean (Min-Max) S.E µm	P/E** ratio	No of Colpi	No of Pores	No of Spines	Spines Length Mean (Min-Max) S.E µm	Spines Width Mean (Min-Max) S.E µm	Colpi Length Mean (Min-Max) S.E µm	Colpi Width Mean (Min-Max) S.E µm	Pores Length Mean (Min-Max) S.E µm	Pores Width Mean (Min-Max) S.E µm
Ageratum conyzoides	4.8(4.2-6.2) ±0.3	39.6(31.7-46.5) ±2.6	40.3(28.2-47.7) ±3.49	0.9	3	3	35	7.15(3.5-9.2) ±1.0	2.6(1.7-4) ±0.42	9.2(5.7-13.7) ±0.4	10.7(4-17.7) ±2.40	11.1(7.2-16) ±1.5	6.8(4.25-8.75) ±0.78
Artemisia absinthimum	3.3(3-3.7) ±0.1	49.3(42.7-60.5) ±3.23	47.0(38-50.5) ±2.31	1.04	3	2	23	2.75(2-3.7) ±0.30	4.9(4.2-5.5) ±0.21	7.9(7.2-8.2) ±0.18	10.1(8.7-11.2) ±0.41	10(9.7-12.2) ±0.41	12.30(11.25-13) ±0.30
Aster squamatus	4.2(3.2-5.2) ±0.3	22.2(20.5-23.7) ±0.57	21.4(19.5-23.5) ±0.74	1.03	3	3	27	2.6(1.7-3.7) ±0.42	1.6(1.2-2) ±0.12	5.0(4.2-6) ±0.34	3.0(2.5-3.7) ±0.21	3(2.7-3.5) ±0.14	2.45(1.75-3.25) ±0.28
Biden pilosa	5.0(4.0-6.0) ±0.37	48.2(41.7-53.5) ±2.05	48.0(41.5-58.5) ±3.4	1.00	3	3	32	3.6(2.7-4.7) ±0.34	2.3(1.7-3.0) ±0.23	12.1(8.0-15.7) ±1.42	9.9 (7-14.2) ±1.21	9.0(4.5-12) ±1.31	7.60(3.5-12.75) ±1.48
Bidens bipinnata	2.2(1.7-2.7) ±0.16	33.4(30.5-35.7) ±0.92	30.9(29.7-31.7) ±0.33	1.07	3	1	0	-	-	8.5(5.5-10.2) ±0.8	10.0(9.2-10.5) ±0.24	11.1(9.7-13) ±0.57	9.75(9-10.25) ±0.23
Calendula arvensis	2.8(2.5-3) ±0.09	15.8(14.7-17.2) ±0.41	16.6(15.2-18) ±0.47	0.95	3	3	17	2.8(2.2-3.2) ±0.16	3.5(2.2-4.2) ±0.34	3.5(2.7-4.7) ±0.36	3.1(2.75-3.50) ±0.12	3(2.5-3.5) ±0.16	3.6(3.25-4) ±0.12
Calendula officinalis	5.0(4.7-5.2) ±0.12	51.8(38-56.2) ±3.49	51.9(38-56.7) ±3.52	0.99	3	3	16	4.9(4.2-5.2) ±0.2	7.8(7.2-8.2) ±0.16	17.6(10.5-21.2) ±1.9	9.50(8-10.25) ±0.47	12(10.2-13.7) ±0.68	12(11.25-13) ±0.29
Carthamus oxyacantha	1.9(1.5-2.2) ±0.14	22.3(22-22.7) ±0.18	29(27.5-30.5) ±0.57	0.76	3	3	21	4.3(3.5-4.5) ±0.20	3.4(3.2-3.7) ±0.09	3.1(3-3.25) ±0.06	5.6(5.2-5.6) ±0.23	4.7(3.5-6.25) ±0.45	4.7(3.50-5.50) ±0.40
Carthamus lanatus	5.5(3.5-7.2) ±0.66	42.6(29.0-54.0) ±4.35	44.2(39.5-51.7) ±2.12	0.96	3	3	28	3.7(2.7-4.5) ±0.28	2.1(1.5-3.2) ±0.30	7.5(3.5-11.5) ±1.29	12.1(2.0-19.0) ±2.89	11.6(6.0-16.0) ±1.76	10.35(7.0-14.5) ±1.25
Causinia prolifera	4.5(3.5-5.2) ±0.28	41.9(40.7-43.7) ±0.51	48.2(45.2-50.7) ±1.17	0.87	3	2	14	5.7(5.2-6.5) ±0.23	4.6(4.2-4.7) ±0.10	9.6(8.7-10.2) ±0.29	7(6.50-7.25) ±0.13	10.5(10.2-10.7) ±0.11	10.00(9.25-10.75)

												±0.250
Cirsium arvense	4.0(3.2-4.7) ±0.26	43.9(41.2-45.7) ±0.90	44.6(41.2-51.2) ±1.84	0.98	3	1	19	5.5(5.2-5.7) ±0.11	4.6(2.7-5.2) ±0.48	11.2(8.6-15.5) ±1.42	8.5(5.5-10.7) ±0.99	11.7(10.2-12.7) ±0.41	9.5(8.25-10.50) ±0.40
Eclipta prostrata	3.1(2.7-3.7) ±0.16	40.9(34.7-47.5) ±2.0	36.9(29.2-44.7) ±2.88	1.10	3	3	29	2.8(2.5-3.0) ±0.09	2.6(2.2-3.2) ±0.20	5.3(5.0-6.0) ±0.18	8.10(7.0-9.0) ±0.34	9.35(7.25-10.50) ±0.56	8.80(7.75-11.0) ±0.60
Erigeron bonariensis	1.2(0.7-1.5) ±0.12	27.5(26.7-28.2) ±0.25	25.6(25.2-26) ±0.12	1.07	4	1	29	2.2(2-2.5) ±0.07	1.8(1.5-2) ±0.10	11.4(10.75-12) ±0.21	8.4(8-9) ±0.16	9.9(9.5-10.50) ±0.18	8.1(7.75-8.50) ±0.12
Erigeron canadensis	2(1.7-2.2) ±0.07	25.6(24.7-26.7) ±0.33	23.8(23-24.7) ±0.32	1.07	3	1	26	1.8(1.5-2) ±0.09	1.2(1-1.5) ±0.07	10.1(8.5-12.2) ±0.69	7.4(7-7.75) ±0.15	8.70(7.25-9.75) ±0.47	7.60(7.25-8) ±0.15
Ixeris polycephala	2.5(2.2-2.7)± 0.12	33.2(30.5-35.2) ±0.9	32.8(29.7-34.7) ±0.9	1.01	3	4	27	4.4(3.7-5.2) ±0.24	3.7(3-4.5) ±0.3	9.3(7.7-10.5) ± 0.6	7.4(6.5-8.7) ±0.4	7.7(6.5-9.7) ±0.5	6.3(4.7-7.2) ±0.4
Lactuca sativa	4.05(2.5-5.2) ±0.45	36.7(32-44.7) ±2.2	38.40(33-45.7) ±2.30	0.95	3	3	33	6.3(4.5-7.7) ±0.57	4(2.2-5.7) ±0.70	8.55(7.2-10) ±0.46	9.7(6.2-13.2) ±1.2	8.5(6.7-10.7) ±0.73	6.3(4.5-10) ±0.98
Lactuca serriola	4.1(3.50-5.25) ±0.30	39.6(33.7-45.7) ±2.24	40.6(34.75-49) ±2.4	0.97	4	1	31	2.9(2.7-3.2) ±0.09	1.7(1.2-2.2) ±0.17	0.8(5.7-10.2) ±0.84	7(4-9.5) ±1.05	7.5(6.2-9.7) ±0.73	8(5.7-11) ±0.97
Launea naudicaulis	4.40(4-4.75) ±0.12	40.9(37.2-40.9) ±1.6	40.8(34-43.25) ±1.71	1.00	4	1	29	3.4(3.2-3.7) ±0.09	1.9(1.5-2.2) ±0.14	9.1(8.2-9.7) ±0.25	6.5(5.7-7.2) ±0.2	8.6(7.7-9.7) ±0.38	6.9(6.5-7.2) ±0.12
Launea procumbens	4.90(3.50-5.75) ±0.38	61.1(59.2-63.0) ±0.67	67.1(64.7-71.2) ±1.1	0.91	3	2	31	2.8(2.2-3.5) ±0.25	3.7(2.7-4.7) ±0.35	7.8(7-8.7) ±0.28	9.6(8-11.0) ±0.51	17.6(13.7-19.7) ±1.07	15.5(13.2-17.7) ±0.9
Parthenium hysterophorus	4.6(2.2-6.2) ±0.67	36.9(30.0-47.0) ±2.84	40.9(34.2-48.7) ±2.81	0.90	4	3	31	4.0(3.2-5.0) ±0.32	2.9(2.0-4.0) ±0.35	5.30(3.50-7.0) ±0.62	7.80(5.50-9.2) ±0.6	6.8(4.75-9.25) ±0.75	5.5(4.25-7.0) ±0.52
Silybum marianum	4.2(3.7-4.7) ±0.16	26.8(25.2-28.7) ±0.68	24.5(22.2-27) ±0.86	1.09	3	0	27	1.4(0.7-2) ±0.21	0.8(0.7-1) ±0.05	6.50(5.75-7.25) ±0.25	5.4(4.75-6.2) ±0.25	-	-
Sonchus arvensis	3.30(2.75-4.25) ±0.25	38.1(32.2-52.7) ±3.7	35.5(30.7-38.2) ±1.3	1.07	3	1	19	5.4(4.7-5.7) ±0.18	4(2.7-4.7) ±0.4	9.8(9.2-10.2) ±0.2	7.4(6.7-8.2) ±0.26	7.8(6.5-9.2) ±0.4	7.8(6.5-9.2) ±0.4
Sonchus asper	3.95(3.25-4.50) ±0.21	39.6(38.2-40.7) ±0.4	45.3(44-46.7) ±0.4	0.87	3	0	0	-	-	8.4(7.7-9) ±0.21	9.1(8.2-9.7) ±0.24	-	-
Sonchus oleraceous	4.40(3.50-5.75) ±0.73	34.4(24.0-47.2) ±3.8	38.1(28.7-46.5) ±3.0	0.90	3	3	27	3.6(3.0-4.2) ±0.23	2.1(1.2-3.0) ±0.30	7.4(3.5-12.0) ±1.74	8.1(3.7-14.5) ±1.90	4.7(2.7-8.5) ±0.99	5.5(4.0-7.2) ±0.53

Sphagneticola trilobata	4.1(3.5-5.0) ±0.25	39.6(33.7-45.7) ±2.24	40.6(34.7-49.0) ±2.45	0.97	3	3	32	2.9(2.5-3.2) ±0.12	1.7(1.2-2.2) ±0.17	7.95(5.75-10.2) ±0.84	7.0(4.0-9.50) ±1.50	7.50(6.25-9.75) ±0.73	8.0(5.75-11.0) ±0.91
Taraxacum offinale	4.9(3.0-6.25) ±5.5	33.6(29.0-39.0) ±1.85	36.4(29.7-41.5) ±2.1	0.92	3	3	29	2.3(1.2-3.2) ±0.3	1.6(1.0-2.5) ±0.25	6.8(4.2-9.5) ±0.94	12.6(8.0-16.7) ±1.4	7.0(3.7-9.5) ±0.98	6.2(4.0-8.7) ±0.86
Taraxacum platycarpum	3.35(3.0-3.75) ±0.28	34.4(30.5-36.7) ±2.5	32.9(28.7-36.2) ±3.08	1.04	3	3	31	3.1(2.7-3.5) ±0.28	2.3(2.5-2.5) ±0.11	6.3(5.2-7.2) ±0.7	9.5(9.0-10.0) ±0.39	7.9(7.0-8.7) ±0.69	7.7(7.2-8.0) ±0.32
Verbisinia eleusoides	4.2(3.5-5.2) ±0.32	36.7(31.0-46.5) ±2.71	36.2(30.5-41.5) ±1.78	1.01	3	3	28	2.0(1.5-2.7) ±0.21	1.9(1.2-2.5) ±0.23	6.90(3.5-10.5) ±1.33	6.2(3.5-9.25) ±1.0	3.50(2.75-4.0) ±0.26	4.20(3.25-5.25) ±0.37
Zinnia elegans	3.5(2.2-4.2) ±0.33	32.2(28.5-34.5) ±1	31.8(26.5-36.8) ±1.84	1.01	3	3	20	6.3(5.2-7.2) ±0.35	2.7(2-3.5) ±0.28	7.45(6.25-8.25) ±0.33	4.6(3-6) ±0.53	3.9(2.75-5.25) ±0.41	2.6(2-3.25) ±0.23

*µm= Micrometer, **P/E= Polar diameter/Equatorial diameter

Table 4: Fertility and Sterility percentages of examined taxa

Sr. No	Taxa	No of Fertile Pollen	No of Sterile Pollen	Fertility %	Sterility %
1.	*Ageratum conyzoides*	149	28	84.18	15.82
2.	*Artemisia absinthimum*	117	18	86.66	13.34
3.	*Aster squamatus*	158	43	78.60	21.4
4.	*Bidens bipinnata*	183	27	87.14	12.86
5.	*Bidens pilosa*	92	11	89.32	10.68
6.	*Calendula arvensis*	47	13	78.33	21.67
7.	*Calendula officinalis*	55	8	87.30	12.7
8.	*Carthamus lanatus*	127	19	86.98	13.02
9.	*Carthamus oxyacantha*	150	14	91.46	8.54
10.	*Cirsium arvense*	120	17	87.59	12.41
11.	*Cousinia prolifera*	164	36	82	18
12.	*Eclipta prostrata*	215	35	86	14
13.	*Erigeron bonariensis*	64	10	86.48	13.52
14.	*Erigeron canadensis*	203	31	86.75	13.25
15.	*Ixeris polycephala*	106	27	79.69	20.31
16.	*Lactuca sativa*	179	33	84.43	15.57
17.	*Lactuca serriola*	69	11	86.25	13.75
18.	*Launea naudicaulis*	132	26	83.54	16.46
19.	*Launea procumbens*	83	15	84.69	15.31
20.	*Parthenium hysterophorus*	98	11	89.90	10.1
21.	*Silybum marianum*	215	19	91.88	8.12
22.	*Sonchus arvensis*	76	16	82.60	17.4
23.	*Sonchus asper*	120	41	74.53	25.47
24.	*Sonchus oleraceous*	123	22	84.82	15.18
25.	*Sphagneticola trilobata*	138	48	74.19	25.81
26.	*Taraxacum offinale*	87	7	92.55	7.45
27.	*Taraxacum platycarpum*	156	17	90.17	9.83
28.	*Verbesina helianthoides*	151	9	94.37	5.63
29.	*Zinnia elegans*	107	14	89.16	10.84

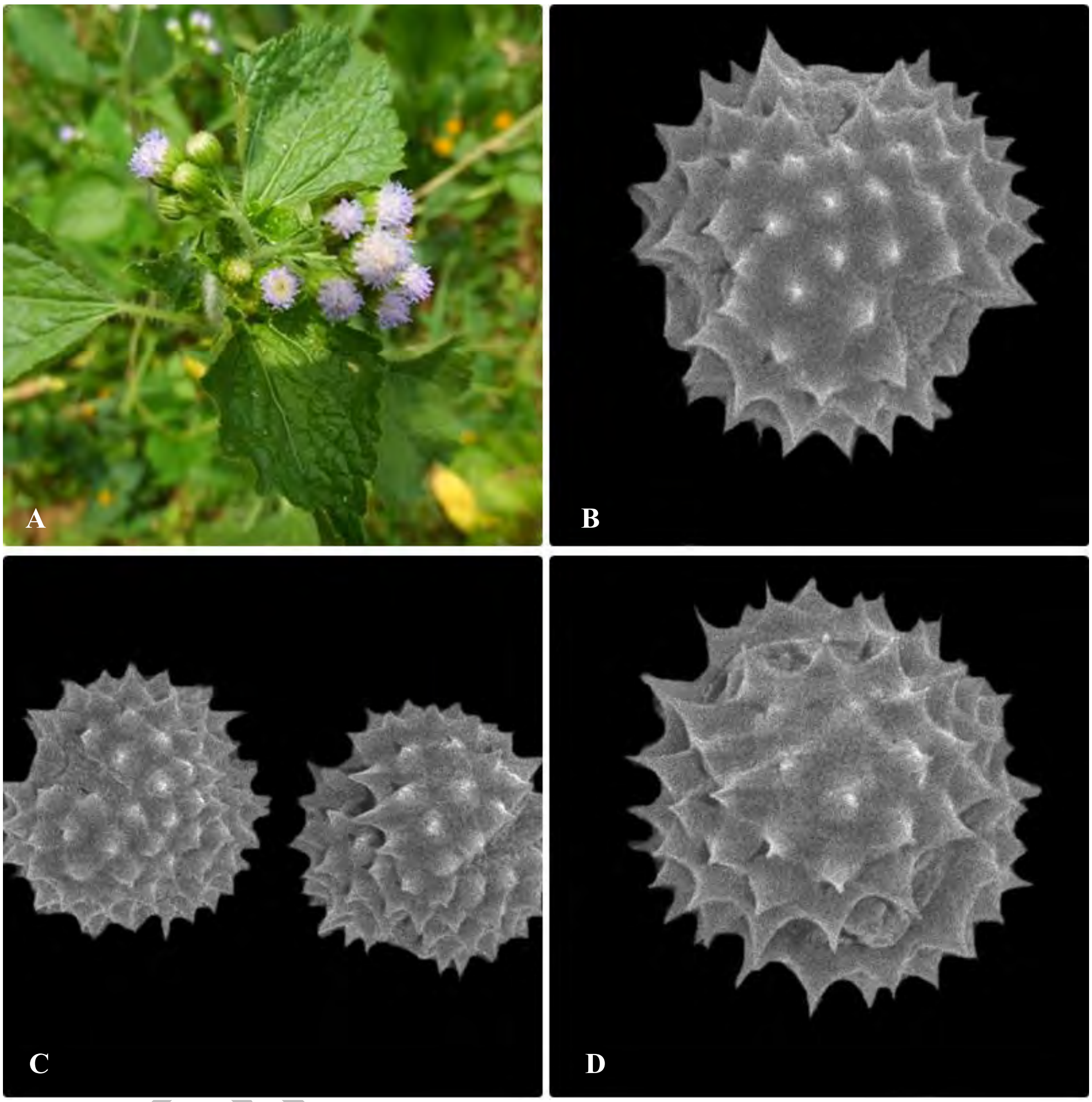

Plate 23: *Ageratum conyzoides* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Elliptical sunken orientation (D) Echinate Exine Sculpturing

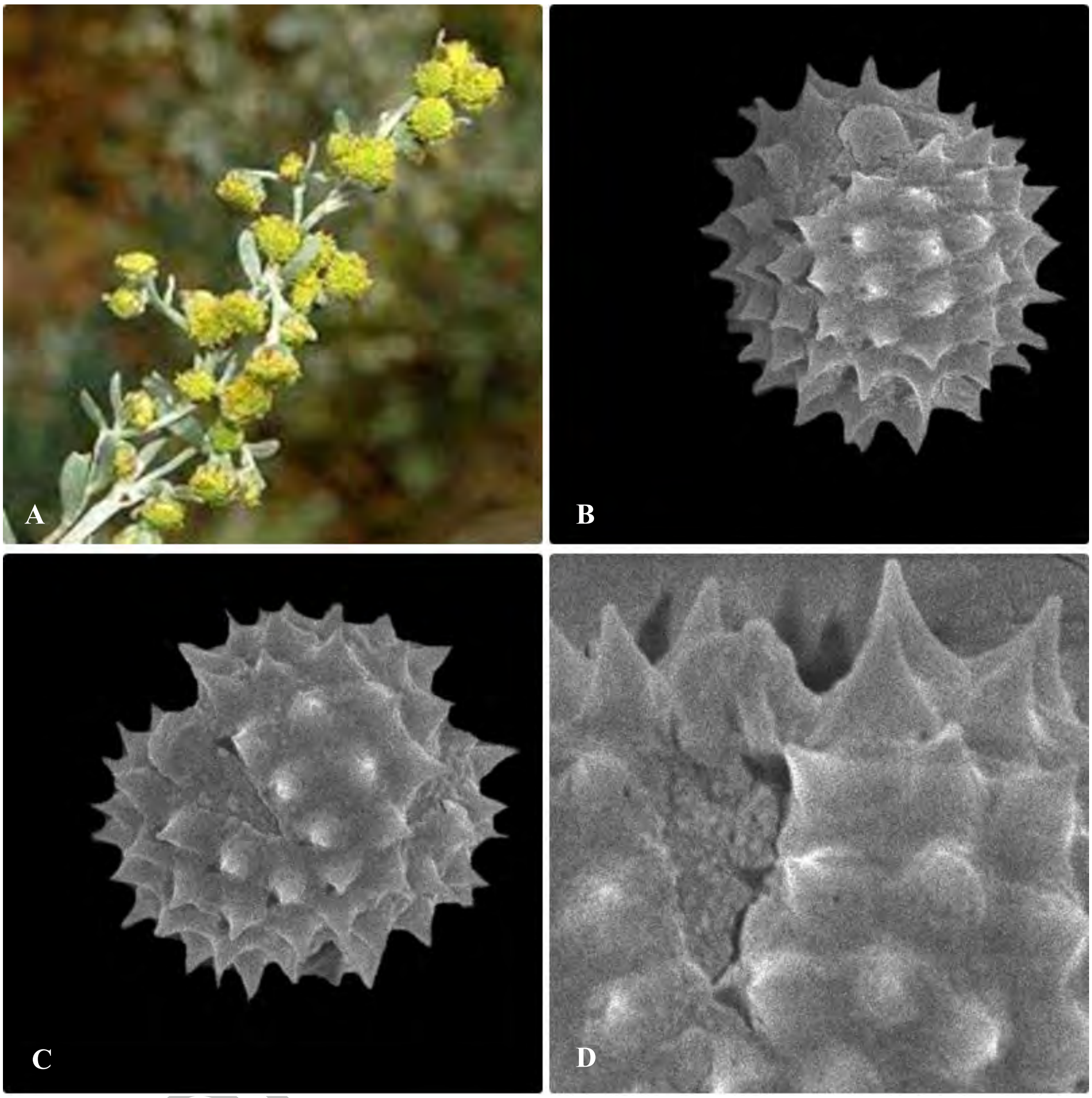

Plate 24: *Artemisia absinthimum* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Elliptical sunken orientation (D) Surface Sculpturing

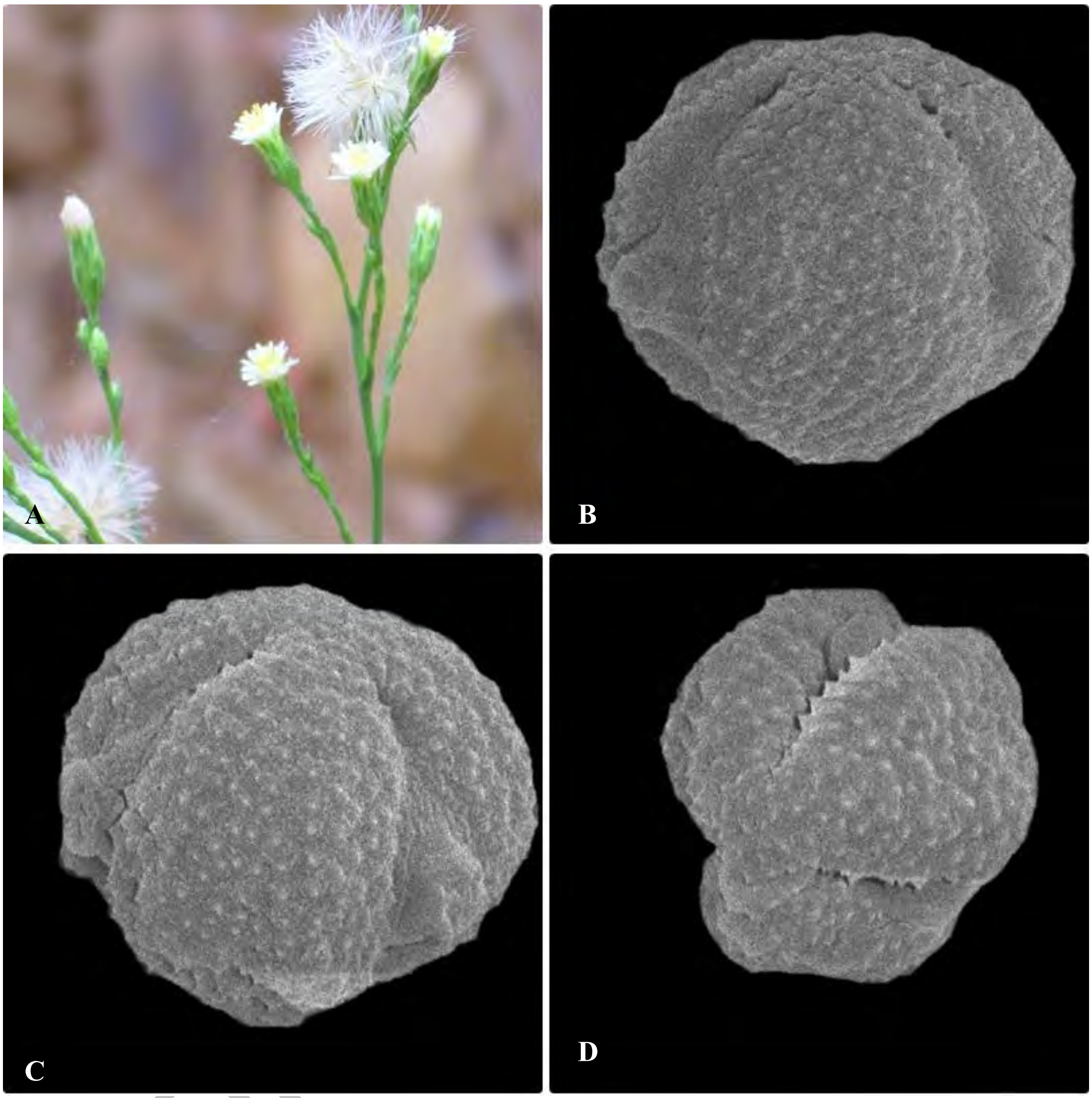

Plate 25: *Aster squamatus* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Sunken Orientation (D) Echinate Exine Sculpturing

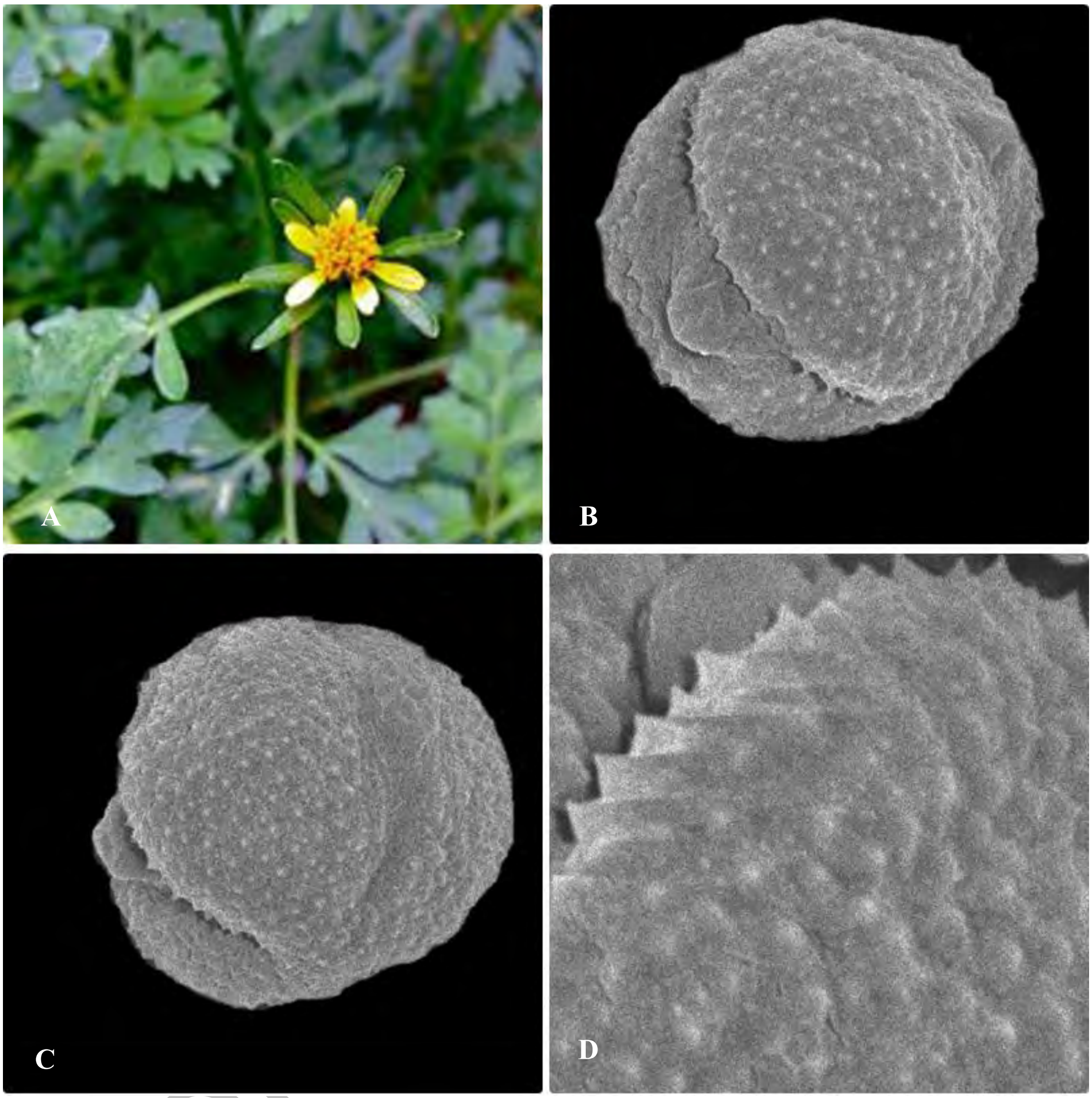

Plate 26: *Bidens bipinnata* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Perforate Ornamentation (D) Echinate Exine Sculpturing

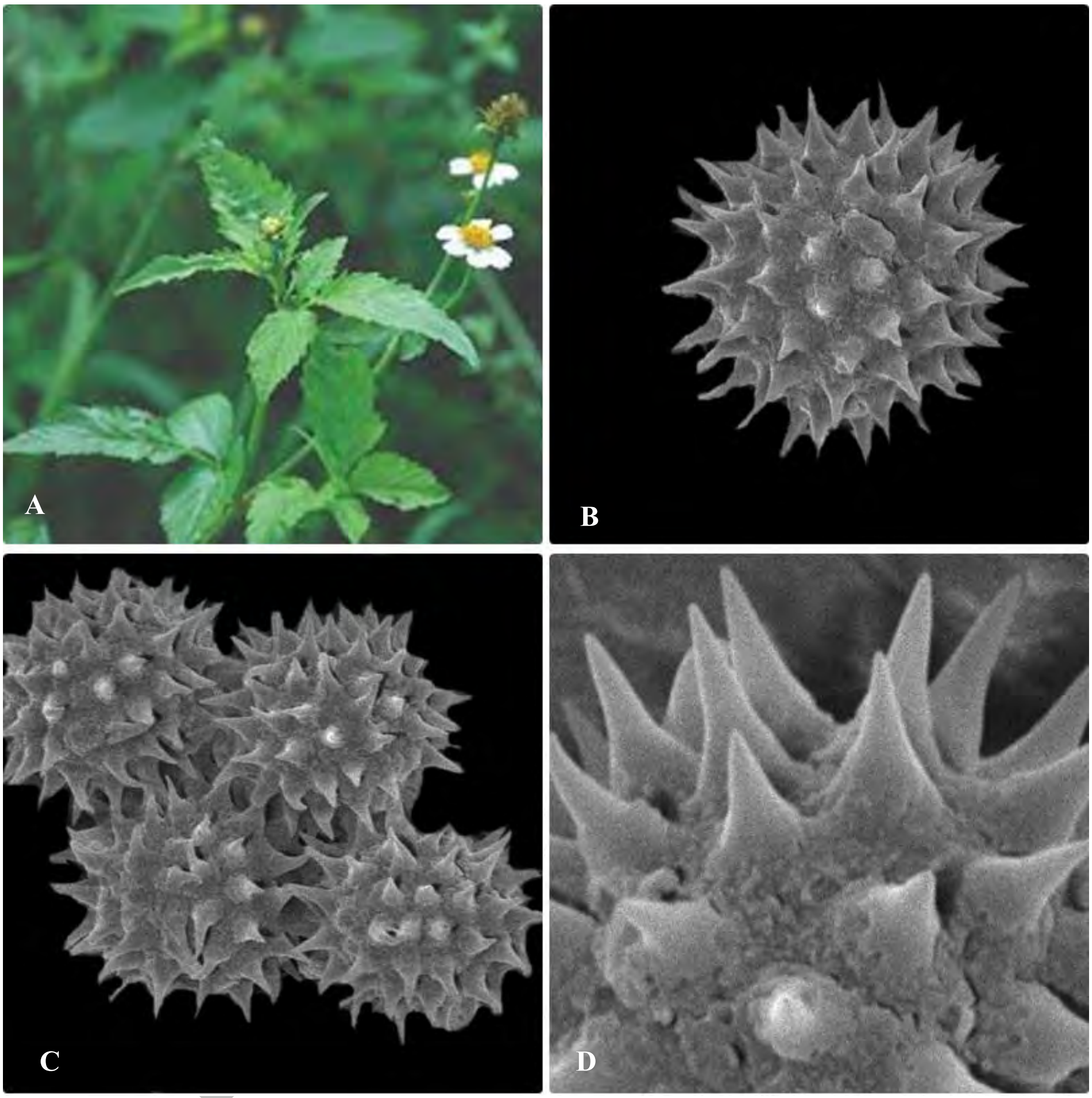

Plate 27: *Bidens pilosa* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Elliptical sunken orientation (D) Echinate Exine Sculpturing

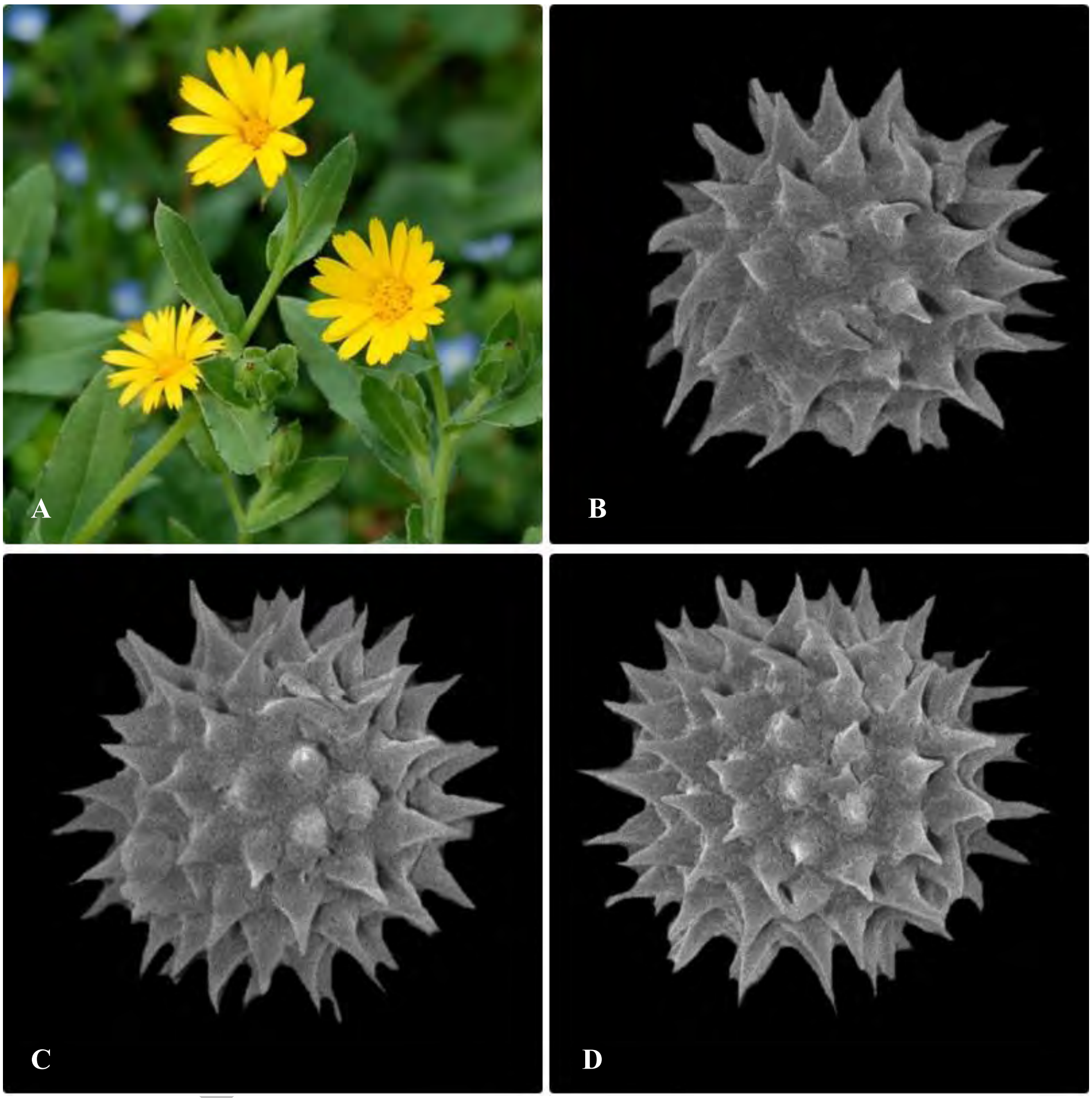

Plate 28: *Calendula arvensis* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Sunken orientation (D) Exine Sculpturing

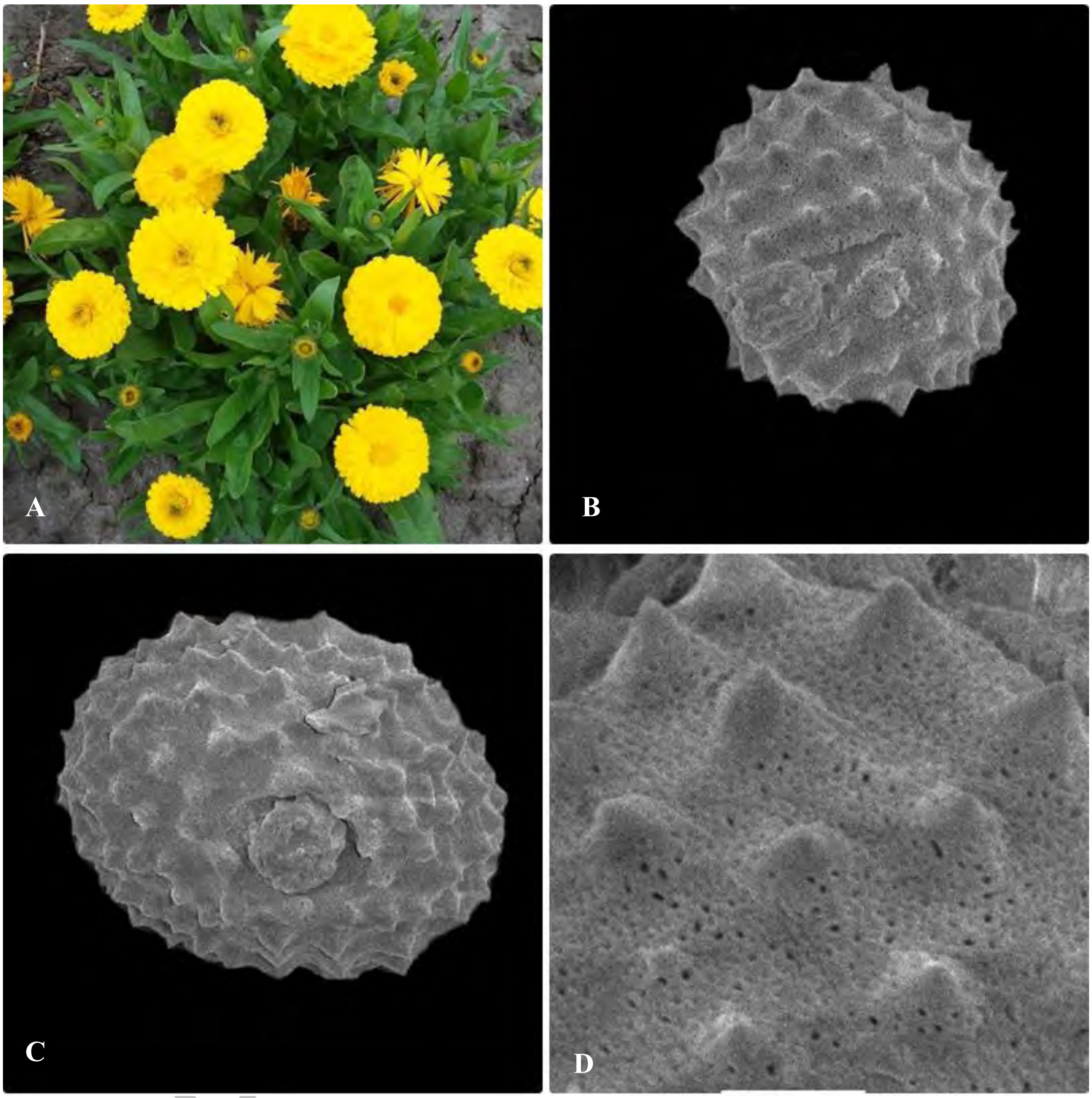

Plate 29: *Calendula officinalis* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Elliptical sunken orientation (D) Surface Sculpturing

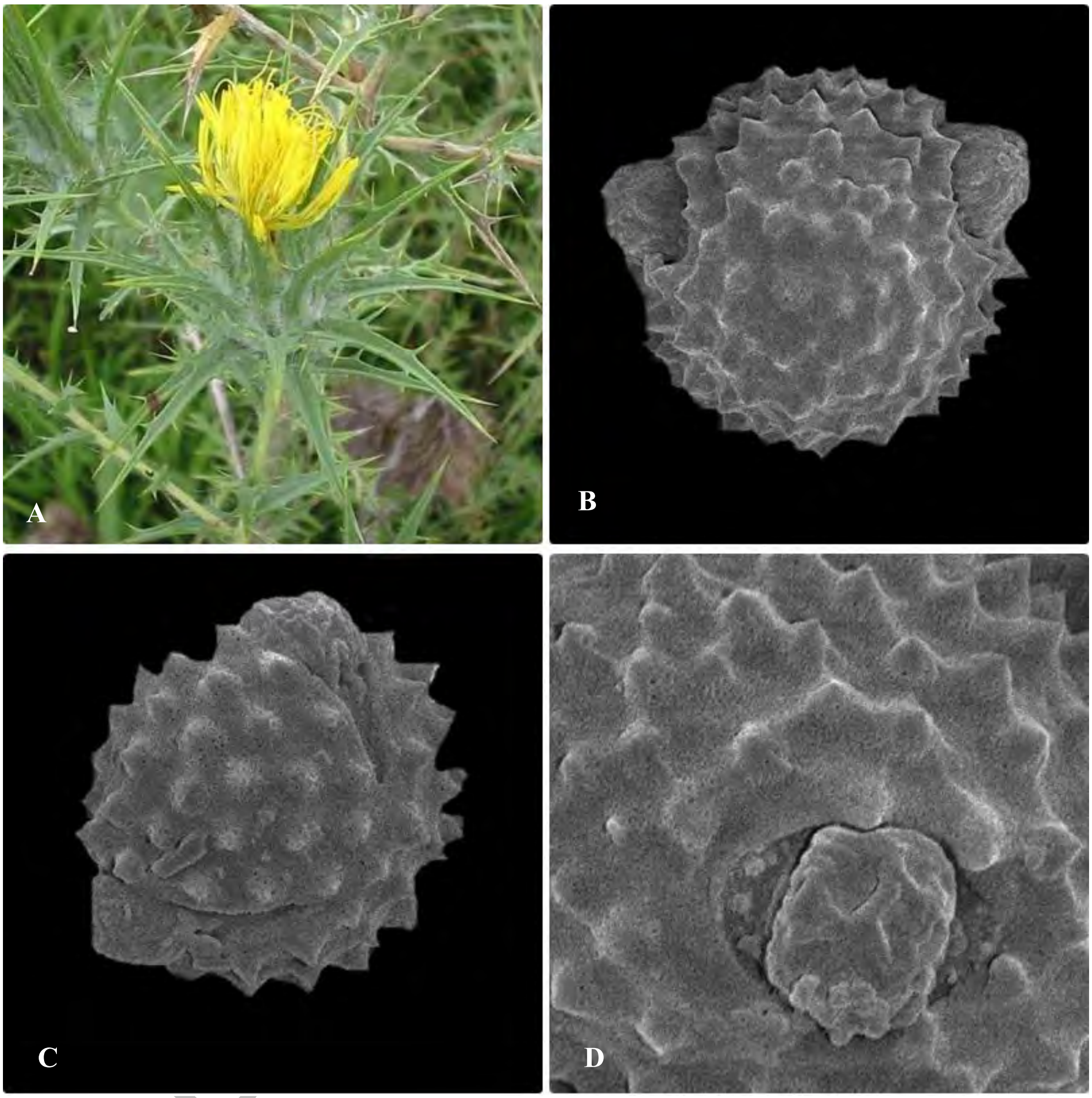

Plate 30: *Carthamus oxyacantha* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Elliptical sunken orientation (D) Surface Sculpturing

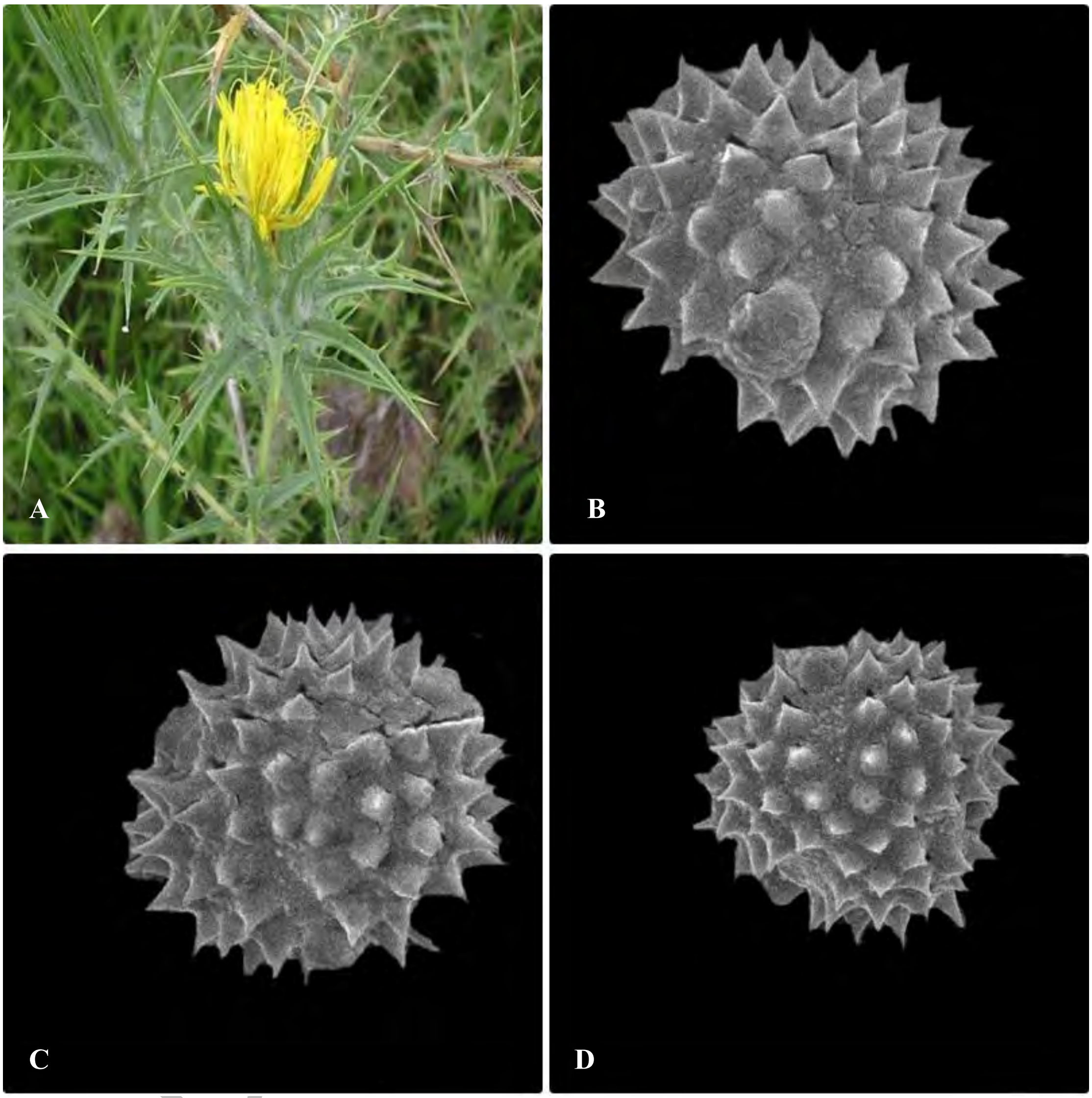

Plate 31: *Carthamus lanatus* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Rounded sunken orientation (D) Echinate Exine Sculpturing

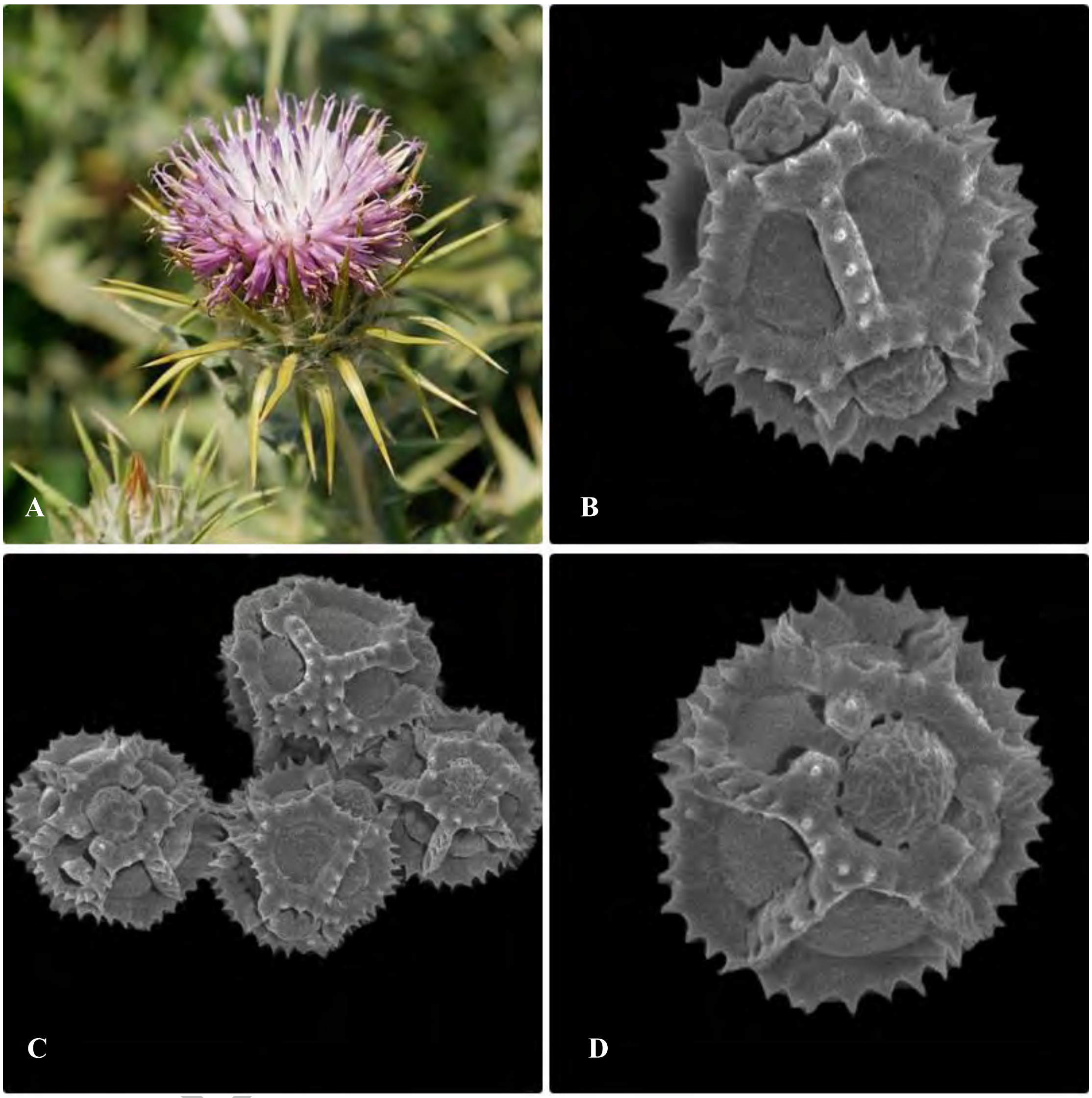

Plate 32: *Causinia prolifera* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Rounded sunken orientation (D) Echinate Exine Sculpturing

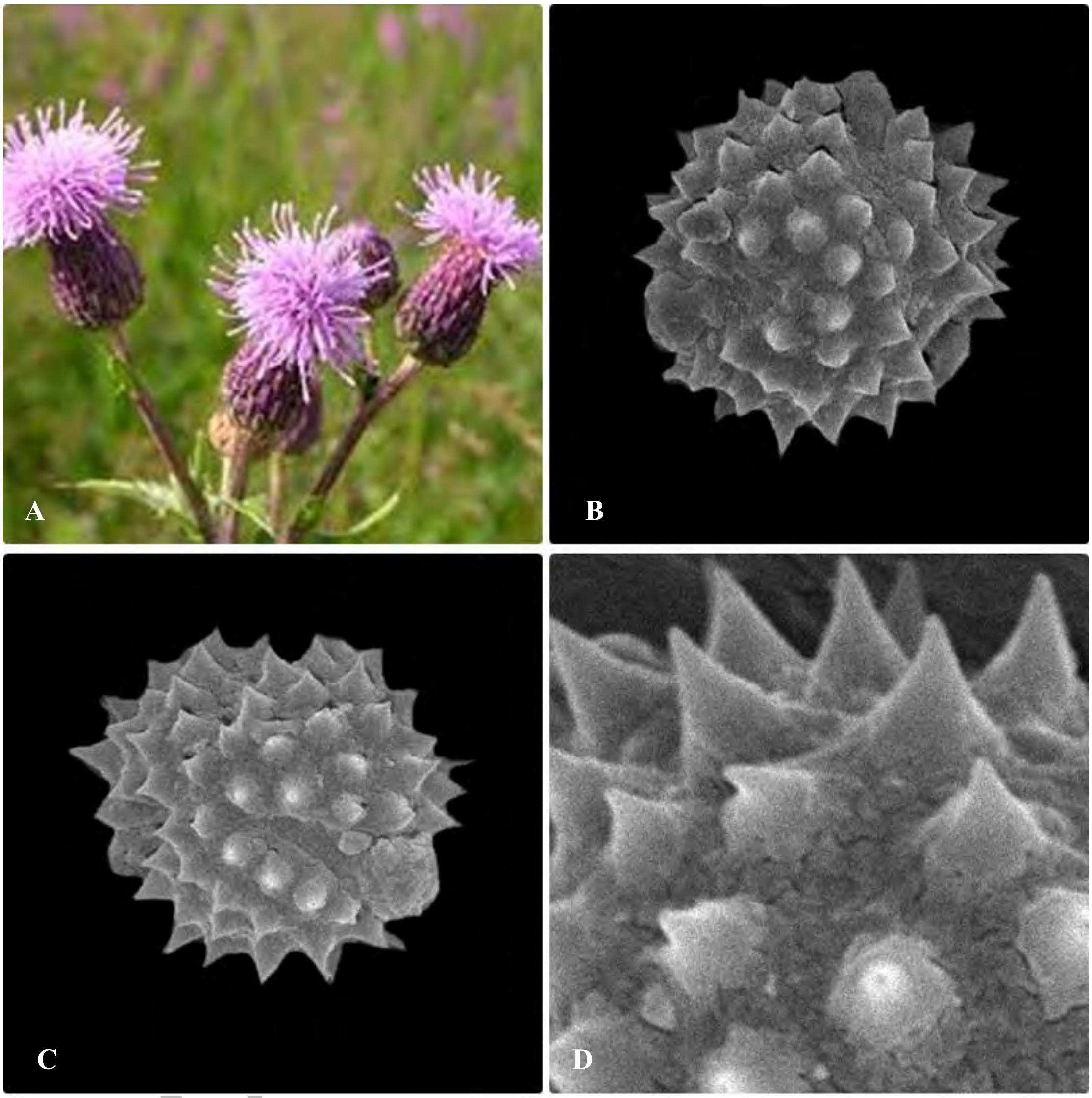

Plate 33: *Cirsium arvense* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Rounded sunken orientation (D) Surface Sculpturing

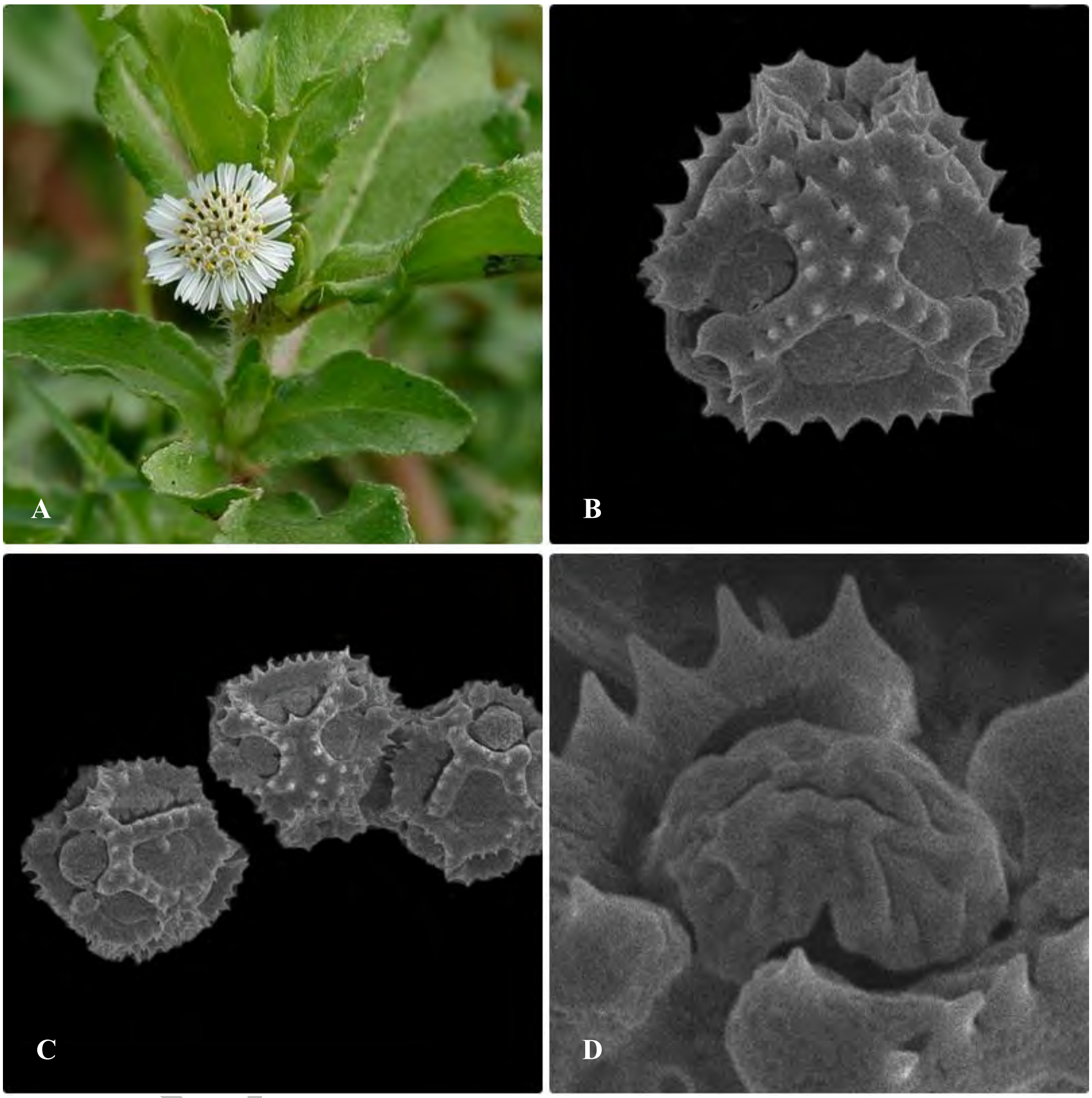

Plate 34: *Eclipta prostrate* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Echino-Lophate Ornamentation (D) Surface Sculpturing

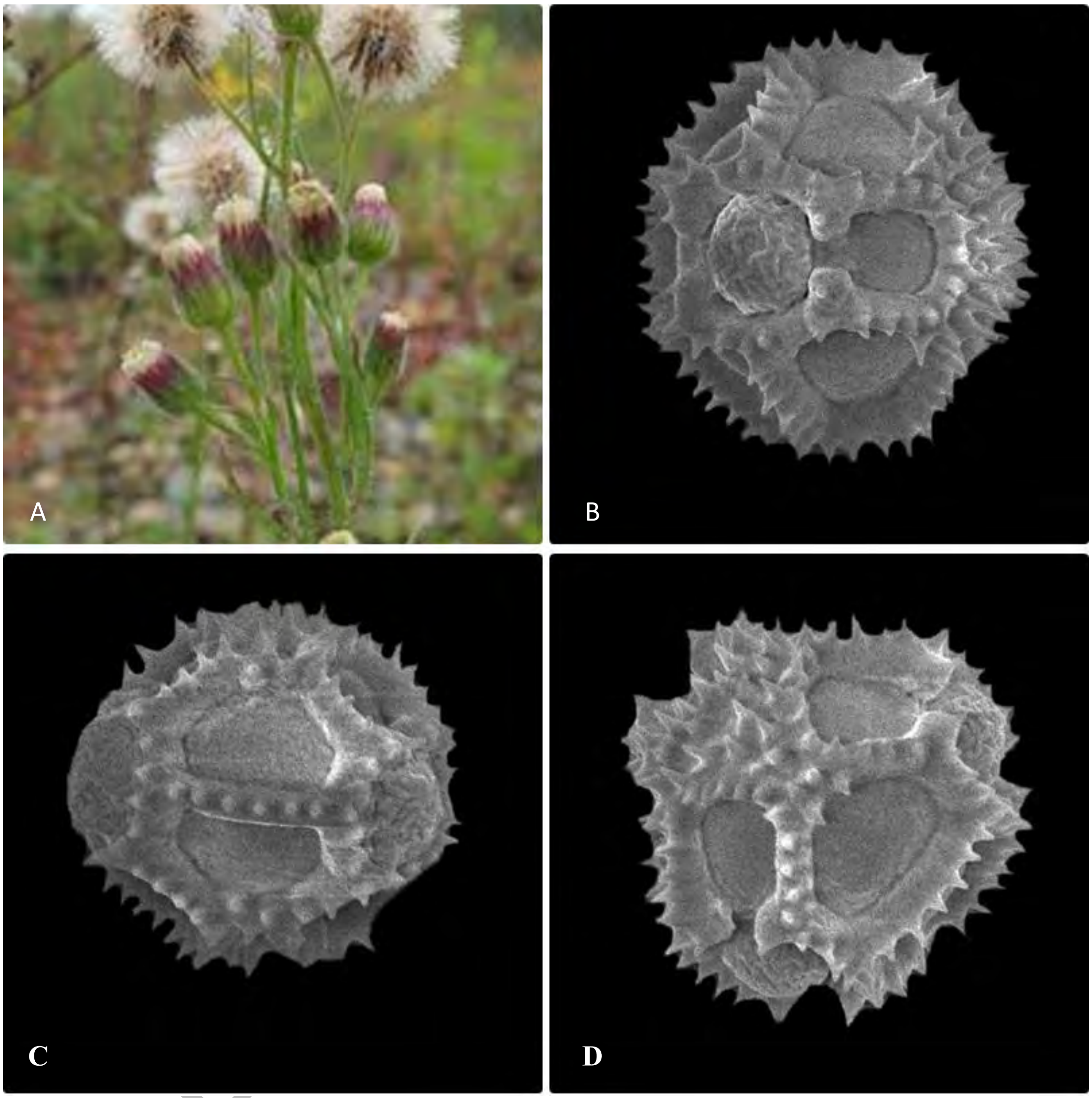

Plate 35: *Erigeron bonariensis* (A)Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Rounded orientation (D) Echinate Exine Sculpturing

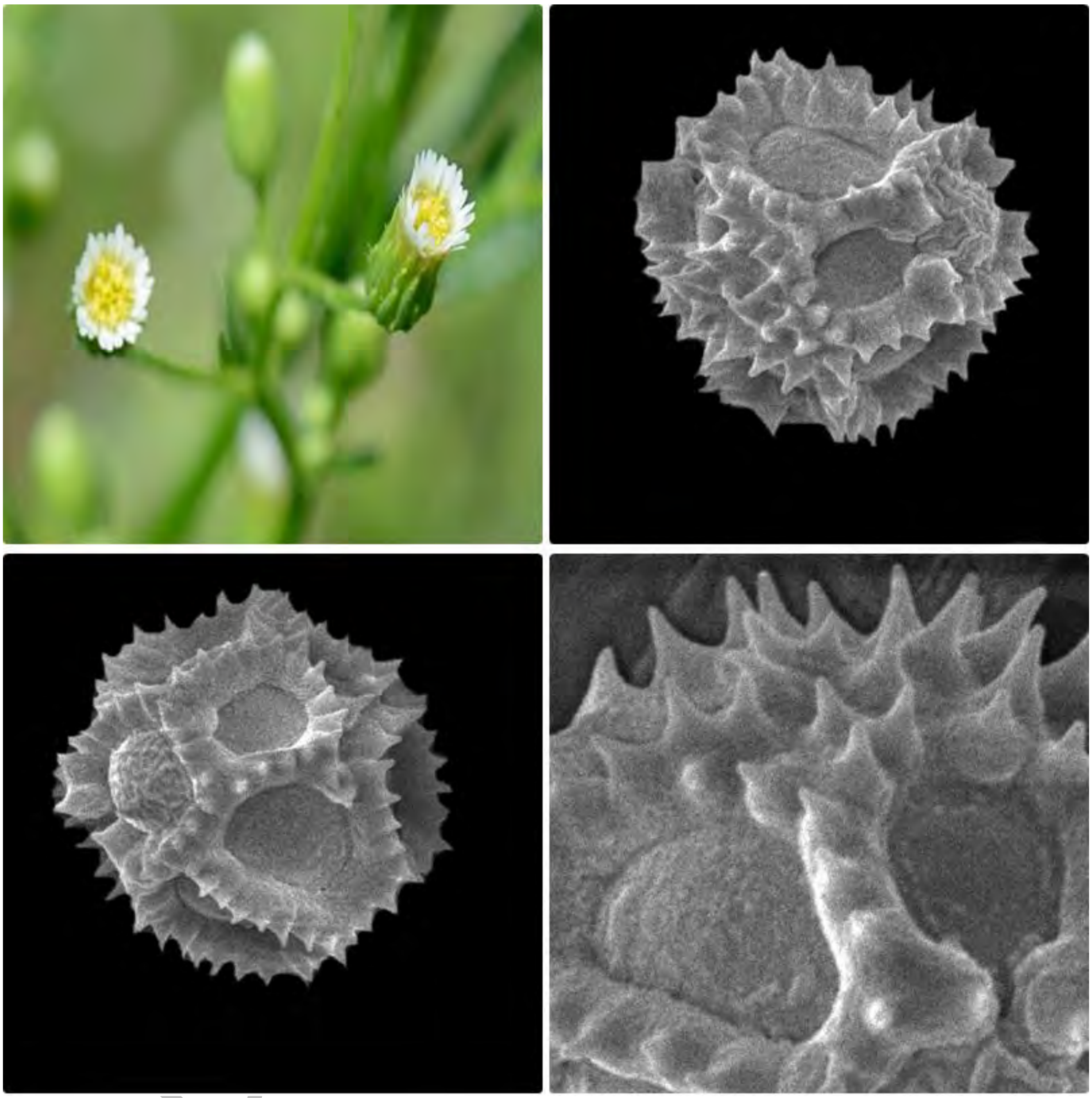

Plate 36: *Erigeron Canadensis* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Rounded sunken orientation (D) Surface Sculpturing

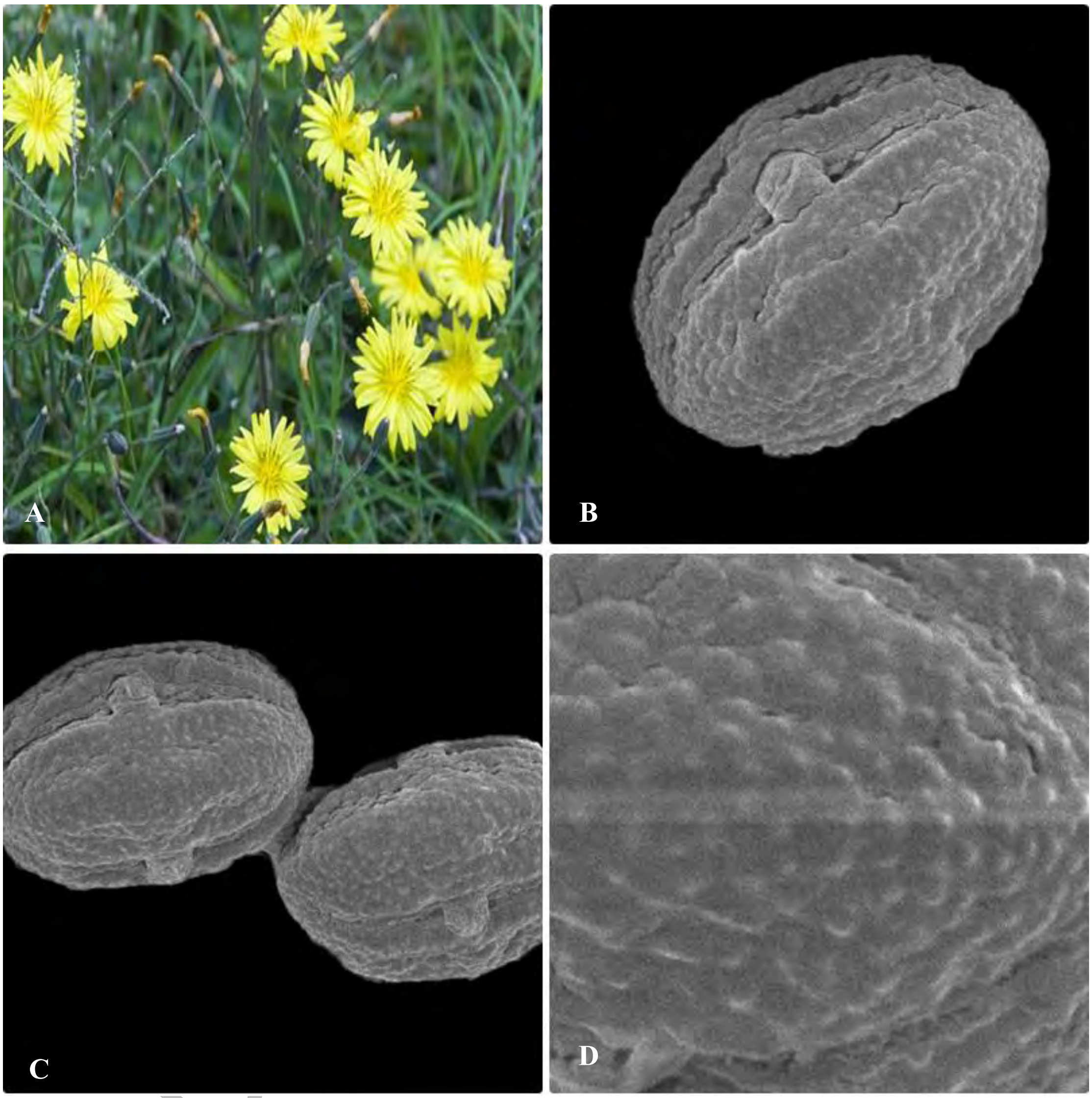

Plate 37:*Ixeris polycephala* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Echinate Pollen Ornamentation (D) Surface Sculpturing

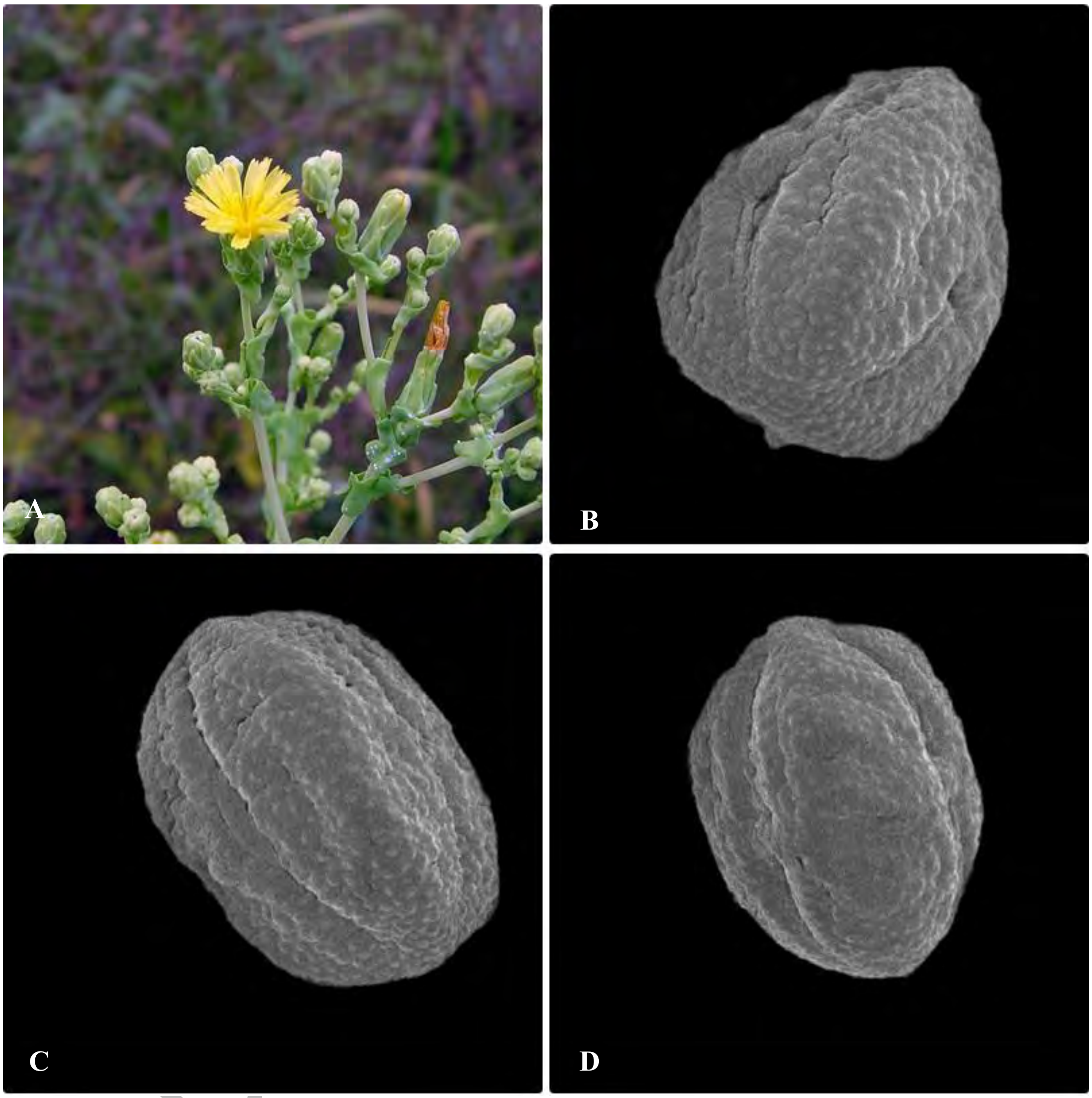

Plate 38:*Lactuca sativa* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Equatorial View (D) Echinate Sculpturing

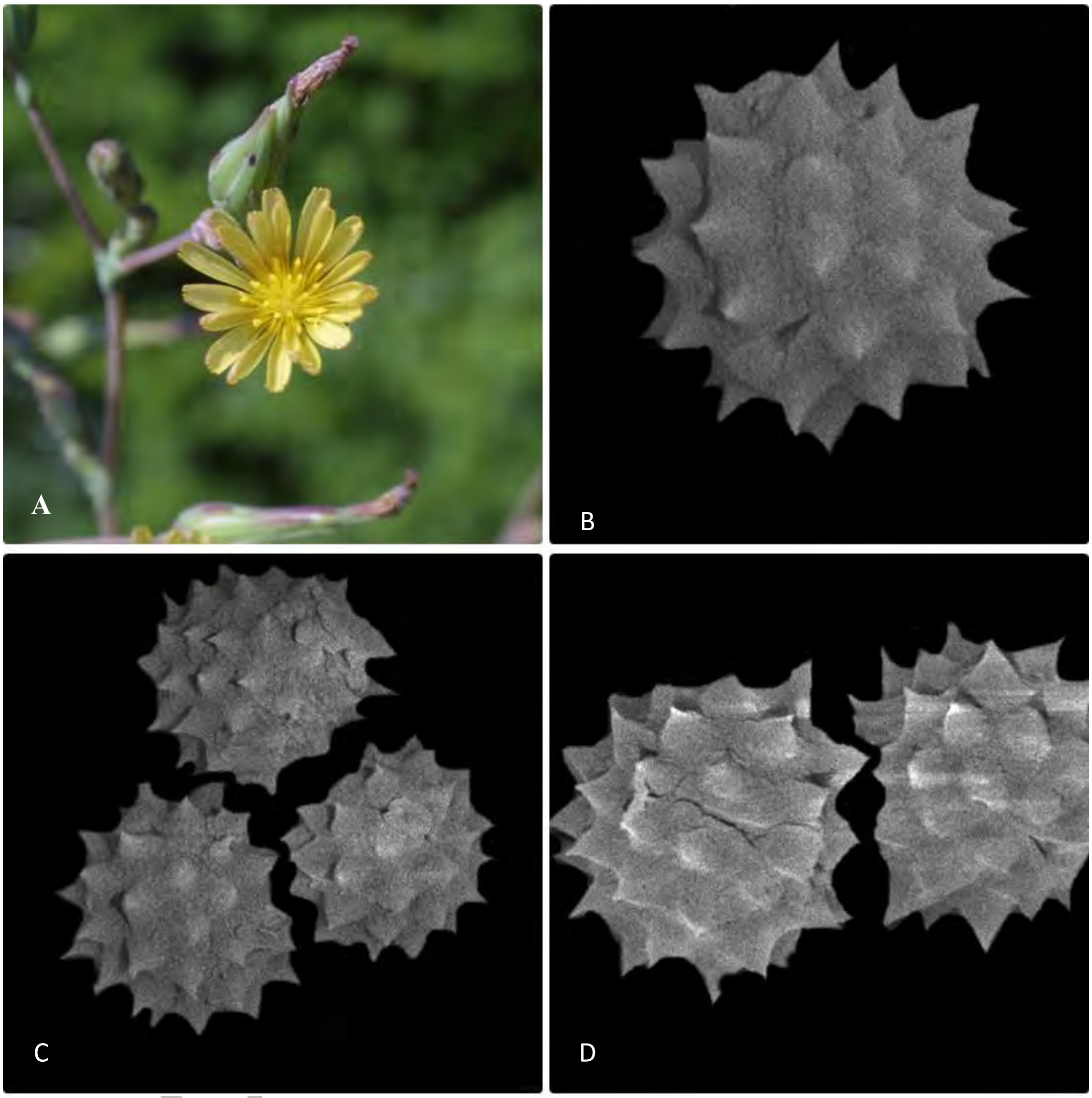

Plate 39:*Lactuca serriola* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Elliptical sunken orientation (D) Echinate Exine Sculpturing

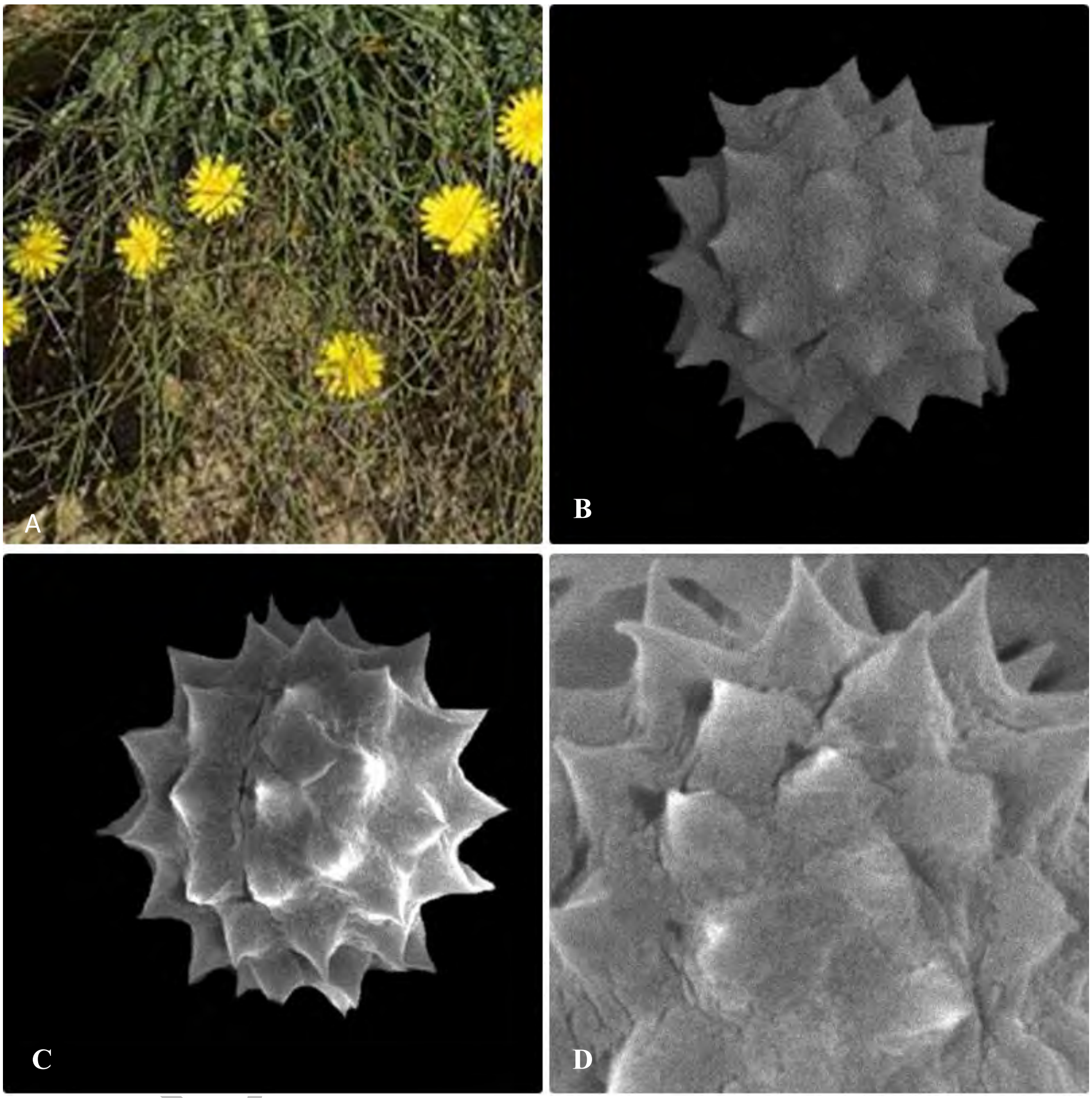

Plate 40:*Launea naudicaulis* (A)Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Rounded sunken orientation (D) Surface Sculpturing

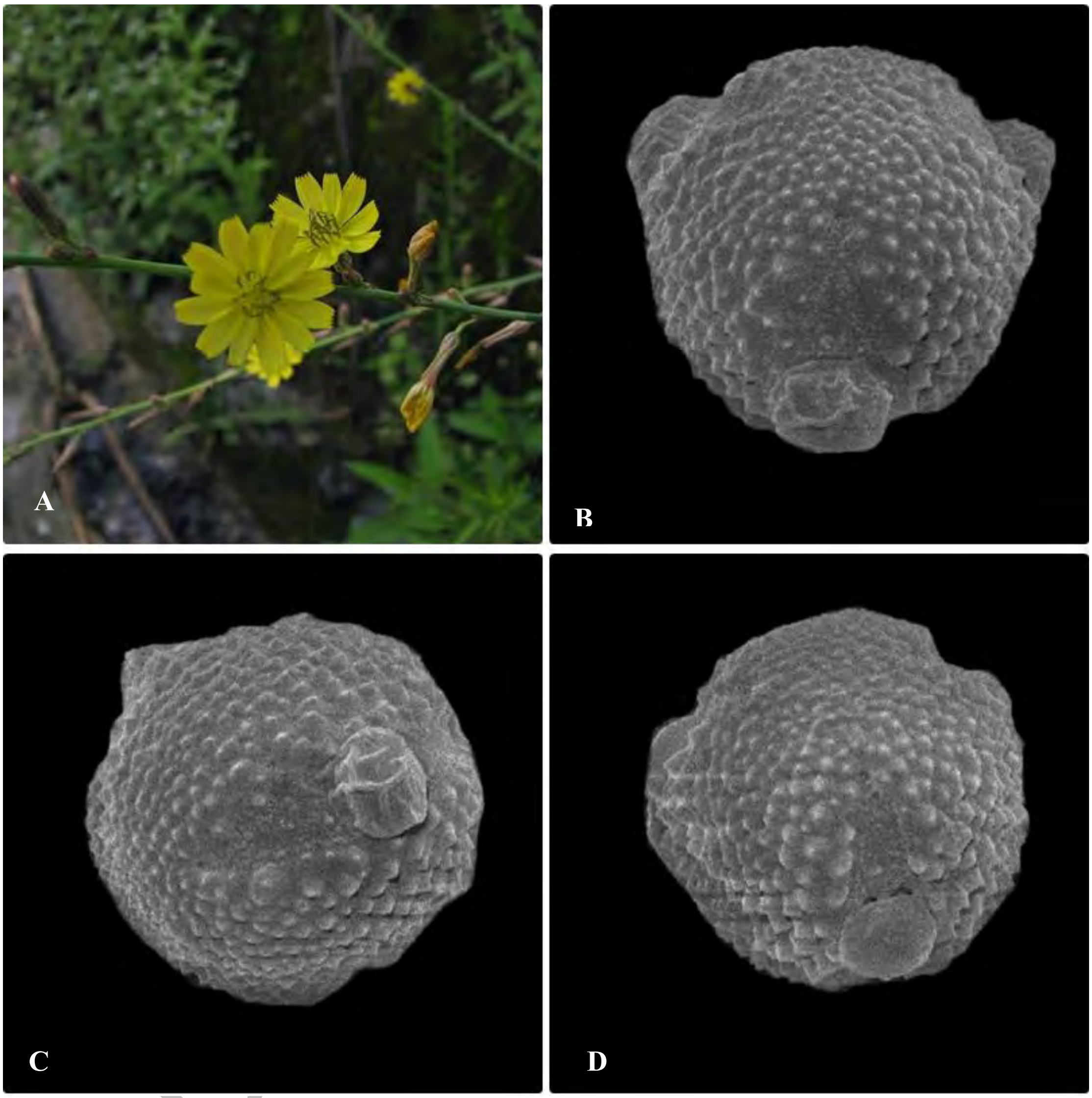

Plate 41: *Launea procumbens* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Elliptical sunken orientation (D) Micro-reticulate Echinate Exine Sculpturing

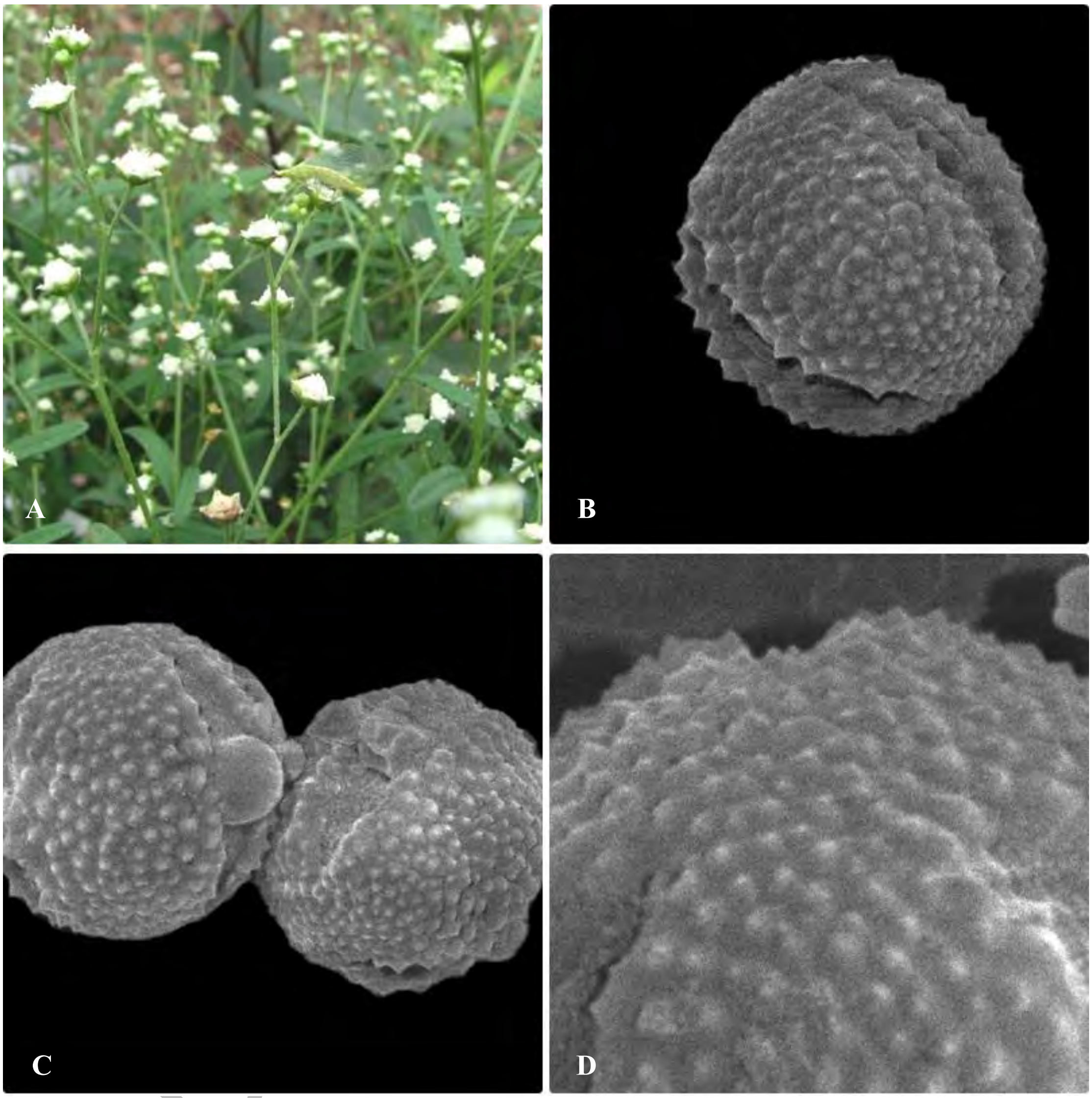

Plate 42: *Parthenium hysterophorus* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Rounded sunken orientation (D) Surface Sculpturing

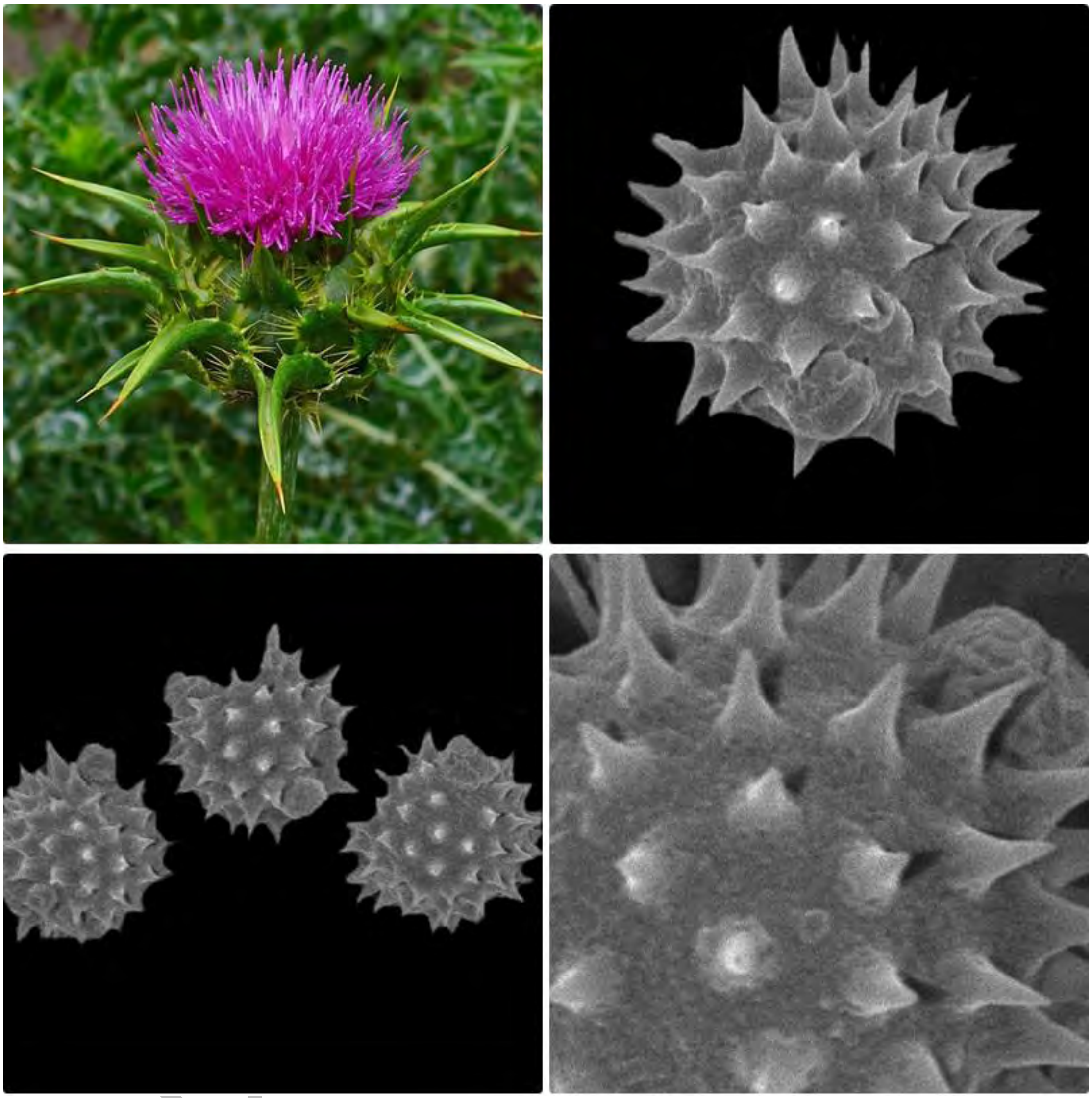

Plate 43: *Silybum marianum* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Echinate Pollen Orientation (D) Surface Sculpturing

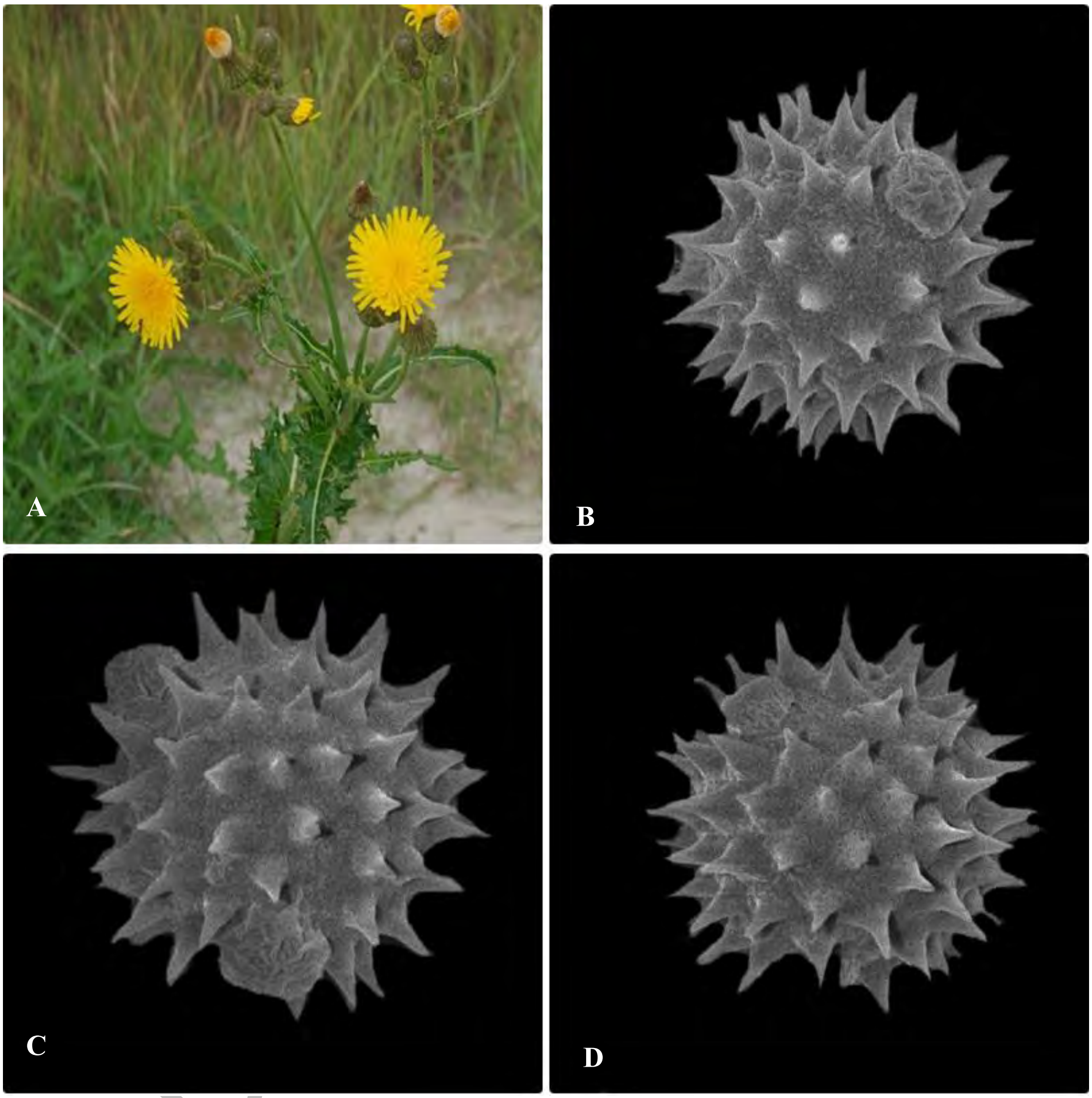

Plate 44: *Sonchus arvensis* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Elliptical sunken orientation (D) Echinate perforate- tectate Exine Sculpturing

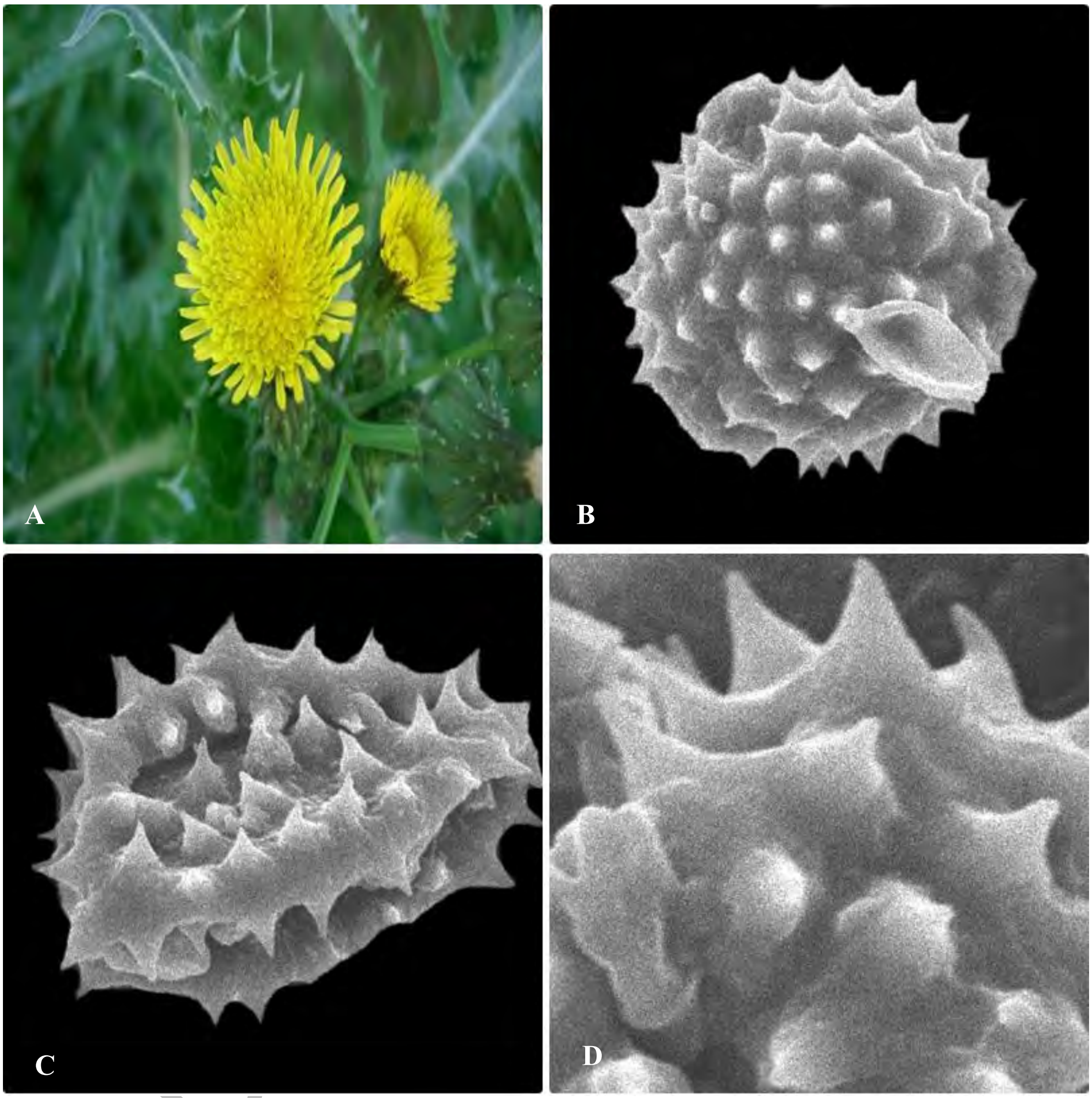

Plate 45:*Sonchus asper* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Elliptical Sunken Orientation (D) Echinate Exine Sculpturing

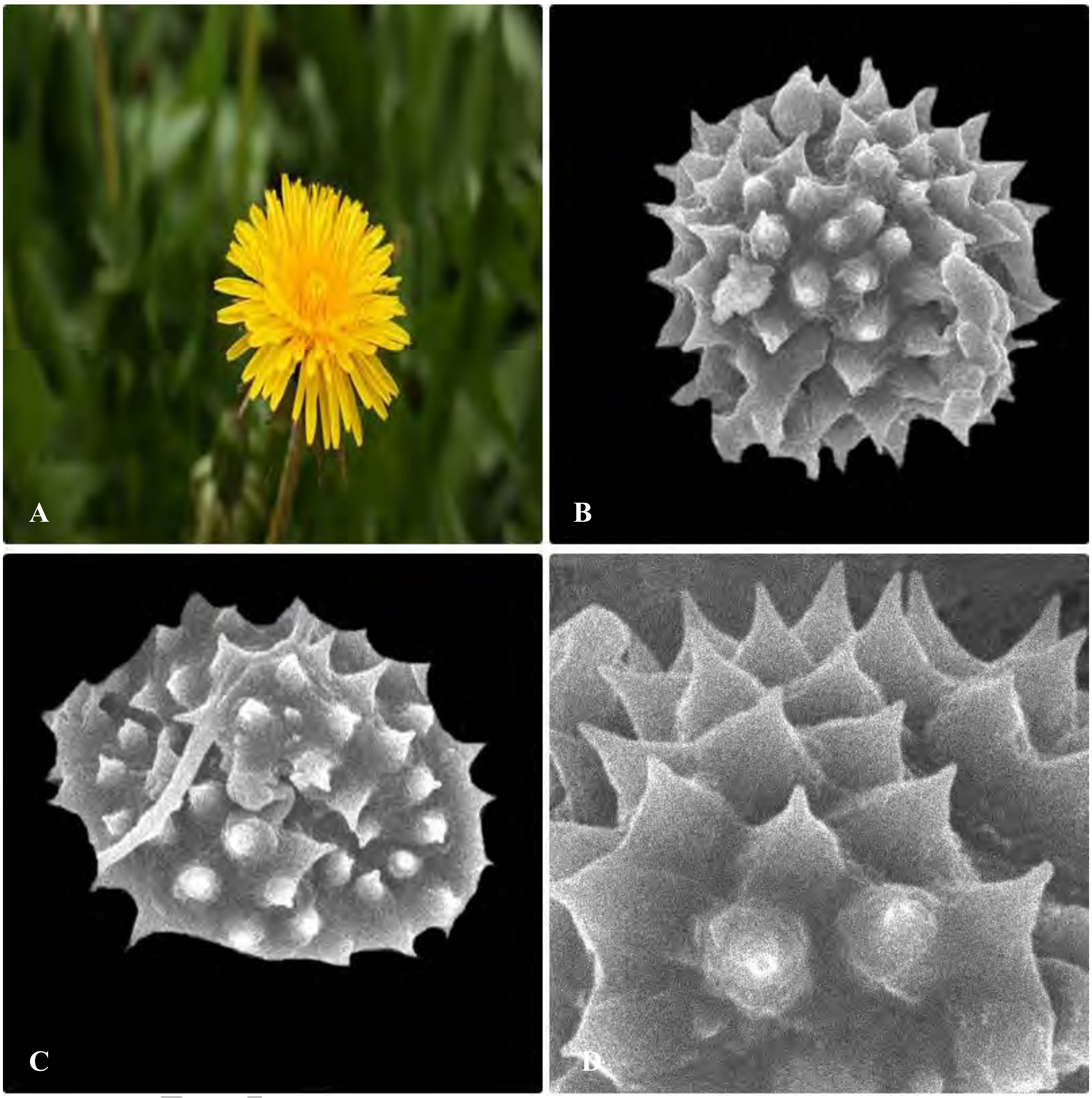

Plate 46:*Sonchus oleraceous* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Elliptical sunken orientation (D) Surface Sculpturing

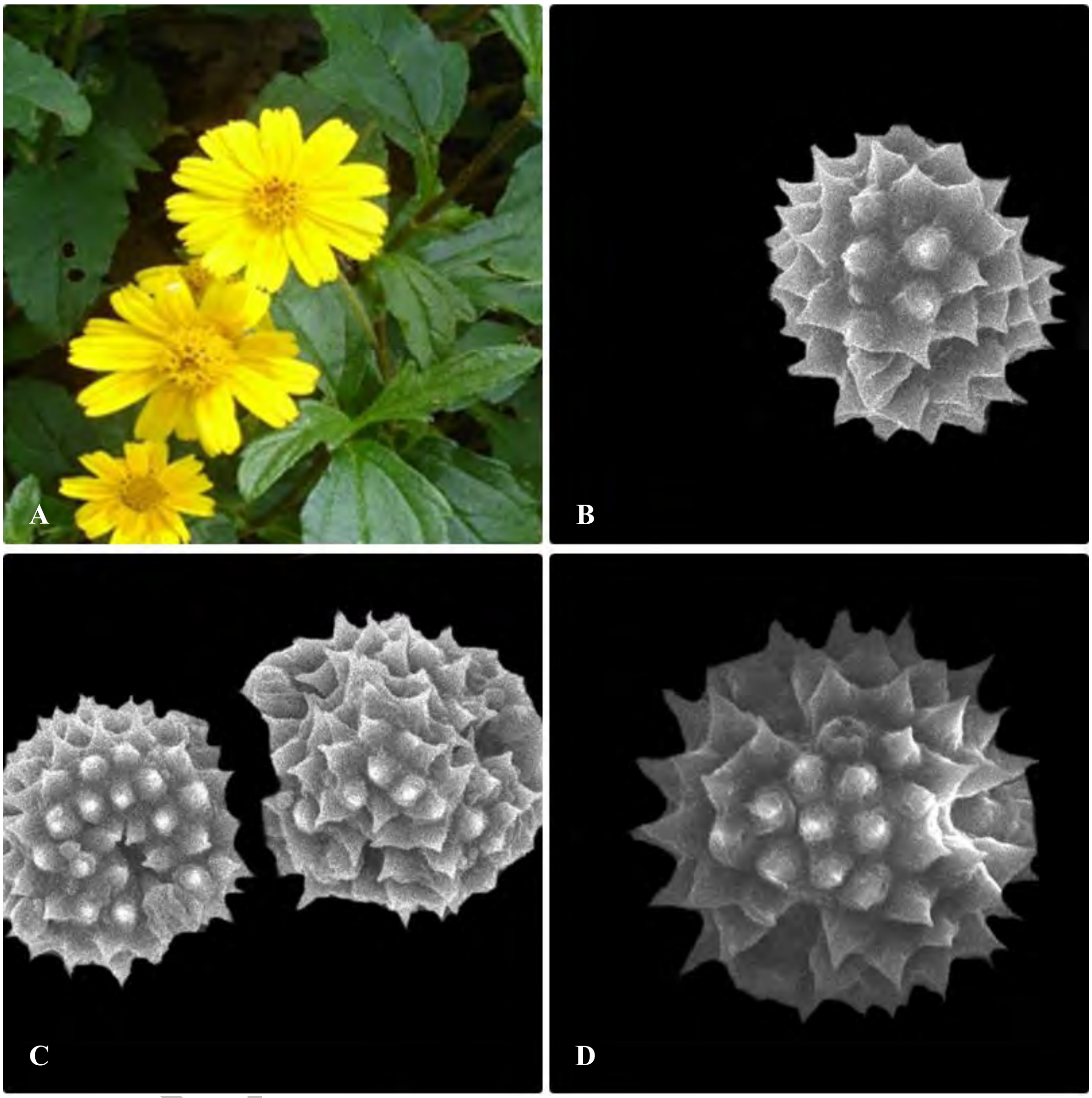

Plate 47:*Sphagneticola trilobata* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Elliptical sunken orientation (D) Echinate Exine Sculpturing

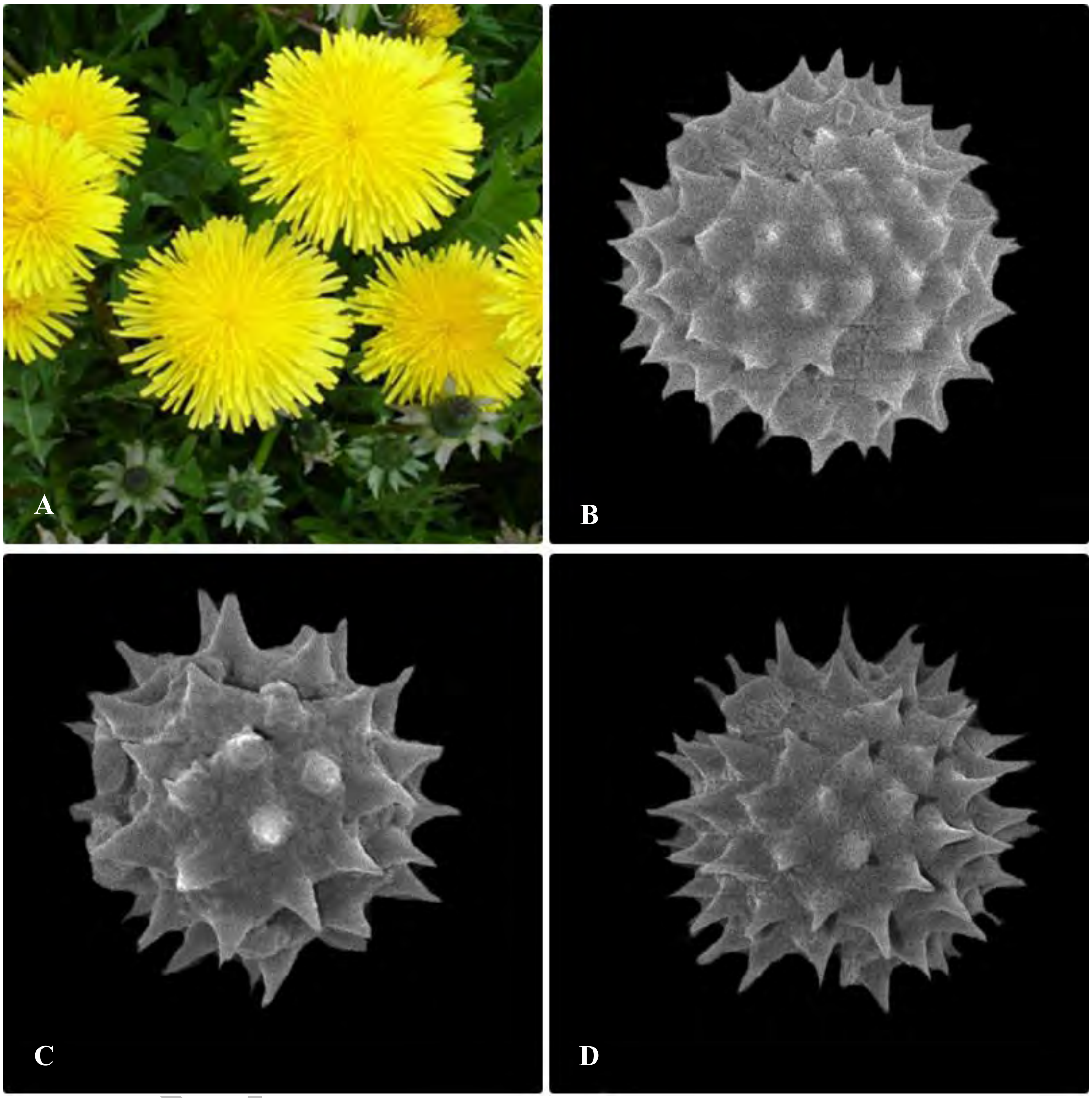

Plate 48:*Taraxacum offinale* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Rounded sunken orientation (D) Echino-lophate perforate Exine Sculpturing

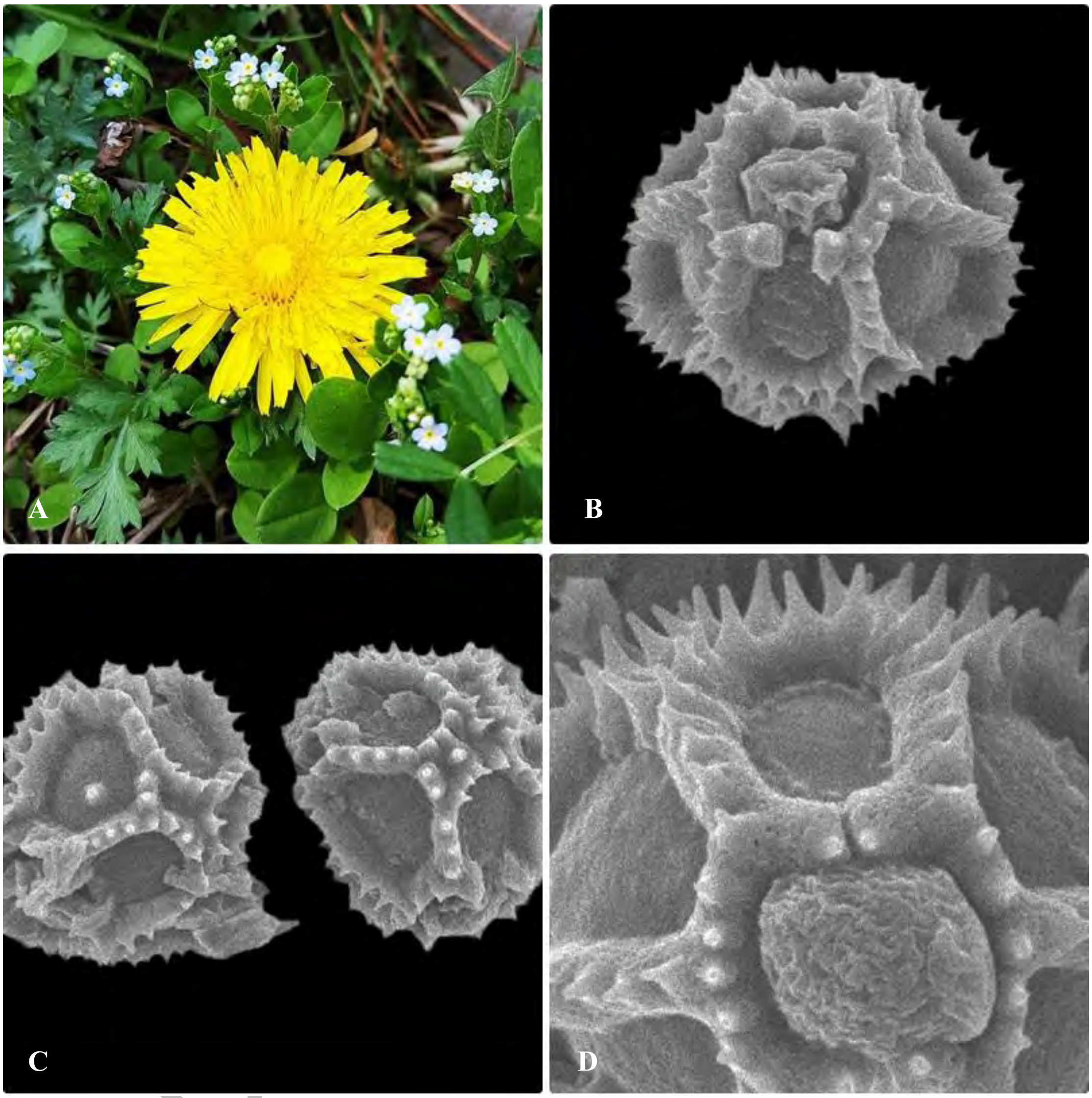

Plate 49:*Taraxacum platycarpum* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Rounded sunken orientation (D) Echinate Surface Sculpturing

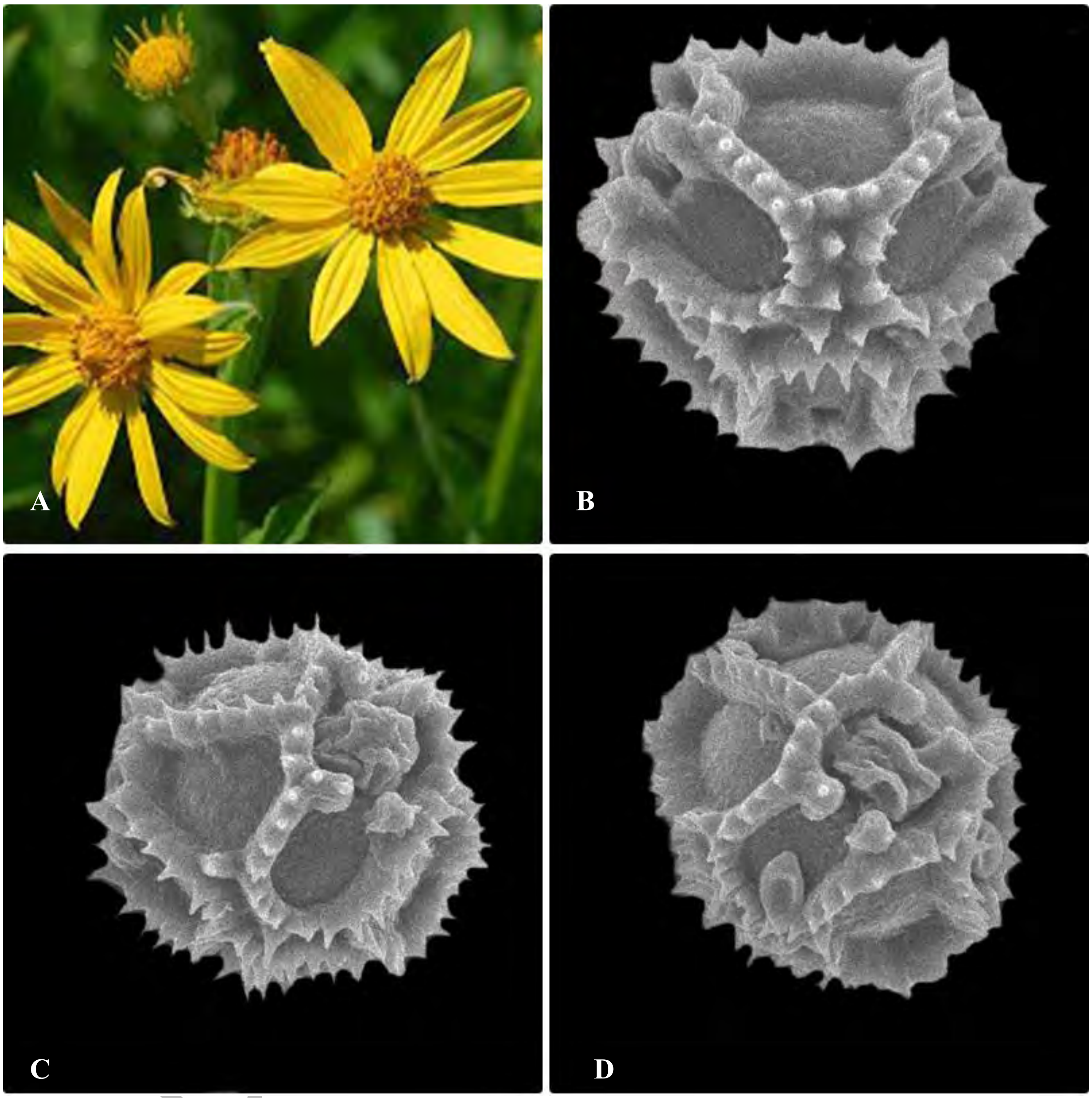

Plate 50: *Verbisinia eleusoides* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Rounded sunken orientation (D) Echino-lophate Exine Sculpturing

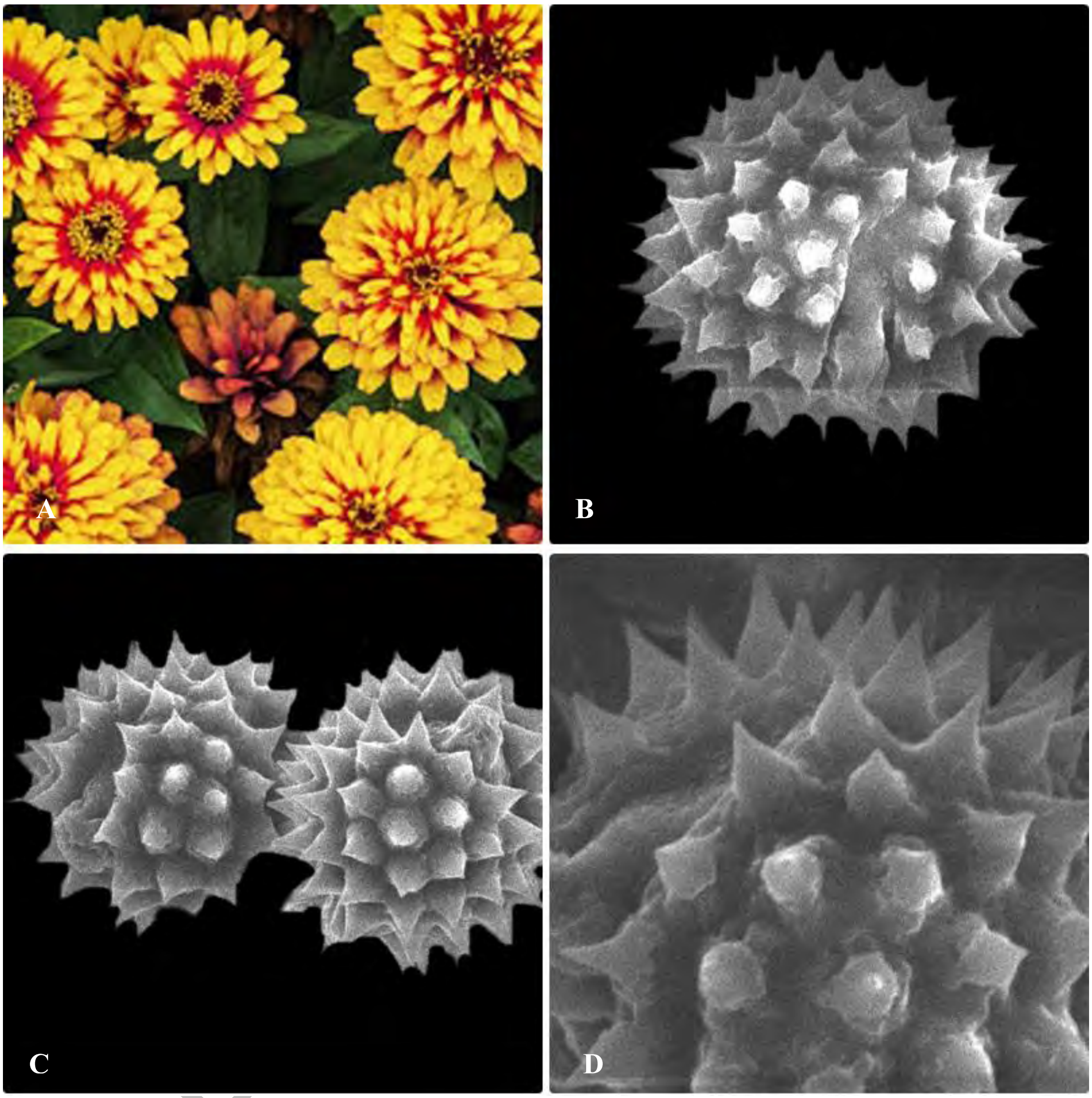

Plate 51: *Zinnia elegans* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Echinate with pointed spines ornamentation (D) Surface Sculpturing

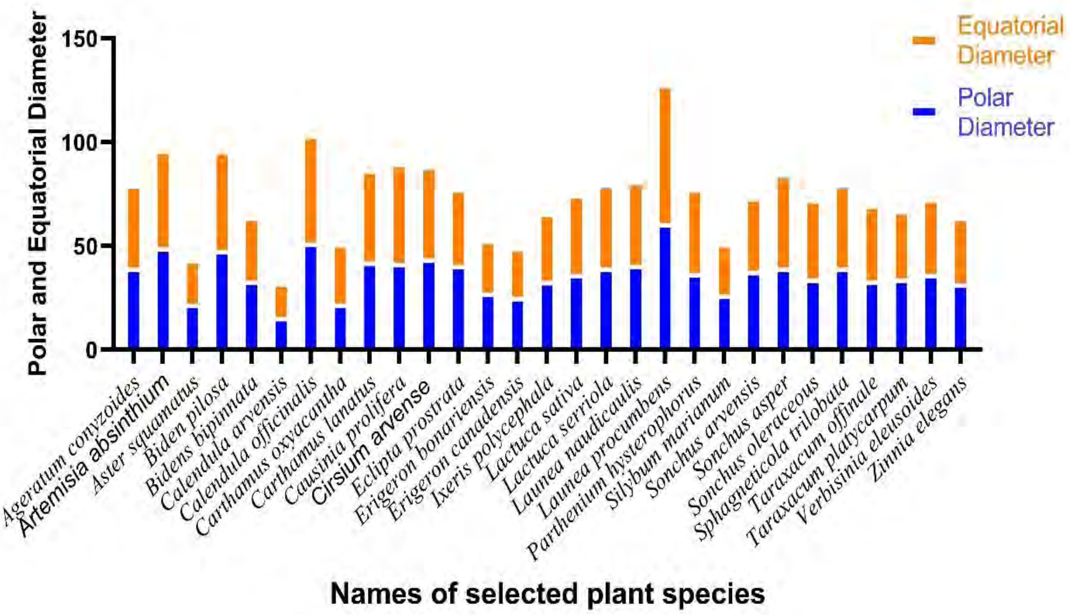

Figure 6: Mean values of Pollen diameter among Asterecious taxa

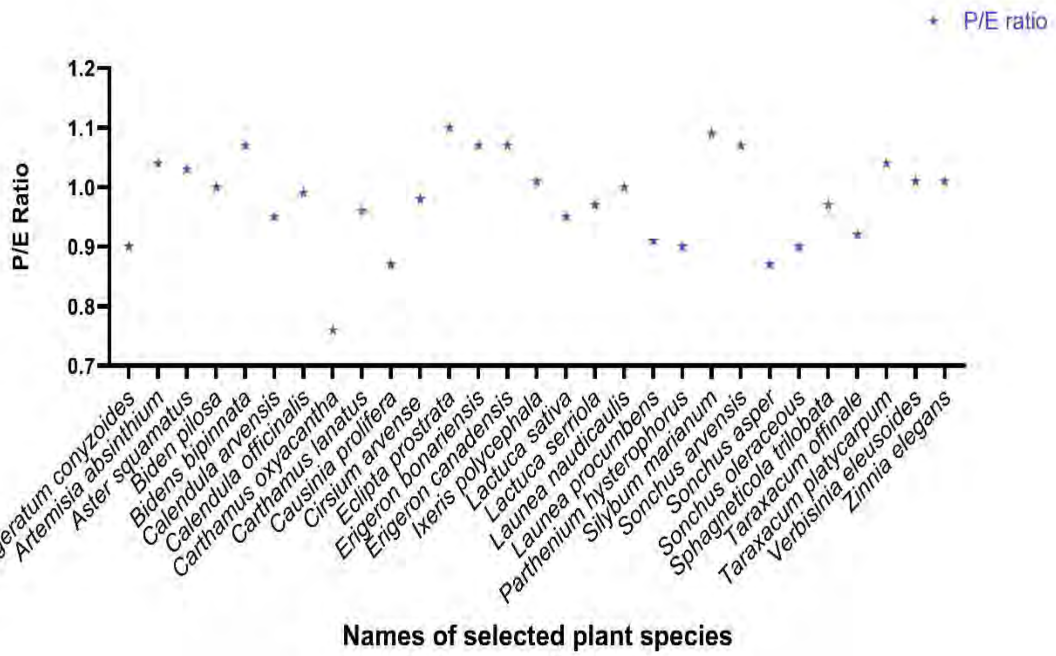

Figure 7: Variation in P/E ratio index of Asterecious taxa

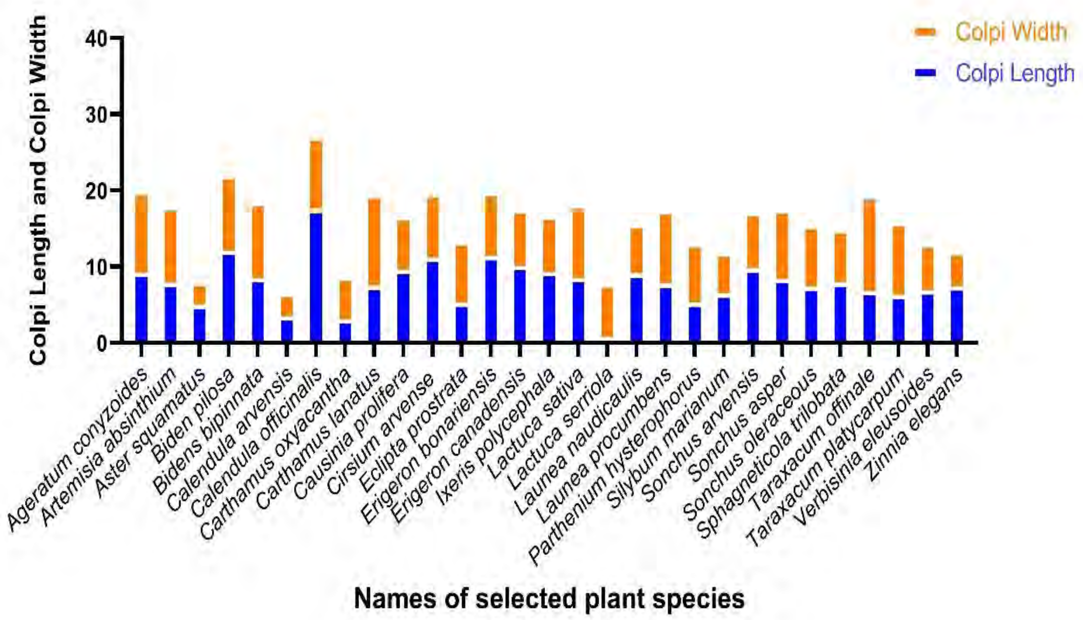

Figure 8: Mean data variations of colpi length and width in Asteracious taxa

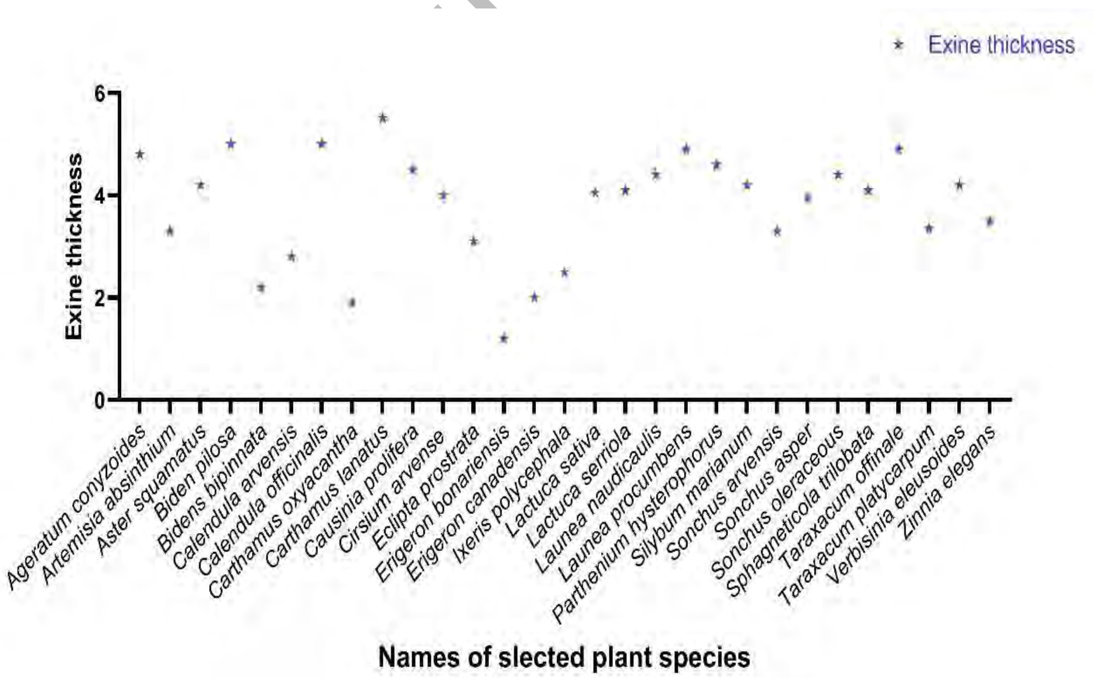

Figure 9: Mean exine thickness in Asteraceous Species.

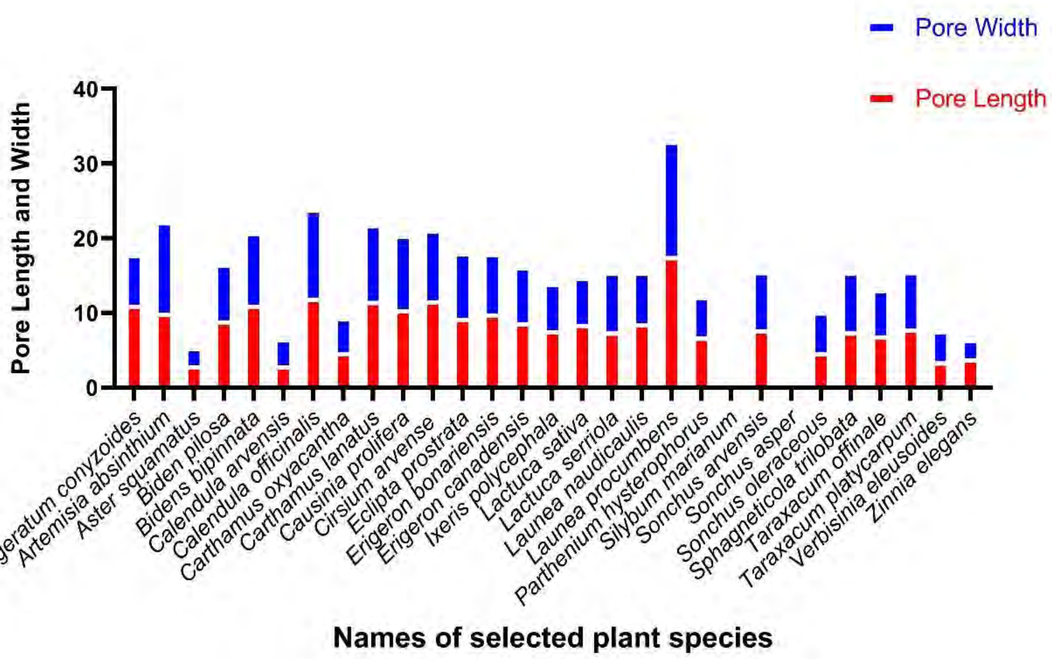

Figure 10: Data variations of pore length and width in Asteraceous species

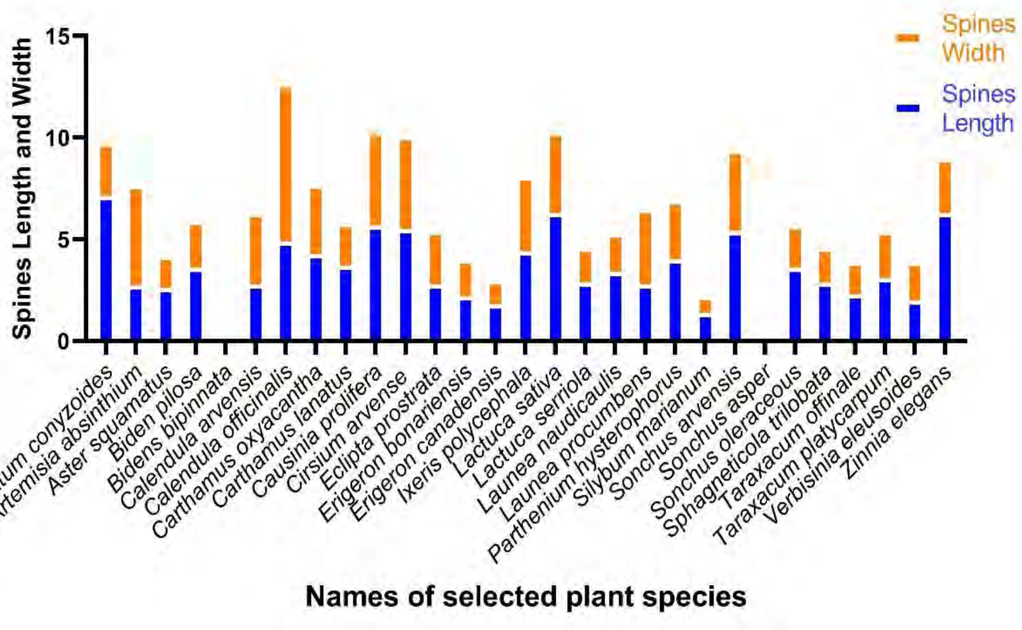

Figure 11: Variations in mean values of Spines Length & Width among Asteraceous taxa

Taxonomic Key based on Asteraceaous Pollen

1a. Lacunae absent ………………………. 2

1b. Lacunae present ……………………. 12

2a. Pollen type tetra colporate …………………… *Launea serriola*

2b. pollen type tri-tetrazononcolporate ……………….. 3

3a. Pores absent ………………………….. *Silybum marianum*

3b. Pores present ………………………….. 4

4a. Pollen shape sub-oblate ……………….*Causinia prolifera*

4b. Pollen shape spheroidal ……………………. 5

5a. Polar view is semi angular ………………. *Calendula officinalis*

5b. Polar view angular or circular ……………………….. 6

6a. Micro-reticulate pollen ornamentation …………………… *Launea procumbens*

6b. Pollen ornamentation is echinate ………………………. 7'

7a. Spine length is above 7µm …………………… *Ageratum conyzoides*

7b. Spine length is below 7 µm ………………………….. 8

8a. Polar view is irregular …………………… *Taraxacum officinale*

8b. Polar view is not circular ………………….. 9

9a. Spine length is below 2 µm …………………… *Erigeron canadensis*

9b. Spine length is above 2 µm……………………. 10

10a. Colpi width is above 10 µm ……………………..*Artemesia annua*

10 b. Colpi width is below 10 µm…………………… 11

11 a. Pore length is below 7 µm …………………. *Calendula arvensis*

11b . Pore length is above 7 µm ……………………… *Taraxacum polycarpum*

*1*2a. Pollen ornamentation is Psilate …………………… *Sonchus asper*

*1*2b. Pollen ornamentation is echinate or rugulate ……………….. 13

13a. Pollen type is tri-tetrazonocolporate ……………….. *Lactuca sativa*

13b. Pollen type is tri and tetrazonocoplorate ………………. 14

14a. Polar view is hexagonal rounded …………….V*erbesinia eleusoides*

14b. Polar view is circular or triangular ………………. 15

15a. Semi angular pollen …………….. *Launea naudicaultis*

15b. Triangular or circular pollen ………………… 16

16a. Tetrazonocolporate pollen ……………….. *Erigeron canadensis*

*1*6b. Tri or tetra colporate pollens ………………… 17

17a. Pollen shape is sub-oblate ………………….. *Carthamus oxyacantha*

17b. Pollen shape is spheroidal …………………….. 18

18a. Pollen ornamentation is tectate ……………………. *Sonchus arvensis*

18b. Pollen ornamentation is echinate ………………. 19

19a. Spines absent ………….. *Bidens bipinnata*

19b. Spines present …………. 20

20a. Pore width is below 3 µm …….. *Zinnia elegans*

20b. Pore width is above3 µm ……………. 21

21a. Polar diameter is above 45 µm ………………. *Bidens pilosa*

21b. Polar diameter is below 45 µm ………………… 22

22a. Rounded triangular pollen …………………… *Parthenium hysterophores*

22b. Polar view is circular or triangular ……………….. 23

23a. Echini arrangement is rather regular ……………. *Carthamus lanatus*

*2*3b. Regularly arranged Echini …………………….. 24

24a. Pollen shape is prolate spheroidal ……………….. *Eclipta prostrata*

24b. Pollen shape is oblate spheroidal ………………….. 25

25a. Pollen type is tetra colporate ……………………. *Sonchus oleraceous*

25b. Pollen type is tri or tetrazonocolporate ……………….. 26

26a. Lacunar shape is tetragonal ………………….. *Cirsium arvensis*

26b. Lacunar shape is pentagonal ………………. 27

27a. Pollen ornamentation is Echinate perforate …….. *Sphagneticola trilobata*

27b. Pollen ornamentation is echinate ……………………. 28

28a. Polar view circular …………………………. *Ixeris polycephala*

28b. Polar view is circular ……………………. *Aster squamatus*

3.1.1Asteraceaous Species

In Current Study 29 species of family Asteraceae were investigated using light and scanning electron microscopy. These micro morphological characters of pollens plays vital role in classification of taxa of Asteraceae family. Two types of pollen class have been observed in present study that is Dizonocolporate and Trizonocolporate. Two types of apertures have been seen among the 19 Asteraceae species that is Lacunae and non-lacunae. Different shapes of the pollens have been observed base on the measurement of P.E ratios (Mbagwu et al., 2009). Pollen character is considered as additional information during systematic studies by (Garnatje and Martin, 2007; Meo and Khan, 2004b). In his work he observed that all the species of genus *Echinops* contains same characters except one species *E. strigosus* on the basis of dissimilarity in pollen characters it is placed on other genus of the family Asteraceae.

(Meo and Khan, 2003) studied the pollen morphology of 2 species of Achellia genus i-e A. millefolium and A. santolina. Variations were observed in counting the number of spines between the coli A. mellifolium contains 5-6 rows of spines and A. santilina contains 4-5 rows of spines between each colpi. Compare the result of this study with (Dauti et al., 2017) A. mellifolium contains 4-5 rows of spines present between the colpi.

1 P/E Ratio

In the present work the smaller P/E ratio was found in *Carthamus oxyacantha* (0.7 µm) while the greater value was found in *Eclipta prostrata* (1.1 µm). Their polar and equatorial ratio, that is, P/E ratio varied between different taxa. Mbagwu et al., (2009) documented that palynological application is miscellaneous and multidisciplinary. Conversely, the role of pollen morphology is of significance in taxonomic argue for classification. The pollen characters are used for the organization of interspecies relationships among species of Asteraceae. From the present study it was concluded that the differences and similarities in pollen morphology are significant and could be subject for biosystematics purpose. Our results are in accordance with the findings of Wodehouse (1935) who recorded echinate and spheroidal pollens in *Berkheya heterophylla* (Arctotidae— Compositae). A similar result was found in the work of Mbagwu et al., (2007), who proposed that the pollens of *G. nigritiana* were spheroidal in shape and their general appearance was circular. According to the present study echinate ornamentation was found approximately in all members of family Asteraceae.

The large sized pollen grains were found in family Asteraceae members such as *G. regins*, *Tagetus erectus* and *C. officinale* and small pollen in *H. annuus* which is in line with the findings of Osman (2011) who studied small pollen in *Lasiopogon muscoides* (19–23 µm) and large in T. minuta (42–45 µm). The pollen grains were less or more similar in shape that is, spheroidal, oblate-spheroidal and prolatespheroidal. Mumtaz et al., (2000) reported a P/E ratio of 1.14 to1.31 in Artemisia species similar to the P/E ratio of C. sulphureus (1.2 µm) which is similar with the present study. Spines were minute and rudimentary in two species of Artemisia and Tanacetum gracile, while other species have well developed spines which are not in accordance with the present work because all pollen in the family Asteraceae in the present study possessed spines on pollen surface. Caramiello and Fossa (1994) noted the exine thickness in the range of 3.1–4.6 µm in four species of Artemisia which agreed with the exine thickness of the present findings. This parameter is useful at the species level, as almost all the species had different exine thickness. Spines are also considered as distinguishing characters in some tribes of family Asteraceae. Usually shorts spines in terms of size are found in *A. conyzoides* and *V. cinerea* while long spines are observed in *B. pilosa*. Walls of the pollen grains of mentioned species are thin same result was also reported by the study conducted by Perveen (1999) for the family Asteraceae.

(Wodehouse, 1935) works on the evolution of spines in family Asteraceae and proposed a decline in spines from long to short. Pollens with spines were considered to the primitive character in comparison with spineless pollens. Tribe Astereae was studied by (Clark et al., 1980) separates some genus on the basis of size of pollens, spine length and the number of spine among the colpi. Spine length and the number of spines between the colpi was also studied by (Abid and Qaiser, 2004; Tomb et al., 1974) and considered them as distinguishing characters for genus Inula of family Asteraceae. Exine morphology of sub tribe Ecliptinae was studied by (Coutinho et al., 2016). Pollen fertility of some genus was studied by (Qureshi et al., 2002) and it revealed that fertility of pollens plays significant role in cytology studies of chromosomes. Much research work is done on family Asteraceae by (Akyalcin et al., 2011; Dematteis and Pire, 2008; Jafari and Ghanbarian, 2007; Skvarla et al., 1977;

Urtubey and Tellería, 1998) and studied different qualitative and qualitative characters of pollens. (Farco and Dematteis, 2017) studied 10 species of genus Campuloclinium in terms of pollen morphology and also worked on diverse mitotic abnormalities. (Tellería, 2017) studied the exine ornamentation of pollen grains of family Asteraceae. (Zafar et al., 2007) studied 7 species of pollens and observed characters that include pollen size shape, exine ornamentation, aperture types, spine length and number of spines between the colpi. The present study could be taxonomically significant for the correct identification and species delimitations of family Asteraceae. Colpi number in pollen plays important role in tracing evolutionary relationship among the reported species of present study. In advanced dicotyledonous plants more number of colpi are present as compared to the primitive ones. Primitive species either contains single colpi (monocolpate) or they are without colpi (acolpate) (Adedeji, 2005).

Apart from generic characters there are some quantitative characters which also help in identification of species. It has been observed in most of the species of this family that the diameter of species is small. Erdtman (1952) categorized pollen according to size into different groups namely perminuta (diameter less than 10µm), minuta (diameter 10-25µm), media (diameter 25-50µm), magna (diameter 50-100µm), permagna (diameter 100-200µm), giganta (diameter greater than 200µm). Keeping in view this classification some species of family Asteraceae belong to the groups' minuta & media. *A. conyzoides* is in the group minuta while the other species belong to the group media which means that the pollen diameter measured is classificatory for others and delimiting for *A. conyzoides*.

2 Pollen Shape

In a study conducted by Khan (2006) documented the presence of tetrazonocolporate pollen in *Calendula officinalis* and also studied the size of spines in comparison with other species zcnm\``of this tribe. The result of present study differs from previousfindings as tri- tetracolporate pollen were found with spine ornamentation echinate having broad base. Akinnubi et al., (2014) reported polypantoporate and circular pollen in genus *Bidens*. Zhang et al., (2004) reported trizonocolporate pollen in *Bidens bipinnata*.

Bülbület al., (2013) studied genus *Carthamus* from flora of turkey and stated tricolporate iso-polar echinate, spheroidal or oblate spheroidal pollen. Jafari et al., (2007) observed diverse outlines of pollen surface in family Asteraceae and detected verrucate pattern of exine in *Cousinia*, sub-echinate or verrucate pattern in C*entaurea*, echinate pollen in *Carthamus* and echinate surface with short colpi in *Cirsium*.

Wróblewska et al., (2016) studied pollens of ornamental taxa of family with respect to bees as a source of pollen and reported tricolporate, echinate and oblate-spheroidal pollen in genus *Zinnia*. Bolick (1978) study exine pattern in different tribe of Compositae Heliantheae, Calenduleae, Sececioneae, Eupatorieae and Calenduleae etc with respect to effect of mechanical stresses on exine and its evolution in response to the factor. Bemer (1987) examined cladistics of 27 different tribe of family Asteraceae relating 81 different character and record that Heliantheae is monophyletic tribe and the hypothesis that other tribe of Asteraceae is evolved from this proven wrong.

Although the study of morphological characters of pollen observed through microscope i.e pattern of surface, ornamentation, spines, colpi, pores, size and shape of tribe Cichorieae has revealed prominent diagnostic characters related to the flora, vegetative and chromosomal characters of the tribe, these characters show some variations with the taxonomic classification of the tribe into sub families and sub tribes. On the other hand in some genera surface pattern is unique and some tribes and sub tribes also show similarity in the surface pattern of pollen grains, although other features such as size range and shapes of pollen grains do not differentiate them from other species of the tribe. So it is clear that only morphological characters cannot be used as the base of taxonomic classification of the family or tribe. Though, it is known that these morphological features of pollen demonstrations evolutionary sequences similar to those in other structures, and then it may need to be given as much weight as any other morphological character. On this assumption, in the pollen morphology of species examined, some in consistencies and alternative relationship have been suggested in correlation with taxonomic classification proposed by (Johnson and Briggs 1975). The general features of tribe Cichorieae, taken together are not repeated in other tribes. This gives tribe Cichorieae a unique taxonomic status. Combined efforts of evolutionary ecological and systematic studies are still important to aid in understanding the advancement of this interesting tribe.

Pollen morphological studies have great importance in taxonomic study of plants and the improvement in microscopic technique has led to the utilization of novel morphological features of pollen for taxonomic purposes. The characteristics of pollen not only provide the information but they are also useful in improving the systematic position of their members with respect to their families, sub-families or tribe. Wodehouse (1935) concluded that not only the overall morphological characters are significant in delimitation of species. Two major groups are formed in Asteraceae based on their pollen characters i.e., non-lophate and lophate pollen. The former ones characterize in *Sonchus* and *Lactuca*. Surface ornamentation of exine is echinate in all the members of Lactuceae, also some members are trizonocolporate while some members are also tetrazonocolporate (Qureshi et al., 2002).

3 Spines Variation

(Wodehouse, 1935) works on the evolution of spines in family Asteraceae and proposed a decline in spines from long to short. Pollen with spines was considered to the primitive character in comparison with spineless pollen. Tribe Astereae was studied by (Clark et al., 1980) separates some genus on the basis of size of pollens, spine length and the number of spine among the colpi. Spine length and the number of spines between the colpi was also studied by (Abid and Qaiser, 2004; Tomb et al., 1974). In current study all the taxa had echinolophate or echinate ornamentation consist both spine and lophae except for *Sonchus asper* it has psilate type of sculpturing. Lophae are the partitions of pollen surface into small cubicle or circular portion separated by walls known as Muri (Wodehouse, 1935).Some species show very clear recognizable lacuna i.e. genus *Lactuca* while *Taraxacum* and *Launeae* showed less visible lacuna which revealed that the type of lacunae was slightly different from that of *Lactuca*.

4 Exine Sculpturing

Echinolophate sculpturing in *Lactuca* is considered recent as compare to echinate sculpture in other tribe of Asteraceae or we can say echinate ornamentation is primitive in Asteraceae (Jafari & Ghanbarian, 2007). In genus *Lactuca* entire surface of pollen was covered by spine except the depression known as lacunae, exine seems smooth in these regions but the wall of lacunae were echinate.

Al-Tameme (2014) observed echinolophate pollen in genus *Koelpinia*. Jeffrey et al., (2007) account echinolophate colporate pollen in genus *Lactuca*. Diez et al., (1999) reported echinolophate and trizonocolporate pollen in *Sonchus* and Launaea. Perveen (1999) investigate echinolophate trizonocolporate and oblate pollen in genus *Sonchus*. Blackmore (1981) reported echinolophate ornamentation in his study.

The ornamentation of exine and characters of spines are very significant in the phylogenetic relationship of the family (Pınar and Dönmez, 2000). Variation in exine thickness among the species in this family was also observed previously (Ahmad et al., 2013). All the studied taxa have tricolporate pollen as the number of colpi on pollen grains has been a useful tool in tracing evolutionary relationship among the species. The advanced dicotyledons have more colpi than the primitive ones, with either a colpus (monocolpate) or none at all (acolpate) (Akinnubi et al., 2014 and Adedeji, 2005). The dendrogram showing the similarity index of the species on bases of the studied taxa of family Asteraceae. Highest similarity found between *T. platycarpum* and *I. polycephala* opposite to the one between *L. sativa* and *S. arvensis* which were distantly related. *S. oleraceous* and *T. officinale* show more similarity index as compared to *L. naudicaulis, L.sativa* and *S. arvensis.*

Table 5: Qualitative data of pollen of family Amaranthaceae members from Potohar region of Pakistan

Sr. No	Taxa	Pollen type	Shape	Pollen ornamentation	Pore ornamentation
1.	*Achyranthus aspera*	Apolar	Spheroidal	Scabrate	Sunken
2.	*Aerva javanica*	Apolar	Spheroidal	Microechinate	Sunken
3.	*Amaranthus gracizens*	Apolar	Spheroidal	Scabrate	Sunken
4.	*Amaranthus hybridus*	Apolar	Spheroidal	Microechinate	Sunken
5.	*Amaranthus spinosus*	Apolar	Spheroidal	Microechinate	Sunken
6.	*Amaranthus viridis*	Apolar	Spheroidal	Microechinate	Sunken
7.	*Atriplex stoeksii*	Apolar	Spheroidal	Scabrate	Sunken
8.	*Celosia Argentia*	Apolar	Spheroidal	Microechinate	Sunken
9.	*Chenopodium album*	Apolar	Spheroidal	Scabrate	Sunken
10.	*Chenopodium ambrosioides*	-	Spheroidal	Microechinate	Sunken
11.	*Chenopodium murale*	Apolar	Spheroidal	Microechinate	Sunken
12.	*Digeria muricata*	Apolar	Spheroidal	Scabrate	Sunken
13.	*Kochia indica*	Apolar	Spheroidal	Scabrate	Sunken
14.	*Kochia lonifolia*	Apolar	Spheroidal	Scabrate	Sunken
15.	*Pupalia lappaceae*	Apolar	Spheroidal	Microechinate	Sunken
16.	*Salsola lubricate*	Apolar	Spheroidal	Scabrate	Sunken
17.	*Sauda fruitcosa*	Apolar	Spheroidal	Microechinate	Sunken

Table 6: Quantitative Data of Amaranthaceae members from Potohar Region of Pakistan

Sr. No	Taxa	Polar diameter (µm) min (mean ± Std error) max	Equatorial diameter (µm) min (mean ± Std error) max	P/E ratio (µm)	Exine thickness (µm) min (mean ± Std error) max	Pore length (µm) min (mean ± Std error) max	Pore width (µm) min (mean ± Std error) max
1	*Achyranthus aspera*	22.75 (23.95 ± 0.52) 25.5	22.25 (23.90 ± 0.72) 25.5	1.00	1.0 (1.55 ± 0.16) 2.0	1.0 (1.85 ± 0.23) 2.25	0.75 (1.2 ± 0.14) 1.5
2	*Aerva javanica*	18.25 (20.2 ± 0.50) 21.0	19.0 (20.1 ± 0.32) 20.75	1.00	1.0 (1.2 ± 0.09) 1.5	1.5 (1.70 ± 0.09) 2.0	1.5 (1.75 ± 0.11) 2.0
3	*Amaranthus gracizens*	12.75 (16.2 ± 1.02) 18.25	12.85 (18.87 ± 1.9) 22.75	0.85	1.0 (1.3 ± 0.09) 1.5	0.02 (0.04 ± 0.01)	0.25 (0.55 ± 0.09) 0.75
4	*Amaranthus hybridus*	23.25 (26.25-21.2)±2.09	27.25 (31.25-23.7)±2.85	0.85	4.55 (5.25-4)±0.48	3(2.5-3.5) ±0.16	3.6(3.25-4) ±0.12
5	*Amaranthus spinosus*	54.25(51.25-56.25)±0.88	49.6(38.75-60.50)±0.29	1.09	5.20(4.50-6.0)±0.28	12(10.2-13.7) ±0.68	12(11.25-13) ±0.29
6	*Amaranthus viridis*	27.8(26.5- 29.7)±0.68	28.5(26.2-31)±0.78	0.97	4.11(2.75-6)±0.72	4.7(3.5-6.25) ±0.45	4.7(3.50-5.50) ±0.40
7	*Atriplex stoeksii*	18.0 (20.0 ± 0.84) 22.75	17.75 (18.85 ± 0.49) 20.2	1.07	1.0 (1.6 ± 0.23) 2.25	0.75 (1.20 ± 0.27) 2.25	0.5 (0.75 ± 0.79) 1.0
8	*Celosia Argentia*	13.50 (16.2 ± 0.85) 18.0	13.25 (15.65 ± 1.0) 18.50	1.03	1.5 (2.15 ± 0.3) 3.0	0.75 (1.05 ± 0.09) 1.25	0.5 (0.7 ± 0.09) 1.0
9	*Chenopodium album*	27.1(25.5-29.2)±0.71	25.8(22.7-31.5)±1.49	1.05	4.40(2.75-6)±0.65	4.75 (3.75-6.00) ±0.93	3.00 (2.25-3.75) ±0.28
10	*Chenopodium ambrosioides*	7.75(11.00-5.25)±0.88	7.67(10.75-5.50)±0.78	1.01	.88(1.25-.50)0±.11	3.85 (2.50-4.50) ±0.38	2.75 (2.25-3.25) ±0.18
11	*Chenopodium murale*	12.75 (14.75-9.50)±2.06	10.75 (12.5-9.75)±1.04	1.18	2.00 (2.75-1.25)±0.5	4.20 (3.75-4.75) ±0.20	3.30 (2.25-4.25) ±0.34

12	*Digeria muricata*	12.75 (16.85 ± 1.73) 20.75	16.25 (17.85 ± 0.53) 19.5	0.96	1.75 (2.0 ± 0.11) 2.25	0.5 (0.6 ± 0.06) 0.75	0.25 (0.50 ± 0.07) 0.75
13	*Kochia indica*	12.0 (13.95 ± 0.63) 15.50	12.0 (13.45 ± 0.70) 15.50	0.99	0.75 (0.95 ± 0.09) 1.25	0.75 (1.1 ± 0.23) 2.0	0.75 (1.0 ± 0.13) 1.5
14	*Kochia lonifolia*	13.0 (15.25 ± 1.21) 19.75	13.5 (15.50 ± 0.75) 17.25	0.98	0.75 (1.05 ± 0.09) 1.25	1.75 (1.95 ± 0.09) 2.25	1.5 (1.9 ± 0.12) 2.25
15	*Pupalia lappaceae*	13.5 (14.25 ± 0.31) 15.0	11.5 (13.35 ± 0.61) 15.25	1.06	1.5 (2.5 ± 0.34) 3.5	0.06 (0.06 ± 0.00) 0.06	0.50 (0.55 ± 0.05) 0.75
16	*Salsola lubricate*	16.0 (17.4 ± 0.45) 18.5	13.5 (16.7 ± 0.81) 18.0	1.06	1.25 (1.8 ± 0.2) 2.25	1.5 (1.95 ± 0.14) 2.25	1.75 (2.1 ± 0.10) 2.25
17	*Sauda fruitcosa*	13.75 (14.9 ± 0.35) 15.75	14.75 (16.8 ± 0.67) 18.25	0.90	1.0 (1.5 ± 0.17) 2.0	0.25 (1.05 ± 0.44) 2.25	0.25 (1.55 ± 0.34) 2.25

Table 7: Fertility and Sterility percentages of examined taxa

Sr. No	Taxa	No of Fertile Pollen	No of Sterile Pollen	Fertility %	Sterility %
1	*Achyranthus aspera*	87	12	87.87	12.12
2	*Aerva javanica*	67	6	91.78	8.21
3	*Amaranthus gracizens*	82	9	90.10	9.89
4	*Amaranthus hybridus*	150	14	91.46	8.54
5	*Amaranthus spinosus*	120	17	87.59	12.41
6	*Amaranthus viridis*	164	36	82	18
7	*Atriplex stoeksii*	71	13	84.52	15.47
8	*Celosia Argentia*	109	5	95.61	4.32
9	*Chenopodium album*	315	88	78.16	21.84
10	*Chenopodium ambrosioides*	373	58	86.54	13.46
11	*Chenopodium murale*	430	62	87.39	12.60
12	*Digeria muricata*	87	11	88.77	11.22
13	*Kochia indica*	105	21	83.33	16.66
14	*Kochia lonifolia*	98	26	79.03	20.96
15	*Pupalia lappaceae*	135	33	80.35	19.64
16	*Salsola lubricate*	126	24	84	16
17	*Sauda fruitcosa*	86	8	91.48	8.51

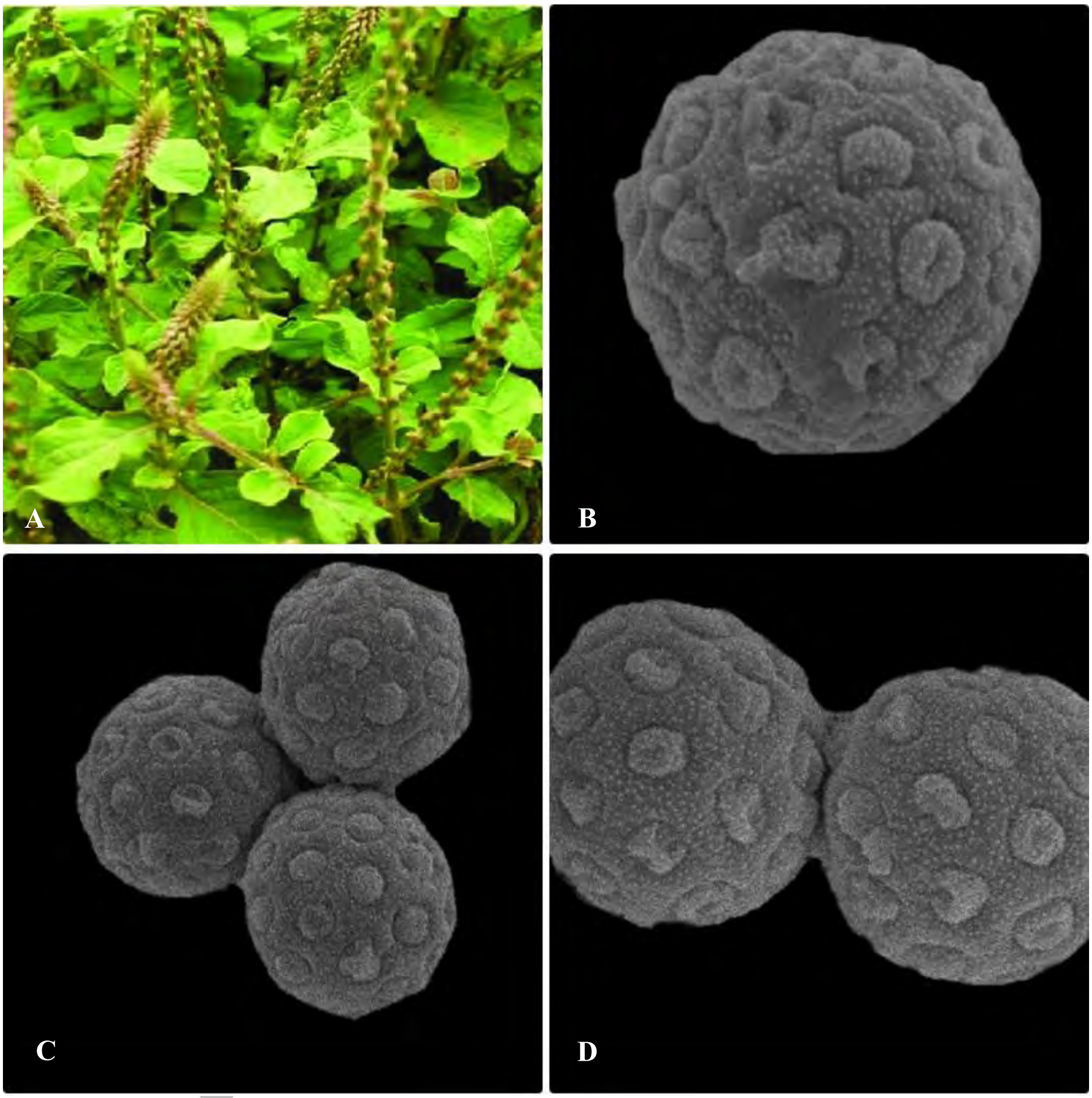

Plate 52: *Achyranthus aspera* (A) Floral Parts .Scanning Electron Micrographs (B) Polar View (C) Sunken Pore orientation (D) Micro-Echinate Exine Sculpturing

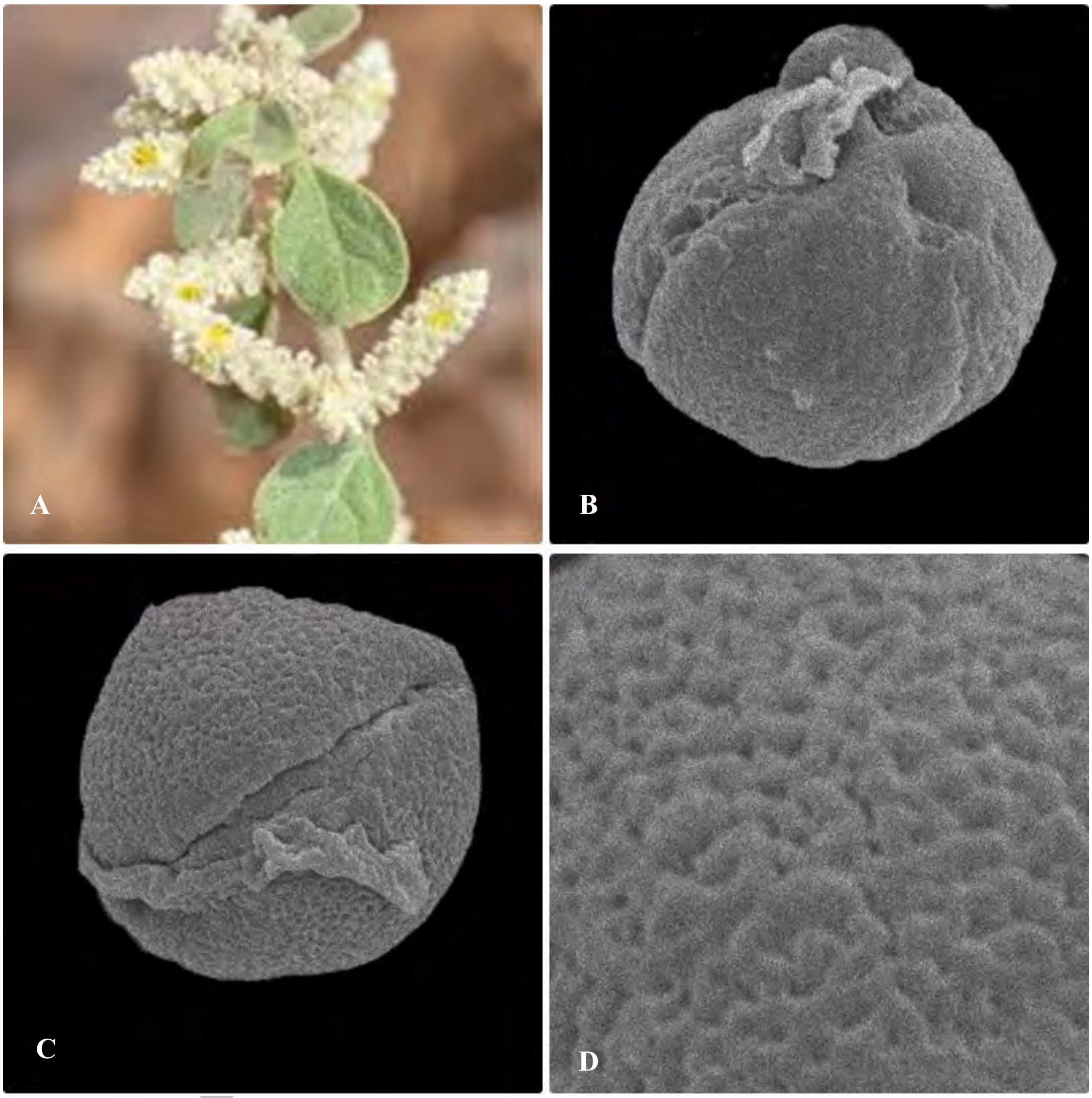

Plate 53: *Aerva javanica* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Equatorial View (D) Surface Sculpturing

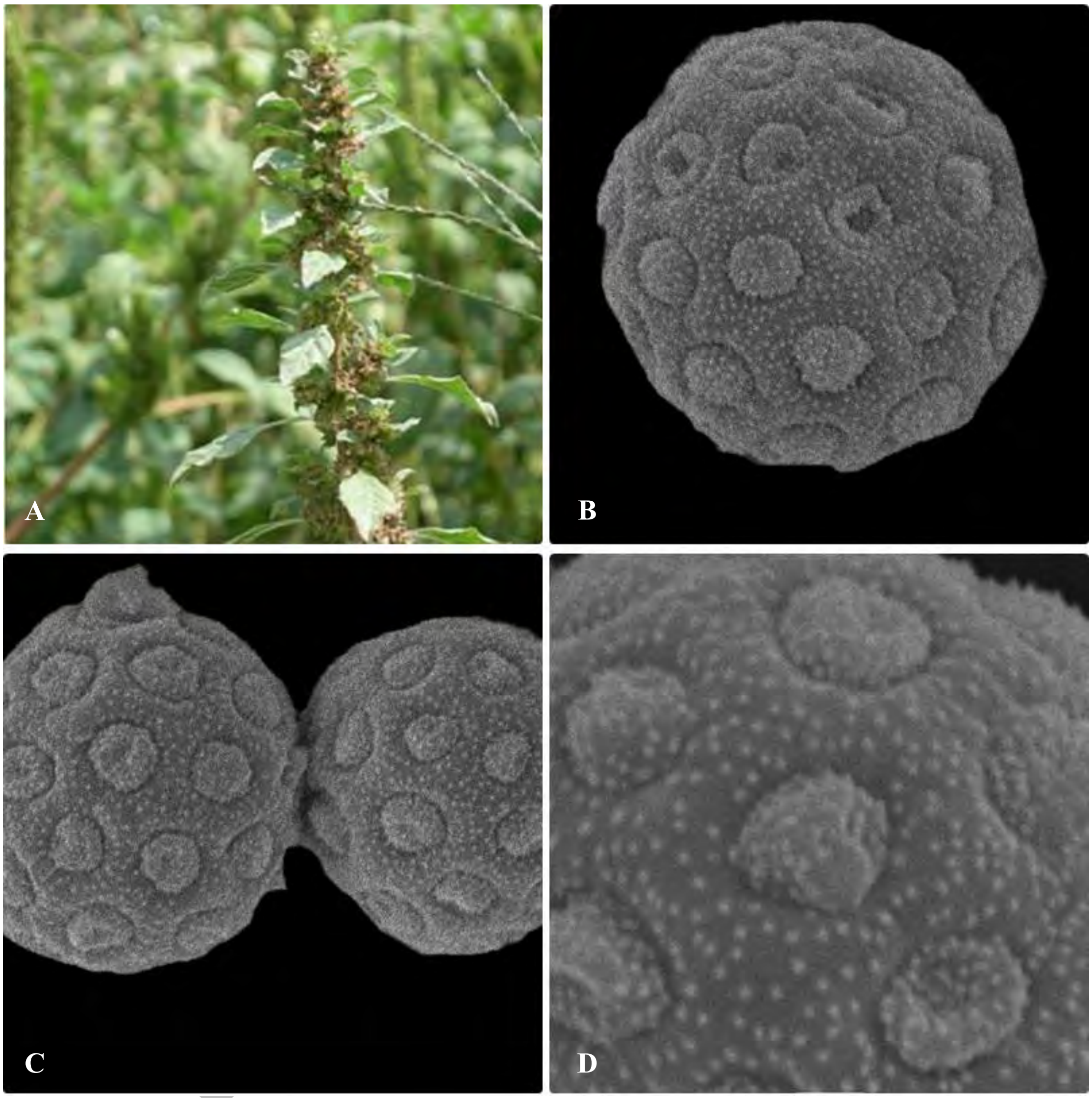

Plate 54: *Amaranthus gracizens* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Sunken Pore Ornamentation (D) Surface Sculpturing

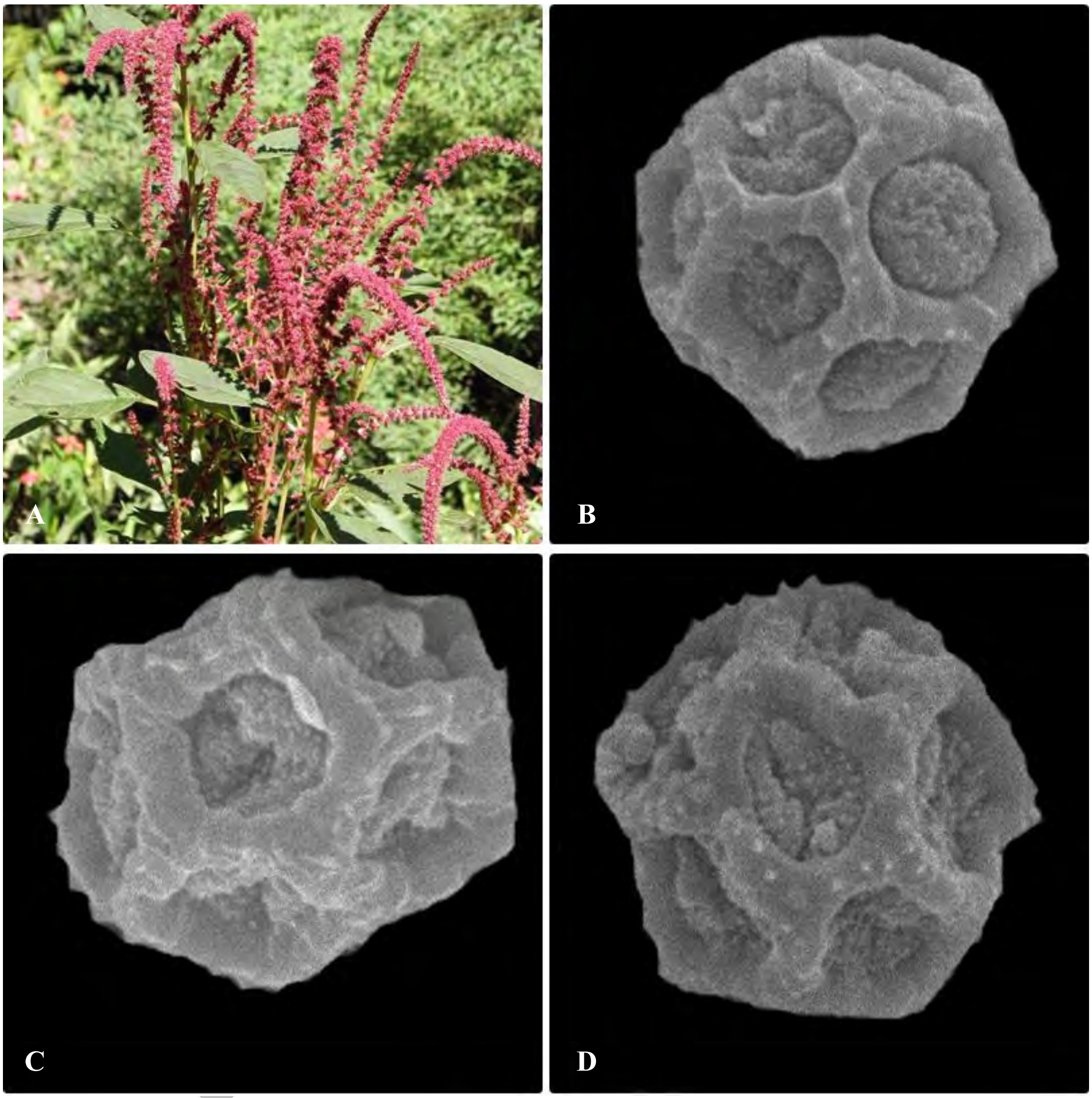

Plate 55: *Amaranthus hybridus* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Sunken Pore orientation (D) Micro-Echinate Exine Sculpturing

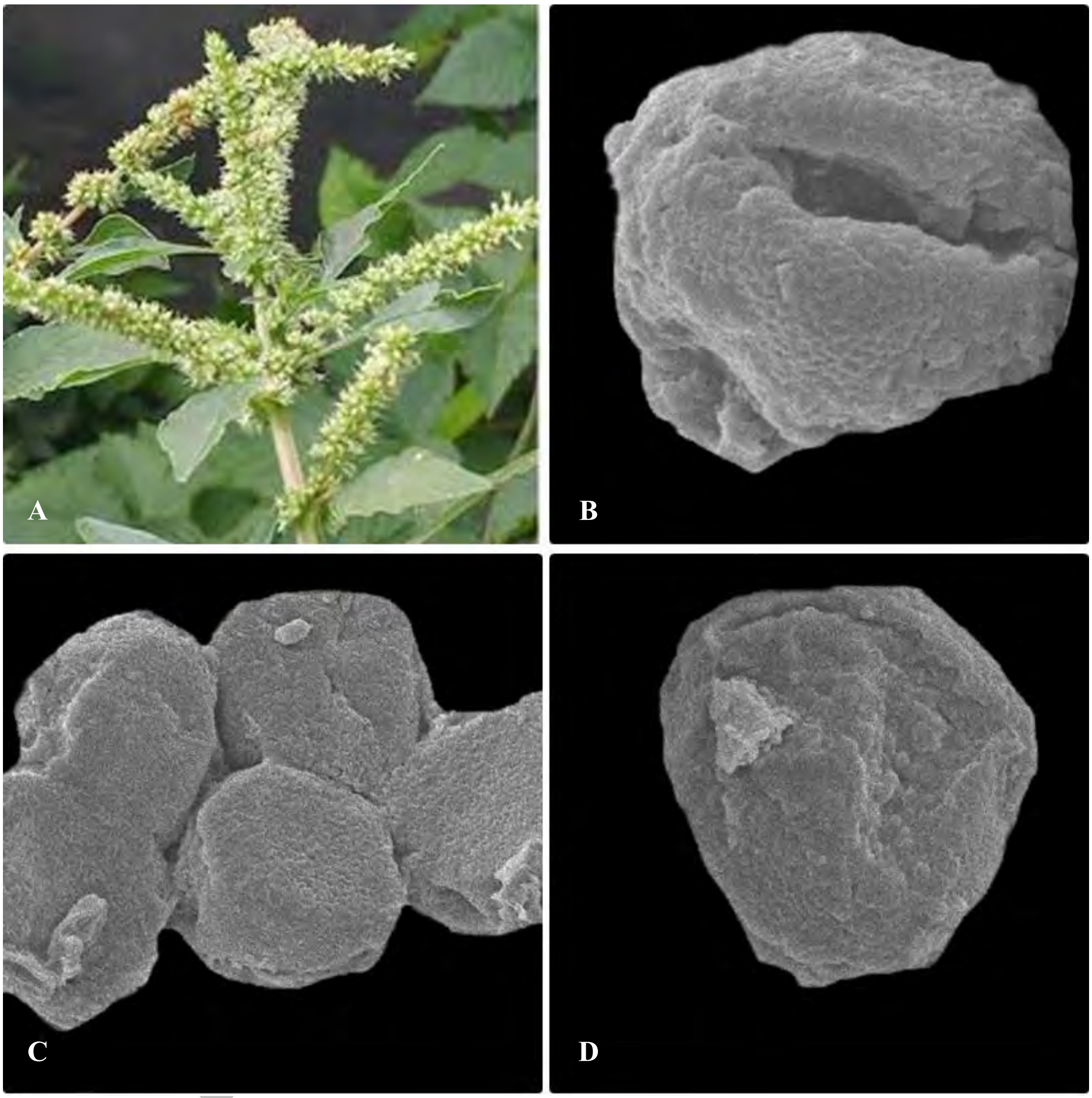

Plate 56: *Amaranthus spinosus* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Equatorial View (C) Polar View (D) Scabrate Exine Sculpturing

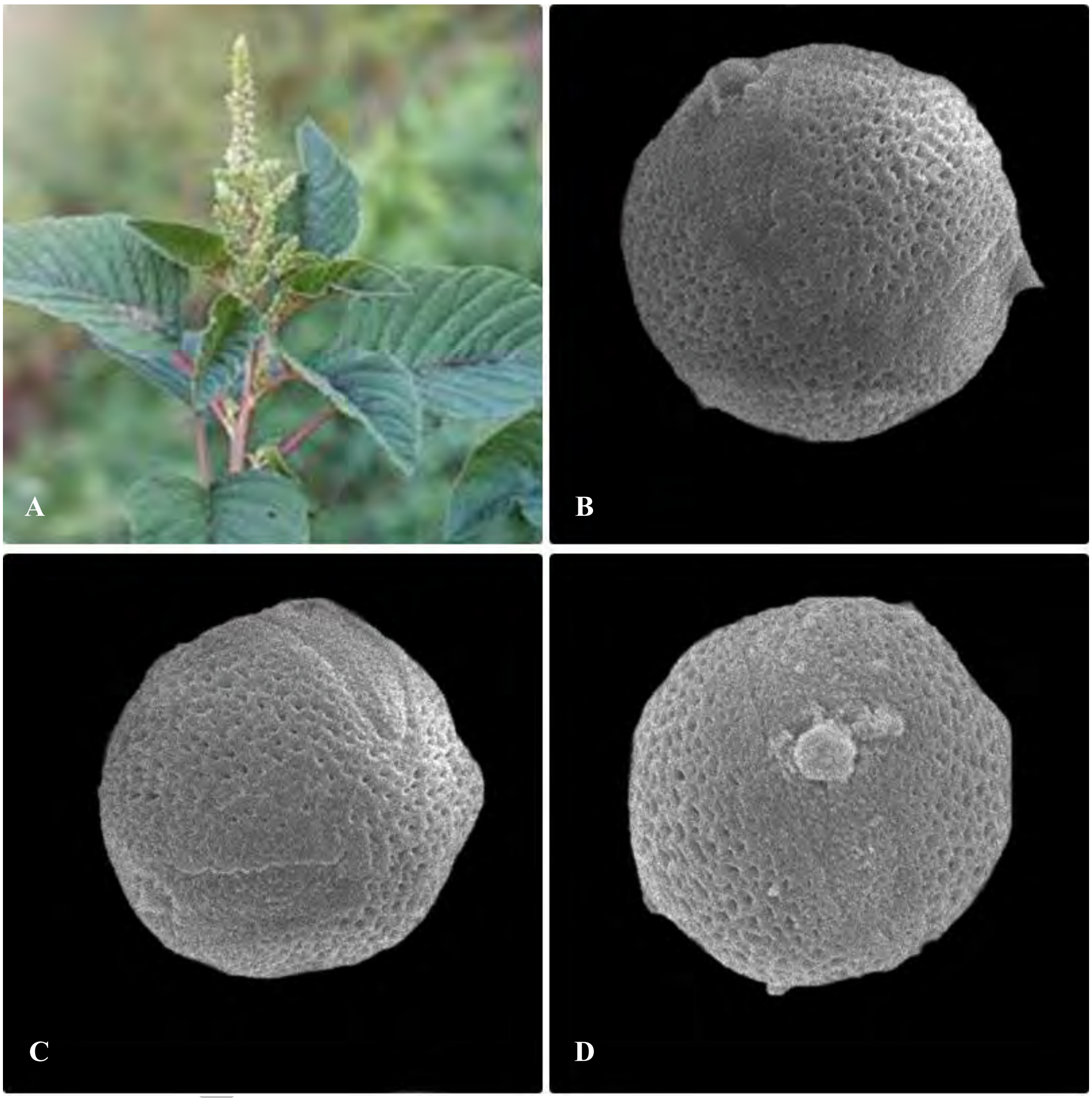

Plate 57: *Amaranthus viridis* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Sunken Pore orientation (D) Micro-Echinate Exine Sculpturing

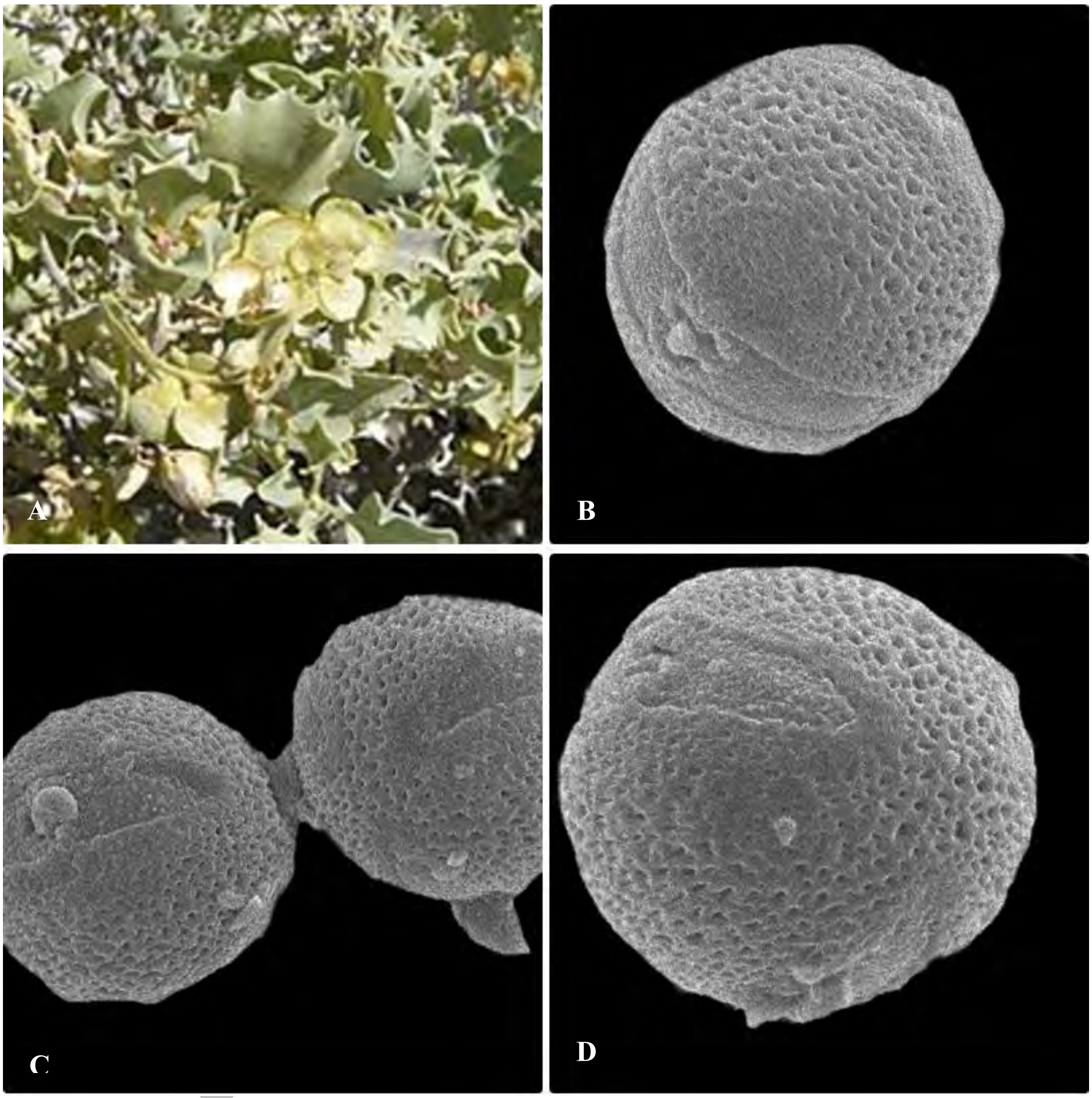

Plate 58: *Atriplex stoeksii* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Sunken Pore orientation (D) Scabrate Exine Sculpturing

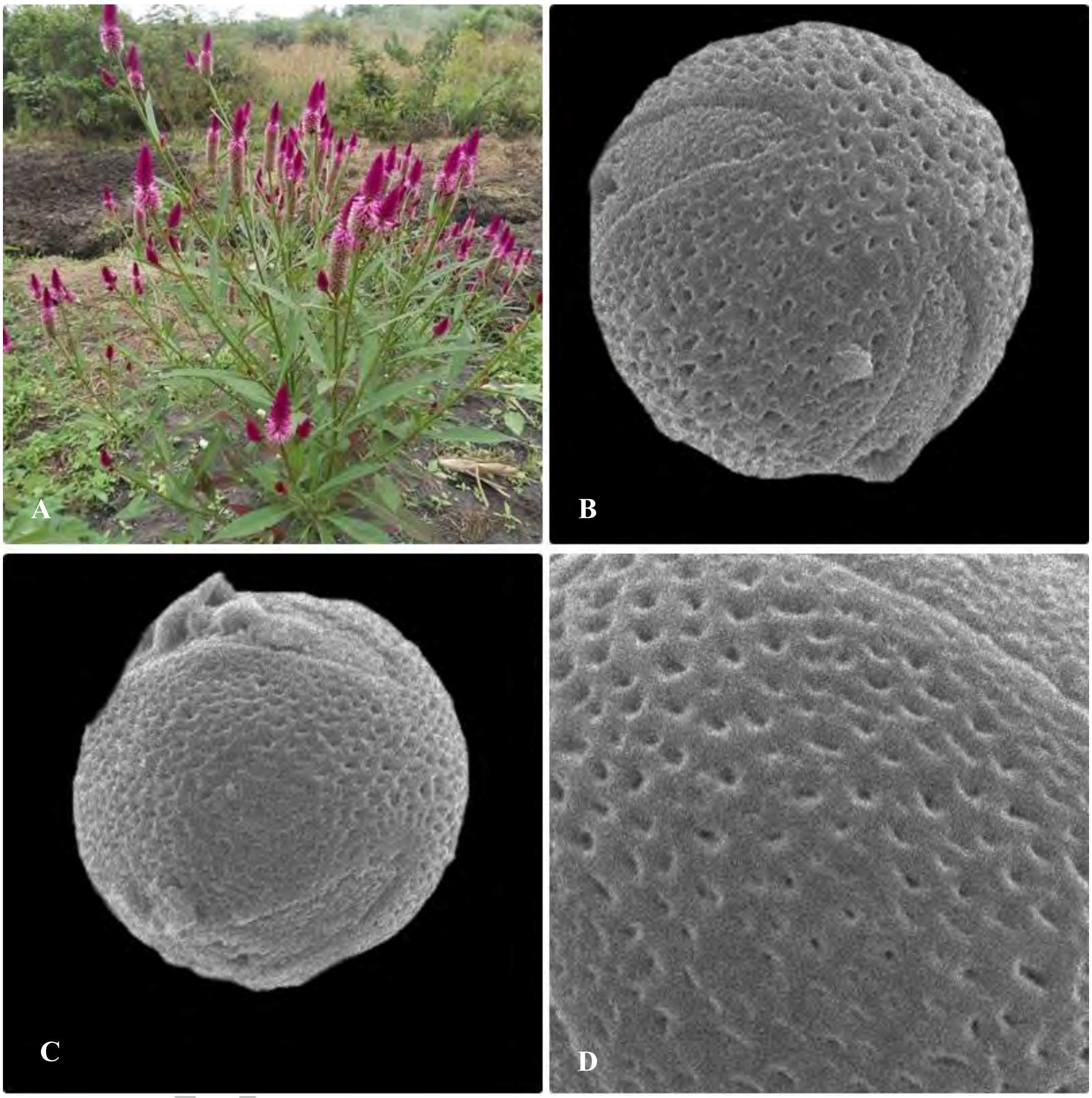

Plate 59: *Celosia Argentia* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Sunken Pore orientation (D) Surface Sculpturing

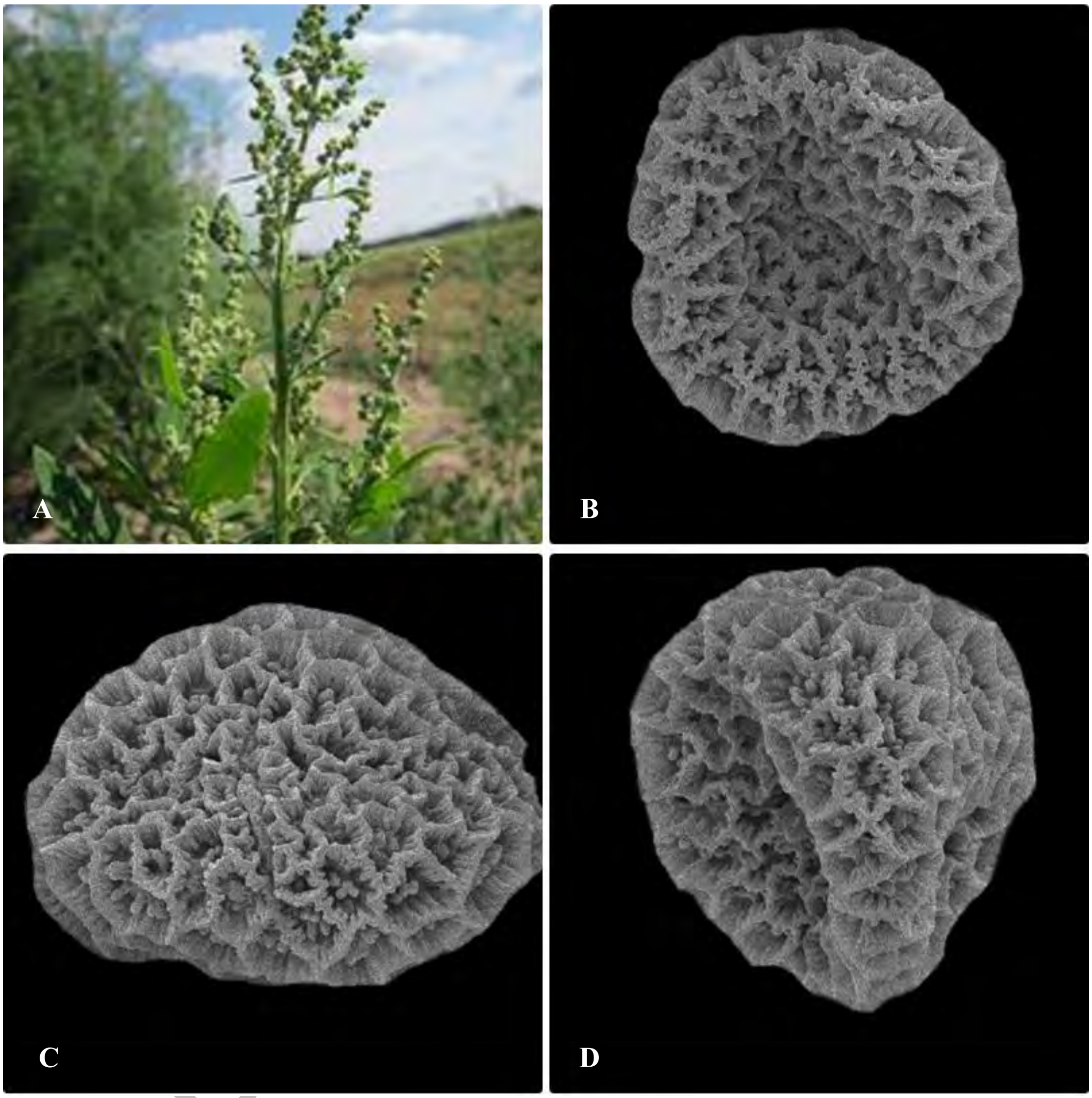

Plate 60: *Chenopodium album* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Equatorial View (D) Scabrate Exine Sculpturing

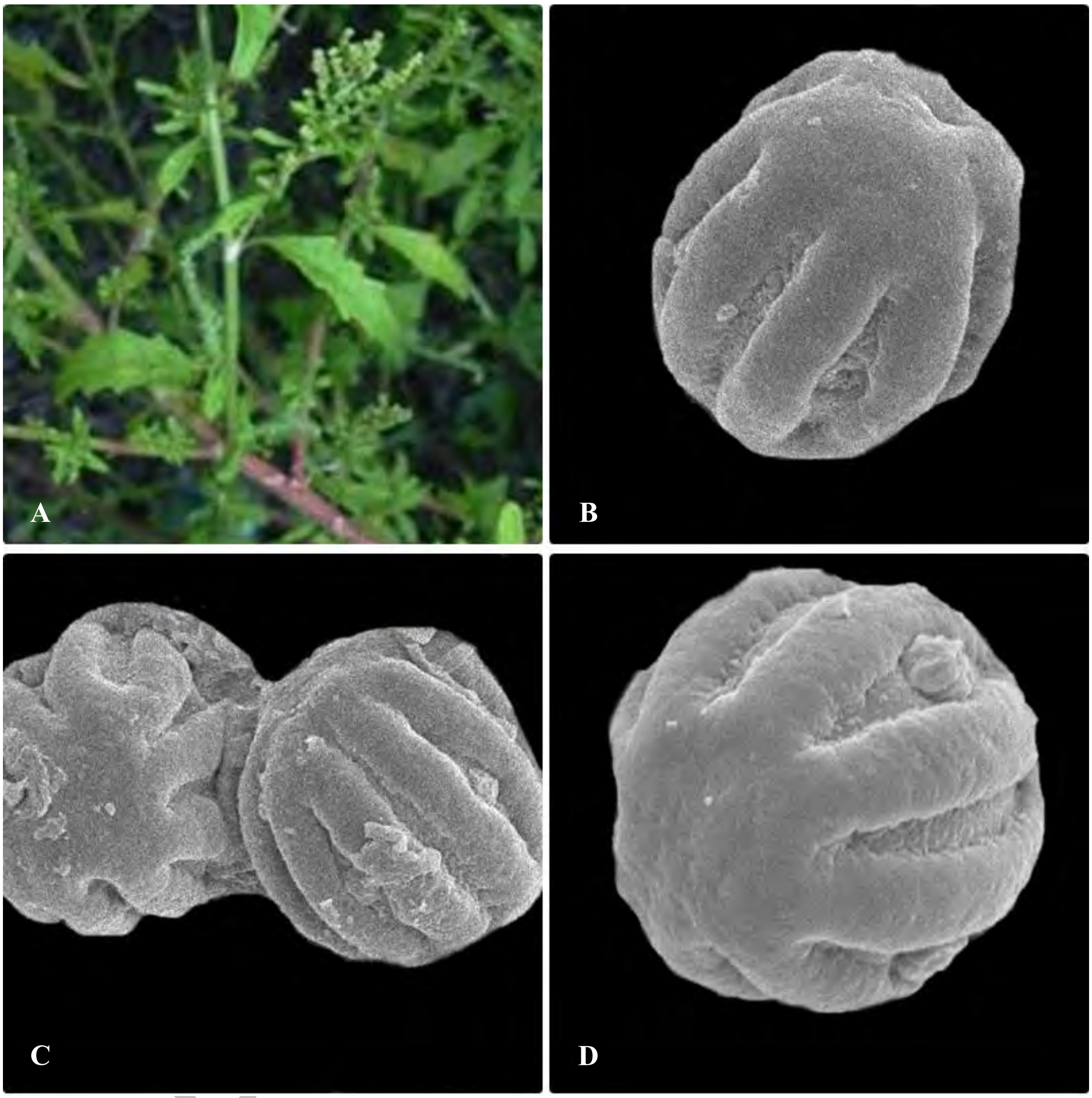

Plate 61: *Chenopodium ambrosioides* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Sunken orientation (D) Micro- Echinate Exine Sculpturing

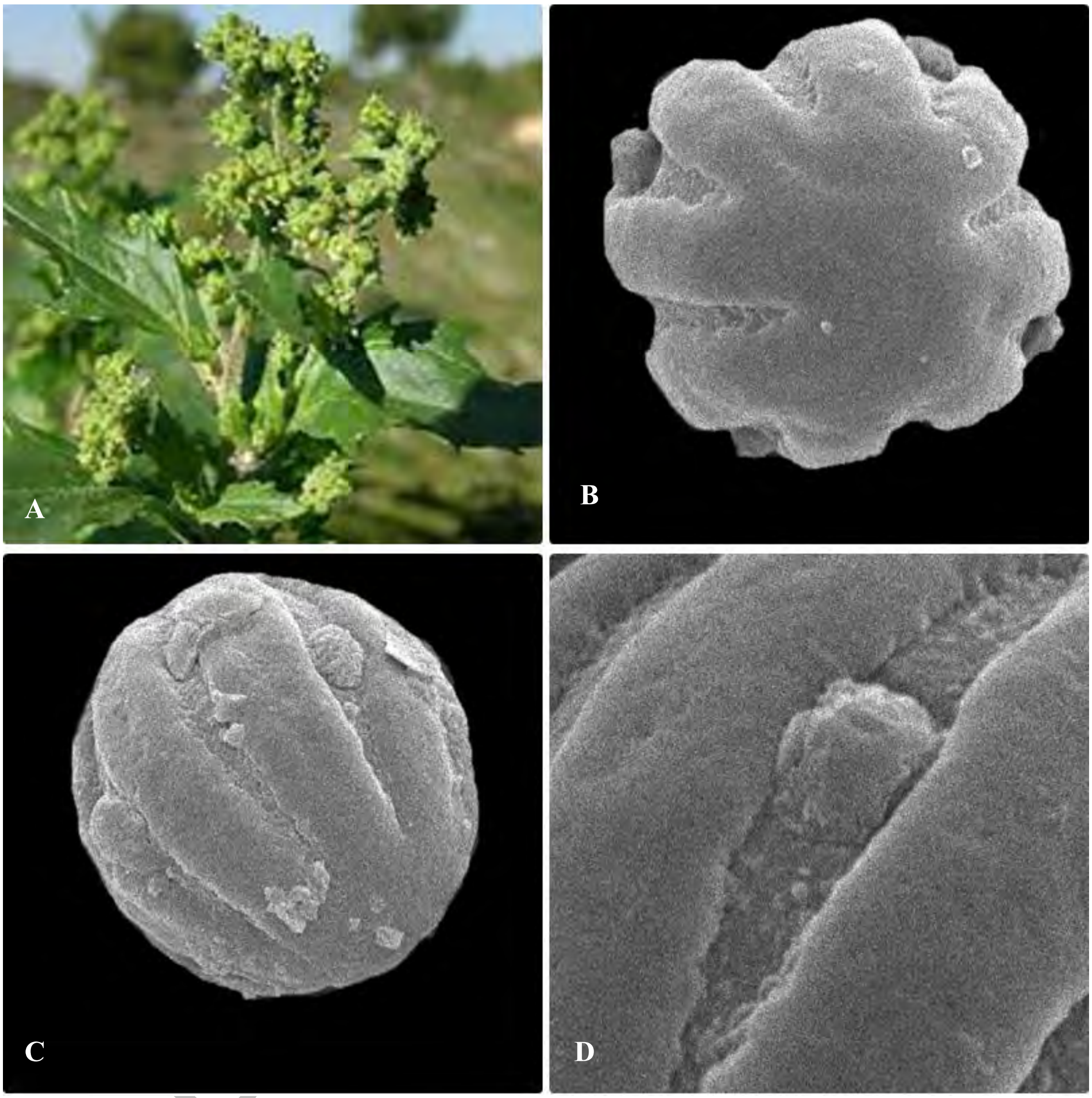

Plate 62: *Chenopodium murale* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Equatorial View (D) Surface Sculpturing

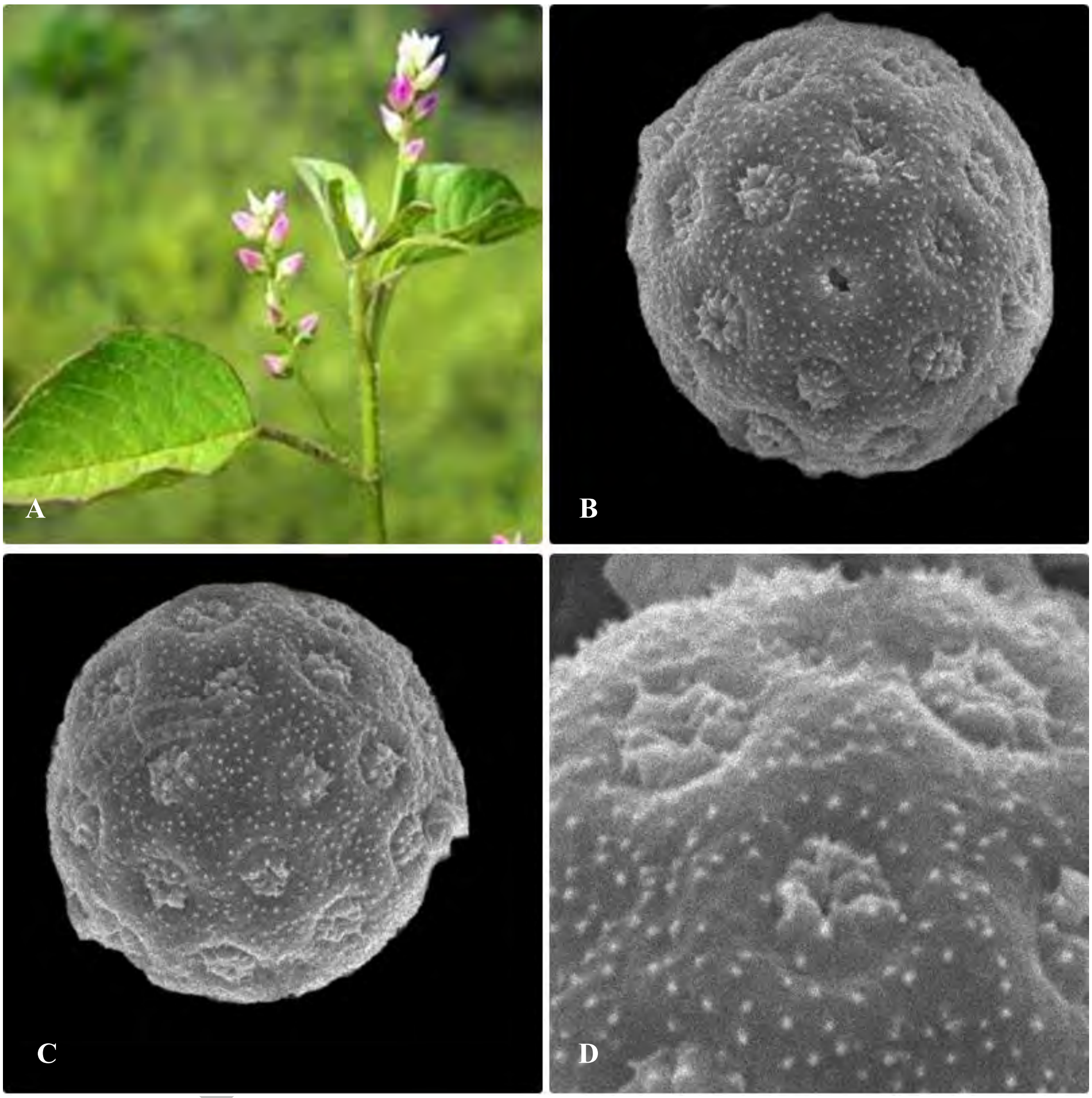

Plate 63: *Digeria muricata* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B)Polar View (C) Sunken Pore orientation (D) Surface Sculpturing

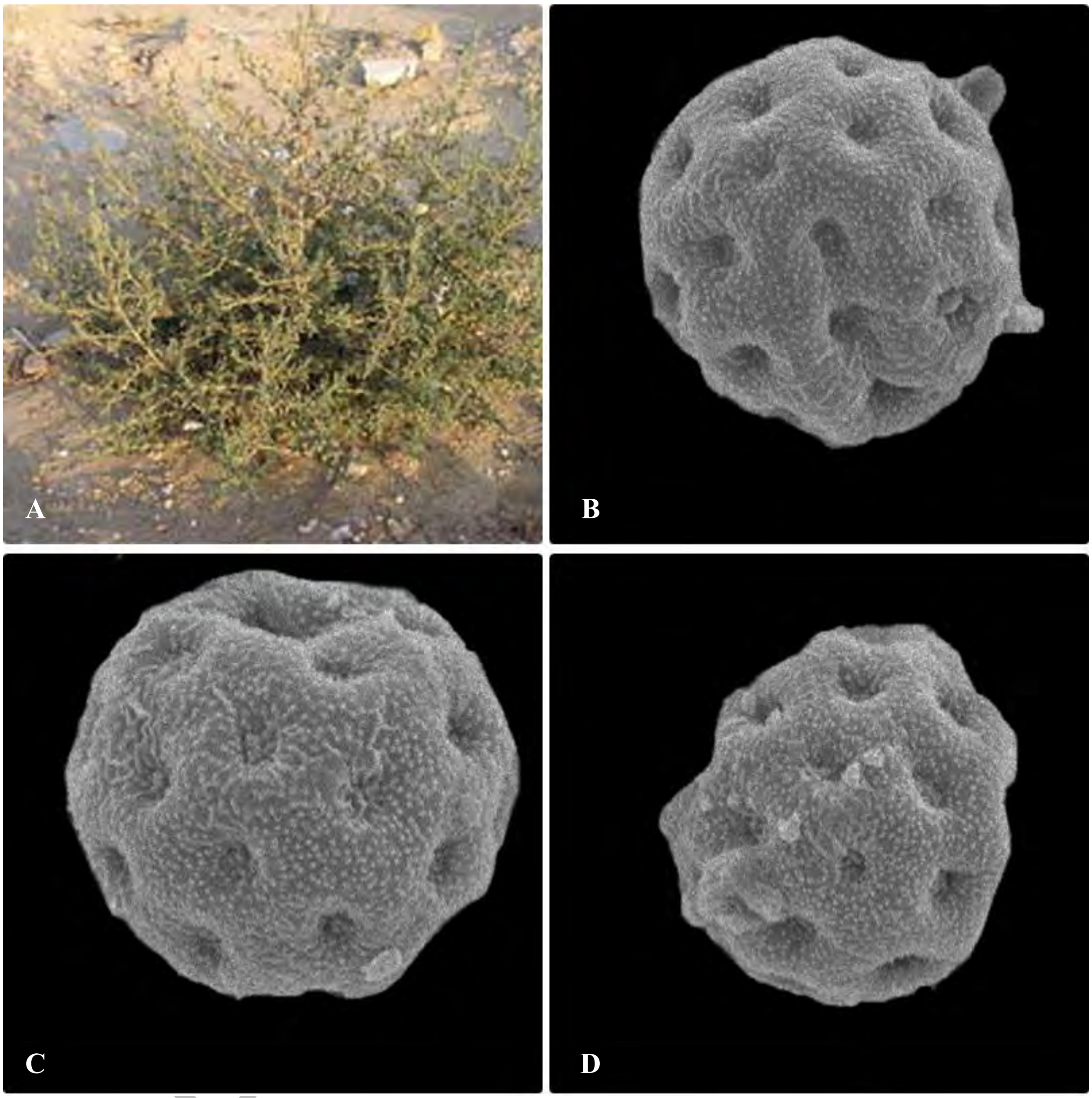

Plate 64:*Kochia indica* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Sunken Pore orientation (D) Scabrate Exine Sculpturing

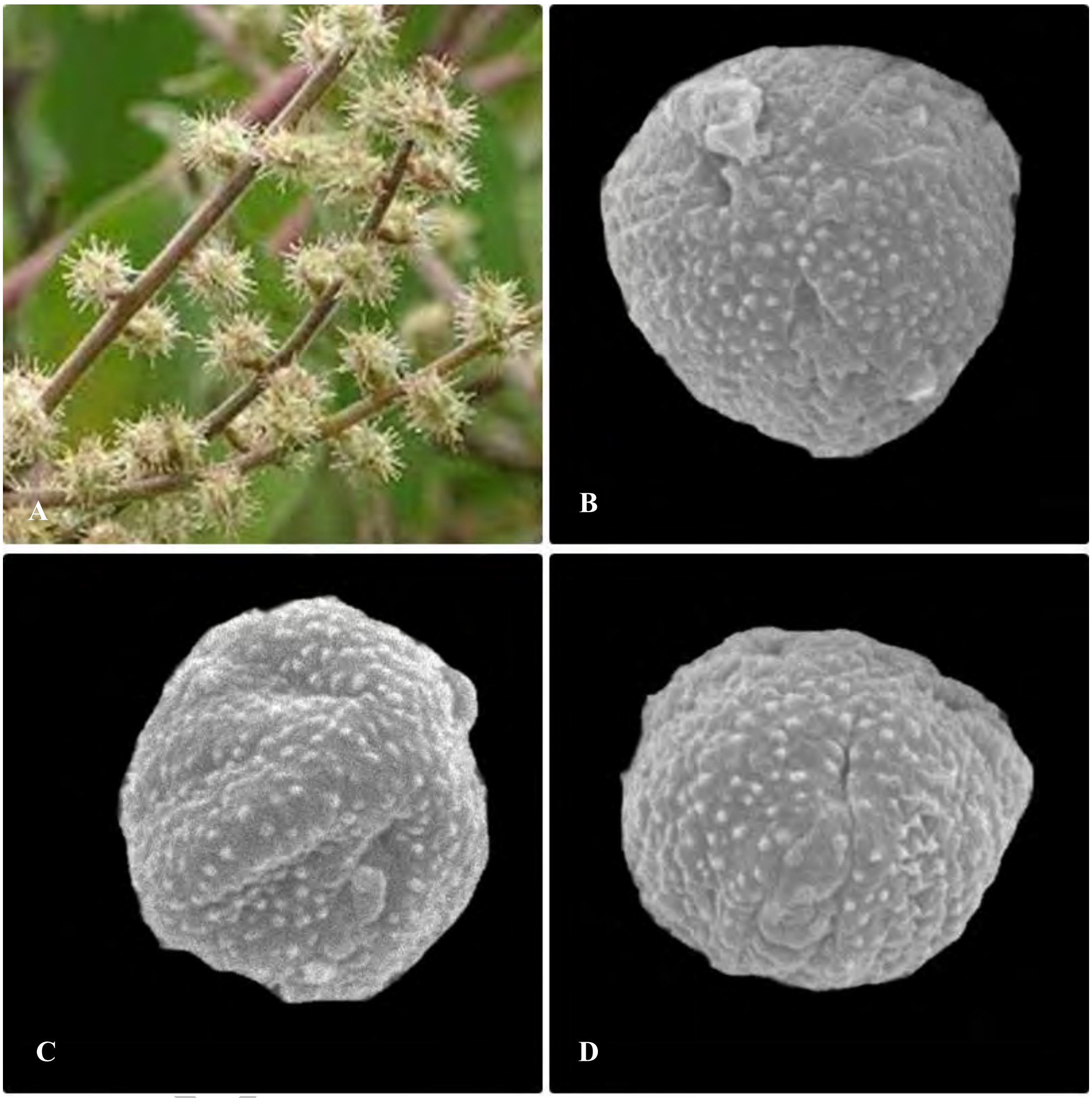

Plate 65: *Pupalia lappaceae* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Equatorial View (D) Micro-Echinate Exine Sculpturing

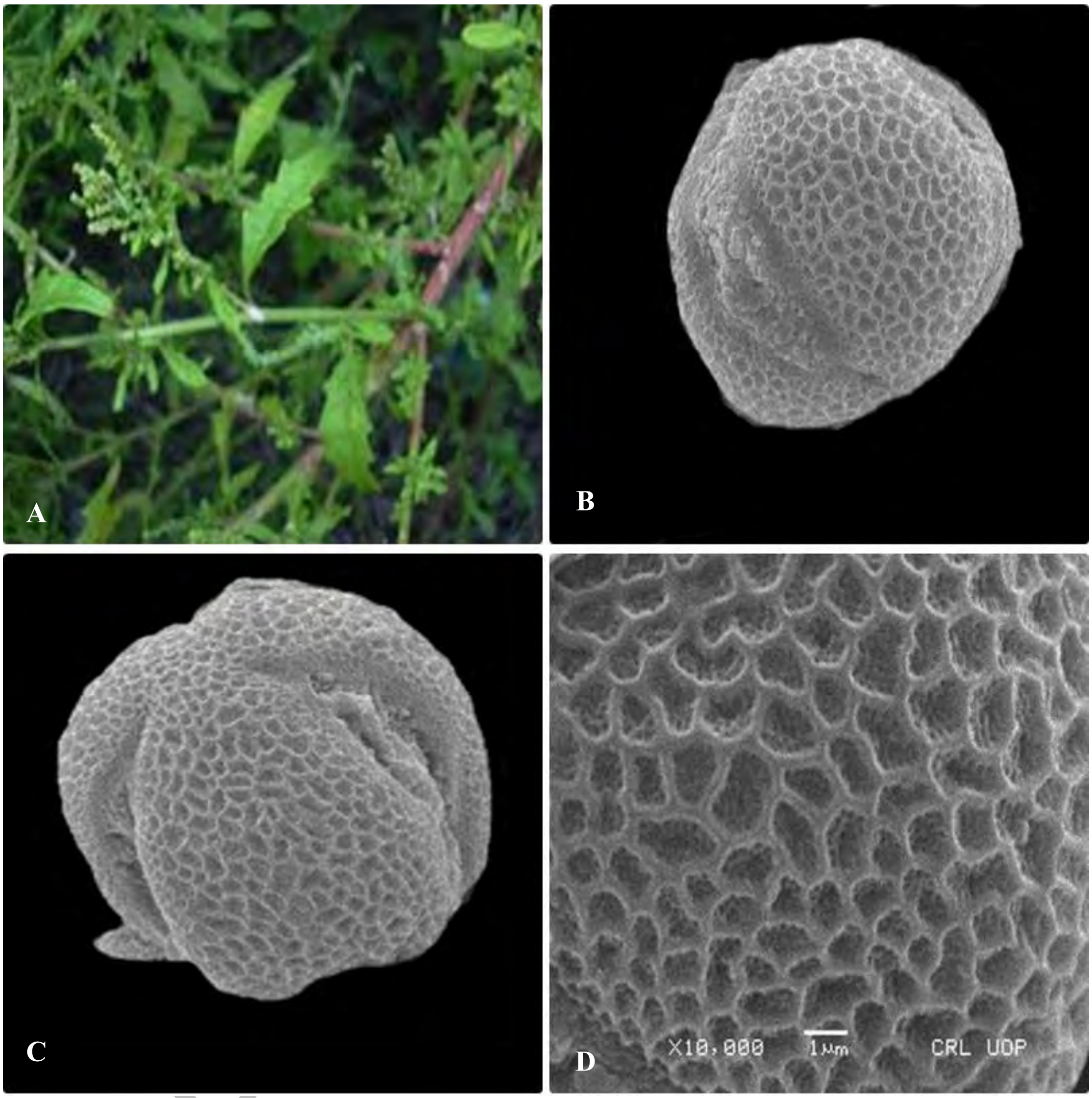

Plate 66: *Sauda fruitcosa* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Sunken Pore orientation (D) Surface Sculpturing

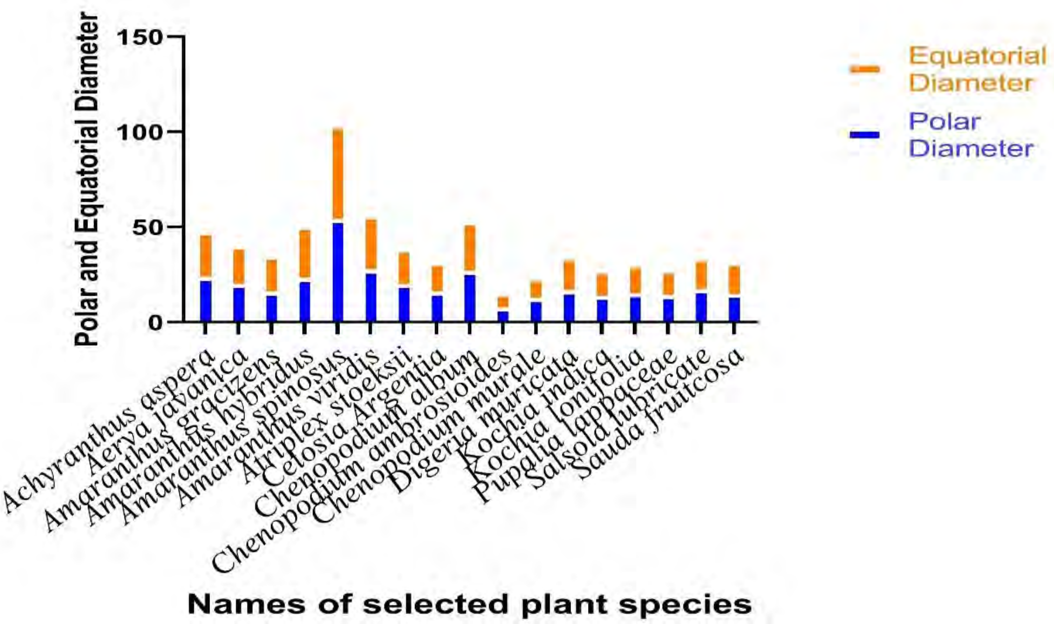

Figure 12: Mean values of Pollen diameter among Amaranthaceous taxa

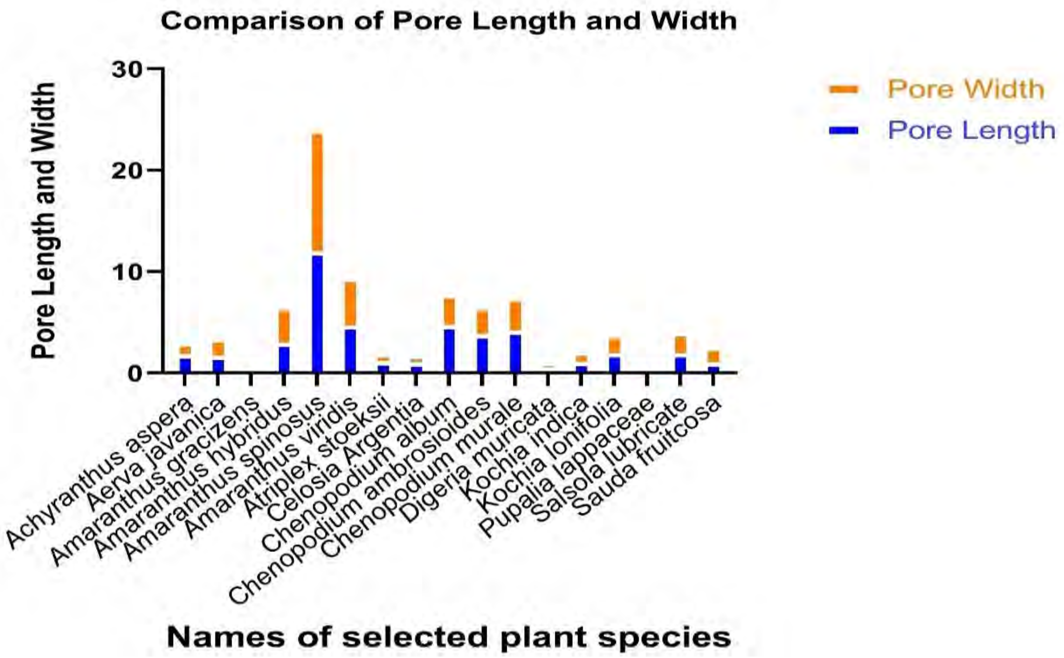

Figure 13: Data variations of pore length and width in Amaranthaceous species

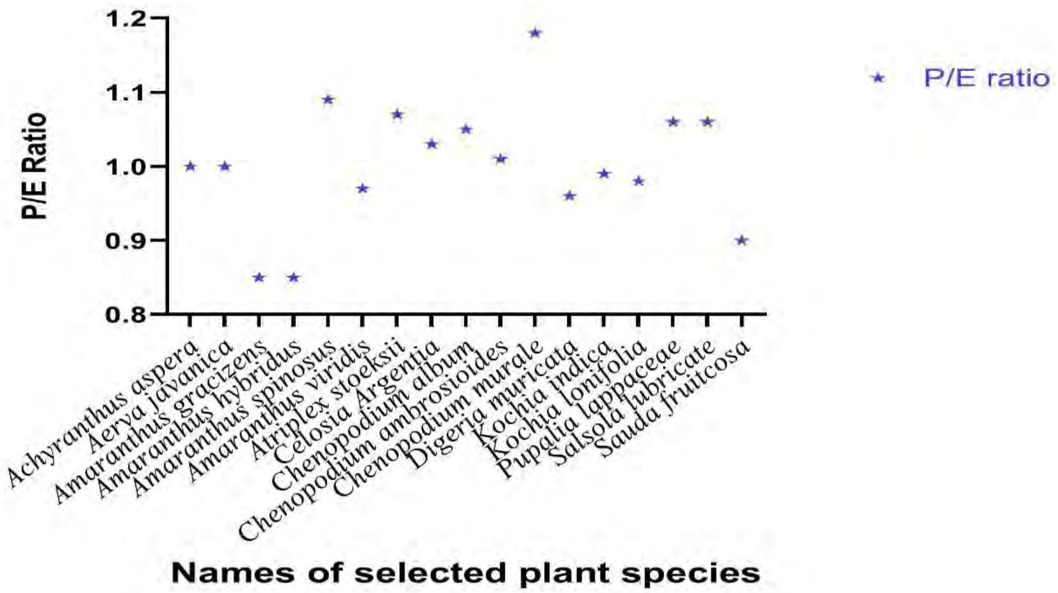

Figure 14: Variation in P/E ratio index of Amaranthaceous taxa

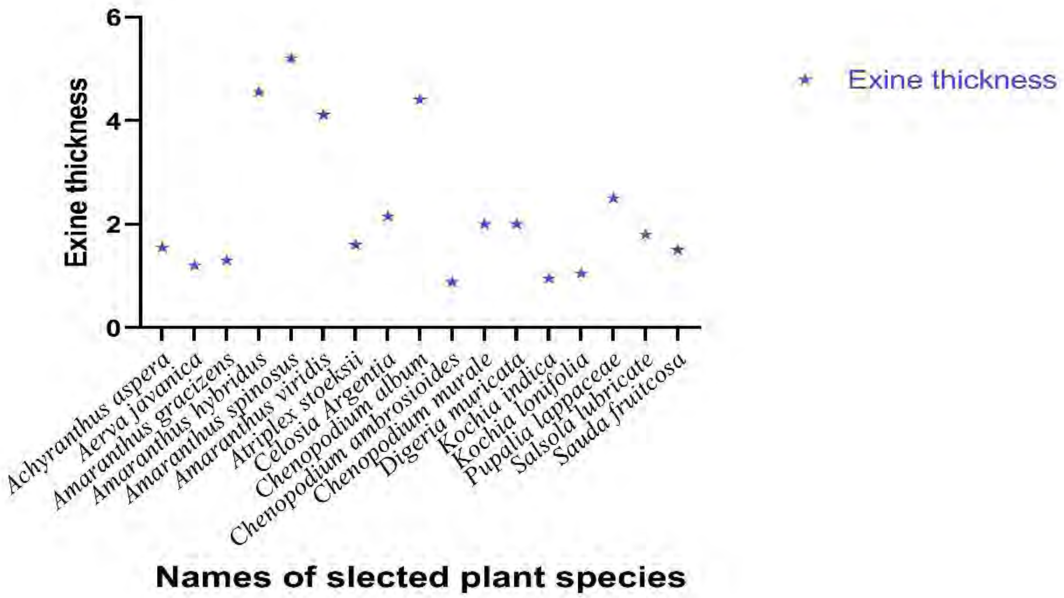

Figure 15: Mean exine thickness in Amaranthaceous Species.

Taxonomic key of Amaranthaceae Taxa

1 + Polar diameter 22.75 to 25.5, P/E ratio 1…………*Achyranthus aspera*

- Polar diameter 12.75 to 18.25, P/E ratio 0.85……………………2

2 + exine thickness 1 to 1.5, polar length 0.02 to 0.04……….*Amaranthus grcizens*

- exine thickness 1 to 1.5, polar length 1.5-1.7……………………3

3 + polar diameter 18.25 to 21, equatorial diameter 19 to 20.75…..*Aerva javanica*

- polar diameter 21.2 to 26.25, equatorial diameter 27.25 to 31.25…4

4 + P/E ratio 0.85, pore width 3.6……………………*Amaranthus hybridus*

- P/E ratio 1.09, pore width 12……………………………………5

5 + polar diameter 54.25 to 56.25, Equatorial diameter 49.6 to 60.5….*A. spinosus*

- polar diameter 27.8 to 29.7, equatorial diameter28.5 to 31………6

6 + P/E ratio 0.97, exine thickness 4.11………………………..*A. viridis*

- pore length 0.75, and pore width 0.5……………………………7

7 + polar diameter 18 to 22.75, equatorial diameter 17.75 to 18.85..*Atriplex stoeksii*

- polar diameter 13.5 to 18, equatorial diameter 13.25 to 8.5……….8

8 + pore length 0.75, pore width 0.5……………………*Celosia argentia*

- pore length 4.75, pore width 3……………………………………..9

9 + polar diameter 27.1 to 29.2, P/E ratio 1.05………*Chenopodium album*

- polar diameter 7.75 to 11, P/E ratio 1.01…………………………10

10 + equatorial diameter 6.67 to 10.75, pore length 3.85….*C. ambrosioides*

- equatorial diameter 10.75 to 12.5, pore length 4.2………………11

11 + polar diameter 12.75 to 14.75……………………………..*C. murale*

- polar diameter 12.75 to 20.75………………………………..12

12 + equatorial diameter 16.25 to 19.5, polar length 0.5………….*Digeria muricata*

- equatorial diameter 12 to 15.5, P/E ratio 0.99…………………13

13 + pore length 0.75, pore width 0.75……………………...*Kochia indica*

- pore length 1.75, pore width 1.5……………………………….14

14 + polar diameter 13 to 19.75, equatorial diameter 13.5 to 17.25……*K. lonifolia*

- polar diameter 13.5 to 15, equatorial diameter 11.5 to 15.25………...15

15 + pore width 0.06 pore length 0.50……………………*Pupalia lappaceae*

- pore length 1.5, pore width 1.75………………………………..16

16 + polar diameter 16 to 18.5, equatorial diameter………*Salsola lubricate*

- Polar diameter 13.75 to 15.75, equatorial diameter 14.75 to 18.2…………….*Sauda fruitcosa*

3.1.2 Amaranthaceous Species

Palynological features of Amaranthaceae family was investigated for qualitative and quantitative characters by utilizing Light microscopy and scanning electron microscopy. In the current research, 17 species belonging to 11 genera were studied for examining pollen characters. All the pollens have the same shape category i-e spheroidal. All pollens of studied species are porate with sunken apertures. Pore number exhibit variations. Plants with triporate to polyporate structure were observed. Variations were observed in terms of pollen ornamentation. 8 species has scabrate pollens while 9 studied species has micro-echinate pollen grains. The fertility and sterility ratio has been estimated for each species. Maximum fertility was observed in *Celotia argentia* (95.61 %) while maximum sterility percentage was observed in *Chenopodium album* (21.84 %). The percentage illustrate the pollens were collected during the mature flowering season. Micrographs (LM and SEM) are also illustrated.

Qualitative and Quantitaive Characters of Pollen and P/E ratio

All the studied species belongs to spheroidal shape group. Maximum polar diameter 54.25 µm (51.25-56.25) is observed for *Amaranthus spinosus* while minimum polar diameter 18.25 µm (20.2 ± 0.50) 21.0 is observed for *Aerva javanica.* In case of equatorial diameter, minimum mean value 10.75 µm (12.5-9.75)is calculated for *Chenopodium murale* while maximum value 49.6 µm (38.75-60.50) is studied for *Amaranthus spinosus.* The pollen shape is determined on the basis of P/E ratio which ranges from 0.85 (*Amaranthus gracizens*) to 1.18 (*Chenopodium murale*).

Morphology of Pores

All the studied plant species have pore uniformly present on their surface. The number of pores varies among species. The pore number is recorded from 3 (*Digeria muricate, Amaranthus viridis*) to 15 (*Amaranthus spinosus*). All the studied species have sunken pores. Maximum pore length is observed for *Chenopodium murale* while minimum pore length is observed for *Amaranthus grezians.* In case of pore width, maximum pore width value is calculated for *Amaranthus spinosus* while minimum pore width value is studied for *Diigaria muricata.*

Exine Thickness

Exine thickness was noted by using SPSS software. Mean, minimum and maximum values were calculated for each species. Minimum mean values were obtained for *Kochia indica* 0.75 μm (0.95 ± 0.09) and *Kochia lonifolia* 0.75 μm (1.05 ± 0.09) whereas maximum range was recorded for *Amaranthus spinosus* 5.20 μm (4.50-6.0).

In this research work, Light and scanning electron microscope was taken into consideration to detect pollen of family Amaranthaceae from Salt Range Pakistan. The studied species have pantoporate and sunken pores. The pollen grain of family Amarantahceae have spheroidal pollen shape based on P/E ratio. Number of pore are various in different species of the Amaranthus family range from 3 in *Digeria muricate, Amaranthus viridis* to 15 in *Amaranthus viroides* stated.

The exine of pollen of Amarnathaceae were thin walled (Ghazalli., 2022; Nazish et al., 2009), our investigated species exine size was also have thin wall. Spheroidal pollen shape in Caryophyllaceae reported in current study agree with that of previous literature (Nazish et al., 2009, Chin et al., 2011, Pino et al., 2016). In present report, the size of exine of *Sauda fruticosa* was observed slightly larger. Different researcher work on the pollen morphology of Amaranthacaee illustrated the small sized pollen grains 5 to 20 um (Asadi et al., 2016; Angelini et al., 2014 ; Hermin et al., 2012 ; Nazish et al., 2019). Our results agreed with the above studied, In all reported species of Amaranthacae zoopoartae pollenss were studied , and they all are sunken. Nazish et al. (2019) and Noor et al., (2021) also described such types of pori in the family Amaranthacae . Nazish et al. (2019), Asadi Et al., (2016), and Hermin et al (2012) used pori number for the taxonomic identification of species in Amaranthaceae. Zooporate type of pollen stated in this research work, and previous researcher also reported same in Amaranthus family (Borsch 1998; Nazish et al., 2019).

Noteworthy dissimilarities in size and sculpture of pollen displays great taxonomic potential in identification and species delimitation (Borsch 1998). Previous workers has demonstrated Amaranthaceae as significant floral family because of its distinct pollen morphology. Accordance to present research, the studied family is very much similar pollen morphology with previous study. Amaranthacaee family is devoid of echini on the surface of pollen. (Nazish et al., 2019, Asadi et al., 2016). Two types of ornamentation microechinate and scabrate were observed here which are in accordance to previous authors (Brosch 1998; Asadi et al., 2016 ; Angelini et al., 2014). Palyno-morphological multiplicity delivers indication about exine thickness, pore ornamentation and pollen type. In our finding, pollen type was spheroidal in all studied species. Zooporate pollen was the basic and primitive type in Amaranthaceae (Brosch 1998; Asadi et al., 2016; Nazish et al., 2019). The pollen ornamentation of the 9 species (*Aerva javanica, Amaranthus hybridus, Amaranthus spinosus ,Amaranthus viridis ,Celosia argentia, Chenopodium ambrosioides, Chenopodium murale, Pupalia lappaceae*) exhibited micro-echinate ornamentation while 8 species *(Achyranthus aspera ,Amaranthus gracizens ,Atriplex stoeksii ,Chenopodium album ,Digeria muricate ,Kochia indica ,Kochia lonifolia)* belongs to scabrate ornamentation. The current findings were found to be similar with previous literature (Nazish et al., 2019, Asadi et al., 2016).

The microscopic examination of pollen morphology exemplify, pollen diameter, pore diameter and P/E ratio play important role in the identification of species (Nazish et al., 2009, Chin et al., 2011, Pino et al., 2016). In present study the pollen diameter in equatorial and polar view, number of pore, exine thickness, P/E ratio, length and width of pore, qualitatively shape of pollen and pollen sculpturing as significant taxonomic tools were described.

Table 8: Qualitative data of pollen of family Fabaceae members from Potohar region of Pakistan

Sr. No	Taxa	Pollen Size	Symmetry	Aperturation	Sculpture type	Exine Texture
1.	*Acacia nilotica*	Medium	Radially symmetric	Tricolporate	Reticulate	Thin
2.	*Acacia modesta*	Medium	Radially symmetric	Tricolporate	Reticulate	Thick
3.	*Arachis hypagae*	Small	Radially symmetric	Bicolpate	Reticulate	Thin
4.	*Astragalus psilocentros*	Medium	Radially symmetric	Tricolporate	Reticulate	Moderately thick
5.	*Astragalus scoripiurus*	Small	Bilitterally symmetric	Bicolpate	Perforate	Moderately thick
6.	*Cassia fistula*	Medium	Bilitterally symmetric	Tricolporate	Perforate	Moderately thick
7.	*Cassia italica*	Small	Bilitterally symmetric	Tricolpate	Psilate	Moderately thick
8.	*Cassia occidentalis*	Small	Radially symmetric	Tetracolpate	Perforate	Moderately thick
9.	*Crotolaria burhia*	Small	Radially symmetric	Tricolporate	Reticulate	Thin
10.	*Dilbergia sisso*	Small	Radially symmetric	Bicolpate	Psilate	Thin
11.	*Lathyrus aphaca*	Medium	Bilitterally symmetric	Bicolporate	Perforate	Thin
12.	*Lespedeza juncea*	Small	Radially symmetric	Bicolpate	Reticulate-Verrucate	Moderately thick
13.	*Leucaena leucocephalla*	Medium	Radially symmetric	Bicolpate	Verrucate	Thin
14.	*Melilotus indicus*	Medium	Bilitterally symmetric	Bicolpate	Reticulate	Thin
15.	*Pigomia pinnata*	Small	Radially symmetric	Tricolpate	Reticulate-Vrrucate	Moderately Thick
16.	*Prosopis cineraria*	Small	Bilitterally symmetric	Tricolporate	Perforate	Thin
17.	*Prosopis juliflora*	Medium	Bilitterally symmetric	Tricolpate	Reticulate-Perforate	Thin
18.	*Pueraria tuberosa*	Medium	Radially symmetric	Bicolpate	Reticulate	Thick
19.	*Rhynchosia capitata*	Small	Radially symmetric	Tricolpate	Reticulate-Perforate	Moderately thick
20.	*Sophora mollis*	Small	Radially symmetric	Tricolporate	Reticulate-Perforate	Thin
21.	*Tephrosia purpurea*	Small	Bilatterally symmetric	Bi-Tricolporate	Reticulate- Perforate	Thin
22.	*Vicia angustifolia*	Medium	Radially symmetric	Bi-Tricolporate	Reticulate-Perforate	Thin

Table 9: Quantitative data of pollen of family Fabaceae members from Potohar region of Pakistan

Plant name	Polar Diameter	Equatorial Diameter	P/E	Exine Thickness	Colpi Length	Colpi Width	Fertility %
Acacia nilotica	23.25 (26.25-21.2)±2.09	27.25 (31.25-23.7)±2.85	0.85	3.90(3.25-3.75)±0.26	2.45(2.00-3.00)±0.18	3.40(2.75-4.25)±0.26	92.6
Accacia modesta	54.25(51.25-56.25)±0.88	49.60(38.75-60.50)±0.29	1.09	20.2 (19.7-22.0)	3.95 (2.75-4.75)	2.70 (2.00-3.25)	81.2
Arachis hypagae	27.8(26.5- 29.7)±0.68	28.5(26.2-31)±0.78	0.97	2.5(2-3.4)±0.22	2.2(0.95-2.8)±0.43	1.1(0.7-1.5)±0.18	60
Astragalus psilocentros	27.1(25.5-29.2)±0.71	25.8(22.7-31.5)±1.49	1.05	0.74(0.5-1.05)±0.35	0.28(0.12-0.56)±0.07	0.16(0.10-0.23)±0.02	59.5
Astragalus scoripiurus	12.75 (14.75-9.50)±2.06	10.75 (12.5-9.75)±1.04	1.18	2.55(1.75-300)±0.24	1.80(0.75-300)±0.39	3.10(2.75-3.75)±0.18	76.2
Cassia fistula	7.75(11.00-5.25)±0.88	7.67(10.75-5.50)±0.78	1.01	3.35(3-3.7)±0.12	4.25(3.75-4.75)±0.17	7.95(7.00-9.75)±0.48	78.16
Cassia italic	19.4(17.7-20.5)±1.14	18.3(16.5-20.5)±1.70	1.06	2.00 (2.75-1.2)±0.55	3.25 (4.00-2.75)±0.46	4.55 (5.50-3.75)±0.77	87.39
Cassia occidentalis	25(22.6-26.7) ±1.49	26.3(21.7-30.1)±2.61	0.95	2.45(2.00-3.00)±0.18	3.65(2.75-4.75)±0.40	6.25(5.25-7.00)±0.30	86.54
Crotolaria burhia	41.2(37.5-43.2)±0.93	36.9(34.7-39.5)±0.77	1.11	4.9(3.25-6.2)±0.52	6.25(4.50-8.00)±0.69	7.10(6.50-8.00)±0.57	83.33
Dilbergia sisso	18.03(16.80-18.6) ±0.34	17.85(15.30-19.65) ±.0.8	1.01	20(21.00-18.7)±0.41	7.75(8.50-7)±0.29	3.30(4.00-2.75)±0.22	84.61
Lathyrus aphaca	20(19.7-20.4)±0.13	19.6(18.2-20)±0.24	1.02	3.35(2.25-4.7)±0.53	2.45(2.00-3.00)±0.18	2.55(2.10-3)±0.18	80.63
Lespedeza juncea	30.8(26.2-35.2)±1.82	24.5(20.2-30.2)±1.96	1.25	3.75(2.75-4.7)±0.35	2.35(1.75-3.00)±0.23	4.85(4.25-5.50)±0.23	89.1
Leucaena leucocephalla	23.3(16.7-30.2) ±3.12	21.2(12.6-27.7) ±2.32	1.09	1.05(0.75-1.2)±0.09	5.2(4.2–6.1)± 0.15	6.4(5.7–7.3)± 0.15	87.6
Melilotus indicus	13.85(15.50-12.00)±0.65	13.9(16.25-11.50)±0.66	0.99	5.35(2.75-6.7)±0.69	6.50(5.25-775)±0.44	7.00(6.00-7.75)±0.37	74.3
Pigomia pinnata	42.4(34.2-52.2)±3.25	41.6(35.5-48.7)±02.52	1.01	0.52(8.75-6.25)±.52	3.20(3.50-3.00)±.09	1.75(2.75-1.25)±0.13	77.8
Prosopis cineraria	33.0(30.2-36.2)±1.10	32.0(28.7-35.2)±1.11	1.03	2.65(2.25-3.0) ±0.12	4.8(4.4–5.4)± 0.29	2.7(2.4–3.1)± 0.2	85
Prosopis juliflora	20.25 (23.75-18.7)±1.00	27.25 (31.25-23.7)±1.27	1.34	1.80 (3.00-1)±0.34	3.25 (3.75-2.75)±0.17	5.60 (6.25-5.25)±0.18	91.3
Pueraria tuberosa	40.1(39.5-40.7)±0.21	38.4(35.7-43.0)±1.21	1.04	4.6(3.9-5.2)±0.18	1.18(0.75-1.85)±0.18	1.3(0.35-2.1)±0.25	73.4
Rhynchosia capitata	36.6(34.7-40.2)	48.9 (44.7-52.7)	1.25	2.65(2.00-3.2)±0.23	3.70(2.75-5.25)±0.42	7.00(5.25-8.00)±0.48	77.7
Sophora mollis	32.3(19.5-36.10±2.78	22.6(18.2-25.7)±1.09	1.42	3.45(4.7-6.25) ±0.29	5.30(6.23-9.75) ±0.54	5.80(5.40-7.65) ±0.42	81.3
Tephrosia purpurea	35.2(30.3-41.2)±1.94	34.3(32.2-36.7)±0.84	1.02	2.70(2.00-3.5)±0.26	3.60(2.75-4.25)±0.26	4.90(4.50-5.50)±0.20	65.5
Vicia angustifolia	37.6(33.0-42.7)±1.85	29.5(25.2-35.2)±1.64	1.27	4.55 (5.25-4)±0.48	21.9(19.7-23.2)±0.6	4.75 (5.25-4.25)±0.39	83.7

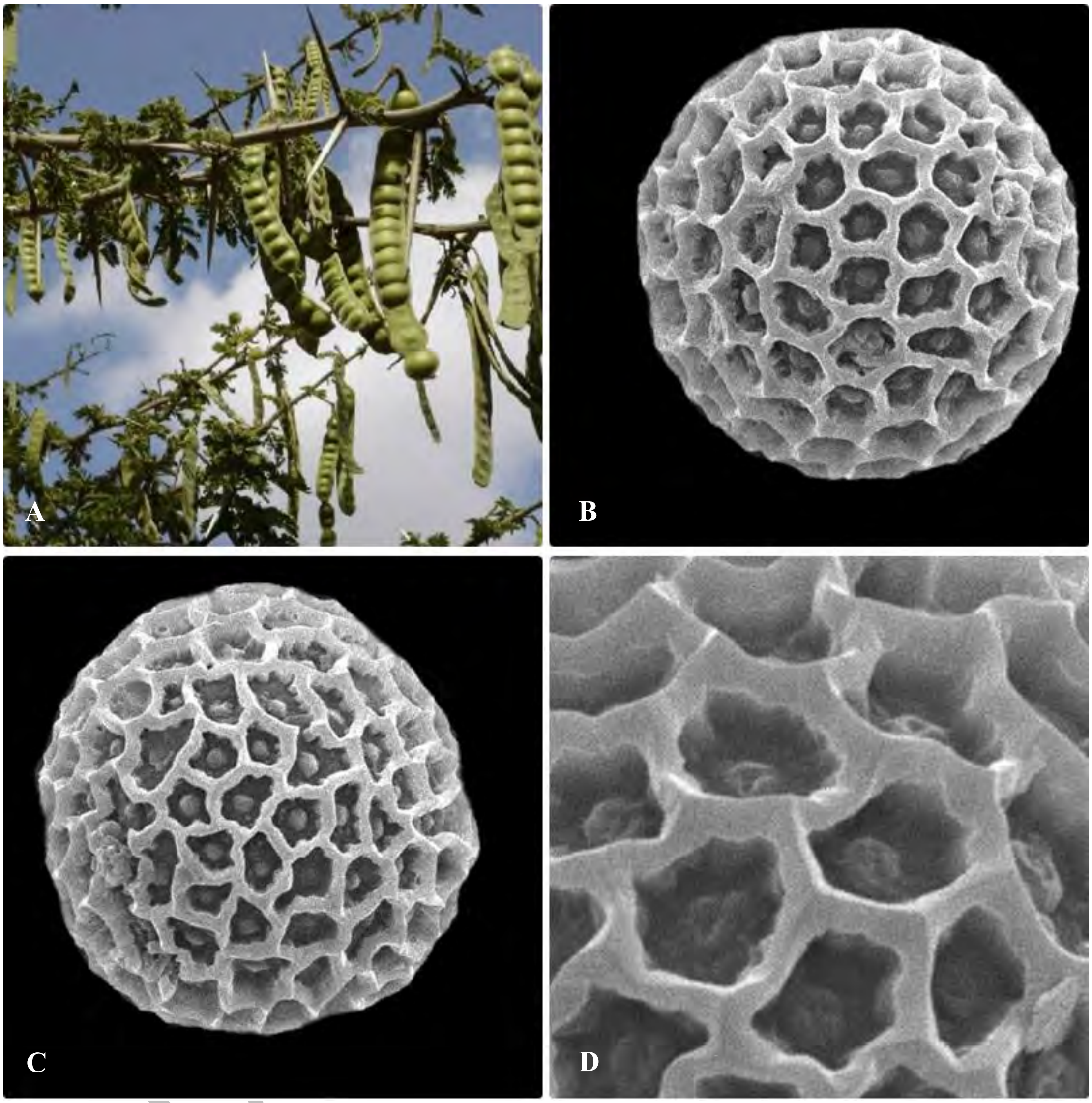

Plate 67: *Acacia nilotica* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Reticulate Exine Sculpturing (D) Surface Sculpturing

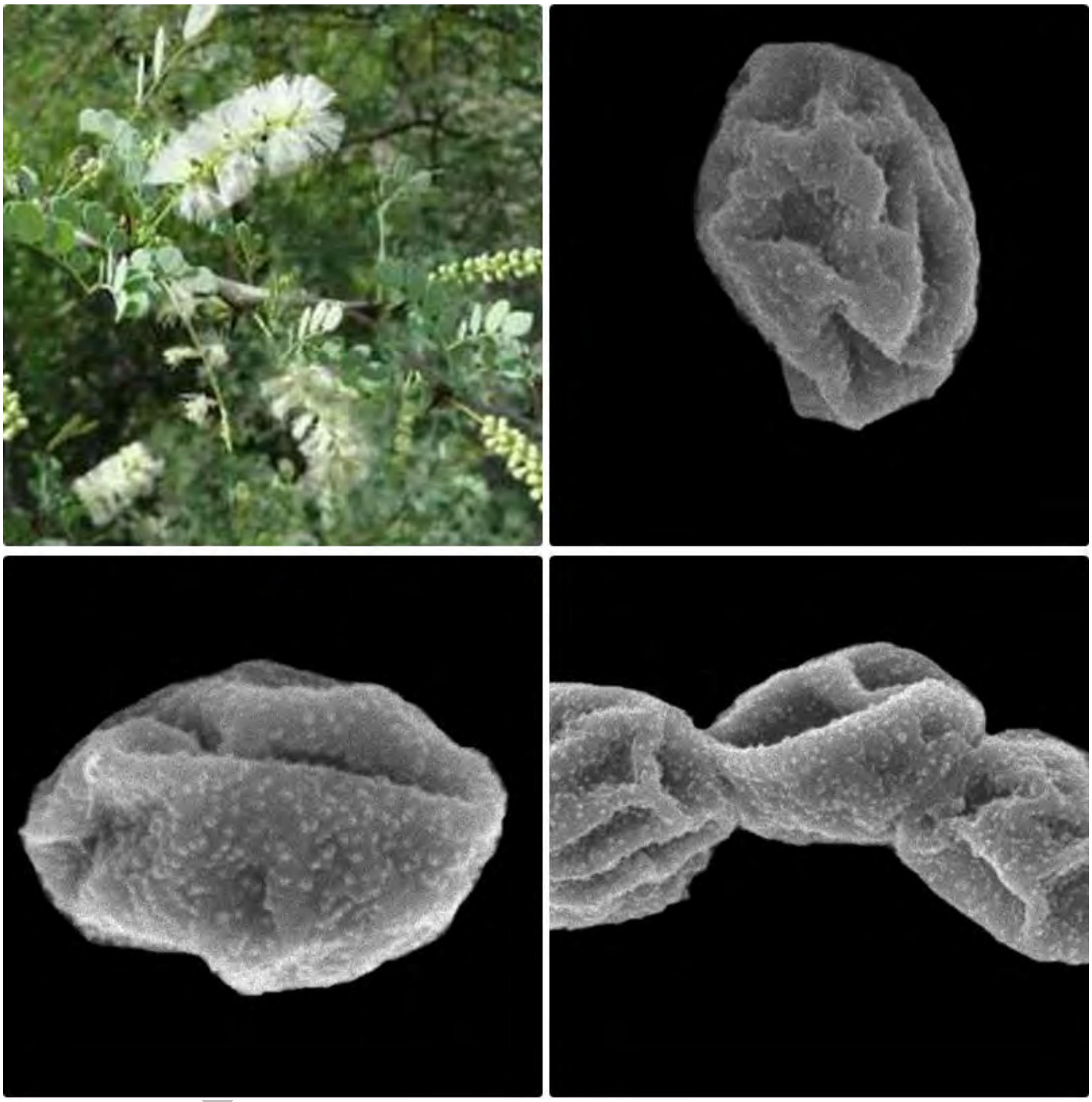

Plate 68: *Acacia modesta*(A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Reticulate orientation (D) Exine Sculpturing

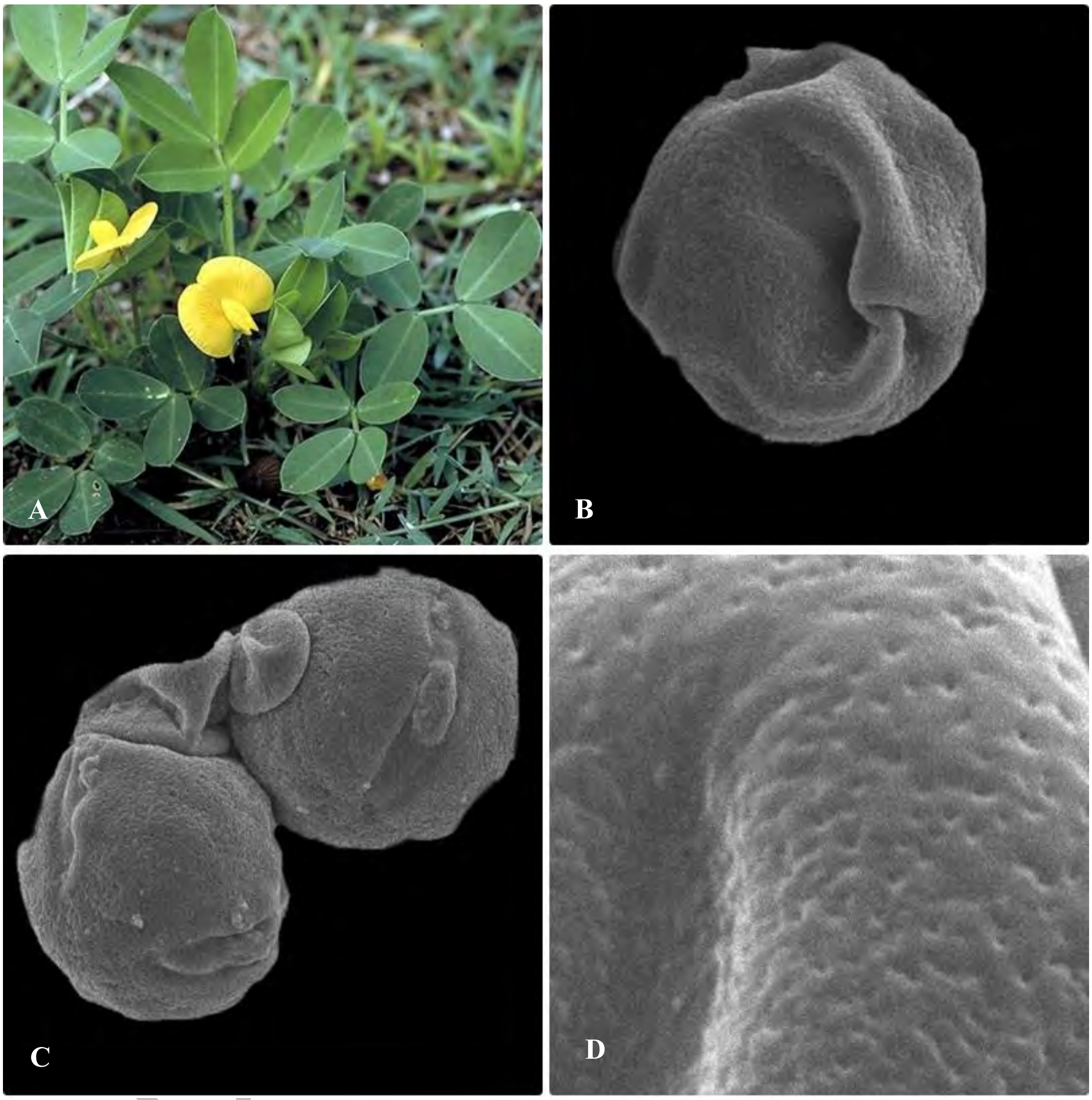

Plate 69: *Arachis hypagae* (A)Floral Parts , Scanning Electron Micrographs of Pollen (B)Polar View (C) Scabrate Surface (D) Exine Sculpturing

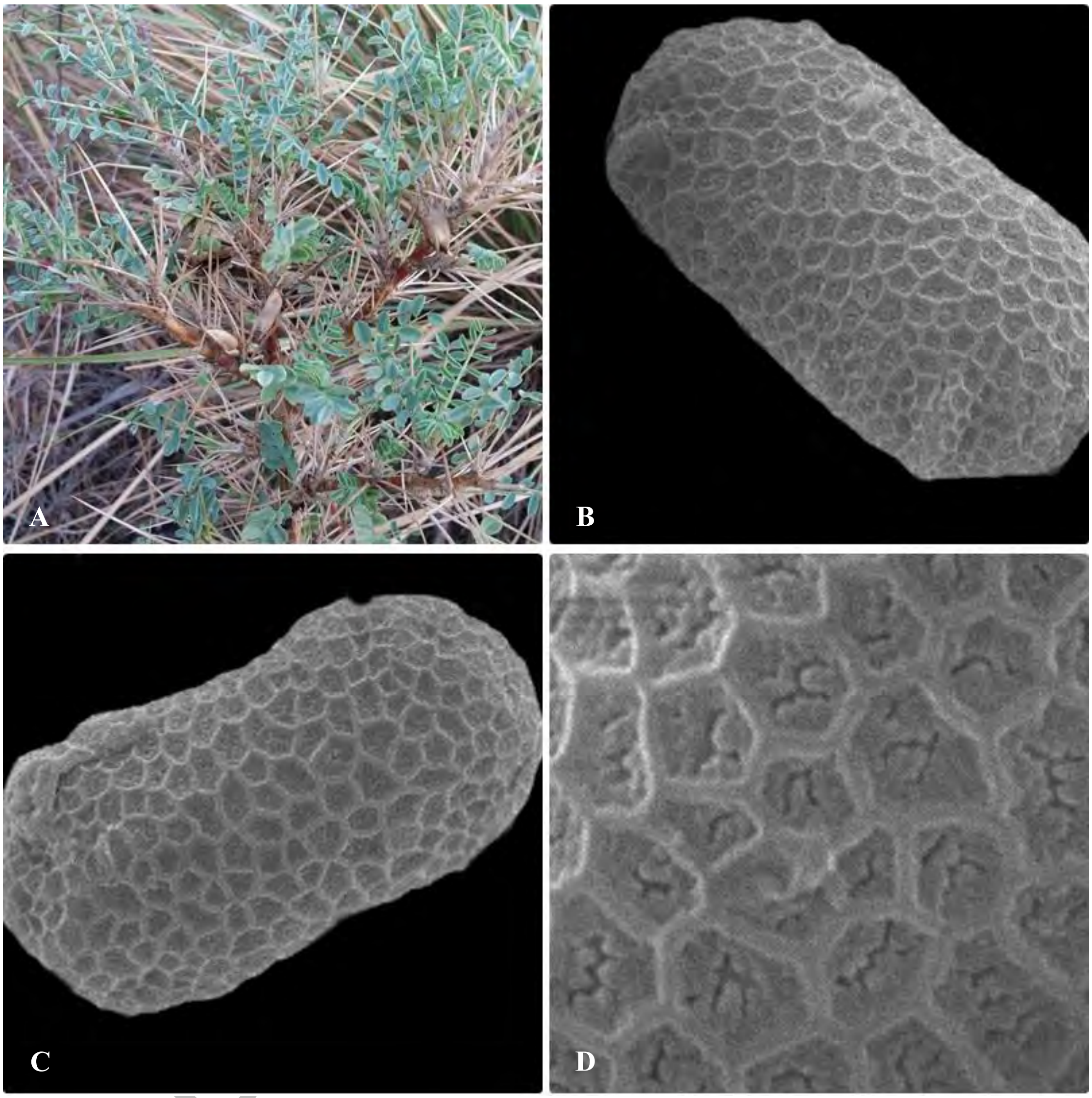

Plate 70: *Astragalus psilocentros* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B)Polar View (C) Moderately Thick Exine Texture (D) Surface Sculpturing

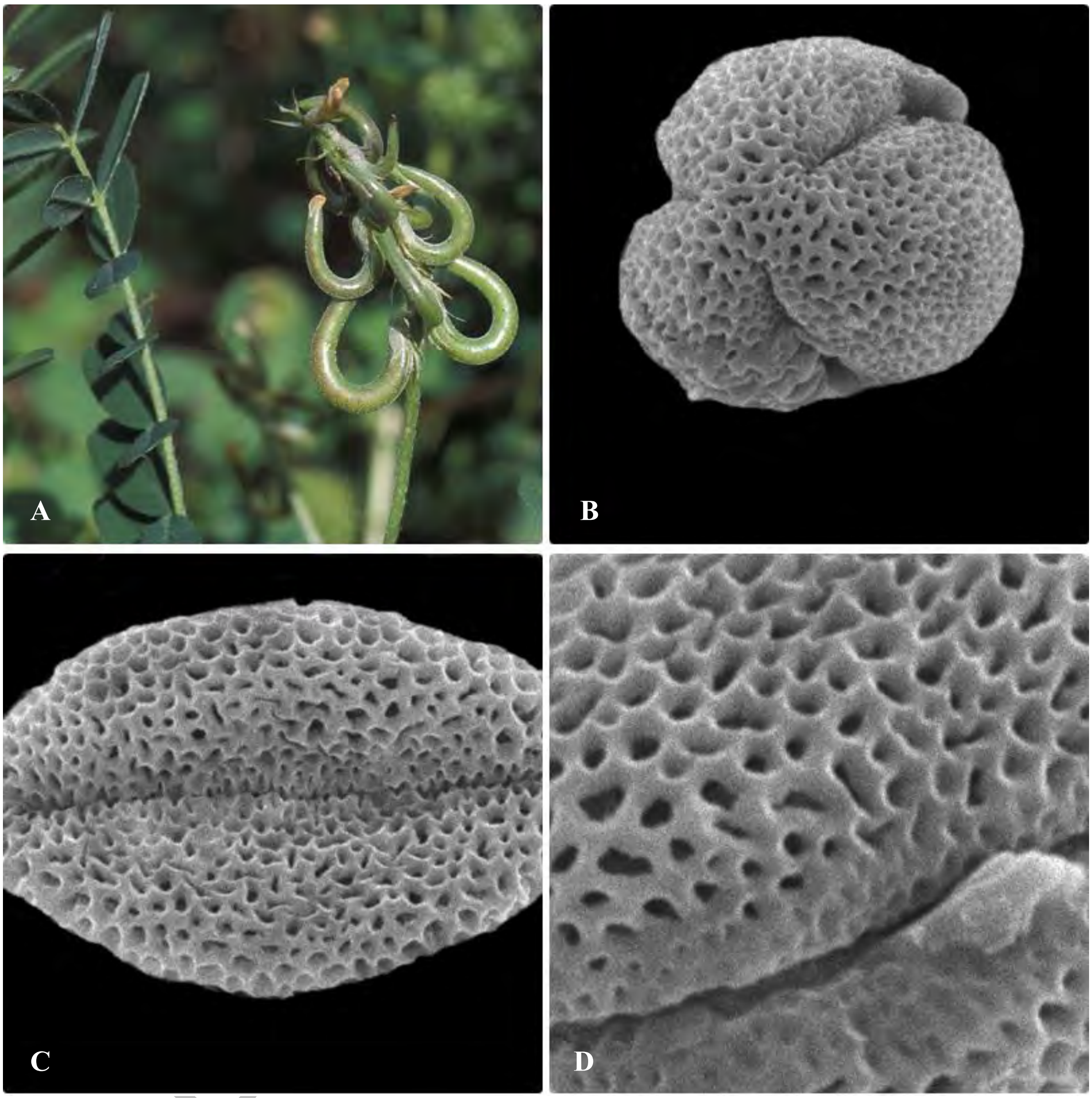

Plate 71: *Astragalus scoripiurus* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B)Polar View (C) Equatorial View (D) Surface Sculpturing

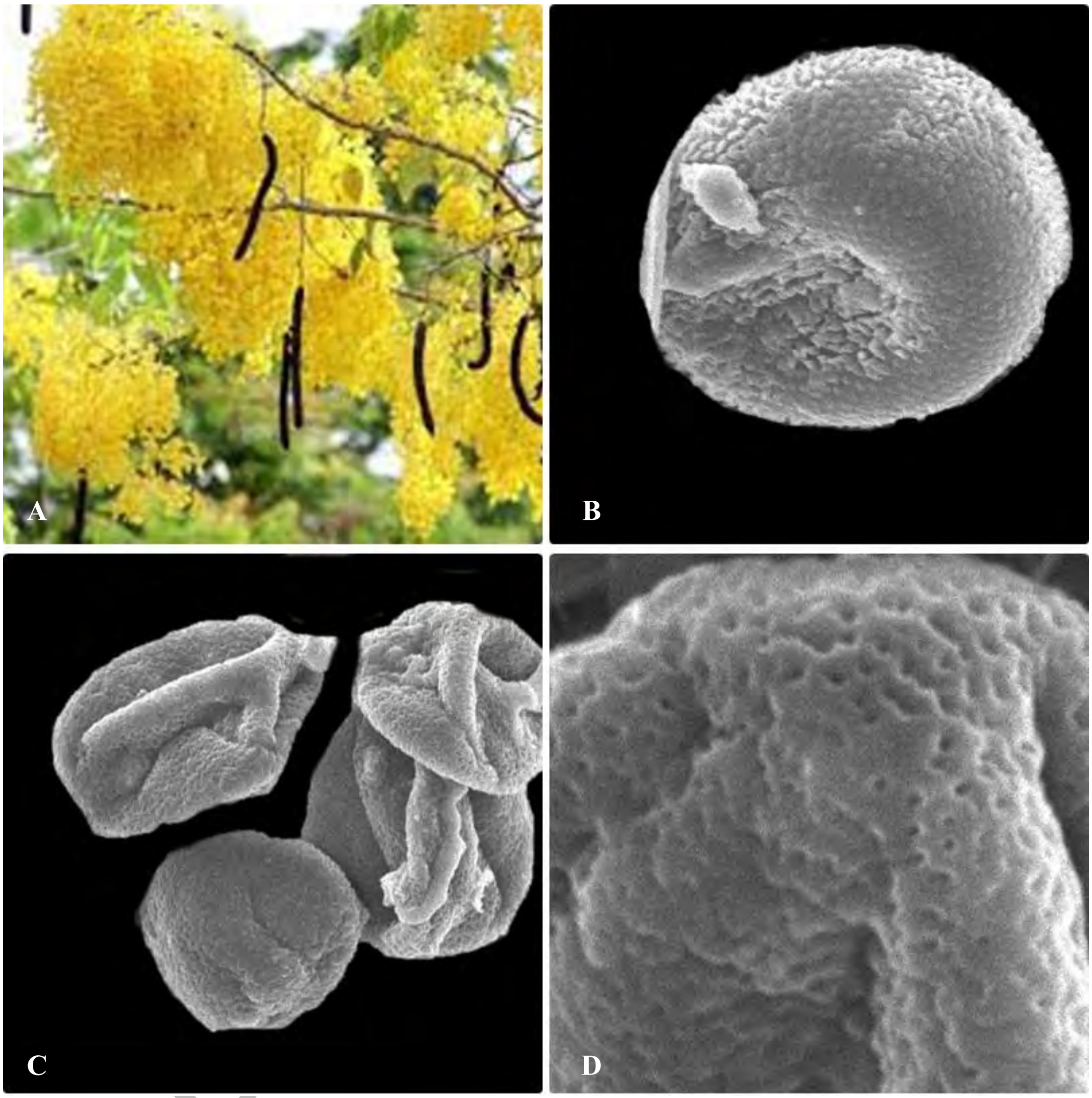

Plate 72: *Cassia fistula* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Equatorial View (D) Surface Sculpturing

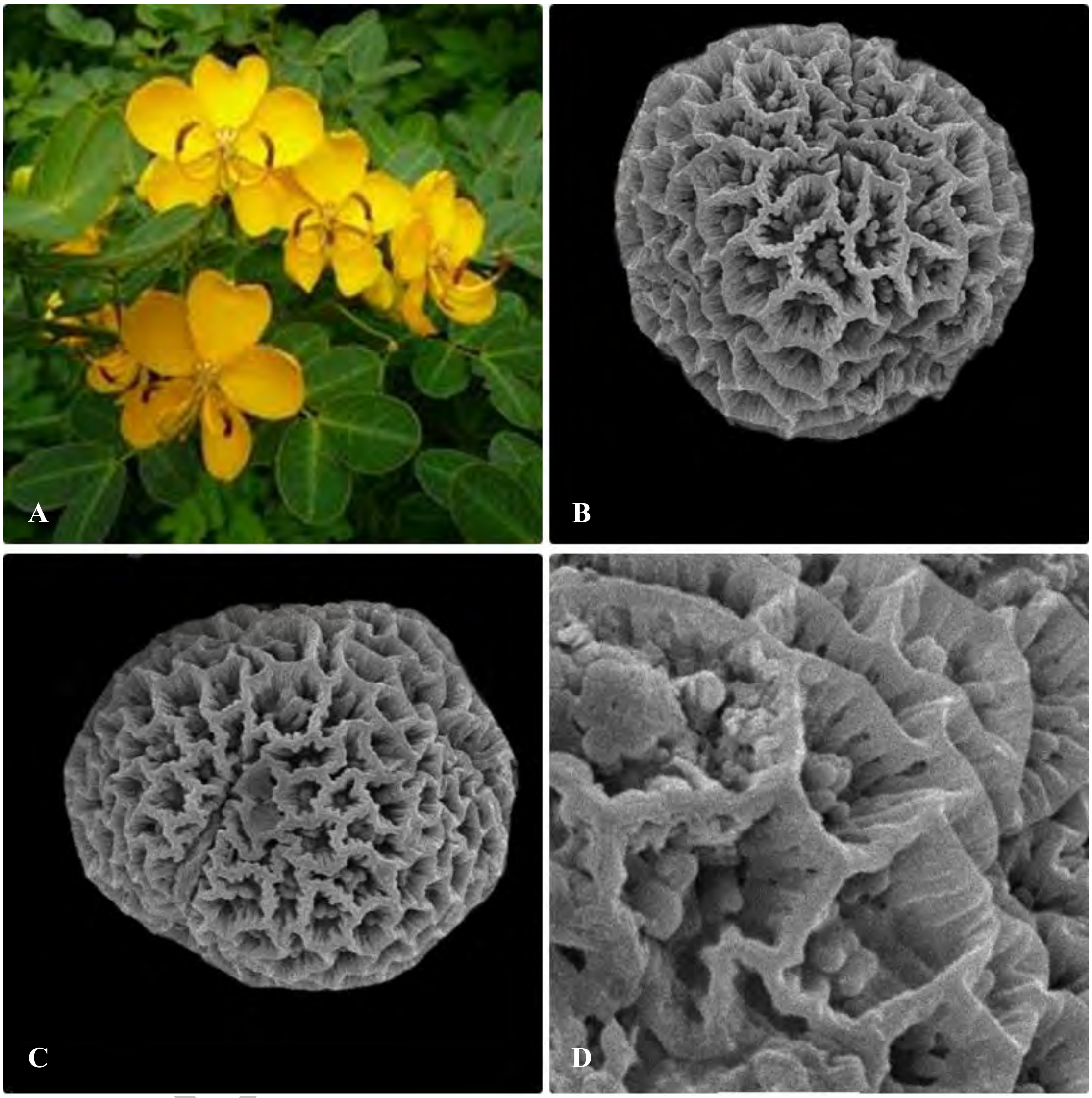

Plate 73: *Cassia italica* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B)Polar View (C) Moderately Thick Exine (D) Surface Sculpturing

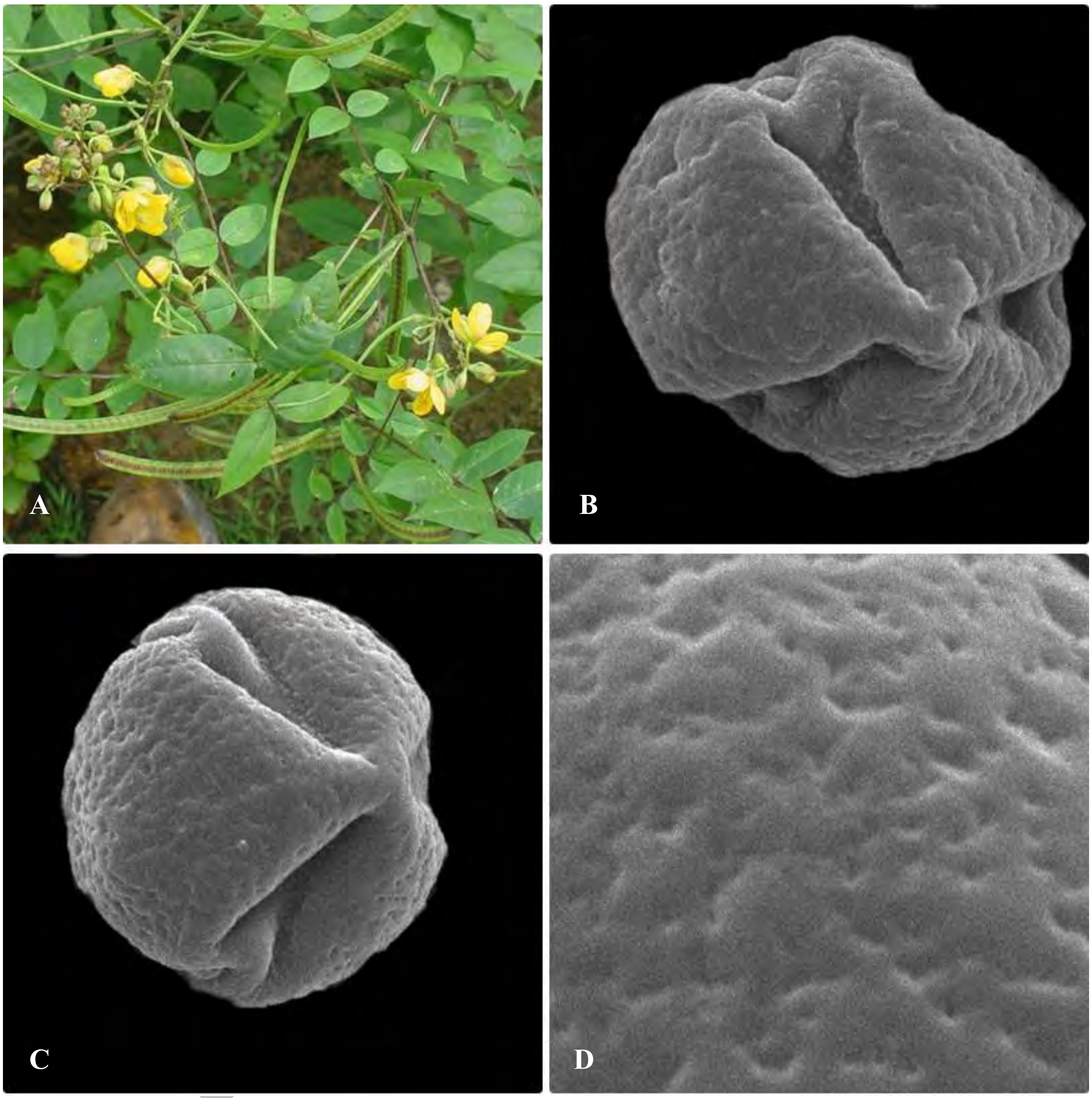

Plate 74: *Cassia occidentalis* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Perforate Sculpturing (D) Surface Sculpturing

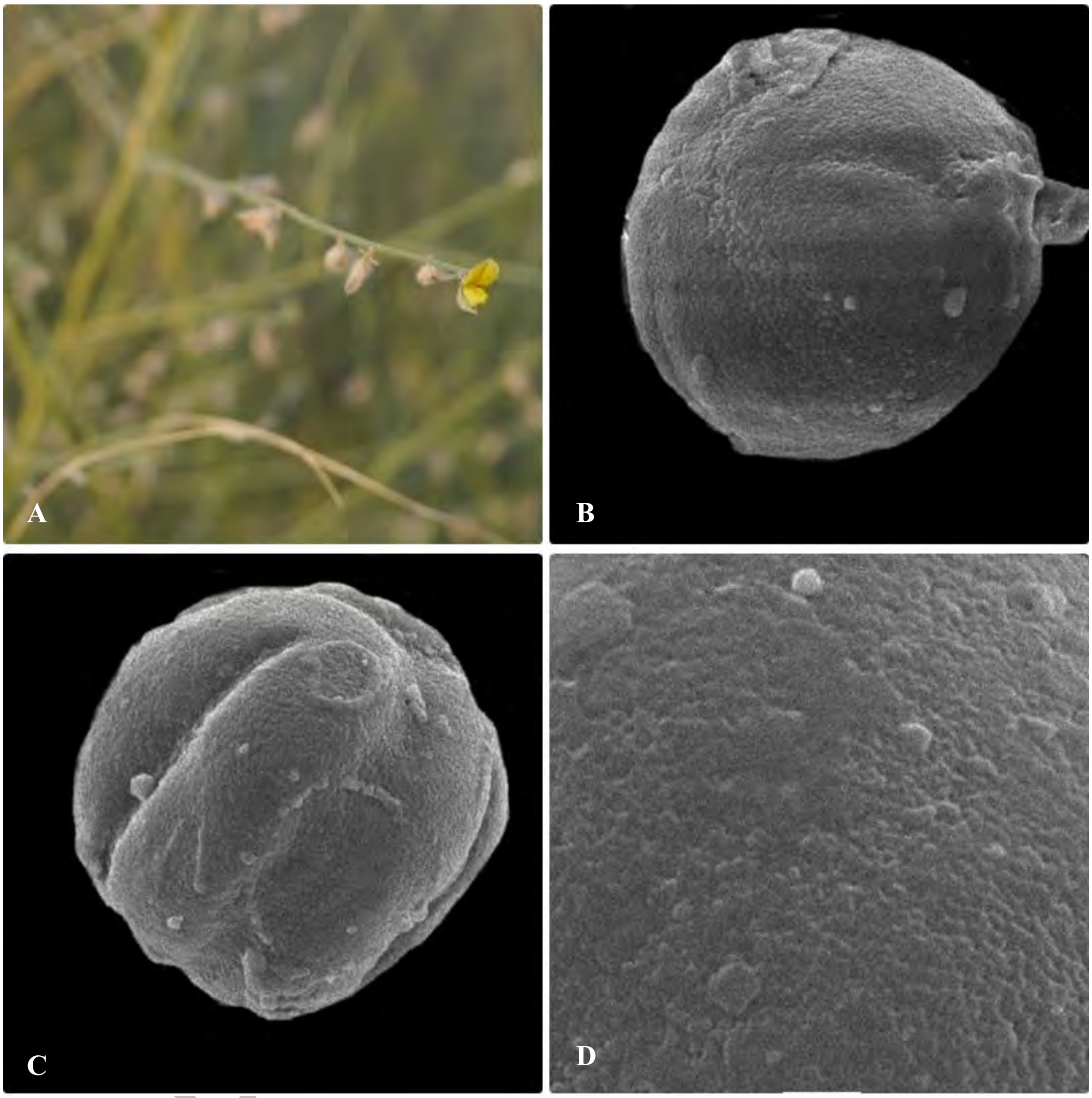

Plate 75: *Crotolaria burhia* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Equatorial View (D) Surface Sculpturing

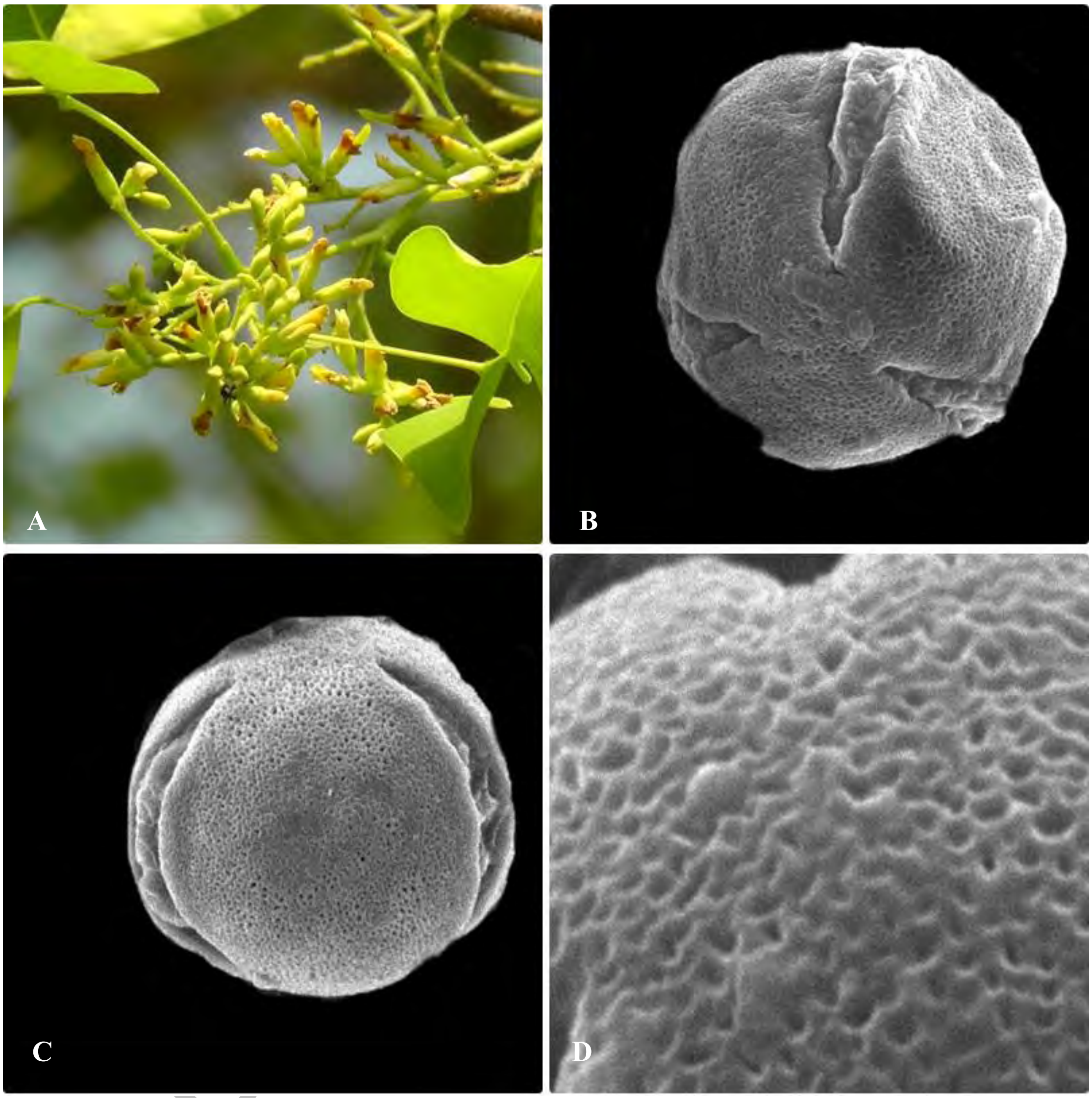

Plate 76: *Dilbergia sisso* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Thin Exine Texture (D) Surface Sculpturing

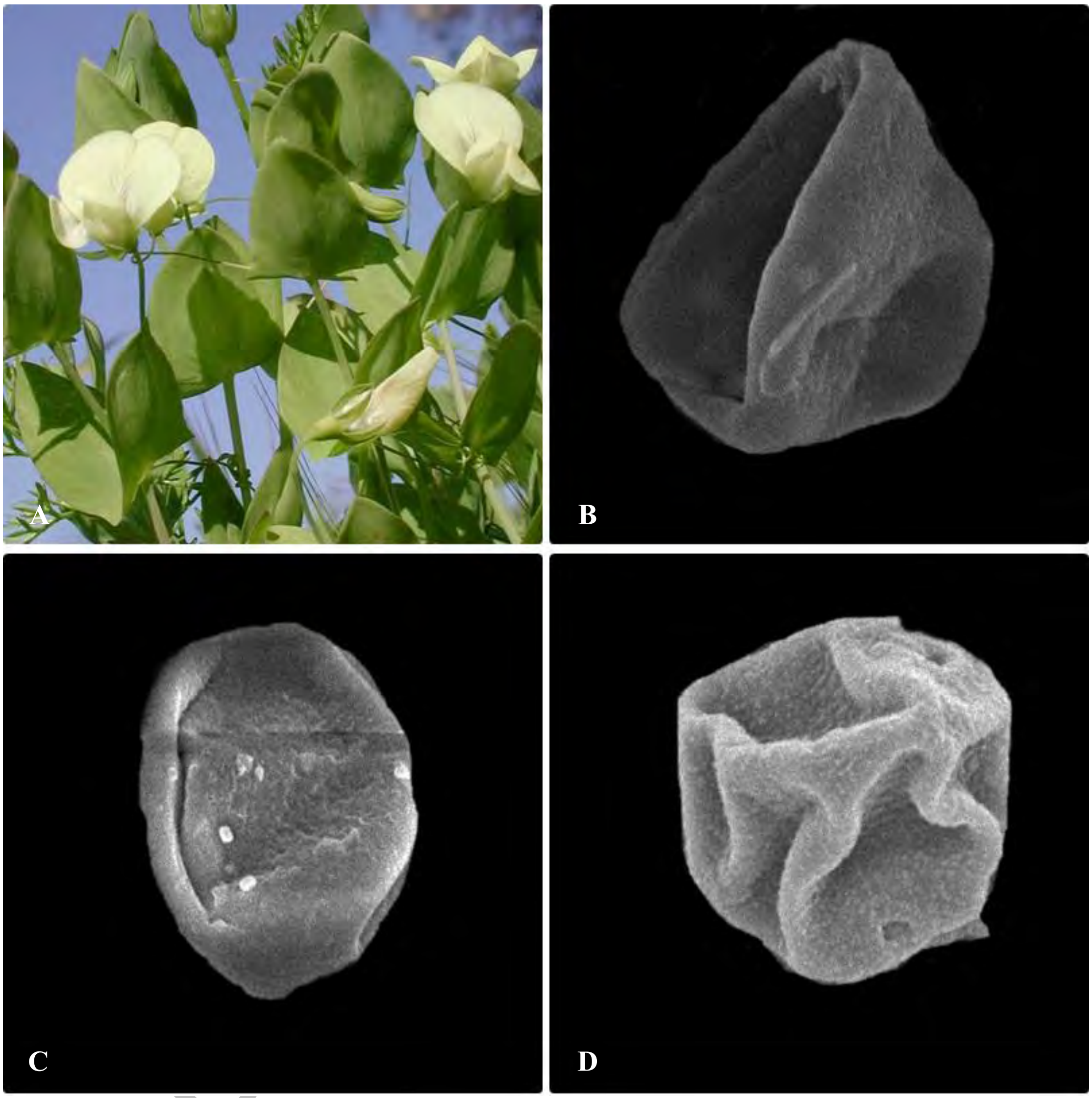

Plate 77: *Lathyrus aphaca* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B)Equatorial View (C) Thin Exine Texture (D) Perforate Sculpturing

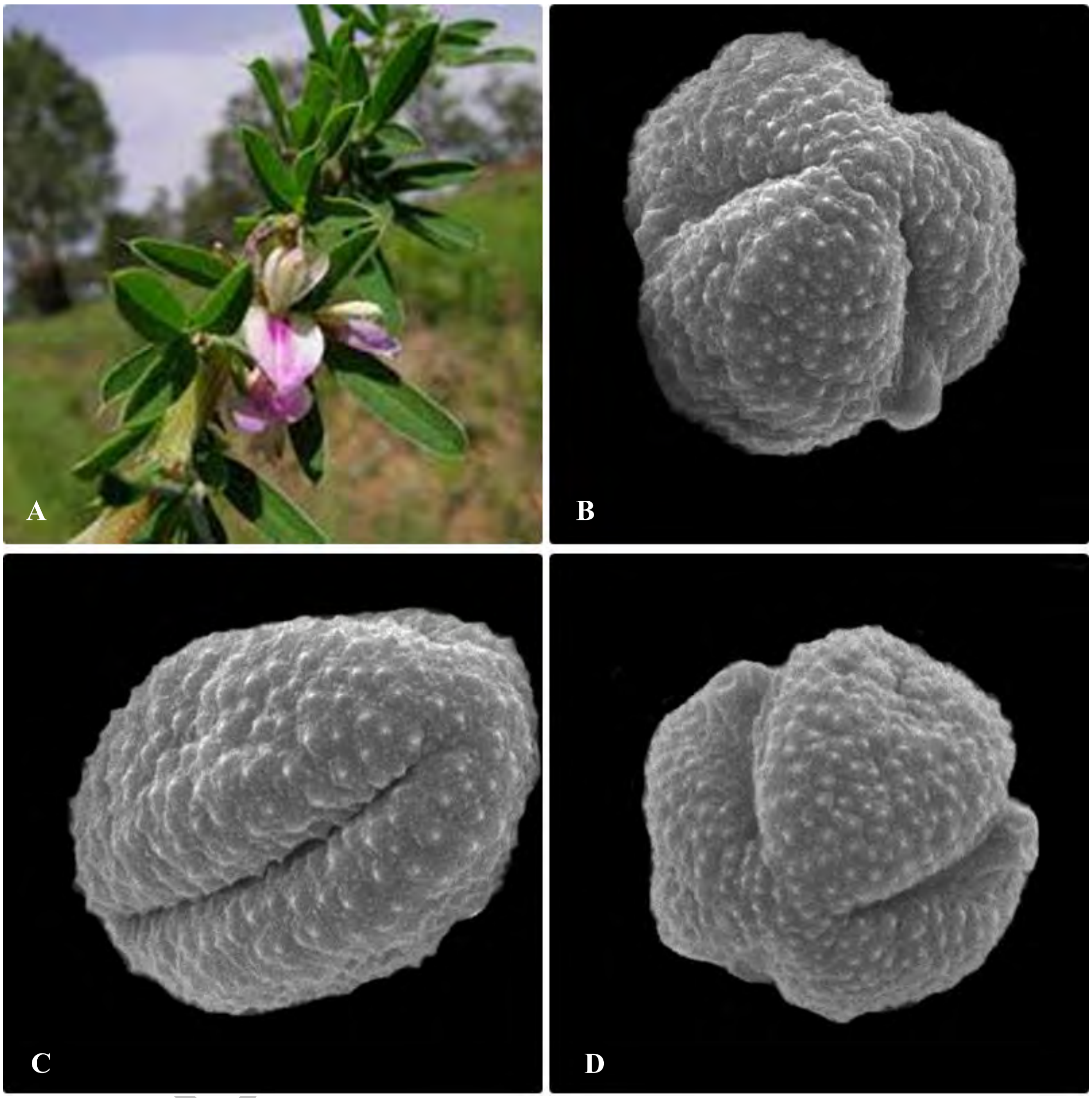

Plate 78: *Lespedeza juncea* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Equatorial View (D) Moderately Thick Exine Sculpturing

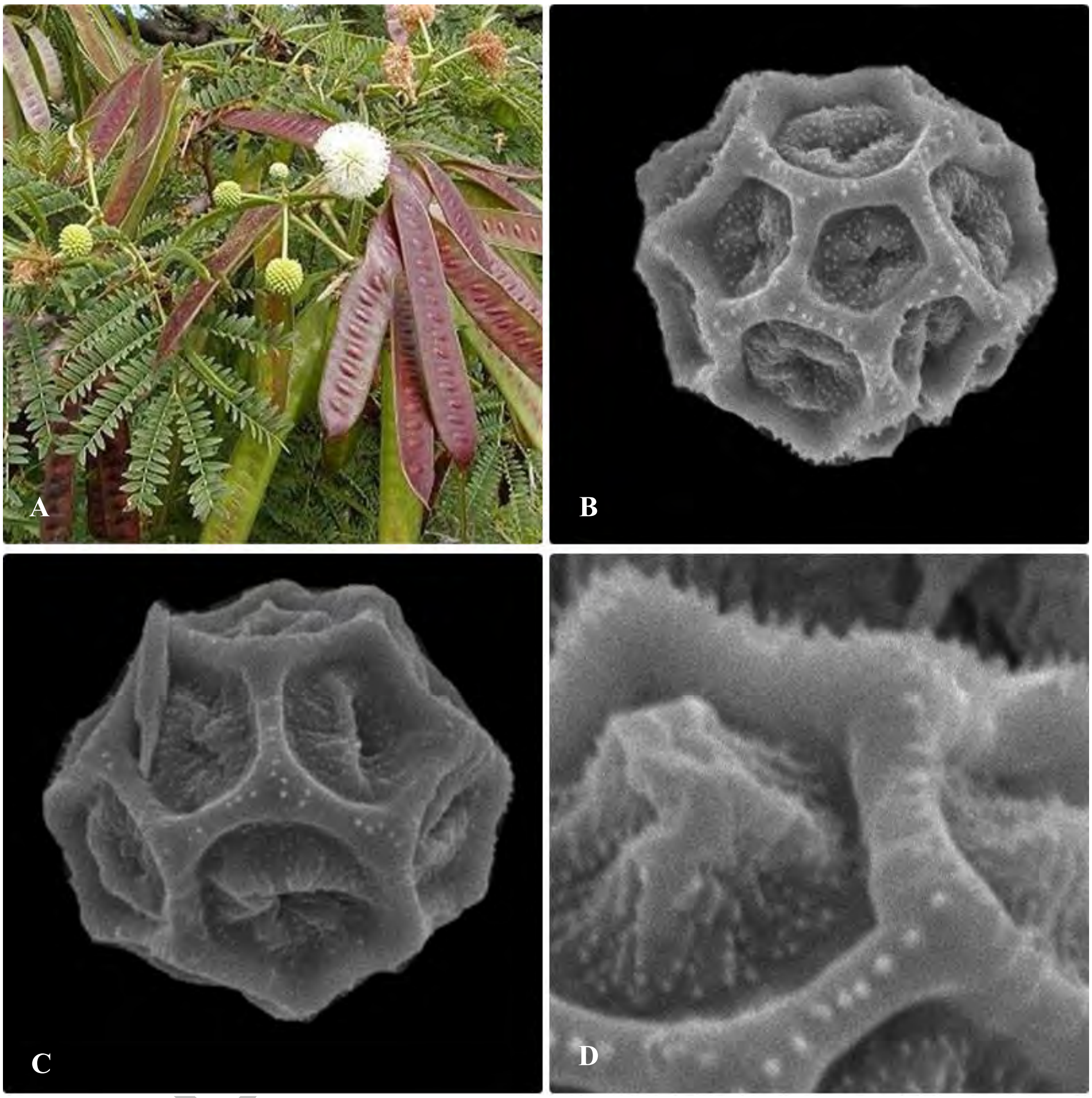

Plate 79: *Leucaena leucocephalla* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Verrucate Exine Sculpturing (D) Surface Sculpturing

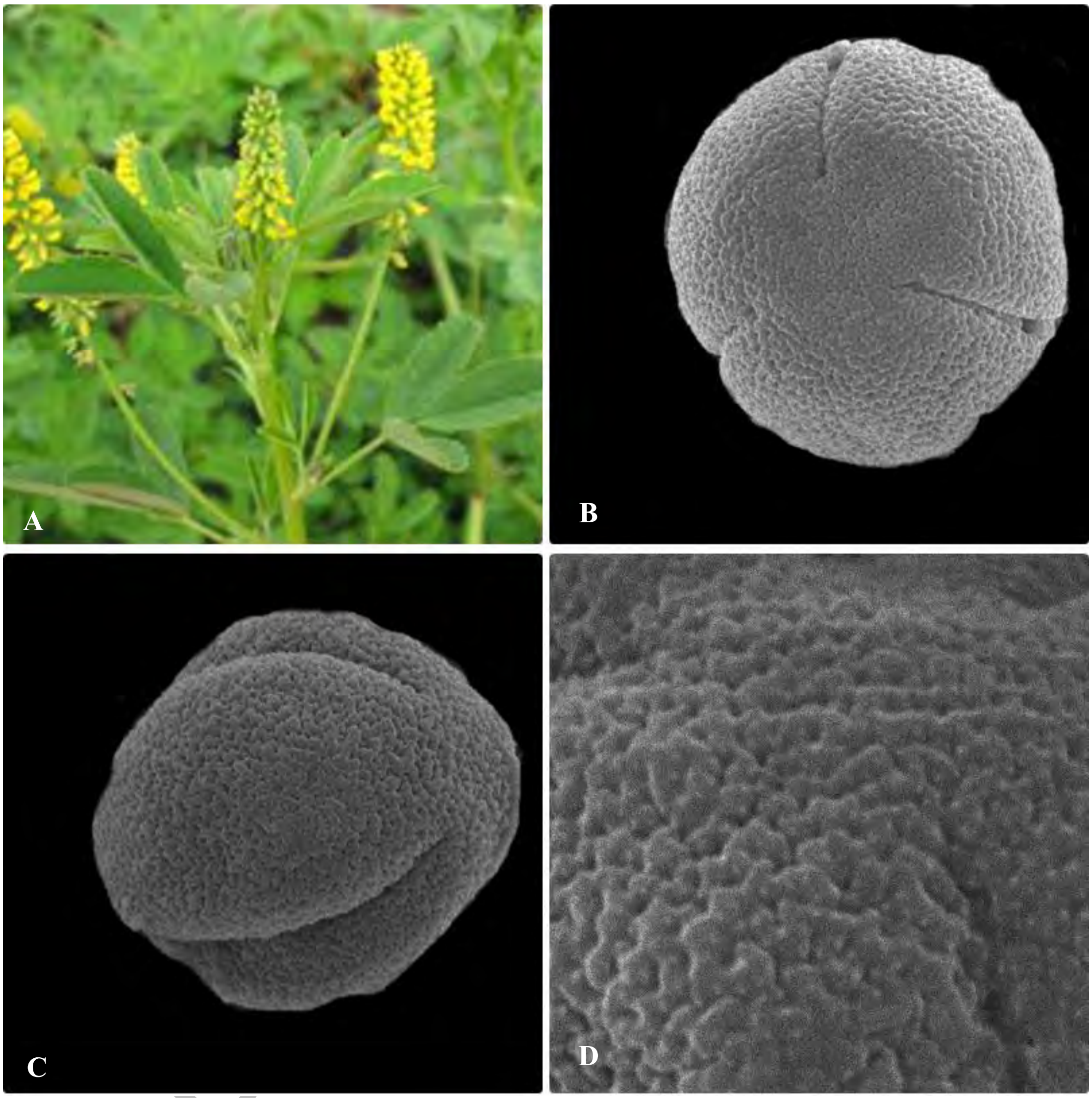

Plate 80: *Melilotus indicus* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Equatorial View (D) Surface Sculpturing

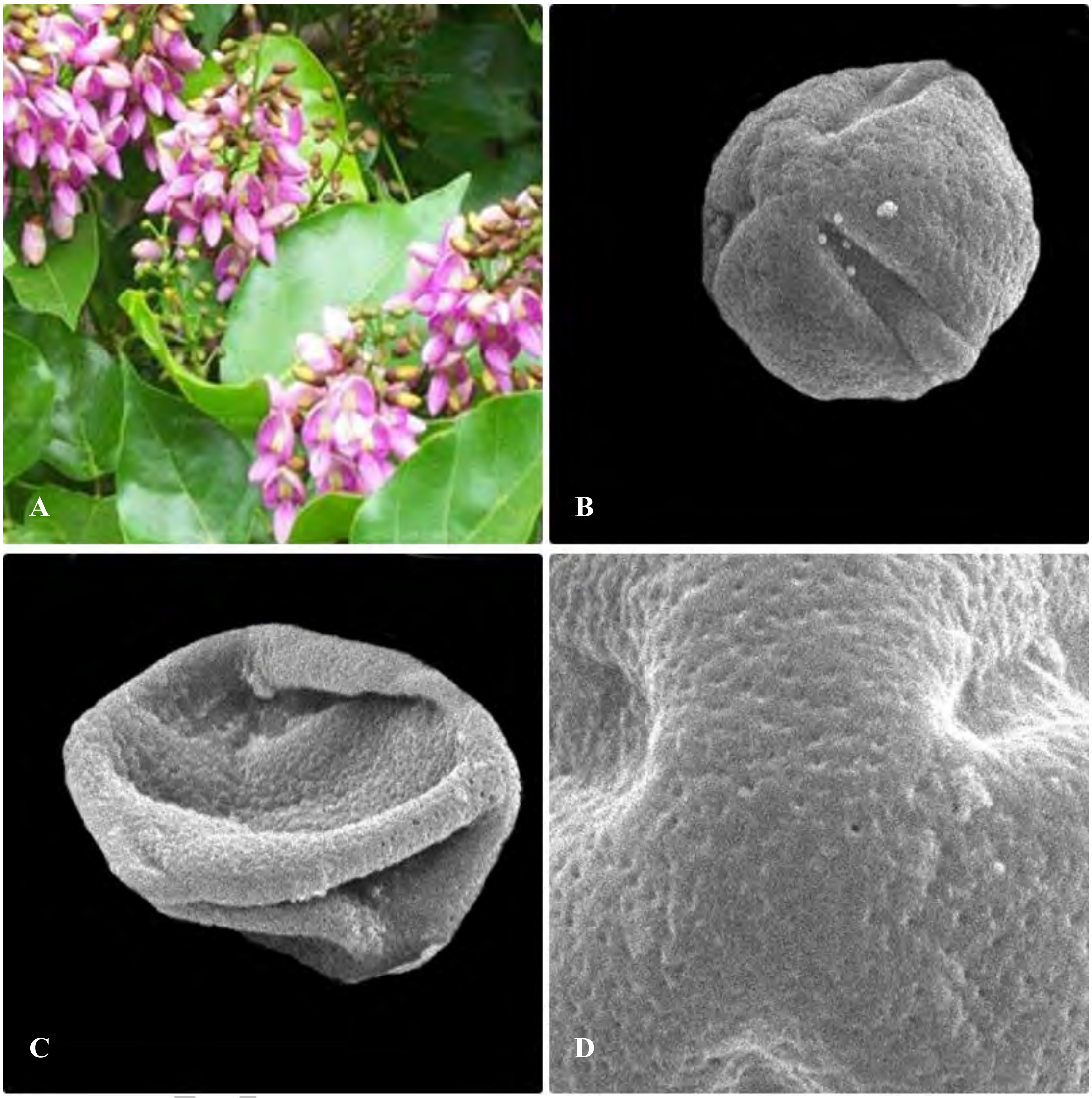

Plate 81: *Pigomia pinnata* (A)Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Equatorial View (D) Surface Sculpturing

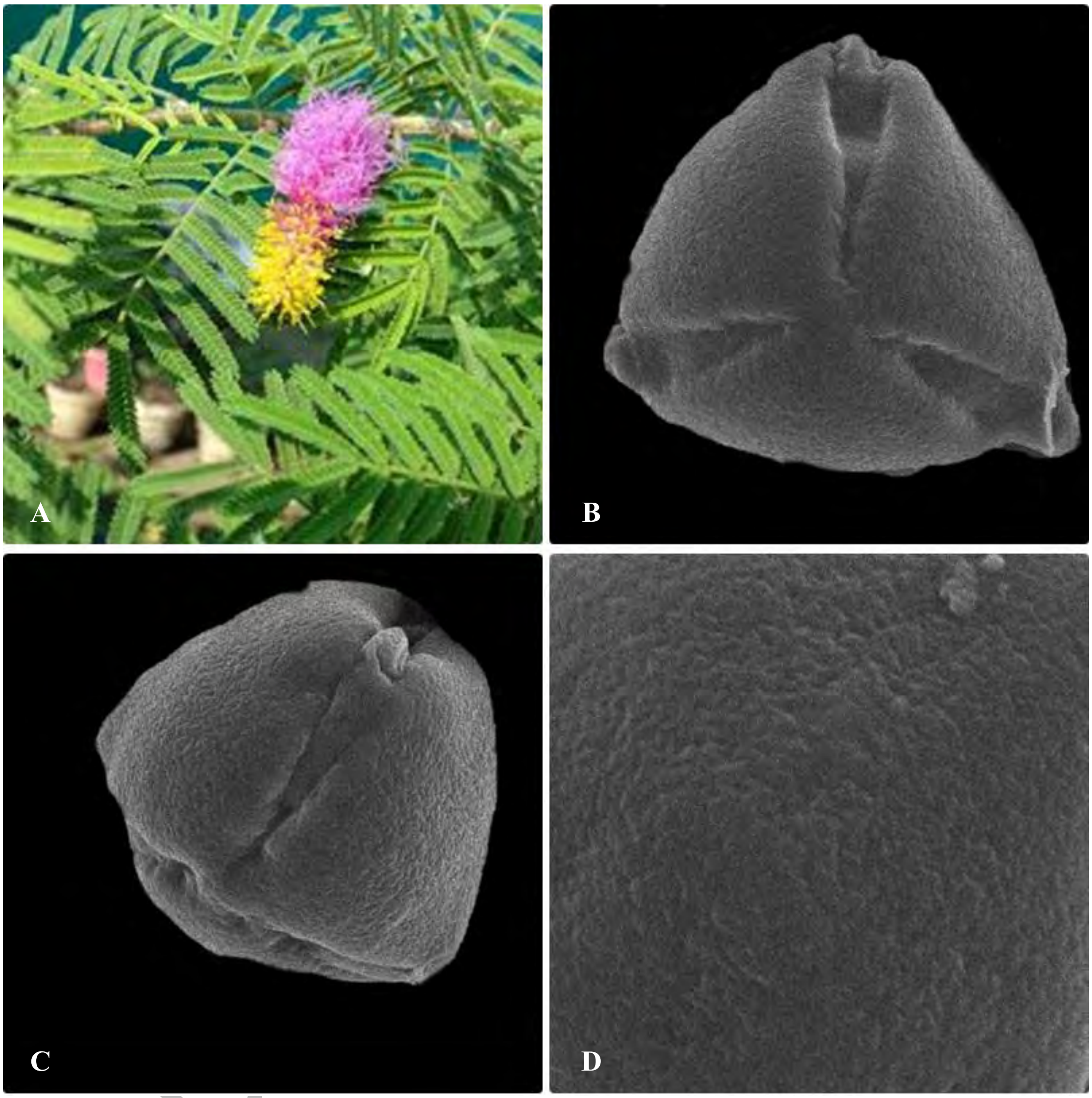

Plate 82: *Prosopis cineraria* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Equatorial View (D) Surface Sculpturing

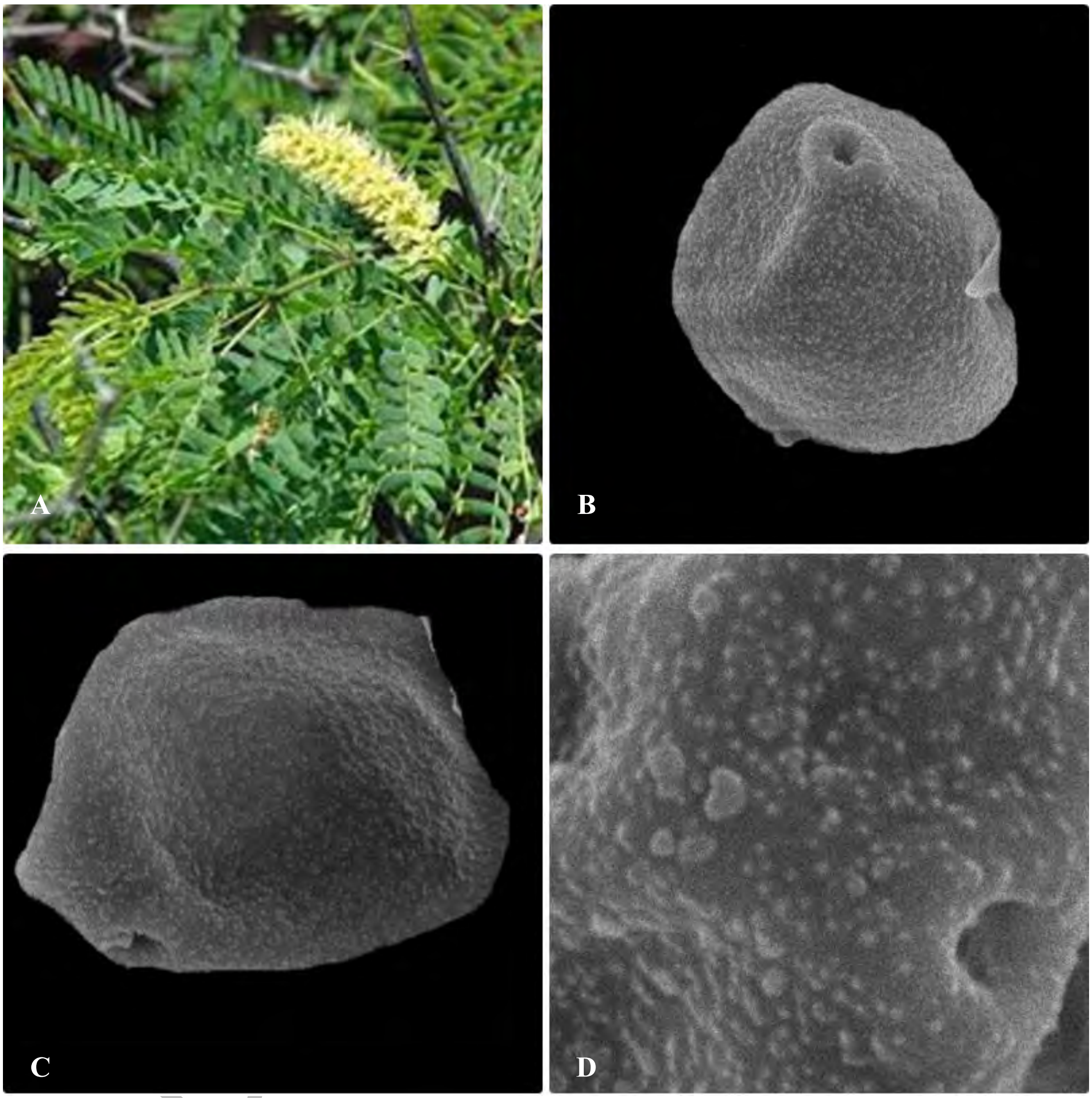

Plate 83: *Prosopis juliflora* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Equatorial View (D) Surface Sculpturing

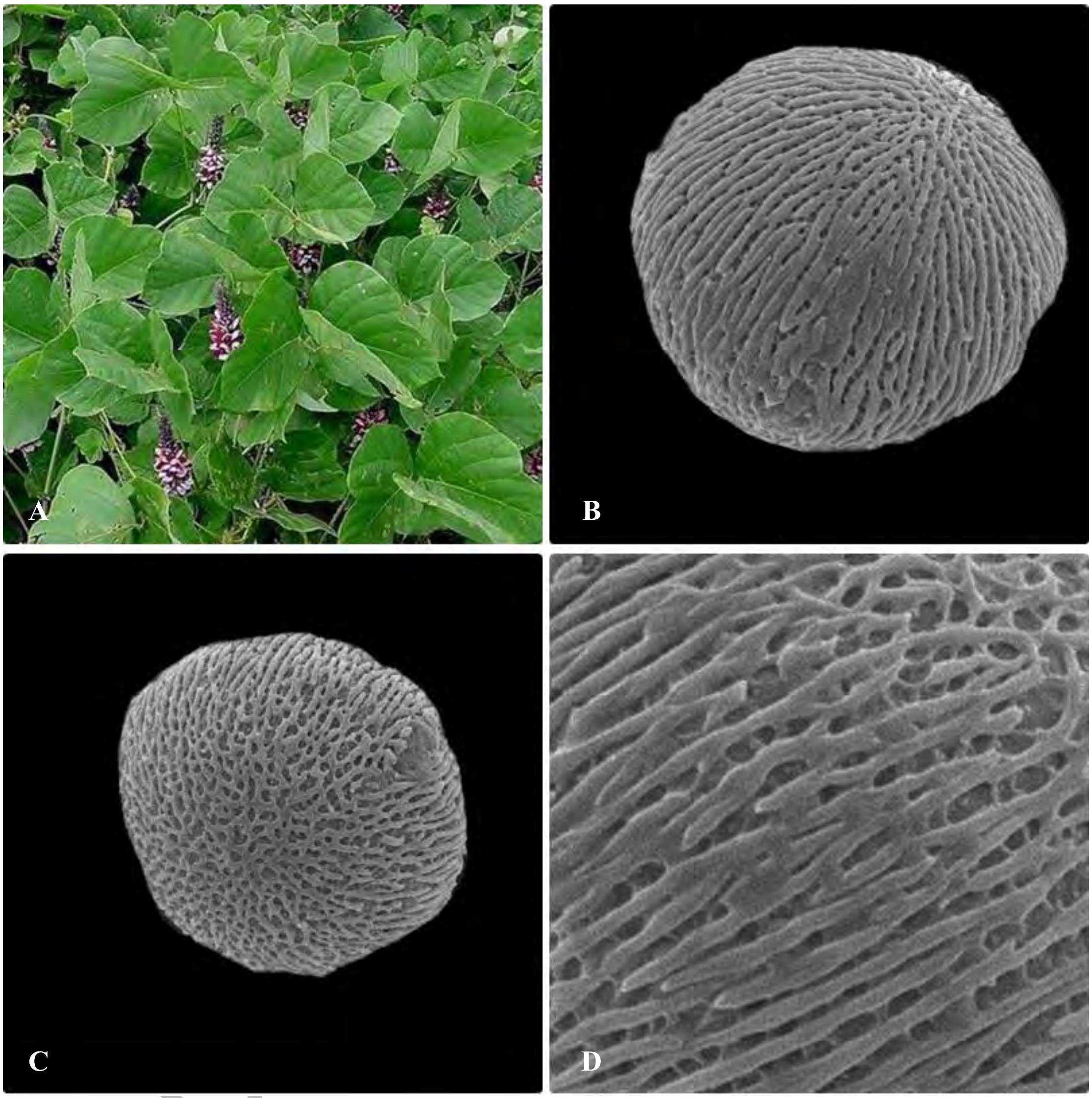

Plate 84: *Pueraria tuberosa* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Reticulate Exine Sculpturing (D) Surface Sculpturing

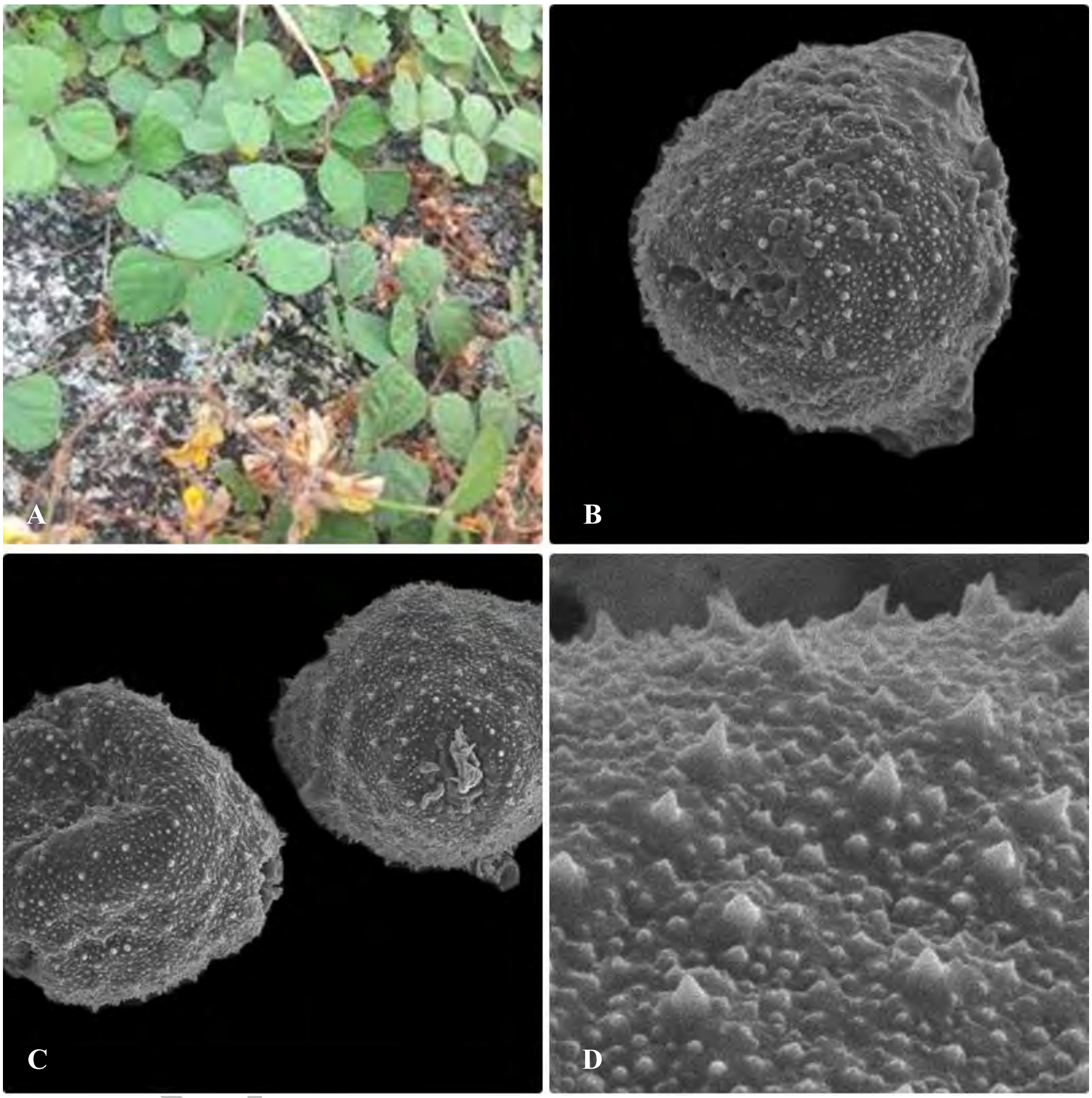

Plate 85: *Rhynchosia capitata* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Reticulate Perforate Exine Texture (D) Surface Sculpturing

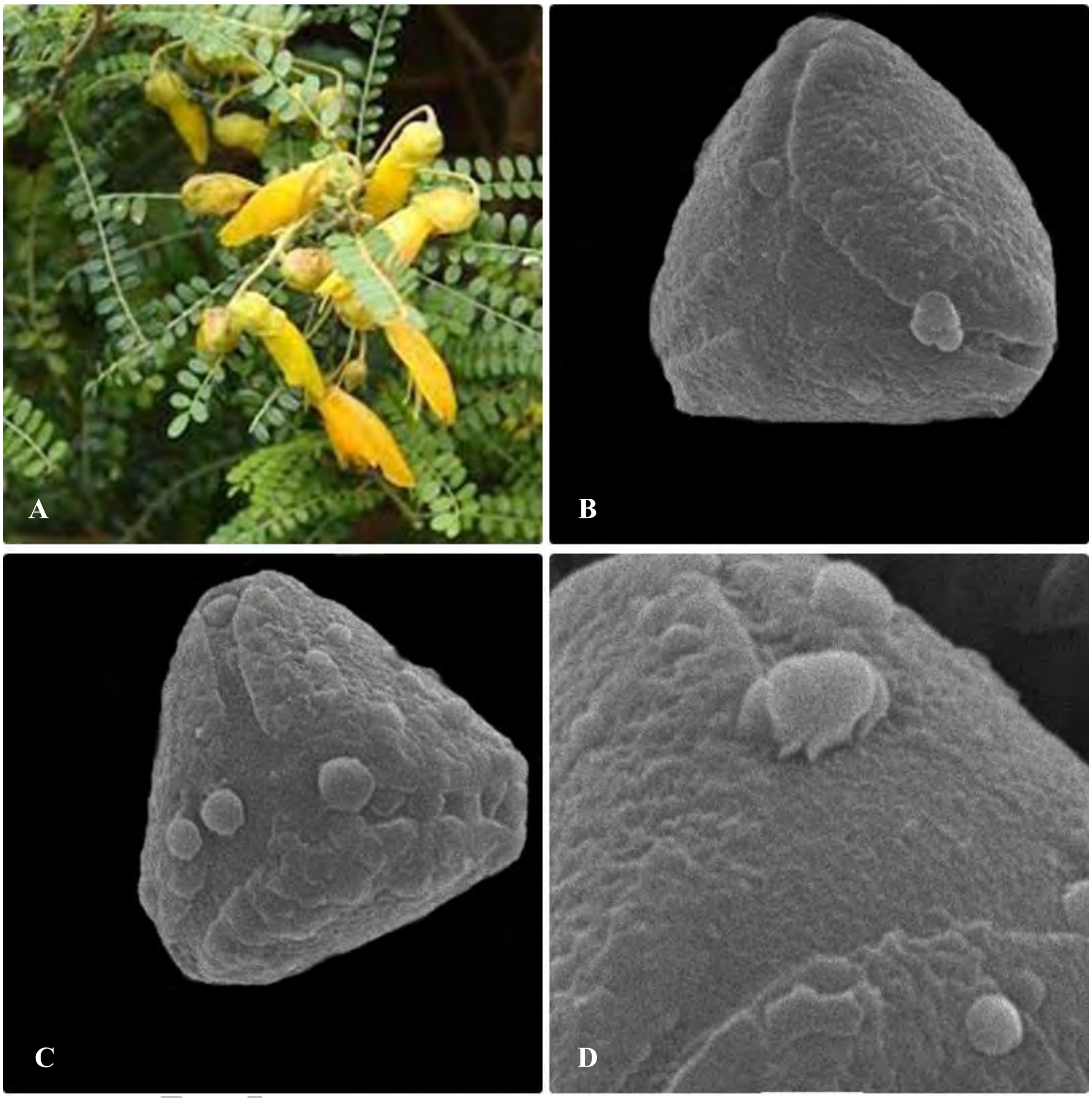

Plate 86: *Sophora mollis* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Perforate Exine Sculpturing (D) Surface Sculpturing

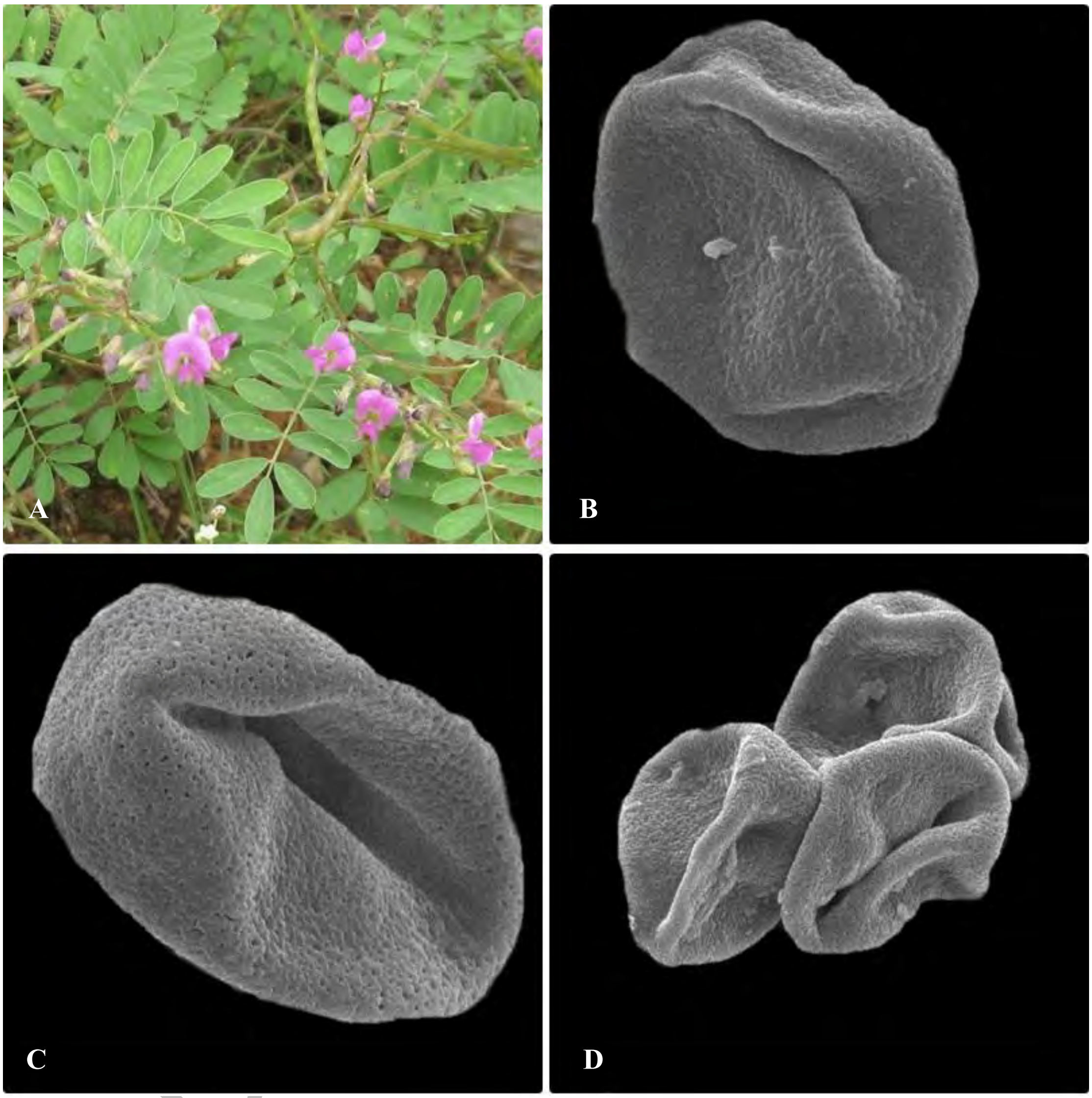

Plate 87: *Tephrosia purpurea* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Reticulate sculpturing(D) Thin Exine Texture

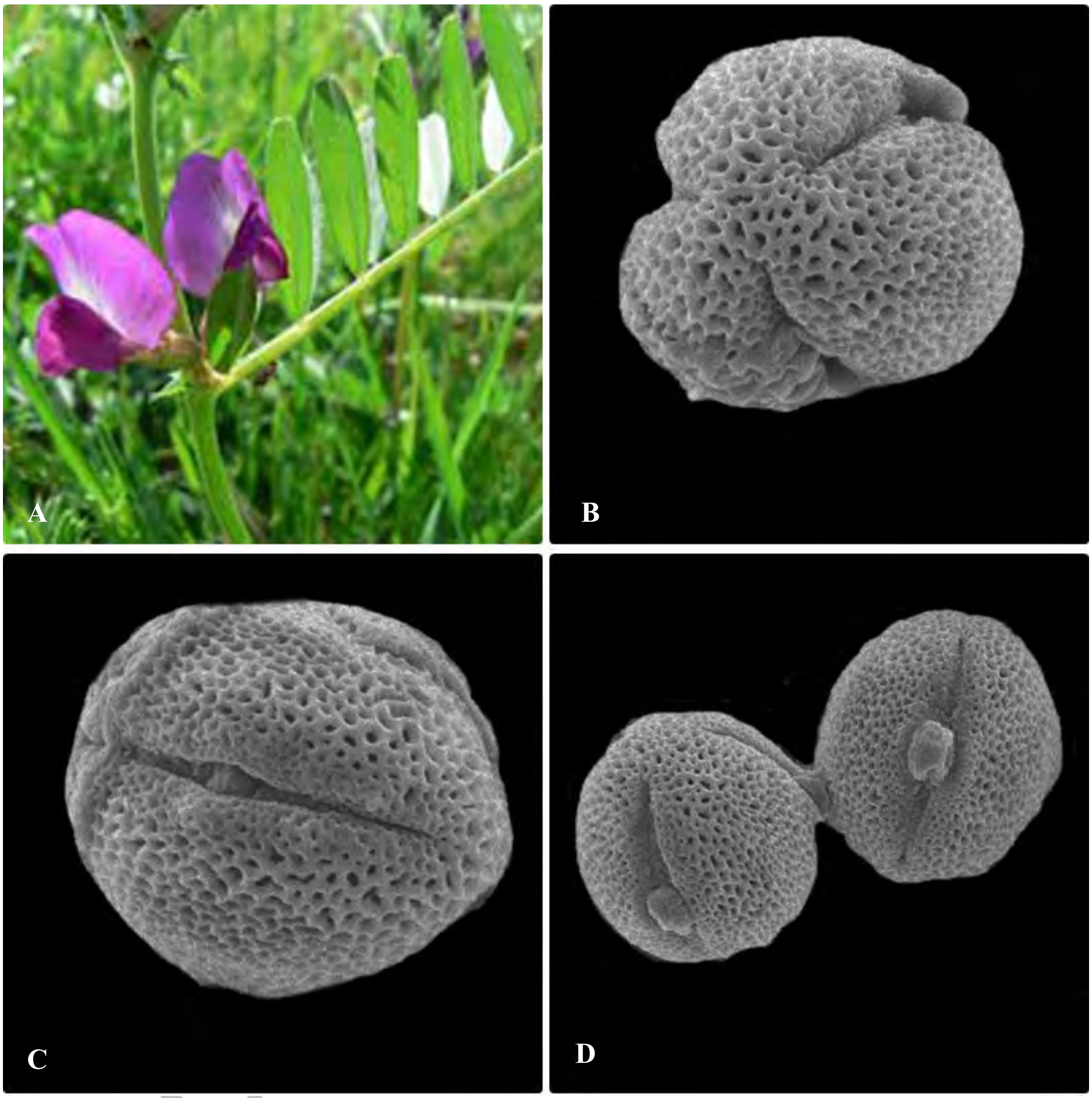

Plate 88: *Vicia angustifolia* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Equatorial View (D) Reticulate-Perforate Sculpturing

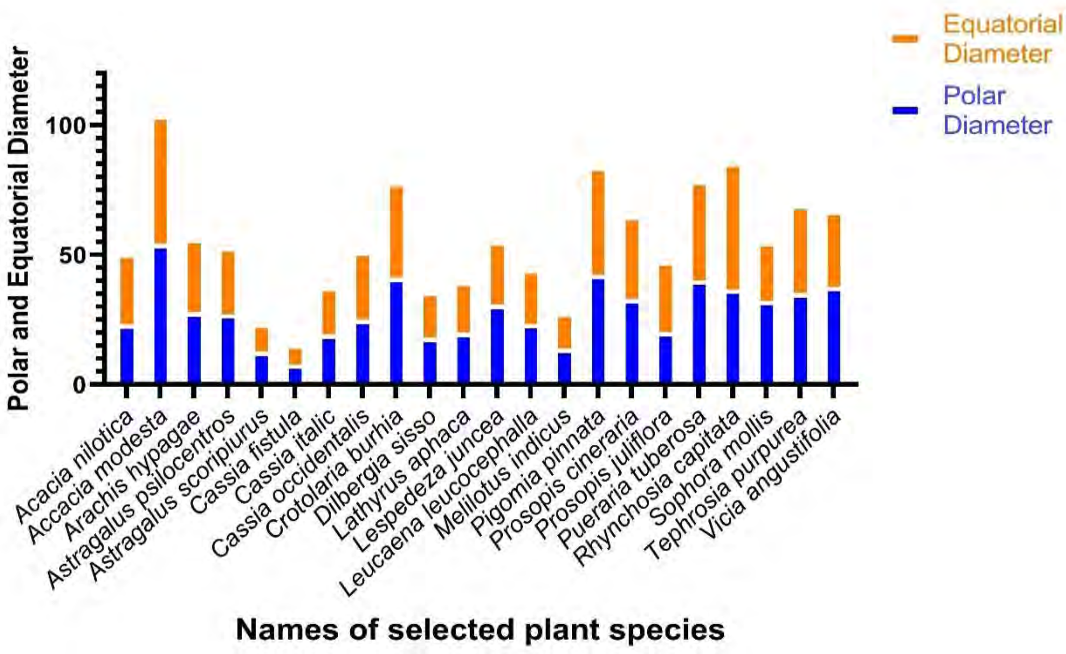

Figure 16: Mean values of Pollen diameter among Fabaceous taxa

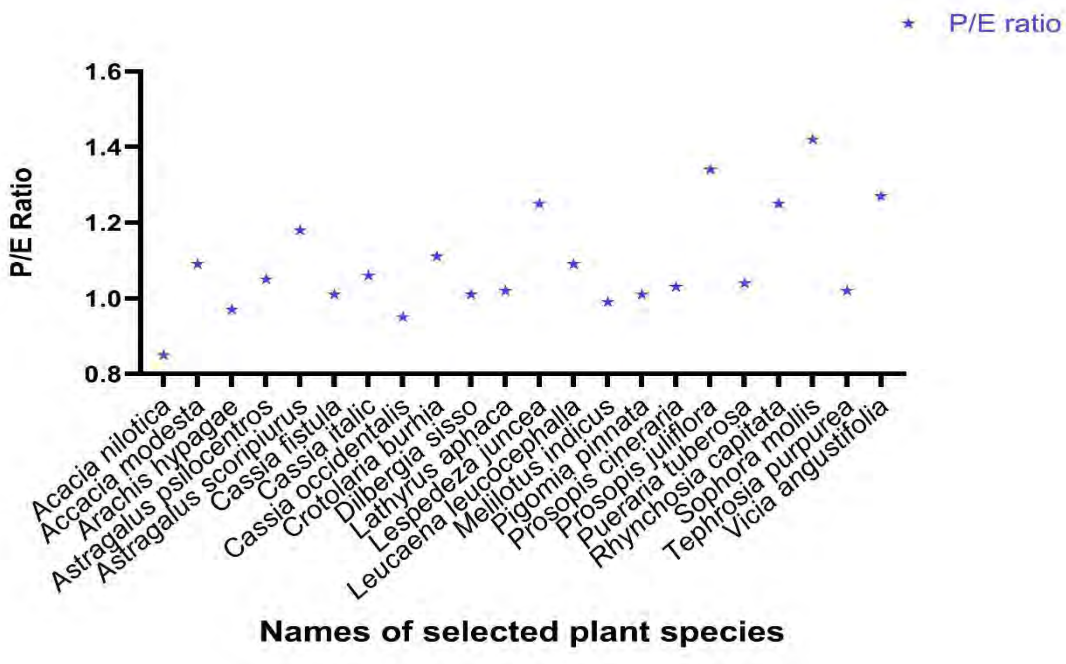

Figure 17: Variation in P/E ratio index of Fabaceous taxa

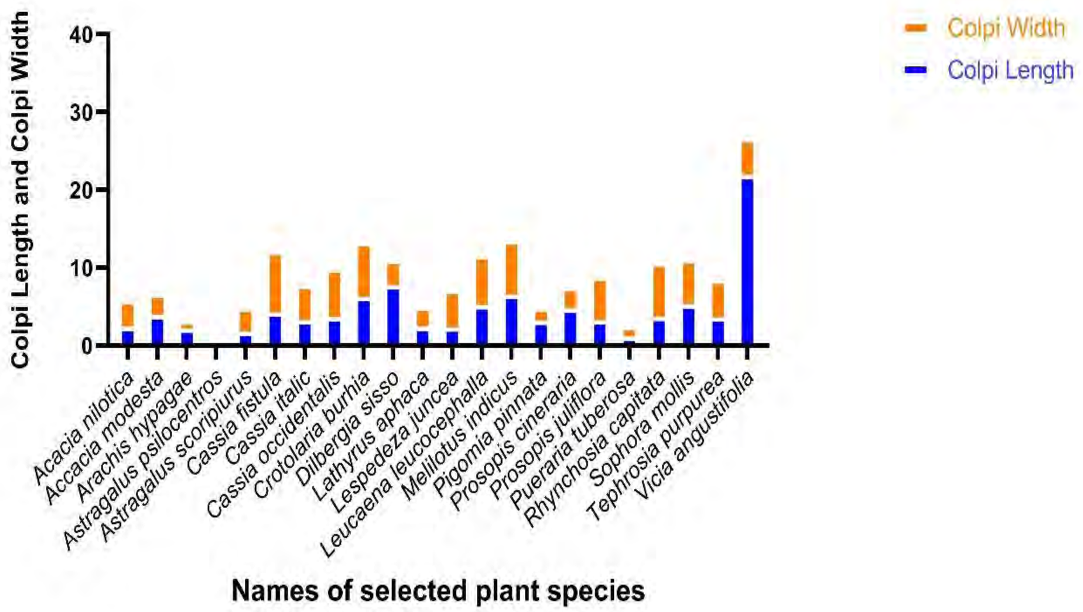

Figure 18: Mean data variations of colpi length and width in Fabaceous taxa

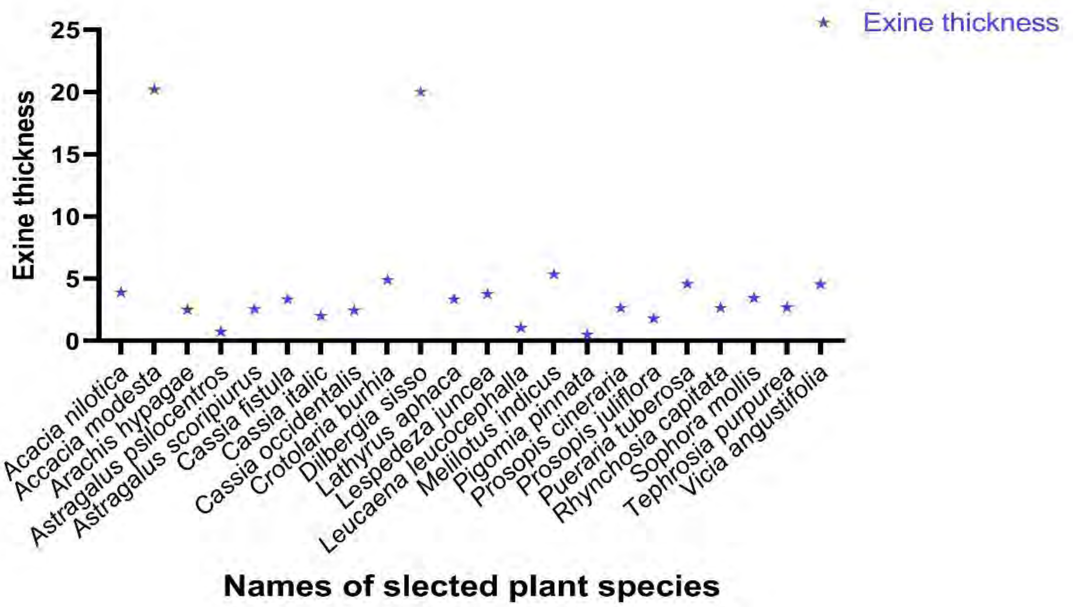

Figure 19: Mean exine thickness in Fabaceous Species.

Taxonomic Key Based on Fabaceaos Pollen

1a. Pollen size is small…………………………………. 2

1b. Pollen size is medium ………………………….. 10

2a. Pollen aperture is tricolpoate ……………………………… *Pueraria tuberosa*
2b. Pollen aperture is bicolpate or tricolporate ……………………….. 3

3a. Exine sculpturing is verrucate ………………………… *Leucaena leucocephalla*

3b. Exine sculpturing is reticulate or perforate …………………………………. 4

4a. Apertural condition is bi-tricolporate ………………………….. *Vicia angustifolia*

4b. Apertural condition is bicolpate or tricolporate ………………………… 5

5a. Pollen sculpture is reticulate-perforate ………………………… *Prosopis juliflora*

5b. Pollen exine is reticulate or perforate ……………………………… 6

6a. Polar diameter is above 50 µm ……………………………. *Accacia modesta*
6b. Polar diameter is blow 50 µm …………………………………… 7

7a. Fertility is below 60% …………………………………… *Astragalus psilocentros*

7b. Fertility is above 60 %.. 8

8a. Exine thickness is moderately thick ……………………………*Cassia fistula*
8b. Exine thickness is thin …………………………… 9

9a. Exine sculpturing is reticulate ………………………………… *Acacia nilotica*

9b. Exine sculpturing is perforate ……………………………… *Lathyrus aphaca*

10a. Tetra colpate pollen ……………………………. *Cassia occidentalis*

10b. Bicolpate, tricolpate or tricolporate pollen ……………………………… 11

11a. P/E ratio is below 1 ……………………………………….. *Arachis hypagae*

11b. P/E ratio is above 1 ………………………………………… 12

12 a. Colpi width is below 2 µm …………………………………… *Pigomia pinnata*

12b. Colpi width is above 2 µm …………………………………………. 13

13a. Colpi length is above 7 µm ………………………………. *Dilbergia sisso*

13b. Colpi length is below 7 µm ………………………………. 14

14a. Exine sculpturing is psilate ……………………………… *Cassia italica*

14 b. Exine sculpturing is not psilate ………………………………. 15

15a. Exine thickness is above 4 µm ……………………………….. *Crotolaria burhia*

15b. Exine thickness is below 4 µm ……………………………….. 16

16 a. Sculpturing of exine is perforate ……………………… *Astragalus scoripiurus*

16b. Exine sculpturing is reticulate ……………………… 17

17a. Bilateral symmetry of seed……………………………… *Tephrosia purpurea*

17b. Radial symmetry of seed ………………………………. 18

18 a. Exine is thin …………………………………………… *Sophora mollis*

18b. Exine is moderately thick ………………………………… 19

19a. Exine sculpture is reticulate verrucate ………………………. *Lespedeza juncea*

19b. Eine sculpture is reticulate perforate ……………………….*.Rhynchosia capitata*

3.1.3 Fabaceaous Species

Astragalus is the biggest and one of the problematical genus from taxonomic point of view. The rich variety of the genus has engrossed the consideration of many systematists in various regions worldwide. Pinar et al. (2014), observed pollens with prolate, subprolate, and prolate-spheroidal shapes in *Astragaleae* (genus *Astragalus*). Akan and Aytac (2014), carried out study on pollen morphology of the section *Alopecuroidei* DC. of genus *Astragalus* and reported subprolate or prolate-spheroid pollen type in the members of this section. The pollen is observed with tricolporate aperturation and the reticulate ornamentation with semiangular amb type (Akan et al., 2005). Oskouian, Ousalou, and Masoumi (2007) examined pollen morphology of 37 *Astragalus* species in section *Malacothrix* and its allies. They reported that the most common exine surface sculpturing is reticulate and pollen shape ranges from spheroidal to prolate. Ekici, Yüzbaşıoğlu, and Aytaç (2005) studied pollen characters of *Astragalus ovalis* and reported prolate pollen with tricolporate aperturation and reticulate sculpturing. Ceter et al. (2013) examined the variations in pollen characters of *Astragalus* L. section *Hololeuce* Bunge in Turkey. The study concluded that the pollen grains appeared subprolate and prolate–spheroidal with few prolate shaped pollens having trizonocolporate and operculate pattern of apertures. Colpi were reported to be long and narrow with perforate or reticulate sculpturing pattern. İlçim and Behçet (2016) carried out palynological investigation on *Astragalus topalanense* and recorded subprolate, tricolporate pollen grains with tricolporate sculpturing pattern. The previous reports on *Astragalus* corroborate with recent findings in which genus has been reported with prolate, subprolate, and prolate-spheroidal pollen grains. Ceter et al. (2013) described pollen morphology of genus *Oxytropis* and reported isopolar, radially symmetric, prolate, or subprolate pollens with great variation in polar and equatorial diameter. These results are in harmony with the pollen features of genus *Oxytropis* recorded in this study. The findings of this study are supported by previous literature including; radially symmetrical, isopolar pollen with trizonocolporate aperturation in genus *Astragalus* (Pinar et al., 2014), three type of apertures observed in members of papilionoidae (Schrire & Sims, 1997), tricolporate and trizonocolporate pollen aperturation pattern in *Astragaleae* (*Oxytropis*) (Ceter et al., 2013); (Pavlova, 2013).

The variations in apertures may be due to genetic factors like ploidy level and environmental circumstances such as temperature fluctuation, high or low humidity, altitude, and pollination activity (do Pico & Dematteis, 2010). Earlier researchers reported that variations that exist in aperture types may be due to heteromorphy in pollens (Inceoglu, 1973). Pinar et al. (2014) studied the LM and SEM features of pollens in section *Onobrychoidei* in genus *Astragalus* and distinguished two types of sculpturing patterns i-e microreticulate and reticulate. Ceter et al. (2013) and (Pavlova, 2013) described microreticulate, psilate, and perforate exine sculpturing in genus *Oxytropis*.

The examined pollen grains in *Oxytropis* species appeared to be small having bi-tricolporate apertures and slight disparity or specialization. These characters closely resemble to pollen grain features in *Astragalus* thus validating previous studies. The tectum was observed to be restricted and primarily reticulate (*O. lapponica*) or reticulate-perforate (*O. staintoniana*). These findings harmonizes with the phylogenetic trend thus suggesting the specialization within genera and delimiting species as well (Ferguson, 1981). The delimitation of taxa in *Oxytropis* is difficult on the basis of pollen characters, even though a few apparent grouping of species could be predictable. The aperturation pattern is of huge significance for classification of the pollen type at genus and tribe level and can also predict associations (Ferguson, 1981). The tendency of increasing the aperture number in members of Fabaceae was explained by Ferguson (1981) as well as Guinet and Ferguson (1989). A little information is present in literature to explain the variation in apertures in genus *Astragalus* (Pinar et al., 2009) and *Oxytropis* (Pavlova, 2013). The pollen wall stratification is considered as a significant character in classification at tribe level but it has less importance at species due to absence of significant variations (Ferguson, 1981). The investigation of the pollen morphological characters is important for certain taxonomical judgments particularly above the rank of species (Amina et al., 2020; Bano et al., 2020). In general, the data on pollen morphology offer reliable facts for resolving taxonomical problems and confer about resemblance as well as association between species.

Table 10: Qualitative characters of some species of family Poaceae.

Sr.No	Plant taxa	Pollen Size	Pollen Type	Pollen shape	Aperture condition	Pore orientation	Exine sculpturing
1	*Brachiaria brizantha*	Medium	Monoporate	Subprolate	Monoporate	Prominent	Perforate, scabrate
2	*Cenchrus biflorus*	Medium	Monoporate	Prolate	Monoporate	Sunken	Scabrate, psilate and sparsely verrucate
3	*Cenchrus ciliaris*	Large	Monoporate	Subprolate	Monoporate	Slightly sunken	Sparsely reticulate scabrate and rugulate at the poles and rest of the area reticulate
4	*Cenchrus pennisetiformis*	Large	Monoporate	Prolate	Monoporate	Oriented	Gemmate–verrucate
5	*Cymbopogon jwarancusa*	Medium	Monoporate	Perprolate	Monoporate	Prominent	Fine gemmate
6	*Cynadon dactylon*	Medium	Monoporate	Subprolate	Monoporate	-	Scabrate–verrucate
7	*Dactyloctenium aegyptium*	Medium	Monoporate	Prolate	Monoporate	Sunken	Scabrate, psilate
8	*Dichanthium annulatum*	Medium	Monoporate	Prolate	Monoporate	Prominent	Gemmate–verrucate
9	*Eleusine indica*	Medium	Monoporate	Subprolate	Monoporate	Prominent	Sparsely Perforate, psilate and scabrate
10	*Pennisetum glaucum*	Medium	Monoporate	Perprolate	Monoporate	Sunken	Echinate Perforate, scabrate, sparsely reticulate and verrucate
11	*Pennisetum typhoides*	Medium	Monoporate	Perprolate	Monoporate	Prominent	Granulate to perforate tectate
12	*Poa annua*	Medium	Monoporate	Perprolate	Monoporate	-	Scabrate–reugulate
13	*Saccharum spontaneum*	Medium	Monoporate	Prolate	Monoporate	Sunken	Fine gemmate
14	*Steria viridis*	Medium	Monoporate	Prolate	Monoporate	Prominent	Gemmate–scabrate
15	*Zea mays*	Large	Monoporate	Prolate	Monoporate	-	Scabrate, psilate

Table 11: Quantitative pollen morphological characters of some species of family Poaceae

Sr. No	Plant Name	Exine Thickness Mean (Min-Max) SE (µm)	Polar Diameter Mean (Min-Max) SE (µm)	Equatorial Diameter Mean (Min-Max) SE (µm)	Pores Length Mean (Min-Max) SE (µm)	Pores Width Mean (Min-Max) SE (µm)
1	*Brachiaria brizantha*	1.25 (1.00-1.50) ±0.79	40.45 (36.50-45.00) ±1.43	40.50 (37.25-43.00) ±1.2	4.20 (3.50-5.00) ±0.27	2.700 (2.25-3.50) ±0.21
2	*Cenchrus biflorus*	1.50 (1.25-1.75) ±0.11	32.95 (28.25-37.75) ±1.73	32.35 (27.00-40.75) ±2.32	4.45 (3.25-5.75) ±0.46	3.35 (2.75-4.25) ±0.26
3	*Cenchrus ciliaris*	1.30 (0.75-1.75) ±0.17	63.25 (57.75-71.75) ±2.36	57.25 (53.50-60.00) ±2.36	4.1 (3.25-4.75) ±0.27	3.30 (1.75-4.75) ±0.49
4	*Cenchrus pennisetiformis*	1.40 (1.00-1.75) ±0.13	55.50 (45.50-65.75) ±3.55	44.74 (33.25-54.25) ±3.63	5.55 (4.00-8.00) ±0.69	3.80 (3.00-5.00) ±0.40
5	*Cymbopogon jwarancusa*	2.70 (1.00-4.50) ±0.73	37.35 (30.00-41.75) ±2.08	34.90 (29.25 -38.00) ±1.63	4.10 (3.50-5.00) ±0.26	3.00 (2.25-4.00) ±0.30
6	*Cynadon dactylon*	1.20 (1.00-1.50) ±0.09	37.20 (33.50-41.75) ±1.50	38.90 (35.00-41.75) ±1.50	5.50 (4.25-7.75) ±0.63	3.100 (2.25-3.75) ±0.27
7	*Dactyloctenium aegyptium*	1.50 (1.00-2.00) ±0.18	39.95 (32.00-47.50) ±2.83	37.00 (32.75-40.00) ±1.35	-	-
8	*Dichanthium annulatum*	1.45 (1.25-1.75) ±0.93	41.70 (36.25-46.00) ±1.79	40.75 (38.00-42.50) ±0.87	4.75 (3.75-6.00) ±0.93	3.00 (2.25-3.75) ±0.28
9	*Eleusine indica*	1.20 (0.75-1.75) ±0.16	34.05 (30.75-38.75) ±1.43	32.70 (27.25-37.75) ±1.86	4.20 (3.75-4.75) ±0.20	3.30 (2.25-4.25) ±0.34
10	*Pennisetum glaucum*	2.20 (1.75-3.00) ±0.24	34.60 (31.75-38.75) ±1.38	37.00 (33.75-40.50) ±2.00	3.85 (2.50-4.50) ±0.38	2.75 (2.25-3.25) ±0.18
11	*Pennisetum typhoides*	2.30 (1.75-3.00) ±0.21	29.25 (25.25-32.00) ±1.13	32.00 (28.25-37.00) ±1.53	5.95 (4.75-7.50) ±0.50	3.70 (3.00-5.00) ±0.35
12	*Poa annua*	2.35 (0.75-3.75) ±0.58	30.05 (26.75-37.75) ±2.04	34.55 (29.75-37.74) ±1.46	3.90 (3.25-4.75) ±0.27	2.15 (1.25-3.00) ±0.30
13	*Saccharum spontaneum*	1.90 (1.25-2.50) ±0.23	37.10 (33.50-46.00) ±2.29	39.15 (32.50-45.00) ±2.49	7.00 (5.25-8.50) ±0.54	4.05 (3.00-5.00) ±0.40
14	*Steria viridis*	1.60 (1.25-2.00) ±0.13	34.65 (30.75-40.00) ±1.75	34.40 (29.25-39.75) ±2.13	5.10 (4.00-6.00) ±0.41	3.55 (2.50-4.50) ±0.34
15	*Zea mays*	1.35 (1.00-1.75) ±0.13	66.65 (61.00-70.00) ±1.59	62.00 (59.00-65.00) ±1.08	-	-

Table 12: Fertility and Sterility percentage of selected species of Poaceae family

Sr. No.	Plant Name	No. of fertile Pollen	No. of sterile pollen	Fertility percentage	Sterility percentage
1	*Brachiaria brizantha*	377	66	85.10	14.89
2	*Cenchrus biflorus*	407	83	83.06	16.94
3	*Cenchrus ciliaris*	289	67	81.18	18.82
4	*Cenchrus pennisetiformis*	315	88	78.16	21.84
5	*Cymbopogon jwarancusa*	430	62	87.39	12.60
6	*Cynadon dactylon*	373	58	86.54	13.46
7	*Dactyloctenium aegyptium*	260	52	83.33	16.67
8	*Dichanthium annulatum*	363	66	84.61	15.38
9	*Eleusine indica*	383	92	80.63	19.37
10	*Pennisetum glaucum*	422	69	85.94	14.06
11	*Pennisetum typhoides*	283	41	87.34	12.65
12	*Poa annua*	377	61	86.07	13.92
13	*Saccharum spontaneum*	285	51	84.82	15.18
14	*Steria viridis*	636	123	83.79	16.21
15	*Zea mays*	283	50	84.98	15.01

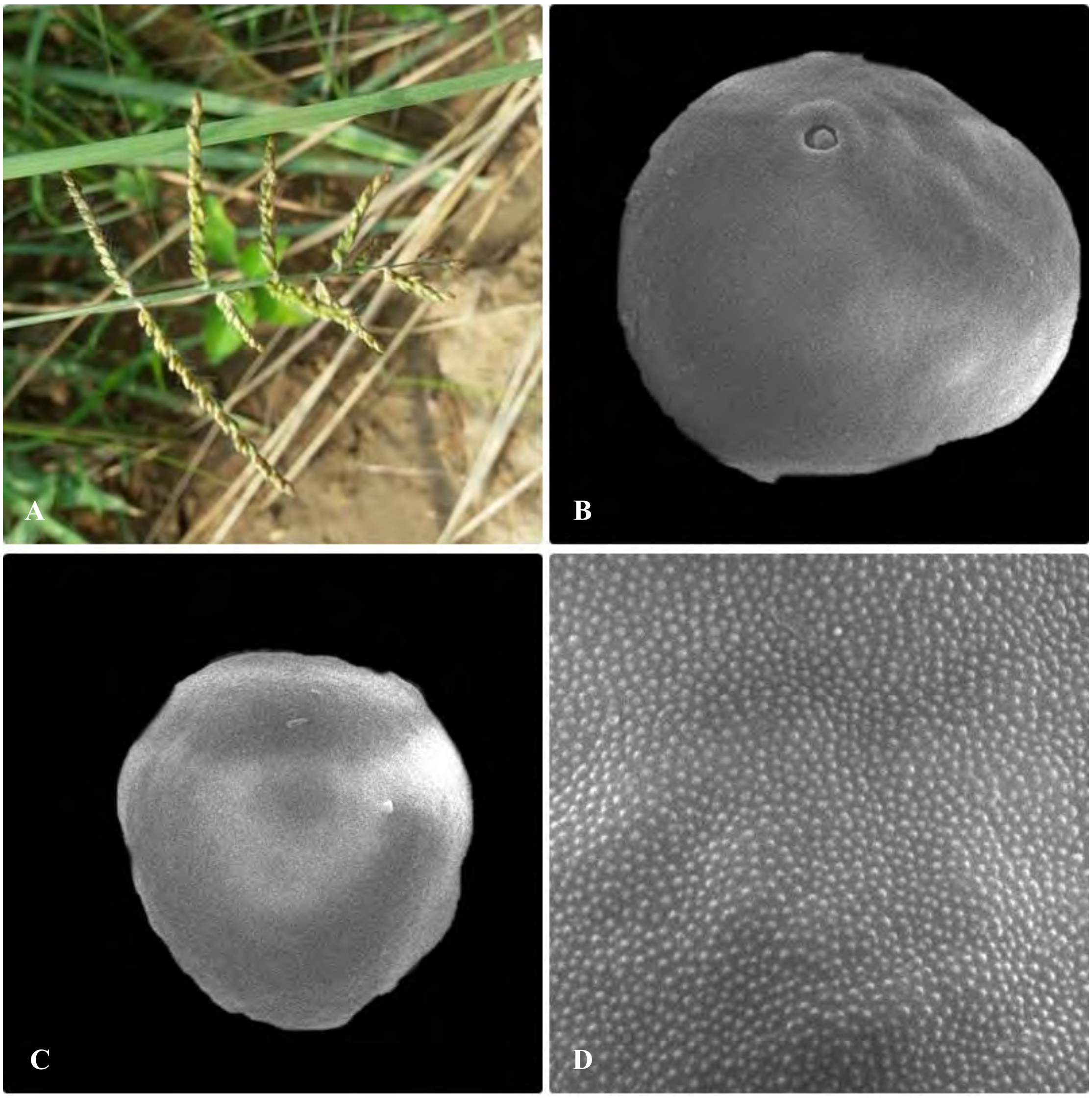

Plate 89: *Brachiaria brizantha* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Prominent Pore Orientation (C) Polar View (D) Surface Sculpturing

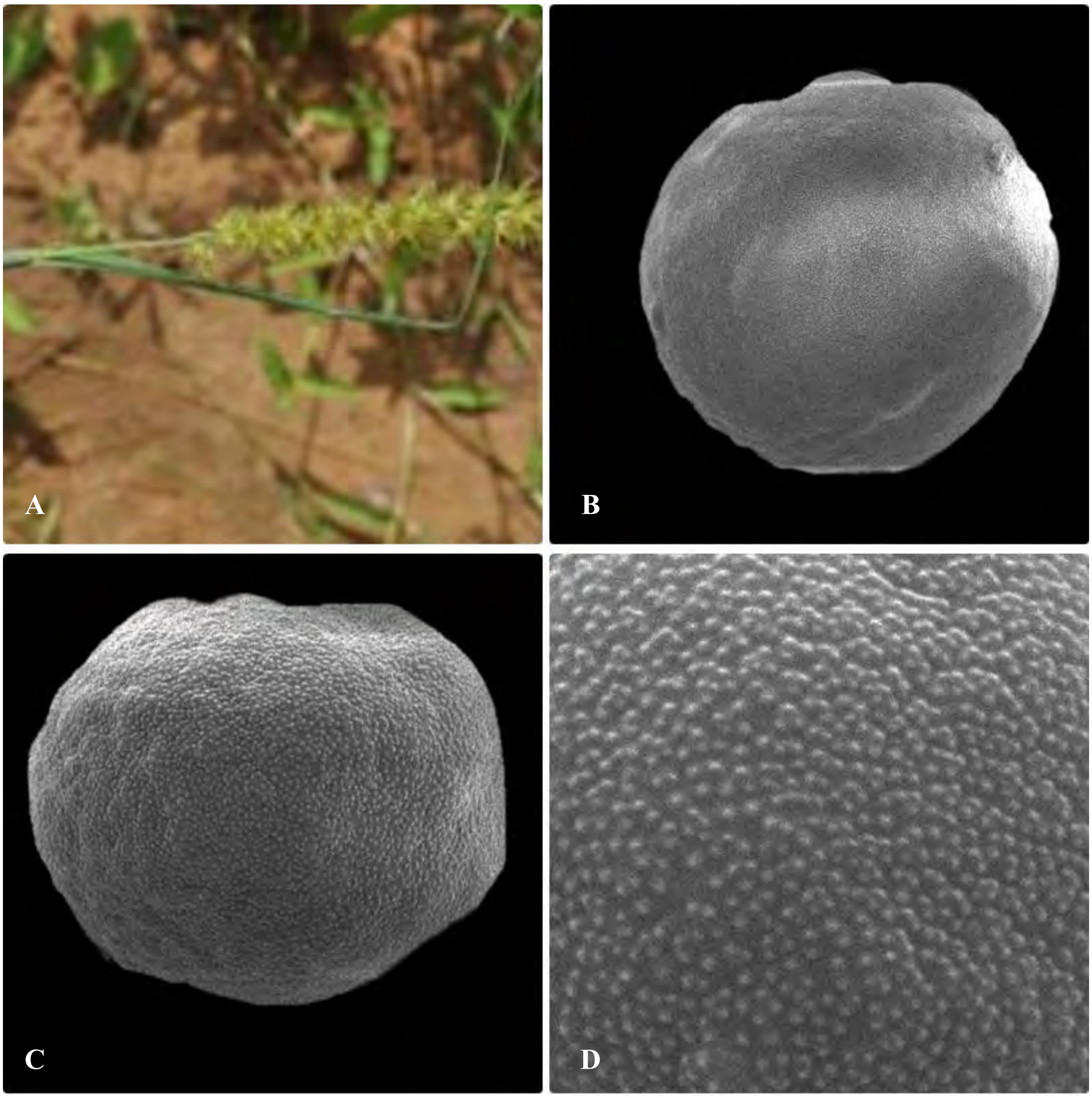

Plate 90: *Cenchrus biflorus* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Sunken Pore orientation (D) Surface Sculpturing

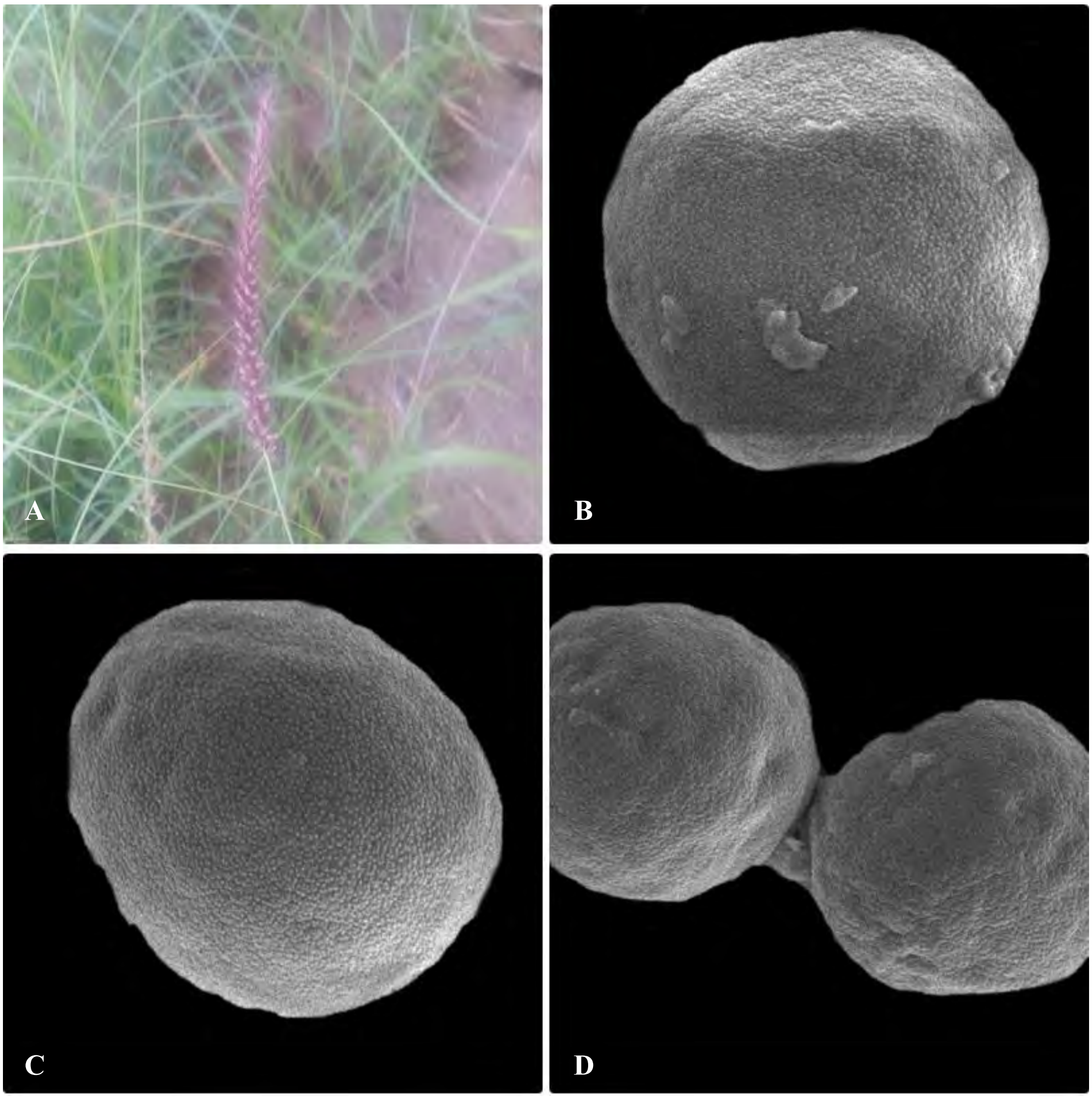

Plate 91: *Cenchrus ciliaris* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Slightly sunken Pore orientation (D) Scabrate Exine Sculpturing

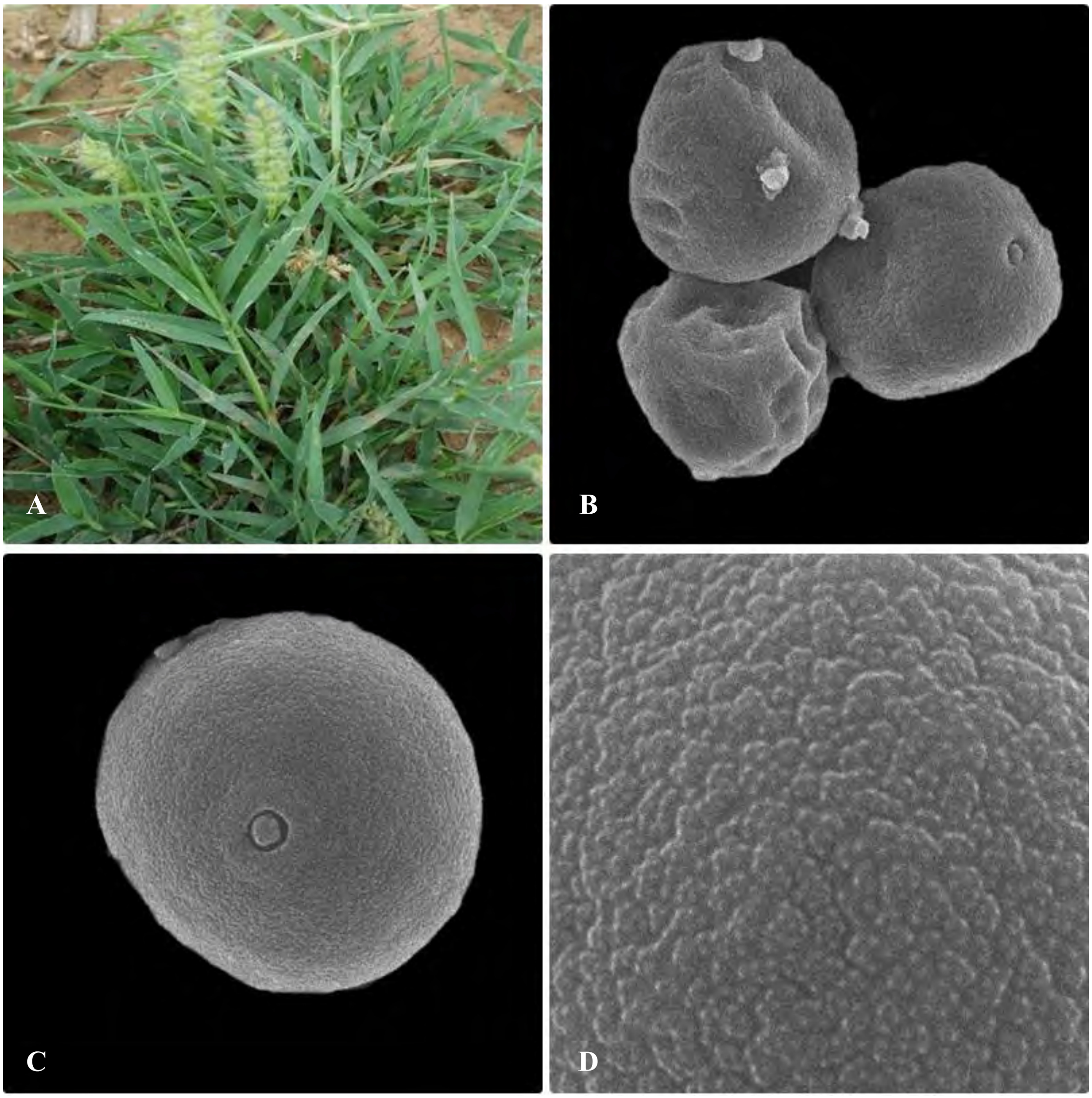

Plate 92: *Cenchrus pennisetiformis* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Oriented Pore orientation (D) Surface Sculpturing

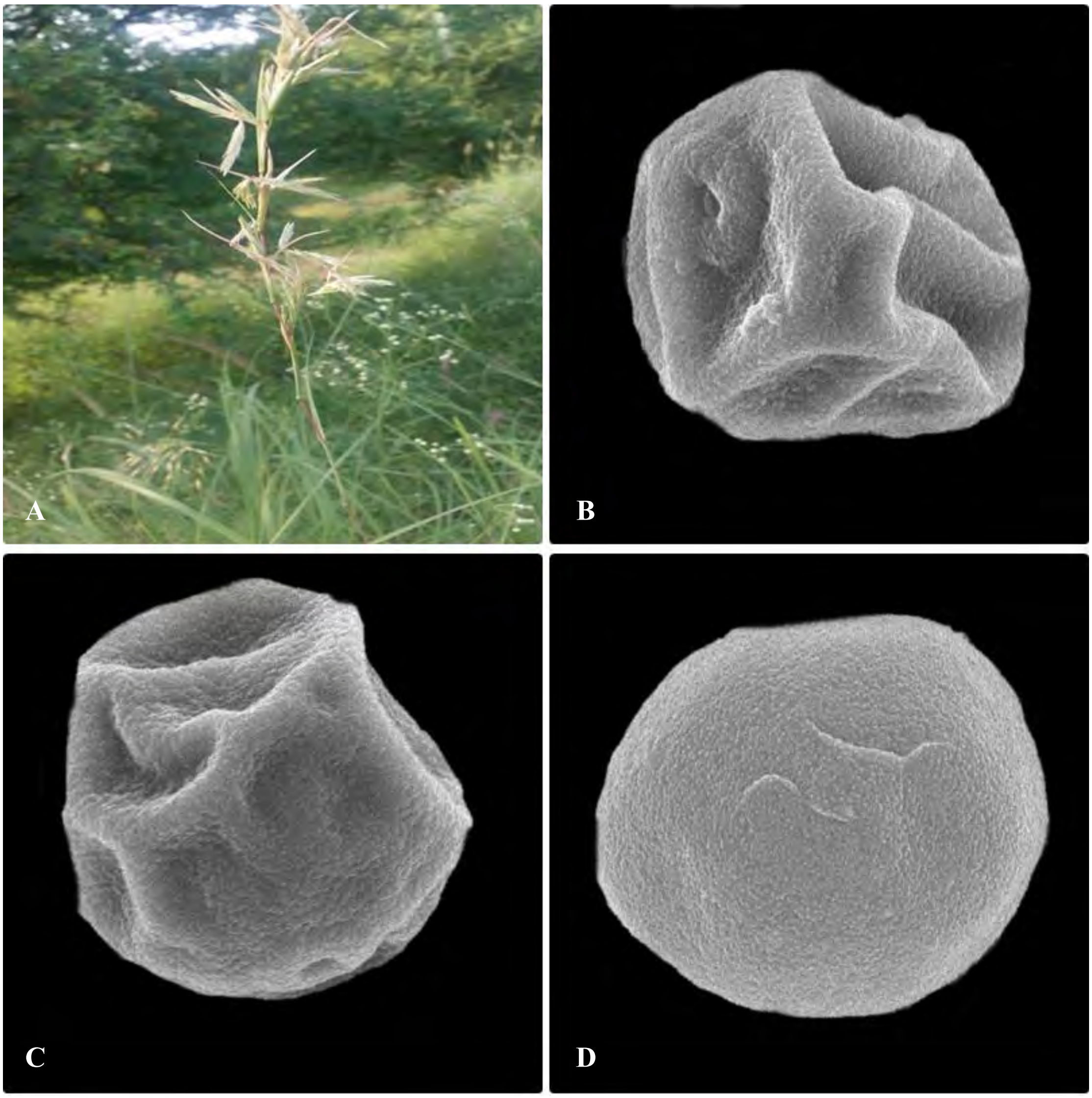

Plate 93: *Cymbopogon jwarancusa* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Sunken Pore Orientation (D) Fine gemmate Exine Sculpturing

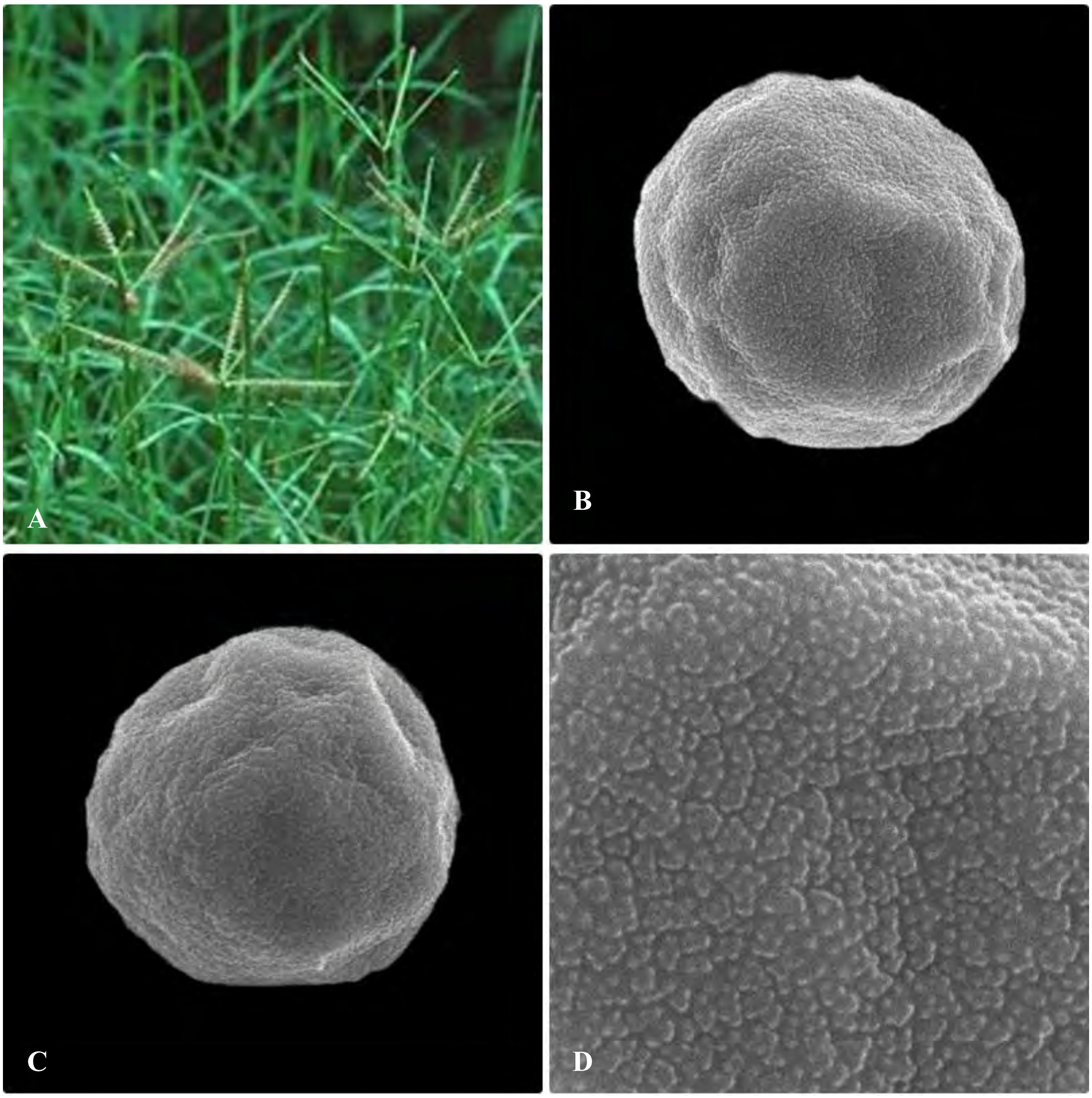

Plate 94: *Cynadon dactylon* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Scabrate-verrucate Exine Sculpturing (D) Surface Sculpturing

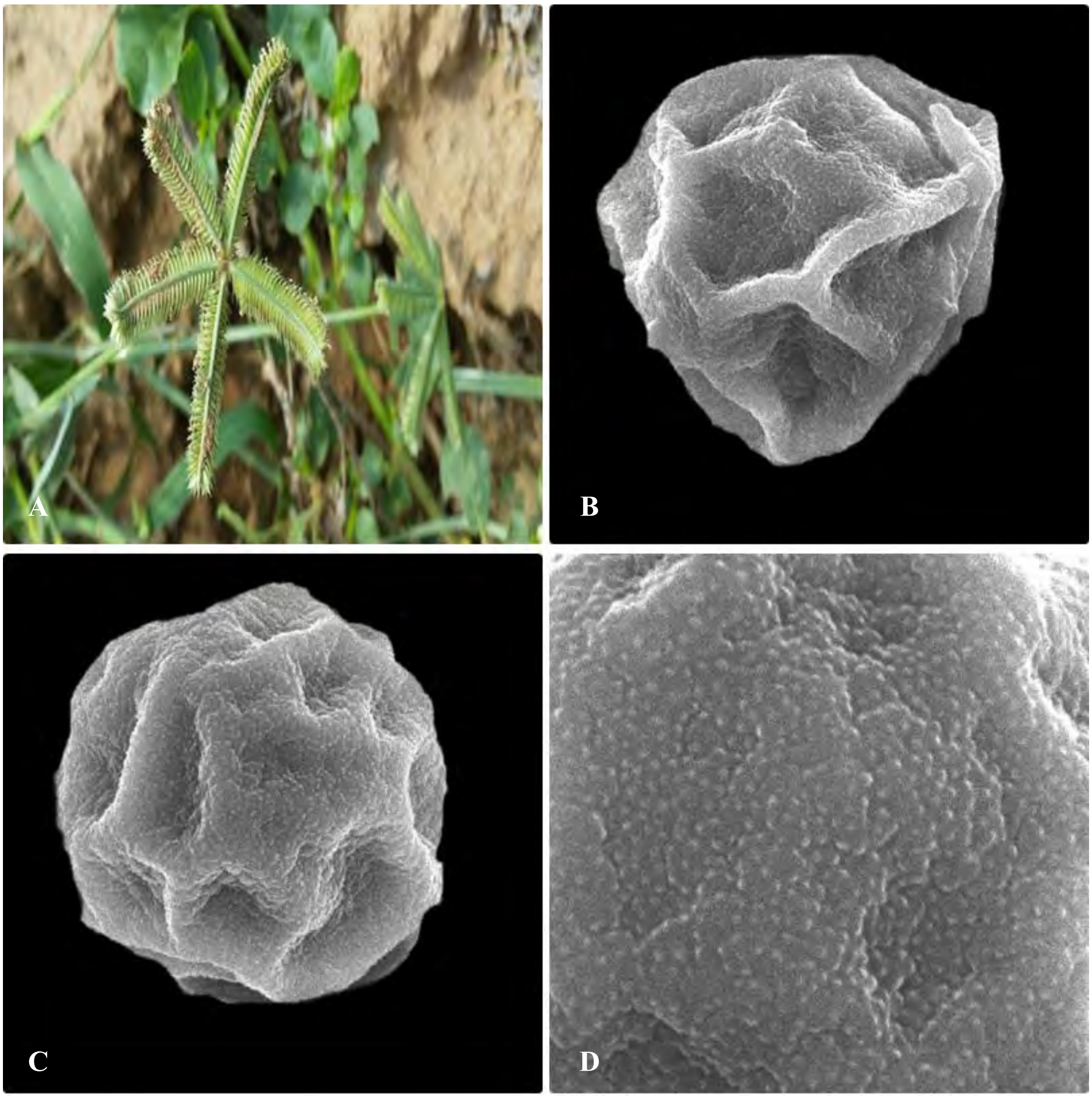

Plate 95: *Dactyloctenium aegyptium* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Sunken Pore orientation (D) Surface Sculpturing

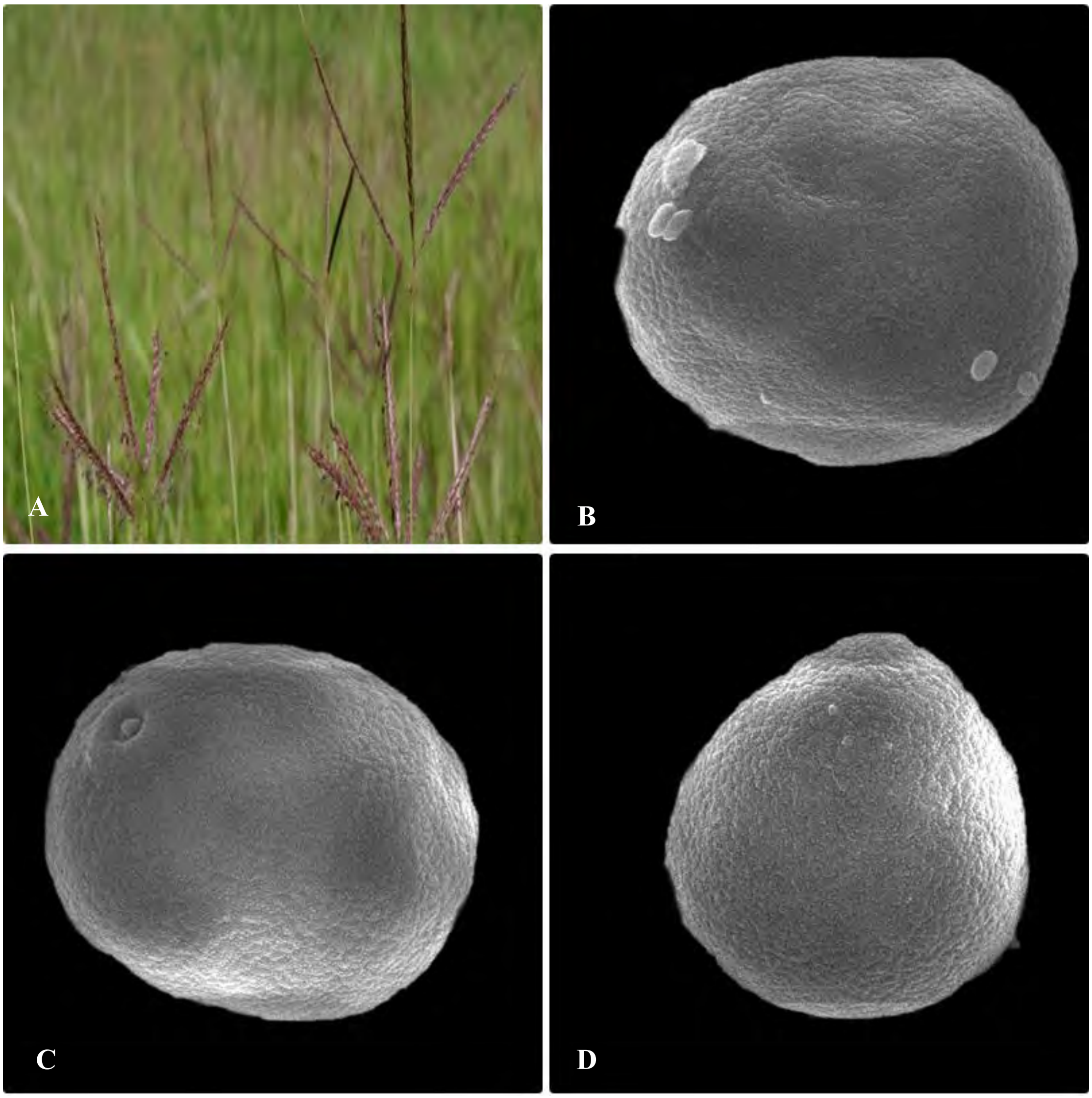

Plate 96: *Dichanthium annulatum* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Prominent Pore orientation (D) Gemmate–verrucate Exine Sculpturing

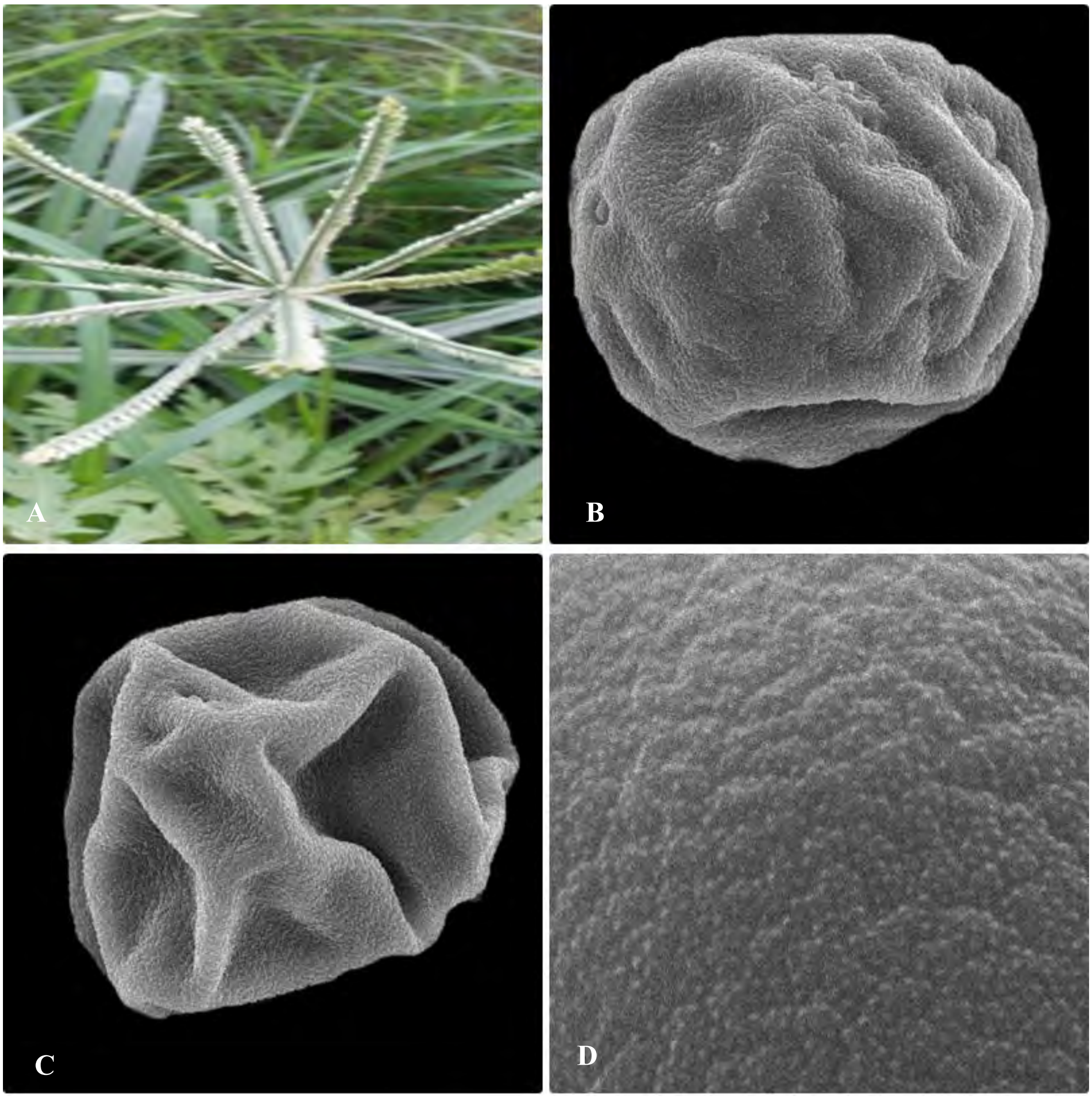

Plate 97: *Eleusine indica* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Psilate-Scabrate Exine Sculpturing (D) Surface Sculpturing

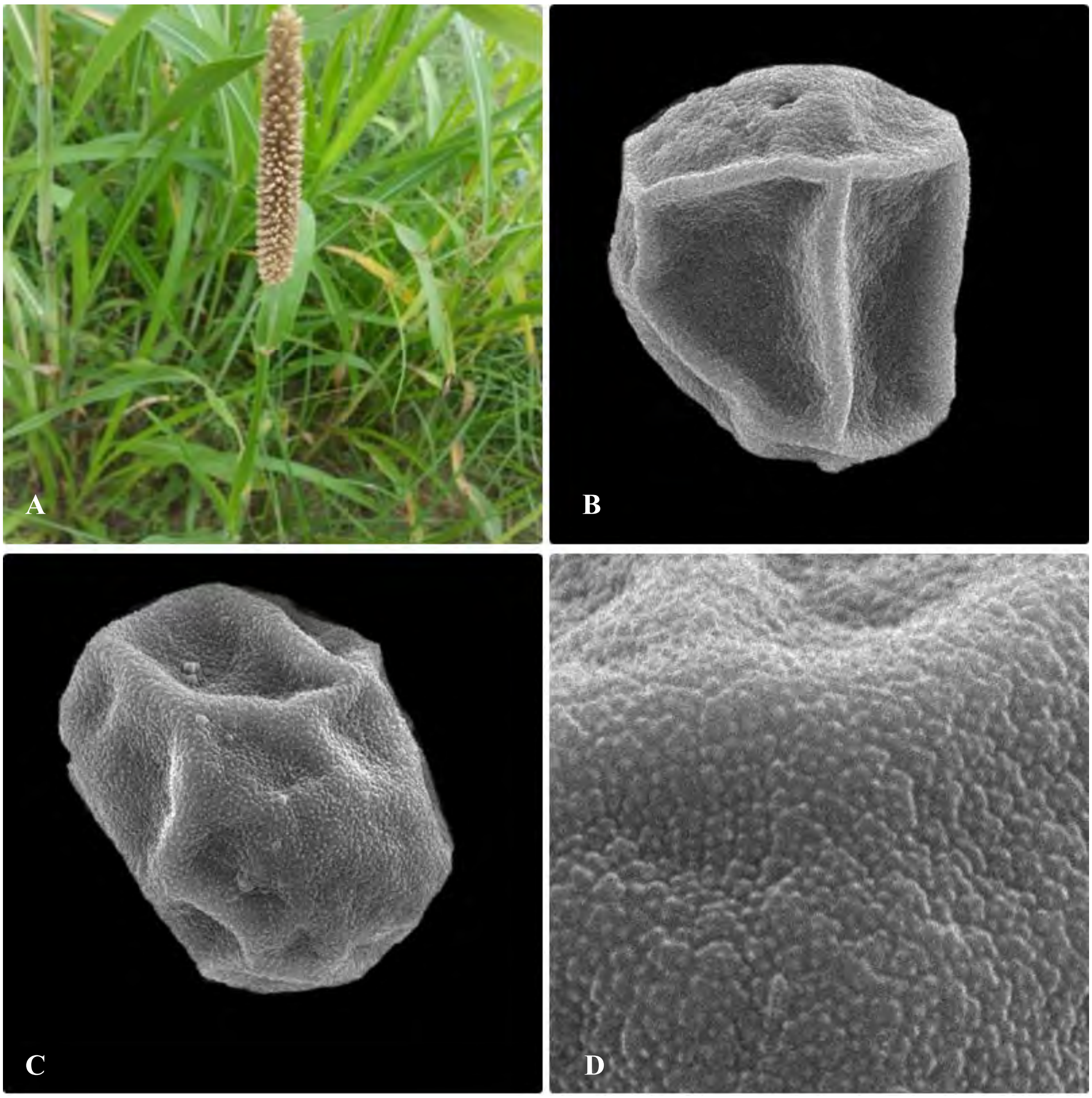

Plate 98: *Pennisetum glaucum* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Equatorial View (D) Surface Sculpturing

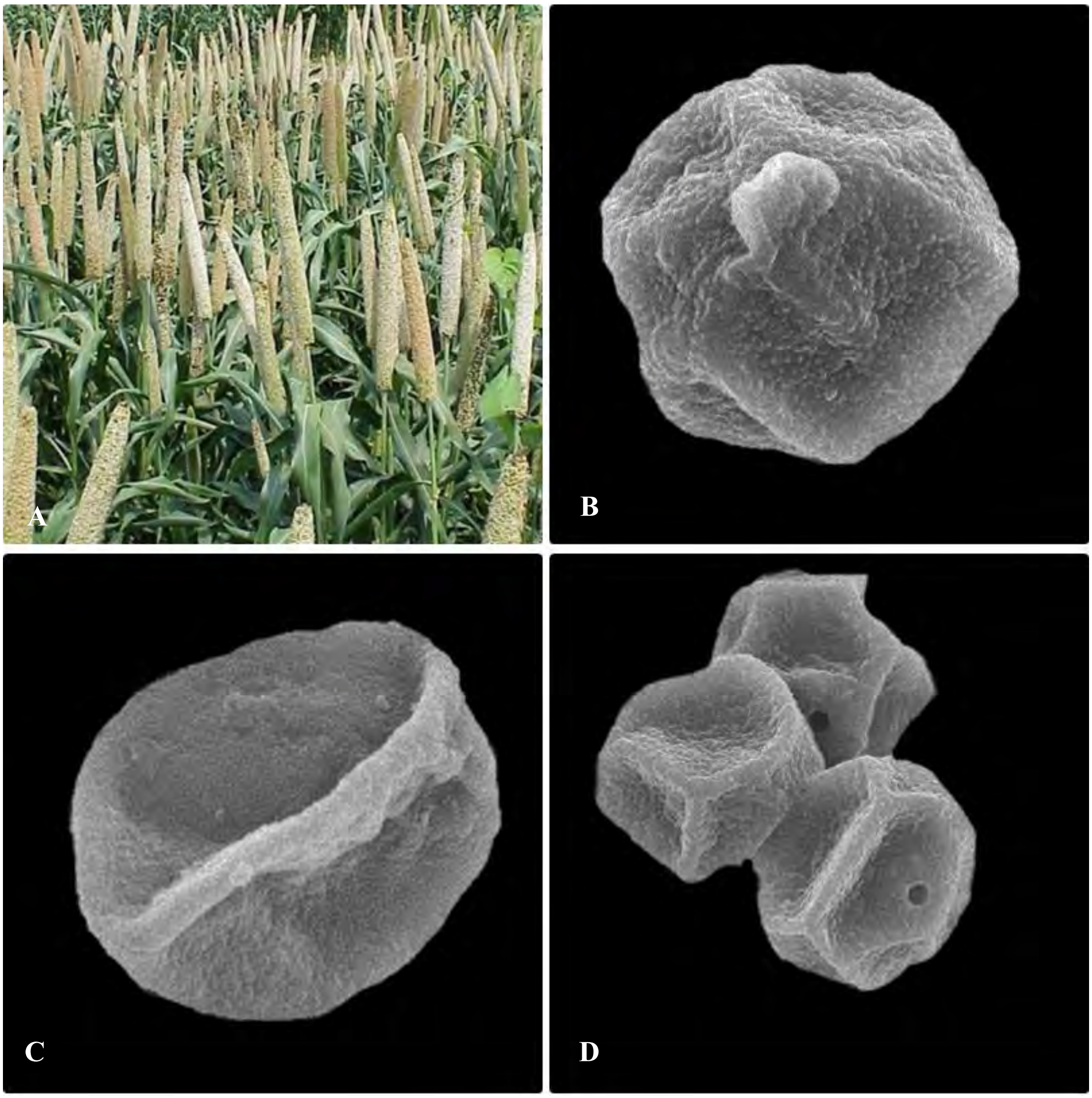

Plate 99: *Pennisetum typhoides* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Equatorial View (D) Granulate to perforate tectate Exine Sculpturing

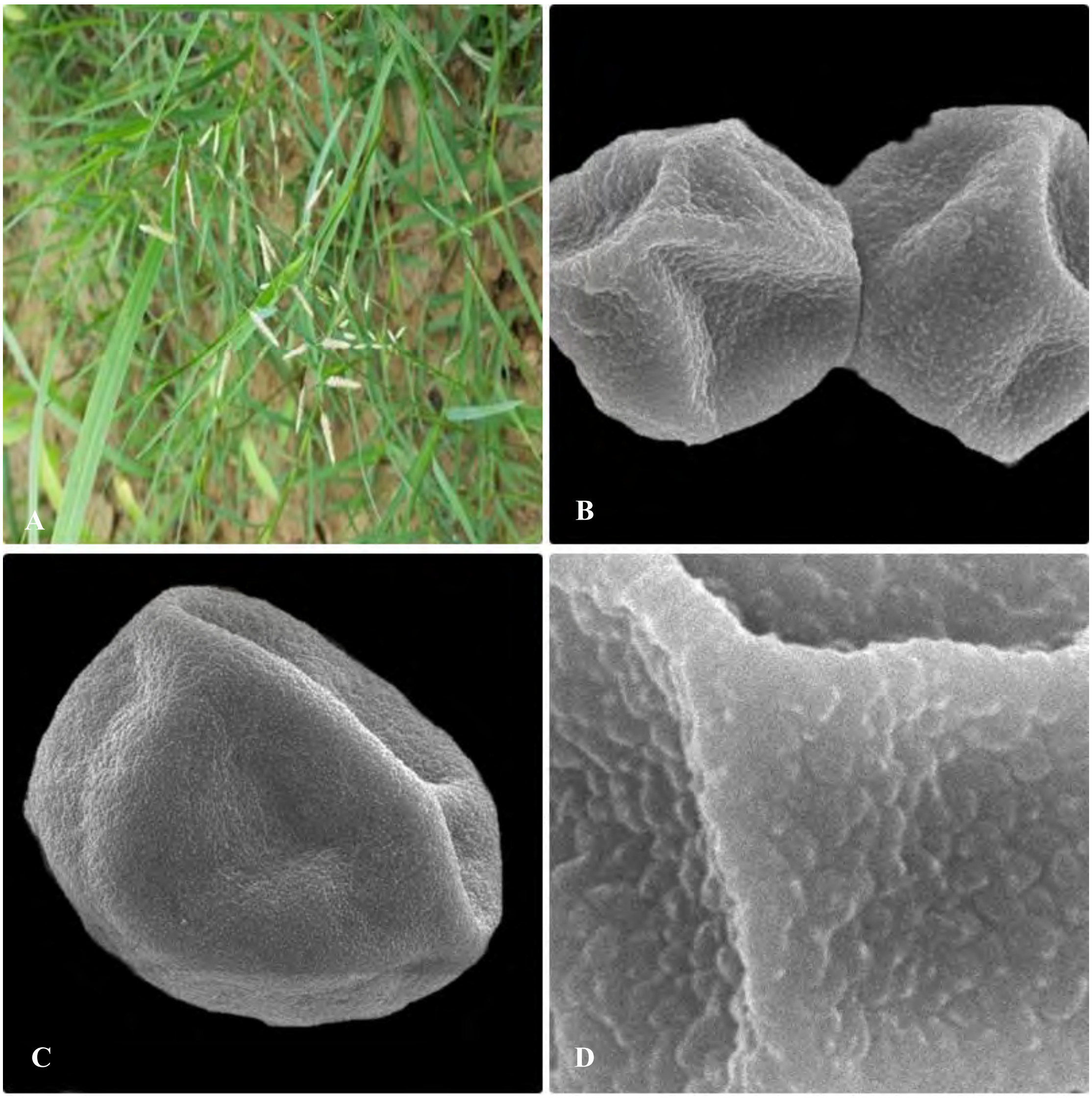

Plate 100: *Poa annua* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Equatorial View (D) Surface Sculpturing

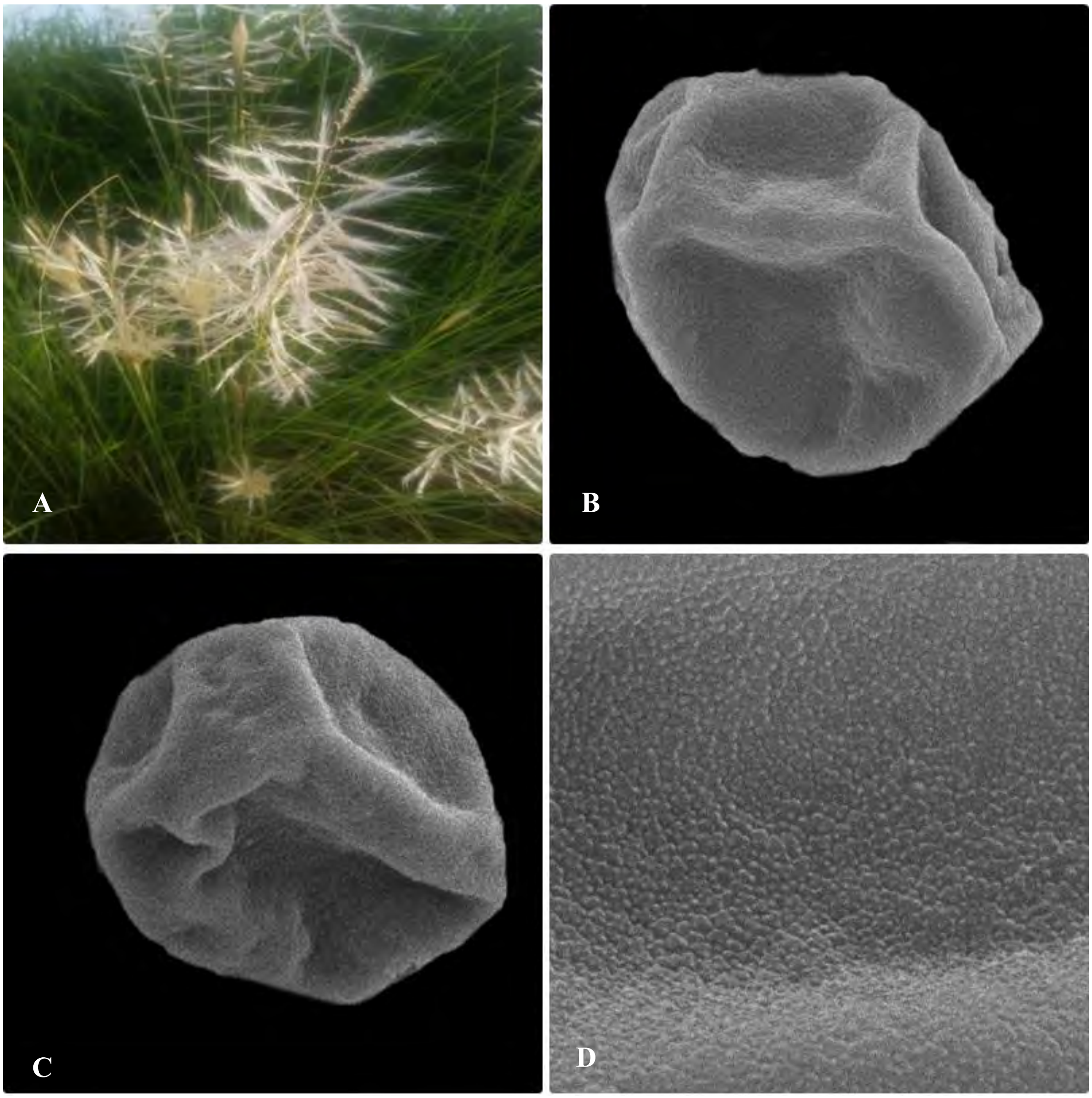

Plate 101: *Saccharum spontaneum* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Sunken Pore orientation (D) Surface Sculpturing

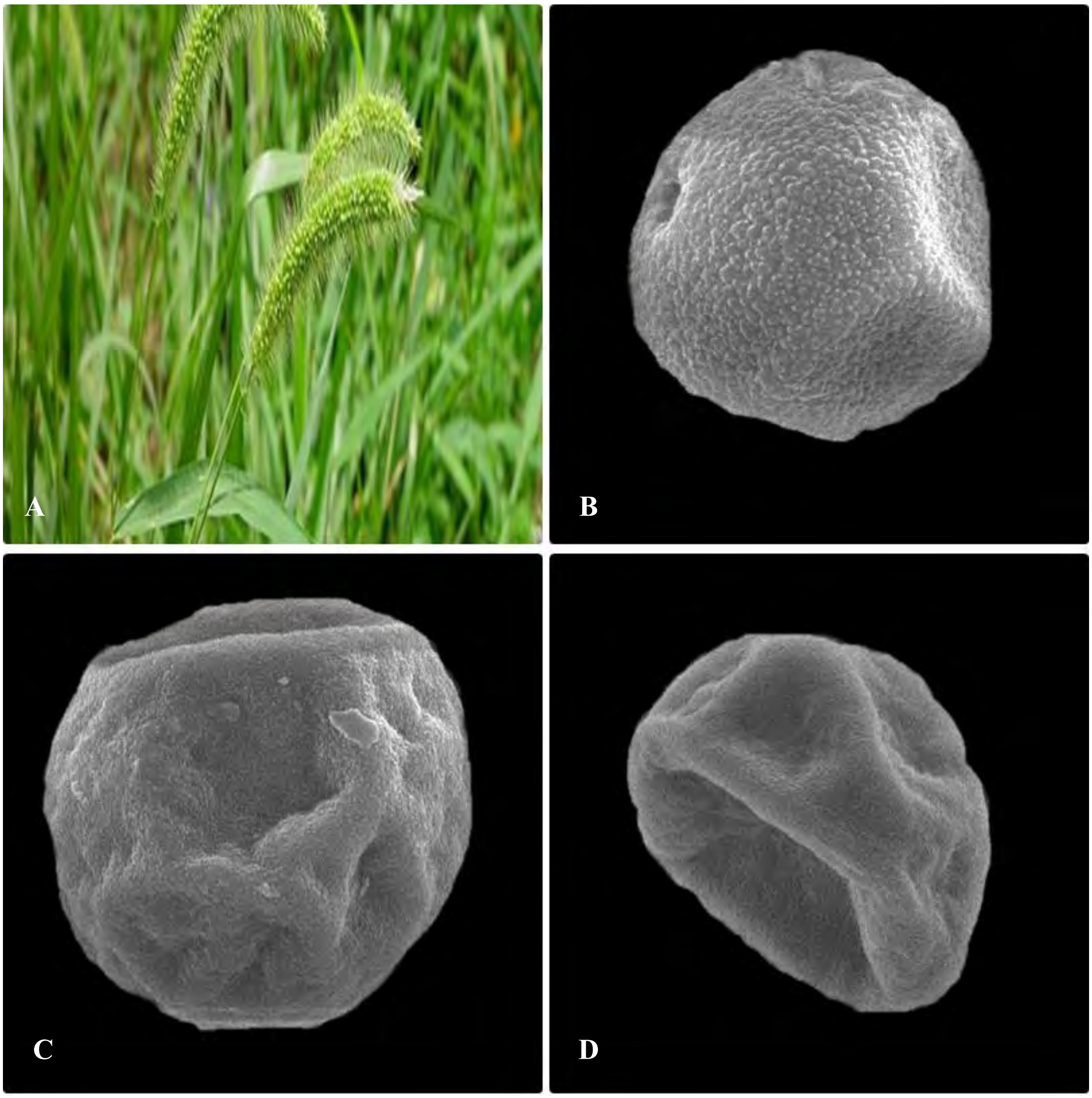

Plate 102: *Steria viridis* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Gemmate–scabrate Exine Sculpturing (D) Equatorial View

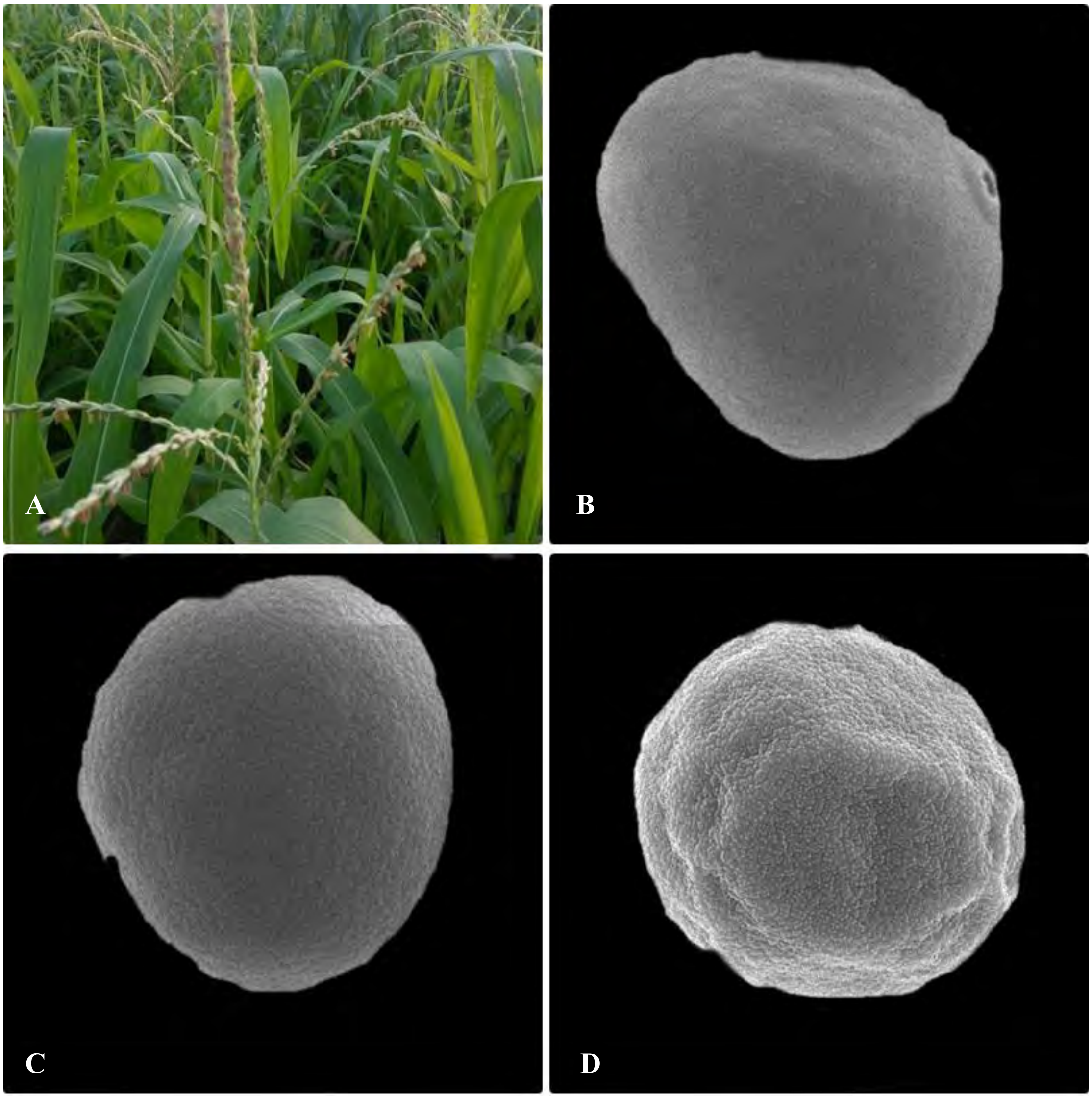

Plate 103: *Zea mays* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Prominent Pore Orientation (C) Polar View (D) Scabrate, psilate Surface Sculpturing

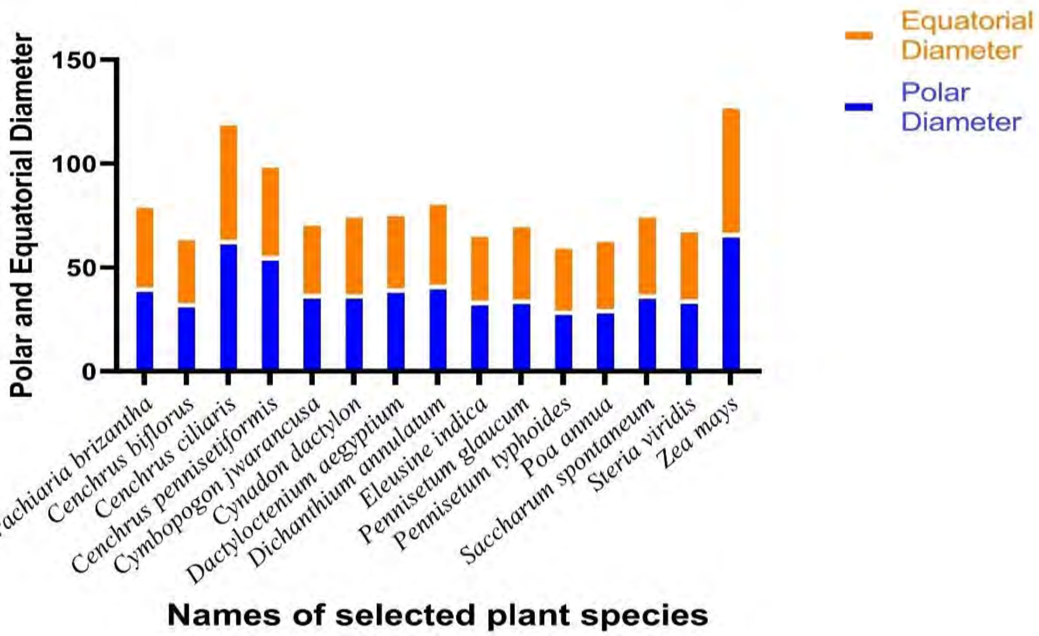

Figure 20: Mean values of Pollen diameter among Poaceous taxa

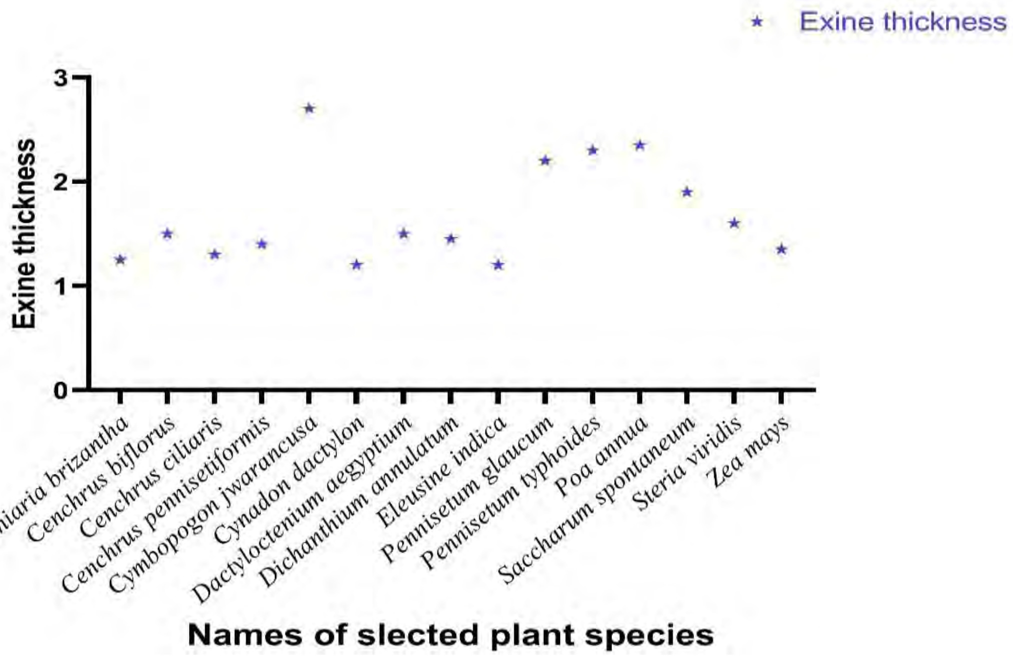

Figure 21: Mean exine thickness in Poaceous Species.

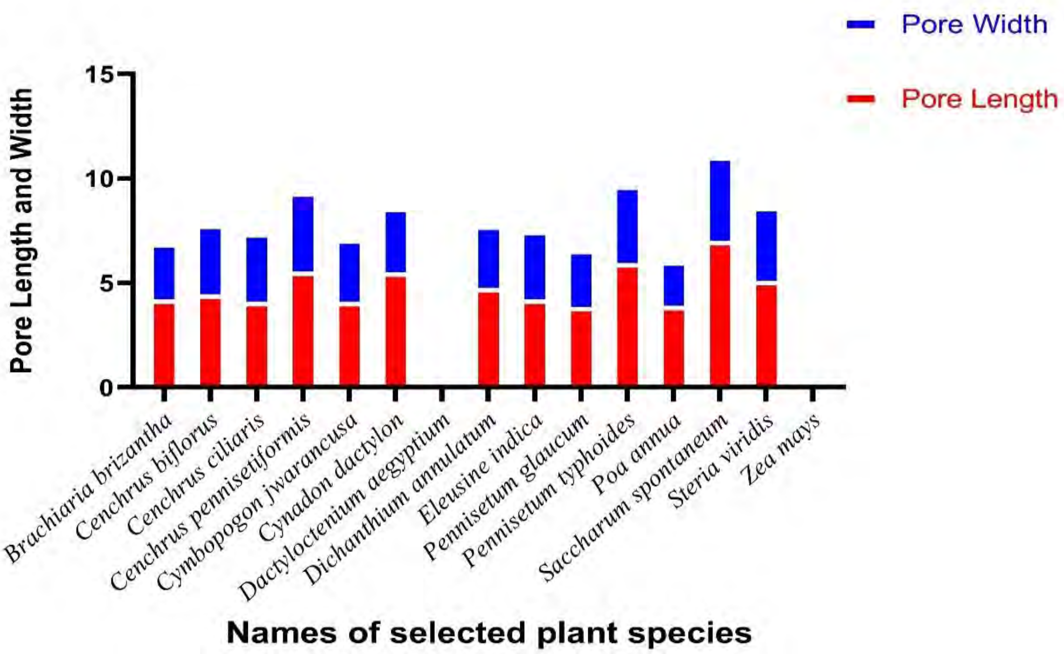

Figure 22: Data variations of pore length and width in Poaceous species

Taxonomic key based on Poaceous Pollen characters

1a. Pollen size large……………………………..…… 2

1b. Pollen size medium ……………………………………..…… 4

2a. Pollen shape sub-prolate……………………..……………… Cenchrus ciliaris

2b. Pollen shape prolate …………………………………….. 3

3a. Exine ornamentation scabrate …………………..………. *Zea mays*

3b.Exine ornamentation gemmate-verrucate ……………… *Cenchrus pennisetiformis*

4a. Polar diameter lies in range above 41 m……………… *Dichanthium annulatum*

4b.Polar diameter lies in range below 41m ………………………… 5

5a. Fertile pollen more than 500 in number ………………………… *Steria viridis*

5b. Fertile pollen less than 500 in number ……………….……….………….. 6

6a. Exine sculpturing is echinate ………………………………….*Pennisetum glaucum*

6b. Exine sculpturing other than echinate ……………………………………….. 7

7a. Fertility percentage is 80% ……………….……..……. *Eleusine indica*

7b. Fertility percentage is more than 80% …….………………………..…… 8

8a. Pore width is above 4 m …………………………………… *Saccharum spontaneum*

8b. Pore width is below 4 m ………………….……….…….. 9

9a. Exine has fine gemmate ornamentation …………………… *Cymbopogon jwarancusa*

9b. Eine ornamentation other than fine gemmate…………………………. 10

10a. Exine sculpture is granulate ……………………..….. *Pennisetum typhoides*

10b. Exine sculpture is scabrate ………………..… 11

11a. Pollen shape prolate …………………………………… *Dactyloctenium aegyptium*

11b. Pollen shape is sub-prolate and perpolate………………………… 12

12a.Pollen shape is prolate …………………………….………. *Cenchrus biflorus*

12b.Pollen shape is sub-prolate ……………………………………………. 13

13a. Exine sculpturing is scabrate perforate ……………………… *Brachiaria brizantha*

13b. Exine sculpturing is scabrate verrucate……………………… *Cynadon dactylon*

3.1.4 Poaceaous Species

The pollen grains of the Poaceae generally present variations in shape, size and type, and exine ornamentation, as portrayed in this study. The pollen morphological characteristics of 15 species of grasses provide morphological and statistical data for identification of Poaceous species according to the shape, size, aperture(s) and sculpture of the pollen. Identifying grasses pollen to the species level with scanning microscopy is very helpful due to the greater variations of micro-morphological features such as single pores and the high similarity of the sculpture patterns in most of the genera. The stenopalynous form having monoporate form of pollen offers an analytical feature for grasses, while trying to distinguish taxa within family this feature creates a limiting factor via morphology of pollen and sculpturing of exine (Chaturvedi et al. 1998). Whereas studying taxonomy of plants pollen morphology has been considered as the most significant tool. In previous studied pollen morphology, it was considered as very hard to categorize grasses only based on pollen features in the past. A combination of SEM and image analyses was successfully used to quantitatively classify the pollen size and density of exine sculptural elements and to measure the ornamentation complexity of 15 grass species.

Morphological characters of pollen can be valuable in solving complications linked with systematics study of grass and study on pollen provides the base for more structures to proper identify the plant species (Aftab and Parveen, 2006). Earlier morphological characters of Poaceae pollen have been studied by Chaturvedi et al., (1994, 1998), Kohler and Lange (1979) and Ma et al., (2001). In the current article quantitative and qualitative features of pollen grains were reported, as features of pollen like size and pattern of sexine are of great taxonomic importance (Woodehouse, 1935). Firbas (1937) in his work reported the size of pollen and utilize this feature for separating cultivated and wild grass species. [1] investigated morphological characters of pollen of *Cenhrus* genus and detected shapes of pollen grains in *C. pennisetiformis* to be spherical to per-oblate and in *C. setigerus* spheroidal to subulate. The position of pore was either ectoporus or endoporus. In this study 3 species such as *C. pennisetiformis, C. ciliaris* and *C. biflorus*, look like endoporus whereas *C. setigerus* is either ectoporous or endoporus. The results of current research are similar to the previous work on this genus. Variations were also observed in the shapes of pollen as they were semi-circular or circular while in equatorial sight, the pollen of *C. ciliaris* are spheroidal in shape and *C. biflorus* pollen are prolate-spheroidal in appearance [2]. Parveen (2006) reported areolate type of exine ornamentation in *Cynodon dactylon* while the sculpturing of *Cynodon dactylon* in present study is scabrate. Ozeler et al., (2009) described pollen grains of Poaceae to be monoporate with scabrate exine sculpturing, size pollen and other characters, such as size of operculum, annulus are key features for identifying the taxa. Chaturvedi (1971) has observed monoporate grains in *Saccharum* which is similar to the findings of current study. In present study *Dichanthium annulatum* shows Gemmate–verrucate type of exine sculpturing was accordance with the findings of Ullah et al., (2018), while Zahoor et al. (2019) and Sardar et al. (2013) reported regulate and areolate scabrate type of sculpturing. While previous work of Ghosh and Karmaker (2017) described monoporate, operculate with micro-reticulated type pollen in *D. annulatum* show dissimilarity with our study. Pollen grains are generally monad in this family, shape of pollen in its polar view is circular, prolate to spheroidal or sometimes oblate to spheroidal, aperture comprises of pores, having operculum and annulus (Corrêa et al. 2005).

Moore et al. (1991) considered that the line of evolution in pollen class as from inaperturate pollen (without aperture) vs aperturate pollen and the latter is from monoaperturate to polyaperturate. Tectum present in the pollen of some members of Poaceae family is either aerolate or scabrate (Parveen, 2004). While same type of tectum has been observed in some members of Poaceae by Faegri and Iversen, (1964) and Andresen and Bertelsen, (1972).

Neha and Kalkar, (2010) earlier results elaborate 1-porate, annulate and brevicerebro ornate sculpture type grains in *P. glaucum* was not according to this research study. Significant difference was reported in *P. typhoides* exine sculpture, thickness, shape, and size of the grains in the earlier study (Ahmad et al. 2020). İnceoğlu and Karamustafa, (1977) observed pollen grains of some members of family Poaceae under light microscope and reported the presence of granulate exine ornamentation while study under scanning electron microscope revealed reticulate exine sculpturing.

The shape of pollen grains were spheroidal or rounded in polar view and in equatorial view shape of pollen were oblate, prolate or spheroidal (Khan et al., 2017). The result of current findings is similar as in equatorial view the shape of pollen is prolate, sub-prolate and polar view has circular pollen grains. Pollen grains are in the form of monad with most species having scabrate exine ornamentation similar findings are reported by Khan et al. (2017). In the pollen grains of *P. annua* monad, medium size, radial symmetry, heteropolar, circular, spheroidal, circular pore with annulus, exina tectate with micro-echinate ornamentation was examined previously by Radaeski et al. (2016). The grains of *P. annua*, we observed sizes slightly larger and examination of pollen sculpture are similar to those reported by Khan et al. (2017). Based on the value of polar to equatorial ratio *Poa annua* is considered to be the smallest size pollen while the study conducted by Meo (1999) documented the diameter at polar axis of *P. annua* is 24.13 μm and diameter at equatorial axis as 24.88 μm which is somehow similar to the findings of the present study. Monoporate type of pollen are found by Khan et al. (2017) which is same as reported in present study. In current study majority of plant species exhibit medium sized pollen grains except *Zea mays* which are similar to the findings of Morgado et al. (2015). *Eleusine indica* contained sub-prolate shape of pollen which is similar to the results of Corrêa et al. (2005) while small pollen and areolate micro-echinate sculpture was reported in *E. indica* by Morgado et al. (2015) was different from current findings. Whereas Begumand Mandal, (2016) examined granulate and oblate-spheroidal grains in *E. indica* somewhat differ from this research outcomes. Melhem et al. (1983), Salgado-Labouriau and Rinaldi (1990) and Salgado-Labouriau et al. (1990), reported in their studies pollen of family Poaceae with shape prolate to spheroidal and oblate to spheroidal.

Meo et al. (1989) investigated morphological characters of pollen of *Cenhrus* genus and detected shapes of pollen grains in *C. pennisetiformis* to be spherical to perbolate and in *C. setigerus* spheroidal to subulate. The position of pore was either ectoporus or endoporus. 3 species such as *C. pennisetiformis, C. ciliaris* and *C. biflorus*, look like endoporus whereas *C. setigerus* is either ectoporous or endoporus. The results of current research are similar to the previous work on this genus. Variations are also observed in the shapes of pollen as they were semi-circular or circular while in equatorial sight, the pollen of *C. ciliaris* are spheroidal in shape and *C. biflorus* pollen are prolate-spheroidal in appearance (Shaheen et al., 2011).

Chaturvedi and Datta, (2001) studied pollen morphology of *Saccharum spontanum* and documented the presence of porate type pollen and insulae ornamentation of exine. However, thick psilate nature of exine was described by El-Amier (2015) in *S. spontanum* while our results revealed fine gemmate sculpturing. Based on microscopic techniques it has been cleared that most of the grasses pollen are monoporate, psilate with sunken pore orientation and this observation of exine sculpturing of *S. spontanum* is fine gemmate, but this result is dissimilar to the results of (Ullah et al. 2021). are similar to Ullah et al. (2021). The findings of present research are different as the pollen grains are monoporate and the exine ornamentation is fine gemmate. Previously Shaheen et al. (2011) examined angular grains in *S. viridis* and exine thickness 0.65 µm while in this study gemmate scabrate sculpture elements as described. Yang et al. (2018) suggested that grains of *Z. mays* was spherical or ovoid and large sized, pore circular, sculpture psilate and slightly wrinkled while in present findings scabrated psilate ornamentation was found.

Fertility and sterility percentages in pollen grains gave indication about the relationship among the ancestors of species. Fertility of pollen grains helps in identifying the genetic variations among the flora (Khan, 1991). It is a useful tool to calculate the strength of species in a specific region. Data on sterile and fertile pollen and fertility levels are presented earlier by Bano et al. (2013) indicates that plant species are well established in given climatic conditions. Ullah et al. (2021) recently estimated pollen fertility and sterility for the development of anthers, is essential for process such as flowering, production of more pollen is linked to the pollen allergy. According to Khan et al. (2017) the fertility percentage of *Poa annua* pollen is highest (92.02%), while in present study *Poa annua* has fertility percentage of 86.07 which shows that this plant is widely distributed. The fertility and sterility rate was determined for the pollen of study area which shows the stability of species in any area. The highest fertility range was determined for *Cymbopogon jwarancusa* in the present study.

The results of the studied of this family are compared with previously published work on these species which reveals that these species are quite similar to the previously reported species, with some differences. Both quantitative and qualitative characters observed through light and scanning electron microscopy revealed important information that may help in identifying the grass family members using advance microscopic techniques. Morphological study of pollen study helps in correct identification of the species.

Table 13: Qualitative data of pollen of weeds members from Potohar region of Pakistan

Sr. No	Taxa	Shape	Aperture Condition	Mesocolpium	Exine ornamentation	Colpi orientation
1.	*Anagallis arvensis* L	Oblate-spheroidal	Tricolporate	Scabrate	Scabrate	Sunken, angular
2.	*Asphodelus tenuifolius* Cav.	Prolate-spheroidal	Tricolporate	Aerolate	Reticulate	Sunken, angular, margins distinct and ends tapering
3.	*Boerhivia procumbense*	Prolate-spheroidal	Trizonocolporate	Reticulate	Scabrate-reticulate	Prominent and rounded at ends
4.	*Brachychiton acerifolius (*A.Cunn. ex G.Don) F.Muell	Oblate-spheroidal	Tricolporate	Scabrate-reticulate	Aerolate	Sunken, slit like margins and end tapering
5.	*Broussonetia papyrifera* (L.) L'Hér. ex Vent.	oblate	Tricolporate	Scabrate	Reticulate-Perforate	Prominent and rounded at ends
6.	*Bryophyllum pinnatum* (Lam.) Oken	oblate-spheroidal	Tricolporate	Reticulate	Scabrate	Sunken, angular, margins distinct
7.	*Capparis decidua (*Forssk.)edgeW.	Spherical	Tricolporate	Scabrate	Echinate	Sunken, further divided in three slit like portions, ends are tapering
8.	*Chorchorus depressus*	oblate-spheroidal	-	Aerolate	Faveolate	Sunken, slit like, margins wavy and slightly pointed at ends
9.	*Cissampelos pareira* L.	oblate-spheroidal	Tricolporate	Perforate	Scabrate	Sunken, slit like, margins distinct and pointed at ends
10.	*Citharexylum spinosum* L.	Prolate-spheroidal	-	Scabrate	Reticulate	Prominent margins
11.	*Cleome brachycarpa* (Forssk.) Vahl ex DC	oblate-spheroidal	Tricolporate	Reticulate	Aerolate	Sunken, long & slit like
12.	*Cleome viscosa* L.	Oblate-spheroidal	Not visible	Scabrate	Reticulate-scabrate	Prominent and tapering ends
13.	*Commelina benghalensis* L.	Sub-oblate	Tricolporate	Reticulate	Perforate	Sunken, angular, margins distinct
14.	*Convolvulus arvensis* L.	oblate-spheroidal	Tricolporate	Aerolate-Perforate	Scabrate	Long & slit like, tapering ends
15.	*Cucumis melo* sub *agerestis* L.	oblate-spheroidal	Tricolporate	Reticulate	Reticulate	Sunken and tapering ends

16.	*Datura innoxia* Mill.	Prolate-spheroidal	Tricolporate	Scabrate	Scabrate-reticulate	Long and slit like margins
17.	*Euphorbia granulata* L.	Oblate-spheroidal	Not Visible	Perforate	Perforate	Sunken, slit like, wavy margins
18.	*Oxalis corniculata* L.	Prolate-spheroidal	-Tricolporate	Scabrate-reticulate	Aerolate	Sunken, wavy and margins distinct
19.	*Solanum surattense*	Sub-oblate	Tricolpate	Aerolate	Reticulate	Sunken and tapering ends
20.	*Trianthema portulastrum*	Spheroidal	Not Visible	Scabrate	Perforate	Prominent and tapering ends

Table 14: Quantitative data of pollen of weeds members from Potohar region of Pakistan

Plant name	Exine thickness Mean (Min-Max) S.E µm	Polar Diameter Mean (Min-Max) S.E µm	Equatorial Diameter Mean (Min-Max) S.E µm	P/E ratio	No of Pores	Colpi Length Mean (Min-Max) S.E µm	Colpi Width Mean (Min-Max) S.E µm	Pores Length Mean (Min-Max) S.E µm	Pores Width Mean (Min-Max) S.E µm
Anagallis arvensis L	1.56(1.35-1.95) ±0.11	14.5(12.1-15.6) ±0.63	15.6(12.3-18.0) ±0.96	0.93	-	3.81(1.65-7.95) ±3.81	2.55(1.50-4.50) ±0.53	-	-
Asphodelus tenuifolius Cav.	1.80(1.35-2.55) ±0.23	18.03(16.8-18.6) ±0.34	17.8(15.3-19.6) ±.0.84	1.01	-	6.12(1.65-10.20) ±1.40	3.45(1.95-7.20) ±0.97	-	-
Boerhivia procumbense	1.50(1.20-1.80) ±0.11	28.8(25.5-33.15) ±1.65	27.0(25.6-30.3) ±1.2	1.07	-	10.05(4.05-17.55) ±2.17	6.24(2.85-13.20) ±1.92	-	-
*Brachychiton acerifolius (*A.Cunn. ex G.Don) F.Muell	6.12(1.65-10.20) ±1.40	3.45(1.95-7.20) ±0.97	6.12(1.6-10.20) ±1.40	0.97	-	12.2(10.0-15.1) 2.44	5.79(3.00-8.55) ±2.31	-	-
Broussonetia papyrifera (L.) L'Hér. ex Vent.	2.01(1.80-2.10) ±0.10	11.7(11.4-11.9) ±0.15	17.3(17.2-17.5) ±0.09	0.67	-	12.30(9.30-15.10) ±1.80	7.20(5.70-9.20) ±1.03	-	-
Bryophyllum pinnatum (Lam.) Oken	0.6(0.5-0.75) ±0.06	13.3(12.2-15.25) ±0.5	13.5(12.2-15.5) ±0.54	0.98	-	4.2(3.2–5.00) ± 0.52	5.4(4.9–6.3) ± 0.45	-	-
*Capparis decidua (*Forssk.)edgeW.	1.55(1.0-2.0) ±0.16	23.9(22.75-25.5) ±0.52	23.9(22.2-25.5) ±0.72	1.00	-	5.5(4.6–6.7) ± 0.62	2.9(2.3–3.5) ± 0.34	-	-
Chorchorus depressus	1.05(0.75-1.25) ±0.09	13.9(12.0-15.50) ±0.63	13.4(12.0-15.5) ±0.70	0.99	-	5.2(4.2–6.1) ± 0.15	6.4(5.7–7.3) ± 0.15	-	-
Cissampelos pareira L.	2.5(2.25-2.75) ±0.11	21.0(15.5-24.75) ±1.63	22.6(18.0-25.2) ±1.3	0.92	-	7.8(6.8–9.1) ± 0.9	4.1(3.4–5.1) ± 0.4	-	-
Citharexylum spinosum L.	2.65(2.25-3.0) ±0.12	15.3(14.7-15.75) ±10.16	14.8(14.0-15.7) ±0.3	1.03	1	4.8(4.4–5.4) ± 0.29	2.7(2.4–3.1) ± 0.2	7.00(5.25-8.50) ±0.54	4.05(3.00-5.00) ±0.40
Cleome brachycarpa	1.9(1.0-2.75) ±0.34	14.0(13.0-14.7)	14.5(13.5-15.2)	0.96	-	6.7(5.8–8.1)	3.1(2.4–4.00)	-	-

(Forssk.) Vahl ex DC		±0.32	±0.3			± 0.6	± 0.4		
Cleome viscosa L.	2.95(2.75-3.25) ±0.09	36.9(33.7-43.00) ±1.74	38.7(37.2-40.5) ±0.65	0.95	-	7.8(5.8–9.5) ± 1.07	4.3(3.7–5.00) ± 0.3	-	-
Commelina benghalensis L.	2.80(2.25-3.25) ±0.16	40.4(35.7-45.50) ±1.68	47.2(45.2-48.5) ±0.65	0.85	-	1.86 (1.35–2.40) ±0.17	1.23 (.75–1.95) ±0.21	-	-
Convolvulus arvensis L.	0.78(0.6-1.1) ±0.09	27.3(22.7-32.7) ±1.65	30.0(24.5-33.5) ±1.77	0.91	-	1.65 (1.05–2.40) ±0.22	1.68 (1.05–2.10) ±0.20	-	-
Cucumis melo sub *agerestis* L.	2.5(2.25-2.75) ±0.11	34.05(29.0-39.0) ±1.69	35.1(32.2-39.2) ±1.32	0.96	-	2.25 (.75–3.45) ±0.47	2.64 (2.10–3.30) ±0.20	-	-
Datura innoxia Mill.	2.15(1.5-3.0) ±0.3	16.2(13.5-18.0) ±0.85	15.6(13.2-18.5) ±1.0	1.03	-	2.70 (1.95–3.30) ±0.22	3.03 (2.40–3.60) ±0.20	-	-
Euphorbia granulata L.	0.95(0.75-1.25) ±0.09	13.9(12.0-15.5) ±0.63	13.4(12.0-15.5) ±0.70	0.99	-	1.14 (.75–1.50) ±0.13	1.77 (1.50–2.10) ±0.12	-	-
Oxalis corniculata L.	2.0(1.50-2.25) ±0.13	19.8(17.2-21.25) ±0.69	18.2(16.2-20.5) ±0.69	1.08	1	-	-		
Solanum surattense	1.85(1.7- 2.1)±0.7	12.8(10.2-15.5)±0.71	11.10(10.3-13.50)±0.6	1.15		4.50(3.25-5.25)±0.38	6.55(5.25-7.75)±0.46	-	-
Trianthema portulastrum	2.8(1.7-4.5)±0.46	20.6(12.5-22.7)±0.57	19.6(18.2-20.7)±0.40	1.05		7.05 (7.75-6.25)±0.69	4.75 (5.25-4.25)±0.39	-	-

Table 15: Pollen Fertility percentages of examined taxa

Sr. No	Taxa	No of Fertile Pollen	No of Sterile Pollen	Fertility %
1.	*Anagallis arvensis* L	70	15	82
2.	*Asphodelus tenuifolius* Cav.	90	40	69
3.	*Boerhivia procumbense*	77	10	88
4.	*Brachychiton acerifolius (*A.Cunn. ex G.Don) F.Muell	99	12	89
5.	*Broussonetia papyrifera* (L.) L'Hér. ex Vent.	88	22	80
6.	*Bryophyllum pinnatum* (Lam.) Oken	50	9	84
7.	*Capparis decidua (*Forssk.)edgeW.	80	2	97
8.	*Chorchorus depressus*	80	7	91
9.	*Cissampelos pareira* L.	75	10	88
10	*Citharexylum spinosum* L.	90	11	89
11	*Cleome brachycarpa* (Forssk.) Vahl ex DC	118	7	94
12	*Cleome viscosa* L.	102	10	91
13	*Commelina benghalensis* L.	90	5	95
14	*Convolvulus arvensis* L.	110	14	89
15	*Cucumis melo* sub *agerestis* L.	86	11	89
16	*Datura innoxia* Mill.	99	12	89
17	*Euphorbia granulata* L.	143	9	94
18	*Oxalis corniculata* L.	81	14	85
19	*Solanum surattense*	363	66	84.61
20	*Trianthema portulastrum*	636	123	83.79

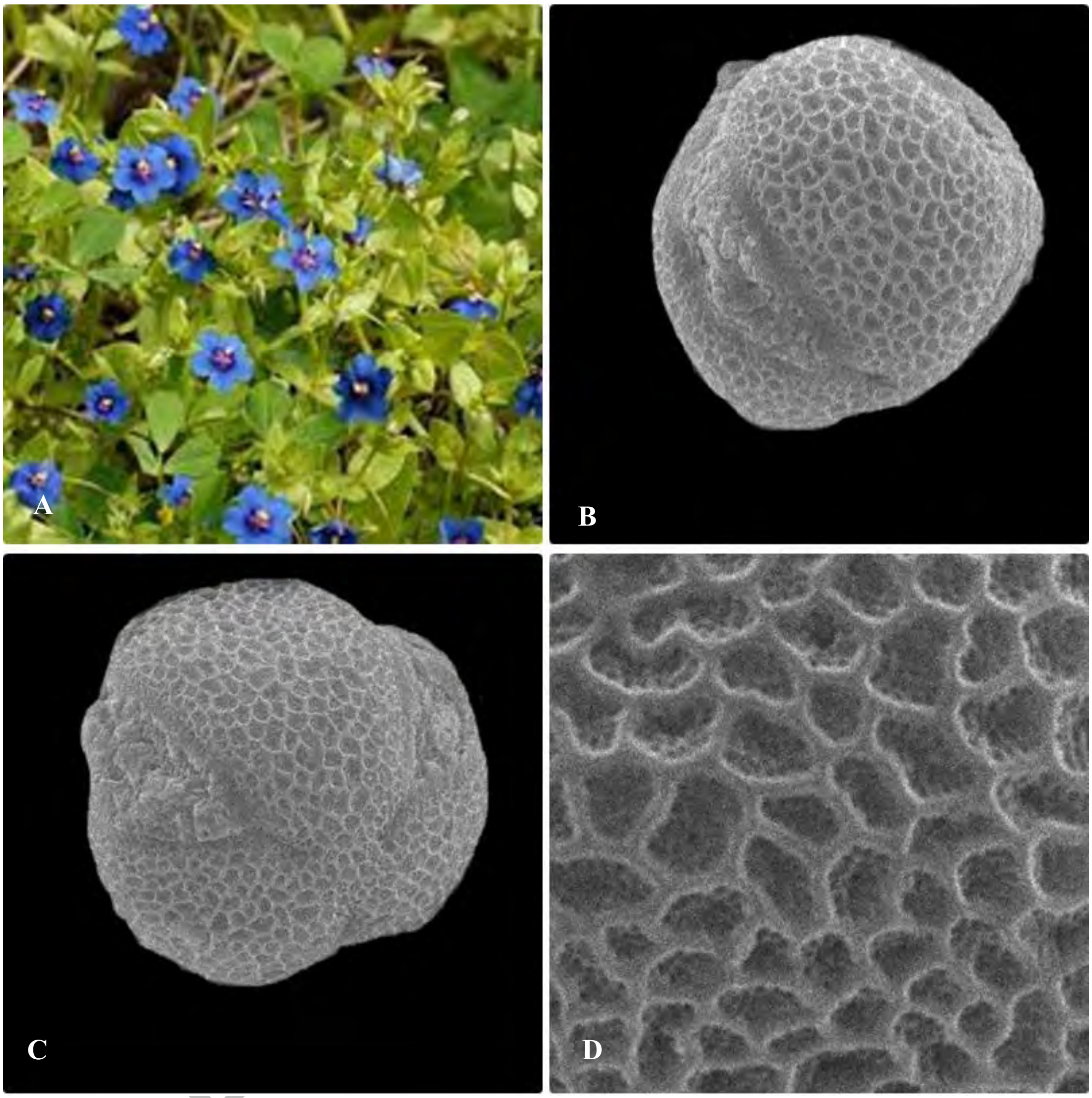

Plate 104: *Anagallis arvensis* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Sunken orientation (D) Surface Sculpturing

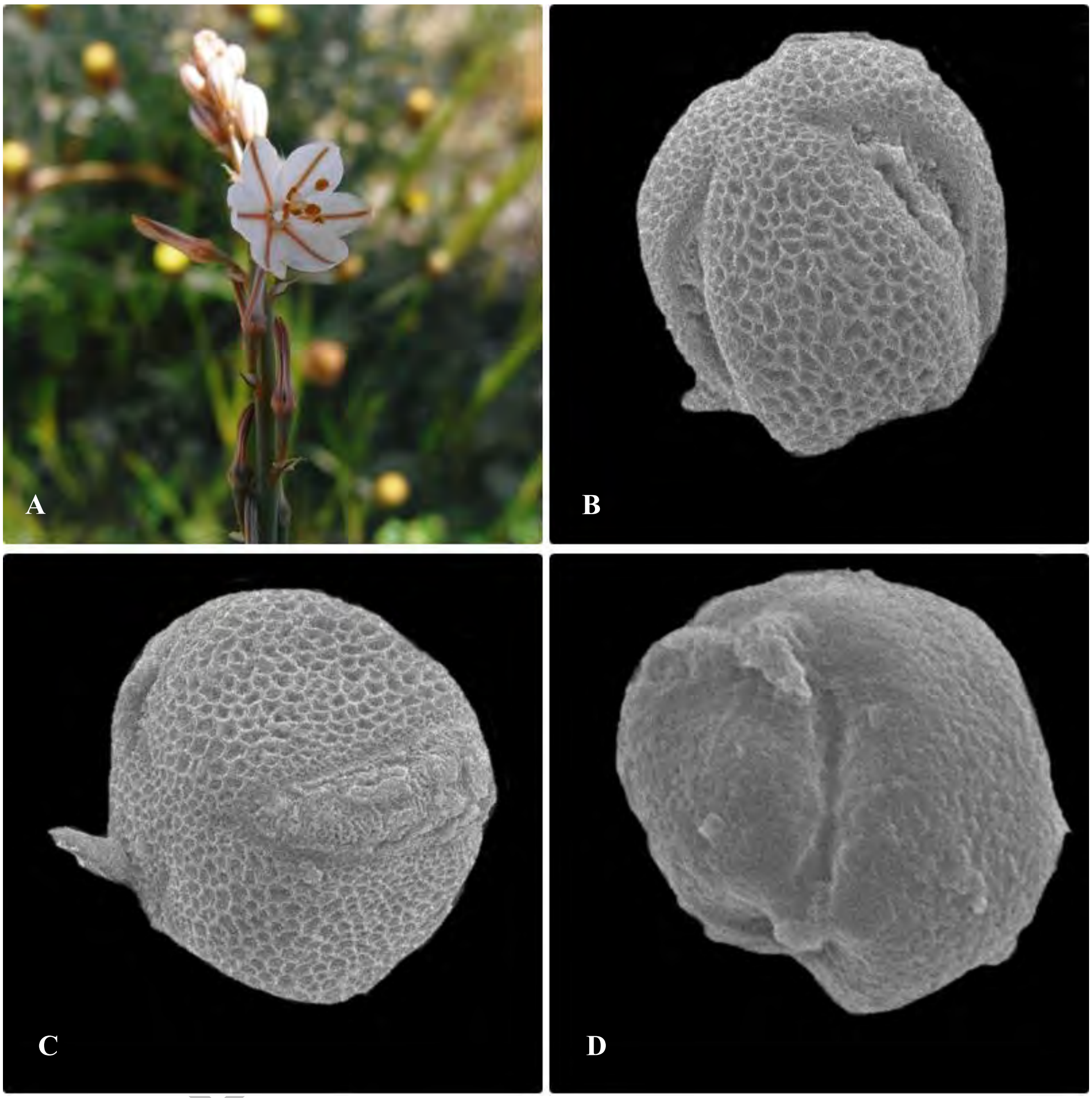

Plate 105: *Asphodelus tenuifolius* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Angular orientation (D) Reticulate Exine Sculpturing

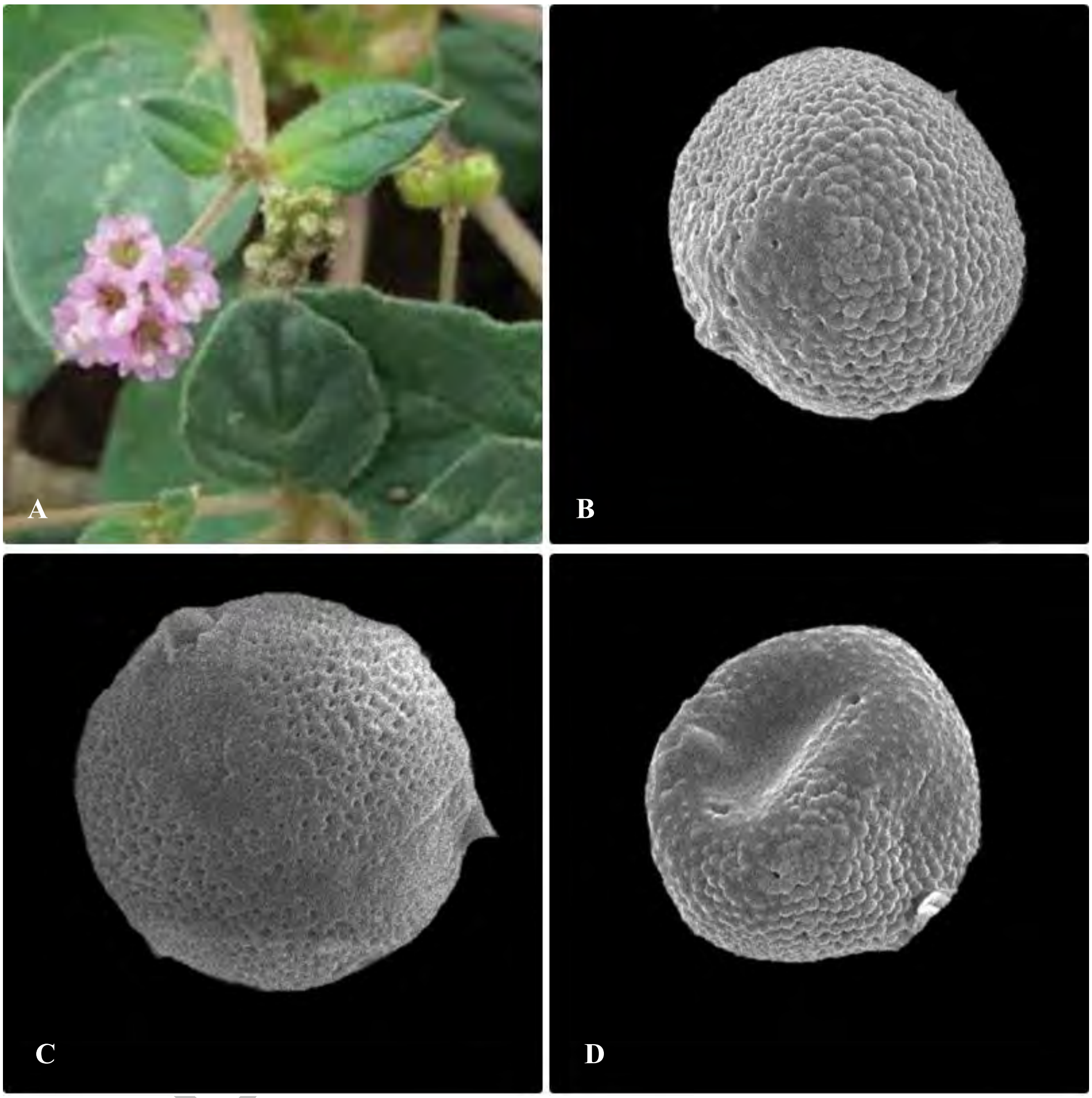

Plate 106: *Boerhivia procumbense* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Rounded orientation (D) Scabrate Exine Sculpturing

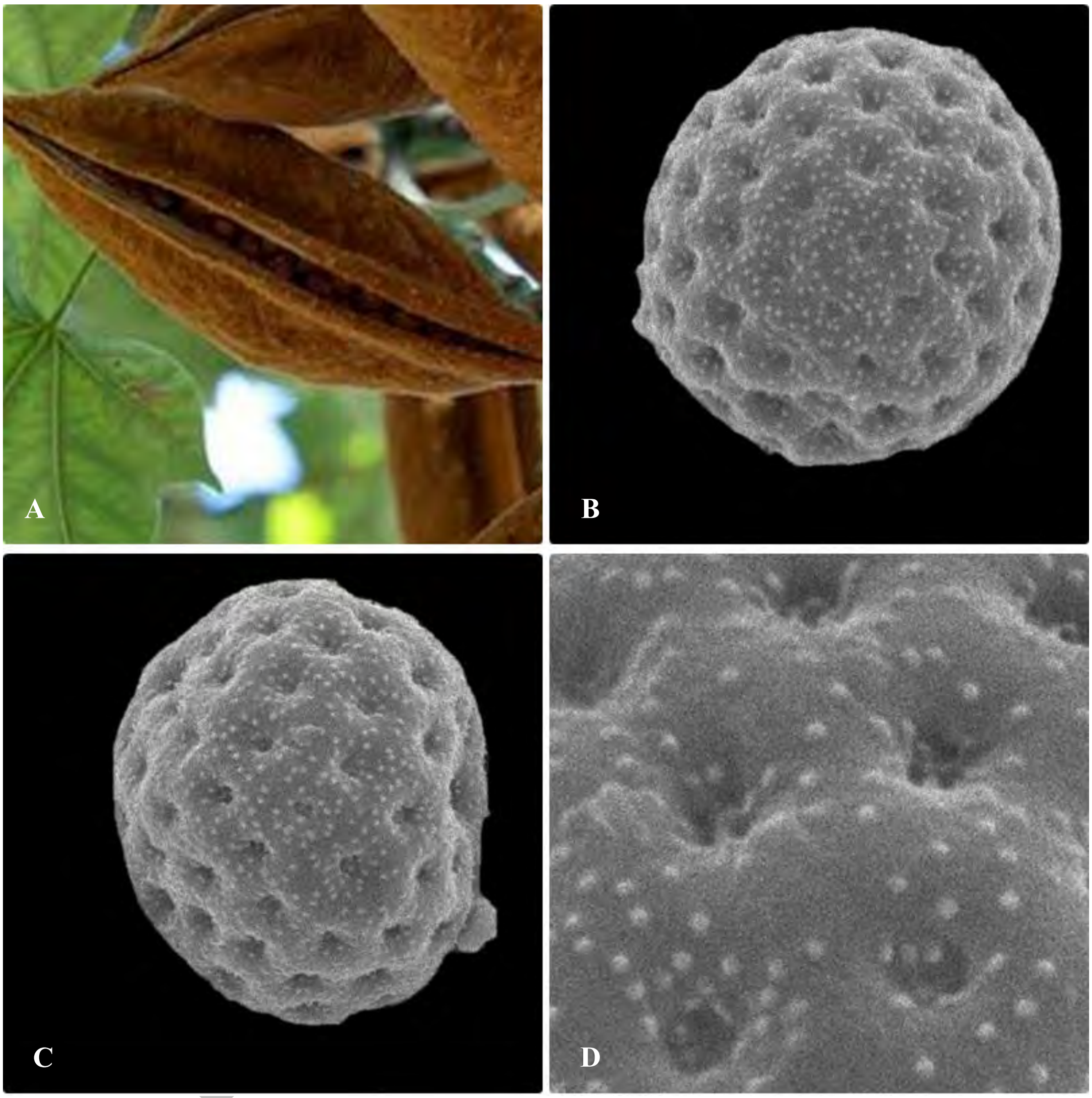

Plate 107: *Brachychiton acerifolius* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Perforate orientation (D) Surface Sculpturing

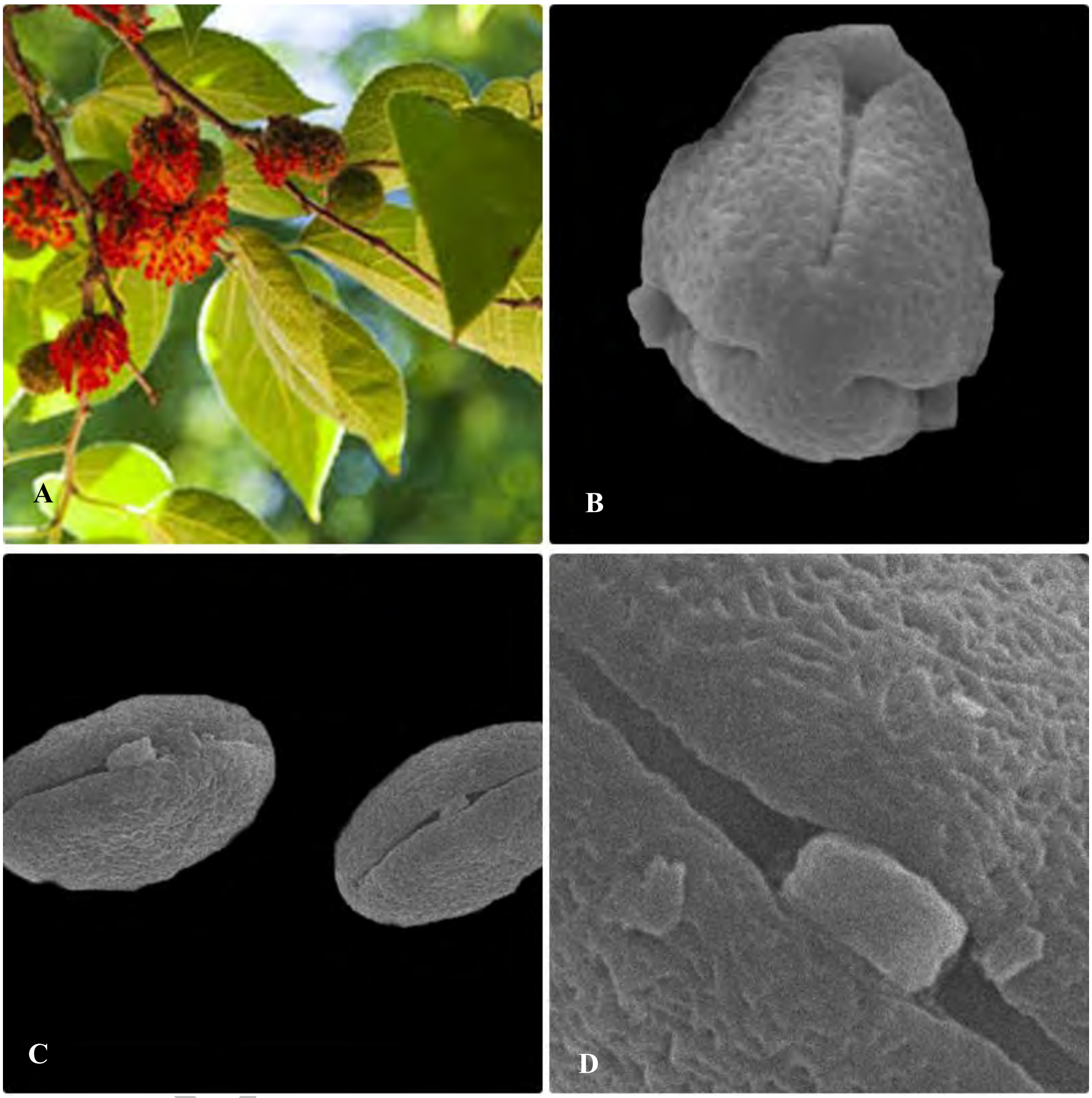

Plate 108: *Broussonetia papyrifera* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Equatorial View (D) Surface Sculpturing

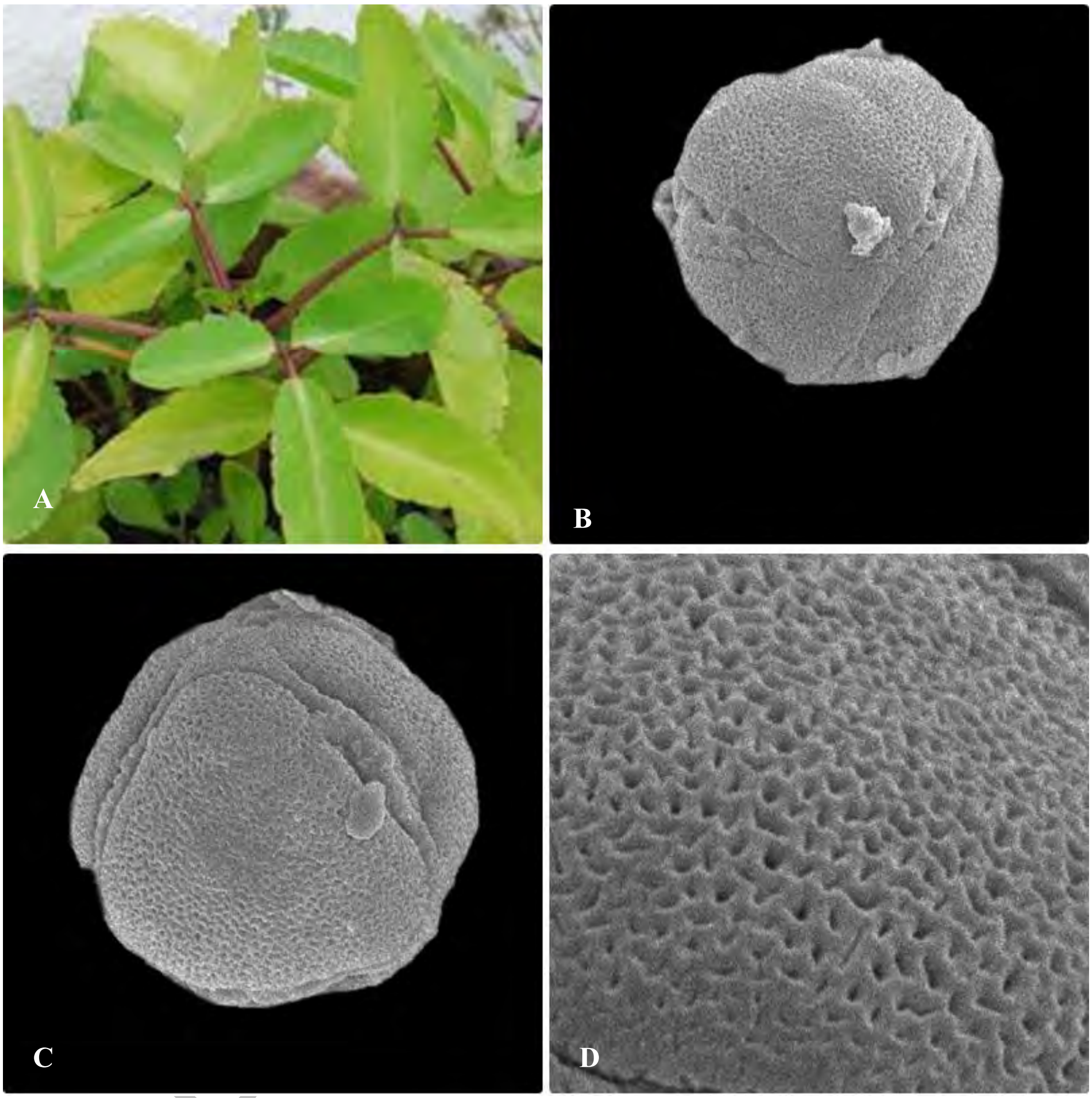

Plate 109: *Bryophyllum pinnatum* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Sunken orientation (D) Surface Sculpturing

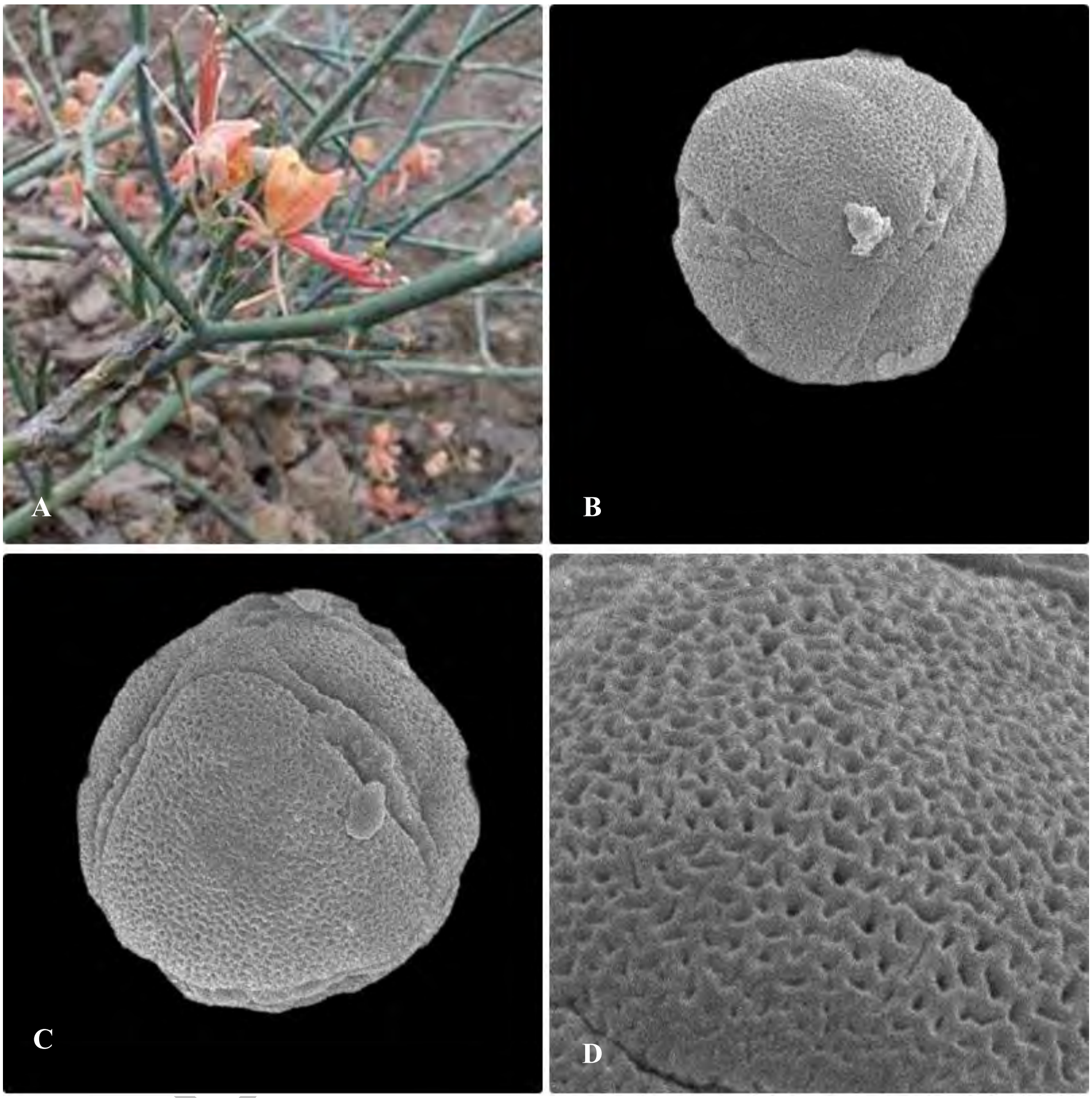

Plate 110: *Capparis decidua* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B)Polar View (C) Sunken orientation (D) Surface Sculpturing

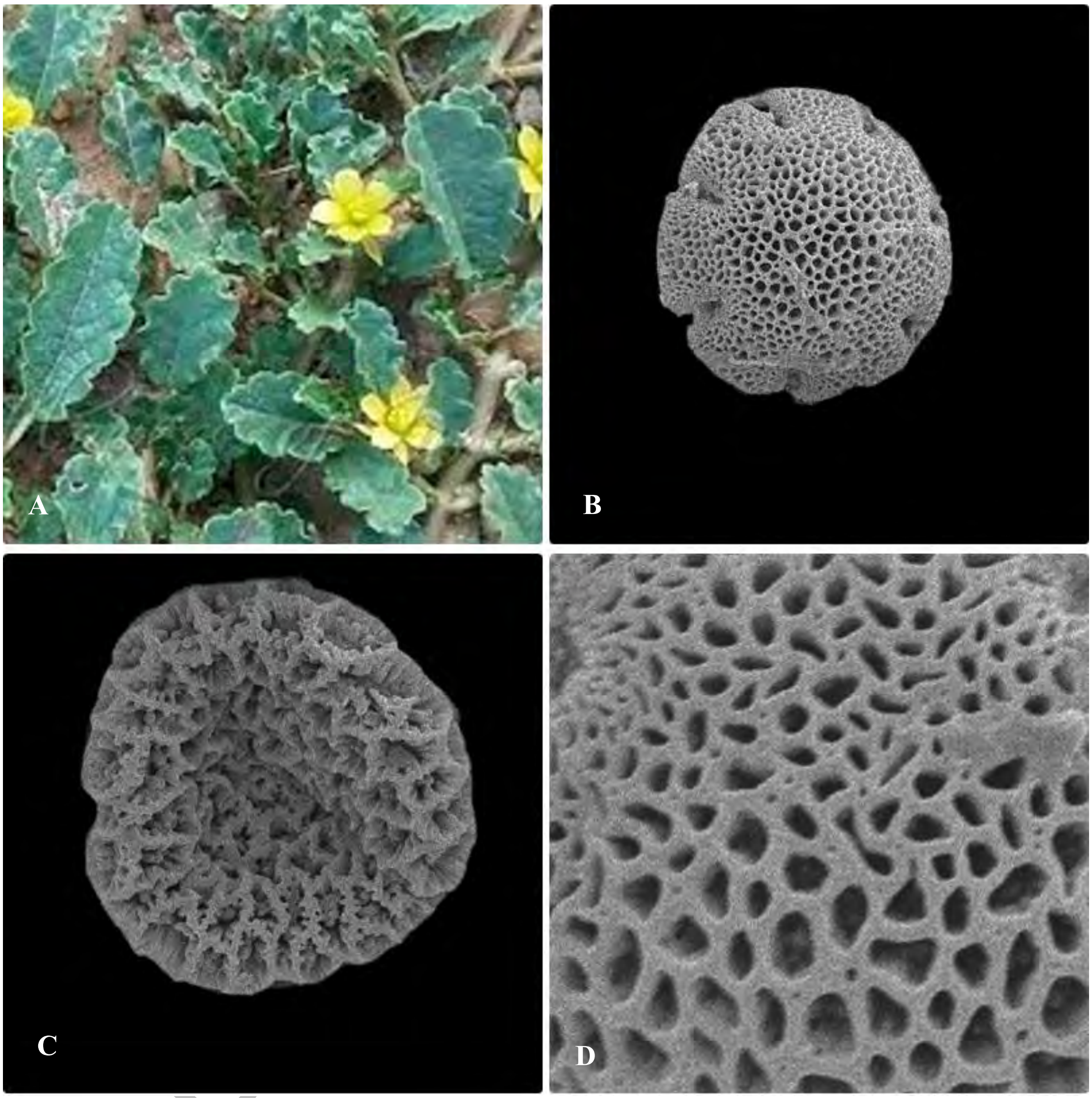

Plate 111: *Chorchorus depressus* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Wavy orientation (D) Surface Sculpturing

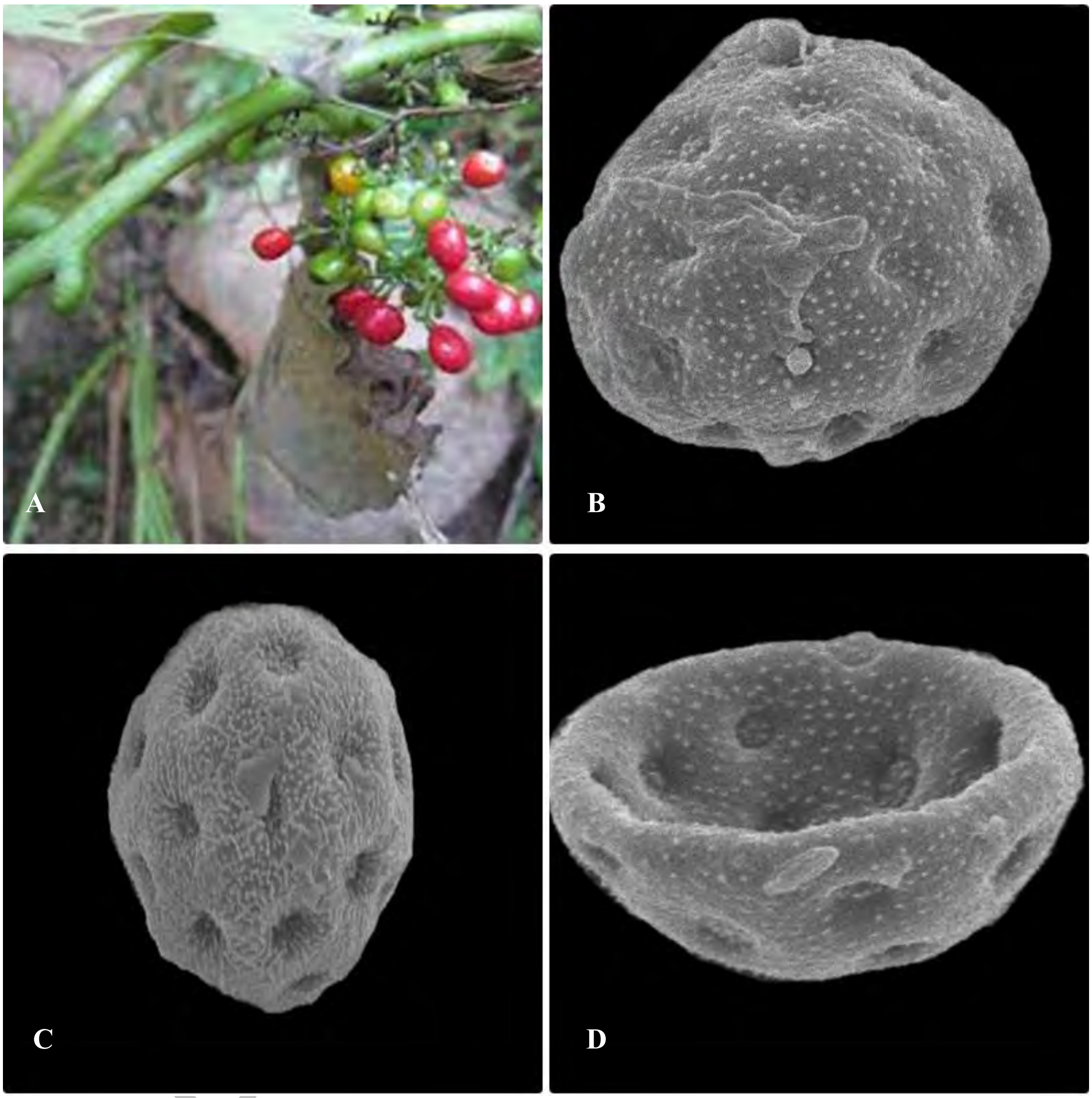

Plate 112: *Cissampelos pareira* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Sunken orientation (D) Exine Sculpturing

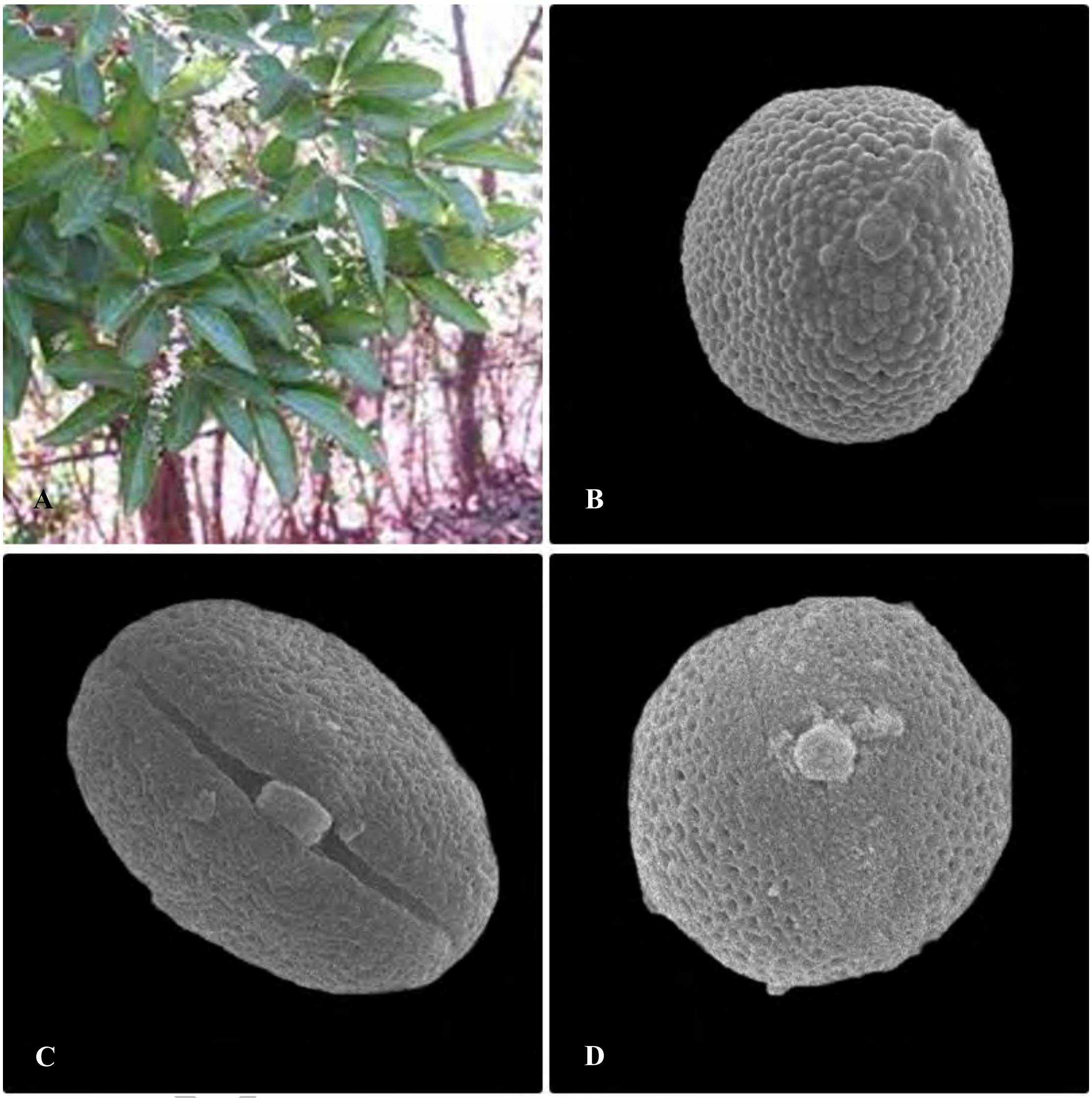

Plate 113: *Citharexylum spinosum* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Equatorial View (D) Exine Sculpturing

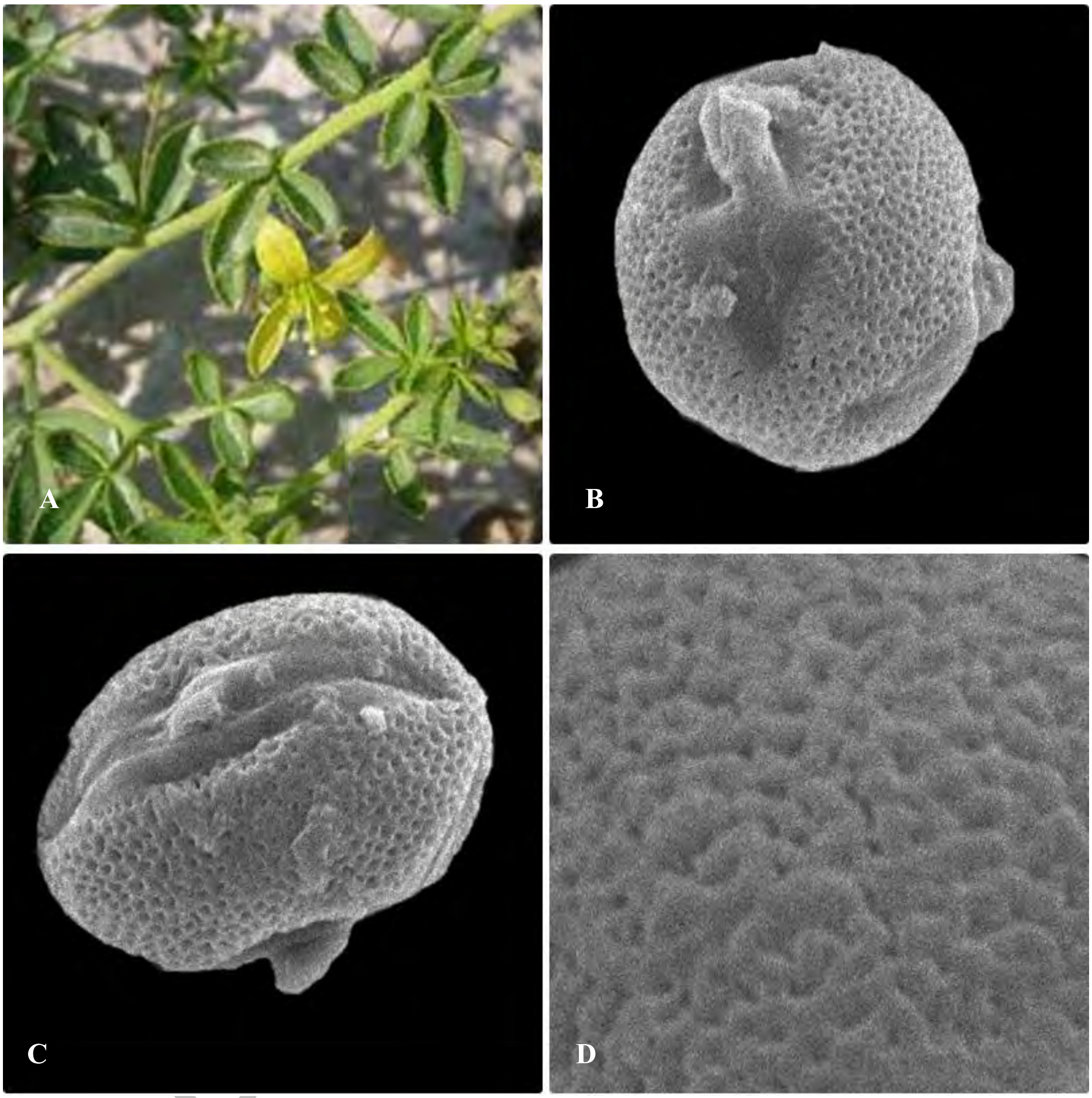

Plate 114: *Cleome brachycarpa* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Sunken orientation (D) Surface Sculpturing

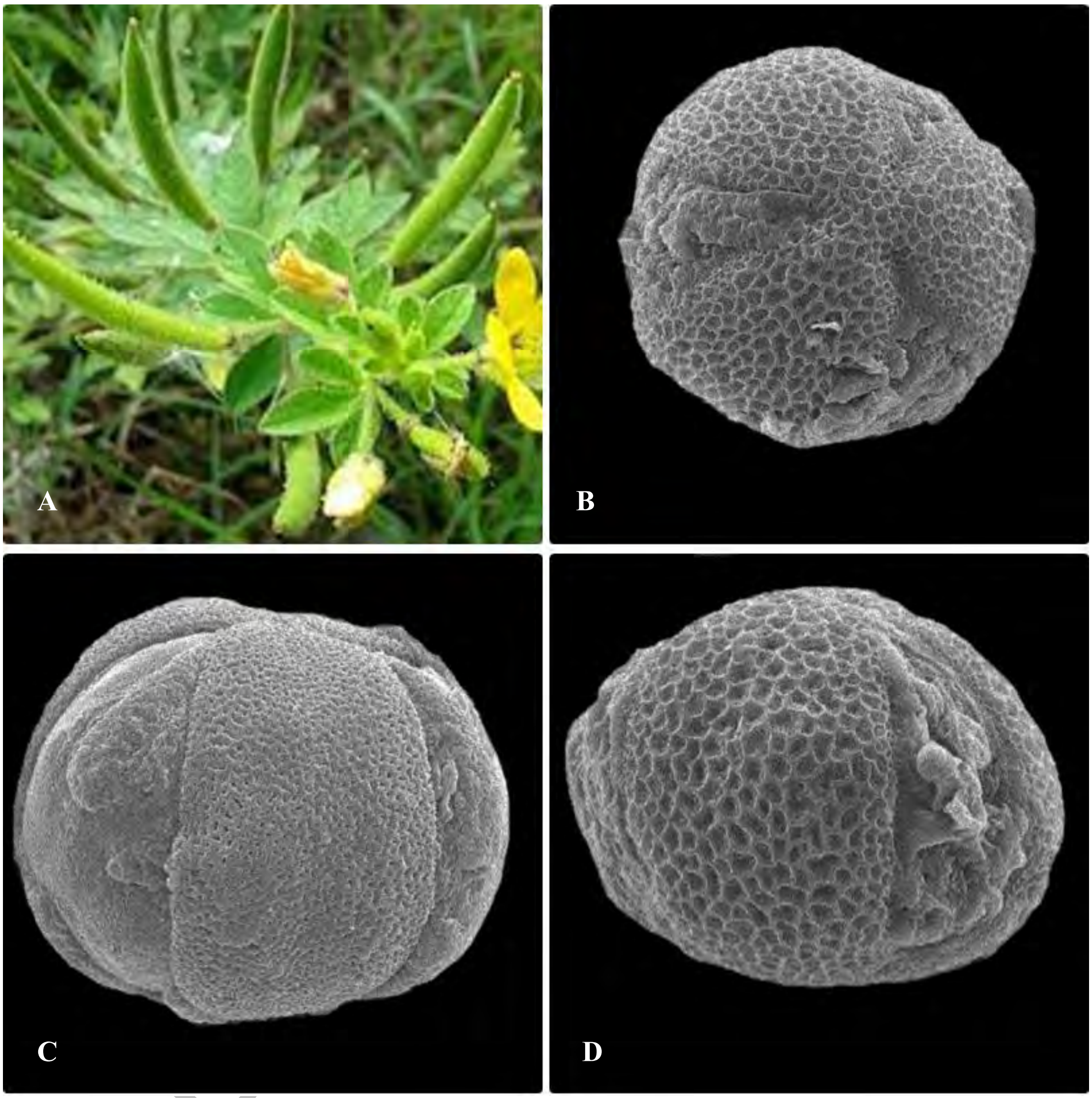

Plate 115: *Cleome viscosa* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Reticulate and Scabrate Surface (D) Exine Sculpturing

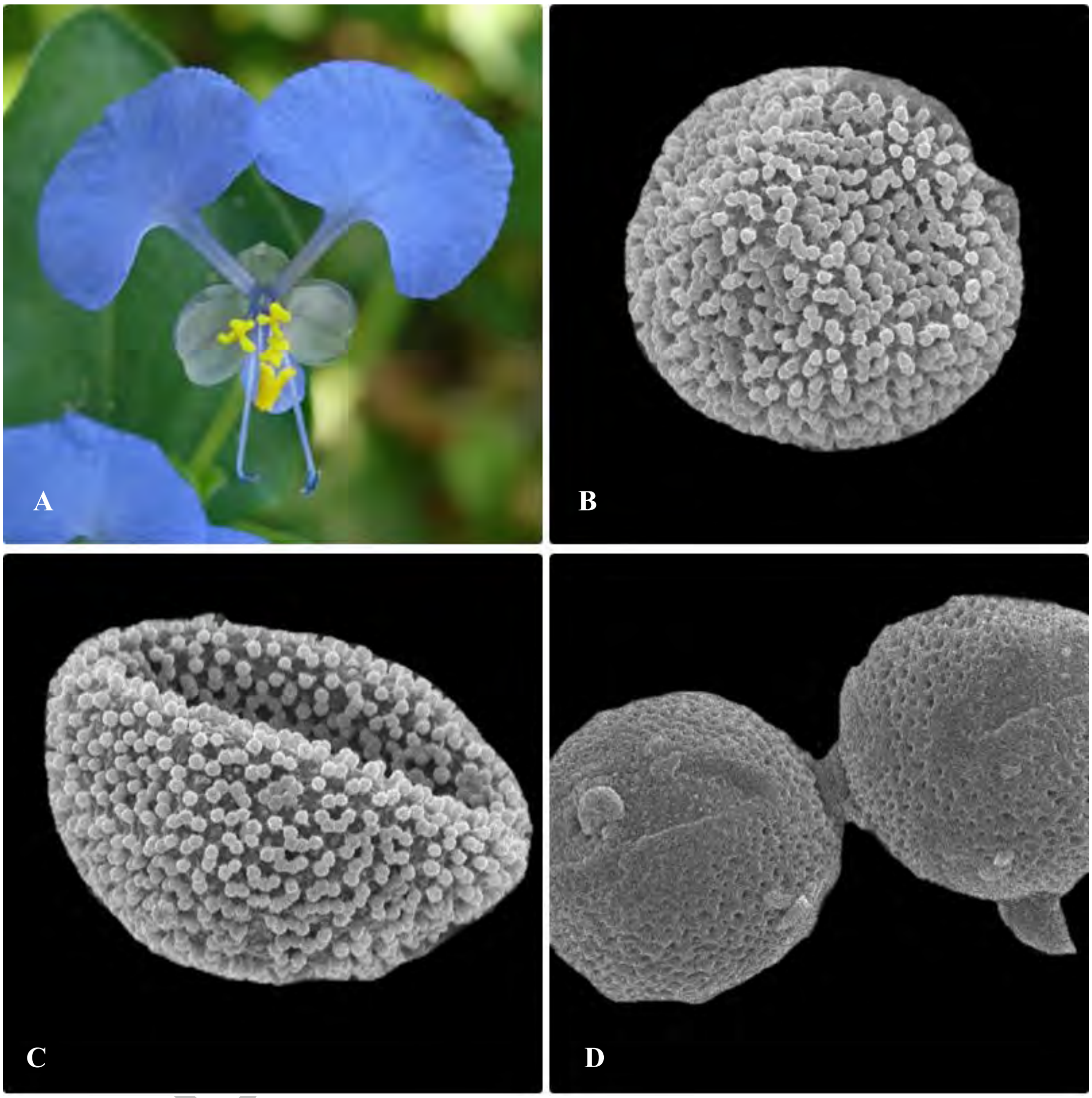

Plate 116: *Commelina benghalensis* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Sunken & Angular orientation (D) Exine Sculpturing

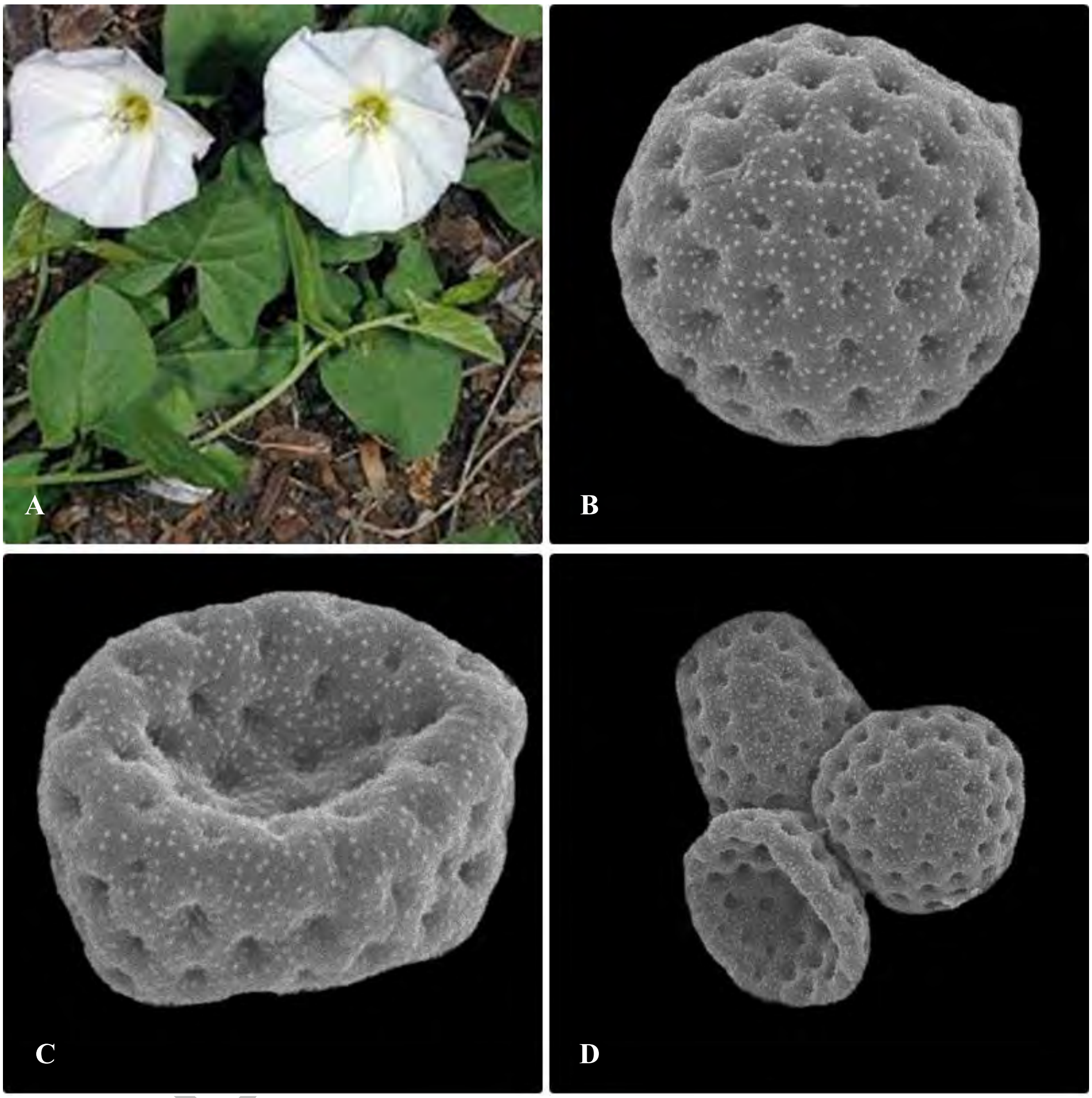

Plate 117: *Convolvulus arvensis* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Scabrate Ornamentation(D) Exine Sculpturing

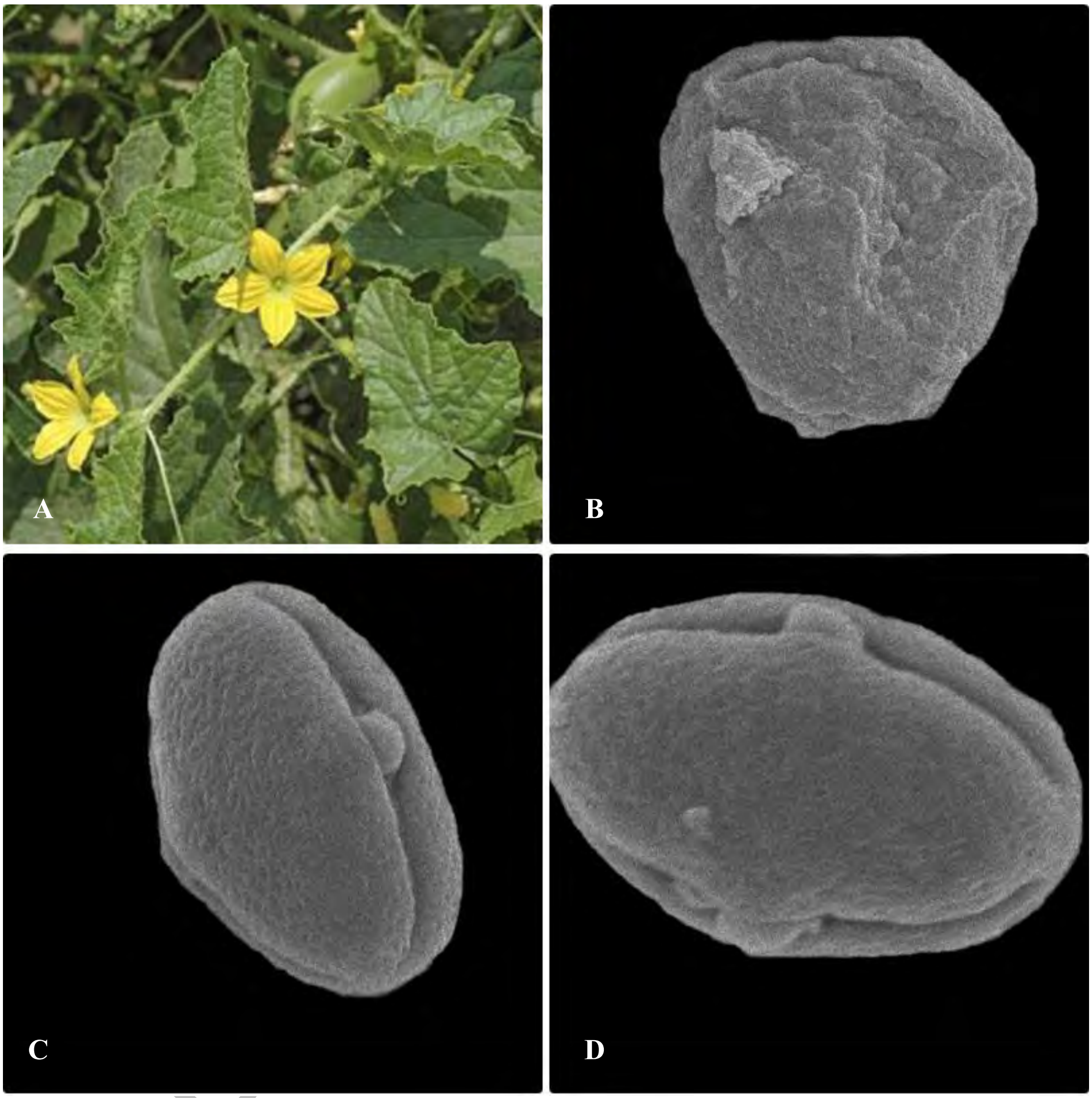

Plate 118: *Cucumis melo* sub *agerestis* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Equatorial View (D) Exine Sculpturing

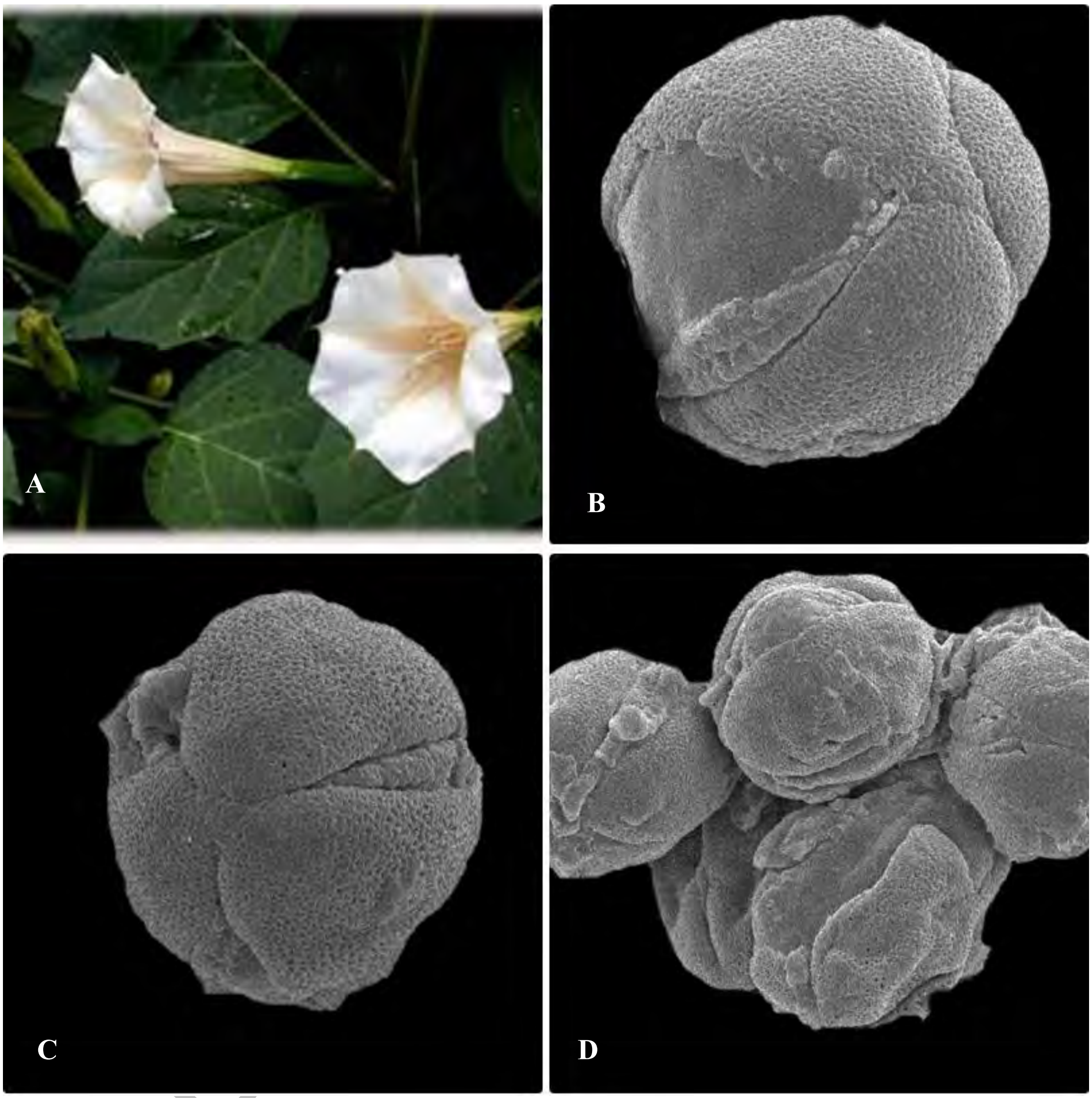

Plate 119: *Datura innoxia* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Scabrate & Reticulate Ornamentation (D) Echinate Exine Sculpturing

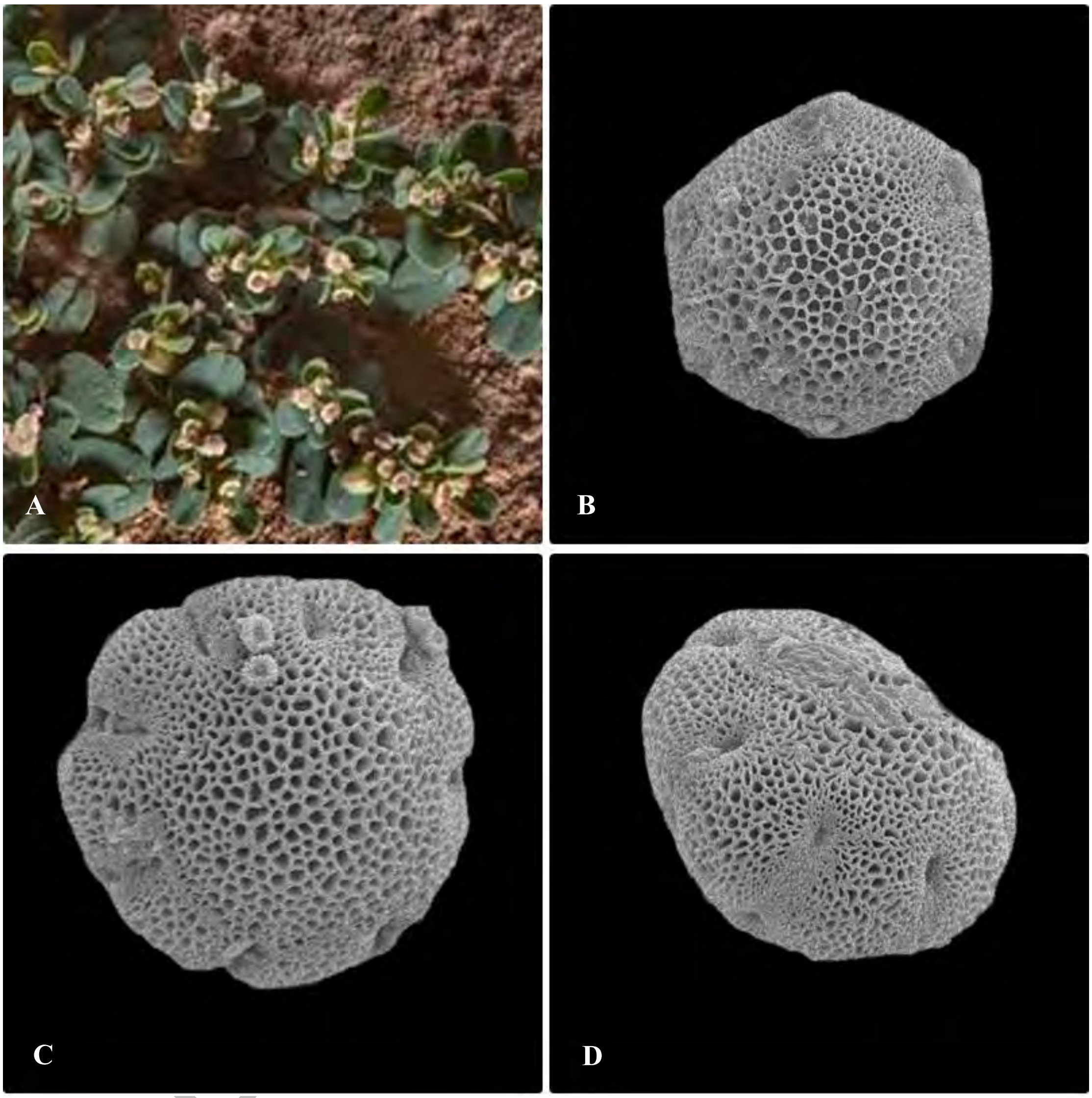

Plate 120: *Euphorbia granulate* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Sunken orientation (D) Exine Sculpturing

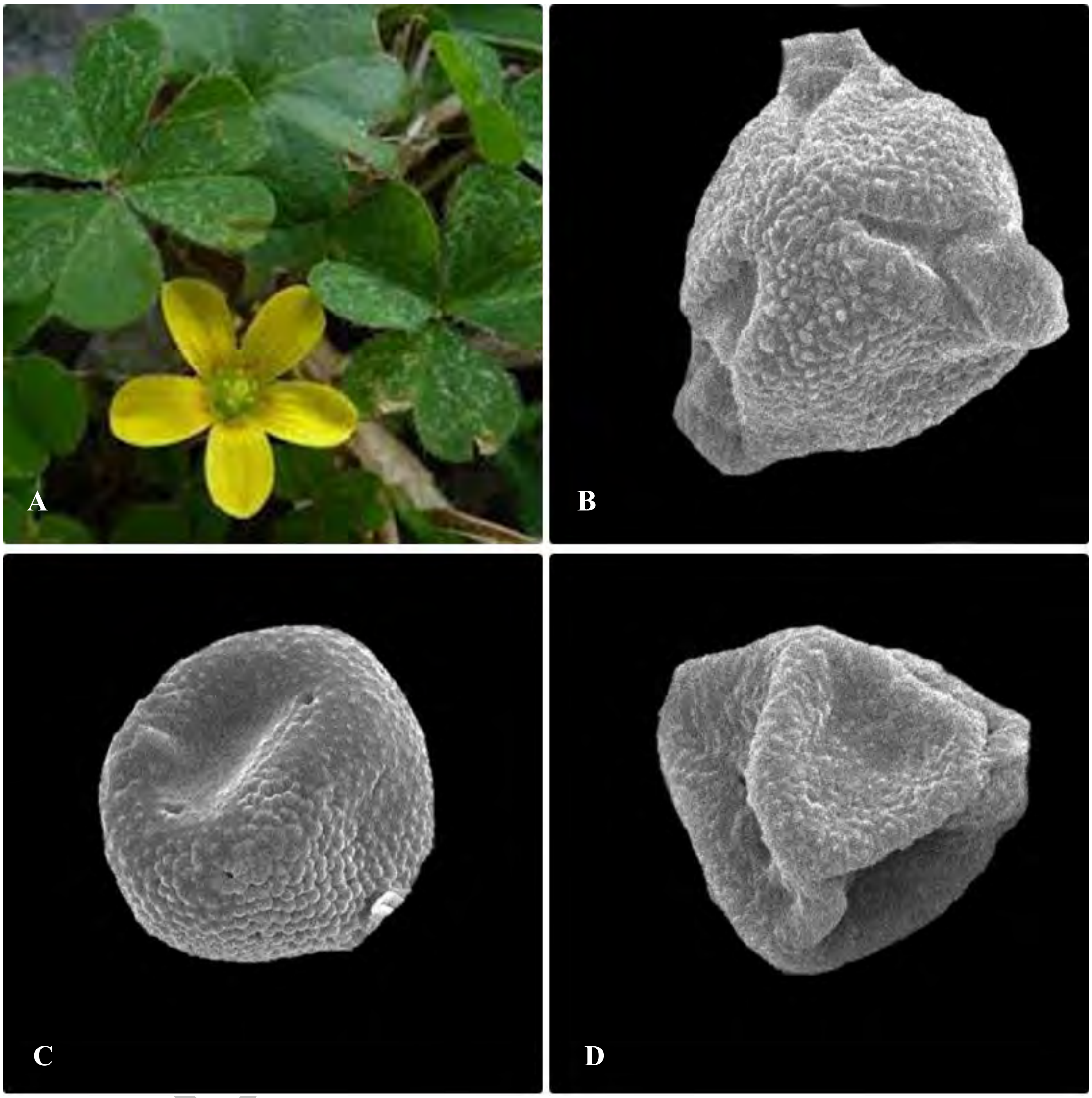

Plate 121: *Oxalis corniculata* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Sunken orientation (D) Exine Sculpturing

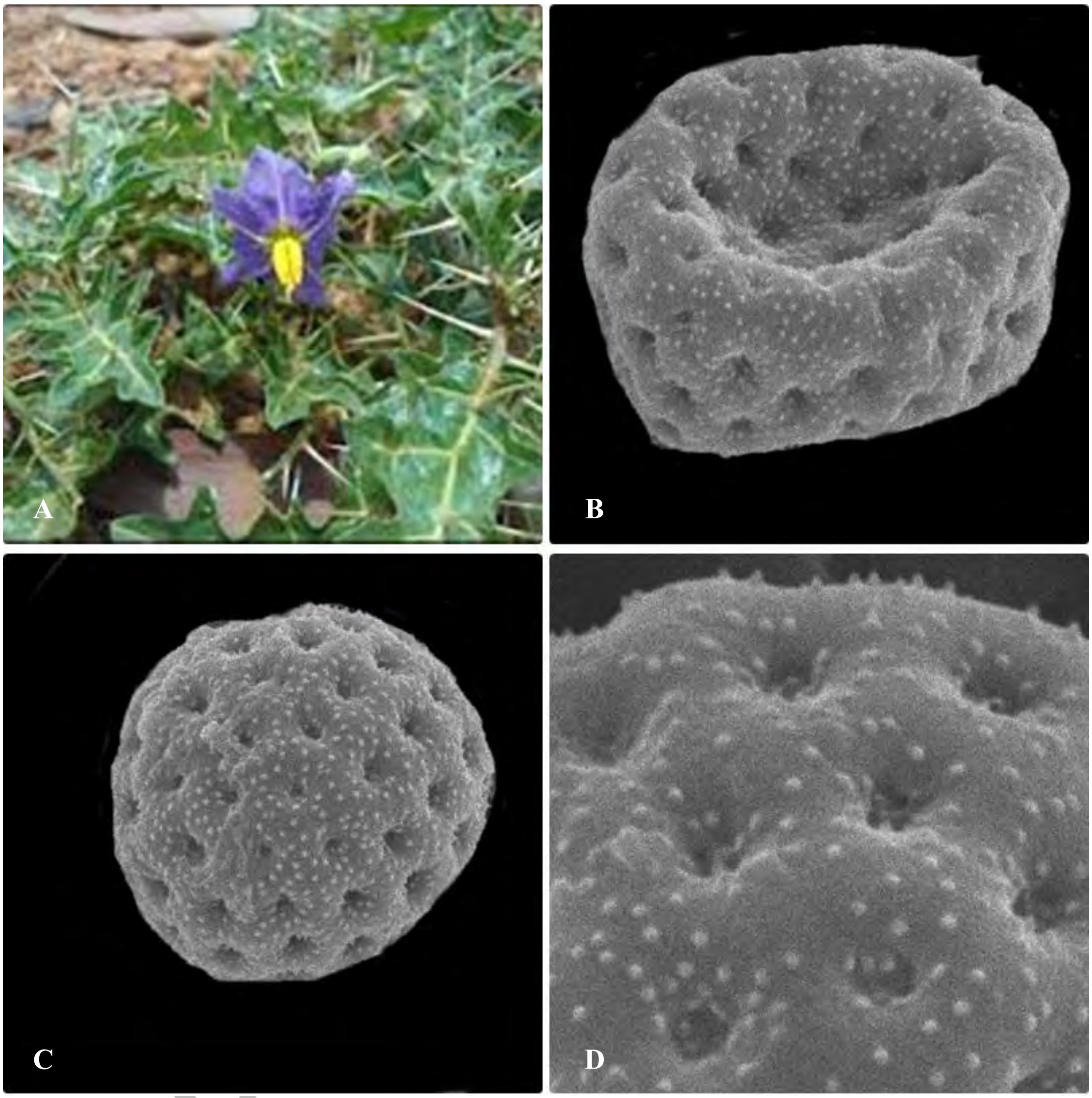

Plate 122: *Solanum surattense* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Reticulate Ornamentation (D) Surface Sculpturing

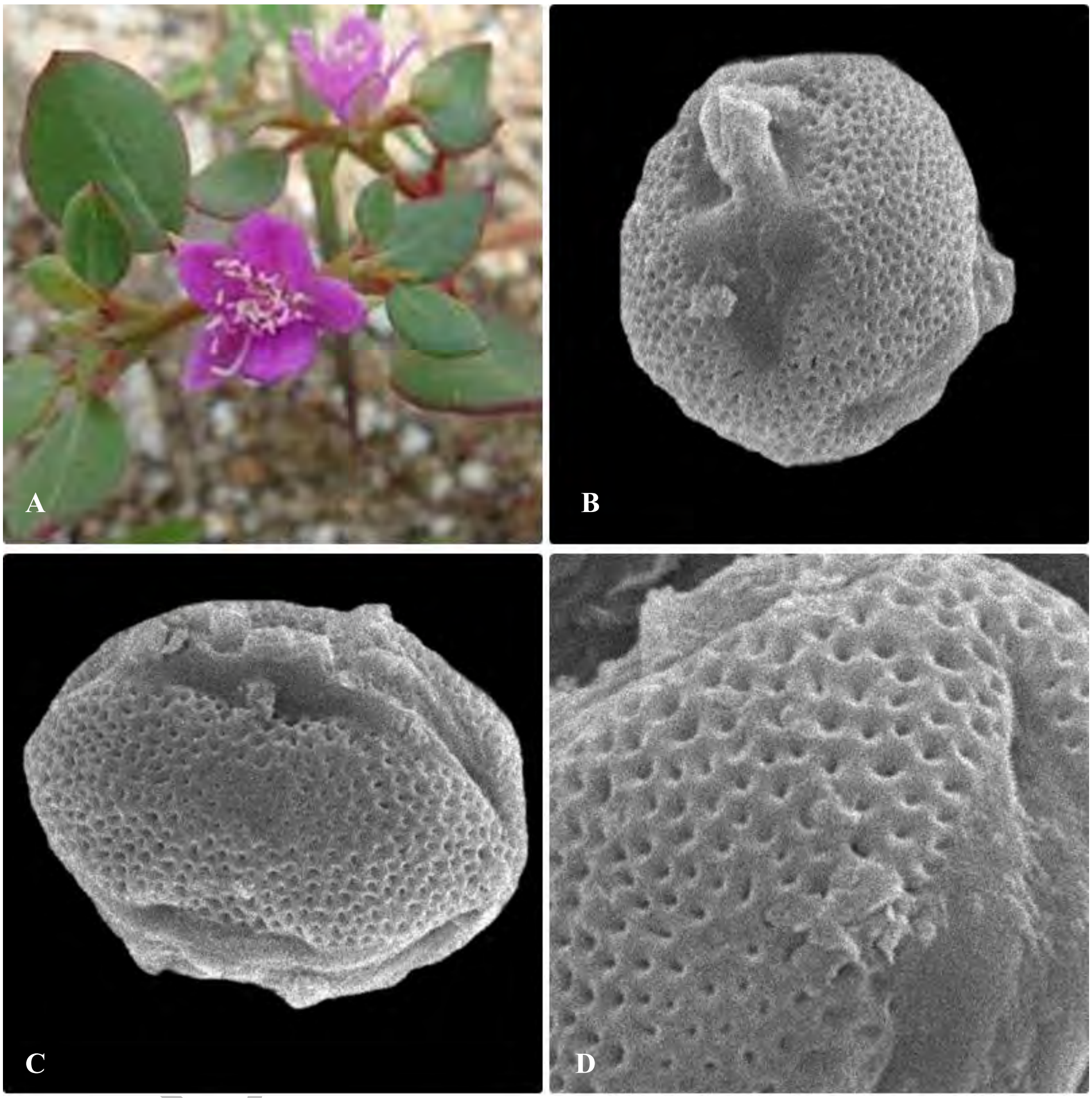

Plate 123: *Trianthema portulastrum* (A) Floral Parts , Scanning Electron Micrographs of Pollen (B) Polar View (C) Perforate Exine Ornamentatin (D) Surface Sculpturing

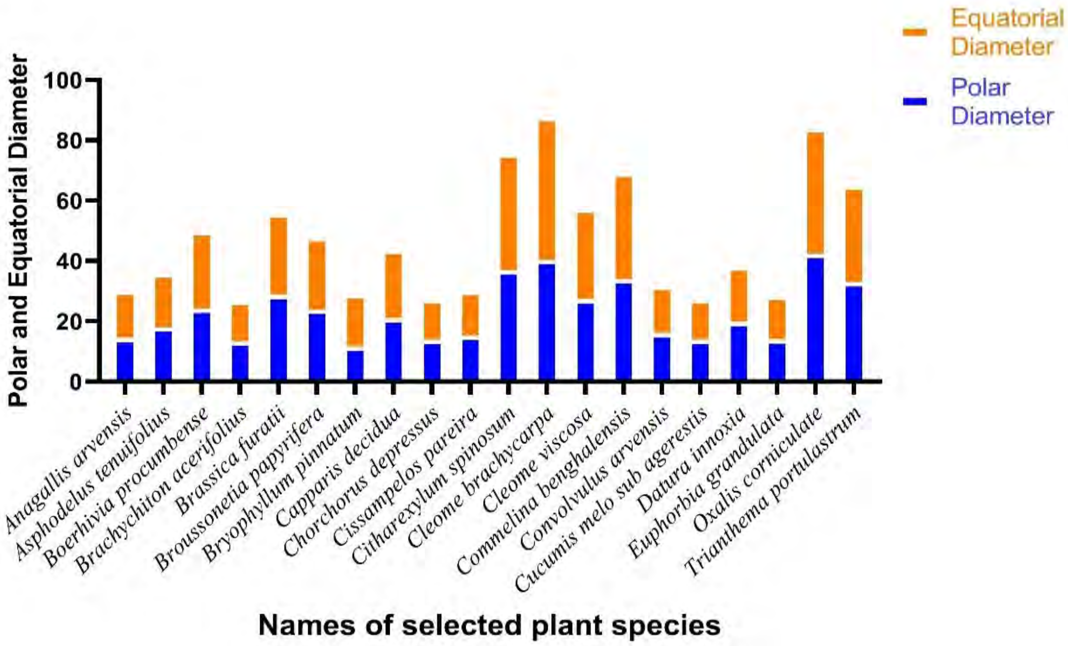

Figure 23: Mean values of Pollen diameter among Weeds

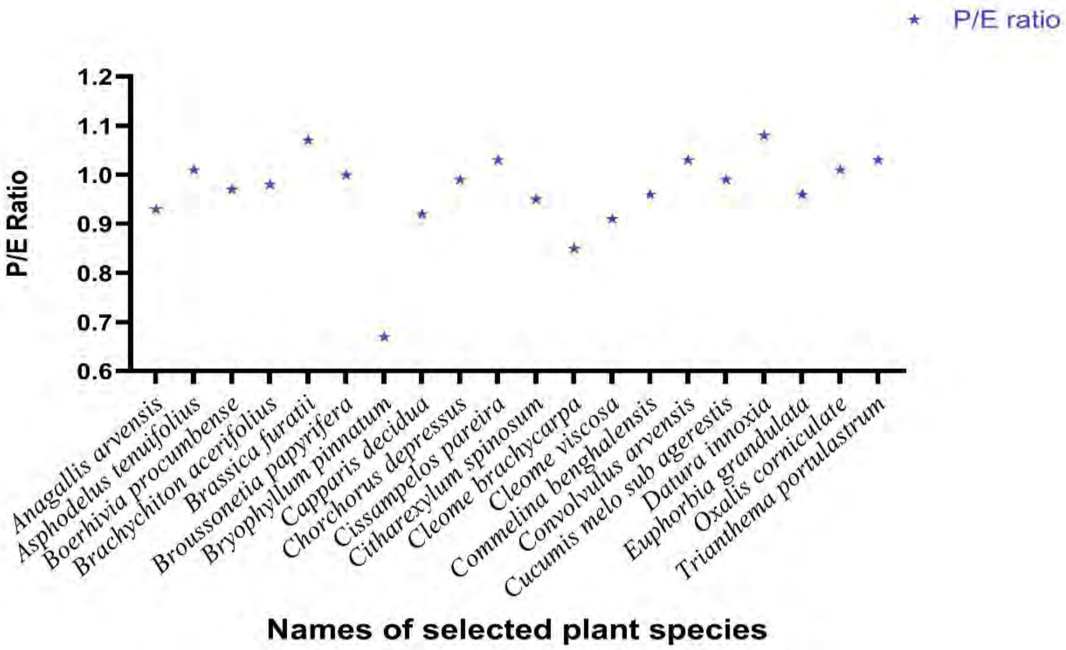

Figure 24: Variation in P/E ratio index of Weeds

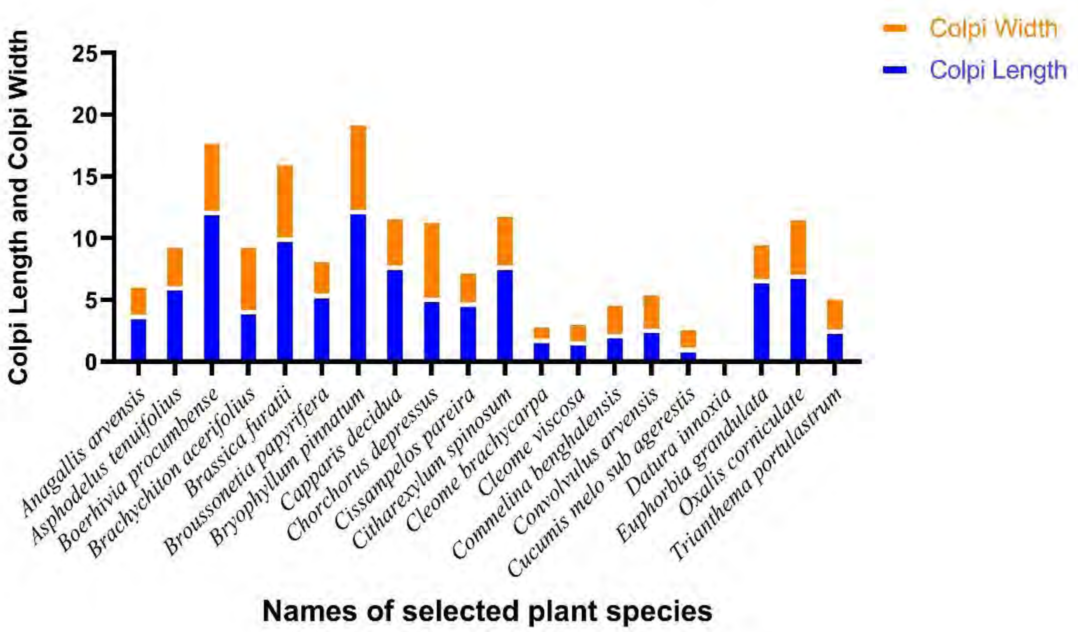

Figure 25: Mean data variations of colpi length and width in Weeds

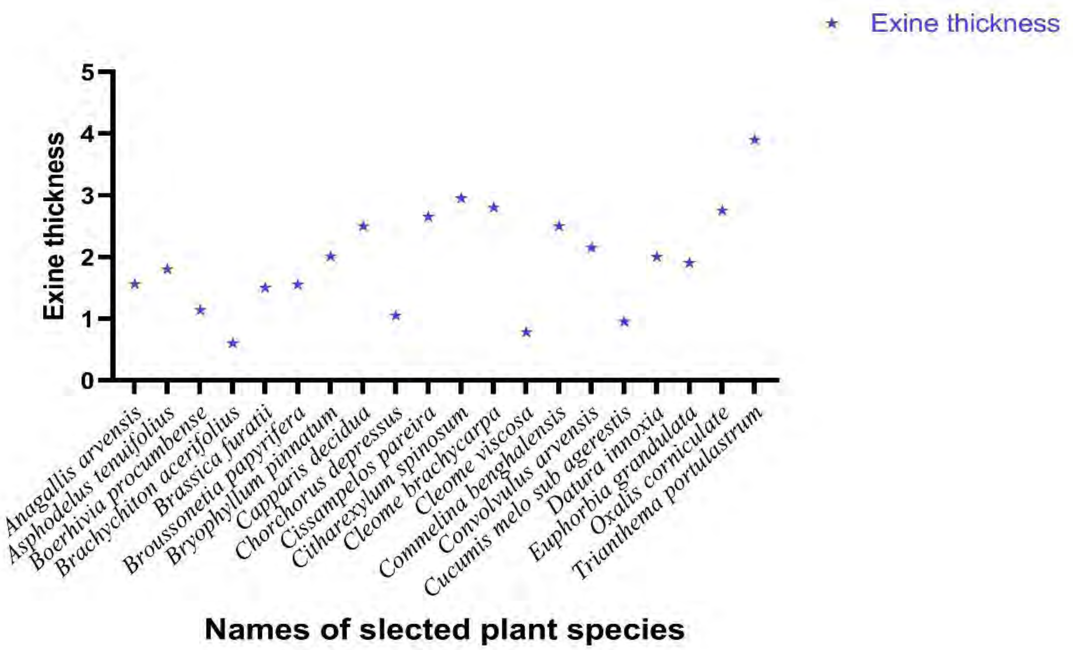

Figure 26: Mean exine thickness in Weeds.

3.1.5 Discussion Of Weeds

The results explained in this part related to weeds demonstrate the role of palynological study for species identifications from the Potohar regions of Pakistan. For the documentation of a detailed description of morphological features of species light and scanning electron microscopic techniques have been used. Pollen grains of the weedy plants vary in shapes, apertures, mesocolpium, colpi orientation, and exine ornamentations. Pollen shape, exine sculpturing, spines, number of colpi, and exine thickness of weeds from district Bannu were described by Ahmad et al.,. A wide variation in different pollen parameters helps to differentiate closely related species and genera. Morphological characters of pollen provide additional knowledge in plant taxonomy and systematics(Ahmad et al. 2019; Amina et al. 2020; Perveen and Qaiser, 2012). Pollen investigated through LM showed great variability in equatorial diameter, polar axis diameter, width and length colpi, and thickness of exine(Aftab and Parveen, 2006). A very wide range of variations was observed in pollen morphology of selected species of weeds from the study area showing that the field of palynology plays a vital role in evolutionary studies of plant species. Variations in exine sculpturing are the diagnostic character in plant systematic study.

The current study showed that pollen morphological features, especially the shape of pollen grains, are the major distinguishing feature for the identification of weeds species. The present study varies from the previous studies conducted on weeds in terms of qualitative and quantitative microscopic characteristics. In the present research family, Amaranthaceae were considered the dominant family of weeds followed by Capparaceae while the rest of each family, i.e., Euphorbiaceae, Cucurbitaceae, Verbenaceae, Menispermaceae, Teliaceae, Chenopodiaceae, Poaceae, Asphodelaceae, Brasicaceae, and Nyctaginaceae contain 1 species each. Pollen grains are in the form of monad with most species having scabrate exine ornamentation similar findings are reported by Nazish et al., examined the apolar, spheroidal, scarbate. Micro Echinate pollen ornamentations and sunken pore ornamentations have a number of pores ranging from 11-23 Butt et al. (2021).

Various researchers working on the palynological study of weeds believed that exine ornamentation is the key feature for the differentiation of taxonomic characters (Aftab and Parveen, 2006). Quite differences were observed in the exine thickness, the diameter of the equatorial and polar axis, the size of the colpus, and the number of pores. Palynological studies are used as a tool for species identifications in plant taxonomy and systematics. The study had links directly with environmental sciences, molecular biology, plant ecology, pharmaceutical studies, genetics, and aerobiology. In our study, some pollen has the same aperture conditions i.e., tricolporate. Khan et al., worked on the pollen morphological features of 16 plants using scanning electron microscopy, whose result is somewhat similar to our results used light and scanning electron microscopy and described the pollen micro-morphology of 24 wetland weeds. Bolick et al., recorded the exine sculpturing patterns of the pollen of Asteraceae with special emphasis on evolution Ahmad et al. (2020).. Morphological characteristics of pollen can be valuable in solving complications linked with the systematic study of grass, and the study of the pollen provides the base for more structures to properly identify the plant species. Palynological study of Asteraceous taxa from the Potohar region helps to differentiate species taxonomically .Research work has been done on many aspects of the flora. The study area has diverse species, but no work is performed on pollen morphological study of weedy species(Khan, 1991).

Oblate-spheroidal observations were observed abundantly in this study. Most of the colpi orientations noted were sunken and angular. Also, many prominent, waxy, long, slit-like, and tapering ends colpi were seen in the pollen. Pollen examined in this study is reticulate in sculpturing, while some contain faveoelate. *Cenhrus ciliaris* contain a single pore in the center of pollen. Fertility and sterility percentages were determined for the stability of pollen in the study area. Fertility and sterility percentages in pollen grains indicated the relationship among species' ancestors. Pollen grains' fertility helps identify the flora's genetic variations. Meo et al., reported different shapes of pollen grains of the genus *Cenchrus*. He observed spherical to perbolate shape in *C. pennisetiformis* and spheroidal to subulate in *C. setigerus*. The pollen of this genus is mono-porate with psilate exine ornamentation. Position of pores is ectoporous but in some cases endoporus pores are also observed. 3 species i.e. *C. ciliaris*, *C. biflorus* and *C. pennisetiformis* are endoporus whereas *C. setigerus* is ectoporus. The size and shape of pollen grains of genus *Cenchrus* is used to distinguish among the species. It is a useful tool for calculating the strength of species in a specific region. Pollen examined in this study were oblate, suboblate, oblate-spheroidal, and Prolate-spheroidal in shape with aperture conditions of tricolporate, mesocolpium scarbate, aerolate, reticulate, and perforated exine ornamentations. While the colpi orientation noted were long, slit-like, sunken, angular, margins distinct, waxy, rounded, and tapering ends.

Perveen et al., documented the morphological characteristics of pollen of the family Brassicaceae which are having reticulate ornamentation of exine compared to current study results *Brassica furatii* exhibit echinate type of exine surface. (Appel and Al-Shehbaz) reported that all pollen grains observed in their research exhibit tricolpate with the reticulate type of exine which is similar to the present study results as *Brassica furatii* has tricolpate pollen grains. Moore et al., reported tricolpate type of pollen with reticulate sculpturing of the exine. Much work has been done on weeds of the family Brassicaceae by (Moore et al.,2018) and concluded that the shape of the lumen is the most significant character in the delimitation of different species in the family Brassicaceae.

Weed flora has been documented previously by many researchers as reported 73 weed species that are medicinally important and utilized for curing different diseases of both human beings and animals. These weed species are helpful for the manufacturing of different plant yields and also useful for the indigenous sellers of crude drugs of plants. The pattern of distribution, richness, and abundance of weed species (e.g *A. viridis*, *P. lanceolata*, *D. annulatum*, *V. thapsus,* and *C. dactylon*) depend on the different environmental conditions such as $CaCO_3$, pH, organic matter, soil texture, phosphorous, electrical conductivity and concentration of nitrogen. Rafay et al. (2014) reported that in the agroecosystem weeds play a significant role by giving the environmental heterogeneity and floral diversity increase in the cropping system. Williams and Kremen defined that different types of invertebrates are supported by non-crop plants because many insects for survival depend upon specific weeds. On the other hand, weeds play a serious role in crop production and threaten the cultivated lands because of the use of nutrients from the soil. Weeds badly affect the yield and growth of crop plants because of nutrient demand. Weed vegetation is eliminated by the use of different control measures for example chemical approaches, cultural procedures, and biological mechanisms. In cultural operations, weeds are thrown away from the rice field. Identification of different weed species and farming practices plan with revised management is suggested.

The results of the present study of this family are compared with previously published data showing that these species are quite similar to the previously reported species, with few variations. Butt et al., described the palynological study of weeds for pollen some features, i.e., pore number, the diameter of the equatorial and polar axis, length, width of colpi, and its outline, which are very helpful for the classification of species in plant taxonomy. According to our results, these characteristics are insufficient for species identifications; sometimes, many species hold similar features. The most vital characteristics are exine thickness, mesocolpium , and aperture conditions. The study also provides information about the delimitation of the species from the genus to the family level. Further research is needed to achieve more conclusive results using more cosmopolitan species.

SECTION 2
Seeds Morphology (LM & SEM)

3.2 Seed Morphology of Asteraceous and Fabaceous Plants from Potohar-Plateau Pakistan

For Plants seeds are means of survival of the species as they carry parent germplasm and protected against heat, cold, drought and water. In current study the macro and micro morphological characters of seeds of Asteraceae and Fabaceae plants of Potohar-Plateau Pakistan, including seed shape, size, surface, seed inner color, position of hilum, compression, length, width and L/W ratio was observed using LM and SEM. Most taxonomists are in support of the idea that macro and micro structure of seeds are very useful for the classification of species and their correct identification. Dahlgren (1979-1980) stated the usefulness of micromorphology and ultrastructural data for evolution and classification of seed plants and play significant role in modern synthetic systems of angiosperms.

Morphological characters of seeds are used in for delimiting the taxa with quite conflicting morphological attributes. In present section morphology of Forty seeds of Asteraceae and Fabaceae Family were studied and data lies in Table 16,17,18 & 19. The Scanning Electron Microscopy (SEM) and Light Microscopy (LM) were applied. The current research study demonstrates the great variation in seed size, shape and ultra micromorphological features. The findings of research study showed that the seed morphological characteristics can be contribute as criteria to distinguish the taxa. Scanning electron microscopy is an innovative method used to study seed ornamentation, seed molding, and evaluation of micromorphological characters of seeds as compared to light microscopy findings (Môro et al., 2001). According to Luqman et al., 2018, seed size and shape along with micromorphological features can be used as diagnostic tools to identify the various plant species. Earlier literature has also proved that seed macro and micromorphological features can be used for correct identification purposes (Karakish et al., 2013)The collected seeds of Asteraceous and Fabaceous plants in present study were examined by using stereomicroscope. Kim et al. (2016) suggested that studies of seeds using stereomicroscope give an aid to facilitate morphological identification of these seeds.

Table 16: Quantitative Seed micro-morphological attributes of Asteraceous species

Sr. No	Plant Taxa	Length (mm)	Width (mm)	L/W ratio	No of Ribs	Pappus Length	No of cypsela
1	*Ageratum conyzoides*	7.56	2.84	2.66	6-7	Absent	25
2	*Artemisia absinthimum*	2.16	0.82	2.63	12-14	3.36	17
3	*Aster squamatus*	3.98	0.92	4.32	Absent	1.76	13
4	*Biden pilosa*	3.52	1.08	3.25	13-15	24.6	14
5	*Bidens bipinnata*	3.36	0.92	3.65	7	16.96	10
6	*Calendula arvensis*	6.74	3.14	2.21	9	3.5	37
7	*Calendula officinalis*	2.04	1.04	1.96	21	4.12	33
8	*Carthamus oxyacantha*	2.82	1.16	2.43	23	17.04	36
9	*Carthamus lanatus*	3.72	0.94	3.95	8-9	5.3	16
10	*Causinia prolifera*	4.26	1.22	3.49	6-7	4	19
11	*Cirsium arvense*	3.28	1.22	2.68	9-12	6	21
12	*Eclipta prostrate*	6.04	3.04	1.98	13	11.87	23
13	*Erigeron bonariensis*	1.86	0.5	3.72	25	6.9	25
14	*Erigeron canadensis*	1.6	1.82	0.87	16	7.8	12
15	*Ixeris polycephala*	4.86	1.38	3.52	6	11.2	31
16	*Lactuca sativa*	3.48	1.28	2.71	15	12.3	121
17	*Lactuca serriola*	2.7	1.16	2.32	13	2.66	33
18	*Launea naudicaulis*	3.56	1.82	1.95	9-13	2.63	54
19	*Launea procumbens*	6.26	2.52	2.48	15-17	2.45	55
20	*Parthenium hysterophorus*	4.9	3.92	1.25	3-5	2.54	23

Table 17: Qualitative Seed micro-morphological attributes of Asteraceous species ..

Sr. No	Plant Taxa	Cypsela Color	Cypsela Shape	Pappus Color	Carpopodium Position	Surface Pubescence	Beak color	Beak Shape
1	*Ageratum conyzoides*	Light Brown	Linear	Absent	Basal	Scabrous	Absent	Absent
2	*Artemisia absinthimum*	Dark Brown	Linear fusiform	Light Brown	Lateral	Glabrous	Brown	Slender
3	*Aster squamatus*	Dark Brown	Curved-ring shaped	Dull White	Sub-Basal	Glabrous	Light Brown	Filiform
4	*Biden pilosa*	Straw White	Oblanceolate	Brown	Lateral	Scabrous	White	Filiform
5	*Bidens bipinnata*	Light to Dark Brown	Obovoid	Brown	Lateral	Scabrous	Brown	Filiform
6	*Calendula arvensis*	Greyish	Cylindrical	Brown	Basal	Scabrous	Greyish	Slender
7	*Calendula officinalis*	Brown	Pointed	White	Basal	Scabrous	Brown	Slender
8	*Carthamus oxyacantha*	Light Brown	Linear lanceolate	White	Basal	Scabrous	Brown	Slender
9	*Carthamus lanatus*	Dark Brown	Linear lanceolate	White	Lateral	Glabrous	White	Slender
10	*Causinia prolifera*	Black	Oblanceolate	Brown	Sub-Basal	Glabrous	White	Filiform
11	*Cirsium arvense*	Brown with black spots	Narrowly lanceolate	Light Brown	Lateral	Glabrous	Light Brown	Filiform
12	*Eclipta prostrate*	Yellowish Brown	Obovoid	Dull White	Basal	Scabrous	Brown	Slender
13	*Erigeron bonariensis*	Black	Oblanceolate	Brown	Lateral	Scabrous	Brown	Slender
14	*Erigeron Canadensis*	Dark Brown	Linear	Brown	Basal	Glabrous	Brown	Slender
15	*Ixeris polycephala*	Black	Linear	Brown	Lateral	Glabrous	Light Brown	Filiform
16	*Lactuca sativa*	Light Brown	Linear	Brown	Sub-Basal	Glabrous	White	Filiform
17	*Lactuca serriola*	Green to Brownish	Curved	White	Lateral	Scabrous	Brown	Filiform
18	*Launea naudicaulis*	Red	Oblanceolate	White	Basal	Scabrous	Light Brown	Slender
19	*Launea procumbens*	Black	Oblanceolate	Light Brown	Basal	Glabrous	White	Filiform
20	*Parthenium hysterophorus*	Brown	Obovate	White	Lateral	Scabrous	Brown	Slender

Table 18: SEM Ultrastructural Seed coat micro-morphological features of Cypsela

Sr. No	Plant Name	Surface Pattern	Epicuticular Projection	Carpopodium Shape	Anticlinal wall Level	Anticlinal wall pattern	Periclinal wall Level	Periclinal wall Protuberance
1	*Ageratum conyzoides*	Striated	Platelets	Incompletely Developed	Raised	Wavy	Depressed	Coarse Textured
2	*Artemisia absinthimum*	Irregularly striated	Bulges	Undeveloped Circular Ring	Raised	Puzzled	Flat	Glabrous
3	*Aster squamatus*	Irregularly Reticulate	Absent	Undeveloped angular Ring	Raised	Wavy	Depressed	Fine Textured
4	*Biden pilosa*	Irregularly Striato-Regulate	Granules	Completely Developed with Circular ring without interruptions	Depressed	Entire	Raised	Glabrous
5	*Bidens bipinnata*	Reticulate	Hair and Granules	Completely developed symmetrical ring without interruptions	Raised	Grooved	Depressed	Medium Textured
6	*Calendula arvensis*	Verrucose papilate	Dome shaped Bulges	Completely Developed asymmetrical ring without interruptions	Depressed	Wavy	Raised	Glabrous
7	*Calendula officinalis*	Striated	Granules	Completely developed square ring without interruptions	Raised	Grooved with acuminate apex	Convex	Glabrous
8	*Carthamus oxyacantha*	Regulate	Micro Hair and Bulges	Completely Developed circular ring without interruptions and 5 Lobed	Depressed	Slightly Wavy	Raised	Fine Textured
9	*Carthamus lanatus*	Reticulate	Hair	Undeveloped	Raised	Wavy	Raised	Coarse Textured with Bulges
10	*Causinia prolifera*	Verrucate-Reticulate	Granules	Incompletely Developed U-Shaped	Raised	Entire	Raised	Fine Textured

				with interruption				
11	*Cirsium arvense*	Verrucate Striate	Granules	Undeveloped circular Ring	Raised	Grooved	Depressed	Glabrous
12	*Eclipta prostrate*	Striated	Bulges	Completely Developed Circular Ring without interruption and slightly lobed	Raised	Undulate	Raised	Glabrous with Bulges
13	*Erigeron bonariensis*	Papilate	Micro Hairs	Incompletely developed asymmetrical Ring	Depressed	Wavy	Slightly Raised and Mostly Depressed	Glabrous
14	*Erigeron canadensis*	Reticulate	Granules	Undeveloped and regular	Depressed	Puzzled	Convex	Medium Textured
15	*Ixeris polycephala*	Regulate	Bulges	Developed Circular Ring	Raised	Entire	Depressed	Coarse Textured
16	*Lactuca sativa*	Scrobiculate	Absent	Undeveloped angular ring	Depressed	Slightly Wavy	Raised	Glabrous
17	*Lactuca serriola*	Striated	Micro Hairs with Bulges	Incompletely angular ring	Raised	Undulate with acute apex	Depressed	Fine Textured
18	*Launea naudicaulis*	Reticulate	Granules	Irregular ring	Raised	Undulate	Raised	Coarse Textured with Bulges
19	*Launea procumbens*	Verrucose	Absent	Completely developed with circular ring without interruptions	Raised	Wavy	Flat	Medium Textured
20	*Parthenium hysterophorus*	Striated	Bulges	Incompletely developed	Raised	Entire	Raised	Glabrous

3.3.1 Micro-morphological characters of cypsela

1. **Morphology of *Ageratum conyzoides* Cypsela**

The surface pattern of Cypsela observed was Striated, Epicuticular projections observed on Cypsela surface was Platelets. Carpopodium Shape was Incompletely Developed .Anticlinal walls level on Cypsela surface were Raised and Anticlinal walls Pattern were Wavy while Periclinal wall level were Depressed and Periclinal Protuberance were Coarse Textured. Cypsela color Light Brown, Cypsela Shape is Linear. Carpopodium position were Basal. Surface Pubescence is Scabrous. Pappus absent. The average length is 7.56mm and the average width is 2.84mm. L/W ratio is 2.66 mm. Number of ribs 6-7. Beak absent. Average number of Cypsela per capitulum 25 (Plate 124).

2. **Morphology of *Artemisia absinthimum* Cypsela**

The surface pattern of Cypsela observed was irregularly striated, Epicuticular projections observed on Cypsela surface was Bulges. Carpopodium Shape was Undeveloped Circular Ring.Anticlinal walls level on Cypsela surface were Raised and Anticlinal walls pattern were Puzzled while Periclinal wall level were flat and Periclinal Protuberance were Glabrous. Cypsela color Dark Brown, Cypsela Shape is Linear fusiform. Carpopodium position were Lateral. Surface Pubescence is Glabrous. Pappus Color Light Brown and length 3.36mm. The average length is 2.16mm and the average width is 0.82mm. L/W ratio is 2.63 mm. Number of ribs 12-14. Beak color is Brown and shape is slender. Average number of Cypsela per capitulum 17 (Plate 124).

3. **Morphology of *Aster squamatus* Cypsela**

The surface pattern of Cypsela observed was Irregularly reticulate, Epicuticular projections observed on Cypsela surface was Absent. Carpopodium Shape was underdeveloped angular ring.Anticlinal walls on Cypsela surface were Raised and Anticlinal walls pattern were Wavy while Periclinal wall level were depressed and Periclinal Protuberance were fine textured. Cypsela color Dark Brown, Cypsela Shape is Curved-ring shaped. Carpopodium position were Sub-Basal. Surface Pubescence is Glabrous. Pappus color dull white and length is 1.76mm. The average length is 3.98mm and the average width is 0.92mm. L/W ratio is 4.32 mm. Number of ribs absent. Beak color is Light Brown and shape is Filiform.. Average number of Cypsela per capitulum 13 (Plate 125)

4. **Morphology of *Biden pilosa* Cypsela**

The surface pattern of Cypsela observed was Irregularly Striato-Regulate, Epicuticular projections observed on Cypsela surface was Granules. Carpopodium Shape was Completely Developed with Circular ring without interruptions.Anticlinal walls level on Cypsela surface were Depressed and Anticlinal walls Pattern were Entire while Periclinal wall level were Raised and Periclinal wall Protuberance were Glabrous. Cypsela color Straw White, Cypsela Shape is Oblanceolate. Carpopodium position were Lateral. Surface Pubescence is Scabrous. Pappus color is Brown and length 24.6mm. The average length is 3.52mm and the average width is 1.08mm. L/W ratio is 3.25mm. Number of ribs 13-15. Beak absent. Average number of Cypsela per capitulum 14 (Plate 125).

5. **Morphology of *Bidens bipinnata* Cypsela**

The surface pattern of Cypsela observed was Reticulate, Epicuticular projections observed on Cypsela surface was Hair and Granules. Carpopodium Shape was completely developed symmetrical ring without interruptions.Anticlinal walls level on Cypsela surface were Raised and Anticlinal walls pattern were grooved while Periclinal wall level were depressed and Periclinal Protuberance were Medium textured. Cypsela color Light to Dark Brown, Cypsela Shape is obovoid. Carpopodium position were lateral. Surface Pubescence is Scabrous. Pappus color Browna and length 16.96. The average length is 3.36mm and the average width is 0.92mm. L/W ratio is 3.65 mm. Number of ribs 7. Beak color Brown and shape filiform. Average number of Cypsela per capitulum 10 (Plate 126).

6. **Morphology of *Calendula arvensis* Cypsela**

The surface pattern of Cypsela observed was Verrucose papilate, Epicuticular projections observed on Cypsela surface was Dome shaped bulges. Carpopodium Shape was completely developed asymmetrical ring without interruptions.Anticlinal walls level on Cypsela surface were Depressed and Anticlinal walls pattern were Wavy while Periclinal wall level were Raised and Periclinal Protuberance were Glabrous. Cypsela color Greyish, Cypsela Shape is cylindrical. Carpopodium position were Basal. Surface Pubescence is Scabrous. Pappus color Brown and length 3.5mm. The average length is 6.74mm and the average width is 3.14mm. L/W ratio is 2.21 mm. Number of ribs 9. Beak color Greyish and shape is slender. Average number of Cypsela per capitulum 37 (Plate 126).

7. Morphology of *Calendula officinalis* Cypsela

The surface pattern of Cypsela observed was Striated, Epicuticular projections observed on Cypsela surface was Granules. Carpopodium Shape was completely developed square ring without interruptions.Anticlinal walls level on Cypsela surface were Raised and Anticlinal walls pattern were grooved with acuminate apex while Periclinal wall level were convex and Periclinal Protuberance were glabrous. Cypsela color Brown, Cypsela Shape is Pointed. Carpopodium position were Basal. Surface Pubescence is Scabrous. Pappus color is white and length 4.12 absent. The average length is 2.04mm and the average width is 1.04mm. L/W ratio is 1.96 mm. Number of ribs 21. Beak color Brown and shape were slender. Average number of Cypsela per capitulum 33 (Plate 127).

8. Morphology of *Carthamus oxyacantha* Cypsela

The surface pattern of Cypsela observed was Regulate, Epicuticular projections observed on Cypsela surface was Micro Hair and Bulges. Carpopodium Shape was completely developed circular ring without interruptions and 5 lobed.Anticlinal walls level on Cypsela surface were Depressed and Anticlinal walls pattern were slightly Wavy while Periclinal wall level were Raised and Periclinal Protuberance were fine textured. Cypsela color Light Brown, Cypsela Shape is Linear lanceolate. Carpopodium position were Basal. Surface Pubescence is Scabrous. Pappus color white . The average length is 2.82mm and the average width is 1.16mm. L/W ratio is 2.43 mm. Number of ribs 23. Beak color Brown and shape slender. Average number of Cypsela per capitulum 36 (Plate 127).

9. Morphology of *Carthamus lanatus* Cypsela

The surface pattern of Cypsela observed was Reticulate, Epicuticular projections observed on Cypsela surface was Hair. Carpopodium Shape was UnDeveloped .Anticlinal walls level on Cypsela surface were Raised and Anticlinal walls pattern were Wavy while Periclinal wall level were raised and Periclinal Protuberance were coarse textured with bulges. Cypsela color Dark Brown, Cypsela Shape is Linear Lanceolate. Carpopodium position were Lateral. Surface Pubescence is Glabrous. Pappus color white and length 5.3 absent. The average length is 3.72mm and the average width is 0.94mm. L/W ratio is 3.95 mm. Number of ribs 8-9. Beak color white and shape slender. Average number of Cypsela per capitulum 16 (Plate 128).

10. Morphology of *Causinia prolifera* Cypsela

The surface pattern of Cypsela observed was Striated, Epicuticular projections observed on Cypsela surface was Platelets. Carpopodium Shape was Incompletely Developed .Anticlinal walls on Cypsela surface were Raised and Anticlinal walls were Wavy while Periclinal wall level were depressed and Periclinal Protuberance were coarse textured. Cypsela color Black, Cypsela Shape is Oblanceolate. Carpopodium position were sub-Basal. Surface Pubescence is Glabrous. Pappus color Brown and length is 4mm. The average length is 4.26mm and the average width is 1.22mm. L/W ratio is 3.49 mm. Number of ribs 6-7. Beak color white and shape Filiform. Average number of Cypsela per capitulum 19 (Plate 128).

11. Morphology of *Cirsium arvense* Cypsela

The surface pattern of Cypsela observed was Verrucate Striate, Epicuticular projections observed on Cypsela surface was Granules. Carpopodium Shape was UnDeveloped Circular Ring .Anticlinal walls level on Cypsela surface were Raised and Anticlinal walls Pattern were Grooved while Periclinal wall level were depressed and Periclinal Protuberance were coarse Glabrous. Cypsela color Brown with black spots, Cypsela Shape is narrowly lanceolate. Carpopodium position were Lateral. Surface Pubescence is Glabrous. Pappus color Light brown and length 6mm. The average length is 3.28mm and the average width is 1.22mm. L/W ratio is 2.68 mm. Number of ribs 9-12. Beak light brown and shape Filiform. Average number of Cypsela per capitulum 21 (Plate 129).

12. Morphology of *Eclipta prostrate* Cypsela

The surface pattern of Cypsela observed was Striated, Epicuticular projections observed on Cypsela surface was Bulges. Carpopodium Shape was completely developed circular ring without interruption and slightly lobed. Anticlinal walls level on Cypsela surface were Raised and Anticlinal walls pattern were undulate while

Periclinal wall level were Raised and Periclinal Protuberance were Glabrous with Bulges. Cypsela color Yellowish Brown, Cypsela Shape is Obovoid. Carpopodium position were Basal. Surface Pubescence is Scabrous. Pappus color Dull White and length 11.87mm . The average length is 6.04mm and the average width is 3.04mm. L/W ratio is 1.98 mm. Number of ribs 13. Beak Color Brown and shape slender. Average number of Cypsela per capitulum 23 (Plate 129).

13. Morphology of *Erigeron bonariensis* Cypsela

The surface pattern of Cypsela observed was Papilate, Epicuticular projections observed on Cypsela surface was Micro Hairs. Carpopodium Shape was Incompletely Developed asymmetrical ring .Anticlinal walls level on Cypsela surface were Depressed and Anticlinal walls Pattern were Wavy while Periclinal wall level were Slightly raised and mostly depressed and Periclinal Protuberance were Glabrous. Cypsela color Black, Cypsela Shape is Oblanceolate. Carpopodium position were Lateral. Surface Pubescence is Scabrous. Pappus color Brown and length 6.9mm. The average length is 1.86mm and the average width is 0.5mm. L/W ratio is 3.72 mm. Number of ribs 25. Beak color Brown and shape slender. Average number of Cypsela per capitulum 25 (Plate 130).

14. Morphology of *Erigeron canadensis* Cypsela

The surface pattern of Cypsela observed was Reticulate, Epicuticular projections observed on Cypsela surface was Granules. Carpopodium Shape was Undeveloped and regular.Anticlinal walls level on Cypsela surface were Depressed and Anticlinal walls Pattern were Puzzled while Periclinal wall level were convex and Periclinal Protuberance were medium textured. Cypsela color Light Brown, Cypsela Shape is Linear. Carpopodium position were Basal. Surface Pubescence is Scabrous. Pappus Length 7.8mm absent. The average length is 1.6mm and the average width is 1.82mm. L/W ratio is 0.87 mm. Number of ribs 16. Beak absent. Average number of Cypsela per capitulum 12 (Plate 130).

15. Morphology of *Ixeris polycephala* Cypsela

The surface pattern of Cypsela observed was Regulate, Epicuticular projections observed on Cypsela surface was Bulges. Carpopodium Shape was Developed circular ring.Anticlinal walls level on Cypsela surface were Raised and Anticlinal walls Entire while Periclinal wall level were depressed and Periclinal Protuberance were coarse textured. Cypsela color Black, Cypsela Shape is Linear. Carpopodium position were Lateral Surface Pubescence is Glabrous. Pappus color brown and length 11.2mm. The average length is 4.86mm and the average width is 1.38mm. L/W ratio is 3.52mm. Number of ribs 6. Beak color Light Brown and shape filiform. Average number of Cypsela per capitulum 31 (Plate 131).

16. Morphology of *Lactuca sativa* Cypsela

The surface pattern of Cypsela observed was Striated, Epicuticular projections observed on Cypsela surface was Platelets. Carpopodium Shape was Incompletely Developed .Anticlinal walls on Cypsela surface were Raised and Anticlinal walls were Wavy while Periclinal wall level were depressed and Periclinal Protuberance were coarse textured. Cypsela color Light Brown, Cypsela Shape is Linear. Carpopodium position were Basal. Surface Pubescence is Scabrous. Pappus absent. The average length is 7.56mm and the average width is 2.84mm. L/W ratio is 2.66 mm. Number of ribs 12. Beak color White and Shape filiform. Average number of Cypsela per capitulum 25 (Plate 131).

17. Morphology of *Lactuca serriola* Cypsela

The surface pattern of Cypsela observed was Striated, Epicuticular projections observed on Cypsela surface was Micro Hairs with Bulges. Carpopodium Shape was Incompletely angular ring.Anticlinal walls level on Cypsela surface were Raised and Anticlinal walls pattern were undulate with acute apex while Periclinal wall level were depressed and Periclinal Protuberance were fine textured. Cypsela color Green to Brownish, Cypsela Shape is Curved. Carpopodium position were Lateral. Surface Pubescence is Scabrous. Pappus color is white and length 2.66mm absent. The average length is 2.7mm and the average width is 1.16mm. L/W ratio is 2.32 mm. Number of ribs 13. Beak color Brown and shape Filiform. . Average number of Cypsela per capitulum 33 (Plate 132).

18. Morphology of *Launea naudicaulis* Cypsela

The surface pattern of Cypsela observed was Reticulate, Epicuticular projections observed on Cypsela surface was Granules. Carpopodium Shape was Irregular ring.Anticlinal walls level on Cypsela surface were Raised and Anticlinal walls pattern were Undulate while Periclinal wall level were Raised and Periclinal Protuberance were coarse textured with bulges. Cypsela color Light Brown, Cypsela Shape is Oblanceolate . Carpopodium position were Basal. Surface Pubescence is Scabrous. Pappus color white and length 2.63 . The average length is 3.56mm and the average width is 1.82mm. L/W ratio is 1.95mm. Number of ribs 9-13. Beak color Light Brown and Shape Slender. Average number of Cypsela per capitulum 54 (Plate 132).

19. Morphology of *Launea procumbens* Cypsela

The surface pattern of Cypsela observed was Verrucose, Epicuticular projections observed on Cypsela surface was Absent. Carpopodium Shape was completely Developed with circular ring without interruptions .Anticlinal walls level on Cypsela surface were Raised and Anticlinal walls pattern were Wavy while Periclinal wall level were flat and Periclinal Protuberance were Medium textured. Cypsela color Black, Cypsela Shape is Oblanceolate. Carpopodium position were Basal. Surface Pubescence is Glabrous. Pappus color Light Brown and length 2.5. The average length is 6.26mm and the average width is 2.52mm. L/W ratio is 2.48 mm. Number of ribs 15-17. Beak color White and shape Filiform. Average number of Cypsela per capitulum 55 (Plate 133)

20. Morphology of *Parthenium hysterophorus* Cypsela

The surface pattern of Cypsela observed was Striated, Epicuticular projections observed on Cypsela surface was Bulges. Carpopodium Shape was Incompletely Developed .Anticlinal walls level on Cypsela surface were Raised and Anticlinal walls pattern were Entire while Periclinal wall level were Raised and Periclinal Protuberance were Glabrous. Cypsela color Brown, Cypsela Shape is Obovate. Carpopodium position were Lateral . Surface Pubescence is Scabrous. Pappus color White and length 2.56. The average length is 4.9mm and the average width is 3.92mm. L/W ratio is 1.25 mm. Number of ribs 3-5. Beak color Brown and shape Slender. Average number of Cypsela per capitulum 23 (Plate 133).

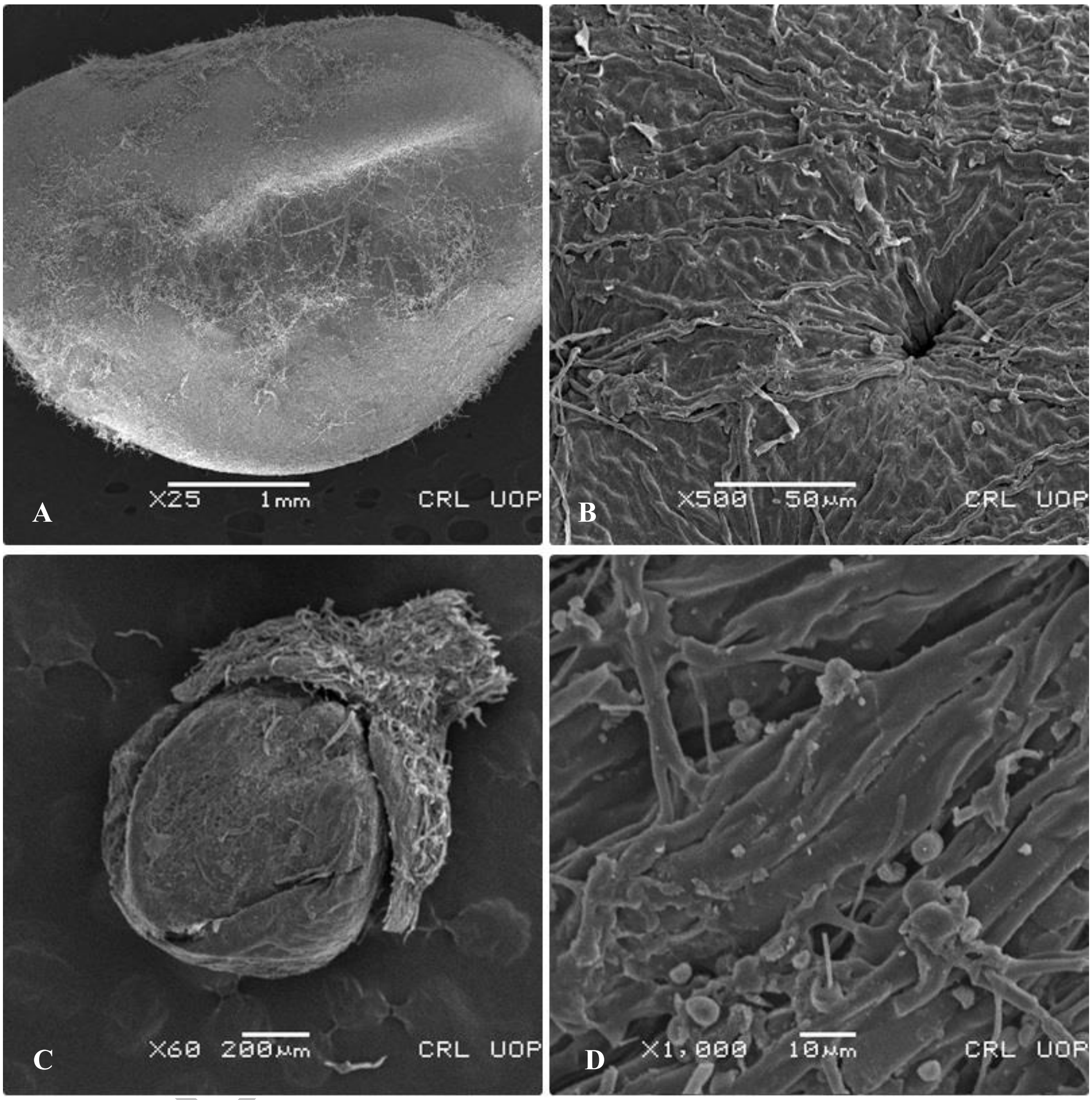

Plate 124: Cypsela micrographs of *Ageratum conyzoides* (A) General View (B) Surface Sculpturing , *Artemesia absanthimum* (C) General View (D) Surface Sculpturing

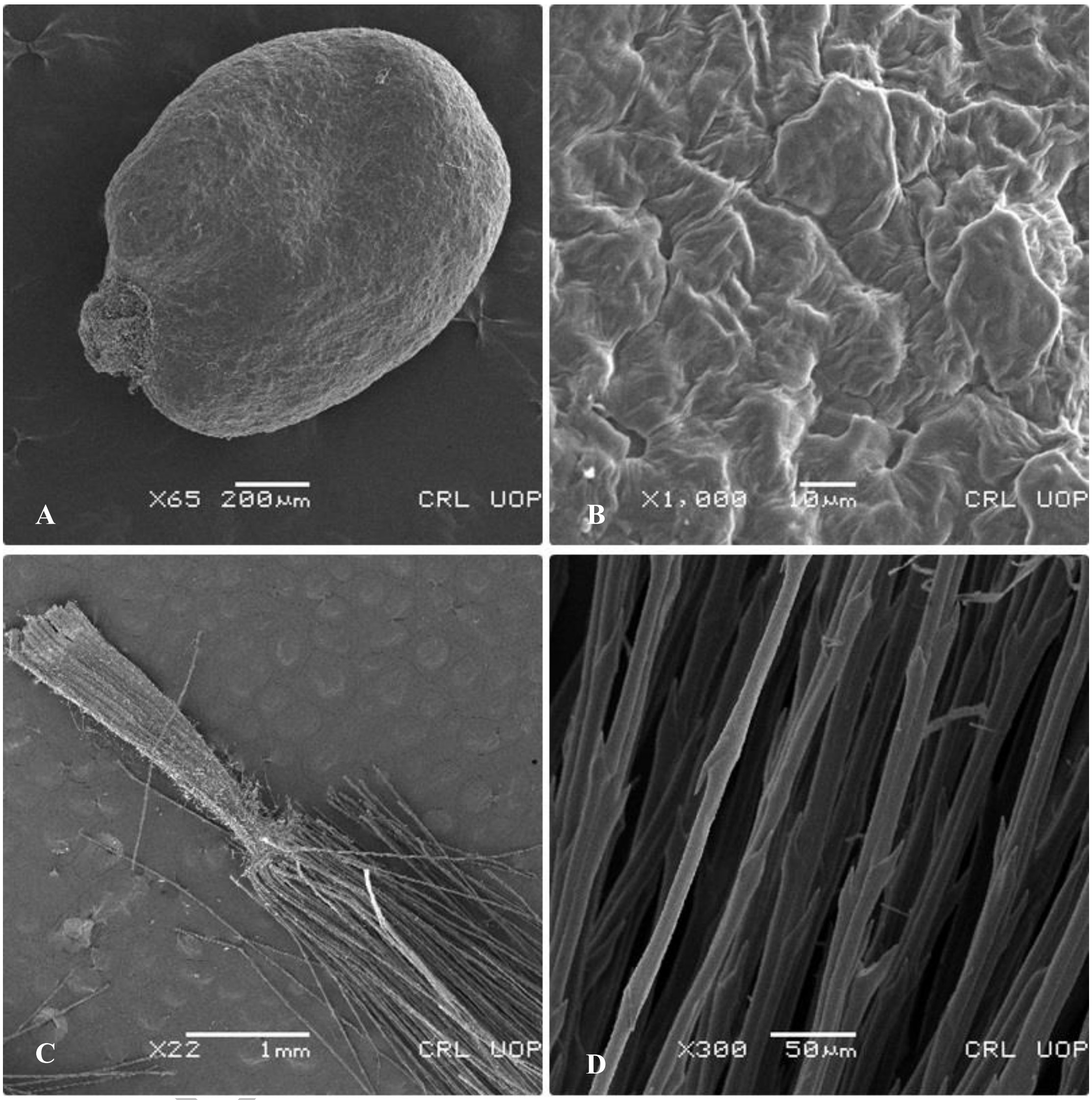

Plate 125: Cypsela micrographs of *Aster squamatus* (A)General View (B) Surface Sculpturing , *Biden pilosa* (C)General View (D) Surface Sculpturing

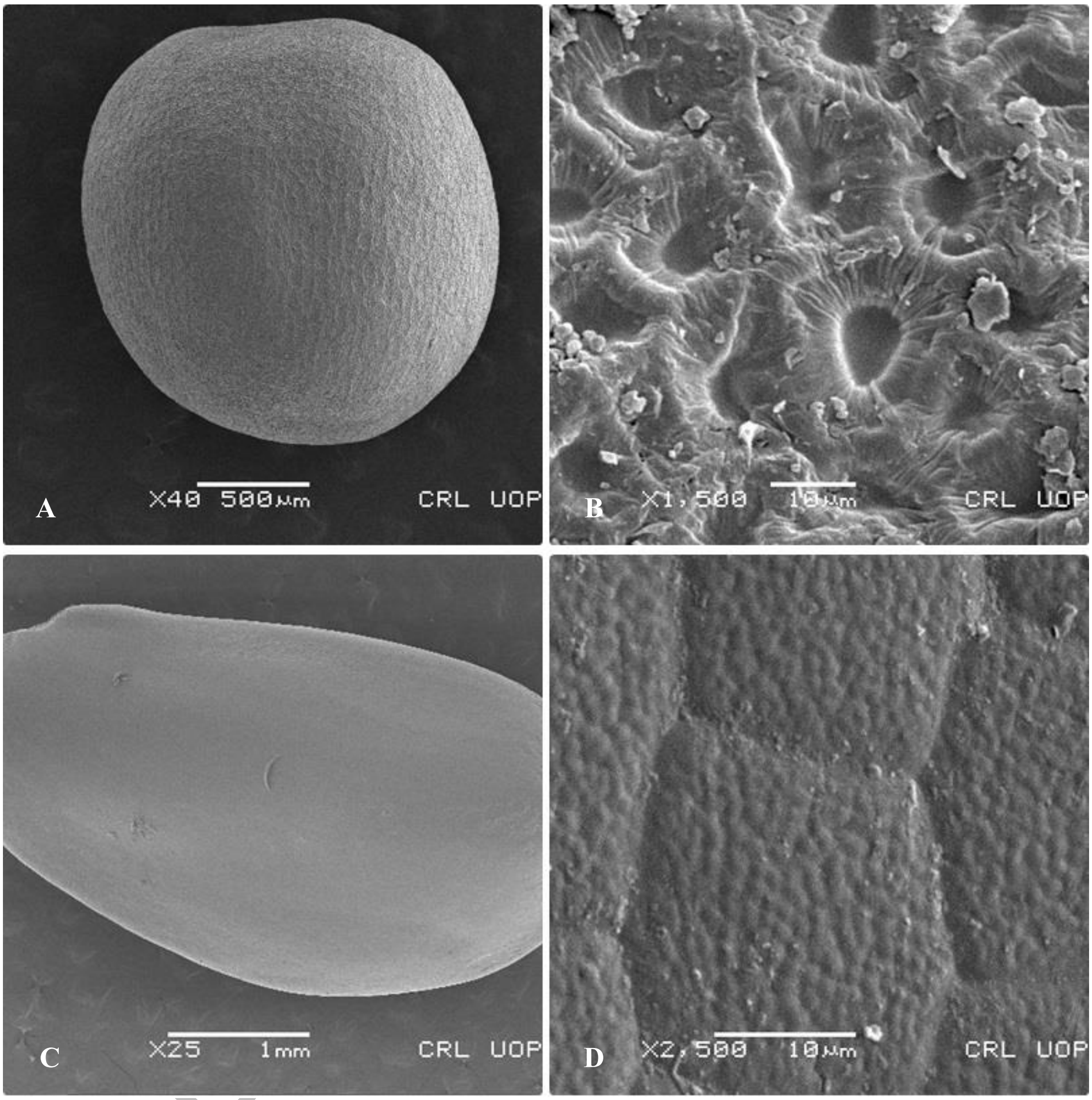

Plate 126: Cypsela micrographs of *Bidens bipinnata*, (A)General View (B) Surface Sculpturing , *Calendula arvensis*(C)General View (D) Surface Sculpturing

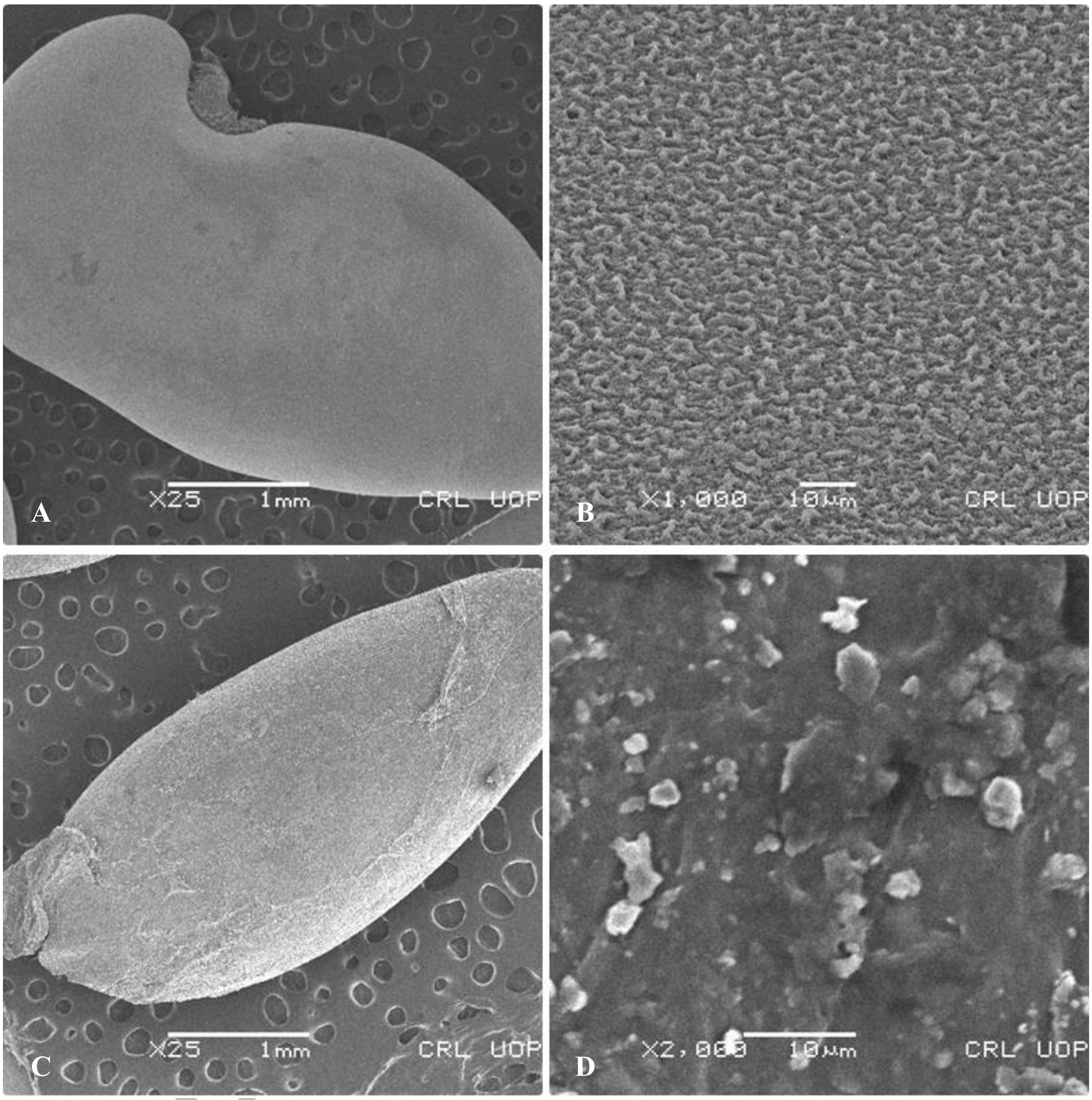

Plate 127: Cypsela micrographs *Calendula officinalis* (A)General View (B) Surface Sculpturing , *Carthamus oxyacantha* (C)General View (D) Surface

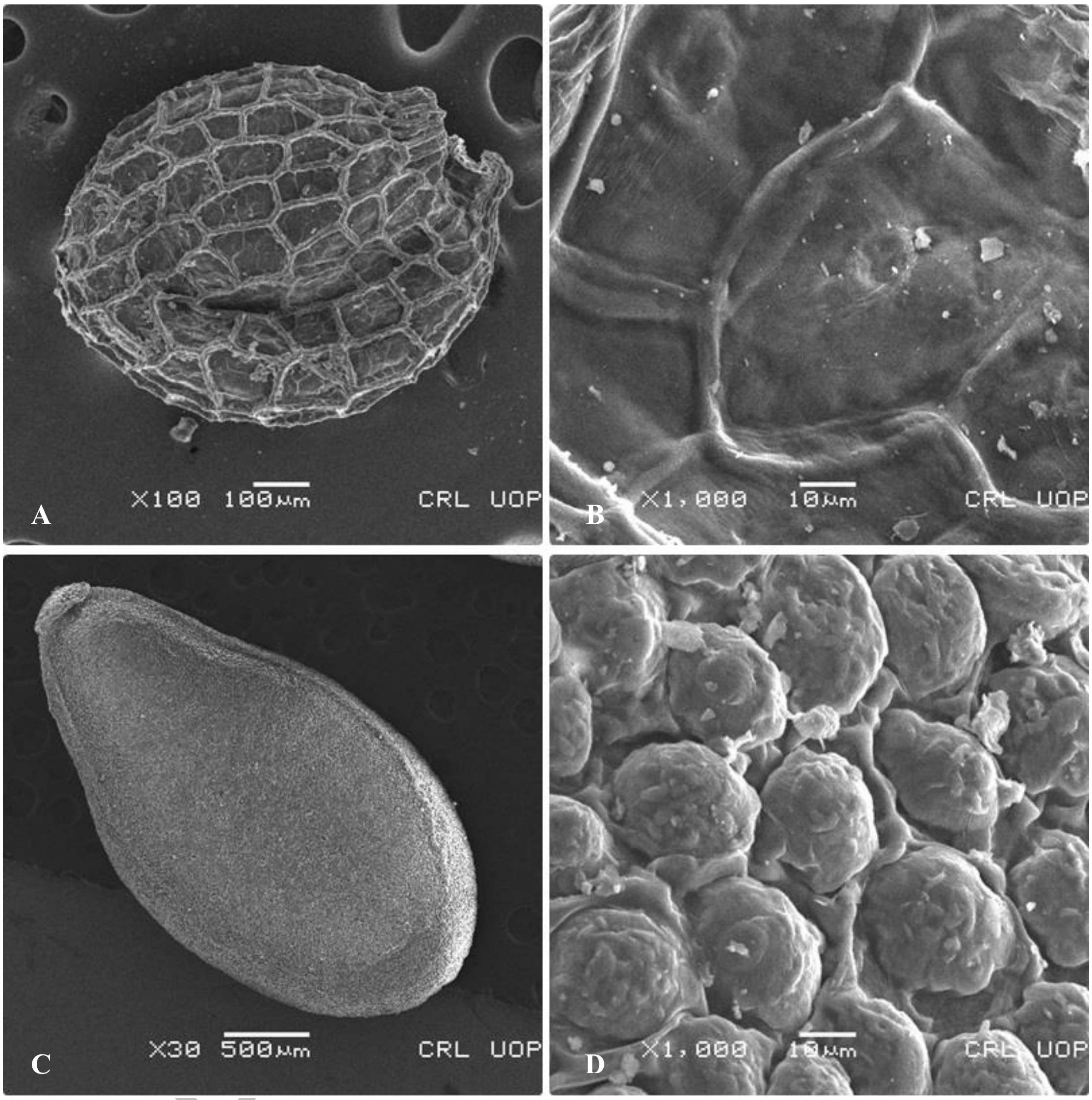

Plate 128: Cypsela micrographs of *Carthamus lanatus*(A)General View (B) Surface Sculpturing , *Causinia prolifera* (C)General View (D) Surface Sculpturing

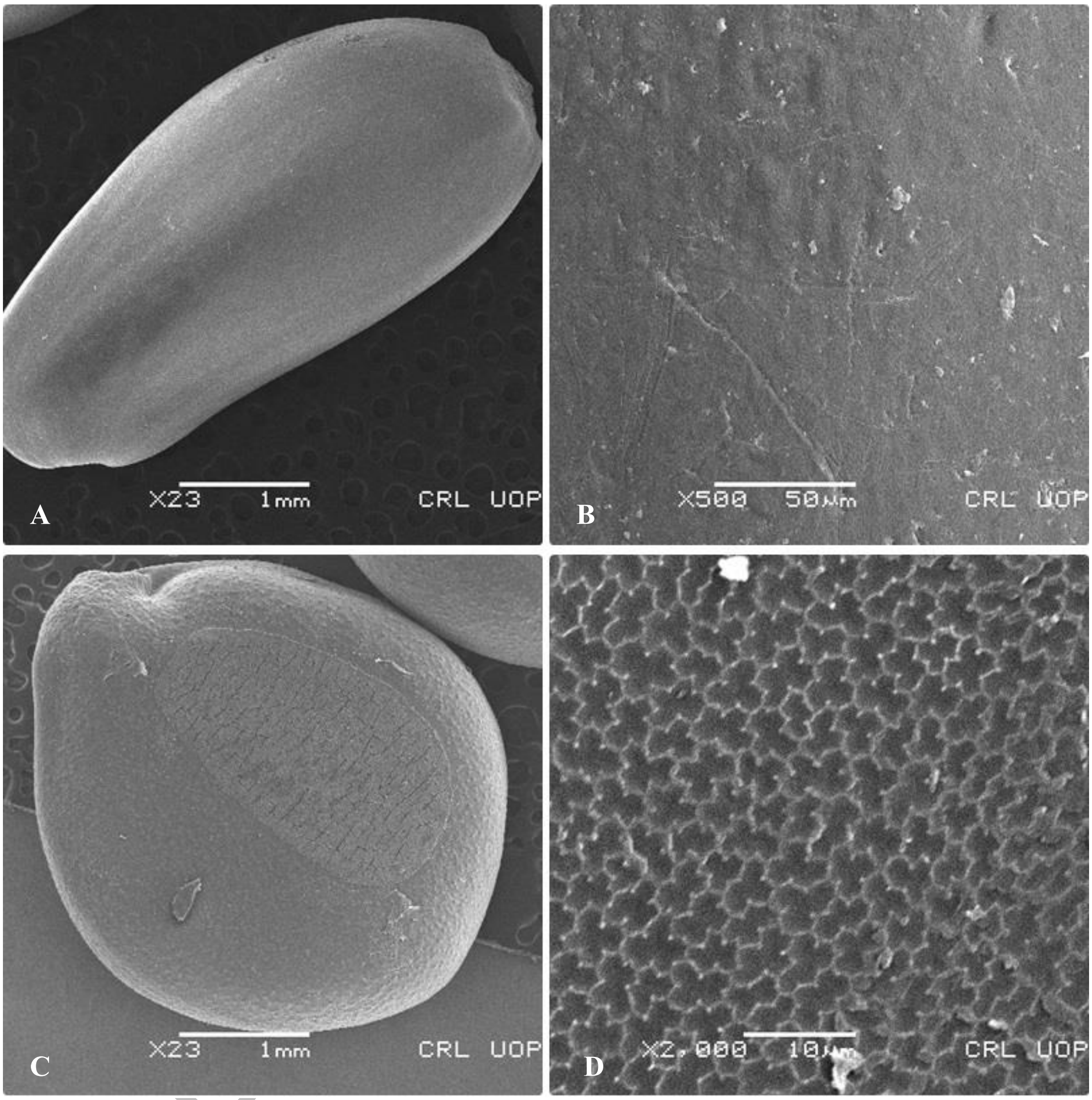

Plate 129: Cypsela micrographs of *Cirsium arvense* (A)General View (B) Surface Sculpturing , *Eclipta prostrate* (C)General View (D) Surface Sculpturing

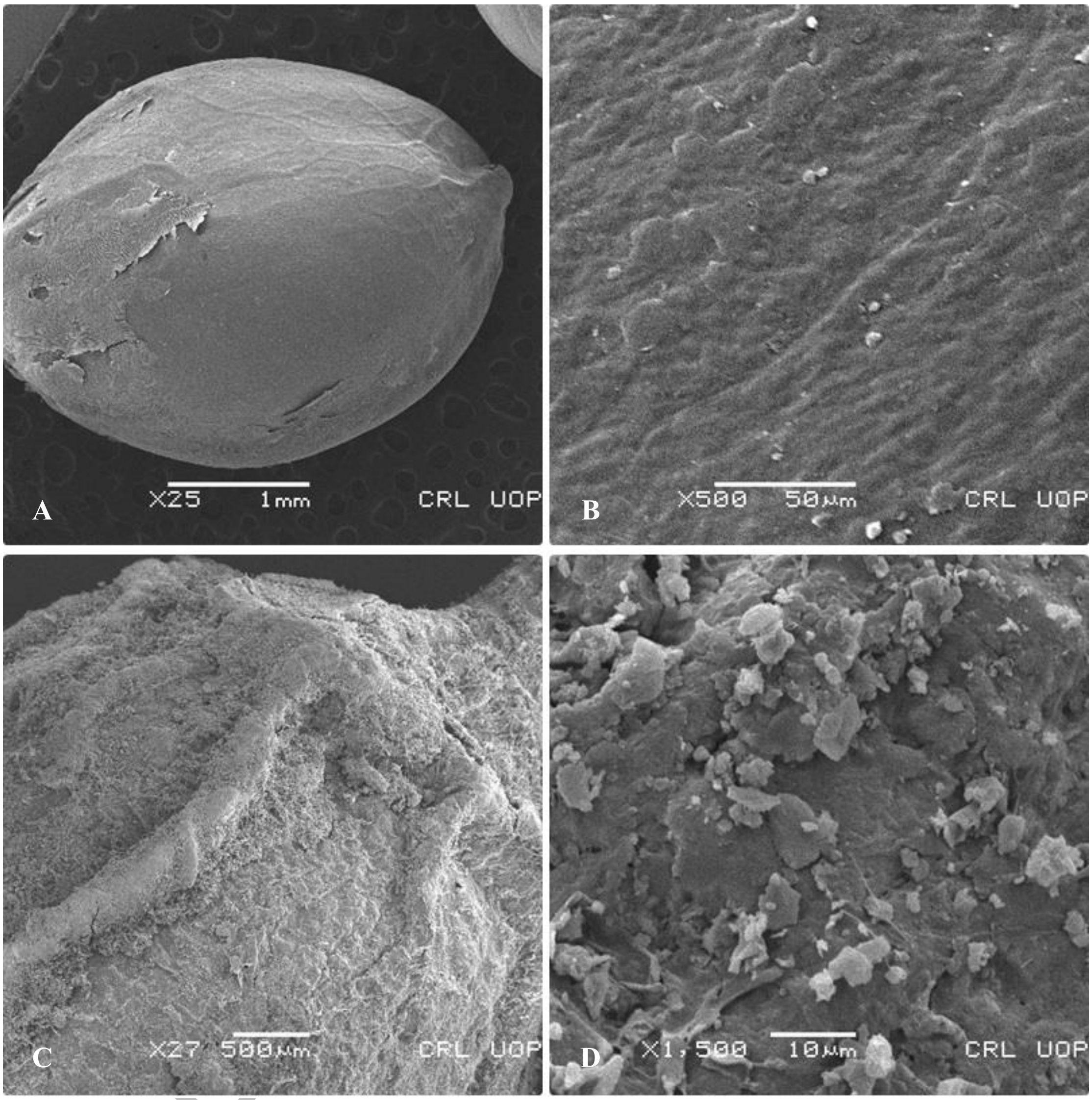

Plate 130: Cypsela micrographs of *Erigeron bonariensis* (A) General View (B) Surface Sculpturing , *Erigeron Canadensis* (C) General View (D) Surface Sculpturing

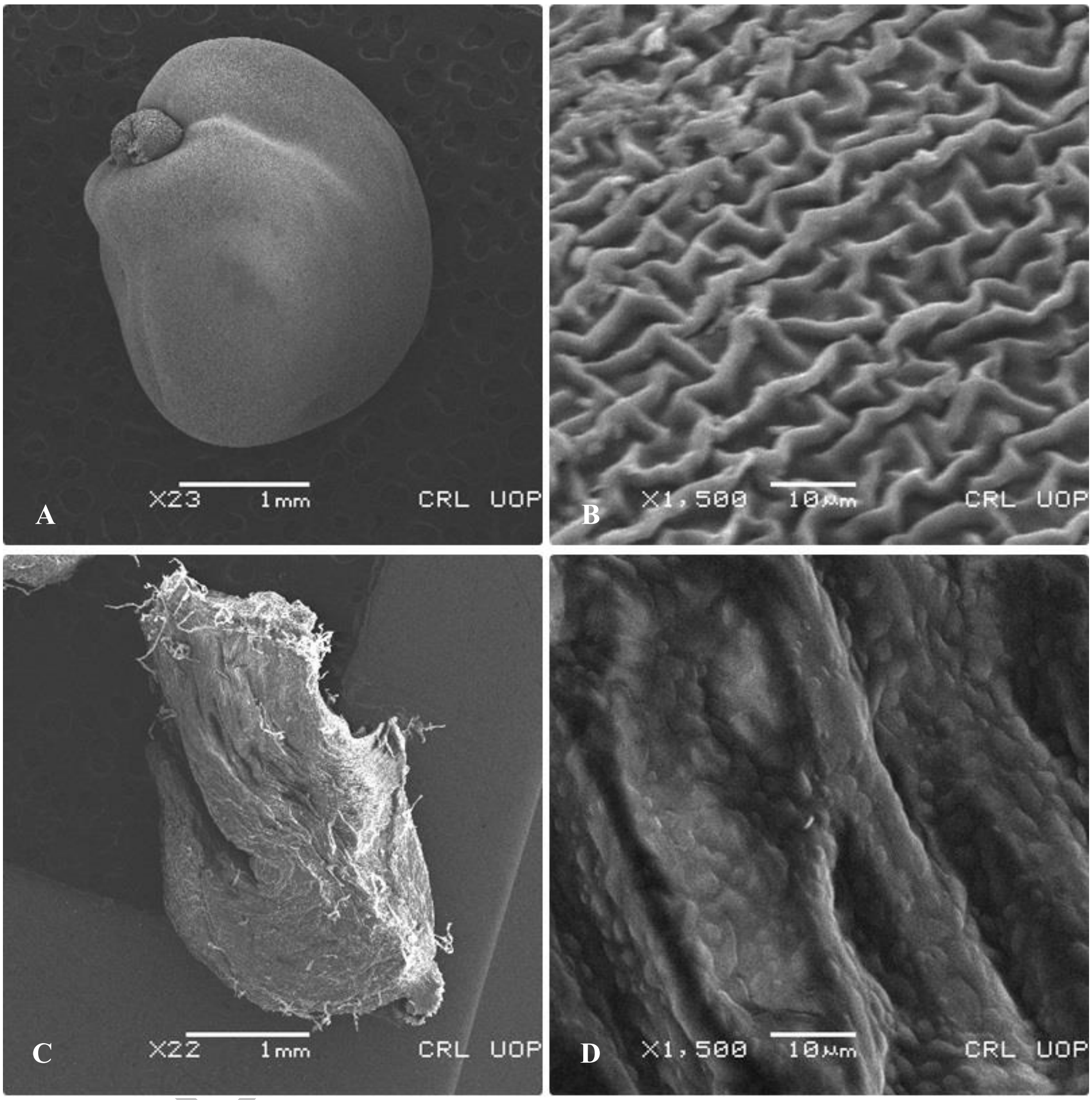

Plate 131: Cypsela micrographs of *Ixeris polycephala* (A) General View (B) Surface Sculpturing , *Lactuca sativa* (C) General View (D) Surface Sculpturing

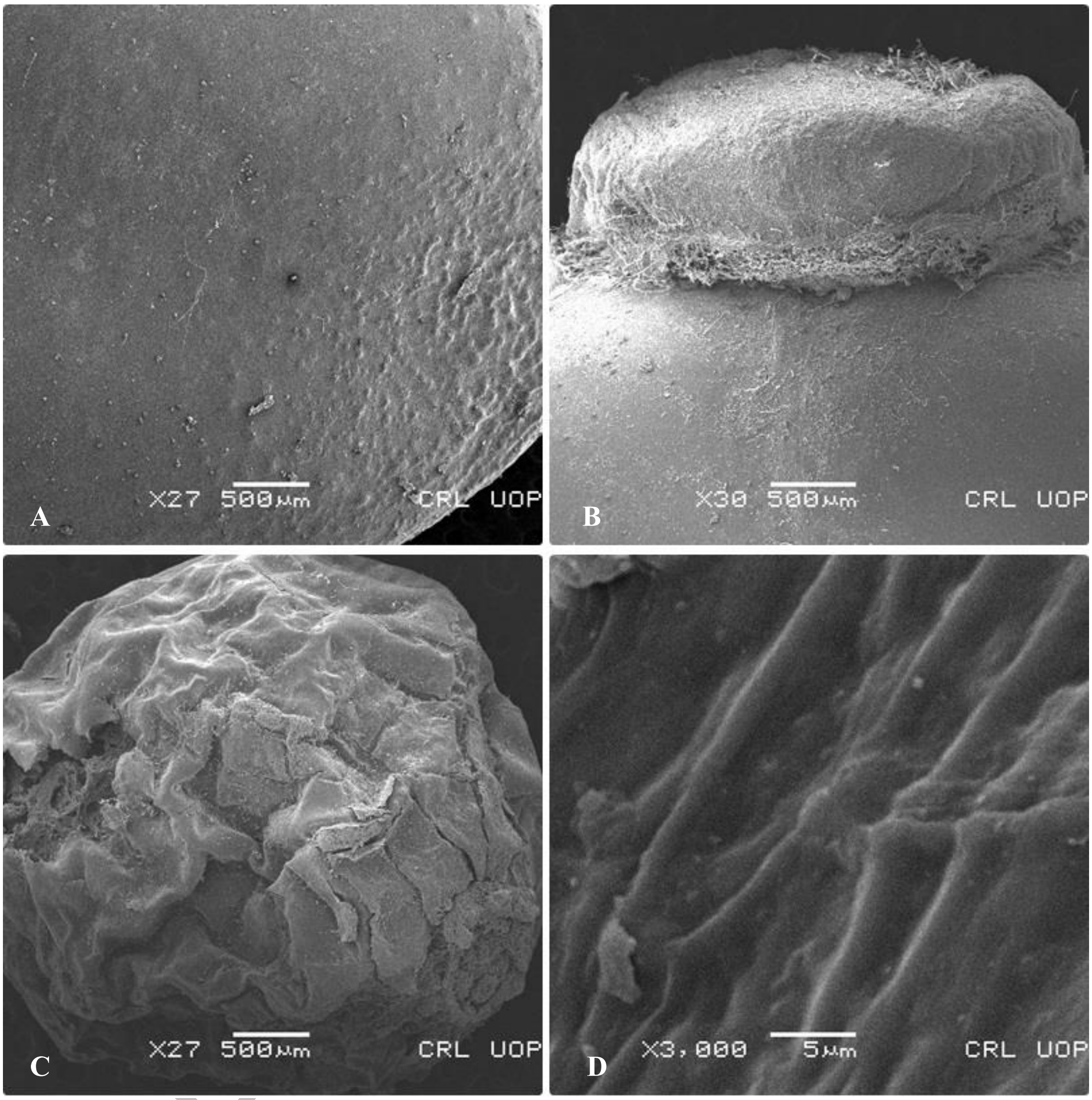

Plate 132: Cypsela micrographs of *Lactuca serriola*(A) General View (B) Surface Sculpturing , *Launea naudicaulis* (C) General View (D) Surface Sculpturing

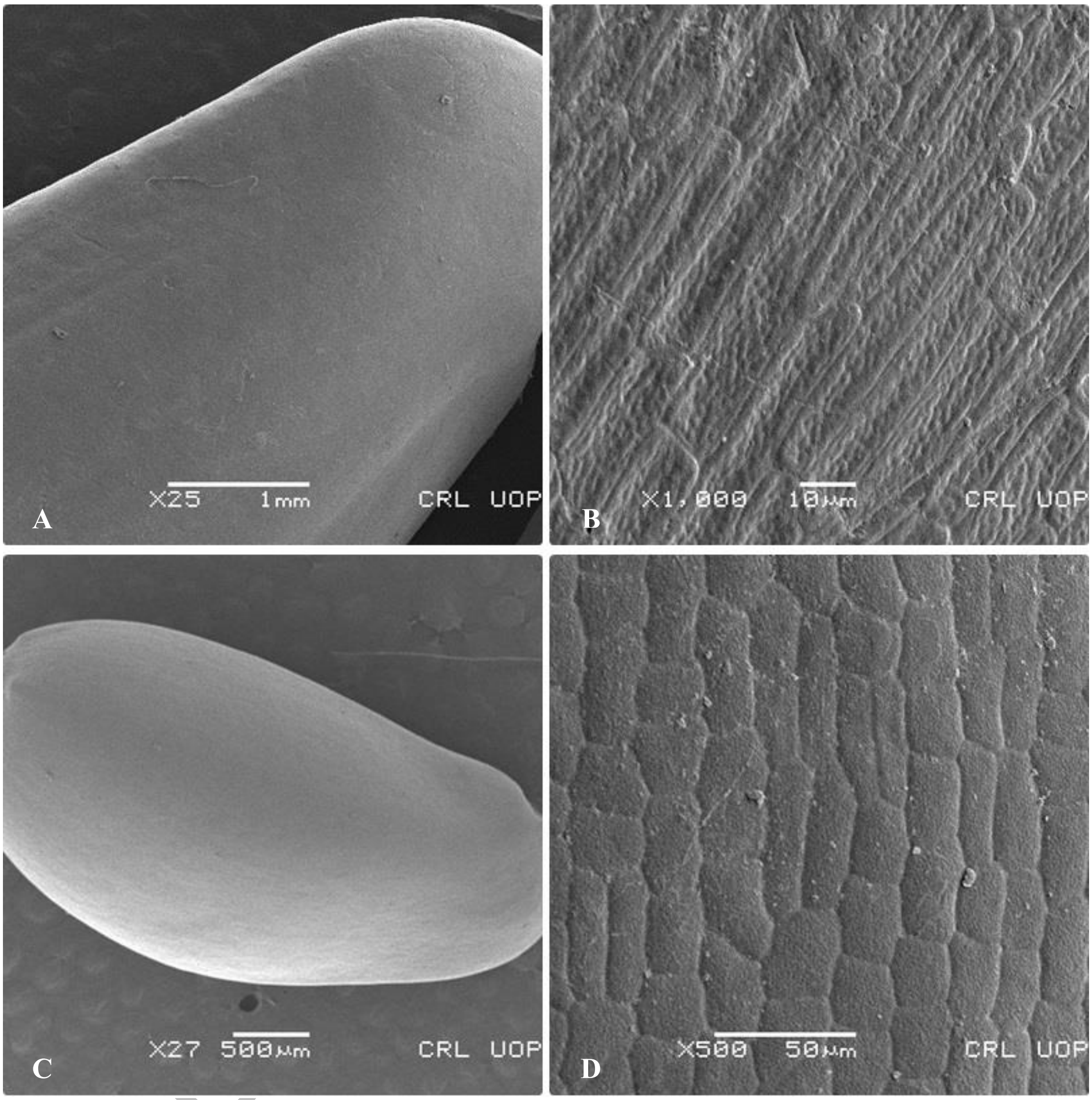

Plate 133: Cypsela micrographs *Launea procumbens* (A) General View (B) Surface Sculpturing , *Parthenium hysterophorus* (C) General View (D) Surface Sculpturing

Taxonomic key based on Seed characters of Asteraceae

1a. Pappus absent……………………………….…*Ageratum conyzoides*

1b. Pollen present…………………………………….…2

2a. Slender beak shape……………………..……………… 3

2b. Filiform beak shape ………………………………….. 11

3a. basal carpopodium …………………..……… *launea procumbens*

3b. sub-basal or lateral carpopodium ……………………………4

4a. Ribs absent ……………………………….…… *Aster squamatus*

4b. Ribs present …………………………………………….5

5a. Seed length is below 3 mm ……………………………*Lactuca serriola*

5b. Seed length is above 3 mm ……………………….……….……….. 6

6a. Seed width is below 1 mm ………………………………… *Bidens bipinnata*

6b. Seed width is above 1 mm……………………………………………..7

7a. Surface pubescence is scabrous ………………….……….……. *Biden pilosa*

7b. Surface pubescence is glabrous ………….…………………..…… 8

8a. Epicuticular projections absent …………………………………*Lactuca sativa*

8b. Epicuticular projections present…………………….……….…….. 9

9a. Surface pattern is rugulate ……………………………….… *Ixeris polycephala*

9b. Surface ornamentation is other than rugulate………………………… 10

10a. Cypsela color is black ………………….………………….. *Causinia prolifera*

10b. Cypsela color is brown……………..……………………. *Cirsium arvense*

11a. Pappus length is above 15 mm …………………… *Carthamus oxyacantha*

11b. Pappus length is below 15 mm………………………………12

12a. L/W ratio is below 1 mm ………………………….… *Erigeron Canadensis*

12b.L/W ratio is above 1 mm……………………………………………. 13

13a. Cypsela color is red …………………………………… *Launea naudicaulis*

13b. Cypsela color is grey, brown or white……………………….. 14

14a.Number of ribs are 5 or less than 5 ……………… *Parthenium hysterophorus*

14b. Number of ribs are more than 5 ………………………………… 15

15a. Anticlinal wall patterns are grooved …………………… *Calendula officinalis*

15b. Anticlinal walls are wavy or puzzled……………………………. 16

16a. Periclinal walls are convex ……. …………………………*Erigeron canadensis*

16b. Periclinal walls are raised or flat ………………………………. 17

17a. Periclinal wall has coarse texture ………………………… *Carthamus lanatus*

17b. Periclinal walls are glabrous ………………………………….. 18

18a. Seed length below 2mm ………………………………… *Erigeron bonariensis*

18b. Seed length above 2 mm ……………….. ………………………………19

19a. Pappus length is above 10 mm ……………………………..*Eclipta prostrate*

19b. Pappus length is below 10 mm ………………………………………. 20

20a. Seed surface glabrous ……………. …………………………*Artemesia annua*

20b. Seed surface scabrous …………………………………… *Calendula arvensis*

3.2.1 Asteraceous Seeds

In this recent Research, macro-morphological and micro-morphological characters of cysela were observed systematically through light microscopy as well as scanning electron microscopy. Cypsela appeared to be variable in terms of exomorphology, as infra generic and infra-specific diversity has been observed for the studied characters of every taxon. Morphological characters of the cypsela such as epicuticular projections and their types, shape of cypsela, surface patterns, anticlinal wall and periclinal wall level were found to be extremely inconsistent within family Asteraceae.

Variations in Cysela Quantitative Features

Size and shape of cypsela along with micro-morphological characters are significant indicative feature in species classification . The features can be utilized at diverse taxonomic positions to demonstrate resemblance among species (Maciejewska-rutkowska and Bednorz,2004) Quantitative characters such as seed length, seed width, pappus length, number of ribs, number of cypsela/ capitulum has been investigated. The results of this research clearly indicated the disparities in cypsela size among the examined species.

The mean length of the studied mature cypselae can be helpful to differentiate cypselae of *Ageratum conyzoides* and *Erigeron canadensis*. Cypsela length ranges from 1.6-7.56 mm. Among the examined species, Ageratum conyzoides is noted with maximum length that is 7.56mm minimum length was observed in *Erigeron Canadensis* that is 1.6mm. Biden pilosa 3.52, *Bidens bipinnata* 3.56,*Calendula arvensis* 6.74.

Width of cypsela was noted in the range of 0.5-3.92. *Parthenium hysterophorus* Has maximum width of cypsela 3.92 whereas *Erigeron bonariensis* has minimum width of 0.5mm . Range Of Length width ratio in studied species was recorded from 0.87 to 4.32. *Aster squamatus* has maximum value that is 4.32 while minimum value was observed for Erigeron Canadensis that is 0.87. *Causinia prolifera* 3.49, *Cirsium arvense* 2.68, *Eclipta prostrate* 1.98 Length and width was recorded in different species.

In the studied species pappus length was recorded from 1 to 24.6mm. Among the examined species *Circium arvense* has maximum value that is 24.6mm followed by *cirsium arvense* 24.6mm, *Cirsium sorocephalum* 17.04mm, and *Himalaiella hetromella* 16.96 mm, wheras *Ageratum conyzoides* has minimum value that is 1mm followed by *centaurea iberica* 1.76mm, and youngia japonica 3mm.

The studied cypselae are either ribbed or ribless, (Hussein and Eldemerdash, 2016) reported that some asteraceous species have reveal disparities in number of ribs made the use of this trait controversial. But, in the identification keys the use of number of ribs as a characteristics for differentiation of species from Asteraceae has been adopted. The number of Cypselae per capitulum had a great diversity . Some taxa such as *sonchus asper* had 123, *Himalaiella hetromella* had 117, and *Sonchus arvensis* has 112 cypselae per capitulum.

Variations in Cypsela Qualitative Characters Via LM

Light microscope was used to examine macro-morphological features of Cypsela. The investigated species have great variation in term of color. Majority of the cypselae has Brown Color. The color of cypsela seems clearly distinctive to cypselae of *Carthamus lanatus* having straw white color. Reference.

Stated that the color of cypsela is not reliable distinctive character because the color changes with the degree of maturity of Cypselae.The Cypsela shape appeared unique in *Calendula arvensis* and *Calendula officinalis* being curved. In addition, the cypsela shape seems to be clearly diagnostic for some of the examined taxa. Most of the species show variations in cypselae shape. Linear to linear lanceolate, oblanceolate to obovate, curved to ring and obovoid cypselae shapes were examined. *Aster squamatus*, *Bidens bipinnata* has linear shape, *Erigeron bonariensis*, *Erigeron candadensis* has linear lanceolate shape while *Bidens bipinnata* has linear fusiform shape. *Centaurea iberica*, *Parthenium hystiphorus*, *Silybum marianum* has obovoid shape, Obovoid shape was observed in *Xanthium stromarium*, *youngia japonica* obovoid to cylindrical cypsela was present in cichorium intybus, While narrowly lanceolate cypsela was present in *Launea procumbens.* Dominant shape type was oblanceolate observed in the *Sonchus*, *Lactuca* and rest of the examined taxa.

Also, color of pappus have been found supportive for taxonomic delimitation of the studied taxa. Pappus is of various colors such as white, dull white, dirty white, silky white, brown. In the investigated species pappus is either fragile or not fragile. Carpodium position have also found supportive for taxonomic limitation of the studied taxa. Carpopodium position is basal, sub-basal, and lateral in the studied taxa. Cypsela surface Pubescence is scabrous in twelve species while remaining species have glabrous surface pubescence.

The presence of beaked cypselaeis diagnostic for the four examined species of *Lactuca* having obviously one long beaked cypselae, also for *Ixeris polycephala,* with two short beaked cypselae and *Bidens bipinnata*, *Bidens psilosa* with four short beaks. Beak was observed in most of the species in tribe Cichorieae *Lactuca sativa*, *Lctuca dissecta*, *Lactuca serriola* and white, filiform beak whereas *Bidens bipinnata*, *Bidens psilosa*, *Ixeris polycephala*, have brown slender beak. Lactuca serriola has white slender beak and rest of the examined species are observed without beak.

Variations in Qualitative features of Cypsela Via SEM

Use of scaning electron microscopy can be very helpful in plant taxonomy as it reveals surface morphology of various vegetative and reproductive organs (Barthlott,1984) . In Present research SEM was used to study micro-morphological features such as surface pattern, epicuticular projections, carpopodium shape, anticlinal and periclinal walls pattern and level.

In studied Plants, surface pattern observed was of 13 types irregularly reticulate, Irregularly striate, Striato-knotted, Irregularly striato- regulate, Verrucate-striate, Reticulate, Scrobiculate, Rugose papillate, Regulate, Striated, Irregularly scrobiculate, Verrucose pappillate, Verrucate reticulate. *Carthamus lanatus*, *Carthamus oxycantha*, *Causinia prolifera* and *Cirsium arvens* has reticulate surface Pattern. While *Lactuca dissecta*, *Lactuca sativa*, *Lactuca serriola*, *Sonchus oleraceus*, and *Carthamus lanatus* has verrucate papillate surface pattern. Certain variations were observed in the species of same genus as sonchus oleraceous has verrucose papillate surface pattern and *Sonchus* arvensisand Sonchus asper has Striated surface Pattern. Surface pattern of the cypsela of *Bidens bipinnata* is irregularly striated whereas *Bidens psilosa* has striato-knotted surface pattern, making surface pattern valuable as one more diagnostic characterto differentiate the genera . *Carthamus lanatus* has verrucose pappillate surface pattern while rest of the species from the same tribe has different surface patterns making it easy to distinguish from each other. In addition the studied five taxa of tribe Heliantheae *Eclipta prostrate*, *Lactuca sativa*, *Parthenium hystiphorus*, *Calendula officinalis*, and *Carthamus lanatus* could be easily delimited at the generic level through their cypsela surface micro- sculpture. *Parthenium hystiphorus* and *Eclipta prostrata* has regulate surface pattern while helianthus annus has irregularly striated surface pattern and *Zinnia elegans* has verrucate reticulate surface pattern.

Epicuticular projections reveal variations in terms of Micro-morphological features Reference add. In studied species, five type of epicuticular projections were observed as granules,Platelets, bulges, hair, dome shaped bulges whereas absent in some taxa. *Lactuca dissecta*, *Lactuca sativa*, *Lactuca serriola*, *Sonchus arvensis*, *Sonchus oleraceous, Calendula arvensis , Launea naudicaulis, Launea procumbens* , has granules. *Calendula arvensis* and *Calendula officinales* has bulges while *Parthenium hystiphorus* has dome shaped bulges. *Bidens bipinnata*, *Bidens psilosa*, *Launea procumbens*, *Ageratum conyzoides* and *sonchus asper* has platelets Epicuticular projections are absent in rest of ythe taxa.

Observations of cypselae under scanning electron microscopy has revealed the presence of the obcission scar termed as carpopodium in all the studied taxa either at a basal or sub-basal or lateral position. The carpopodium in *Aster squamatus*, *Bidens bipinnata*, *Bidens psilosa*, *Centaurea ibrica*, *Cirsium arvense*, *Cirsium sorocephalum*, *Eclipta prostrate*, *Erigeron bonariensis, Helianthus annus*, *Himalaiella hetromalla*,*Lactuca dissecta*, *Silybum marianum*, *Taraxacum campylodes*, *Youngia japonica* is completely developed without any interruption. Undeveloped in *Cichorium intybus* and *Launea procombens* and incompletely developed in rest of examined taxa. This observation matches with that previously reported by Refernces add. The shape of the Carpodium may seem to be a reliable character for generic separation as observed in the three studied species of Lactuca. Carpopodium features have always been found useful for the taxonomic delimitation of the various taxa of the family asteraceae. Anticlinal and periclinal wall except *Calendula officinalis*, *Carthamus lanatus*, *Carthamus oxycantha*, *Cirsium arvense*, *Parthenium hystiphorus*, *Sonchus oleraceous*, *Launea naudicaulis, Launea procumbens* in which anticlinal wall is depressed. Anticlinal wall pattern were observed as entire, slightly wavy to wavy, grooved and puzzled. The examined species have flat, depressed, raised,and convex level of periclinal walls. The protuberance of periclinal wall is mainly glabrous, five species have fine texture while four species are medium textured. But coarse texture protuberance is observed in three species *Parthenium hystiphorus*, *Lactuca sativa*, *Launea procumbens.*

Table 19: Micro- morphological attributes of seeds of family Fabaceae

Sr. No	Plant Taxa	Seed Color	Seed Shape	Seed outline	Seed apex	Seed Base	Hilum Position	Sculpturing	Anticlinal Wall Pattern	Epidermal cell shape	Hilum
1	Acacia nilotica	Gray	Flat	Irregular	Slightly Round	Round	NA	Papillate	Wavy	Irregular	Not Visible
2	Accacia modesta	Dark Gray	Oval-Flat	Oblong	Round	Pointed	NA	Striate	Wavy	Radiate	Not Visible
3	Arachis hypagae	Grayish Black	Round-Oval	Elliptic	Round	Oval-Round	NA	Reticulate	Undulate	Flat	Not Visible
4	Astragalus psilocentros	Gray	Ovate	Irregular	Round	Round	Terminal	Reticulate	Not-visible	Flat	Visible
5	Astragalus scoripiurus	Gray	Oblong	Oblong	Pointed	Round	NA	Reticulate	Smooth	Round	Not Visible
6	Cassia fistula	Light Gray	Ovate	Ovate	Pointed	Slightly Round	NA	Striate	Straight	Wavy	Not Visible
7	Cassia italica	Grayish Black	Elliptic	Oval	Beak Like	Narrow	Central	Granulate	Wavy	Wavy	Visible
8	Cassia occidentalis	Gray	Slightly Round	Irregular	Flat	Round	Central	Smooth	Undulate	Curved	Visible
9	Crotolaria burhia	Gray	Bean Shaped	Ovate	Round	Narrow	Terminal	Granulate	Undulate	Flat	Visible
10	Dilbergia sisso	Gray	Oval	Oblong	Round	Pointed	NA	Slightly-Striate	Wavy	Round	Not Visible
11	Lathyrus aphaca	Grayish Black	Elliptic	Ovate	Pointed	Round	NA	Granulate	Smooth	Round	Not Visible
12	Lespedeza juncea	Grayish Black	Ovate	Irregular	Beak Like	Oval-Round	Central	Striate	Straight	Radiate	Visible
13	Leucaena	Gray	Round	Oval	Flat	Slightly	Terminal	Papillate	Straight	Irregular	Visible

	leucocephalla					-Round					
14	Melilotus indicus	Gray	Flat	Elliptic	Pointed	Pointed	Central	Striate	Undulate	Round	Visible
15	Pigomia pinnata	Light Gray	Ovate	Oblong	Pointed	Round	Central	Reticulate	Wavy	Flat	Visible
16	Prosopis cineraria	Grayish Black	Elliptic	Elliptic	Round	Pointed	NA	Papillate	Wavy	Round	Not Visible
17	Prosopis juliflora	Grayish Black	Slightly Rpound	Oval	Flat	Narrow	NA	Granulate	Wavy	Radiate	Not Visible
18	Pueraria tuberosa	Gray	Ovate	Oblong	Beak Like	Narrow	Central	Striate	Undulate	Wavy	Visible
19	Rhynchosia capitata	Gray	Elliptic	Elliptic	Round	Round	Terminal	Reticulate	Smooth	Irregular	Visible
20	Sophora mollis	Light Gray	Flat	Oval	Pointed	Round	Central	Papillate	Wavy	Radiate	Visible

3.3.2 Seeds Micromorphology of Fabaceous Species

1. ***Acacia nilotica***

The seed color observed was Gray, shape flat,seed outline regular,seed apex was slightly round and seed base is round. Epicuticular projections observed on seed surface was Papillate. .Anticlinal walls pattern Wavy. Epidermal cell shape Irregular and Hilum not visible (Plate 134).

2. ***Accacia modesta***

The seed color observed was Dark Gray, shape Oval-Flat,seed outline Oblong,seed apex was round and seed base is Pointed. Epicuticular projections observed on seed surface was Striate. .Anticlinal walls pattern Wavy. Epidermal cell shape Radiate and Hilum not visible (Plate 134).

3. ***Arachis hypagae***

The seed color observed was Grayish Black, shape Round-Oval,seed outline Elliptic, seed apex was Round and seed base is Oval-Round. Epicuticular projections observed on seed surface was Reticulate. .Anticlinal walls pattern Undulate. Epidermal cell shape Flat and Hilum not visible (Plate 135).

4. ***Astragalus psilocentros***

The seed color observed was Gray, shape Ovate,seed outline Irregular,seed apex was round and seed base is round. Epicuticular projections observed on seed surface was Reticulate. Anticlinal walls pattern not visible. Epidermal cell shape Round and Hilum not visible (Plate 135).

5. ***Astragalus scoripiurus***

The seed color observed was Gray, shape oblong,seed outline oblong,seed apex was slightly pointed and seed base is round. Epicuticular projections observed on seed surface was Reticulate. .Anticlinal walls pattern smooth. Epidermal cell shape Round and Hilum not visible (Plate 136).

6. ***Cassia fistula***

The seed color observed was Light Gray, shape ovate ,seed outline ovate,seed apex was slightly pointed and seed base is slightly round. Epicuticular projections observed on seed surface was striate. Anticlinal walls pattern straight. Epidermal cell shape wavy and Hilum not visible (Plate 136).

7. *Cassia italica*

The seed color observed was Grayish black, shape Elliptic,seed outline oval,seed apex was sbeak like and seed base is narrow. Hilum position central.Epicuticular projections observed on seed surface was Granulate. .Anticlinal walls pattern Wavy. Epidermal cell shape wavy and Hilum visible (Plate 137).

8. *Cassia occidentalis*

The seed color observed was Gray, shape slightly round,seed outline irregular,seed apex was slightly round and seed base is round. Hilum position central.Epicuticular projections observed on seed surface was smooth. .Anticlinal walls pattern undulate. Epidermal cell shape curved and Hilum visible (Plate 137).

9. *Crotolaria burhia*

The seed color observed was Gray, bean shaped, seed outline ovate,seed apex was round and seed base is narrow. Hilum position terminal. Epicuticular projections observed on seed surface was Granulate. .Anticlinal walls pattern undulate. Epidermal cell shape flat and Hilum visible (Plate 138).

10. *Dilbergia sisso*

The seed color observed was Gray, shape oval,seed outline oblong,seed apex was round and seed base is pointed. Epicuticular projections observed on seed surface was Granulate. .Anticlinal walls pattern smooth. Epidermal cell shape smooth and Hilum not visible (Plate 138).

11. *Lathyrus aphaca*

The seed color observed was Grayish black, shape elliptic ,seed outline ovate,seed apex was pointed and seed base is round. Epicuticular projections observed on seed surface was Granulate. .Anticlinal walls pattern smooth. Epidermal cell shape round and Hilum not visible (Plate 139).

12. *Lespedeza juncea*

The seed color observed was Grayish black, shape ovate,seed outline irregular,seed apex was beak like and seed base is oval round. Hilum Position is central.Epicuticular projections observed on seed surface was striate. .Anticlinal walls pattern straight. Epidermal cell shape radiate and Hilum visible (Plate 139).

13. *Leucaena leucocephalla*

The seed color observed was Gray, shape round,seed outline oval,seed apex was slightly round and seed base is round. Epicuticular projections observed on seed surface was Papillate. .Anticlinal walls pattern Wavy. Epidermal cell shape Irregular and Hilum not visible (Plate 140)

14. *Melilotus indicus*

The seed color observed was Gray, shape flat,seed outline regular,seed apex was slightly round and seed base is round. Epicuticular projections observed on seed surface was Papillate. .Anticlinal walls pattern Wavy. Epidermal cell shape Irregular and Hilum not visible (Plate 140).

15. *Pigomia pinnata*

The seed color observed was Gray, shape flat,seed outline regular,seed apex was slightly round and seed base is round. Epicuticular projections observed on seed surface was Papillate. .Anticlinal walls pattern Wavy. Epidermal cell shape Irregular and Hilum not visible (Plate 141)

16. *Prosopis cineraria*

The seed color observed was Gray, shape flat,seed outline regular,seed apex was flat and seed base is slightly round. Hilum position terminal. Epicuticular projections observed on seed surface was Papillate. .Anticlinal walls pattern straight. Epidermal cell shape Irregular and not visible (Plate 141)

17. *Prosopis juliflora*

The seed color observed was Grayish black, shape slightly round, seed outline oblong, seed apex was beak like and seed base is narrow. Hilum position central. Epicuticular projections observed on seed surface was striate. .Anticlinal walls pattern Wavy. Epidermal cell shape Irregular and Hilum not visible (Plate 142).

18. *Pueraria tuberosa*

The seed color observed was Gray, shape ovate,seed outline oblong,seed apex was beak like and seed base is narrow. Hilum position central.Epicuticular projections observed on seed surface was striate. .Anticlinal walls pattern undulate. Epidermal cell shape wavy and Hilum visible (Plate 142).

19. *Rhynchosia capitata*

The seed color observed was Gray, shape elliptic,seed outline elliptic,seed apex was round and seed base is round. Hilum position is Terminal. Epicuticular projections observed on seed surface was Reticulate. .Anticlinal walls pattern smooth. Epidermal cell shape Irregular and Hilum visible (Plate 143).

20. ***Sophora mollis***

The seed color observed was Light Gray, shape flat,seed outline oval,seed apex was pointed and seed base is round. Hilum position central. Epicuticular projections observed on seed surface was Papillate. .Anticlinal walls pattern Wavy. Epidermal cell shape radiate and Hilum visible (Plate 143).

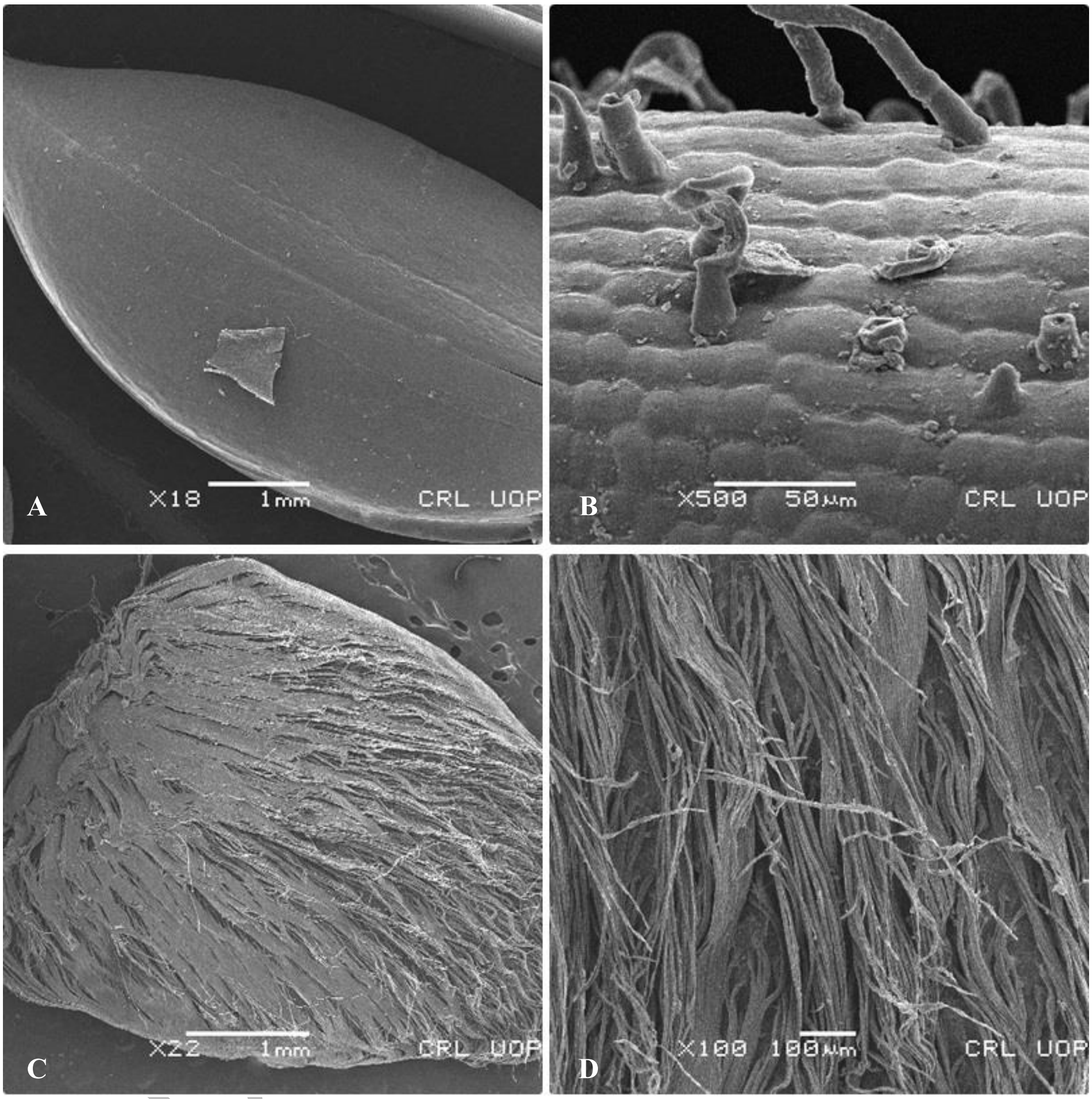

Plate 134: Seed micrographs of *Acacia nilotica* (A) General View (B) Surface Sculpturing, *Accacia modesta (*C) General View (D) Surface Sculpturing

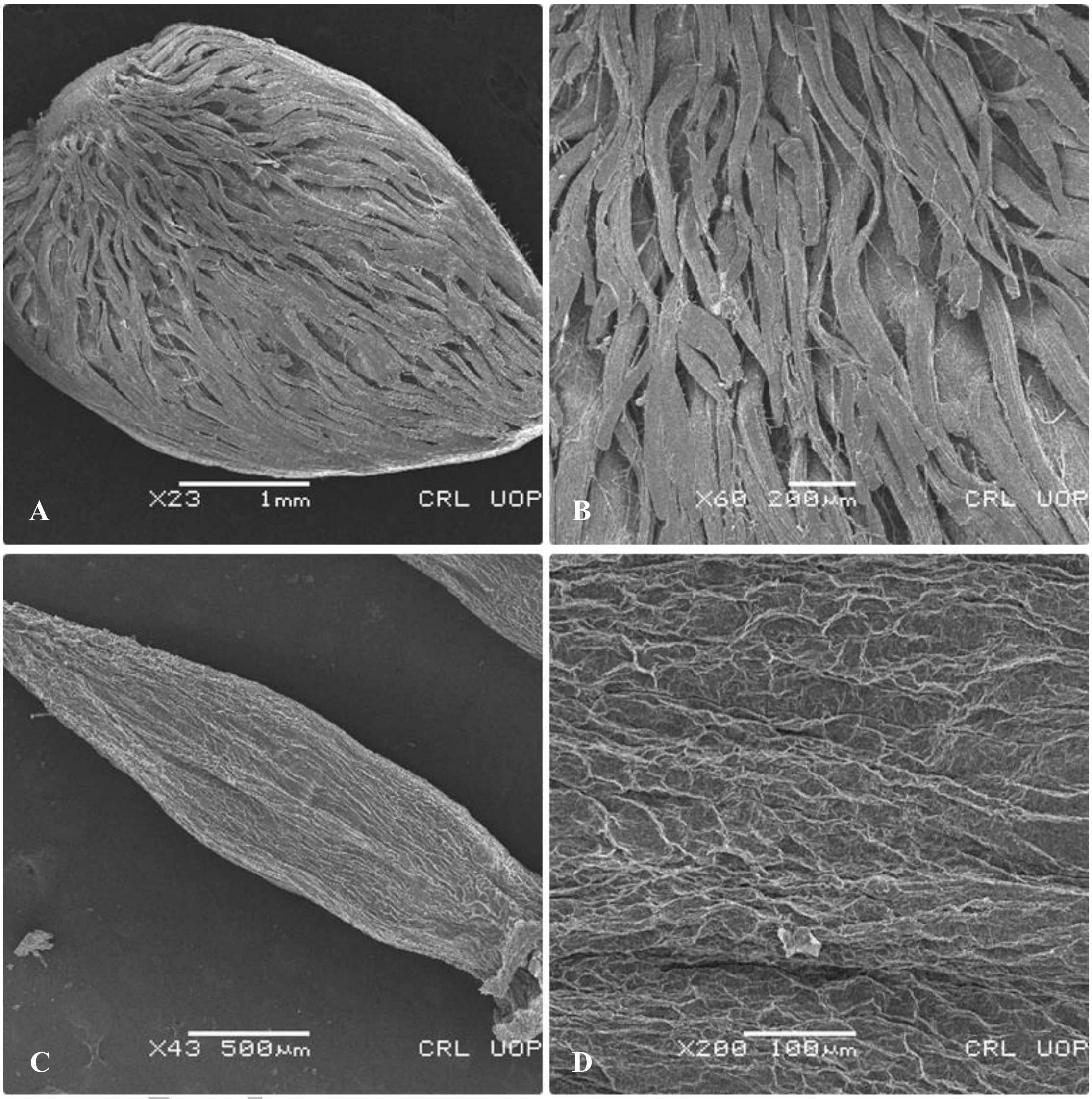

Plate 135: Seed micrographs *Arachis hypagae* (A) General View (B) Surface Sculpturing , *Astragalus psilocentros* (C)General View (D) Surface Sculpturing

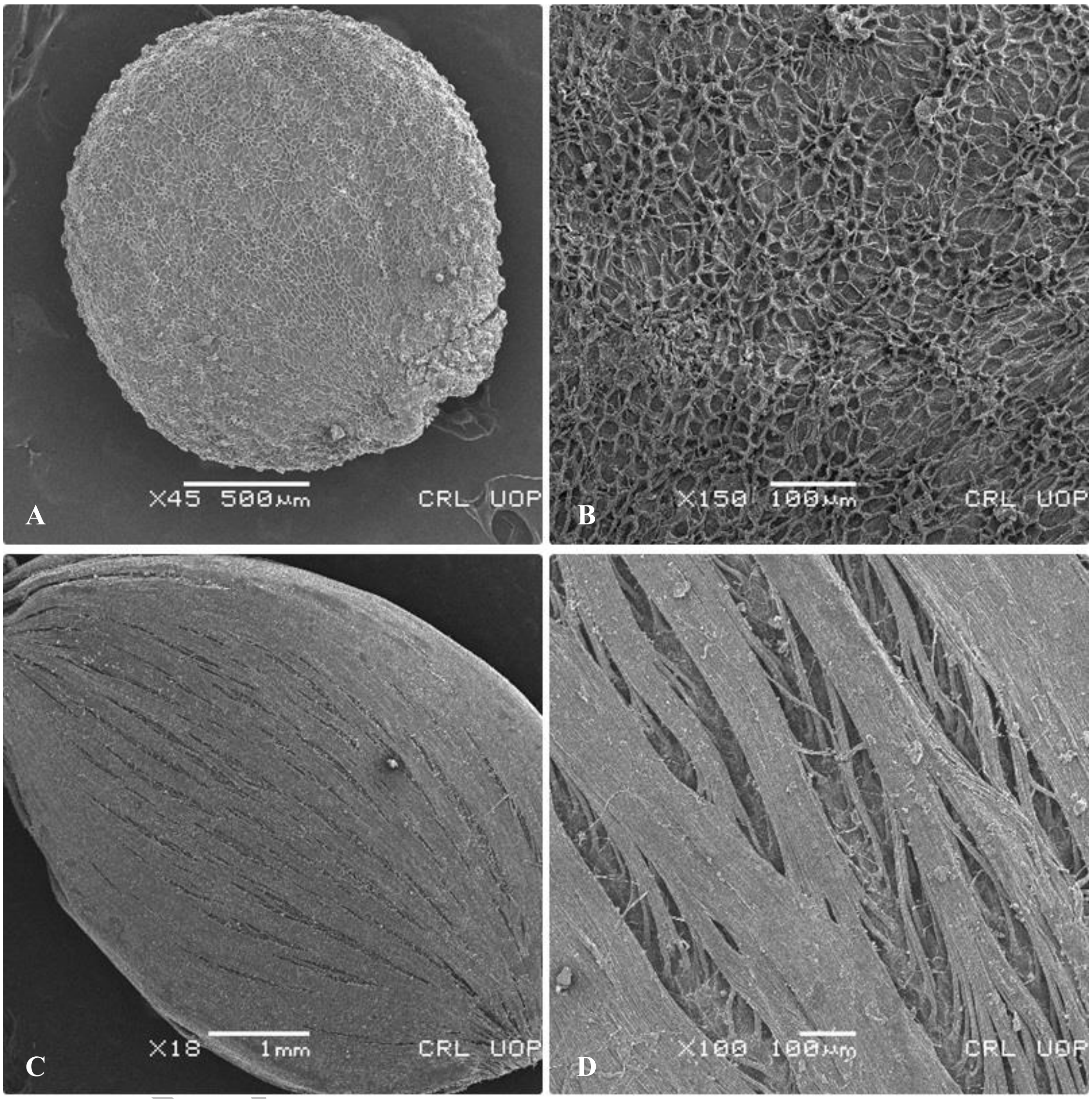

Plate 136: Seed micrographs of *Astragalus scoripiurus* (A) General View (B) Surface Sculpturing , *Cassia fistula* (C)General View (D) Surface Sculpturing

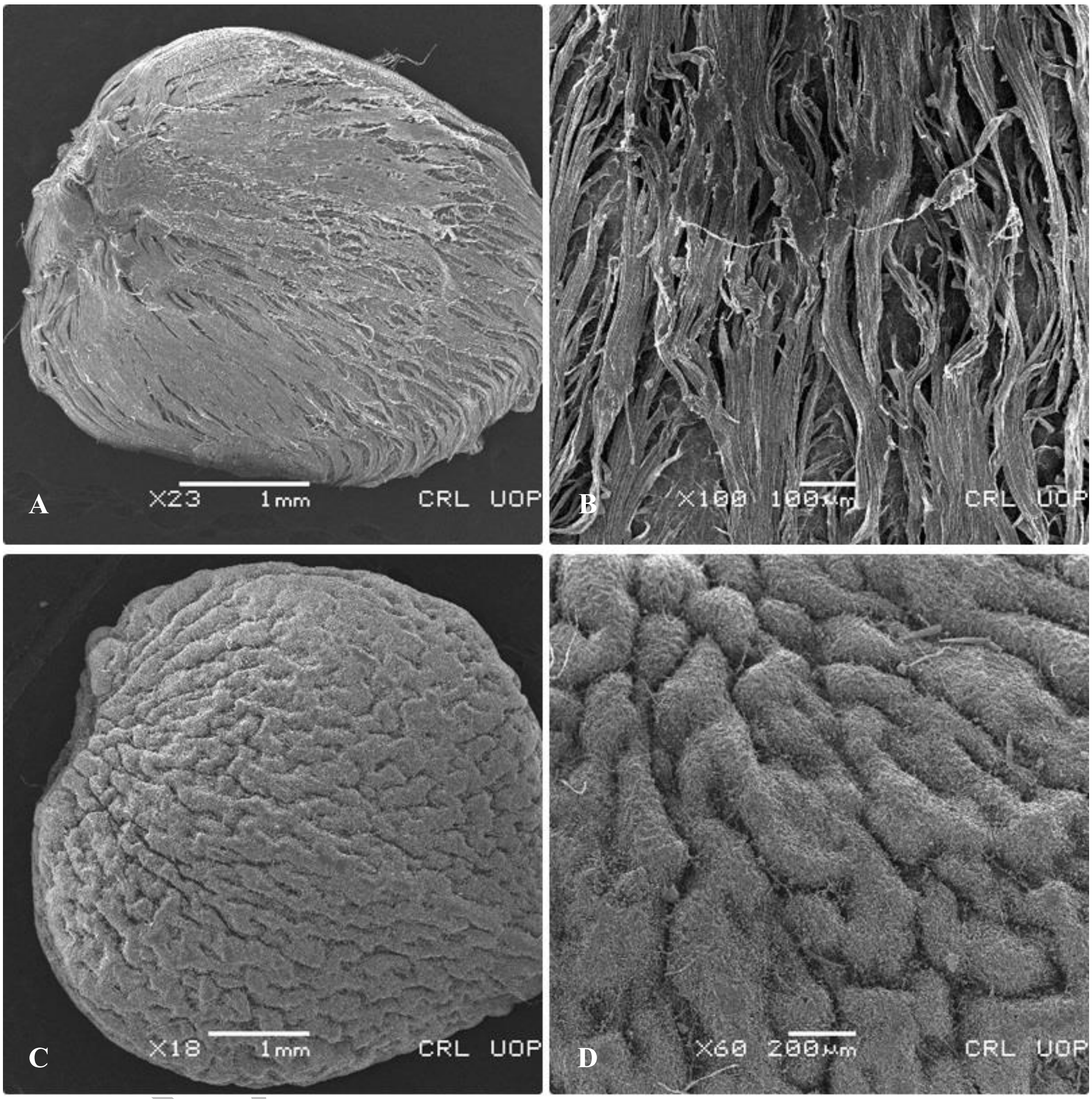

Plate 137: Seed micrographs, *Cassia italic* (A) General View (B)Surface Sculpturing , *Cassia occidentalis* (C) General View (D) Surface Sculpturing

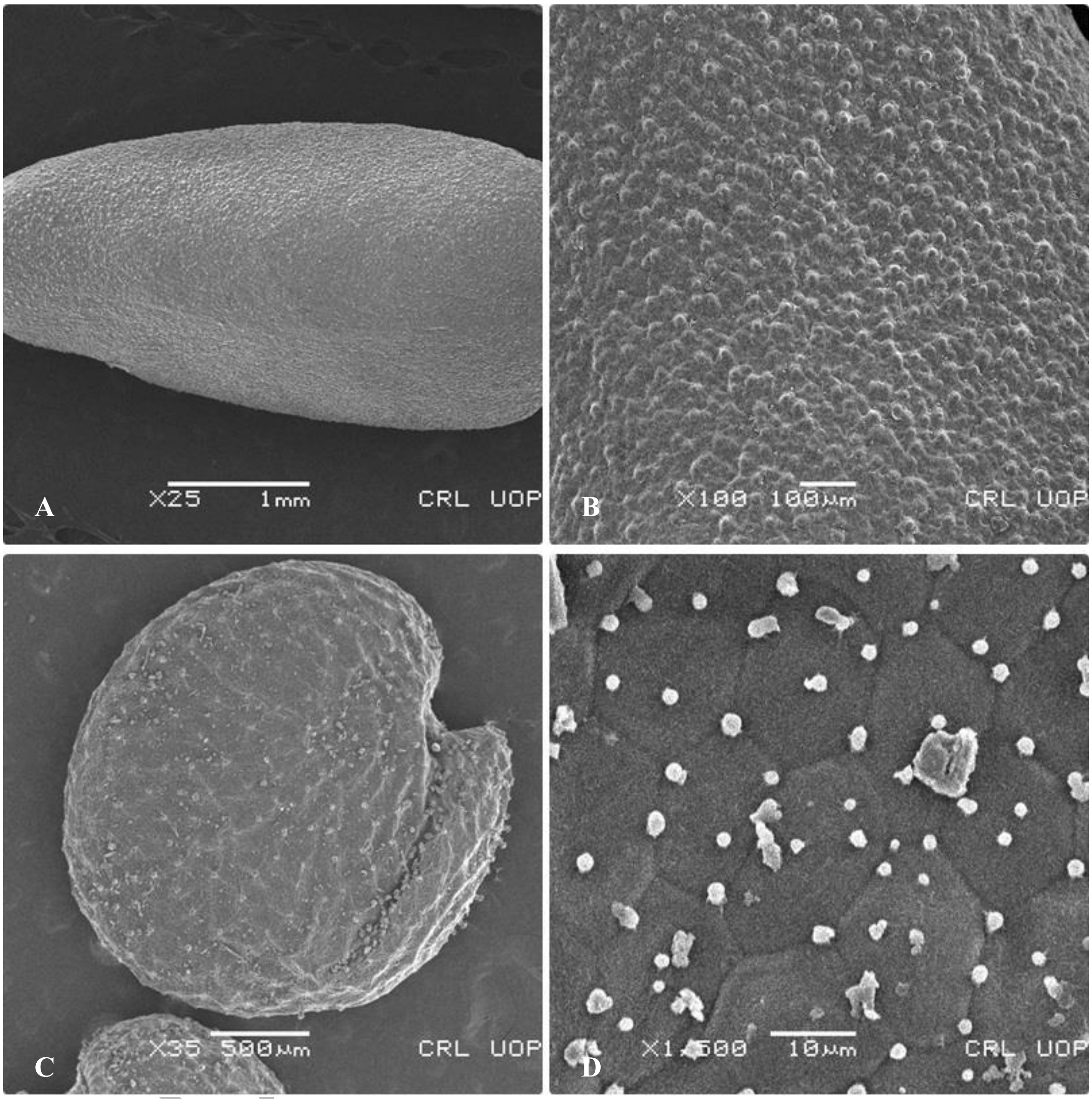

Plate 138: Seed micrographs of *Crotolaria burhia* (A) General View (B) Surface Sculpturing , *Dilbergia sisso* (C) General View (D) Surface Sculpturing

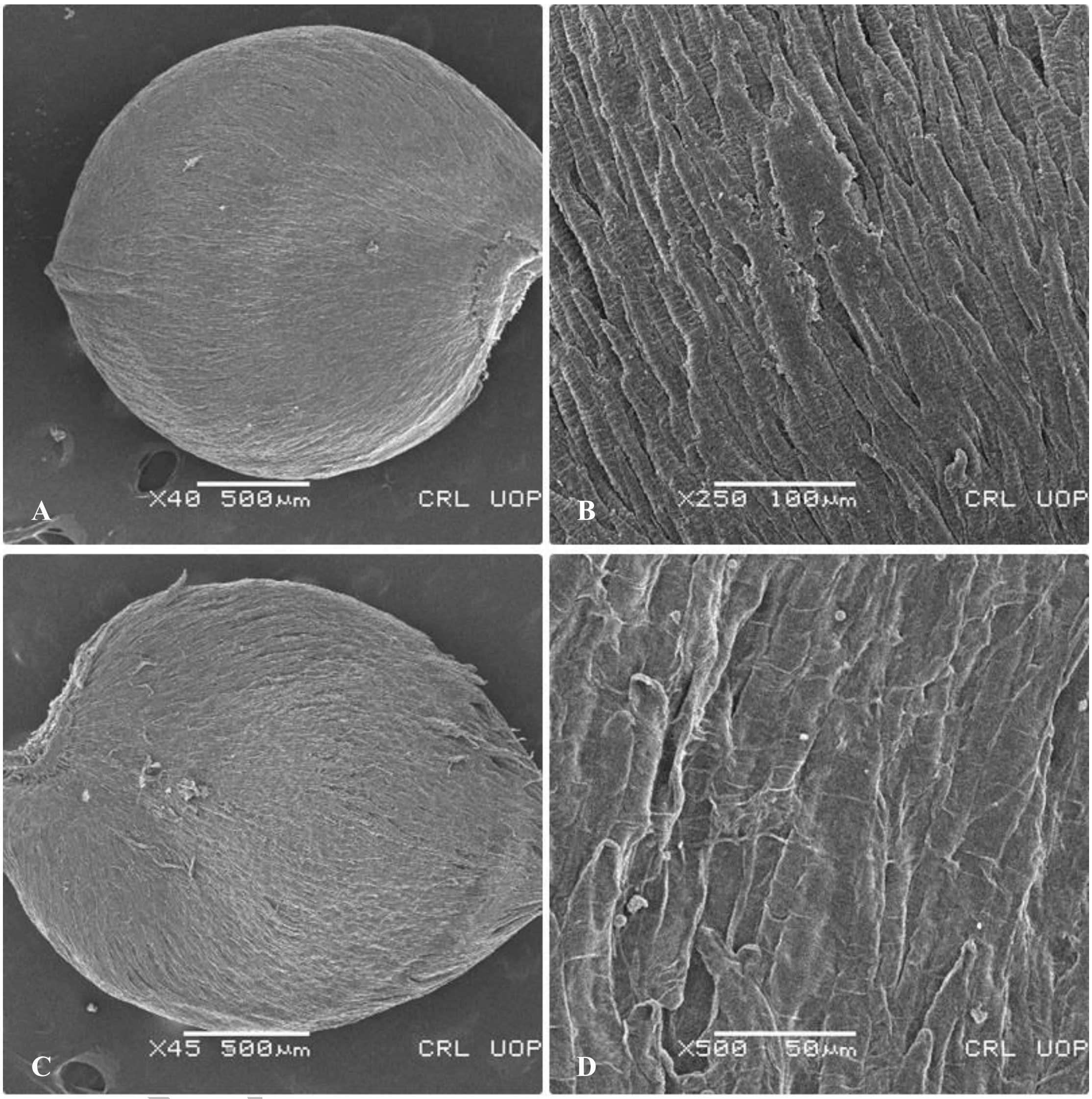

Plate 139: Seed micrographs of *Lathyrus aphaca*, (A) General View (B) Surface Sculpturing , *Lespedeza juncea* (C) General View (D) Surface Sculpturing

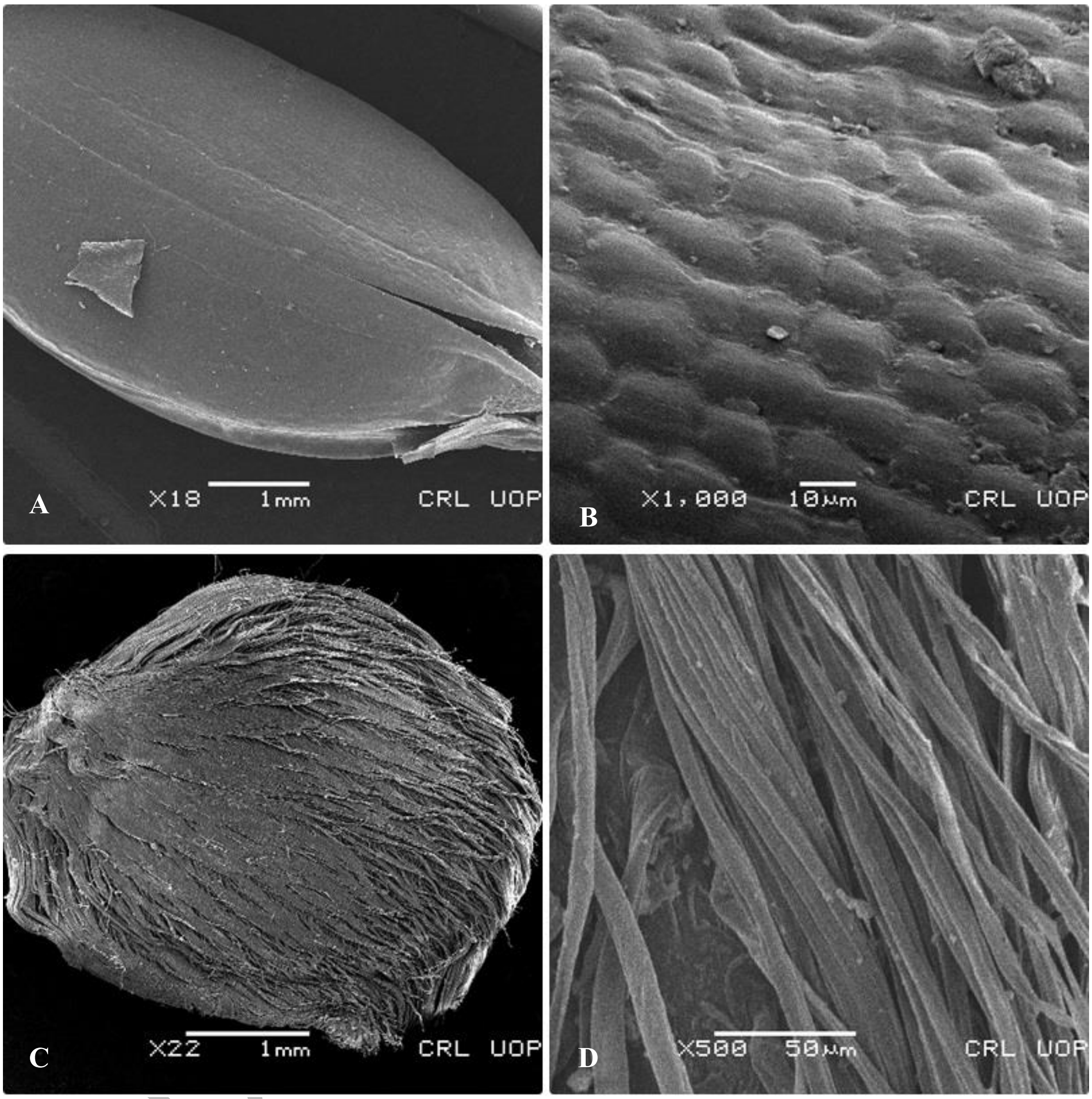

Plate 140: Seed micrographs of *Leucaena leucocephalla* (A) General View (B) Surface Sculpturing , *Melilotus indicus* (C)General View (D) Surface Sculpturing

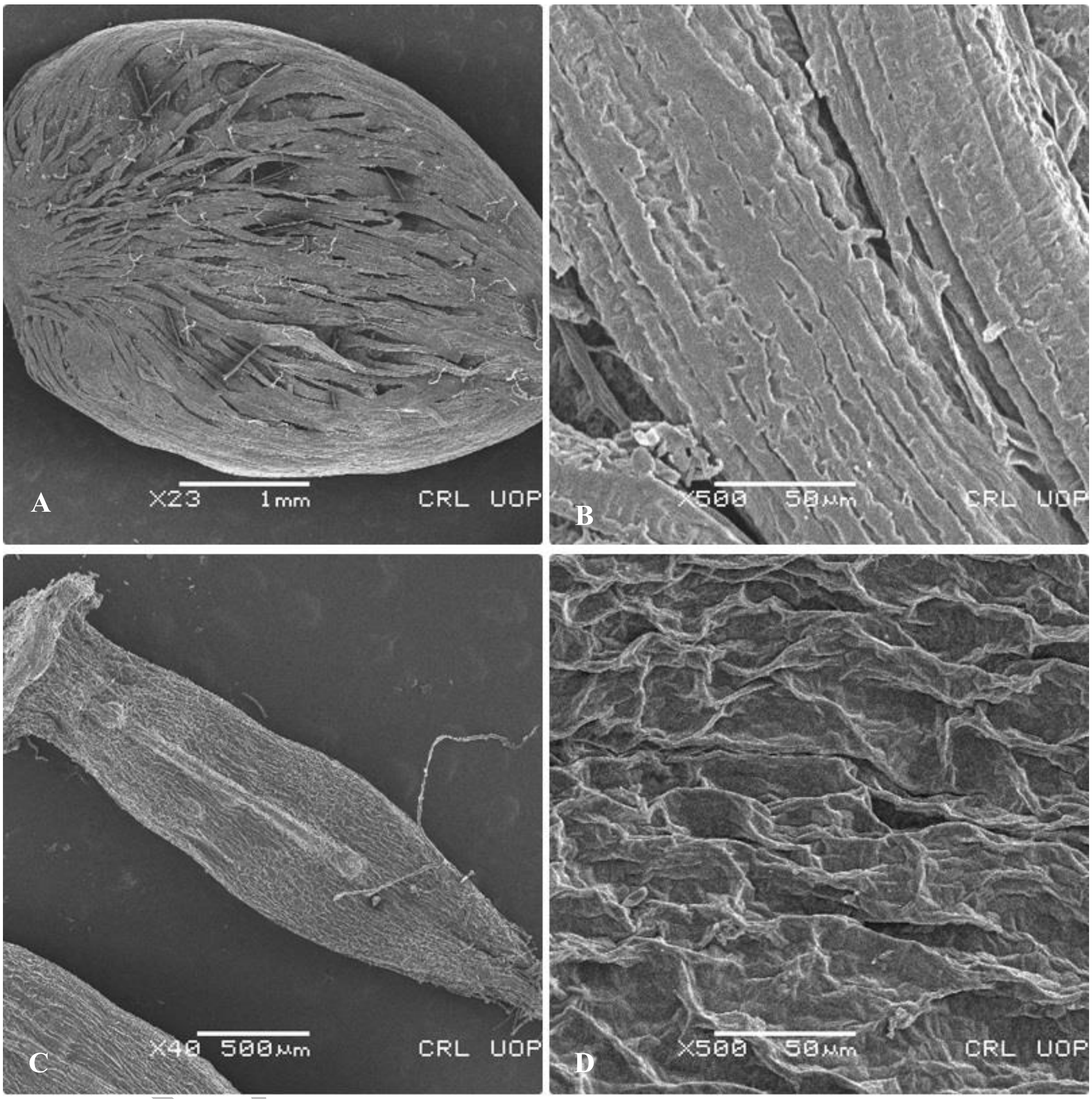

Plate 141: Seed micrographs *Pigomia pinnata* (A)General View (B) Surface Sculpturing , *Prosopis cineraria* (C)General View (D) Surface Sculpturing

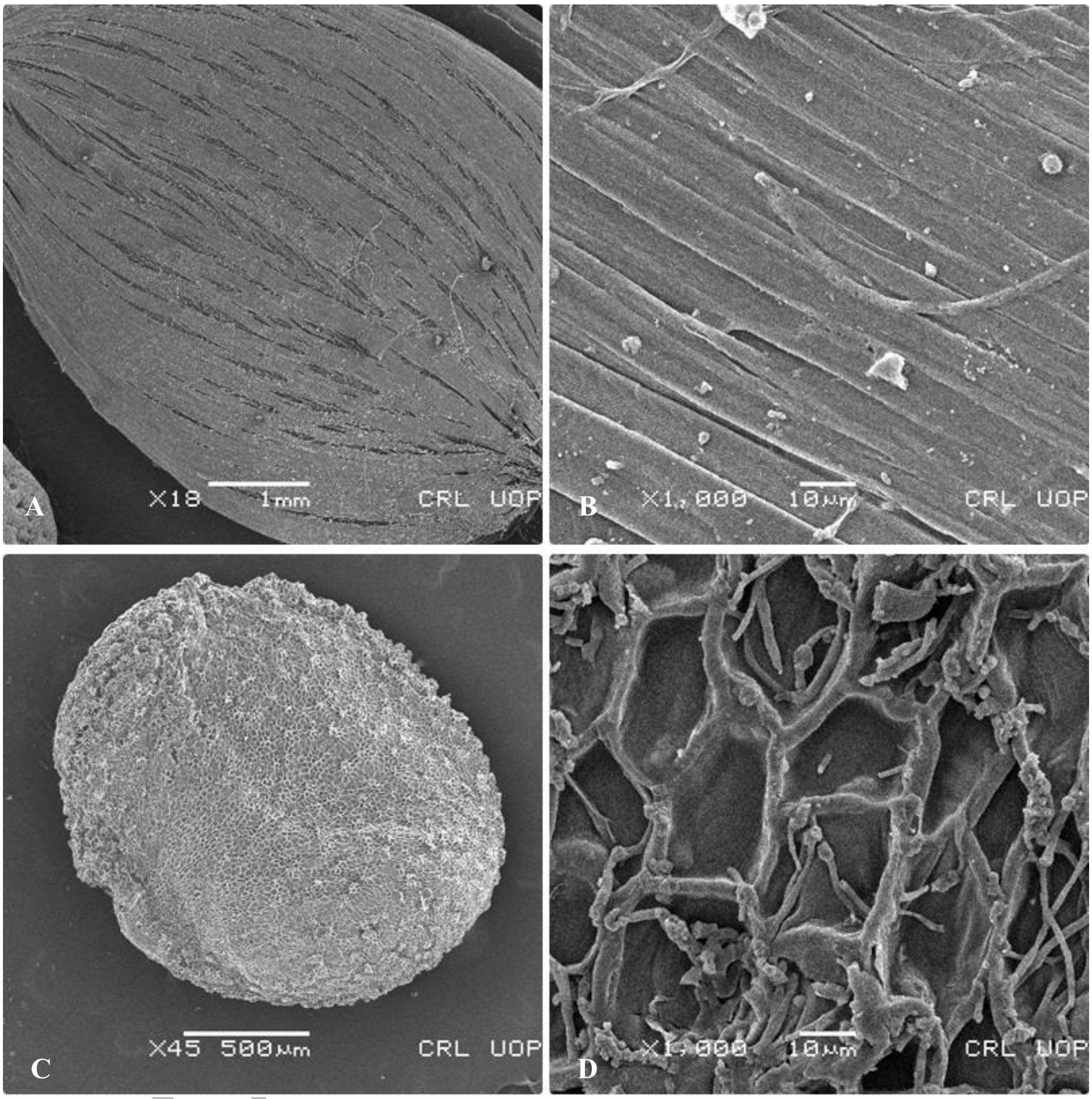

Plate 142: Seed micrographs of *Prosopis juliflora* (A) General View (B) Surface Sculpturing , *Pueraria tuberose* (C) General View (D) Surface Sculpturing

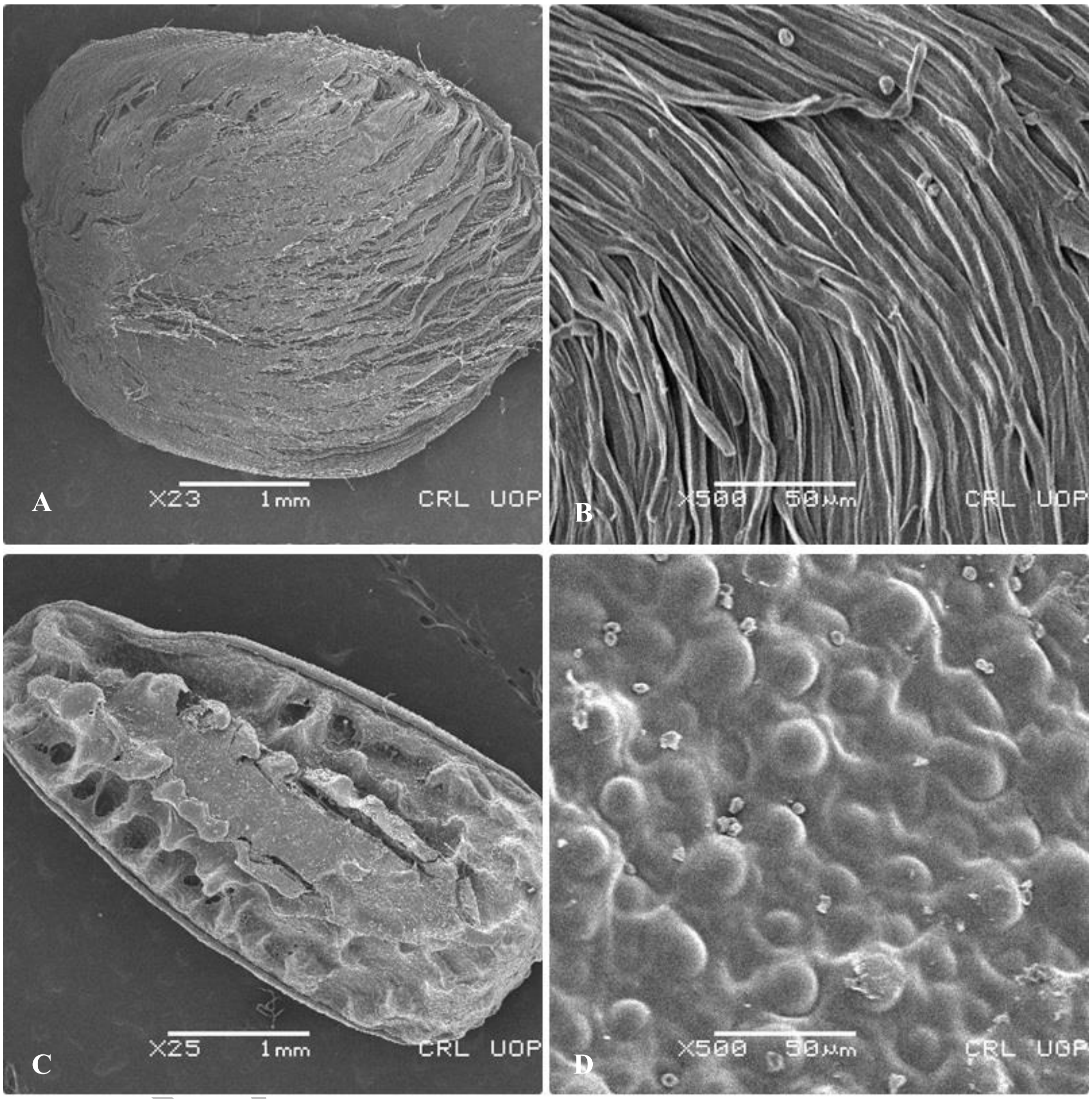

Plate 143: Seed micrographs of *Rhynchosia capitata* (A) General View (B) Surface Sculpturing , *Sophora mollis*(C) General View (D) Surface Sculpturing

Taxonomic key of seed morphological characters of Fabaceaous Species

1a. Hilum position is visible ……………………….. 2

1b. Hilum position is not visible …………………………. 10

2a. Seed apex is flat ……………………….. *Prosopis juliflora*

2b. Seed apex round or pointed ………………. 3

3a. Seed outline is irregular ……………….. *Acacia nilotica*

3b. Seed outline is regular …………….. 4

4a. Seed shape is ovate ……………………. *Cassia fistula*

4b. Seed shape other than ovate ……………….. 5

5a. Epidermal cell shape is radiated …………… *Accacia modesta*

5b. Epidermal cells are flat or round ………………. 6

6a. Cell of epidermis are flat ………………………. *Arachis hypagae*

6b. Cell of epidermis are round …………………. 7

7a. Seed shape is oblong ………………………. *Astragalus scoripiurus*

7b. Seed shape is oval and elliptic ………………….. 8

8a. Anti clinal wall pattern is smooth ………………. *Lathyrus aphaca*

8b. Anti clinal wall pattern is wavy ………………….. 9

9a. Seed sculpturing is slightly striated ………………. *Dilbergia sisso*

9b. Seed sculpturing is pappilate ………………. *Prosopis cineraria*

10a. Seed sculpturing is smooth ………………. *Cassia occidentalis*

10b. Seed is sculptured with pattern ……………………. 11

11a. Seed is bean shaped …………………. *Crotolaria burhia*

11b. Seed shape is other than bean shaped …………………. 12

12 a. Anticlinal wall pattern is in visible ………………. *Astragalus psilocentros*

12 b. Anticlinal wall pattern is visible ………………. 13

13a. Granulate seed surface ………………….. *Cassia italic*

13b. Seed surface is reticulate, papillate and striate …………………… 14

14a. Epidermal cell are flat ……………….. *Pigomia pinnata*

14b. Epidermal cell has specific pattern ……… 15

15a. Seed shape is round ……………………… *Leucaena leucocephalla*

15b. Seed Shape is other than round ……………………. 16

16 a. Irregular seed outline ………………….. *Lespedeza juncea*

16 b. Regular seed outline …………………. 17

17 a. Hilum position terminal …………………………… *Rhynchosia capitata*

17 b. Hilum position central …………………………… 18

18a. Seed shape is ovate ………………………………. *Pueraria tuberosa*

18b. Seed shape is flat ………………………………… 19

19a. Seed sculpturing striate ……………………… *Melilotus indicus*

19b. Seed sculpturing papillate …………………….. *Sophora mollis*

3.2.2 Fabaceaous Seeds

This study describes the seed morphological characters of 20 Fabaceaous Plants. Seeds display variation in features like shape, texture, color, sculpturing, testa wall, epidermal cell shape and presence or absence of papillae.

Seeds morphology provide useful characters for investigating systematic affinities in various plant families (Bus et.al; 2001) Gontcharova et.al;2009, Zhang et.al 2005). The seed morphology as well as sculpturing and texture attributes were observed to vary greatly among different taxa and can play important role in systematic plant studies. (Al-Ghoray and Mohamed, 2007, Chowdhary and Buth, 1970). The outer surface features of seeds studied by scanning electron Microscopy(SEM), have been extensively applied in resolving taxonomic ambiguities within plant groups and evolutionary relationships(Koul et.al 2000. Sagarra and Mateu, 2001). The ultra structural pattern of the seed coat examined under the SEM is known as trustworthy tool to evaluate phonetic affinities and delimitation of Plant taxa (Barthlott,1981; Koul et.al, 2000; Yoshizaki. 2003).

1 Seed Shape and Size

Seed shape varies from oval to roundin majority of studied taxa with few exceptions including flat shaped seed in *Argyrolobium roseum, Astragalus, astragalus psilentros* and bean shaped in Acacia nilotica, Accacia modesta, Arachis hypagae .Seed outline appears ovate or oblong in most of the species with addition of elliptic, round and irregular seed outline in few species. Two types of seed texture are recorded i.e smooth (9 species) Hairy (11 species) . Seed display less variation in color ranging from gray (6 species) , grayish black (7 species) or dark gray(7 species) . Seed size varies from 1-15 mm.

Previous studies on seed micromorphology and surface structure specify that seed characteristics are valuable in the systematics of Fabaceous species (Gune and Ali 2011; Lersten, 1979).Taia, (2004b) studied the seed morphological characters in genus Lythrus and noticed oval shaped seeds thus supporting the present findings. IICIM AND Behcet,(2016), described sub-reniform seed shape in three Astragalus species in Turkey. This studied also reported elliptic and oblong seed outline in genus Astragalus. Similarly members of genus Trigonella were observed to be globoseobovoid in outline in earlier literature (Muuml et.,2012). These findings corroborate with recent results reporting seeds of Trigonella foenumgraceum and Trigonella monantha with oblong outline.

Even though the shape and size of seeds are reasonably consistent among the species examined, yet some features have been recognized as distinctive like seed size in Cassia italic and Cassia occidentalis are small (1-4mm) in comparsion to other species. Vural et.al;(2008) and Saghi et.al; (2015) observed oblate-sub-oblate and ovoid-reniform seed shape in Crotolaria burhia, Dilbergia sisso, Lespedeza juncea thus supporting the recent results. Abid et.al; (2018) studied the seed micromorphology in genus Melilotus and reported elliptic seed shape. These findings corroborate with findings presented in this study. Similarly, Lazarevic et.al;(2017) studied the seed morphology in field pea genotypes and noticed spherical or round seed shape which supports the result of present study. Comparative seed morphological features of Trifolium taxa was studied by Zoric et.al; (2010) describing round-ovoid seeds which is in line with the results presented in the current study. The members of genus vicia are reported with round shaped seed which is confirmed by reviewing earlier study of Hosseinzadeh et.al;(2008) and Lersten,(1979) reporting spherical shaped seeds inVicia species.

2 Seed Sculpturing

Seed sculpturing pattern display great variation in studied taxa. On the basis of seed coat surface features, the studied plant species are separated into five groups. (i) Species with papillate sculpturing pattern (ii) Species having reticulate seed sculpturing (iii) Species with striate seed sculpturing (iv) Species with granulate surface pattern (v) Species\ having smooth seed coat surface.

Acacia nilotica, Leucaena leucocephalla, Prosopis cineraria, Sophora mollis are observed with Papillate surface sculpturing.. Papillae are described as protuberances appearing from the testa cells. In Leucaena leucocephalla Papillae come into view as prominent, simple, and often showing a very complex pattern toward the apex. Intra specific inconsistency of this characteristics is observed in Posopis as both conditions exist in genus. In Leucaena leucocephalla, simple and small simple papillae are noticed close to the notch. While recorded mainly on the sides of the seed members of genus except Pigomia pinnata.

Earlier studied carried out to study the variation in seed coat morphology by using SEM techniques, documented practical morphological and structural features of seed comprising the pattern of testa cell arrangement (Clark and Jamstedt, 1978) Cell shape (Canne,1979) radial wall outline as well as Papilleae distribution (Carolin 1980) . The current study supports the use of seed structural features as descrete characters used in delimitation of plant taxa. Heyn and Hermstdt , (1977) revealed differences in surface characters of Sophora seed using SEM techniques and concluded seed morphology can prove significant in systematics.

In tribe Phoseoleae ,Sharma et.al; (1977) also used SEM in investigating seed structural pattern in distinguishable the plant species within the genus Phoseoleus. Similarly Gutterman and Heydecker, (1973) reported that the seed surface characters play an important role in delimitation of genus Ononis Species. A distinct seed coat pattern was reported in tribe Genisteae descriing its importance in delimitation of Plant species and genera within this tribe (Polhill,1976) . In tribe Vicia Lerstern (1979) observed a reduced rim of hilum and conspicuous papillose pattern of ornamentation reporting these features characteristics for this tribe. The Striate testa pattern in genus Lythrus and Cicer, the reticulate pattern in Vicia hirsute are new characters for the tribe.

The papillose testa pattern reported in literature in Vicieae (Lersten, 1979; Chernoff et.al, 1992; Lersten and Gunn,1982) , has also been noticed this study in Astragalus scoripiurus, Astragalus psilocentros, Cassia fistula,. The study carried out by Abou-El-Enain et.al; (2007) on the seed surface features in genus Lythrus described the anticlinal wall pattern in detail. About nine multi-cellular ornamentation patterns and three secondary ornamentation patterns had been recorded with stellate like structures present on the sides of the anticlinal walls. These are similar with the fndings of the recent study with the little difference in sculpturing pattern. A similar study on the seed morphology of various species of tribe vicie was carried out by khalik and Al-Ghiory (2013) and noticed that the secondary sculpturing pattern in seed coat wall consists of papillose pattern in majority of Vicia species with excepotion of Vicia hirsute bearing lophate ornamentation pattern . These findings are in agreement with the study under discussion reporting papillose seed ornamentation in Genus Vicia.

Regarding the Phenomenon of Polymorphism in the vicia about 50% of the taxa exhibit fairly dissimilar seed texture thus confirming the high rate of Polymorphism in tribe than observed in previous studies. Even inside the general grouping, a distinct discrepancy has been recorded reagarding papillae distribution and significant for systematic delimitation. For example in genus Acacia and Lhythrus large papilleae are observed wheras in genus Sophara generally small papilleae noticed. The characteristics testa features observed Pueraria tuberosa make it distinct from rest of the studied vetch taxa. These findings are in harmony with the earlier study of smykal et.al (2014) . The members of Vicia are distinct from rest of genera in Vicieae by bearing small papilleae. The presence of a characteristics striate testa pattern in Sophora mollis can prove helpful since taxonomic ambiguities exist in this genus and its addition and elimination from Vicieae is debatable till now.

Javadi and Yamaguchi,(2004) documented three different types of sculpturing patterns (tuberculate, granulate-pappilate & reticulate) in thirteen species of genus Astragalus. This study also describes that Astragalus displayed significant seed morphological features distinctive from rest of genera in Vicieae. Similar findings were reported on monotypic genus Astragalus by Kupicha,(1977). The common sculpturing pattern is illustrated by presence of elongated cells in majority of Plant species but disparity observed in epidermal cells shape as well as density provides additional data important for identification and classification of the taxa. In Vicieae radiate-wavy cells are observed generally on seed surface while some species such as Arachis hypagae, Astragalus psilocentros, Astragalus scoripiurus, are noticed with curved, irregular, and round shaped cells respectively. The degree of differentiation exhibited by species in testa cells possibly reveals their characteristics configuration pattern (smykal et.al,2014). The variation observed in seed morphological features in this study may prove helpful at species, genus and tribe level.

Conclusion & Future Recommendations

Conclusion

This is the first comprehensive documentation with respect to taxonomic characteristics (LM & SEM) of floral diversity of 103 species belonging to 15 families from Potohar-Plateau Pakistan. It is concluded from this study that palynological, Seed micromorphological features are very helpful in the identification and delimitation of flora of Potohar Plateau.

Palynology

The Pollen attributes of the 103 species were helpful in the comparison among the species, the statistical analysis revealed significant information about the resemblance among the species. Asteraceae was the most dominating family representing 29 species revealed different types of exine stratification such as smooth sparsely granulate, scabrate-spinolose, micro-spinolose, micro-spinolose perforate, meta-reticulate, nano-spinulate, granulate-spinulose perforate, and granulate-perforate echinate. Exine thickness was highest in *Biden psilosa* 2.17um and lowest in *Eclipta prostrate* 0.65um. Taxonomic keys were constructed based on findings that highlight the importance of the micromorpholgical ultrastructural diversity of Pollen.

Seed Morphology

The Present study has revealed that utilization of SEM proved to be a significant attribute in the study of seed morphology of family Asteraceae and Fabaceae as SEM exposed the surface sculpture pattern and epicuticular projection types of Seeds. Previously, surface sculpture pattern of Seeds was given less or no importance but present studied showed that major variations among the studied Asteraceous and Fabaceous species was observed for surface pattern and epicuticular projection types of Seeds. Hence the present study offers valuable diagnostic characters for morphological characterization of Seeds. Moreover, use of advance microscopic techniques is recommended to study internal features of Seeds, as it can be helpful to establish phylogenetic relationship among the taxa of Asteraceae and Fabaceae.

Future Recommendations

- The establishment of district based regional floras is immediately required in Potohar Plateau for Eco-taxonomist, botanist and herbalist to protect the potohar Plateau biodiversity of plants for sustainable utilization.

- Necessary to conserve the plant resources of Potohar plateau and to document the associated indigenous knowledge for the welfare of mankind.
- The relationship of different species and genera of the selected family may be explained by phylogenetic studies in future in Potohar Plateau.
- Awareness program at gross root level should be introduced in the potohar plateau to educate the local people. There is a need to provide technical assistance and training for proper and sustainable collection of Plants.
- Efforts are required to identify the endemic, endangered and threatened flora of potohar plateau in order to highlight the ways of their conservation.
- It is suggested that endangered plants of Potohar Plateau may be cultivated and promoted through the In Situ and Ex situ practices.

References

- Abbasvand, E., S. Hassannejad, J. Shafagh-Kolvanagh and S. Zehtab Salmasi. 2014. Altitude and soil properties affected grassland and weed distribution. J. Biodiv. Environ. Sci., 4: 231-235.
- Adler, P.B. and J.M. Levine. 2007. Contrasting relationships between precipitation and species richness in space and time. Oikos, 116: 221-232.
- Ahmad, I., M.S.A. Ahmad, M. Hussain, M. Ashraf, M.Y. Ashraf and M. Hameed. 2010. Spatiotemporal aspects of plant community structure in open scrub rangelands of submountainous Himalayan plateaus. Pak. J. Bot., 42: 3431-3440
- Amir, S., & GILANI, A. (2019). Floral diversity of Balkassar, District Chakwal Pakistan. *FUUAST Journal of Biology*, *9*(2), 185-193.
- Ara, T., Nisa, W. U., Aziz, R., Rafiq, M. T., Gill, R. A., Hayat, M. T., & Afridi, U. (2021). Health risk assessment of hexachlorocyclohexane in soil, water and plants in the agricultural area of Potohar region, Punjab, Pakistan. *Environmental Geochemistry and Health*, *43*(9), 1-17.
- Ashraf, M. (2004). Impact Evaluation of water resources development in the command area of small dams, Pakistan Council of research in Water Resources (PCRWR), Islamabad.
- Aslam, S., Rafi, M. A., & Zia, A. (2017). Non-Apis bees of family Apidae (Hymenoptera) from Potohar region of Pakistan. *J. Entomol. Zool. Stud*, *5*(2), 6-12.
- Bijlsma, R. and V. Loeschcke. 2005. Environmental stress, adaptation and evolution: an overview. J. Evol. Biology, 18: 744-749.
- Bodlah, I., Amjad, M., Bodlah, M. A., & Qayyum, A. (2016). First record of two genera of Anthophorini and one genus of Melectini (Apinae: Apidae: Hymenoptera) from Pothwar Punjab, Pakistan.
- Chang, D., F.Y. Yang, J.J. Yan, Y.Q. Wu, S.Q. Bai, X.Z. Liang, Y.W. Zhang and Y.M. Gan. 2012. SRAP analysis of genetic diversity of nine native populations of wild sugarcane, Saccharum spontaneum, from Sichuan, China. Gen. Mol. Res., 11: 1245-53
- Charrier, G., M. Pramsohler, K. Charra-Vaskou, M. Saudreau, T. Ameglio, G. Neuner and S. Mayr. 2015. Ultrasonic emissions during ice nucleation and propagation in plant xylem. New Phytologist, 207: 570-578.

- Chaudhry, A. A., Hameed, M. A. N. S. O. O. R., Ahmad, R., & Hussain, A. N. W. A. R. (2001). Phytosociological studies in Chhumbi Surla wildlife sanctuary, Chakwal, Pakistan II. Phytoecology. *International Journal of Agriculture and Biology*, *3*(4), 369-374.
- Chaudhry, A.A., M. Hameed, R. Ahmad and A. Hussain. 2001. Phytosiciology of Chhumbi-Surla wildlife sanctuary, Chakwal, Pakistan. I. Species Diversity. Int. J. Agri. Biol., 3: 363-368
- Dawe, G. S., Schantz, J. T., Abramowitz, M., Davidson, M. W., & Hutmacher, D. W. (2006). Light microscopy. *Techniques in Microscopy for Biomedical Applications*, *2*(9).
- Dutra, F. V., & Gasparino, E. C. (2018). Pollen morphology of Rutaceae from Brazilian forest fragments. *Palynology*, *42*(1), 43-54.
- Faiz, A. H., FI-Abbas, Z., Zahra, M. M. L., & Safder, L. (2015). SMALL MAMMALS'DIVERSITY OF SELECTED VILLAGES OF POTHWAR (PUNJAB), PAKISTAN. *J. Anim. Pl. Sci*, *25*(3 Suppl), 441-445.
- GoP (2006). District Censes Report, Population Censes Organization, Federal Bureau of Statistics, Islamabad, Pakistan. PARC (1980). Agro-Ecological Regions of Pakistan, Pakistan Agricultural Research Council, Islamabad.
- Goulet, H., & Huber, J. T. (1993). *Hymenoptera of the world: and identification guide to families* (No. 595.79 G8).
- Guimarães, J. T. F., Carreira, L. M. M., Alves, R., e Souza Filho, P. W. M., Giannini, T. C., Macambira, H. J. & Rodrigues, T. M. (2018). Pollen morphology of the Poaceae: implications of the palynological and paleoecological records of the southeastern Amazon in BrazilJ. TF GUIMARÃES ET AL. PALYNOLOGY. *Palynology*, *42*(3), 311-323.
- Hameed, M., N. Naz, M.S.A. Ahmad, Islam-ud-Din and A. Riaz. 2008. Morphological adaptations of some grasses from the Salt Range, Pakistan. Pak. J. Bot., 40: 1571-1578.
- Hameed, M., Naz, N., Ahmad, M. S. A., Shazad, I., & Riaz, A. (2008). Morphological adaptations of some grasses from the salt range, Pakistan. *Pak. J. Bot*, *40*(4), 1571-1578.

- Hasan Riaz, M. A., Mukhtar, T., Shah, M. K. N., & Malik, S. I.(2016) Incidence and distribution of begomoviruses from pothwar region of Pakistan. *J.Bio.Env.Sci*, 9(5),p.11-16.
- Hussain, N. (2011). Performance of sorghum varieties in potohar region. *Gomal University Journal of Research*, *27*(2), 26-30.
- Ijaz, S. S., Ahmad, S. (2006). New ideas for Potwar Agriculture, University of Arid Agriculture, Rawalpindi, Agri Overview www.pakissan.com.
- Kazmi, D. H., & Rasul, G. (2009). Early yield assessment of wheat on meteorological basis for Potohar region. *Pakistan Journal of Meteorology*, *6*(11), 73-87.
- Lenoir, J., J.C. Gegout, P.A. Marquet, P. De-Ruffray and H. Brisse. 2008. A significant upward shift in plant species optimum elevation during the 20th century. Sci., 320: 1768-71.
- Li, L., M. Rutlin, V.E. Abraira, C. Cassidy, L. Kus, S. Gong, M.P. Jankowski, W. Luo, N. Heintz, H.R. Koerber, C.J. Woodbury and D.D. Ginty. 2011. The functional organization of cutaneous low-threshold mechanosensory neurons. Cell, 147: 1615-1627.
- Mahmood, T., R. Hussain, N. Irshad, F. Akrim and M.S. Nadeem. 2012. Illegal mass killing of Indian pangolin (*Manis crassicaudata*) in Potohar region, Pakistan. Pak. J. Zool., 44: 1457-61.
- Nawaz, T., M. Hameed, M. Ashraf, F. Ahmad, M.S.A. Ahmad, M. Hussain, I. Ahmad, A. Younis and K.S. Ahmad. 2012. Diversity and conservation status of economically important flora of the Salt Range, Pakistan. Pak. J. Bot., 44: 203-211.
- Noor, M. J., & Kalsoom, U. (2011). Ethnobotanical studies of selected plant species of Ratwal village, district Attock, Pakistan. *Pak J Bot*, *43*(2), 781-786.
- PARC (1980), Agro ecological regions of Pakistan, Pakistan Agricultural Research Council, Islamabad
- Parmesan, C. 2006. Ecological and evolutionary responses to recent climate change. Annu. Rev. Ecol. Syst., 37: 637-669.
- Qureshi, R., Waheed, A., Arshad, M., & Umbreen, T. (2009). Medico-ethnobotanical inventory of tehsil Chakwal, Pakistan. *Pak J Bot*, *41*(2), 529-38.

- Rashid, K., & Rasul, G. (2011). Rainfall variability and maize production over the Potohar Plateau of Pakistan. *Pakistan Journal of Meteorology*, *8*(15), 63-74.
- Shahzad, K., Zafar, M., Khan, A. M., Mahmood, T., Abbas, Q., Ozdemir, F. A., & Sultana, S. (2022). Characterization of anatomical foliar epidermal features of herbaceous flora of Tilla Jogian, Pakistan by using light microscopy techniques. *Microscopy Research and Technique*, *85*(1), 135-148.
- Song, J. H., & Hong, S. P. (2021). A taxonomic revision of the genus Sorbaria (Rosaceae) with a new infrageneric classification based on morphology, micromorphology, and palynology. *Phytotaxa*, *487*(1), 1-25.
- Tariq, A., Riaz, I., Ahmad, Z., Yang, B., Amin, M., Kausar, R., & Rafiq, M. (2020). Land surface temperature relation with normalized satellite indices for the estimation of spatio-temporal trends in temperature among various land use land cover classes of an arid Potohar region using Landsat data. *Environmental Earth Sciences*, *79*(1), 1-15.
- Vernon-Parry, K. D. (2000). Scanning electron microscopy: an introduction. *III-Vs Review*, *13*(4), 40-44.
- Vitasse, Y., A.J. Porté, A. Kremer, R. Michalet and S. Delzon. 2009. Responses of canopy duration to temperature changes in four temperate tree species: relative contributions of spring and autumn leaf phenology. Oecologia, 161: 187-198.
- Wang, A. B., Tan, D. Y., Baskin, C. C., & Baskin, J. M. (2010). Effect of seed position in spikelet on life history of Eremopyrum distans (Poaceae) from the cold desert of north-west China. *Annals of Botany*, *106*(1), 95-105.
- Wilson, K., R.L. Pressey, A. Newton, M. Burgman, H. Possingham and C. Weston. 2005. Measuring and incorporating vulnerability into conservation planning. Environmental management, 35: 527-43.
- Wortley, A. H., Blackmore, S., Chissoe, W. F., & Skvarla, J. J. (2012). Recent advances in Compositae (Asteraceae) palynology, with emphasis on previously unstudied and unplaced taxa. *Grana*, *51*(2), 158-179.
- Abid, R., Qaiser, M., 2004. A micromorphological study for the generic delimitation of Inula L.(s. str.) and its allied genera (Inuleae-Compositae) from Pakistan and Kashmir. *Pakistan Journal of Botany*. 36, 719-724.

- Ahmad, M., Bano, A., Zafar, M., Khan, M.A., Jamshed, I.C., Sultana, S., 2013. Pollen morphology of some species of the family Asteraceae from the alpine zone, Deosai Plateau, northern Pakistan. *Palynology*. 37, 189-195.
- Akinnubi, F.M., Akinloye, A.J., Oladipo, O.T., 2014. Pollen Grain Morphology Of Some Selected Species Of Asteraceae In South Western Nigeria. *Research In Plant Biology*,4.
- Akyalcin, H., Arabaci, T., Yildiz, B., 2011. Pollen morphology of six Achillea L. sect. Achillea (Asteraceae) species in Turkey. *Turkish Journal of Botany*. 35, 183-201.
- Ashfaq, S., Ahmad, M., Zafar, M., Sultana, S., Bahadur, S., Ahmed, S. N., & Nazish, M. (2020). Pollen morphology of family Solanaceae and its taxonomic significance. *Anais da Academia Brasileira de Ciências*, 92.
- Blackmore, S., Wortley, A., Skvarla, J., Robinson, H., 2009. Evolution of pollen in Compositae. Systematics, evolution, and biogeography of compositae. Sheridan Books Inc, Ann Arbor, Michigan. 101-130.
- Bolick, M.R., 1978. Taxonomic, Evolutionary, and Functional Considerations Ofcompositae Pollen Ultrastructure and Sculpture. *Plant Systematics and Evolution*, 130, 209-218.
- Bremer, K., 1987. Tribal Interrelationships of the Asteraceae. *Cladistics*, 3, 210-253.
- Bülbül, A.S., Tarikahya-Hacioğlu, B., Arslan, Y., Subaşi, İ., 2013. Pollen Morphology Of Carthamus L. Species In Anatolian Flora. *Plant Systematics And Evolution*, 299, 683-689.
- Butt, M. A., Zafar, M., Ahmad, M., Sultana, S., Ullah, F., Jan, G., & Naqvi, S. A. Z. (2018). Morpho-palynological study of Cyperaceae from wetlands of Azad Jammu and Kashmir using SEM and LM. *Microscopy Research and Technique*, 81(5), 458-468.
- Caramiello, R., & Fossa, V. (1994). Palynological Italian flora: Morphopalynological cards, S216: Artemisia borealis Pallas: Artemisia compestris L: S246: Artemisia scoparia W. et K. (Compositae) of acetolyzed pollen. *Allionia*, 32, 27–38.

- Clark, W.D., Brown, G.K., Mayes, R.A., 1980. Pollen morphology of Haplopappus and related genera (Compositae-Astereae). *American Journal of Botany*. 1391-1393.
- Coutinho, A. P., Silveira, P., Pita, C., Santos, M. J., Saraiva, C., & Perpétuo, N. C. (2021). Pollen morphology of Xanthium L.(sl)(Asteraceae, Asteroideae, Heliantheae, Ambrosiinae) in the Iberian Peninsula-a palynotaxonomic approach to a poisonous, allergenic and invasive genus. *Grana*, 60(1), 35-56.
- Dauti, A., Kapidani, G., Pupuleku, B., Kallajxhiu, N., Jançe, A., Turku, S., 2017. Palynomorphological Data of Some Species of the Genus Achillea. *Academic Journal of Interdisciplinary Studies*. 5, 74.
- Dematteis, M., Pire, S.M., 2008. Pollen morphology of some species of Vernonia sl (Vernonieae, Asteraceae) from Argentina and Paraguay. *Grana*. 47, 117-129.
- d'Urville, J.S.C.D., 1835. Voyage pittoresque au tour du monde, 2: resumé général des voyages de découvertes. L. Teuré.
- Erdtman, G. 1952. Pollen Morphology and Plant Taxonomy. Angiosperms. Almqvist and Wiksell, Stockholm.
- Farco, G.E., Dematteis, M., 2017. Pollen morphology and its relation with meiotic irregularities in ten species of Campuloclinium (Eupatorieae, Asteraceae). *Grana*. 56, 339-350.
- Funk, V.A., 2009. Systematics, evolution, and biogeography of Compositae. *International Association for Plant Taxonomy*.
- Garnatje, T., Martin, J., 2007. Pollen studies in the genus Echinops L. and Xeranthemum group (Asteraceae). *Botanical journal of the Linnean Society*. 154, 549-557.
- Hayat, M.Q., Khan, M.A., Ashraf, M., Jabeen, S., 2009. Ethnobotany of the genus Artemisia L. (Asteraceae) in Pakistan. *Ethnobotany Research and Applications*. 7, 147-162.
- Jafari, E., Ghanbarian, G., 2007. Pollen morphological studies on selected taxa of Asteraceae. *Journal of Plant Sciences*. 2, 195-201.
- KHAN, A. (2006). Palynological observations on the genus Calendula (Calenduleae-Compositae) from Pakistan. *Pak. J. Bot*, 38(3), 511-520.

- Mbagwu, F. N., Chime, E. G., & Unamba, C. I. N. (2007). Palynological studies of five species of Asteraceae. *Life Science Journal*, 5(1), 46–49.
- Mbagwu, F. N., Chime, E. G., & Unamba, C. I. N. (2009). Palynological studies on five species of Asteraceae. *African Journal of Biotechnology*, 8(7), 1222–1225.
- Mbagwu, F., Chime, E., Unamba, C., 2009. Palynological studies on five species of Asteraceae. *African Journal of Biotechnology*. 8.
- Meo, A., Khan, M., 2004a. Pollen morphology as an aid to the identification of Scorzonera (Cichorieae-Compositae) from Pakistan. *Pakistan Journal of Botany*. 36, 701-710.
- Meo, A.A., Khan, M.A., 2003. Pollen morphology of Achillea (Compositae-Anthemoideae). *Pakistan Journal of Weed Science Research*. 9,253-258.
- Meo, A.A., Khan, M.A., 2004b. Palynological studies of some weeds of Asteraceae from Pakistan. *Pakistan Journal of Weed Science Research* (Pakistan).
- Mumtaz, A. S., Khan, M. A., & Tanweer, A. (2000). Palynological studies of Artemisia Linn. From Murree and Hazara. *Pakistan Journal of Forestry*, 50(1/2), 57–65.
- Adedeji, O. (2005). Pollen morphology of the three species of the genus Emilia Cass.(Asteraceae) from Nigeria. *Thaiszia Journal of Botany*, 15, 1-9
- Osman, A. K. E. D. (2011). Pollen morphology of tribes Gnaphalieae, Helenieae, Plucheeae and Senecioneae (subfamily Asteroideae) of Compositae from Egypt. *American Journal of Plant Sciences*, 2(02), 120–133.
- Ozmen, E., Kizilpinar, I., Ozudogru, B., Dogan, C., Erik, S., 2009. Pollen morphology of some taxa of aromatic genus Tanacetum L.(Asteraceae). *Fabad Journal of Pharmaceutical Sciences*. 34, 1-11.
- Perveen, A., Qaiser, M., 1999. Pollen Flora of Pakistan-XV Geraniaceae. *Turkish Journal of Botany*. 23, 263-270.
- Qureshi, S., Khan, M., Arshad, M., Rashid, A., Ahmad, M., 2009. Pollen fertility (viability) status in Asteraceae species of Pakistan. *Trakia Journal of Sciences*. 7, 12-16.

- Rigamoto, R.R., Tyagi, A.P., 2002. Pollen fertility status in coastal plant species of Rotuma Island. *The South Pacific Journal of Natural and Applied Sciences*. 20, 30-33.
- Ronald, O. K. (2000). Pollen and spores. American Association of Stratographic Palynologists, edn, 2, 13-21.
- Skvarla, J., Turner, B., Patel, V., Tomb, A.S., 1977. Pollen morphology in the Compositae and in morphologically related families. Heywood, V, H., Harborne, J, B., Turner, B, L ed (s). The Biology and chemistry of the Compositae 1.
- Skvarla, J., Turner, B., Patel, V., Tomb, A.S., 1977. Pollen morphology in the Compositae and in morphologically related families. Heywood, V, H., Harborne, J, B., Turner, B, L ed (s). *The Biology and chemistry of the Compositae* 1.
- Stix, E., 1960. Pollen morphologische untersuchungen an Compositen. *Grana*. 2, 41-104.
- Tellería, M.C., 2017. Spines vs. microspines: an overview of the sculpture exine in selected basal and derived Asteraceae with focus on Asteroideae. *Journal of Plant Research*. 1-11.
- Tomb, A.S., Larson, D.A., Skvarla, J.J., 1974. Pollen morphology and detailed structure of family Compositae, tribe Cichorieae. I. Subtribe Stephanomeriinae. *American Journal of Botany*. 486-498.
- Urtubey, E., Tellería, Ma.C., 1998. Pollen morphology of the subfamily Barnadesioideae (Asteraceae) and its phylogenetic and taxonomic significance. *Review of Palaeobotany and Palynology*. 104, 19-37.
- Wodehouse, R.P., 1935: Pollen grains. Mcgraw-Hill Book Company, Inc; New York; London.
- Wróblewska, A., Stawiarz, E., Masierowska, M., 2016. Evaluation of Selected Ornamental Asteraceae As A Pollen Source For Urban Bees. *Journal Of Apicultural Science*, 60, 179-192.
- Zafar, M., Ahmad, M., Khan, M., 2007. Palynology of family Asteraceae from flora of Rawalpindi-Pakistan. *International Journal of Agriculture and Biology*. 9, 156-161.

- Zhang, Y., Fountain, D., Hodgson, R., Flenley, J., Gunetileke, S., 2004. Towards Automation Of Palynology 3: Pollen Pattern Recognition Using Gabor Transforms And Digital Moments. *Journal Of Quaternary Science*, 19, 763-768.
- Adedeji, O., Pollen morphology of the three species of the genus Emilia Cass. (Asteraceae) from Nigeria, *Thaiszia – J. Bot*., 2005, vol. 15, pp. 1 – 9.
- Ahmad, M., Ali, M., Zafar, M., Sultana, S., Majeed, S., Yaseen, G., and Ahmad, S., Palynological Diversity of Melliferous flora around Apiaries from District Mardan Khyber Pakhtunkhwa-Pakistan, *The Botanical Review*, 2021, pp. 1-34.
- Ahmad, M., Bano, A., Zafar, M., Khan, M. A., Chaudhry, M. J. I., and Sultana, S., Pollen morphology of some species of the family asteraceae from the alpine zone, Deosai Plateau, northern Pakistan, *Palynology*, 2013, vol. 37(2), pp. 189-195.
- Ahmad, S., Zafar, M., Ahmad, M., Lubna, Yaseen, G., Sultana, S., Microscopic investigation of palyno-morphological features of melliferous flora of Lakki Marwat district, Khyber Pakhtunkhwa, Pakistan, *Microscopy Research and Technique*, 2019, vol. 82(6), pp. 720-730.
- Ahmad, S., Zafar, M., Ahmad, M., Ozdemir, F. A., Yaseen, G., Sultana, S., & Kutlu, M. A., Palynological studies of winter weeds melliferous flora of district Bannu, Khyber Pakhtunkhwa, Pakistan, *Annali di Botanica*, 2020, vol. 10, pp. 77-86.
- Akinnubi, F. M., Akinloye, A. J., and Oladipo, O. T., Pollen grain morphology of some selected species of Asteraceae in South Western Nigeria, *Research in Plant Biology*, 2014., vol. 4(6), pp. 17-23
- Al-Tameme, H.J., Taxonomical Study Of The Genus Koelpinia Pallas (Asteraceae) In Iraq, *Journal Of Natural Sciences Research*, 2014., vol. 4, pp. 39-47.
- Ashfaq, S., Ahmad, M., Zafar, M., Sultana, S., Bahadur, S., Ahmed, S.N., Gul, S., and Nazish, M., Pollen morphology of family Solanaceae and its taxonomic significance, *Anais da Academia Brasileira de Ciências*, 2020, vol. 92(3), pp. e20181221
- Ayaz, S., Ahmad, M., Zafar, M., Ali, M.I., Sultana, S., Mustafa, M.R.U., Kilic, O., Çobanoğlu, D.N., Demirpolat, A., Ghani, A., and Afza, R., Taxonomic

significance of cypsela morphology in tribe Cichoreae (Asteraceae) using light microscopy and scanning electron microscopy, *Microscopy Research and Technique*, 2019, vol. 83(3), pp. 239-248.

- Bano, A., Ahmad, M., Khan, M.A., Zafar, M., Sultana, S., and Ullah, Z., Pollen morphology of four endemic species of Pedicularis L. from alpine zone of the Deosai Plateau, Himalayan range, Bangladesh *Journal of Plant Taxonomy*, 2012, vol. 19(1), pp.1-5.
- Bhutta, A.A., Palynological study of pollen and spores, *Horizon*., 1968., vol. 10, pp. 47-49.
- Blackmore, D. G., Golmohammadi, M. G., Large, B., Waters, M. J., and Rietze, R. L., Exercise increases neural stem cell number in a growth hormone-dependent manner, augmenting the regenerative response in aged mice, *Stem cells*, 2009., vol. 27(8), pp. 2044-2052.
- Blackmore, S., Palynology and intergeneric realtionships in subtribe Hyoseridinae (Compositae: Lactuceae), *Botanical Journal of the Linnean Society*, 1981., vol. 82, pp. 1–13.
- Blackmore, S., Palynology And Intergeneric Relationships In Subtribe Hyoseridinae (Compositae: Lactuceae), *Botanical Journal Of The Linnean Society*, 1981., vol. 82, pp. 1-13.
- Blackmore, S., Palynology of subtribe Scorzonerinae (Compositae: Lactuceae) and its taxonomic significance, *Grana*, 1982b., vol. 21, pp. 149–160.
- Blackmore, S., The Northwest European pollen flora 32. Compositae – Lactuceae, *Review of Palaeobotany and Palynology*, 1984., vol. 42, pp. 45–85.
- Butt, M. A., Zafar, M., Ahmad, M., Sultana, S., Ullah, F., Jan, G., and Naqvi, S. A. Z., Morpho-palynological study of Cyperaceae from wetlands of Azad Jammu and Kashmir using SEM and LM, *Microscopy Research and Technique*, 2018, vol. 81(5), pp. 458-468.
- Dawar, R., M. Qaiser and A. Perveen., Pollen morphology of Inula L., (s.str.) and allied genera (Inuleae – Compositae) from Pakistan and Kashmir, *Pak. J. Bot*., 2018, vol. 34(1), pp. 9-22.
- Díez, M.J., Mejías, J., Moreno-Socías, E., Pollen Morphology of Sonchus and Related Genera, and A General Discussion, *Plant Systematics and Evolution*, 1999, vol. 214, pp. 91-102.

- d'Urville, J. S. C. D.,Voyage pittoresque autour du monde: résumé général des voyages de découvertes de Magellan, Tasman, Dampier, 1835, (Vol. 2). Tenré.
- Gul, S., Ahmad, M., Zafar, M., Bahadur, S., Zaman, W., Ayaz, A., Shuaib, M., Butt, M.A., Ullah, F., Saqib, S., and Nizamani, M.M., Palynological characteristics of selected Lamioideae taxa and its taxonomic significance, *Microscopy Research and Technique*, 2021, vol. 84(3), pp.471-479.
- Hayat, M. Q., Ashraf, M., Khan, M. A., Yasmin, G., Shaheen, N., and Jabeen, S., Palynological study of the Genus Artemisia (Asteraceae) and its systematic implications, *Pak J Bot*., 2010, vol. 42(2), pp. 751-763.
- Jafari, E., and Ghanbarian, G. H., Pollen morphological studies on selected taxa of Asteraceae, *Journal of Plant Sciences*, 2007, vol. 2(2), pp.195-201.
- Jeffrey, C., Compositae: Introduction with Key to Tribes, *Families and Genera Of Vascular Plants*, 2007, vol. 8, pp. 61-87.
- Johnson, L. A., and Briggs, B. G., On the Proteaceae—the evolution and classification of a southern family, *Botanical journal of the Linnean Society*, 1975, vol. 70(2), pp. 83-182.
- Kayani, S., Hussain, M., Ahmad, M., Zafar, M., Sultana, S., Butt, M.A., Ali, S., Shah, G.M., and Mir, S., Scanning Electron Microscopy (SEM) and Light Microscopy (LM)-based Palyno-morphological views of Solanaceae in Western Himalaya, *Microscopy Research and Technique*, 2019, vol. 82, pp. 63–74.
- Khan, A.S., Ahmad, M., Gilani, S.A.A., Zafar, M., Butt, M.A., Birjees, M., Akhtar, W., Waheed, A., and Kaleem, M., Taxonomic implications of macro and micromorphological characters in the genus Brachythecium (Brachytheciaceae, Bryopsida) from the Western Himalayas: A combined light and scanning electron microscopic analysis, *Microscopy Research and Technique*, 2021, pp. 1-23.
- Khan, A.S., Ahmad, M., Zafar, M., Athar, M., Ozdemir, F.A., Gilani, S.A.A., Sultana, S., Ahmad, S., Butt, M.A., Majeed, S., and Khan, S.U., Morphological characterization of Hypnaceae (Bryopsida, Hypnales): Investigating four genera from Western Himalayas by using LM and SEM techniques, *Microscopy Research and Technique*, 2020, vol. 83(6), pp.676-690.
- Khan, S., Jan, G., Ahmad, M., Gul, F., Zafar, M., Mangi, J. U. D., and Majeed, S., (2021). Morpho-palynological assessment of some species of family

Asteraceae and Lamiaceae of District Bannu, Pakistan on the bases of light microscope & scanning electron microscopy, *Microscopy Research and Technique*, 2021, vol. 84(6), pp. 1220-1232.

- Majeed, S., Zafar, M., Ahmad, M., Kilic, O., Sultana, S., Raza, J., Yaseen, G., Gul, H., Mir, S., and Jabeen, M., Pollen morphological investigations of family Cactaceae and its taxonomic implication by light microscopy and scanning electron microscopy, *Microscopy Research and Technique*, 2021, vol. 83(7), pp. 767-777.
- Malik, N. A., Rehman, S. A., and Rahmat, A. J., Pollen morphology of some Pakistani medicinal plants, *Pak. J. Sci. IND. Res*, 1964, vol. 7, pp. 130-136.
- Meo, A.A., H.M.I. Hafiz., F. Baig., and N.A. Baig., Studies of pollen morphology of some Gramineous (Poaceae) species, *Sarhad J. of Agric*., 1988, vol. 4, pp. 99-103.
- Meo, A.A., H.M.I., Hafiz, F. Baig., Pollen grain description of 13-non-allergic and 4-allergic Graminaeceous (Poaceae) species, *J. Pure and Applied Sci*., 1989, vol. 8(2), pp. 19-26.
- Meo, A.A., Impact of pollen and inter-genetic crosses between Graminaceous (Poaceae) plants, *Pak. J. Biological Sci*., 1999, vol. 2(3), pp. 809-812.
- Mumtaz, A.S., M.A. Khan., and T. Akhtar., Palynological studies of Artemisia L., from Murree and Hazara, *Pak. J. Forestry*, 2000, vol. 50 (1-2), pp. 57-65.
- Nasreen, U., and M.A. Khan., Palynological studies of Matricaria chamomilla L., (Babuna) and its related genera, *Hamdard*., 1998, vol. 4, pp. 94-97.
- Perveen, A., and M. Qaiser., Pollen flora of Pakistan-Malvaceae, Grewioideae-LII, *Pak. J. Bot*., 2007, vol. 39, pp. 1-7.
- Perveen, A., Contributions to the Pollen Morphology of the Family Compositae, *Turkish Journal of Biology*, 1999, vol. 23, pp. 523-536.
- Pınar, N. M., and Dönmez, E. O., Pollen morphology of some Turkish endemic Helichrysum Gaertner species (Compositae), *Pakistan Journal of Botany*, 2000, vol. 32(2), pp. 295-301.
- Qureshi, S. J., Awan, A. G., Khan, M. A., & Bano, S., Palynological study of the genus Sonchus from Pakistan, *Journal of Biological Sciences*, 2002, vol. 2(2), pp. 98-105.

- Rigamoto, R. R., and Tyagi, A. P., Pollen fertility status in coastal plant species of Rotuma Island, *The South Pacific Journal of Natural and Applied Sciences*, 2002, vol. 20(1), pp. 30-33.
- Saddiqa, A., Pollen grains of Medical plants, *Pak. J. Sci. Ind. Res*., 1964, vol. 7, pp. 130.
- Wodehouse, R.P., Pollen Grains. Mcgraw-Hill Book Company, Inc; New York; London, 1935.
- Zafar, M., Ahmad, M., and Khan, M. A., Palynology of family Asteraceae from flora of Rawalpindi-Pakistan, *International Journal of Agriculture and Biology*, 2007, vol. 9(1), pp. 156-161.
- Zafar, M., Ahmad, M., Shah, G. M., Khan, A. M., Kilic, O., Yilmaz, E., and Ahmad, S., Application and implication of scanning electron microscopy for evaluation of palyno-morphological features of Vitaceae from Pakistan, *Microscopy Research and Technique*, 2021, vol. 84(4), pp. 608-617.
- Zahur, M.S., A.A. Bhutta., and M. Ashraf., 1975-78. Palynological studies of the a) plants growing in Punjab, b) seasonal variation in the frequencies of airborne pollen spores which cause allergies and asthma with species reference to "Central Punjab" Pakistan Science Foundation (PSF). Final Research Report.
- Abubakar, A., Falusi, O. A., Adebola, M. O., Olayemi, I. K., & Daudu, O. A. Y. (2019). Genetic diversity studies for morphological traits in pearl millet (Pennisetum glaucum L.) landraces of Northern Nigeria.
- Aftab, R., Perveen, A., 2006: A palynological study of some cultivated trees from Karachi. Pakistan Journal of Botany 38(1), 15-28.
- Ahmad, F., Khan, M. A., Ahmad, M., Zafar, M., Khan, A., & Iqbal, Z. (2011). Palynological studies in tribe Chlorideae (Poaceae) from salt range of Pakistan. African Journal of Biotechnology, 10(44), 8909-8913.
- Ahmad, F., Khan, M.A., Ahmad, M., Hameed, M., Tareen, R.B., Zafar, M., Jabeen, A. 2011. Taxonomic application of foliar anatomy in grasses of tribe Eragrostideae (poaceae) from salt range of Pakistan. Pakistan Journal of Botany. 43(5): 2277-2284.
- Ahmad, M., Bano, A., Zafar, M., Khan, M.A., Chaudhary, M.J.I., Sultana, S. 2013.Pollen morphology of some species of the Family Asteraceae from the Alpine Zone, Deosai Plateau, northern Pakistan, Palynology. 37 (2), 189-195.

- Ahmad, S., Zafar, M., Ahmad, M., Ali, M.I., Sultana, S., Rashid, N., Butt, M.A., Shah, S.N., Ozdemir, F.A., Kutlu, M.A. and Afza, R., 2020. Seed morphology using SEM techniques for identification of useful grasses in Dera Ghazi Khan, Pakistan. Microscopy Research and Technique, 83(3), pp.249-258.
- Ali, Q., Ahsan, M., Ali, F., Aslam, M., Khan, N. H., Munzoor, M., & Muhammad, S. (2013). Heritability, heterosis and heterobeltiosis studies for morphological traits of maize (Zea mays L.) seedlings. Advancements in Life sciences, 1(1).
- Amina, H., Ahmad, M., Bhatti, G. R., Zafar, M., Sultana, S., Butt, M. A., Bahadur, S., Haq, I. U., Ghufran, M. A., Ahmad, S., Ashfaq, S., 2020:. Microscopic investigation of pollen morphology of Brassicaceae from Central Punjab-Pakistan. Microscopy Research and Technique 83(4), 446-454.
- Andersen, T. S., Bertelsen, F., 1972: Scanning electron microscope studies of pollen of cereals and other grasses. Grana 12(2), 79-86.
- Arshad, M., Ashraf, M. Y., Ahmad, M., & Zaman, F. (2007). Morpho-genetic variability potential of Cenchrus ciliaris L., from Cholistan desert, Pakistan. Pak. J. Bot, 39(5), 1481-1488.
- Ashfaq, S., Ahmad, M., Zafar, M., Sultana, S., Bahadur, S., Ahmed, S.N., Gul, S. and Nazish, M., 2020. Pollen morphology of family Solanaceae and its taxonomic significance. Anais da Academia Brasileira de Ciências, 92(3).
- Bahadur, S., Ahmad, M., Zafar, M., Sultana, S., Begum, N., Ashfaq, S., Gul, S., Khan, M.S., Shah, S.N., Ullah, F., Saqib, S., 2019: Palyno-anatomical studies of monocot taxa and its taxonomic implications using light and scanning electron microscopy. Microscopy research and technique 82(4), 373-393.
- Bashir, S., Khan, M. A., 2003: Pollen morphology as an aid to the identification of medicinal plants: Trianthema portulacastrum L., Boerhaavia procumbens banks ex Roxb., and Alternanthera pungens Kunth. Hamdard Medicus XLVI, 7–10.
- Behre, K. E., 2007: Evidence for Mesolithic agriculture in and around central Europe?. Vegetation History and Archaeobotany 16(2), 203-219.
- Boldrini II, Longhi-Wagner HM, Boechat SC., 2005: Morfologia de taxonomia de gramíneas sul-rio-grandenses. Porto Alegre: UFRGS Editora Botany 44, 747-756.

- Bush, M. B., 2002: On the interpretation of fossil Poaceae pollen in the lowland humid neotropics. Palaeogeography, palaeoclimatology, palaeoecology 177(1-2), 5-17.
- Butt, M. A., Zafar, M., Ahmad, M., Sultana, S., Ullah, F., Jan, G., Irfan, A., Naqvi, S. A. Z., 2018: Morpho-palynological study of Cyperaceae from wetlands of Azad Jammu and Kashmir using SEM and LM. Microscopy Research and Technique 81(5), 458-468.
- Carlo, D., Paula, R., 2004: New insights into pollen evolution. International Journal of Plant sciences 164, 835.
- Chase A, Sendulsky T., 1991: Primeiro livro das gramíneas: Noções sobre a estrutura com exemplos da flora brasileira. São Paulo: Instituto de Botânica.
- Chaturvedi, M., & Datta, K. (2001). Pollen morphology in saccharum l.(poaceae)—wild and cultivated sugar cane species: With one figure and one table. Feddes Repertorium, 112(5-6), 387-390.
- Chaturvedi, M., Datta, K., 2001: Pollen morphology in Saccharum l.(Poaceae)—wild and cultivated sugar cane species: With one figure and one table. Feddes Repertorium 112(5-6), 387-390.
- Chaturvedi, M., Datta, K., Nair, P.K.K., 1998: Pollen morphology of Oryza (Poaceae). Grana 37, 79–86
- Chaturvedi, M., Yunus, D., Datta, K., 1994: Pollen morphology of Sorghum Moench-Sections Eu-sorghum and Para-sorghum. Grana 33,117–123.
- Chaudhry, M. S., Saeed, M., Khan, A. A., Sial, N., & Jamil, M. (2012). Morphological diversity of arbuscular mycorrhiza colonizing two aromaic grasses veteviria zizanioides and cymbopogon jwarancusa. Pak. J. Bot, 44(4), 1479-1485.
- Chemisquy, M. A., Giussani, L. M., Scataglini, M. A., Kellogg, E. A., & Morrone, O. (2010). Phylogenetic studies favour the unification of Pennisetum, Cenchrus and Odontelytrum (Poaceae): a combined nuclear, plastid and morphological analysis, and nomenclatural combinations in Cenchrus. Annals of botany, 106(1), 107-130.
- Clayton, W. D., Renvoize, S. A., 1986: Genera Gramineum, Grasses of the World. Kew bulletin additional series 13, Royal Botanic gardens Kew.p:389.

- Corrêa, A.M.S., Guimarães, M.I.T.M., Cruz-Barros, M.A.V., Begale, F.F., 2005: Flora polínica da Reserva do Parque Estadual das Fontes do Ipiranga (São Paulo, Brasil), Família: 176 – Poaceae (Gramineae). Hoehnea 32, 269–282.
- Datta, K., Chaturvedi, M., 2004: Pollen morphology of Basmati cultivars (Oryza sativa race Indica) – exine surface ultrastructure. Grana 43, 89–93.
- Dorea, M.C., 2011: Morfologia polınica, fenologia reprodutiva e biologia floral de especies florestais de Poaceae [PhD Thesis]. Feira de Santana: Universidade Federal de Feira de Santana; 166 p.
- Erdtman, G., 1952: Pollen Morphology and Plant Taxonomy. Angiosperms. Chronica.
- Fægri, K., Iversen, J., 1964: Textbook of pollen analysis. Copenhagen: Munksgaard.
- Firbas, F., 1937: Der pollen analytische Nachweis des Getreidebaus. Österreichische Botanische Zeitschrift 31, 447-478.
- Fischer, H.J., 1890: Beitrag zur vergleichenden. Morphological der Pollen Koner Bresien. Thesis.
- Forey, E., Coulibaly, S. F., & Chauvat, M. (2015). Flowering phenology of a herbaceous species (Poa annua) is regulated by soil Collembola. Soil Biology and Biochemistry, 90, 30-33.
- Galera, H., Chwedorzewska, K. J., & Wódkiewicz, M. (2015). Response of Poa annua to extreme conditions: comparison of morphological traits between populations from cold and temperate climate conditions. Polar Biology, 38(10), 1657-1666.
- Gamble, J. S., 1934: Flora of the Presidency of Madras. Part 10. Gramineae. Flora of the Presidency of Madras. Part 10. Gramineae.
- Good, R., 1953: The geography of the flowering plants. 2nd ed Longmans, Green & Co., Ltd., London.
- Gould, F. W., 1969: Grass Systematics. Mc. Graw. Hill book company, New York. pp. 40 – 41.
- Guimarães, J. T. F., Carreira, L. M. M., Alves, R., Martins e Souza Filho, P. W., Giannini, T. C., Macambira, H. J., & Rodrigues, T. M. (2018). Pollen morphology of the Poaceae: implications of the palynological and

paleoecological records of the southeastern Amazon in Brazil. Palynology, 42(3), 311-323.

- Gul, S., Ahmad, M., Zafar, M., Bahadur, S., Sultana, S., Ashfaq, S., Ullah, F., Kilic, O., Hassan, F. U., Siddiq, Z., 2019:. Foliar epidermal anatomy of Lamiaceae with special emphasis on their trichomes diversity using scanning electron microscopy. Microscopy research and technique 82(3), 206-223.
- Gul, S., Ahmad, M., Zafar, M., Bahadur, S., Zaman, W., Ayaz, A., Shuaib, M., Butt, M.A., Ullah, F., Saqib, S. and Nizamani, M.M., 2021. Palynological characteristics of selected Lamioideae taxa and its taxonomic significance. Microscopy Research and Technique, 84(3), pp.471-479.
- Harman, H. H., 1976: Modern factor analysis. University of Chicago press.
- Harun, N., Shaheen, S., Ahmad, M., & Shahid, M. N. (2020). Light and scanning electron microscopy-based foliar micro morphological tools for the identification of fodder grass taxa. Microscopy research and technique, 83(8), 953-978.
- Hussain, A. N., Zafar, M., Ahmad, M., Khan, R., Yaseen, G., Khan, M. S., Shaheen, S. 2018. Comparative SEM and LM foliar epidermal and palyno-morphological studies of Amaranthaceae and its taxonomic implications. Microscopy Research and Technique. 81(5): 474-485.
- Jianxiu, L., Aigui, G., & Hailin, G. (2003). Morphological variation and types of Cynodon dactylon. Acta Prataculturae Sinica, 12(6), 99-104.
- Joly, C., Barillé, L., Barreau, M., Mancheron, A., Visset, L., 2007: Grain and annulus diameter as criteria for distinguishing pollen grains of cereals from wild grasses. Review of Palaeobotany and Palynology 146(1-4), 221-233.
- Jones, R., 1999: The Biogeography of the grasses and low grasslands of South eastern Australia. Indigenous Flora and Fauna Association 11–16.
- Khan, A., Vijay, R., Singaravelu, D. L., Sanjay, M. R., Siengchin, S., Verpoort, F., & Asiri, A. M. (2019). Extraction and characterization of natural fiber from eleusine indica grass as reinforcement of sustainable fiber-reinforced polymer composites. Journal of Natural Fibers, 1-9.
- Khan, M.A., 1991: Cytotaxonomic studies in some species of Brachypodium P. Beauv. Pak. Phyton 3, 141-151.

- Khan, M.A., Stace, C.A., 1999: Breeding relationship in the genus Brachepodium (Poaceae). Nordic Journal of Botany 19, 257-269.
- Khan, R., Ul Abidin, S. Z., Mumtaz, A. S., Jamsheed, S., Ullah, H., 2017: Comparative leaf and pollen micromorphology on some Grasses taxa (Poaceae) distributed in Pakistan. International Journal of Nature and Life Sciences 1(2), 72-82.
- Kohler E, Lange E., 1979: A contribution to distinguishing cereal from wild grass pollen by LM and SEM. Grana 18, 133 -134.
- Kumar, C. A. S., Varadharajan, R., Muthumani, P., Meera, R., Devi, P., & Kameswari, B. (2010). Psychopharmacological studies on the stem of Saccharum spontaneum. International Journal of PharmTech Research, 2(1), 319-321.
- Lawrence, G.H.M., 1951: Taxonomy of vascular plants. Mc Millan Co. New York.
- Layton, D. J., & Kellogg, E. A. (2014). Morphological, phylogenetic, and ecological diversity of the new model species Setaria viridis (Poaceae: Paniceae) and its close relatives. American Journal of botany, 101(3), 539-557.
- Lindley, J., 1840: The genera and species of orchidaceous plants. Ridgways.
- Liu, Q., N.-X. Zhao., G. Hao., 2004: Pollen morphology of the Chloridoideae (Gramineae). Grana 43, 238-248
- Longhi-Wagner, H.M., Bittrich, V., Wanderley, M.G.L., Shepherd, G.J., 2001: Introdução. In: Wanderley MG, Shepherd GJ, Giulietti AM, eds. Flora fanerogâmica do estado de São Paulo, Volumen 1, 17–21. São Paulo: Editora Hucitec.
- Ma, G.H., Zhao, N.X., Hu, X.Y., 2001: Pollen morphology and poly-aperture in Paspalum. Journal of Tropical and Subtropical Botany 9, 201-204.
- Mabberley, D.I., 2008: The Plant Book Cambridge. Univ. Press, Cambridge, New York.
- Mander, L., Li, M., Mio, W., Fowlkes, C.C., Punyasena, S.W., 2013: Classification of grass pollen through the quantitative analysis of surface ornamentation and texture. Proceedings of the Royal Society B 280, 20131905.

- Mehra, K. L. (2015, February). Cytotaxonomic notes on the Dichanthium annulatum complex. In Proceedings of the Oklahoma Academy of Science (Vol. 38, pp. 22-25).
- Melhem, T.S., Cruz, M.A.V., Makino, H., Cristovam, M.A., 1983: Grãos de pólen de plantas alergógenas: Gramineae. Hoehnea 10, 9–32.
- Meo, A. A., 1999: Impact of pollen and intergenetic crosses between graminaceous (Poaceae) plants. Pakistan Journal of Biological Sciences 2(3), 809-812.
- Meo, A., Hafiz, H., Baig, I. M., 1989: Pollen grain description of 13 non allergic and four allergic Graminaceous species. Journal of Pure and Applied Sciences 8(2), 19-26.
- Mitra, S., S. K. Mukherjee., 2004: Ethnobotanical usages of Grasses by the tribals of West Dinajpur District, West Bengal. Indian Journal of Traditional Knowledge 4 (4), 396 – 402.
- Morgado, L. N., Gonçalves-Esteves, V., Resendes, R., & Ventura, M. A. M. (2015). Pollen morphology of Poaceae (Poales) in the Azores, Portugal. Grana, 54(4), 282-293.
- Morgado, L. N., Gonçalves-Esteves, V., Resendes, R., Ventura, M. A. M., 2015: Pollen morphology of Poaceae (Poales) in the Azores, Portugal. Grana 54(4), 282-293.
- Mseddi, K., Mnif, L., Chaieb, M., Neffati, M., & Roux, M. (2004). Aboveground phytomass productivity and morphological variability of Tunisian accessions of Cenchrus ciliaris L. African Journal of Range and Forage Science, 21(1), 49-55.
- Munawarti, A., Taryono, T., Semiarti, E., & Sismindari, S. (2014). Morphological And Biochemical Responses Of Saccharum Spontaneum L. Accessions To Drought Stress. Journal of Tropical Life Science, 4(1), 61-66.
- Nazir, A., Khan, M. A., Ahmad, F., Ullah, K., & Shah, A. (2013). Foliar epidermal studies as an aid to the identification of grasses of tribe Andropogoneae (Poaceae) from Potohar region of Pakistan. Pakistan Journal of Botany, 45(1), 235-241.

- Olivera, Y., Machado, R., Ramírez, J., del Pozo, P. P., & Castañeda, L. (2014). Morphological characterization of 19 Brachiaria brizantha accessions on an acid soil. Pastures and Forages, 7(2).
- Özler, H., E. Cabi, E. Us, M. Doğan., S. Pehlivan., 2009: Pollen morphology of Agropyron Gaertner in Turkey. Bangladesh Journal of Plant Taxonomy 16(1), 21-28.
- Perveen, A., 2006: A contribution to the pollen morphology of family Gramineae. World Applied Sciences Journal 1, 60–65.
- Perveen, A., Qaiser, M., 2012: Pollen Flora of Pakistan L.XIX. Poaceae. Pakistan Journal of Botany 44, 747-756.
- Radaeski, J.N., Bauermann, S.G., Pereira, A. B., 2016: Poaceae pollen from Southern Brazil: distinguishing grasslands (Campos) from forests by analyzing a diverse range of Poaceae species. Frontiers in Plant Science 7, 1833.
- Ronald, O.K., 2000: Pollen and spores. 2 nd Ed. American Association of Stratographic Palynologists 13-21.
- Sachdeva, S. K., & Kals, R. (1981). Cytologic, morphologic and chemotaxonomic studies inDactyloctenium aegyptium (L.) Beauv. complex. Proceedings: Plant Sciences, 90(3), 217-225.
- Salgado-Labouriau, M.L., Rinaldi, M., 1990: Palynology of Gramineae of the Venezuelan Mountains. Grana 29, 119–128.
- Saw, K. O. (2011). Morphological and Microscopical characters of Eleusine indica (L.) Gaertn. Universities Res J, 4(1), 225-244.
- Schuler, L., Behling, H. €., 2011a: Poaceae pollen grain size as a tool to distinguish past grasslands in South America: a new methodological approach. Vegetation History and Archaeobotany 20, 83–96.
- Schuler, L., Behling, H. €., 2011b: Characteristics of Poaceae pollen grains as a tool to assess palaeoecological grassland dynamics in South America. Vegetation History and Archaeobotany 20, 97–108.
- Shaheen, S., Ahmad, M., Khan, F., Zafar, M., Sultana, S., Khan, M. A., Fatima, H., 2011: Morpho-playnological and foliar epidermal anatomy of genus Cenchrus L. Journal of Medicinal Plants Research 5(16), 3796-3802.

- Shaheen, S., Ahmad, M., Khan, F., Zafar, M., Sultana, S., Khan, M. A., & Fatima, H. (2011). Morpho-playnological and foliar epidermal anatomy of genus Cenchrus L. Journal of Medicinal Plants Research, 5(16), 3796-3802.
- Siddiqui, T., M. Qaiser., 1988: A palynological study of the family Poaceae from Karachi. Pakistan Journal of Botany 20, 161-176.
- Simon, B.K., Clayton, W.D., Harman, K.T., Vorontsova, M., Brake, I., Healy, D., Alfonso, Y., 2011: GrassWorld, http://grassworld. myspecies.info/; accessed 21 April 2014.
- Singh, A. K., Singh, A. K., & Srivastava, M. K. (2017). Morphological Variations in Caryopses and Seedlings of Two Grass Species of the Genus Dactyloctenium Willd. Notulae Scientia Biologicae, 9(2), 301-306.
- Singh, S., Yadav, Y. P., Yadav, H. P., Vart, D., & Yadav, N. (2016). Morphological characterization of pearl millet hybrids [Pennisetum glaucum (L.) R. Br.] and their parents. African Journal of Agricultural Research, 11(5), 371-378.
- Skvarla, J.J., J.R. Rowley, V.C. Hollowell., W.F. Chissoe., 2003: Annulus–pore relationship in Poaceae (Poaceae) pollen: the pore margin of Pariana. American Journal of Botany 90, 924-930.
- Tellaria, M.C., 1991: Comparative palynological analysis of species of MedicagoL., Melilotus Mill and Trifolium L.(Leguminoseae) in the phytographic pampas region (Argentina). Industria Apicola 1, 4-13
- Tripathi, D. K., Chauhan, D. K., Kumar, D., & Tiwari, S. P. (2012). Morphology, diversity and frequency based exploration of phytoliths in Pennisetum typhoides Rich. National Academy Science Letters, 35(4), 285-289.
- Ullah, F., Zafar, M., Ahmad, M., Dilbar, S., Shah, S. N., Sohail, A., Tariq, A., 2018: Pollen morphology of subfamily Caryophylloideae (Caryophyllaceae) and its taxonomic significance. Microscopy Research and Technique 81(7), 704-715.
- Usma, A., Ahmad, M., Zafar, M., Ali, M. I., Kilic, O., Ozdemir, F. A., & Kalsoom, N. (2019). Taxonomic significance of caryopsis in subfamily Panicoideae (Poaceae) using scanning electron microscopy and light microscopy. Microscopy research and technique, 82(10), 1649-1659.

- Vigna, B. B. Z., Jungmann, L., Francisco, P. M., Zucchi, M. I., do Valle, C. B., & de Souza, A. P. (2011). Genetic diversity and population structure of the Brachiaria brizantha germplasm. Tropical Plant Biology, 4(3), 157-169.
- Wang, M., Zhang, J., Guo, Z., Guan, Y., Qu, G., Liu, J., & Yan, X. (2020). Morphological variation in Cynodon dactylon (L.) Pers., and its relationship with the environment along a longitudinal gradient. Hereditas, 157(1), 1-11.
- Wodehouse, R.P., 1935: Pollen grains. New York: McGraw-Hill.
- Zahoor, A., Ahmad, F., Naseer, M. H. M., Irum, N., 2019: Palynological features of medicinal plants from Salt Ranges of Pakistan. Journal of Environmental & Agricultural Sciences 21, 29-37.
- Abubakar, A., Falusi, O. A., Adebola, M. O., Olayemi, I. K., & Daudu, O. A. Y. (2019). Genetic diversity studies for morphological traits in pearl millet (Pennisetum glaucum L.) landraces of Northern Nigeria.
- Aftab, R., Perveen, A., 2006: A palynological study of some cultivated trees from Karachi. Pakistan Journal of Botany 38(1), 15-28.
- Ahmad, F., Khan, M. A., Ahmad, M., Zafar, M., Khan, A., & Iqbal, Z. (2011). Palynological studies in tribe Chlorideae (Poaceae) from salt range of Pakistan. African Journal of Biotechnology, 10(44), 8909-8913.
- Ahmad, F., Khan, M.A., Ahmad, M., Hameed, M., Tareen, R.B., Zafar, M., Jabeen, A. 2011. Taxonomic application of foliar anatomy in grasses of tribe Eragrostideae (poaceae) from salt range of Pakistan. Pakistan Journal of Botany. 43(5): 2277-2284.
- Ahmad, M., Bano, A., Zafar, M., Khan, M.A., Chaudhary, M.J.I., Sultana, S. 2013.Pollen morphology of some species of the Family Asteraceae from the Alpine Zone, Deosai Plateau, northern Pakistan, Palynology. 37 (2), 189-195.
- Ahmad, S., Zafar, M., Ahmad, M., Ali, M.I., Sultana, S., Rashid, N., Butt, M.A., Shah, S.N., Ozdemir, F.A., Kutlu, M.A. and Afza, R., 2020. Seed morphology using SEM techniques for identification of useful grasses in Dera Ghazi Khan, Pakistan. Microscopy Research and Technique, 83(3), pp.249-258.
- Ali, Q., Ahsan, M., Ali, F., Aslam, M., Khan, N. H., Munzoor, M., & Muhammad, S. (2013). Heritability, heterosis and heterobeltiosis studies for morphological traits of maize (Zea mays L.) seedlings. Advancements in Life sciences, 1(1).

- Amina, H., Ahmad, M., Bhatti, G. R., Zafar, M., Sultana, S., Butt, M. A., Bahadur, S., Haq, I. U., Ghufran, M. A., Ahmad, S., Ashfaq, S., 2020:. Microscopic investigation of pollen morphology of Brassicaceae from Central Punjab-Pakistan. Microscopy Research and Technique 83(4), 446-454.
- Andersen, T. S., Bertelsen, F., 1972: Scanning electron microscope studies of pollen of cereals and other grasses. Grana 12(2), 79-86.
- Arshad, M., Ashraf, M. Y., Ahmad, M., & Zaman, F. (2007). Morpho-genetic variability potential of Cenchrus ciliaris L., from Cholistan desert, Pakistan. Pak. J. Bot, 39(5), 1481-1488.
- Ashfaq, S., Ahmad, M., Zafar, M., Sultana, S., Bahadur, S., Ahmed, S.N., Gul, S. and Nazish, M., 2020. Pollen morphology of family Solanaceae and its taxonomic significance. Anais da Academia Brasileira de Ciências, 92(3).
- Bahadur, S., Ahmad, M., Zafar, M., Sultana, S., Begum, N., Ashfaq, S., Gul, S., Khan, M.S., Shah, S.N., Ullah, F., Saqib, S., 2019: Palyno-anatomical studies of monocot taxa and its taxonomic implications using light and scanning electron microscopy. Microscopy research and technique 82(4), 373-393.
- Bashir, S., Khan, M. A., 2003: Pollen morphology as an aid to the identification of medicinal plants: Trianthema portulacastrum L., Boerhaavia procumbens banks ex Roxb., and Alternanthera pungens Kunth. Hamdard Medicus XLVI, 7–10.
- Behre, K. E., 2007: Evidence for Mesolithic agriculture in and around central Europe?. Vegetation History and Archaeobotany 16(2), 203-219.
- Boldrini II, Longhi-Wagner HM, Boechat SC., 2005: Morfologia de taxonomia de gramíneas sul-rio-grandenses. Porto Alegre: UFRGS Editora Botany 44, 747-756.
- Bush, M. B., 2002: On the interpretation of fossil Poaceae pollen in the lowland humid neotropics. Palaeogeography, palaeoclimatology, palaeoecology 177(1-2), 5-17.
- Butt, M. A., Zafar, M., Ahmad, M., Sultana, S., Ullah, F., Jan, G., Irfan, A., Naqvi, S. A. Z., 2018: Morpho-palynological study of Cyperaceae from wetlands of Azad Jammu and Kashmir using SEM and LM. Microscopy Research and Technique 81(5), 458-468.

- Carlo, D., Paula, R., 2004: New insights into pollen evolution. International Journal of Plant sciences 164, 835.
- Chase A, Sendulsky T., 1991: Primeiro livro das gramíneas: Noções sobre a estrutura com exemplos da flora brasileira. São Paulo: Instituto de Botânica.
- Chaturvedi, M., & Datta, K. (2001). Pollen morphology in saccharum l.(poaceae)—wild and cultivated sugar cane species: With one figure and one table. Feddes Repertorium, 112(5-6), 387-390.
- Chaturvedi, M., Datta, K., 2001: Pollen morphology in Saccharum l.(Poaceae)—wild and cultivated sugar cane species: With one figure and one table. Feddes Repertorium 112(5-6), 387-390.
- Chaturvedi, M., Datta, K., Nair, P.K.K., 1998: Pollen morphology of Oryza (Poaceae). Grana 37, 79–86
- Chaturvedi, M., Yunus, D., Datta, K., 1994: Pollen morphology of Sorghum Moench-Sections Eu-sorghum and Para-sorghum. Grana 33,117–123.
- Chaudhry, M. S., Saeed, M., Khan, A. A., Sial, N., & Jamil, M. (2012). Morphological diversity of arbuscular mycorrhiza colonizing two aromaic grasses veteviria zizanioides and cymbopogon jwarancusa. Pak. J. Bot, 44(4), 1479-1485.
- Chemisquy, M. A., Giussani, L. M., Scataglini, M. A., Kellogg, E. A., & Morrone, O. (2010). Phylogenetic studies favour the unification of Pennisetum, Cenchrus and Odontelytrum (Poaceae): a combined nuclear, plastid and morphological analysis, and nomenclatural combinations in Cenchrus. Annals of botany, 106(1), 107-130.
- Clayton, W. D., Renvoize, S. A., 1986: Genera Gramineum, Grasses of the World. Kew bulletin additional series 13, Royal Botanic gardens Kew.p:389.
- Corrêa, A.M.S., Guimarães, M.I.T.M., Cruz-Barros, M.A.V., Begale, F.F., 2005: Flora polínica da Reserva do Parque Estadual das Fontes do Ipiranga (São Paulo, Brasil), Família: 176 – Poaceae (Gramineae). Hoehnea 32, 269–282.
- Datta, K., Chaturvedi, M., 2004: Pollen morphology of Basmati cultivars (Oryza sativa race Indica) – exine surface ultrastructure. Grana 43, 89–93.
- Dorea, M.C., 2011: Morfologia polınica, fenologia reprodutiva e biologia floral de especies florestais de Poaceae [PhD Thesis]. Feira de Santana: Universidade Federal de Feira de Santana; 166 p.

- Erdtman, G., 1952: Pollen Morphology and Plant Taxonomy. Angiosperms. Chronica.
- Fægri, K., Iversen, J., 1964: Textbook of pollen analysis. Copenhagen: Munksgaard.
- Firbas, F., 1937: Der pollen analytische Nachweis des Getreidebaus. Österreichische Botanische Zeitschrift 31, 447-478.
- Fischer, H.J., 1890: Beitrag zur vergleichenden. Morphological der Pollen Koner Bresien. Thesis.
- Forey, E., Coulibaly, S. F., & Chauvat, M. (2015). Flowering phenology of a herbaceous species (Poa annua) is regulated by soil Collembola. Soil Biology and Biochemistry, 90, 30-33.
- Galera, H., Chwedorzewska, K. J., & Wódkiewicz, M. (2015). Response of Poa annua to extreme conditions: comparison of morphological traits between populations from cold and temperate climate conditions. Polar Biology, 38(10), 1657-1666.
- Gamble, J. S., 1934: Flora of the Presidency of Madras. Part 10. Gramineae. Flora of the Presidency of Madras. Part 10. Gramineae.
- Good, R., 1953: The geography of the flowering plants. 2nd ed Longmans, Green & Co., Ltd., London.
- Gould, F. W., 1969: Grass Systematics. Mc. Graw. Hill book company, New York. pp. 40 – 41.
- Guimarães, J. T. F., Carreira, L. M. M., Alves, R., Martins e Souza Filho, P. W., Giannini, T. C., Macambira, H. J., & Rodrigues, T. M. (2018). Pollen morphology of the Poaceae: implications of the palynological and paleoecological records of the southeastern Amazon in Brazil. Palynology, 42(3), 311-323.
- Gul, S., Ahmad, M., Zafar, M., Bahadur, S., Sultana, S., Ashfaq, S., Ullah, F., Kilic, O., Hassan, F. U., Siddiq, Z., 2019:. Foliar epidermal anatomy of Lamiaceae with special emphasis on their trichomes diversity using scanning electron microscopy. Microscopy research and technique 82(3), 206-223.
- Gul, S., Ahmad, M., Zafar, M., Bahadur, S., Zaman, W., Ayaz, A., Shuaib, M., Butt, M.A., Ullah, F., Saqib, S. and Nizamani, M.M., 2021. Palynological

characteristics of selected Lamioideae taxa and its taxonomic significance. Microscopy Research and Technique, 84(3), pp.471-479.

- Harman, H. H., 1976: Modern factor analysis. University of Chicago press.
- Harun, N., Shaheen, S., Ahmad, M., & Shahid, M. N. (2020). Light and scanning electron microscopy-based foliar micro morphological tools for the identification of fodder grass taxa. Microscopy research and technique, 83(8), 953-978.
- Hussain, A. N., Zafar, M., Ahmad, M., Khan, R., Yaseen, G., Khan, M. S., Shaheen, S. 2018. Comparative SEM and LM foliar epidermal and palyno-morphological studies of Amaranthaceae and its taxonomic implications. Microscopy Research and Technique. 81(5): 474-485.
- Jianxiu, L., Aigui, G., & Hailin, G. (2003). Morphological variation and types of Cynodon dactylon. Acta Prataculturae Sinica, 12(6), 99-104.
- Joly, C., Barillé, L., Barreau, M., Mancheron, A., Visset, L., 2007: Grain and annulus diameter as criteria for distinguishing pollen grains of cereals from wild grasses. Review of Palaeobotany and Palynology 146(1-4), 221-233.
- Jones, R., 1999: The Biogeography of the grasses and low grasslands of South eastern Australia. Indigenous Flora and Fauna Association 11–16.
- Khan, A., Vijay, R., Singaravelu, D. L., Sanjay, M. R., Siengchin, S., Verpoort, F., & Asiri, A. M. (2019). Extraction and characterization of natural fiber from eleusine indica grass as reinforcement of sustainable fiber-reinforced polymer composites. Journal of Natural Fibers, 1-9.
- Khan, M.A., 1991: Cytotaxonomic studies in some species of Brachypodium P. Beauv. Pak. Phyton 3, 141-151.
- Khan, M.A., Stace, C.A., 1999: Breeding relationship in the genus Brachepodium (Poaceae). Nordic Journal of Botany 19, 257-269.
- Khan, R., Ul Abidin, S. Z., Mumtaz, A. S., Jamsheed, S., Ullah, H., 2017: Comparative leaf and pollen micromorphology on some Grasses taxa (Poaceae) distributed in Pakistan. International Journal of Nature and Life Sciences 1(2), 72-82.
- Kohler E, Lange E., 1979: A contribution to distinguishing cereal from wild grass pollen by LM and SEM. Grana 18, 133 -134.

- Kumar, C. A. S., Varadharajan, R., Muthumani, P., Meera, R., Devi, P., & Kameswari, B. (2010). Psychopharmacological studies on the stem of Saccharum spontaneum. International Journal of PharmTech Research, 2(1), 319-321.
- Lawrence, G.H.M., 1951: Taxonomy of vascular plants. Mc Millan Co. New York.
- Layton, D. J., & Kellogg, E. A. (2014). Morphological, phylogenetic, and ecological diversity of the new model species Setaria viridis (Poaceae: Paniceae) and its close relatives. American Journal of botany, 101(3), 539-557.
- Lindley, J., 1840: The genera and species of orchidaceous plants. Ridgways.
- Liu, Q., N.-X. Zhao., G. Hao., 2004: Pollen morphology of the Chloridoideae (Gramineae). Grana 43, 238-248
- Longhi-Wagner, H.M., Bittrich, V., Wanderley, M.G.L., Shepherd, G.J., 2001: Introdução. In: Wanderley MG, Shepherd GJ, Giulietti AM, eds. Flora fanerogâmica do estado de São Paulo, Volumen 1, 17–21. São Paulo: Editora Hucitec.
- Ma, G.H., Zhao, N.X., Hu, X.Y., 2001: Pollen morphology and poly-aperture in Paspalum. Journal of Tropical and Subtropical Botany 9, 201-204.
- Mabberley, D.I., 2008: The Plant Book Cambridge. Univ. Press, Cambridge, New York.
- Mander, L., Li, M., Mio, W., Fowlkes, C.C., Punyasena, S.W., 2013: Classification of grass pollen through the quantitative analysis of surface ornamentation and texture. Proceedings of the Royal Society B 280, 20131905.
- Mehra, K. L. (2015, February). Cytotaxonomic notes on the Dichanthium annulatum complex. In Proceedings of the Oklahoma Academy of Science (Vol. 38, pp. 22-25).
- Melhem, T.S., Cruz, M.A.V., Makino, H., Cristovam, M.A., 1983: Grãos de pólen de plantas alergógenas: Gramineae. Hoehnea 10, 9–32.
- Meo, A. A., 1999: Impact of pollen and intergenetic crosses between graminaceous (Poaceae) plants. Pakistan Journal of Biological Sciences 2(3), 809-812.

- Meo, A., Hafiz, H., Baig, I. M., 1989: Pollen grain description of 13 non allergic and four allergic Graminaceous species. Journal of Pure and Applied Sciences 8(2), 19-26.
- Mitra, S., S. K. Mukherjee., 2004: Ethnobotanical usages of Grasses by the tribals of West Dinajpur District, West Bengal. Indian Journal of Traditional Knowledge 4 (4), 396 – 402.
- Morgado, L. N., Gonçalves-Esteves, V., Resendes, R., & Ventura, M. A. M. (2015). Pollen morphology of Poaceae (Poales) in the Azores, Portugal. Grana, 54(4), 282-293.
- Morgado, L. N., Gonçalves-Esteves, V., Resendes, R., Ventura, M. A. M., 2015: Pollen morphology of Poaceae (Poales) in the Azores, Portugal. Grana 54(4), 282-293.
- Mseddi, K., Mnif, L., Chaieb, M., Neffati, M., & Roux, M. (2004). Aboveground phytomass productivity and morphological variability of Tunisian accessions of Cenchrus ciliaris L. African Journal of Range and Forage Science, 21(1), 49-55.
- Munawarti, A., Taryono, T., Semiarti, E., & Sismindari, S. (2014). Morphological And Biochemical Responses Of Saccharum Spontaneum L. Accessions To Drought Stress. Journal of Tropical Life Science, 4(1), 61-66.
- Nazir, A., Khan, M. A., Ahmad, F., Ullah, K., & Shah, A. (2013). Foliar epidermal studies as an aid to the identification of grasses of tribe Andropogoneae (Poaceae) from Potohar region of Pakistan. Pakistan Journal of Botany, 45(1), 235-241.
- Olivera, Y., Machado, R., Ramírez, J., del Pozo, P. P., & Castañeda, L. (2014). Morphological characterization of 19 Brachiaria brizantha accessions on an acid soil. Pastures and Forages, 7(2).
- Özler, H., E. Cabi, E. Us, M. Doğan., S. Pehlivan., 2009: Pollen morphology of Agropyron Gaertner in Turkey. Bangladesh Journal of Plant Taxonomy 16(1), 21-28.
- Perveen, A., 2006: A contribution to the pollen morphology of family Gramineae. World Applied Sciences Journal 1, 60–65.
- Perveen, A., Qaiser, M., 2012: Pollen Flora of Pakistan L.XIX. Poaceae. Pakistan Journal of Botany 44, 747-756.

- Radaeski, J.N., Bauermann, S.G., Pereira, A. B., 2016: Poaceae pollen from Southern Brazil: distinguishing grasslands (Campos) from forests by analyzing a diverse range of Poaceae species. Frontiers in Plant Science 7, 1833.
- Ronald, O.K., 2000: Pollen and spores. 2 nd Ed. American Association of Stratographic Palynologists 13-21.
- Sachdeva, S. K., & Kals, R. (1981). Cytologic, morphologic and chemotaxonomic studies inDactyloctenium aegyptium (L.) Beauv. complex. Proceedings: Plant Sciences, 90(3), 217-225.
- Salgado-Labouriau, M.L., Rinaldi, M., 1990: Palynology of Gramineae of the Venezuelan Mountains. Grana 29, 119–128.
- Saw, K. O. (2011). Morphological and Microscopical characters of Eleusine indica (L.) Gaertn. Universities Res J, 4(1), 225-244.
- Schuler, L., Behling, H. €., 2011a: Poaceae pollen grain size as a tool to distinguish past grasslands in South America: a new methodological approach. Vegetation History and Archaeobotany 20, 83–96.
- Schuler, L., Behling, H. €., 2011b: Characteristics of Poaceae pollen grains as a tool to assess palaeoecological grassland dynamics in South America. Vegetation History and Archaeobotany 20, 97–108.
- Shaheen, S., Ahmad, M., Khan, F., Zafar, M., Sultana, S., Khan, M. A., Fatima, H., 2011: Morpho-playnological and foliar epidermal anatomy of genus Cenchrus L. Journal of Medicinal Plants Research 5(16), 3796-3802.
- Shaheen, S., Ahmad, M., Khan, F., Zafar, M., Sultana, S., Khan, M. A., & Fatima, H. (2011). Morpho-playnological and foliar epidermal anatomy of genus Cenchrus L. Journal of Medicinal Plants Research, 5(16), 3796-3802.
- Siddiqui, T., M. Qaiser., 1988: A palynological study of the family Poaceae from Karachi. Pakistan Journal of Botany 20, 161-176.
- Simon, B.K., Clayton, W.D., Harman, K.T., Vorontsova, M., Brake, I., Healy, D., Alfonso, Y., 2011: GrassWorld, http://grassworld. myspecies.info/; accessed 21 April 2014.
- Singh, A. K., Singh, A. K., & Srivastava, M. K. (2017). Morphological Variations in Caryopses and Seedlings of Two Grass Species of the Genus Dactyloctenium Willd. Notulae Scientia Biologicae, 9(2), 301-306.

- Singh, S., Yadav, Y. P., Yadav, H. P., Vart, D., & Yadav, N. (2016). Morphological characterization of pearl millet hybrids [Pennisetum glaucum (L.) R. Br.] and their parents. African Journal of Agricultural Research, 11(5), 371-378.
- Skvarla, J.J., J.R. Rowley, V.C. Hollowell., W.F. Chissoe., 2003: Annulus–pore relationship in Poaceae (Poaceae) pollen: the pore margin of Pariana. American Journal of Botany 90, 924-930.
- Tellaria, M.C., 1991: Comparative palynological analysis of species of MedicagoL., Melilotus Mill and Trifolium L.(Leguminoseae) in the phytographic pampas region (Argentina). Industria Apicola 1, 4-13
- Tripathi, D. K., Chauhan, D. K., Kumar, D., & Tiwari, S. P. (2012). Morphology, diversity and frequency based exploration of phytoliths in Pennisetum typhoides Rich. National Academy Science Letters, 35(4), 285-289.
- Ullah, F., Zafar, M., Ahmad, M., Dilbar, S., Shah, S. N., Sohail, A., Tariq, A., 2018: Pollen morphology of subfamily Caryophylloideae (Caryophyllaceae) and its taxonomic significance. Microscopy Research and Technique 81(7), 704-715.
- Usma, A., Ahmad, M., Zafar, M., Ali, M. I., Kilic, O., Ozdemir, F. A., & Kalsoom, N. (2019). Taxonomic significance of caryopsis in subfamily Panicoideae (Poaceae) using scanning electron microscopy and light microscopy. Microscopy research and technique, 82(10), 1649-1659.
- Vigna, B. B. Z., Jungmann, L., Francisco, P. M., Zucchi, M. I., do Valle, C. B., & de Souza, A. P. (2011). Genetic diversity and population structure of the Brachiaria brizantha germplasm. Tropical Plant Biology, 4(3), 157-169.
- Wang, M., Zhang, J., Guo, Z., Guan, Y., Qu, G., Liu, J., & Yan, X. (2020). Morphological variation in Cynodon dactylon (L.) Pers., and its relationship with the environment along a longitudinal gradient. Hereditas, 157(1), 1-11.
- Wodehouse, R.P., 1935: Pollen grains. New York: McGraw-Hill.
- Zahoor, A., Ahmad, F., Naseer, M. H. M., Irum, N., 2019: Palynological features of medicinal plants from Salt Ranges of Pakistan. Journal of Environmental & Agricultural Sciences 21, 29-37.

- Akçin, T. A., & Camili, B. (2018). Micromorphological and anatomical characters of the Turkish endemic *Marrubium trachyticum* Boiss. (Lamiaceae). Trakya University. *Journal of Natural Sciences*, **19**(1), 77– 83.
- Angelini, P., Bricchi, E., Gigante, D., Poponessi, S., Spina, A., & Venanzoni, R. (2014). Pollen morphology of some species of Amaranthaceaes. Lat. Common in Italy. *Flora Mediterranea*, **24**, 247– 272.
- Arora, A., & Modi, A. (2008). An acetolysis technique for pollen slide preparation. *Indian Journal of Aerobiology*, **21**(2), 90– 91.
- Ashfaq, S., Zafar, M., Ahmad, M., Sultana, S., Bahadur, S., Khan, A., & Shah, A. (2018). Microscopic investigations of palynological features of convolvulaceous species from arid zone of Pakistan. *Microscopy Research and Technique*, **81**(2), 228– 239.
- Assadi, M., Hamdi, S., & Fajani, F. (2016). Palynological studies on some species of *Anabasis* L.(Amaranthaceae) from Iran. *Bangladesh Journal of Plant Taxonomy*, **23**(2), 247– 253.
- Averdieck, F. (1958). Pollen vom Chenopodiaceen-Typ im Flöz Frimmersdorf—ein Hinweis auf seine strandnahe Entstehung. *Fortschritte in der Geologie von Rheinland und Westfalen*, **1**, 101– 112.
- Bahadur, S., Ahmad, M., Mir, S., Zafar, M., Sultana, S., Ashfaq, S., & Arfan, M. (2018). Identification of monocot flora using pollen features through scanning electron microscopy. *Microscopy Research and Technique*, **81**(6), 599– 613.
- Borsch, T. (1998). Pollen types in the Amaranthaceae. Morphology and evolutionary significance. *Grana*, **37**(3), 129– 142.
- Butt, M. A., Zafar, M., Ahmad, M., Sultana, S., Ullah, F., Jan, G., … Naqvi, S. A. Z. (2018). Morpho-palynological study of Cyperaceae from wetlands of Azad Jammu and Kashmir using SEM and LM. *Microscopy Research and Technique*, **81**(5), 458– 468.
- Caçador, I., & Duarte, B. (2015). Mechanisms of salt stress tolerance in halophytes: Biophyscial and biochemical adaptations. In S. H. Wani & M. A. Hossain (Eds.), *Managing salt tolerance in plants: Molecular and genomic perspectives* (pp. 19– 34). CRC Press.

- Chase, M. W., Christenhusz, M., Fay, M., Byng, J., Judd, W., Soltis, D., … Stevens, P. (2016). An update of the angiosperm phylogeny group classification for the orders and families of flowering plants: APG IV. *Botanical Journal of the Linnean Society*, **181**(1), 1– 20.
- Clark, W. D., Brown, G. K., & Mayes, R. A. (1980). Pollen morphology of Haplopappus and related genera (Compositae-Astereae). *American Journal of Botany*, **67**, 1391– 1393.
- Cuénoud, P., Savolainen, V., Chatrou, L. W., Powell, M., Grayer, R. J., & Chase, M. W. (2002). Molecular phylogenetics of Caryophyllales based on nuclear 18S rDNA and plastid rbcL, atpB, and matK DNA sequences. *American Journal of Botany*, **89**(1), 132– 144.
- Dehghani, M., & Akhani, H. (2009). Pollen morphological studies in subfamily Suaedoideae (Chenopodiaceae). *Grana*, **48**(2), 79– 101.
- Erdtman, G. (1960). The Acetolysis method-a revised description. *Svensk Botanisk Tidskrift*, **54**, 516– 564.
- Erdtman, G. (1966). *Pollen morphology and plant taxonomy. Angiosperms. An introduction to palynology I*. New York: Hafner Publishing Company.
- Erdtman, G. (1986). *Pollen morphology and plant taxonomy: Angiosperms: Brill archive*. Leiden, Netherlands: E.J. Brill.
- Grigore, M.N., & Toma, C. (2008). *Ecological anatomy of halophyte species from the Chenopodiaceae Family*. 4th WSEAS international conference on mathematical biology and ecology (MABE'08) Acapulco, Mexico, 62–67.
- Grindrod, J. (1988). The palynology of Holocene mangrove and saltmarsh sediments, particularly in Northern Australia. *Review of Palaeobotany and Palynology*, **55**(1–3), 229– 245.
- Guma, I., Padrón-Mederos, M., Santos-Guerra, A., & Reyes-Betancort, J. (2010). Effect of temperature and salinity on germination of *Salsola vermiculata* L.(Chenopodiaceae) from Canary Islands. *Journal of Arid Environments*, **74**(6), 708– 711.
- Hasanuzzaman, M., Nahar, K., Alam, M., Bhowmik, P. C., Hossain, M., Rahman, M. M., … Fujita, M. (2014). Potential use of halophytes to remediate saline soils. *BioMed Research International*, **2014**, 12.

- Hedge, I. C., Akhani, H., Freitag, H., Kothe-Heinrich, G., Podlech, D., Rilke, S., & Uotila, P. (1997). *Flora iranica: no. 172*. Chenopodiaceae: Akademische Druck-u. Verlagsanstalt.
- Hussain, A. N., Zafar, M., Ahmad, M., Khan, R., Yaseen, G., Khan, M. S., … Shaheen, S. (2018). Comparative SEM and LM foliar epidermal and palyno-morphological studies of Amaranthaceae and its taxonomic implications. *Microscopy Research and Technique*, **81**(5), 474– 485.
- Iamonico, D., & Mosyakin, S. (2018). Studies on *Chenopodium album* SL (Chenopodiaceae/Amaranthaceae SL): *Chenopodium Pedunculare*. *Annali Di Botanica*, **8**, 67– 74.
- Jeong, Y. J., & Lee, S. T. (1995). Pollen morphology of some Korean Chenopodiaceae. *Korean Journal of Plant Taxonomy*, **25**(4), 255– 255.
- Judd, W., Campbell, C. S., Kellogg, E., Stevens, P., & Donoghue, M. (2008). *Plant systematics. A phylogenetic approach* (3rd ed.). Sunderland, MA: Sinauer Assoc.
- Kanwal, D., & Abid, R. (2017). Taxonomic assessment of the family Amaranthaceae with special emphasis on seed morphology. *Pakistan Jouranl of Botany*, **49**, 43– 68.
- Khan, M. A., & Qaiser, M. (2006). Halophytes of Pakistan: Characteristics, distribution and potential economic usages. In M. A. Khan, B. Böer, G. S. Kust , H. J. Barth (Eds.), *Tasks for Vegetation Science: vol. 42*. *Sabkha Ecosystems* (pp. 129– 153) Dordrecht: Springer.
- Khan, M. A., & Qaiser, M. (2006). Halophytes of Pakistan: Characteristics, distribution and potential economic usages. In M. A. Khan, B. Böer, G. S. Kust , H. J. Barth (Eds.), *Tasks for Vegetation Science: vol. 42*. *Sabkha Ecosystems* (pp. 129– 153) Dordrecht: Springer.
- Khan, M. A., & Stace, C. A. (1999). Breeding relationships in the genus *Brachypodium* (Poaceae: Pooideae). *Nordic Journal of Botany*, **19**(3), 257– 269.
- Khan, R., Abidin, U., Zain, S., Ahmad, M., Zafar, M., Liu, J., & Amina, H. (2018). Palyno-morphological characteristics of gymnosperm flora of Pakistan and its taxonomic implications with LM and SEM methods. *Microscopy Research and Technique*, **81**(1), 74– 87.

- Khan, R., Ahmad, M., Zafar, M., & Ullah, A. (2017). Scanning electron and light microscopy of foliar epidermal characters: A tool for plant taxonomists in the identification of grasses. *Microscopy Research and Technique*, **80**(10), 1123– 1140.
- Koyro, H., Geissler, N., Hussin, S., Debez, A., & Huchzermeyer, B. (2008). *Strategies of halophytes to survive in a salty environment. Abiotic stress and plant responses* (pp. 83– 104). New Delhi: *IK International Publishing House*.
- Moquin-Tandon, C. (1849). Amaranthaceae. In A. P. Candolle (Ed.), *Prodromus systematis naturalis regni vegetabilis* (pp. 231– 424). Paris: V. Masson.
- Mostafavi, G., & Mehregan, I. (2014). Pollen micro-morphology of the Minuartia species (Caryophyllaceae) in Iran. *International Journal of Modern Botany*, **4**(1), 8– 21.
- Mudie, P. J., Greer, S., Brakel, J., Dickson, J. H., Schinkel, C., Peterson-Welsh, R., … Washington, R. (2005). Forensic palynology and ethnobotany of Salicornia species (Chenopodiaceae) in Northwest Canada and Alaska. *Canadian Journal of Botany*, **83**(1), 111– 123.
- Müller, K., & Borsch, T. (2005). Phylogenetics of Amaranthaceae based on matK/trnK sequence data: Evidence from parsimony, likelihood, and Bayesian analyses. *Annals of the Missouri Botanical Garden*, **92**(1), 66– 102.
- Nazir, A., Khan, M. A., Abbasi, A. M., & Zahidullah. (2013). Palynological studies in tribe Aveneae (Poaceae) from Potohar of Pakistan. *International journal of Sciences: Basic and Applied Research*, **10**, 120– 125.
- Nowicke, J. W. (1975). Pollen morphology in the order Centrospermae. *Grana*, **15**(1–3), 51– 77.
- Nowicke, J. W., & Skvarla, J. J. (1979). Pollen morphology: The potential influence in higher order systematics. *Annals of the Missouri Botanical Garden*, **66**, 633– 700.
- Olvera, H. F., Fuentes-Soriano, S., & Hernández, E. M. (2006). Pollen morphology and systematics of Atripliceae (Chenopodiaceae). *Grana*, **45**(3), 175– 194.

- Perveen, A., & Qaiser, M. (2006). Pollen flora of Pakistan-LI-Caryophyllaceae. *Pakistan Journal of Botany*, **38**(4), 901.
- Perveen, A., & Qasier, M. (2012). Pollen flora of Pakistan-LXX: Chenopodiaceae. *Pakistan Journal of Botany*, **44**(4), 1325– 1333.
- Pinar, N. M., & İnceoglu, Ö. (1999a). Pollen morphology of Turkish Chenopodium L.(Chenopodiaceae). *Turkish Journal of Botany*, **28**(3), 179– 186.
- Pinar, N. M., & İnceoglu, Ö. (1999b). Pollen morphology of Turkish Chenopodium L.(Chenopodiaceae). *Turkish Journal of Botany*, **23**(3), 181– 189.
- Punsalpaamuu, G., Schluetz, F., Gegeensuvd, T., & Saindovdon, D. (2012). On the importance of pollen morphology in classification of Chenopodiaceae in Mongolia. *Erforschung Biologischer Ressourcen der Mongolei*, **2012**(12), 429– 436.
- Quamar, M., Ali, S. N., Pandita, S. K., & Singh, Y. (2018). Modern pollen rain from Udhampur (Jammu and Kashmir), India: Insights into pollen production, dispersal, transport and preservation. *Palynology*, **42**(1), 55– 65.
- Rastogi, A., & Shukla, S. (2013). Amaranth: A new millennium crop of nutraceutical values. *Critical Reviews in Food Science and Nutrition*, **53**(2), 109– 125.
- Ronald, O. (2000). Pollen and spores. *American Association of Stratographic Palynologists*, **2**, 13– 21.
- Safiallah, S., Hamdi, S. M. M., Grigore, M. N., & Jalili, S. (2017). Micromorphology and leaf ecological anatomy of Bassia halophyte species (Amaranthaceae) from Iran. *Acta Biologica Szegediensis*, **61**(1), 85– 93.
- Sánchez-del Pino, I., Fuentes-Soriano, S., Solis-Fernández, K. Z., Pool, R., & Alfaro, R. (2016). The metareticulate pollen morphology of Alternanthera Forssk.(Gomphrenoideae, Amaranthaceae) and its taxonomic implications. *Grana*, **55**(4), 253– 277.
- Shinwari, M., Shinwari, M., & Khan, M. (2004). Variation in pollen-morphology of selected genera belonging to Amaranthaceae from Pakistan. *Science Technology and Development (Pakistan)*, **23**(3), 53– 60.

- Smith, M. E., Koteyeva, N. K., Voznesenskaya, E. V., Okita, T. W., & Edwards, G. E. (2009). Photosynthetic features of non-Kranz type C4 versus Kranz type C4 and C3 species in subfamily Suaedoideae (Chenopodiaceae). *Functional Plant Biology*, **36**(9), 770– 782.
- Talebi, S. M., Noori, M., & Nasiri, Z. (2016). Palynological study of some Iranian Amaranthus taxa. *Environmental and Experimental Biology*, **14**, 1– 7.
- Toderich, K. (2008). *Genus Salsola of central Asian Flora: Structure, function and adaptive evolutionary trends* (Postdoctoral Thesis). Tokyo University of Agriculture and Technology Publisher, 1–196.
- Toderich, K., Idzikowska, K., Wozny, A., & Takabe, K. (2000). Pollen morphology of Asiatic and European species of genus Salsola (Chenopodiaceae) and its taxonomic relationships. *Proceedings of the 12th European Congress of Electron Microscopy*, 4, 33–34.
- Toderich, K. N., Shuyskaya, E. V., Ozturk, M., Juylova, A., & Gismatulina, L. (2010). Pollen morphology of some asiatic species of genus *Salsola* (Chenopodiaceae) and its taxonomic relationships. *Pakistan Journal of Botany*, **42**, 155– 174.
- Townsend, C. (1985). *Flora of tropical East Africa-Amaranthaceae (1985)*. Rotterdam: AA Balkema. 136p.-illus. kEIG, 5., editor.
- Tsukada, M. (1967). Chenopod and amaranth pollen: Electron-microscopic identification. *Science*, **157**(3784), 80– 82.
- Ullah, F., Zafar, M., Ahmad, M., Dilbar, S., Shah, S. N., Sohail, A., … Tariq, A. (2018). Pollen morphology of subfamily Caryophylloideae (Caryophyllaceae) and its taxonomic significance. *Microscopy Research and Technique*, **81**(7), 704– 715.
- Uotila, P. (1974). Pollen morphology in European species of *Chenopodium* sect. *Chenopodium*, with special reference to *C. album* and *C. suecicum*. *Annales Botanici Fennici*, **11**(1), 44– 58.
- Volponi, C. (1987). Palynological study of argentine species of *Arenaria* L. and *Stellaria* L.(Caryophyllaceae). *Candollea*, **42**(2), 545– 551.
- Wang, X., Zhou, T., Bai, G., & Zhao, Y. (2018). Complete chloroplast genome sequence of *Fagopyrum dibotrys*: Genome features, comparative analysis and phylogenetic relationships. *Scientific Reports*, **8**(1), 12379.

- Yang, R., Wang, S., Wang, J., Luo, X., Zhao, W., Zhang, Q., … Wang, S. (2017). Comparison of manual and automatic processing of biological samples for electron microscopy. *Microscopy Research and Technique*, **80**(6), 570– 577.
- Zare, G., & Keshavarzi, M. (2007). Morphological study of Salicornieae (Chenopodiaceae) native to Iran. *Pakistan Journal of Biological Sciences*, **10**(6), 852– 860.
- Zhigila, D., Yuguda, U., Akawu, J., & Oladele, F. (2014). Palynomorphs and floral bloom as taxonomic characters in some species of the genus *Amaranthus* l. (Aamaranthaceae). *Bayero Journal of Pure and Applied Sciences*, **7**(2), 164– 168.
- Abu-Asab, M. S., & Cantino, P. D. (1994). Systematic implications of pollen morphology in subfamilies Lamioideae and Pogostemonoideae (Labiatae). *Annals of the Missouri Botanical Garden*, **81**, 653– 686.
- Abdul, W., Mushtaq, A., Asad, G. M., Asma, J., Ahmet, O. F., Muhammad, Z., … Shehzad, K. A. (2021). Implication of scanning electron microscopy in the seed morphology with special reference to three subfamilies of Fabaceae. *Microscopy Research and Technique*, **84**(9), 2176– 2185.
- Abida, B., Mushtaq, A., Ajab, K. M., Muhammad, Z., Shazia, S., & Zahid, U. (2012). Pollen morphology of four endemic species of Pedicularis L. from alpine zone of the Deosai Plateau, Himalayan range. *Bangladesh Journal of Plant Taxonomy*, **19**(1), 1– 5.
- Abida, B., Sofia, R., Mushtaq, A., Bhatti Ghulam, R., Ghulam, Y., Farida, A., … Omer, K. (2020). Comparative pollen and foliar micromorphological studies using light microscopy and scanning electron microscopy of some selected species of Lamiaceae from Alpine Zone of Deosai Plateau, Western Himalayas. *Microscopy Research and Technique*, **83**(6), 579– 588.

- Abida, B., Sofia, R., Mushtaq, A., Bhatti Ghulam, R., Ghulam, Y., Farida, A., … Omer, K. (2020). Comparative pollen and foliar micromorphological studies using light microscopy and scanning electron microscopy of some selected species of Lamiaceae from Alpine Zone of Deosai Plateau, Western Himalayas. *Microscopy Research and Technique*, **83**(6), 579– 588.

- Ahmad, M., Khan, M. A., Zafar, M., Arshad, M., Sultana, S., & Abbasi, B. H. (2010). Use of chemotaxonomic markers for misidentified medicinal plants used in traditional medicines. *Journal of Medicinal Plants Research*, **4**(13), 1244– 1252.
- Ahmad, M., Zafar, M., Sultana, S., Ahmad, M., Abbas, Q., Ayoub, M., … Ullah, F. (2018). Identification of green energy ranunculaceous flora of district Chitral, Northern Pakistan using pollen features through scanning electron microscopy. *Microscopy Research and Technique*, **81**(9), 1004– 1016.
- Akan, H., & Aytac, Z. (2014). The revision of the section Alopecuroidei of the genus *Astragalus* (Fabaceae) in Turkey. *Turkish Journal of Botany*, **38**, 37– 59.
- Akan, H., Tatlidil, S., & Bicakci, A. (2005). Pollen morphology of *Astragalus* L. section *Alopecuroidei* DC.(Fabaceae) in Turkey. *International Journal of Botany*, **1**, 50– 58.
- Akram, B. M., Muhammad, Z., Mushtaq, A., Shazia, S., Fazal, U., Gul, J., … Zahra, N. S. A. (2018). Morpho-palynological study of Cyperaceae from wetlands of Azad Jammu and Kashmir using SEM and LM. *Microscopy Research and Technique*, **81**(5), 458– 468.
- Aman, U. S., Muhammad, Z., Mushtaq, A., Asad, G. M., Ercan, B., Omer, K., … Salman, M. (2021). Microscopic implication and evaluation of herbaceous melliferous plants of southern Khyber Pakhtunkhwa-Pakistan using light and scanning electron microscope. *Microscopy Research and Technique*, **84**(8), 1750– 1764.
- Barghi, N., & Siljak-Yakovlev, S. (1990). Karyological study in three species of *Glycyrrhiza* genus (G. glabra, G. lepidota and G. echinata). *Caryologia*, **43**(3–4), 223– 234.
- Butt, M. A., Muhammad, Z., Mushtaq, A., Sadaf, K., Saraj, B., Fazal, U., & Shazia, K. (2021). The use of taxonomic studies to the identification of wetlands weeds. *Advances in Weed Science*, **39**.
- Ceter, T., Erkul, S. K., Aytac, Z., & Baser, B. (2013). Pollen morphology of the genus *Oxytropis* DC. in Turkey. *Bangladesh Journal of Botany*, **42**(1), 167– 174.
- Davis, P. H. (1970). *Flora of Turkey and the East Aegean Islands* (Vol. **3**). Edinburgh: University Press.

- do Pico, G. M. V., & Dematteis, M. (2010). Meiotic behavior and pollen morphology variation in Centaurium pulchellum (Gentianaceae). *Plant Systematics and Evolution*, **290**(1–4), 99– 108.
- Ekici, M., Yüzbaşıoğlu, D., & Aytaç, Z. (2005). Morphology, pollen, seed structure and karyological study on *Astragalus ovalis* Boiss. and Balansa (sect. Ammodendron) in Turkey. *International Journal of Botany*, **1**(1), 74– 78.
- Erdtman, G. (1960). The acetolysis method-a revised description. *Svensk Botanisk Tidskrift*, **54**, 516– 564.
- Erdtman, G. (1969). *Handbook of palynolgy: Morphology, taxonomy, ecology. An introduction to the study of pollen grains and spores*. New York, NY: Hafner.
- Faegri, K., & Iversen, J. (1989). In K. Faegri, P. E. Kaland, & K. Krzywinski (Eds.), *Textbook of pollen analysis* (4th ed.). New York: Wiley.
- Farhat, U., Mushtaq, A., Muhammad, Z., Bushra, P., Shomaila, A., Saraj, B., … Muhammad, L. (2021). Pollen morphology and its taxonomic potential in some selected taxa of Caesalpiniaceae observed under light microscopy and scanning electron microscopy. *Microscopy Research and Technique*.
- Faria, U., Muhammad, Z., Riaz, U., Ahmed, B., Yahya, K. M., Mushtaq, A., & Shazia, S. (2021). Implication of light and scanning electron microscopy for pollen morphology of selected taxa of family Asteraceae and Brassicaceae. *Microscopy Research and Technique*.
- Fazal, U., Muhammad, Z., Mushtaq, A., Shazia, D., Nasar, S. S., Aamir, S., … Akash, T. (2018). Pollen morphology of subfamily Caryophylloideae (Caryophyllaceae) and its taxonomic significance. *Microscopy Research and Technique*, **81**(7), 704– 715.
- Fazal, U., Wajid, Z., Alessio, P., Muhammad, Z., Nasar, S. S., Mushtaq, A., … Aamir, S. (2019). Using multiple microscopic techniques for the comparative systematic ofSpergula fallaxandSpergula arvensis(Caryophyllaceae). *Microscopy Research and Technique*, **82**(4), 352– 360.
- Fazal, U., Syed, N. S., Wajid, Z., Muhammad, Z., Mushtaq, A., Asma, A., … Saddam, S. (2019). Using palynomorphological characteristics for the

identification of species of Alsinoideae (Caryophyllaceae): a systematic approach. *Grana*, **58**(3), 174– 184.

- Ferguson, I. (1981). *The pollen morphology of the subfamily Papilionoideae (Leguminosae)*. London: Royal Botanic Gardens.
- Grant-Downton, R. (2009). *Pollen terminology. An illustrated handbook*. Oxford University Press, UK: Annals of Botany Company.
- Guimarães, J. T. F., Carreira, L. M. M., Alves, R., Martins e Souza Filho, P. W., Giannini, T. C., Macambira, H. J., … Rodrigues, T. M. (2018). Pollen morphology of the Poaceae: Implications of the palynological and paleoecological records of the southeastern Amazon in Brazil. *Palynology*, **42**(3), 311– 323.
- Guinet, P., & Ferguson, I. (1989). Structure, evolution and biology of pollen in Leguminosae. Advances in legume biology. *Monographs in Systematic Botany*, **29**, 77– 103.
- Güner, A., Özhatay, N., Ekim, T., & Başer, K. (2000). *Flora of Turkey and the East Aegean Islands*. Edinburgh: Edinburgh University.
- Güner, A., Özhatay, N., Ekim, T., & Başer, K. (2000). *Flora of Turkey and the East Aegean Islands*. Edinburgh: Edinburgh University.
- Halbritter, H., Weber, M., Zetter, R., Frosch-Radivo, A., Buchner, R., & Hesse, M. (2007). *PalDat–Illustrated handbook on pollen terminology*. Vienna: Society of the Promotion of Palynological Research in Austria.
- Hayat, M. Q., Ashraf, M., Khan, M. A., Yasmin, G., Shaheen, N., & Jabeen, S. (2010). Palynological study of the genus Artemisia (Asteraceae) and its systematic implications. *Pakistan Journal of Botany*, **42**(2), 751– 763.
- Hafiza, A., Mushtaq, A., Raza, B. G., Muhammad, Z., Shazia, S., Akram, B. M., … Shomaila, A. (2020). Microscopic investigation of pollen morphology of Brassicaceae from Central Punjab-Pakistan. *Microscopy Research and Technique*, **83**(4), 446– 454.
- İlçim, A., & Behçet, L. (2016). Astragalus topalanense (Fabaceae), a new species from Turkey. *Turkish Journal of Botany*, **40**(1), 74– 80.
- Izhar, U., Mushtaq, A., Asma, J., Osman, Y. M., Muhammad, A., Omer, K., … Anwer, U. (2021). Palyno-morphological characterization of selected

allergenic taxa of family Poaceae from Islamabad-Pakistan using microscopic techniques. *Microscopy Research and Technique*, **84**(11), 2544– 2558.

- Inceoglu, O. (1973). Asyneuma canescens (WK) Griseb. & Schenk'in Polen morfolojisi ve heteremof polenler. *Türk Biyoloji Derg*, **23**, 89– 94.
- Jamil, R., Mushtaq, A., Muhammad, Z., Mohammad, A., Shazia, S., Salman, M., … Amir, H. (2020). Comparative foliar anatomical and pollen morphological studies of Acanthaceae using light microscope and scanning electron microscope for effective microteaching in community. *Microscopy Research and Technique*, **83**(9), 1103– 1117.
- Khan, R., Ul Abidin, S. Z., Ahmad, M., Zafar, M., Liu, J., & Amina, H. (2018). Palyno-morphological characteristics of gymnosperm flora of Pakistan and its taxonomic implications with LM and SEM methods. *Microscopy Research and Technique*, **81**(1), 74– 87.
- Khan, S. U., Muhammad, Z., Mushtaq, A., Farida, A., Shazia, S., Omer, K., … Salman, M. (2019). Pollen micromorphological analysis of tribe Acacieae (Mimosaceae) with LM and SEM techniques. *Microscopy Research and Technique*, **82**(9), 1610– 1620.
- Li, X., Feng, D., Wei, L., & Lu, Y. (1992). Studies on germplasm of *Glycyrrhiza* by using different taxonomic methods. *Advances in Plant Taxonomy in Northwest China*, **1**, 7– 24.
- Lubna, Z. M., Mushtaq, A., Mujtaba, S. G., Muhammad, K. A., Omer, K., Erkan, Y., … Shabir, A. (2021). Application and implication of scanning electron microscopy for evaluation of palyno-morphological features of Vitaceae from Pakistan. *Microscopy Research and Technique*, **84**(4), 608– 617.
- Massoumi, A. (1998). *Astragalus in the old world*. Tehran: Research Institute of Forest and Rangelands Pub.
- Maimoona, B., Mushtaq, A., Muhammad, Z., Shehzad, K. A., & Izhar, U. (2021). Palyno-anatomical characters and their systematic significance in the family Apiaceae from Chitral, eastern Hindu Kush, Pakistan. *Microscopy Research and Technique*
- Moore, P. D., Webb, J. A., & Collison, M. E. (1991). *Pollen analysis*. United States: Blackwell Scientific Publications.

- Moona, N., Muhammad, Z., Mushtaq, A., Shazia, S., Riaz, U., Alqahtani Ali, S., … Fazal, U. (2019). Palyno-morphological investigations of halophytic taxa of Amaranthaceae through SEM from Salt range of Northern Punjab, Pakistan. *Microscopy Research and Technique*, **82**(3), 304– 316.
- Muhammad S., Ikram B., Mushtaq A., Muhammad Z., Saraj B., Neelam R. Identification of Medicinally Used Flora Using Pollen Features Imaged in the Scanning Electron Microscopy in the Lower Margalla Hills Islamabad Pakistan. *Microscopy and Microanalysis*. 2018; **24**:(3): 292– 299.
- Nasar, S. S., Ali, C., Mushtaq, A., Fazal, U., Wajid, Z., Muhammad, Z., … Saraj, B. (2019). Leaf epidermal micromorphology and its implications in systematics of certain taxa of the fern family Pteridaceae from Northern Pakistan. *Microscopy Research and Technique*, **82**(3), 317– 332.
- Naeem, Q. M., Naureen, T., Mushtaq, A., Muhammad, Z., & Shomaila, A. (2019). Morpho-palynological investigations of natural resources: A case study of Surghar mountain district Mianwali Punjab, Pakistan. *Microscopy Research and Technique*, **82**(7), 1047– 1056.
- Oskouian, R., Ousalou, S. H. K., & Masoumi, A. A. (2007). Pollen morphology of *Astragalus* section Malacothrix and its allies (Fabaceae) in Iran. *Journal of Science*, **32**, 177– 181.
- Park, J.-M., & Song, U.-S. (2010). Pollen morphology of the genus rhododendron (Ericaceae) in Korea. *Journal of Korean Society of Forest Science*, **99**(5), 663– 672.
- Pavlova, D. (2013). Pollen morphology of some Balkan species from genus *Oxytropis* DC (Fabaceae). *Genetics and Plant Physiology*, **3**(1–2), 42– 54.
- Perveen, A., & Qaiser, M. (1998). Pollen Flora of Pakistan-VIII Leguminosae (subfamily: Papilionoideae). *Turkish Journal of Botany*, **22**(2), 73– 92.
- Pinar, M., Ekici, M., Aytaç, Z., Akan, H., Çeter, T., & Alan, Ş. (2009). Pollen morphology of *Astragalus* L. sect. Onobrychoidei DC.(Fabaceae) in Turkey. *Turkish Journal of Botany*, **33**(4), 291– 303.
- Pinar, N. M., Akan, H., Ceter, T., Aytac, Z., Ekici, M., Acar, A., & Akdogan, S. (2014). Comparative pollen morphology of annual *Trigonella* L.(Fabaceae) in Turkey. *Plant Systematics and Evolution*, **300**(4), 689– 708.

- Polhill, R. (1994). Classification of the Leguminosae. In *Phytochemical dictionary of the Leguminosae*. London, UK: Chapman and Hall 1(XXXV–XLVIII).
- Polhill, R., & Raven, P. (1981). *Advances in legume systematics. Part 1*. Richmond, VA: Kew: Royal Botanic Gardens & Ministry of Agriculture. Fisheries and Food.
- Punt, W., Hoen, P., Blackmore, S., Nilsson, S., & Le Thomas, A. (2007). Glossary of pollen and spore terminology. *Review of Palaeobotany and Palynology*, **143**(1–2), 1– 81.
- Raees, K., Zain, U. A. S., Mushtaq, A., Muhammad, Z., Jie, L., & Hafiza, A. (2018). Palyno-morphological characteristics of gymnosperm flora of pakistan and its taxonomic implications with LM and SEM methods. *Microscopy Research and Technique*, **81**(1), 74– 87.
- Reitsma, T. (1969). Size modification of recent pollen grains under different treatments. *Review of Palaeobotany and Palynology*, **9**(3–4), 175– 202.
- Saba, G., Mushtaq, A., Muhammad, Z., Saraj, B., Shazia, S., Najla, B., … Uzma, H. (2019). Taxonomic study of subfamily Nepetoideae (Lamiaceae) by polynomorphological approach. *Microscopy Research and Technique*, **82**(7), 1021– 1031
- Sadaf, K., Manzoor, H., Mushtaq, A., Muhammad, Z., Shazia, S., Akram, B. M., … Sehrosh, M. (2019). Scanning Electron Microscopy (SEM) and Light Microscopy (LM)-based Palyno-morphological views of Solanaceae in Western Himalaya. *Microscopy Research and Technique*, **82**(2), 63– 74.
- Salman, M., Muhammad, Z., Mushtaq, A., Omer, K., Shazia, S., Jamil, R., … Munazza, J. (2020). Pollen morphological investigations of family Cactaceae and its taxonomic implication by light microscopy and scanning electron microscopy. *Microscopy Research and Technique*, **83**(7), 767– 777.
- Saraj, B., Mushtaq, A., Muhammad, Z., Saba, G., Asma, A., Shomaila, A., … Shakil, A. (2020). Taxonomic study of one generic and two new species record to the flora of Pakistan using multiple microscopic techniques. *Microscopy Research and Technique*, **83**(4), 345– 353.
- Sehrosh, M., Mushtaq, A., Ajab, K. M., Muhammad, Z., Sarwat, J., Shazia, S., … Salman, M. (2019). Palyno-morphological investigations of subtropical

endangered flora of Capparidaceae through light and scanning electron microscopy. *Microscopy Research and Technique*, **82**(9), 1401– 1409.

- Schrire, B. (2005). Phaseoleae. In *Legumes of the world* (pp. 393– 431). Kew, UK: Royal Botanic Gardens.
- Schrire, B., & Sims, J. (1997). A re-evaluation of pollen morphology and taxonomy in the tribe Indigofereae (Leguminosae-Papilionoideae). *Kew Bulletin*, **52**, 841– 878.
- Shah, S. N., Ahmad, M., Zafar, M., Malik, K., Rashid, N., Ullah, F., … Ali, M. (2018). A light and scanning electron microscopic diagnosis of leaf epidermal morphology and its systematic implications in Dryopteridaceae: Investigating 12 Pakistani taxa. *Micron*, **111**, 36– 49.
- Shah, S. N., Ahmad, M., Zafar, M., Razzaq, A., Malik, K., Rashid, N., … Zaman, W. (2018). Foliar epidermal micromorphology and its taxonomic implications in some selected species of Athyriaceae. *Microscopy Research and Technique*, **81**(8), 902– 913.
- Shehzad, K. A., Mushtaq, A., Muhammad, Z., Mohammad, A., Ahmet, O. F., Ahmad, G. S. A., … Ullah, K. S. (2020). Morphological characterization of Hypnaceae (Bryopsida, Hypnales): Investigating four genera from Western Himalayas by using LM and SEM techniques. *Microscopy Research and Technique*, **83**(6), 676– 690
- Shomaila, A., Muhammad, Z., Mushtaq, A., Shazia, S., Siraj, B., Adeel, K., & Amin, S. (2018). Microscopic investigations of palynological features of convolvulaceous species from arid zone of Pakistan. *Microscopy Research and Technique*, **81**(2), 228– 239.
- Shomaila, A., Mushtaq, A., Muhammad, Z., Shazia, S., Saraj, B., Ahmed Siidr, N., … Moona, N. (2020). Pollen morphology of family Solanaceae and its taxonomic significance. *Anais da Academia Brasileira de Ciências*, **92**(3).
- Simons, E., & Chinnappa, C. (2004a). Pollen morphology and taxonomic status of North American Astragalus and Oxytropis (Papilinoideae=Fabaceae). *Beitröge Zur Biologie der Pflanzen*, **73**, 307– 319.
- Simons, E., & Chinnappa, C. (2004b). Pollen morphology and taxonomic status of North American *Astragalus* and *Oxytropis* (Papilionoideae: Fabaceae). *Beitröge Zur Biologie der Pflanzen*, **73**, 307– 319.

- Siraj, B., Mushtaq, A., Sehrosh, M., Muhammad, Z., Shazia, S., Shomaila, A., & Muhammad, A. (2018). Identification of monocot flora using pollen features through scanning electron microscopy. *Microscopy Research and Technique*, **81**(6), 599– 613.
- Siraj, K., Gul, J., Mushtaq, A., Farzana, G., Muhammad, Z., Din, M. J. U., … Salman, M. (2021). Morpho-palynological assessment of some species of family Asteraceae and Lamiaceae of District Bannu, Pakistan on the bases of light microscope & scanning electron microscopy. *Microscopy Research and Technique*, **84**(6), 1220– 1232.
- Sneath, P. H., & Sokal, R. R. (1973). Numerical taxonomy. The principles and practice of numerical classification.
- Tewari, R., & Nair, P. (1979). Pollen morphology of some Indian Papilionaceae. *Journal of Palynology*, **15**(2), 49– 73.
- Ullah, K. S., Muhammad, Z., Riaz, U., Shahat Abdelaaty, A., Mushtaq, A., Shazia, S., & Khafsa, M. (2021). Pollen diversity and its implications to the systematics of mimosaceous species by LM and SEM. *Microscopy Research and Technique*, **84**(1), 42– 55.
- ur Rahman, S., Mulk, K. S., Muhammad, Z., Mushtaq, A., Raees, K., Sajad, H., … Sadaf-Ilyas, K. (2019). Pollen morphological variation of Berberis L. from Pakistan and its systematic importance. *Microscopy Research and Technique*, **82**(9), 1593– 1600.
- Verma, S., & Nadkarni, R. (1985). Chromosome number and karyotypic studies in *Glycyrrhiza*. *Current Science (Bangalore)*, **54**(1), 45– 47.
- Walker, J. W., & Doyle, J. A. (1975). The bases of angiosperm phylogeny: Palynology. *Annals of the Missouri Botanical Garden*, **62**, 664– 723.
- Wodehouse, R. P. (1935). *Pollen grains*. New York; London: Mcgraw-Hill Book Company Inc.
- Yamazaki, M., Sato, A., Shimomura, K., Saito, K., & Murakoshi, I. (1994). Genetic relationships among Glycyrrhiza plants determined by RAPD and RFLP analyses. *Biological and Pharmaceutical Bulletin*, **17**(11), 1529– 1531.

- Zarre, S., & Azani, N. (2013). Perspectives in taxonomy and phylogeny of the genus *Astragalus* (Fabaceae): A review. *Progress in Biological Sciences*, **3**(1), 1– 6.

Publications from Thesis

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Article

Palynological Study of Weed Flora from Potohar Plateau

Anwer Usma [1], Mushtaq Ahmad [1,*], Muhammad Zafar [1], Shazia Sultana [1], Fazal Ullah [2], Saddam Saqib [3,4], Asma Ayaz [5] and Wajid Zaman [6,*]

1 Department of Plant Sciences, Quaid-i-Azam University, Islamabad 45320, Pakistan
2 State Key Laboratory of Grassland Agro-Ecosystems, School of Life Sciences, Lanzhou University, Lanzhou 730000, China
3 State Key Laboratory of Systematic and Evolutionary Botany, Institute of Botany, Chinese Academy of Sciences, Beijing 100093, China
4 University of Chinese Academy of Sciences, Beijing 100049, China
5 State Key Laboratory of Biocatalysis and Enzyme Engineering, School of Life Sciences, Hubei University, Wuhan 434200, China
6 Department of Life Sciences, Yeungnam University, Gyeongsan 38541, Korea
* Correspondence: mushtaqflora@hotmail.com (M.A.); shangla123@gmail.com (W.Z.)

Abstract: The pollen morphology of weeds was investigated by scanning electron microscopy (SEM). A morpho-palynological investigation of 18 species of weeds that belongs to 16 angiosperms families was performed using SEM to document distinguishable microscopic features. The main objective of the present study was to provide basic knowledge about morpho-palynological features of weed species that helps delimit the weed flora of the Potohar Plateau. The results show diversity among the qualitative and quantitative characteristics of pollen shape, equatorial and polar axis diameter, the exine's thickness, and the exine's surface ornamentation. The pollen grains were spherical, prolate-spheroidal, oblate-spheroidal, and sub-oblate. The exine ornamentation in most species was reticulate, scarbate, aerolate, faveolate, reticulate-perforate, and reticulate-scabrate. All the species described possessed tricolpate pollen. The variations found in the thickness of the exine and other characters were helpful at the genus and species-specific levels. In accordance with these variations, a taxonomic key was prepared using these characteristics to identify and differentiate weed plant species. SEM images of pollen grains can help delimit the taxa to the species level. This study provides baseline information to distinguish the species of weeds.

Keywords: exine sculpturing; palynomorph; pollen grains; scanning electron microscopy; Pakistan

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1. Introduction

Weeds are considered undesirable plants competing with crops' growth and development. The growth of weeds in agricultural fields can limit the production of staple crops and causes severe damage to their production [1]. According to Khan et al. [2] weeds grow in cultivated and wild habitats and damage the growing crop plants [3]. Weedy plants threaten human health, welfare, biodiversity, ecosystem services, and food security. Here, weeds are defined as any plants that have detrimental socioeconomic and environmental effects, endanger human health, and jeopardize global food security, biodiversity, and ecosystem services [4]. Weeds play an important role in achieving an ecological balance in a cropping system by supporting different life forms. Throughout the world, major vegetation of weeds belongs to families such as Asteraceae, Poaceae, Amaranthaceae, and Fabaceae. The growth of weeds depends mostly on climatic conditions [5]. In some previously reported studies, the most commonly grown weeds of cotton crops are *Cynodon dactylon*, *Amaranthus viridis*, *Phyla nodiflora*, and *Phragmites australis* [6]. Common weeds of wheat crops are *Phragmites* sp., *Cynodon* sp., *Ranunculus* spp., and *Polypogon* sp. [6]. Similarly, *Achyranthes aspera* is a common weed in sugarcane crops and *Plantago lanceolata* is an important weed in chickpea fields [7]. Weeds belonging to the family Fabaceae can

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RESEARCH ARTICLE

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Micro-morphological diversity of pollen among Asteraceous taxa from Potohar Plateau-Pakistan

Anwer Usma[1] | Mushtaq Ahmad[1] | Mohamed Fawzy Ramadan[2] | Amir Muhammad Khan[3,4] | Muhammad Zafar[1] | Mohammed Hamza[5] | Shazia Sultana[1] | Ghulam Yaseen[1,6]

[1]Department of Plant Sciences, Quaid-i-Azam University, Islamabad, Pakistan

[2]Deanship of Scientific Research, Umm Al-Qura University, Makkah, Saudi Arabia

[3]Department of Botany, University of Mianwali, Mianwali, Pakistan

[4]Department of Botany, University of Sargodha, Sargodha, Pakistan

[5]Horticulture Department, Al-Azhar University, Cairo, Egypt

[6]Department of Botany, Division of Science and Technology, University of Education, Lahore, Pakistan

Correspondence

Mushtaq Ahmad and Muhammad Zafar, Department of Plant Sciences, Quaid-i-Azam University, Islamabad, Pakistan.

Email: mushtaqflora@hotmail.com and zafar@qau.edu.pk

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Quaid-i-Azam University Islamabad

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Abstract

Microscopic pollen characters from 19 species of family Asteraceae collected from different areas of the Potohar Plateau of Pakistan have been investigated using light and scanning electron microscopy. This study uses microscopic techniques to provide detailed information on pollen and its exine structure based on qualitative and quantitative characters. The present study has observed three types of pollen grains based on their apertures, that is, trizonocolporate, tetrazonocolporate, and tricolporate. Exine sculpturing is echinate in all studied taxa. Some species also exhibit Lacunae which differ in their shape and sizes. The size of the spines and the number of spines between the colpi play a vital role in differentiating the species of the same genus. Pollen fertility ranges from 94.3 to 74.19, showing that these species are well established in the study area. For the correct identification of species, a light and scanning electron microscopy was used that provides sufficient information for a taxonomist to distinguish species taxonomically.

Research Highlights

- Light and Scanning electron microscope is comparatively used to investigate the pollen characters of some species of the family Asteraceae.
- A scanning electron microscopy is used to study the micro-morphological characters of pollen grains.
- Qualitative and quantitative characters of pollen were studied.

KEYWORDS

Asteraceae, echinate, Pakistan, pollen morphology, Potohar Plateau

1 | INTRODUCTION

Potohar Plateau is situated northeast of Pakistan with approximately 25,000 Square kilometers; topographically, the area includes hilly and plain areas. The area is situated between attitude 32.534°N and longitude 71.3073°E. The lowest altitude from sea level is Jhelum plain 250 m (825 ft), and the crop production depends upon monsoon rains (Rashid and Rasul, 2011). Potohar Plateau is a densely populated area with residents from different cultures, frequently introducing exotic plants. The construction of houses, roads, and industries limits the range of natural vegetation through land use, leading to soil composition changes. To increase greenery in the study area, foreign plants are being introduced intentionally for afforestation. The native flora of the Potohar region consists of dry deciduous scrubby vegetation and few tree species.

Family Asteraceae consist of 1530 genus and approximately 2300 species distributed within 3 subfamilies and 17 tribes (Anar et al., 2022; Hayat et al., 2009; Khan et al., 2021). It is the largest family of angiosperms and is cosmopolitan in distribution. For example, in Pakistan, this family comprises 650 species distributed in 15 tribes

Publications Submitted

- Pollen diversity of Poaceous Taxa using microscopy in Potohar Plateau – Pakistan. **(Under-Review in NASB Journal Elsevier)**
- Pollen morphological characters of tribe Cichorieae (Asteraceae) and its systematic implications **(Submitted in JAPS)**
- Pollen Morphology and Taxonomic Relations among the Genera of Amaranthaceae from Potohar-Plateau**.(Under-Review in Plants Journal**)