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Research Article

# Exploring the micromorphological diversity of palynomorphic flora from lesser Himalaya biodiversity hotspot

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## Abstract

Palynology, a prominent field in plant systematics and biodiversity studies, plays a vital role in identifying and determining the plant species present in a specific region. The current study was performed to evaluate the micromorphological traits of pollen from flora of Lesser Himalaya. Pollen microstructural variations aid in the identification of species belonging to specific botanical families and various geographic habitats. Flowers of 24 selected species categorized into 16 families were collected, preserved and then acetolysis protocol followed. Pollen was examined under a light and scanning microscopy (LM and SEM) for palynomorph description. The palynomorphs characteristics such as size, shape, exine surface, and aperture

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orientation, were examined. Status of these plants show that herbs are being dominant (11 species), while shrubs (7 species), climbers (3 species), bulbous plants (2 species), small tree, sedge, weed (1 species each). Pollen shape determined in equatorial view were; spheroidal, sub-prolate, oblate-spheroidal, prolate, spherical and sub-oblate. The variations were seen among pollen types; tricolpate, tricolporate and polyporate in most of the species. Exine stratification was observed mostly scabrate while echinate, cristate-reticulate, granulate, punctate, rugulate-perforate, striate-rugulate, verrucate, cristate-foveolate was visualized in each different species. Palynomorph apertural patterns were observed sunken, furrowed, slightly bulged, scabrate, granulate, slit like, and perforate. The largest polar diameter was measured in *Hymenocallis littoralis* (138.6 µm) whereas smallest in *Parthenium hysterophorus* (14.70 µm). Equatorial distance was calculated maximum for *Cascabela thevetia* (110.1 µm) and minimum for *Hibiscus rosa-sinensis* (1.7 µm). P/E ratio was calculated largest in *Hymenocallis littoralis* (1.8) and lowest in *Duranta erecta* (0.89). The palynomorphs taxonomic characters investigated can be helpful in species level identification and provide a baseline to conduct more systematic research with respect to specific plant families and genera.

***Keywords:*** mesocolpium distance; palynomorphs; pollen furrows; SEM; sculpturing; taxonomy

## Introduction

The diversity of flora in a given region is important to note, since it is sometimes defined to intense competition among closely related plant species for survival in their natural environments. Palynology is the scientific study of living or fossil pollen grains and spores, produced by male part of angiosperm plants. The term palynology was first introduced by Hyde and William in 1945. It is an extensive field that includes the study of microfossils taken from ancient rocks and sediments and pollen morphology (Majeed *et al*., 2020).

Pollen characters are genetically sustained and persistent exhibiting significant variations in wall structure, exine sculpturing, size, shape, aperture ornamentation, polarity, and symmetry etc. These traits are useful to determine the systematic categorization of angiosperm species (Chatterjee *et al*., 2014). The pollen is microscopic but exceptionally durable due to the presence of sporopollenin, a complex polymer found in the outer layer known as exine, while the inner layer (intine) is formed from pecto-cellulosic substances. Exine sculpturing is particularly important in taxonomy and systematic classification. The arrangement and orientation of pollen apertures are interesting aspects of pollen identification. Both pollen apertures and shapes are key criteria for identifying flora.

Palynology also deals with the seasonal allergenic diseases that affect almost 400 million people worldwide, reported by World Health Organization (Kailas *et al*., 2017). The analysis of the different types of pollen in the honey can reveal the sources of nectar and the foraging habits of honeybees (Al-Kahtani *et al*., 2020). The observation of pollen in forensic palynology has made easier to investigate the various crimes and legal problems. Pollen study can also be used to determine the season and time of the year that aids in forensic investigations of suspectable crime scene (Pasarelli and Cortes, 2017).

Palynological data has been used in various disciplines as applications to resolve ambiguity. In Pakistan, applied and basic palynological research has prevailed, although there is still a lot of work to be done in this area (Majeed *et al*., 2020). Generally, the potential study of micromorphological features, in the field of plant systematics has increased globally (Lu *et al*., 2015). Nowadays, it's critical to study pollen features for new plant species, especially to understand their phylogenetic and evolutionary interactions (Xu *et al*., 2008).

The examination of micromorphological traits are valuable for identification and classification plant species within various angiosperm including ferns, bryophytes, and monocots (Katata-Seru *et al*., 2018; Khan *et al*., 2019a). Taxonomists rely on the examination of morpho-palynological characters to define accurate taxonomic hierarchical of diverse floral species (Amina *et al*., 2020; Majeed *et al*., 2022; Noor *et al*., 2023; Nazish *et al*., 2019).

Light microscopy is commonly used to determine basic features of pollen; diameter, shape, size, mesocolpium, and aperture ornamentation and exine patterns. However, in depth features of pollen grains and exine sculpturing can be studied using SEM more effectively as compared to light microscopy (Ashfaq *et al*., 2020; Attique *et al*., 2022). SEM enhanced high resolution to visualize ultrastructural micron level features. This powerful technique allows for the qualitative analysis of samples, providing insights into their unique characteristics and properties (Gul *et al*., 2021; Rashid *et al*., 2022). SEM imaging has significantly advanced the field of plant taxonomy by enabling better visualization of pollen structural features (Muniraja *et al*., 2020; Ullah *et al*., 2022). Naz *et al*. (2020) explored pollen flora of lactiferous plants of Apocynaceae from Rawalpindi, while (Ullah *et al.*, 2022) examined the honeybee flora from the Margalla Hills surrounding to elaborate palyno-morphological features.

This study represents the first attempt to use SEM tool to identify the pollen micromorphological characters of 24 angiosperm species belong to Lesser Himalayan region. This morpho pollinic illustration was essential for conservation efforts of flora as its help to identify endangered species. However, the palynological description of green angiosperm flora allows for a comprehensive dynamic of the regional plant biodiversity, providing valuable insights into the ecological and evolutionary relationships.

## Materials and Methods

### *Sampling area and climatic conditions*

Pakistan is occupied by tallest mountain peaks known as Himalayas, reflected in the attractive beauty and unique cultures of the people who live in their shadow. Lesser Himalayas have a total area of 23295 $km^2$ (Khan *et al*., 2019b) and the whole population of this region is around 10 million (Yang *et al*., 2012). The area possesses sub-tropical and semi-humid zones with temperature lower in October to February warm and moist summers from month of May to June and rainy season during July to August as summarized in Table 1 (Usma *et al*., 2022a). Its geographical aspects, altitudes, heights, vegetation cover and climatic conditions vary dramatically (Waheed *et al*., 2013; Umber *et al*., 2022; Yousaf *et al*., 2022).

**Table 1.** Sampling data and GPS coordinates and distribution of selected flora from Lesser Himalaya

| Sr. No | Plant taxa | Family | English name | Habit | Flowering season | Global distribution | Distribution in Pakistan | Collection site | Coordinates | Voucher no. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. | *Bougainvillea spectabilis* Willd. | Nyctaginaceae | Great bougainvillea | Climbing shrub | Throughout year | Africa North & Central America | Islamabad, Rawalpindi, Ayubia, Lahore | Shamsabad | 33°44'44" N 73° 08'18" E | BS-01 |
| 2. | *Cannabis sativa* L. | Cannabaceae | Marijuana or Hemp | Herb | Late summer-Early fall | Worldwide, Native of Brazil, widely found In Tropics | Throughout Pakistan | QAU Islamabad | 33°44'44" N 72° 08'14" E | CS-02 |
| 3. | *Cascabela thevetia* (L.) Lippold | Apocynaceae | Yellow oleander | Small tree/shrub | Late summer-Early fall | North America Africa | Rawalpindi, Gujranwala, Jhelum, Lahore, | Murree road | 33°44'56" N 73° 08'21" E | CT-14 |
| 4. | *Celosia argentea* L. | Amaranthaceae | Silver cock's comb | Annual herb | Summer-Fall | East Africa and Several of The Indian Ocean Islands | W. Pakistan, Swat and Hazara Eastwards | QAU Islamabad | 33°42'44" N 73° 08'11" E | CA-15 |
| 5. | *Convolvulus arvensis* L. | Convolvulaceae | Bindweed | Climbing/trailing herb | Summer-Early autumn | America, Tropical Africa | Lahore, Gujranwala, Chakwal, Faisalabad | Chakwal | 33°43'44" N 73° 08'16" E | CP-16 |
| 6. | *Cucumis melo* var. agrestis Naudin | Cucurbitaceae | Wild melon | climbing vine | Summer-Early autumn | Tropical And Subtropical Asia and Africa | Islamabad, Murree, Kashmir, Himalayas | Rawalpindi | 33°44'51" N 73° 08'17" E | CM-13 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 7. | *Cyperus niveus* Retz. | Cyperaceae | White galingale | Perennial sedge | Summer-Early autumn | Ethiopia to Africa, Syria to Arabian Peninsula | Throughout the Pakistan | Chakwal | 33º44’54” N 73 º 08’14” E | CN-07 |
| 8. | *Datura stramonium* L. | Solanaceae | Jimson weed | Annual/ biennial herb | Summer-Autumn | Tropical & S. Africa to S. Central China | Mianwale, Bhakar, Chakwal, Rawalpindi | Pindora | 33º44’44” N 73 º 08’18” E | DS-06 |
| 9. | *Duranta erecta* L. | Verbenaceae | Golden dewdrop | Evergree n shrub, small tree | Summer-Fall | America, West Indies, Western USA. | Punjab, Sindh, Bhakar, Mianwale | Rawat | 33º45’44” N 73 º 08’16” E | DE-17 |
| 10. | *Dodonaea viscosa* (L.) Jacq. | Sapindaceae | Hopbush | Shrub/tr ee | Summer-Fall | Throughout Tropical America from S. USA Southwards | Tropical And Subtropical Areas of Pakistan | QAU Islamabad | 32º44’44” N 73 º 86’18” E | DV-18 |
| 11. | *Hibiscus rosa-sinensis* L. | Malvaceae | Chinese hibiscus | Shrub/s mall tree | Throughout year | India: Assam, Bihar, Gujarat, Maharastra, Manipur | Rawalpindi, Islamabad, Balochistan, Sindh | Margalla hills | 33º44’50” N 73 º 08’19” E | HR-24 |
| 12. | *Hymenocallis littoralis* (Jacq.) Salisb. | Amaryllidaceae | Beach spider lily | Bulbous perennial | Summer-Fall | India, Native to South America, Pakistan | Rawalpindi, Islamabad, Peshawar, Lahore | Shahdara | 32º44’44” N 73 º 09’18” E | HL-19 |
| 13. | *Ipomoea cairica* (L.) Sweet | Convolvulaceae | Mile-a-minute vine | Climbin g vine | Throughout year | Minnesota, Oregon, Texas, The Dakotas, California, | Attock, Faisalabad, Vehari, Sialkot, Thatta Badin, Swat, | Gujhar Khan | 33º43’44” N 72 º 08’18” E | IB-21 |
| 14. | *Ipomoea carnea* Jacq. | Convolvulaceae | Pink morning glory | Shrub | Summer-Fall | Tanzania To South Africa, Pakistan to India | Mainly In the Tropical and Subtropical Regions of Pakistan | Margalla hills | 33º44’44” N 73 º 08’18” E | IA-20 |
| 15. | *Lantana camara* L. | Verbenaceae | Common lantana | Perennial shrub | Throughout year | South Africa Mexico, Colombia | Tropical And Subtropical Regions of Pakistan | Chakwal | 33º44’44” N 73 º 08’03” E | LC-04 |
| 16. | *Malvastrum coromandeli anum* (L.) Garcke | Malvaceae | Indian mallow | Perennial herb or sub-shrub | May-November | Tropical & S. Africa, Arabian Peninsula to Temp. E. Asia. | Chakwal, Sindh, KPK, Islamabad, Rawalpindi | Ramli | 33º44’54” N 73 º 08’13” E | MC-08 |
| 17. | *Parthenium hysterophorus* L. | Asteraceae | Congress grass | Annual/ biennial herb | Throughout year | Asia, Africa, and North America | Chakwal, Sindh, Peshawar, Islamabad, Rawalpindi | Mandra | 33º44’44” N 73 º 08’18” E | PH-09 |
| 18. | *Physalis angulata* L. | Solanaceae | Cut leaf ground cherry | Annual herb | Summer-Fall | Tropical Africa and Madagascar India to North Australia | Through Pakistan, | Margalla hills | 31º43’44” N 73 º 08’16” E | PA-03 |
| 19. | *Ricinus communis* L. | Euphorbiaceae | Castor bean plant | Perennial shrub/tre e | Summer-Fall | Southeastern Asia, India, Australia, Africa Climates | Sindh, Chakwal, Multan, Rawapindi | QAU Islamabad | 33º44’44” N 73 º 06’18” E | RC-22 |
| 20. | *Taraxacum officinale* (L.) Weber ex F.H.Wigg. | Asteraceae | Dandelio n | Herbace ous perennial | Spring-Early summer | West Indies and Some Southern States of the USA | Lahore, Gujranwala, Sindh, Chakwal | Margalla hills | 33º44’54” N 73 º 08’16” E | TO-05 |
| 21. | *Tribulus terrestris* L. | Zygophyllaceae | Puncturev ine | Perennial herb | Summer-Fall | China, India, Japan, Myanmar, *Paki stan*, Sri Lanka, Vietnam; | Sindh, Balochistan, Bhakar, Mianwali | Rawalpindi | 33º45’44” N 73 º 09’18” E | TT-11 |
| 22. | *Trichodesma indicum* (L.) Lehm. | Boraginaceae | Indian borage | Perennial herb | Late winter-Early summer | Mexico And extending to Ecuador and Venezuela. | Northern Areas of Pakistan | QAU Islamabad | 33º44’45” N 73 º 05’18” E | TI-12 |
| 23. | *Verbena officinalis* L. | Verbenaceae | Common vervain | Perennial herb | Summer-Fall | Tropical And Sub-Tropical America, Mexico | West Pakistan, Swat | NARC Islamabad | 32º44’44” N 74 º 08’18” E | VO-10 |
| 24. | *Zephyranthes carinata* H erb. | Amaryllidaceae | Pink rain lily | Perennial herb | Summer-Fall | Tropical & Subtropical Asia to N. Australia | Tropical And Subtropical Areas of Pakistan | Faizabad | 33º44’44” N 72 º 08’13” E | ZC-23 |

*Collection and preservation of plant specimens*

The Margalla Hills has an area of about 12,606 hectares. The research area, where plant species from various families were collected, included Margalla Hills and the surrounding areas of Islamabad. Masks, surgical gloves, cutters, scissors, zipper bags and newspapers have been used for the plant's assemblage. The flowered plant species present abundantly were collected. These plant species belonging to the sixteen different families were brought in the Herbarium of Pakistan (ISL) and compared with preserved specimens and expert taxonomist.

*LM analysis of pollen grains*

Slides of pollen grains were made according to the acetolysis method of Erdtman (1969). Mature flowers were collected from different field trips, anthers have been cast out from flowers and put on the glass slides by the help of forceps. 1-2 droplets of acetic acid were added on the anthers and mashed them by using needles. Debris was removed from the crushed anthers using the camel brush. Then glycerin jelly was added on the slides for staining of pollen. Finally slide was covered with cover slip and tagged. After visualizing the presence of pollen by light microscope, slides were made long lasting by the help of melted paraffin (Umber *et al.*, 2022). Slides of pollen grains were observed in the Meiji Techno Japan Microscope (Model: MT4200H) at 100X and 400× magnification. Pollen photomicrographs were captured on 40× resolutions of Leica Dialux 20 Light microscope. Almost 10-15 pollen were observed, and 10-20 readings were noted for each character of pollen. Morphological characters calculated involve polar and equatorial diameter, P/E index, number of colpi and spores, colpi length, colpi width, mesocolpium, exine size, no of pores, pores length, pore width, pollen type, pollen shape and size (Bano *et al*., 2012; Candeias *et al*., 2021).

*Utilization of SEM for pollen imaging and sculpturing applications*

Scanning electron microscopy is used an advanced tool to differentiate closely related species by visualizing the ultra-sculpture of pollen wall. Anthers were treated with 45% acetic acid and then crushed, before being placed on metallic stubs coated with gold palladium and observed under (Model: JEOL JSM5910) SEM at the Central Resources Library (CRL), Department of Physics at the University of Peshawar.

*Quantitative statistical analysis*

Five consecutive measurements were recorded and analyzed using SPSS 16 statistical programming of quantitative parameters in randomly 15 grains per species. The mean value and standard error (SE) for each element were computed and presented in a table format as mean (minimum-maximum) ±SE. The existing terminology reported by Punt *et al*. (2007) and Halbritter *et al*. (2018) was followed to describe the qualitative morpho pollinic aspects.

*P/E index*

Polar to equatorial diameter was calculated to determine the pollen shape. The given formula (Majeed *et al*., 2022) was followed.

$$P/E = PA/ED \times 100$$

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

*Pollen fertility and sterility estimation*

The percentage of pollen fertility and sterility was calculated based on the color of the pollen. Pollen not tainted or damaged were considered infertile, whereas stained pollen was determined fertile. According to below formula, fertility and sterility was calculated (Raza *et al*., 2020).

$$Fertility\ \% = Fertility\ of\ pollen\ /\ F + S \times 100$$
$$Sterility\ \% = Sterility\ of\ pollen\ /\ S + F \times 100$$

S indicates sterile and F indicates the fertile pollen.

## Results

In this study, 24 plant species belonging to the 16 different families from Lesser Himalayas were collected and observed for their palynomorphs characteristics (Figures 1-3). Qualitative and quantitative micromorphology of pollen flora were examined using the LM and SEM (Figures 4 to 11; Tables 2, 3 and 4).

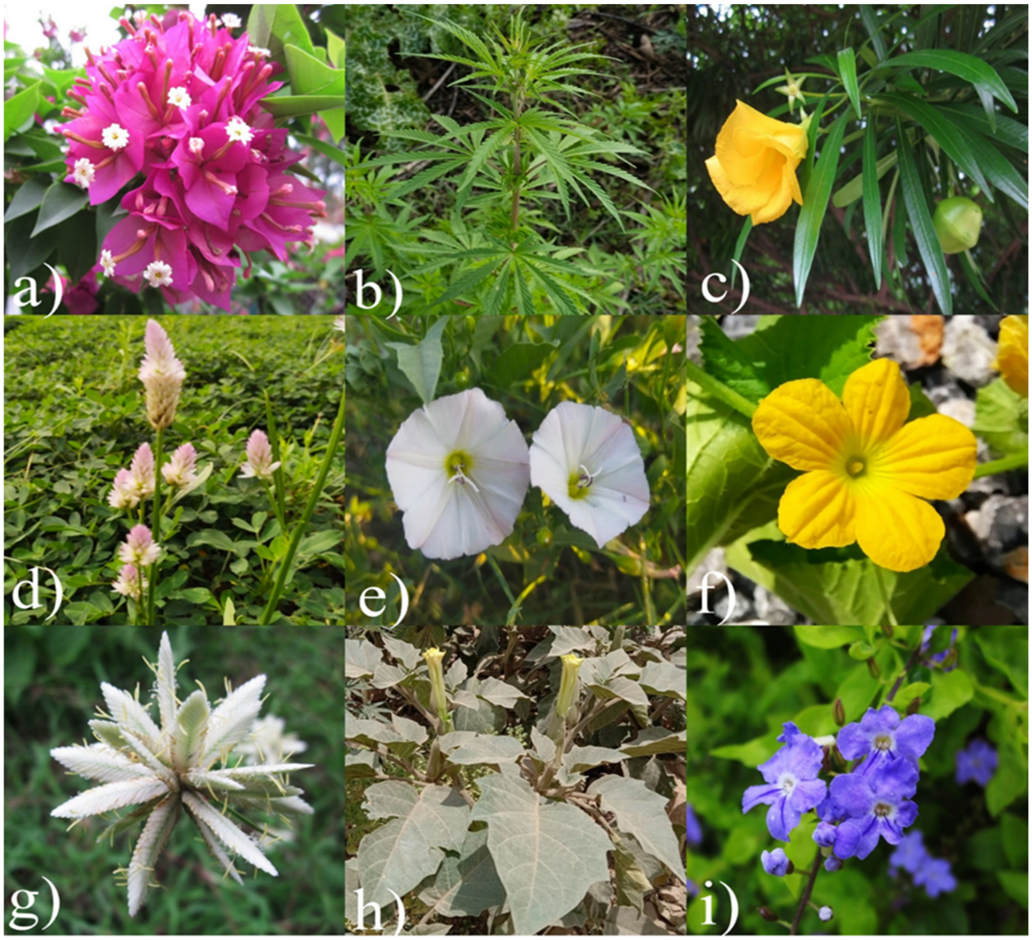


**Figure 1.** Lesser Himalaya plants field pictorial view: (a) *Bougainvillea spectabilis*, (b) *Cannabis sativa*, (c) *Cascabela thevetia*, (d) *Celosia argentea,* (e) *Convolvulus arvensis*, (f) *Cucumis melo*, (g) *Cyperus niveus*, (h) *Datura stramonium*, (i) *Duranta erecta*

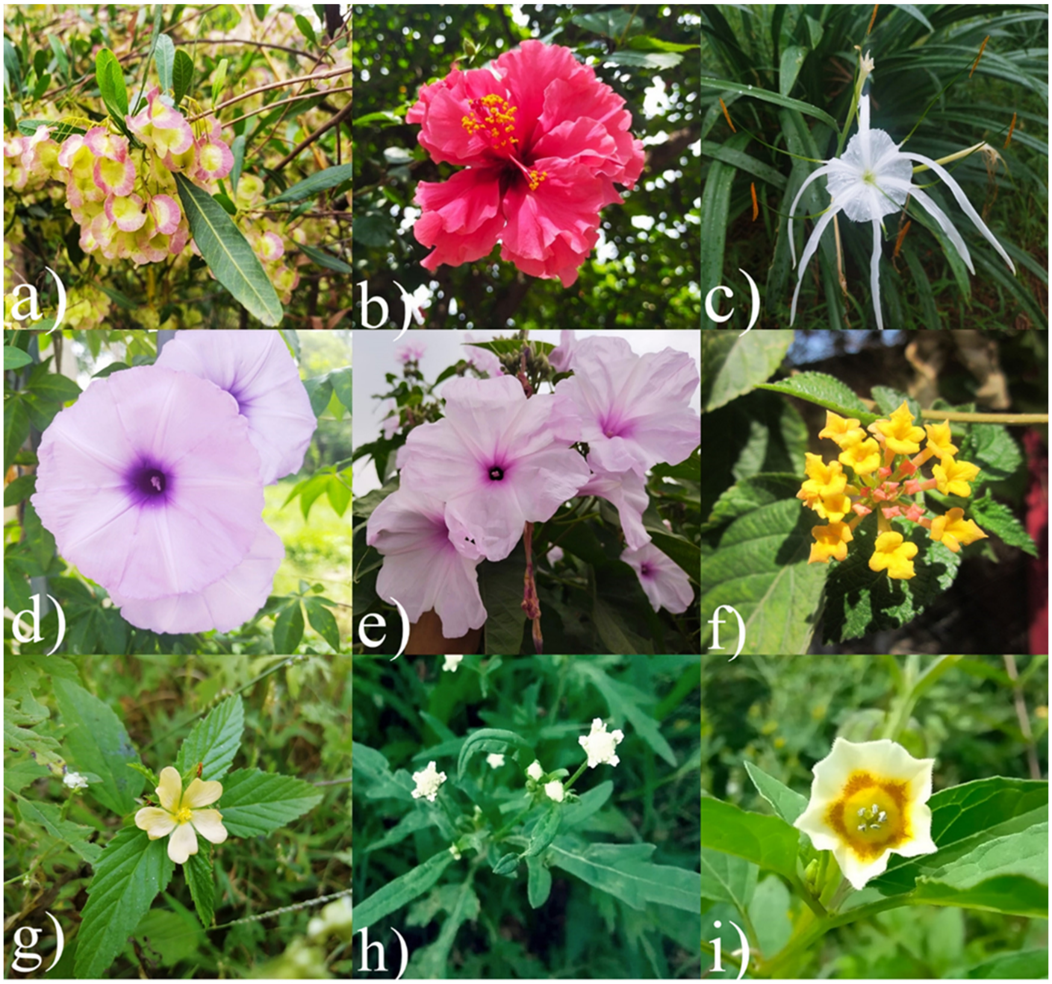


**Figure 1**. Lesser Himalaya plants field pictorial view: (a) *Dodonaea viscosa*, (b) *Hibiscus rosa-sinensis*, (c) *Hymenocallis littoralis*, (d) *Ipomoea cairica*, (e) *Ipomoea carnea*, (f) *Lantana camara*, (g) *Malvastrum coromandelianum*, (h) *Parthenium hysterophorus*, (i) *Physalis angulata*


**Figure 2**. Lesser Himalaya plants field pictorial view: (a) *Ricinus communis*, (b) *Taraxacum officinale*, (c) *Tribulus terrestris*, (d) *Trichodesma indicum*, (e) *Verbena officinalis*, (f) *Zephyranthes carinata*


**Figure 3.** Light microscope pollen photomicrographs. Polar view and equatorial view: (a) *Bougainvillea spectabilis*, (b,c) *Cannabis sativa*, (d,e) *Cascabela thevetia*, (f) *Celosia argentea*, (g,h) *Convolvulus arvensis*, (i,j) *Cucumis melo*, (k) *Cyperus niveus*, (l,m) *Datura stramonium*, (n,o) *Duranta erecta*, (p) *Dodonaea viscosa*, (q) *Hibiscus rosa-sinensis*, (r) *Hymenocallis littoralis*, (s) *Ipomoea cairica*, (t) *Ipomoea carnea*

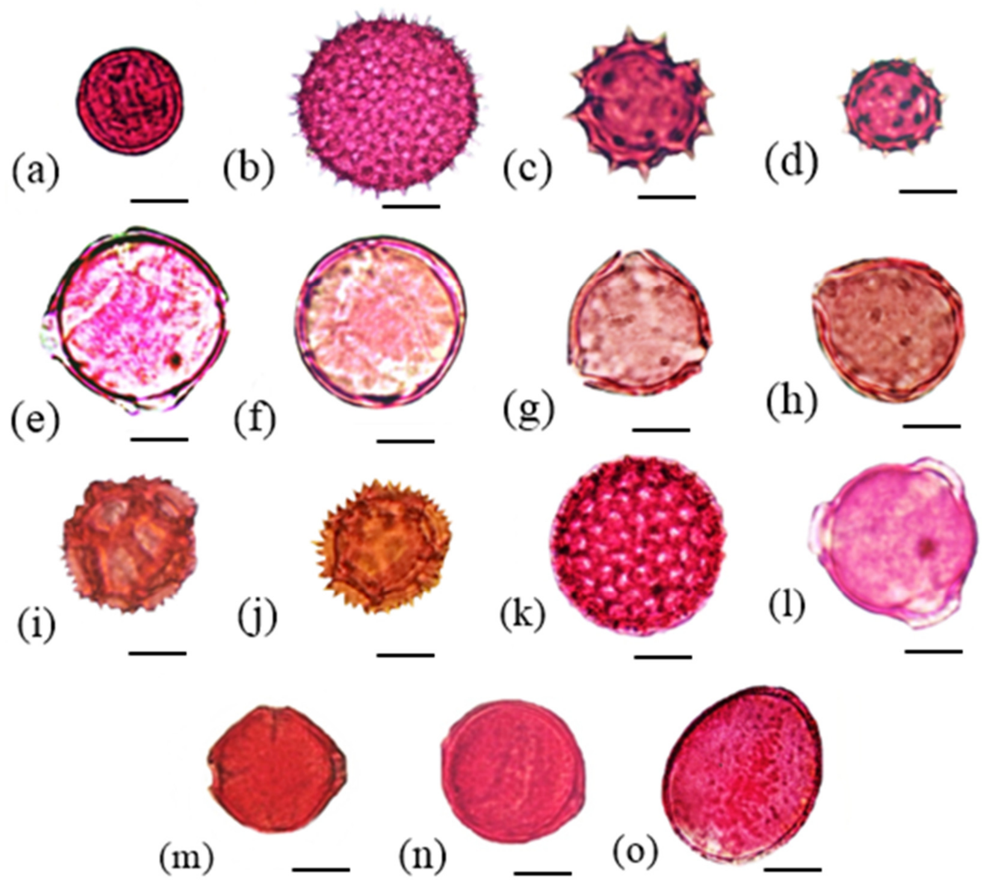


**Figure 4**. Light microscope pollen photomicrographs. Polar view and equatorial view: (a) *Lantana camara*, (b) *Malvastrum coromandelianum*, (c,d) *Parthenium hysterophorus*, (e,f) *Physalis angulata*, (g,h) *Ricinus communis*, (i,j) *Taraxacum officinale*, (k) *Tribulus terrestris*, (l) *Trichodesma indicum*, (m,n) *Verbena officinalis*, (o) *Zephyranthes carinata*

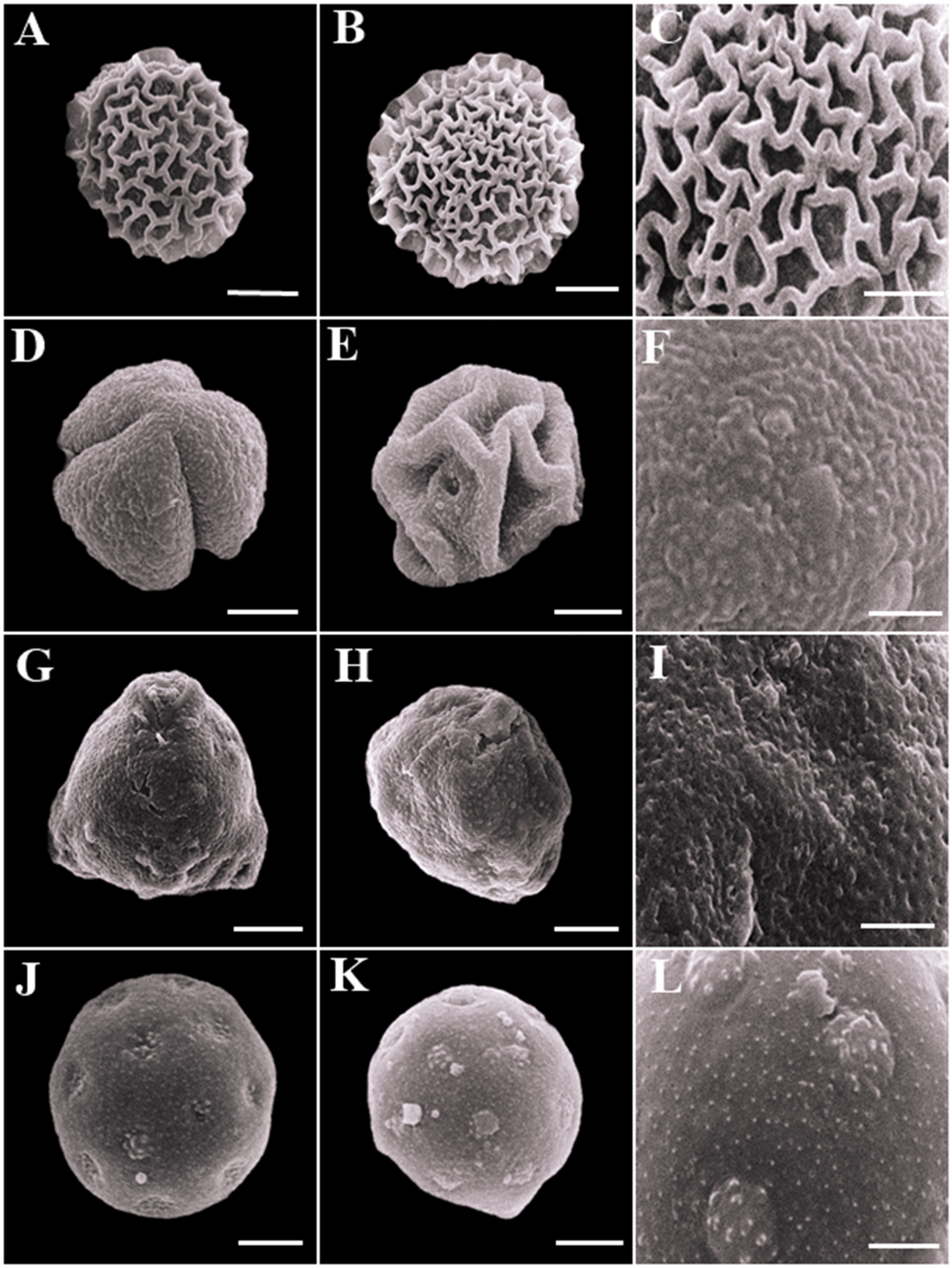


**Figure 5**. Pollen SEM micrographs showing polar view (PV), equatorial view (EV) and exine sculpturing (ES). *Bougainvillea spectabilis* (A) PV-5µm (B) EV-10 µm (C) ES-5µm; *Cannabis sativa*, (D) PV-5µm (E) EV-5µm (F) ES-2 µm; *Cascabela thevetia*, (G) PV-10µm (H) EV-10µm (I) ES- 5µm; *Celosia argentea* (J) PV-5µm (K) EV-10µm (L) ES-2 µm

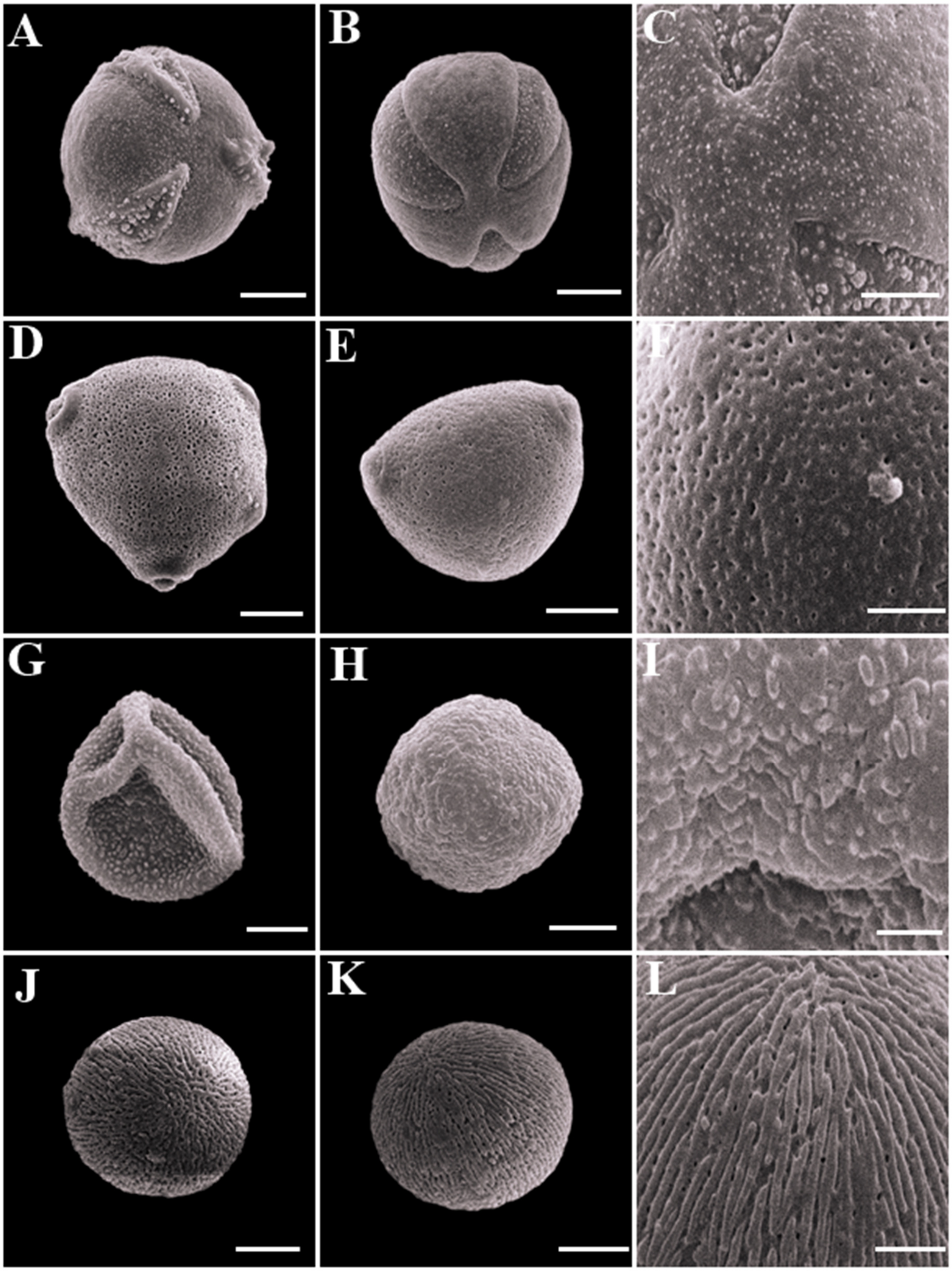


**Figure 6**. Pollen SEM micrographs showing polar view (PV), equatorial view (EV) and exine sculpturing (ES). *Convolvulus arvensis* (A) PV-10µm (B) EV-10µm (C) ES-5µm; *Cucumis melo* (D) PV- 10µm (E) EV-10µm (F) ES-5µm; *Cyperus niveus* (G) PV-2µm (H) EV-10µm (I) ES-5µm; *Datura stramonium* (J) PV-10µm (K) EV-10µm (L) ES-5µm

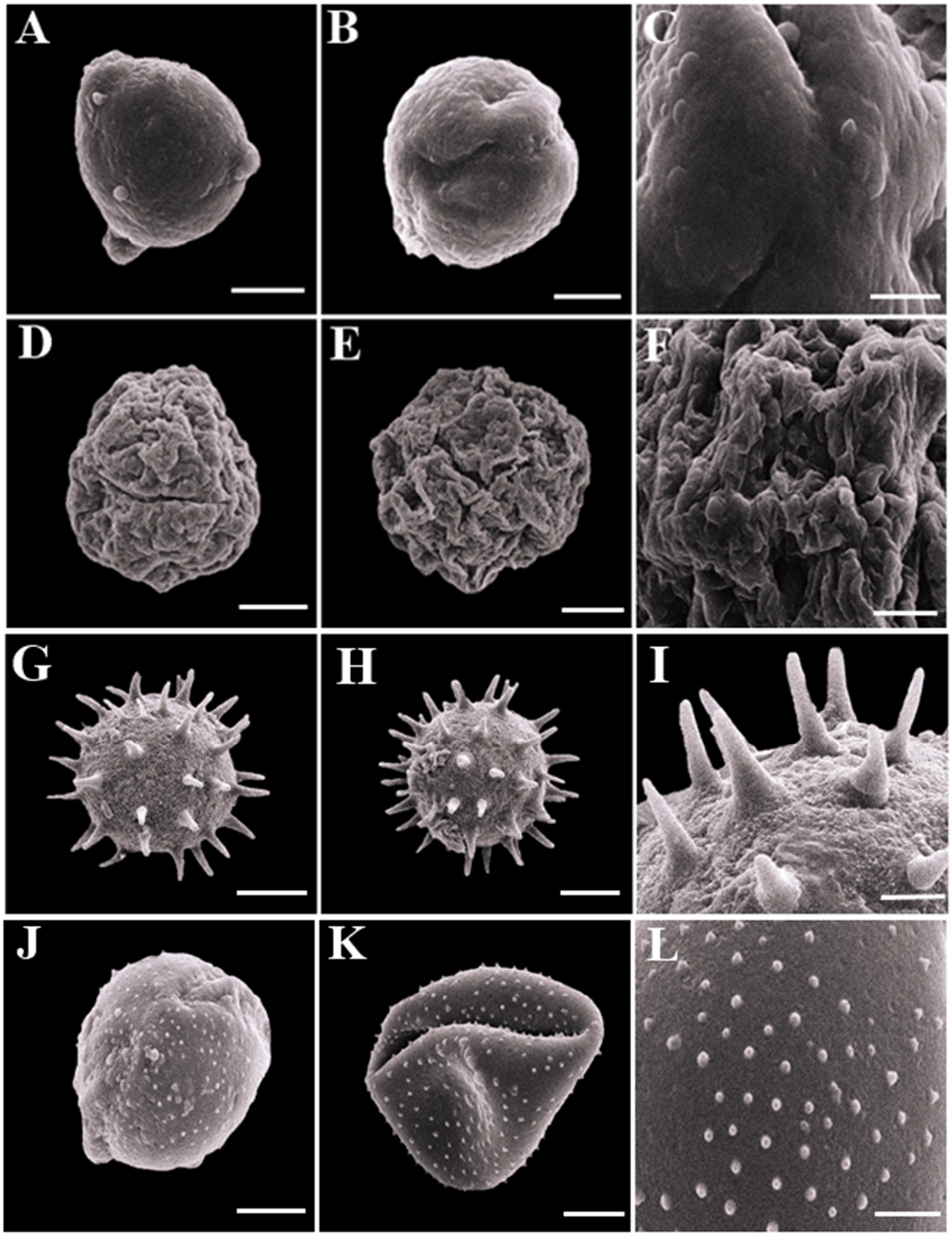


**Figure 7**. Pollen SEM micrographs showing polar view (PV), equatorial view (EV) and exine sculpturing (ES). *Duranta erecta* (A) PV-2µm (B) EV-10µm (C) ES-5µm; *Dodonaea viscosa* (D) PV-10µm (E) EV-10µm (F) ES-5µm *Hibiscus rosa-sinensis*, (G) PV-20µm (H) EV-20µm (I) ES-10µm *Hymenocallis littoralis*. (J) PV-10µm (K) EV-10µm (L) ES-5µm

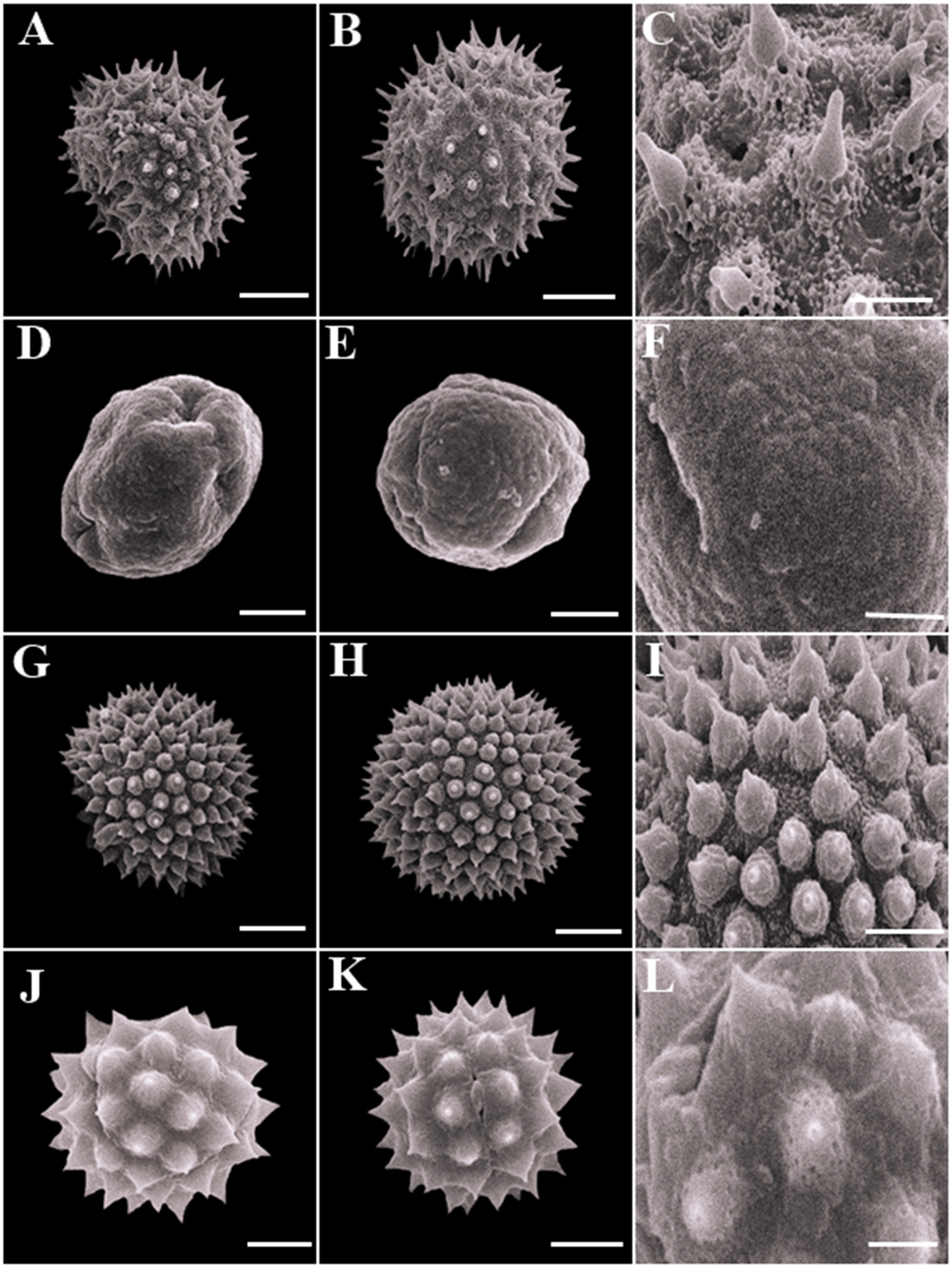


**Figure 8**. Pollen SEM micrographs showing polar view (PV), equatorial view (EV) and exine sculpturing (ES). *Ipomoea cairica* (A) PV-20µm (B) EV-20µm (C) ES-10µm; *Lantana camara* (D) PV- 10µm (E) EV-10µm (F) ES- 5µm *Malvastrum coromandelianum* (G) PV- 10µm (H) EV- 10µm (I) ES-10µm *Parthenium hysterophorus* (J) PV- 5µm (K) EV- 5µm (L) ES- 2µm.

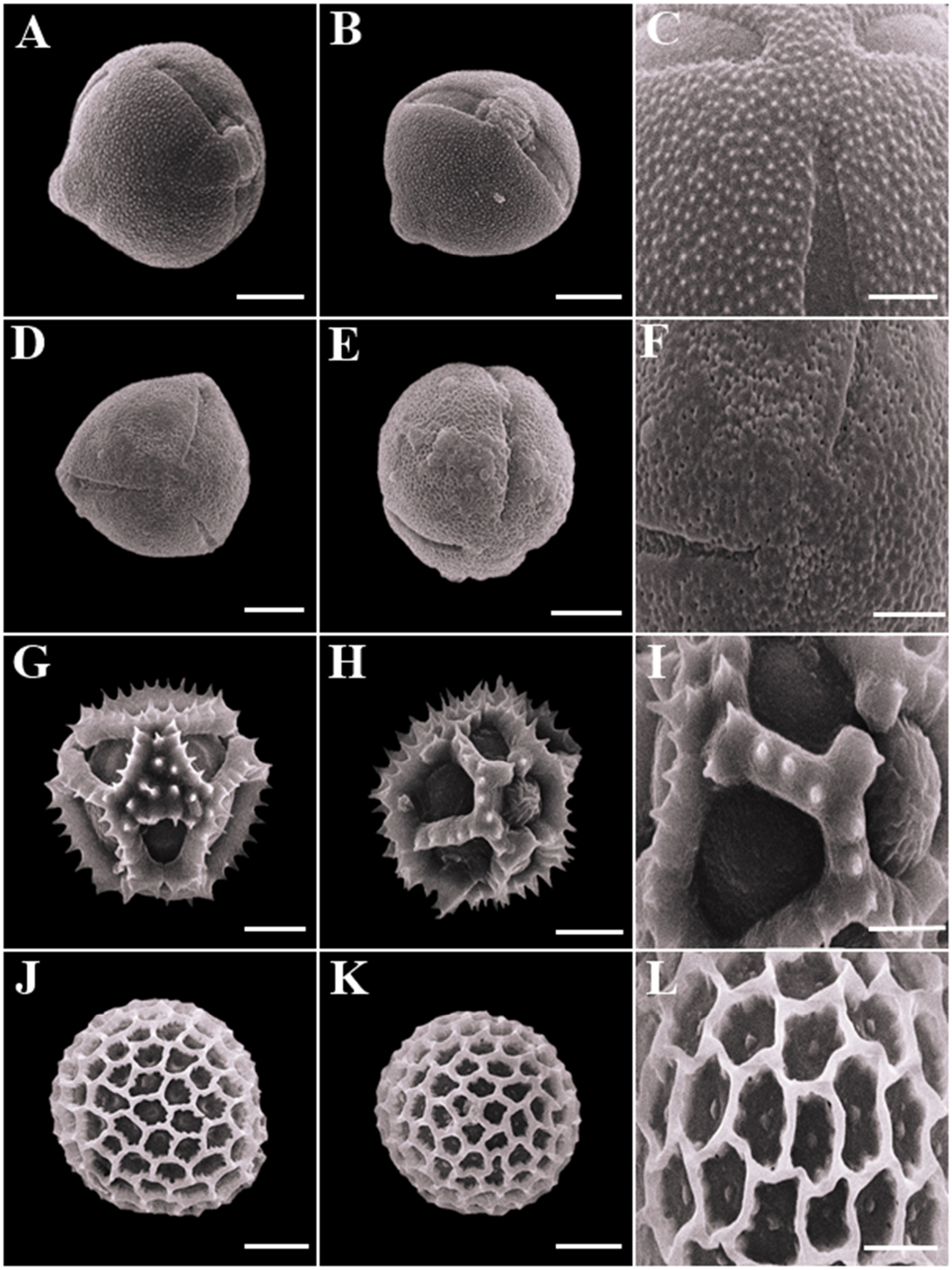


**Figure 9**. Pollen SEM micrographs showing polar view (PV), equatorial view (EV) and exine sculpturing (ES). *Physalis angulata* (A) PV-5µm (B) EV-5µm (C) ES-2µm; *Ricinus communis* (D) PV- 5µm (E) EV-5µm (F) ES-2µm; *Taraxacum officinale* (G) PV-5µm (H) EV-5µm (I) ES-5µm *Tribulus terrestris* (J) PV-10µm (K) EV-10µm (L) ES-5µm.

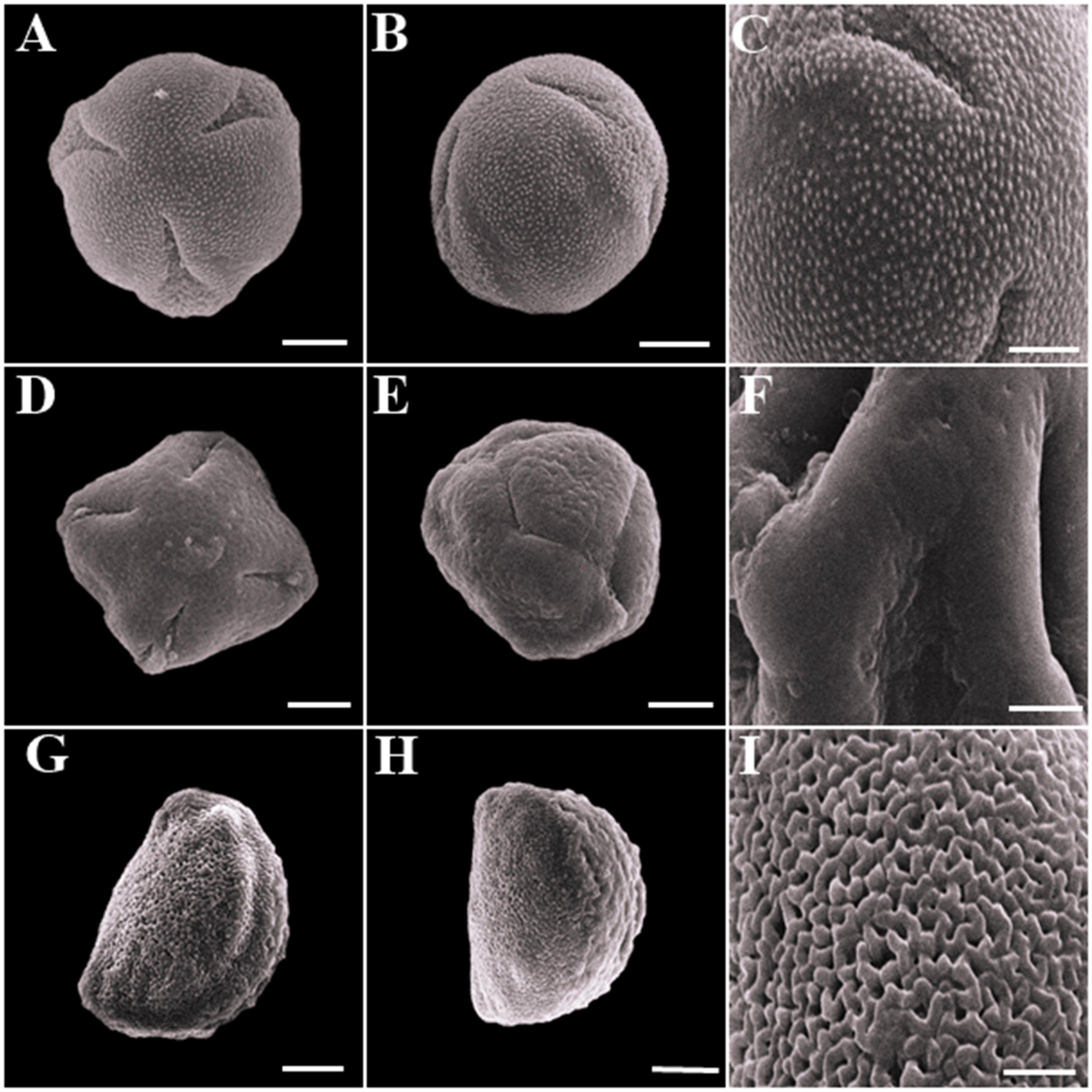


**Figure 10**. Pollen SEM micrographs showing polar view (PV), equatorial view (EV) and exine sculpturing (ES). *Trichodesma indicum* (A) PV-5µm (B) EV-5µm (C) ES-2µm; *Verbena officinalis* (D) PV-10µm (E) EV-10µm (F) ES-2µm *Zephyranthes carinata* (G) PV-10µm (H) EV-10µm (I) ES-5µm

**Table 2.** Quantitative analysis of pollen morphology and size in the studied taxa

| Sr.No | Plant taxa | Polar diameter Mean (Min-Max) S.E µm | Equatorial diameter Mean (Min-Max) S.E µm | P/E ratio | Exine thickness Mean (Min-Max) S.E µm | Mesocolpium Mean (Min-Max) S.E µm | Fertility % | Sterility % |
|---|---|---|---|---|---|---|---|---|
| 1. | *Bougainvillea spectabilis* Willd. | 35.05(29.75-38.75) ±1.66 | 34.80(27.75-38.50) ±1.96 | 1.0 | 2.55(2.25-2.75) ±0.12 | - | 85% | 3% |
| 2. | *Cannabis sativa* L. | 20.4 (20.25-20.75) ± 0.09 | 19.05 (18.25-19.75) ± 0.26 | 1.07 | 0.35 (0.25-0.50) ± 0.06 | - | 83% | 10% |
| 3. | *Cascabela thevetia* (L.) Lippold | 113.1(110.5-115.2) ±0.83 | 110.1(108.7-111.2) ±0.45 | 1.02 | 3.20(2.75-3.75) ±0.16 | 87.0(80.25-109.5) ±5.64 | 72% | 8% |
| 4. | *Celosia argentea* L. | 30.3(27.75-32.0) ±0.73 | 29.3(28.0-30.25) ±0.40 | 1.03 | 2.95(2.75-3.25) ±0.09 | - | 80% | 16% |
| 5. | *Convolvulus arvensis* L. | 71.2(70.50-72.0) ±0.31 | 68.2(67.25-69.50) ± 0.40 | 1.04 | 4.50(4.25-4.75) ±0.11 | 45.0(43.75-45.75) ±0.35 | 84% | 12% |
| 6. | *Cucumis melo* var. agrestis Naudin | 54.75(53.0-55.50) ±0.45 | 52.0(49.75-53.0) ±0.58 | 1.05 | 2.15(2.0-2.25) ±0.61 | 48.75(48.50-49.0) ± 0.07 | 90% | 5% |
| 7. | *Cyperus niveus* Retz. | 28.55(27.25-29.75) ±0.47 | 24.90(24.50-25.25) ±0.15 | 1.16 | 1.80(1.25-2.25) ±0.16 | - | 74% | 5% |
| 8. | *Datura stramonium* L. | 56.8(56.5-57.0) ±0.10 | 55.0(53.7-56.0) ±0.37 | 1.03 | 0.40(0.25-0.50) ±0.06 | - | 89% | 11% |
| 9. | *Duranta erecta* L. | 26.4(6.25-32.2) ±5.04 | 29.4(28.75-29.7) ±0.18 | 0.89 | 0.7(0.50-1.0) ±0.09 | 18.74(16.65-21.24) ±0.40 | 74% | 26% |
| 10. | *Dodonaea viscosa* (L.) Jacq. | 23.9(23.7-24.2) ±0.09 | 23.4(23.2-23.7) ±0.09 | 1.02 | 3.05(2.75-3.50) ±0.14 | 10.34(10.25-10.50) ±0.06 | 82% | 18% |
| 11. | *Hibiscus rosa-sinensis* L. | 1.7(145.2-190.2) ±8.34 | 1.7(147.2-198.1) ±8.22 | 1.0 | 2.8(2.25-3.25) ±0.16 | - | 78% | 22% |
| 12. | *Hymenocallis littoralis* (Jacq.) Salisb. | 138.6(134.75-149.5) ±2.75 | 76.60(40.50-91.0) ±9.47 | 1.80 | 3.25(3.0-3.50) ±0.11 | - | 83% | 6% |
| 13. | *Ipomoea cairica* (L.) Sweet | 97.10(95.50-98.0) ±0.43 | 89.80(89.0-90.50) ±0.25 | 1.08 | 2.60(2.25-3.0) ±0.15 | - | 85% | 4% |
| 14. | *Ipomoea carnea* Jacq. | 102.85(92.0-111.25) ±3.26 | 102.80(94.75-114.5) ±3.43 | 1.0 | 3.55(3.0-4.50) ±0.26 | - | 80% | 4% |
| 15. | *Lantana camara* L. | 27.65(25.50-32.25) ±1.22 | 29.85(27.75-33.0) ±1.23 | 0.92 | 2.30(2.0-2.75) ±0.12 | - | 74% | 7% |
| 16. | *Malvastrum coromandelianum* (L.) Garcke | 85.0(80.25-92.25) ±2.14 | 84.10(78.75-93.75) ±2.68 | 1.01 | 2.60(2.25-3.0) ±0.15 | - | 81% | 2% |
| 17. | *Parthenium hysterophorus* L. | 14.70(14.25-15.25) ±0.16 | 14.50(14.25-14.75) ±0.11 | 1.01 | 1.30(1.0-1.50) ±0.09 | 10.30(9.75-10.75) ±0.16 | 88% | 5% |
| 18. | *Physalis angulata* L. | 33.60(33.0-34.0) ±0.16 | 31.80(31.25-32.25) ±0.18 | 1.05 | 2.50(2.0-2.75) ±0.15 | 25.05(20.50-28.25) ±1.80 | 88% | 5% |
| 19. | *Ricinus communis* L. | 25.3(25.2-25.5) ±0.06 | 28.5(28.2-28.7) ±0.09 | 0.81 | 2.41(2.2-2.7) ±0.11 | 24.3(24.0-24.7) ±0.12 | 79% | 21% |
| 20. | *Taraxacum officinale* (L.) Weber ex F.H.Wigg. | 26.2(25.2-27.0) ±0.36 | 24.9(24.5-25.2) ±0.15 | 1.05 | 2.45(2.25-2.75) ±0.12 | 17.4(15.2-18.7) ±0.58 | 81% | 19% |
| 21. | *Tribulus terrestris* L. | 53.40(50.25-58.0) ±1.53 | 55.30(47.75-58.25) ±1.94 | 0.96 | 2.40(2.0-2.75) ±0.15 | - | 84% | 8% |
| 22. | *Trichodesma indicum* (L.) Lehm. | 25.25(24.75-25.50) ±0.13 | 24.50(24.0-24.75) ±0.13 | 1.03 | 1.60(0.50-5.0) ±0.85 | 14.9(14.50-15.25) ±0.15 | 58% | 4% |
| 23. | *Verbena officinalis* L. | 46.25(43.0-49.75) ±1.10 | 48.75(47.0-50.25) ±0.67 | 0.84 | 2.40(2.0-2.75) ±0.15 | 34.85(32.75-37.75) ±0.95 | 82% | 8% |
| 24. | *Zephyranthes carinata* Herb. | 78.55(74.75-82.75) ±1.31 | 58.45(56.60-59.75) ±0.70 | 1.34 | 2.45(2.25-2.75) ±0.12 | - | 82% | 10% |

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

**Table 1.** Variations in quantitative readings of colpi, spines and pores among pollen grains of examined species

| Sr. No | Plant name | Number of | | | | Length Mean (Min-Max) S.E µm | | | Width Mean (Min-Max) S.E µm | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Colpi | Spines | Pores | Spines between colpi | Colpi | Spine | Pores | Colpi | Spine | Pores |
| 1. | *Cascabela thevetia* (L.) Lippold | 03 | - | - | - | 5.25(4.75-5.50) ±0.13 | - | - | 15.80(15.25-16.25) ±5.64 | - | - |
| 2. | *Celosia argentea* L. | - | - | 05 | - | - | - | 4.6(4.25-4.75) ±0.10 | - | - | 3.0(2.75-3.25) ±0.07 |
| 3. | *Convolvulus arvensis* L. | 03 | - | - | - | 20.4(20.25-20.75) ± 0.09 | - | - | 20.6(20.25-21.0) ±0.16 | - | - |
| 4. | *Cucumis melo* var. agrestis Naudin | 03 | - | - | - | 2.30(2.0-2.75) ±0.32 | - | - | 6.60(5.50-7.25) ±0.32 | - | - |
| 5. | *Duranta erecta* L. | 03 | - | - | - | 10.43(8.74-11.23) ±0.44 | - | - | 7.23(5.50-9.24) ± 0.70 | - | - |
| 6. | *Dodonaea viscosa* (L.) Jacq. | 03 | - | - | - | 2.70(2.0-3.0) ±0.18 | - | - | 6.90(6.75-7.25) ±0.10 | - | - |
| 7. | *Hibiscus rosa-sinensis* L. | - | 17 | - | - | - | 15.4(15.25-15.75) ±0.09 | - | - | 10.5(10.2-11.2) ±0.18 | - |
| 8. | *Ipomoea cairica* (L.) Sweet | - | 27 | 28 | - | - | 5.0(4.50-5.75) ±0.22 | 5.5(5.25-5.75) ±0.09 | - | 2.75(2.25-3.0) ±0.13 | 6.05(5.75-6.25) ±0.09 |
| 9. | *Ipomoea carnea* Jacq. | - | 38 | 48 | - | - | 9.45(8.75-9.75) ±0.18 | 5.4(5.25-5.75) ±0.09 | - | 2.40(2.0-2.75) ±0.15 | 6.70(6.25-7.0) ±0.14 |
| 10. | *Malvastrum coromandelianum* (L.) Garcke | - | 38 | - | - | - | 4.55(4.25-4.75) ±0.09 | - | - | 3.25(3.0-3.50) ±0.11 | - |
| 11. | *Parthenium hysterophorus* L. | 03 | 16 | - | 05 | 0.50(0.25-0.75) ±0.07 | 0.95(0.75-1.25) ±0.09 | - | 4.30(3.75-4.75) ±0.18 | 0.04(0.25-0.50) ±0.06 | - |
| 12. | *Physalis angulata* L. | 04 | - | - | - | 4.20(2.75-5.50) ±0.60 | - | - | 5.95(5.50-6.50) ±0.18 | - | - |
| 13. | *Ricinus communis* L. | 03 | - | - | - | 0.4(0.25-0.50) ±0.06 | - | - | 0.3(0.25-0.50) ±0.06 | - | - |
| 14. | *Taraxacum officinale* (L.) Weber ex F.H.Wigg. | 06 | 29 | - | 11 | 2.45(2.25-2.75) ±0.12 | 0.06(0.50-0.7) ±0.06 | - | 5.35(5.25-5.50) ±0.06 | 0.35(0.25-0.50) ±0.06 | - |
| 15. | *Trichodesma indicum* (L.) Lehm. | 03 | - | - | - | 3.25(3.0-3.50) ±0.07 | - | - | 8.10(7.75-8.50) ±0.12 | - | - |
| 16. | *Verbena officinalis* L. | 04 | - | - | - | 2.60(2.0-3.0) ±0.20 | - | - | 6.05(4.75-7.0) ±0.36 | - | - |

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

**Table 4.** Qualitative features of pollen flora from Lesser

| Sr. No | Plant taxa | Pollen Shape | Shape in polar view | Pollen size | Polarity | Dispersal unit | Pollen type | Aperture orientation | Spine shape | Fastigium cavity | Exine ornamentation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | *Bougainvillea spectabilis* Willd. | Spheroidal | Spherical | Medium | Apolar | Monad | Tricolpate | Sunken | - | - | Cristate-reticulate |
| 2. | *Cannabis sativa* L. | Prolate-spheroidal | Spherical | Small | Isopolar | Monad | Tricolpate | Sunken and furrowed | - | + | Scabrate and rough |
| 3. | *Cascabela thevetia* (L.) Lippold | Prolate-spheroidal | Triangular | Very large | Isopolar | Monad | Tricolpate | Slightly bulged, scabrate | - | - | Scabrate |
| 4. | *Celosia argentea* L. | Prolate-spheroidal | Round | Medium | Apolar | Monad | Polyporate | Circular, bulged and granulate | - | - | Microgranulate and punctate |
| 5. | *Convolvulus arvensis* L. | Prolate-spheroidal | Round | Large | Isopolar | Monad | Tricolpate | Slit like, bulged, and regulate, granulate | - | + | Rough and microscabrate-punctate |
| 6. | *Cucumis melo var. agrestis* Naudin | Prolate-spheroidal | Triangular | Large | Isopolar | Diad | Tricolporate | Slightly bulged, circular, perforate | - | - | Rough and rugulate perforate |
| 7. | *Cyperus niveus* Retz. | Sub-prolate | Spherical | Medium | Apolar | Monad | - | - | - | - | Scabrate-granulate |
| 8. | *Datura stramonium* L. | Prolate-spheroidal | Spherical | Large | Apolar | Diad | - | - | - | - | Striate-rugulate |
| 9. | *Duranta erecta* L. | Oblate-spheroidal | Triangular | Medium | Heteropolar | Monad | Tricolpate | Bulged and scabrate | - | - | Scabrate with slight bumps and ridges |
| 10. | *Dodonaea viscosa* (L.) Jacq. | Prolate-spheroidal | Round | Small | Apolar | Monad | - | - | - | - | Verrucate with rough and warty texture |
| 11. | *Hibiscus rosa-sinensis* L. | Spheroidal | Spherical | Very large | Apolar | Monad | - | - | Regular spines with blunt tips and bulged base | - | Echinate-scabrate |
| 12. | *Hymenocallis littoralis* (Jacq.) Salisb. | Prolate | Oval | Large - Very large | Heteropolar | Diad | Diocolpate | Bulged and scabrate | Regular, small with blunt tips | - | Rough and Microechinate |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 13. | *Ipomoea cairica* (L.) Sweet | Prolate-spheroidal | Spherical | Large | Apolar | Monad | - | - | Regular, pointed spines with bulged bases. | - | Echinate |
| 14. | *Ipomoea carnea* Jacq. | Spherical | Spherical | Large - Very large | Isopolar | Monad | Polyporate | - | Regular, broad, and bulbous at base, blunt tip apex | - | Echinate with conical spines |
| 15. | *Lantana camara* L. | Oblate-spheroidal | Round | Medium | Isopolar | Monad | Tricolpate | Sunken and perforated | - | - | Scabrate |
| 16. | *Malvastrum coromandelianum* (L.) Garcke | Prolate-spheroidal | Round | Large | Isopolar | Monad | - | - | Regular, broad, and bulbous at base, blunt tip apex | - | Echinate |
| 17. | *Parthenium hysterophorus* L. | Prolate-spheroidal | Round | Small | Isopolar | Monad | Tricolpate | Sunken | Regular, perforated, and bulbous base, pointed apex | - | Echinate and perforated |
| 18. | *Physalis angulata* L. | Prolate-spheroidal | Spherical | Medium | Isopolar | Diad | Tri or tetracolpate | Slit like psilate but bulged, and granulate at tips | - | + | Microscabrate-punctate |
| 19. | *Ricinus communis* L. | Sub-oblate | Triangular | Medium | Isopolar | Polyad | Tricolpate | Sunken and slit like | - | + | Scabrate to perforate |
| 20. | *Taraxacum officinale* (L.) Weber ex F.H.Wigg. | Prolate-spheroidal | Triangular | Medium | Isopolar | Monad | Tricolporate | Bulged and circular | Psilate pointed spines with broader base and acute tips | - | Echinate |
| 21. | *Tribulus terrestris* L. | Oblate-spheroidal | Round | Medium -Large | Apolar | Monad | - | - | - | - | Cristate-reticulate with slightly wavy margins |
| 22. | *Trichodesma indicum* (L.) Lehm. | Prolate-spheroidal | Triangular | Small | Isopolar | Tetrad | Tricolpate | Bulged and microgranulate | - | + | Microgranulate |
| 23. | *Verbena officinalis* L. | Sub-oblate | Triangular | Medium -Large | Heteropolar | Monad | Tri or tetracolpate | Sunken and slit like | - | + | Microscabrate |
| 24. | *Zephyranthes carinata* Herb. | Prolate | Oval | Large | Isopolar | Monad | - | - | - | - | Cristate-foveolate |

*Qualitative analysis*

Prolate-spheroidal shape was dominantly observed (13 species) followed by spheroidal, sub-prolate, oblate-spheroidal, prolate, spherical and sub-oblate. Slight variations were seen in pollen types; tricolpate, tricolporate, polyporate in most of the species whereas dicolpate in *Hymenocallis littoralis* and tetracolpate in *Physalis angulata.* Exine sculptural patterns was examined mostly scabrate. However, echinate stratification was visualized in Asteraceous, Malvaceous and Convolvulaceous species. The exine muri elements in other species were cristate-reticulate, granulate, micro-granulate, punctate, micro-scabrate, rugulate-perforate, striate-regulate, verrucate and cristate-foveolate. Various aperture patterns were observed; sunken, furrowed, slightly bulged, scabrate, granulate, slit like, perforate, circular as shown in Table 4. The *Cucumis melo* has the highest fertility (90%), with the sterility and fertility percentages of each species were mentioned in Table 2.

*Quantitative parameters*

Pollen diameter and P/E ratio

The largest polar diameter was observed in *Hymenocallis littoralis* (138.6 µm) while the smallest was observed in *Parthenium hysterophorus* (14.70 µm). Equatorial diameter is measured maximum in *Cascabela thevetia* (110.1 µm) and minimum in *Hibiscus rosa-sinensis* (1.7 µm) as shown in Figure 12. P/E ratio was calculated to be largest in *Hymenocallis littoralis* (1.8), while minimum in *Duranta erecta* (0.89).

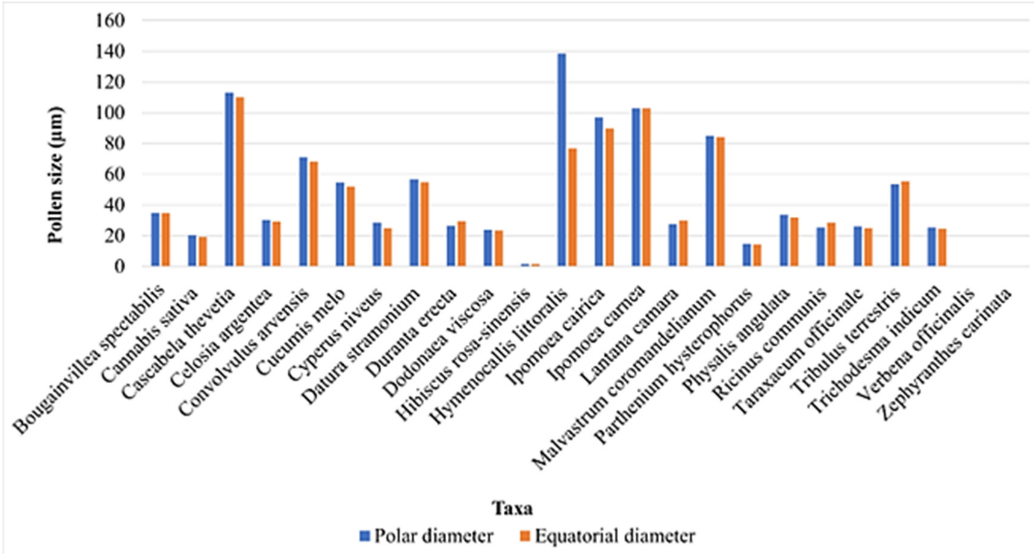


**Figure 12.** Polar and equatorial diameter comparison among palynomorphs

Aperture size

The largest colpi length and width was noted maximum in *Convolvulus arvensis* (20.4 µm and 20.6 µm) whereas the smallest was in the *Ricinus communis* (0.4 µm and 0.3 µm) as shown in Figure 13. Length of spine was observed largest in *Hibiscus rosa-sinensis* (15.4 µm) and smallest in *Taraxacum officinale* (0.06 µm). Width of spine was observed greater in *Hibiscus rosa-sinensis* (10.5 µm) while minimum in *Parthenium hysterophorus* (0.04 µm). The largest pore length was noted in *Ipomoea cairica* (5.5 µm) whereas smallest was observed in the *Celosia argentea* (4.6 µm). *Ipomea carnea* has the widest pores 6.70 µm, while *Celosia argentea* has the narrowest 3.00 µm.

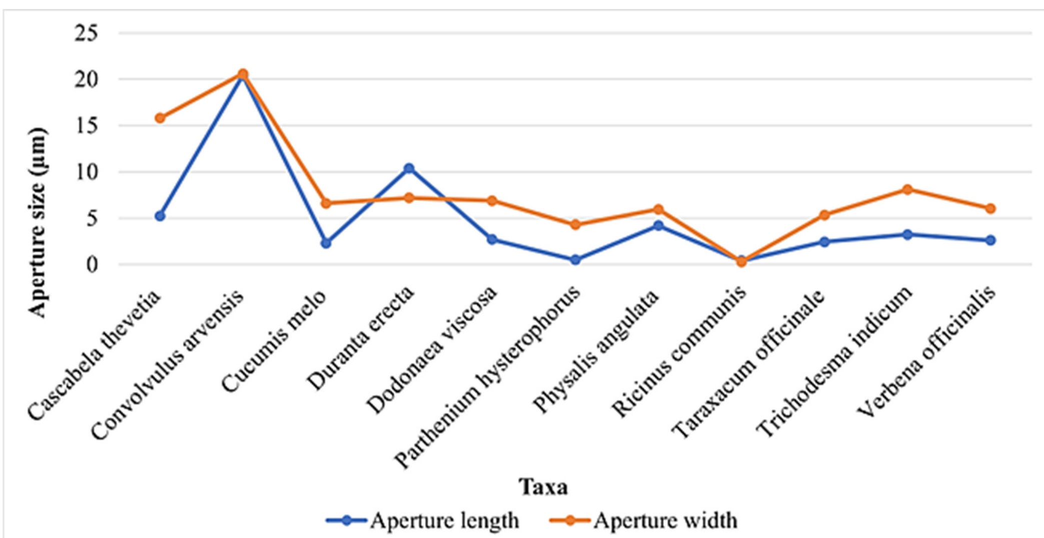


**Figure 13.** Mean variations in colpi size variations among palynomorphs

Exine thickness and mesocolpium distance

Exine thickness was observed maximum in *Ipomoea carnea* (3.55 µm) whereas minimum in the *Cannabis sativa* (0.35 µm). Mesocolpium is the distance between two colpi. It was observed maximum in the

*Cascabela thevetia* (87.05 µm) while minimum in *Parthenium hysterophorus* (10.30 µm) illustrated in Figure 14.

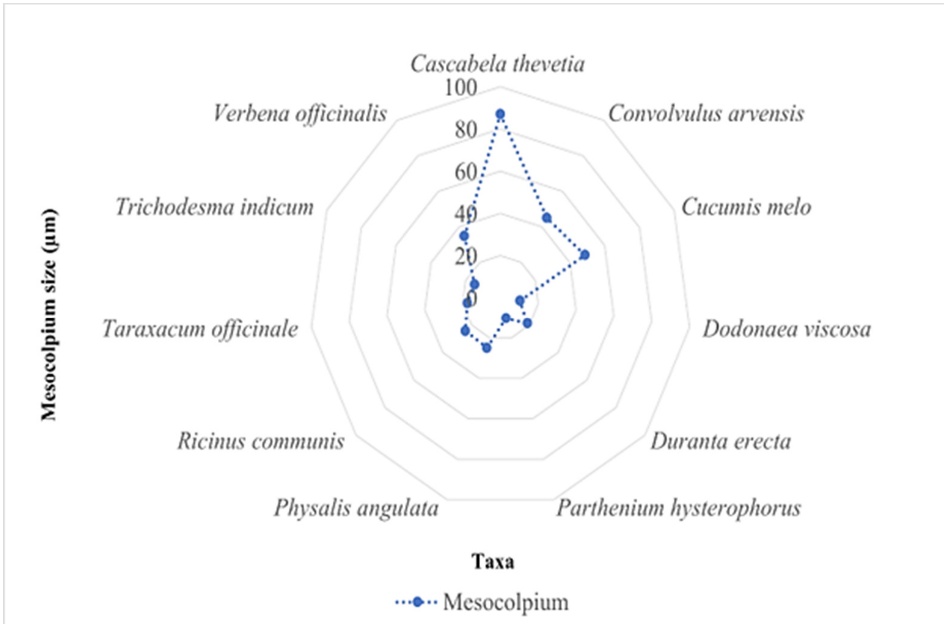


**Figure 14.** Mean variations in mesocolpium distance among palynomorphs

## Discussion

The relationship between various plant families and groups can be more easily determined by the taxonomic study of pollen (Joujeh *et al*., 2019). Researchers classify plants of various areas and regions on basis of pollen morphology (Najar *et al*., 2022). The Lesser Himalayan region boasts a breath-taking array of plant life, with many species still waiting to be uncovered.

*Bougainvillea spectabilis* pollen was observed radially symmetrical, oblate, tricolpate, having long colpate colpi without endo apertures, reticulate exine sculpturing and hetero brochate lumina in past research (Maw *et al*., 2020). While we have observed pollen of *Bougainvillea spectabilis*. as spheroidal shape, medium sized, a polar, monad, tricolpate, sunken colpi with cristate-reticulate exine sculpturing. In the past study pollen of *Cannabis sativa* was observed as triporate, when viewed from the polar and equatorial angles the shape of the pollen appeared either oblate or spheroidal. (Kayani *et al*., 2015). While in our findings pollen of *Cannabis sativa L.* was recorded prolate- spheroidal, spherical, small, iso-polar, monad, having sunken and furrowed 3-colpate, with scabrate and rough exine surface.

*Cascabella thevetia* pollen were noted as monad, sub-spheroidal shape with three colpi, the outline appears lobate, colpus have obtuse ends, which are classified as brevicolporus. The exine sculpturing was observed micro-reticulate to perforate in the previous research (Naz *et al*., 2019). However, our findings on *Cascabella thevetia* revealed pollen were prolate- spheroidal, triangular, isopolar, very large monad, three slightly bulged scabrate colpi and scabrate exine surface. *Celosia argentea* grains were found to be monad with radial symmetry, spheroidal shape, and small size. They have a total of 18 apertures and poly-pantoporate, collapsed circular-like shapes and sparse granules. The exine sculpturing was rough and punctuate with numerous sparsely distributed granules (Usma *et al*., 2022b). In our research we have observed pollen of *C. argentea* as prolate- spheroidal, round, medium, a polar and monad. Polyporate, circular, bulged and granulate colpi with exine surface micro-granulate and punctate.

Pollen of *Convolvulus arvensis* were medium sized, prolate shape, tricolpate, perforate-scabrate exine sculpturing. The colpi are long and narrow, and the colpus membrane is sparsely perforated and does not have any spines (Amina *et al*., 2020; Ashfaq *et al*., 2020). Our findings indicate the pollen of *C. arvensis* as prolate-spheroidal, round, large, iso-polar, monad. Three colpi that are slit like, bulged, and rugulate, granulate while with exine surface is rough and micro scabrate-punctate. Pollen of *Cucumis melo* var. *agrestis* were recorded prolate, sub-oblate to oblate, reticulate ornamentation previously (Perveen and Qaiser, 2008). While in present research pollen of *C. melo* var. *agrestis* were recorded prolate- spheroidal, triangular, iso-polar, dyad and large size. Colpi are slightly bulged, circular and rugulate perforate while exine sculpturing is rough and perforate.

Pollen of *Cyperus niveus* was monoporate, spherical in polar view, oblate-spheroidal in the equatorial view with P/E ratio 0.94 and exine thickness 0.89 µm (Ahmad *et al*., 2020). While we observed pollen of *C. niveus* was sub-prolate, spherical, medium, a polar, monad and scabrate-granulate exine. The pollen grains of *Datura stramonium* were observed either roughly spherical or oblate in shape, with a circular impressions, three furrowed, brevi-colpate (Kayani *et al*., 2019). While we have observed pollen of *D. stramonium* prolate-spheroidal, spherical, large, a polar, and exine surface striate-regulate.

Pollen of *Duranta erecta* were previously characterized as medium-sized, triangular, prolate-spheroidal and is either di-colporate or tricolporate with psilate exine. Pollen were oblate-spheroidal, tricolporate, and have a semi-reticulate exine (Sousa *et al*., 2011). However, our research indicated the pollen of *D. erecta* oblate-spheroidal, triangular, medium sized, heteropolar and monad. Tricolpate, bulged apertures with scabrate exine having slight bumps and ridges are present. *Dodonaea viscosa* grains were observed monad, medium size with a prolate spheroidal shape that can appear either circular or triangular. It was also discovered iso-polar, tricolpate, and has a psilate exine (Alnagger *et al*., 2022). In our research, pollen of *D. viscosa* were observed prolate-spheroidal, round, small, a polar, monad, exine surface was verrucaate with rough and warty texture.

In previous findings *Hibiscus rosa-sinesis* pollen were seen spheroidal shape, a polar, displays radial symmetry in polar view and bilateral symmetry in equatorial view. The spines on the surface were mostly curved and directed away from the center with blunt or rounded tips (NAGGAR, 2004). While in our study pollen of *H. rosa-sinesis* were spheroidal, spherical, very large, a polar, monad and having regular spines with blunt tips bulged base, exine ornamentation echinate-scabrate. Previous studies on *Hymenocallis littoralis* grains were described as large, circular, scabrate with a prolate shape and the absence of colpi (Zafar *et al*., 2022). In another research it was showed scabrate, verrucate colpi, psilate and scabrate exine at the apocolpium, while rest of the area reticulate with well oriented muri (Bahadur *et al*., 2018). We observed pollen of *H. littoralis* as prolate, oval shape, large to very large, heteropolar, two colpi that are bulged, regular, small spines with blunt tips and exine sculpturing rough and micro-echinate present.

Pollen of *Ipomoea cairica* were described medium sized, sub-spheroidal, scabrate and echinate (Ashfaq *et al*., 2019). While this research observed pollen of *I. cairica* as prolate- spheroidal, spherical, large, monad, regular, pointed spines with bulged bases with echinate exine. In previous literature the pollen of *Ipomoea carnea* were spherical in shape, has multiple pores, and is covered with spines that create a tetragonal pattern. At the base of these spines, there are bulbous projections, and the pollen also features circular apertures (Basarkar and Technology, 2017; Farid, 2022). In current study pollen of *I. carnea* were spherical, large to very large, a polar, monad and polyporate. Exine sculpturing echinate with conical spines. Spines are regularly arranged on the surface with broad and bulbous at base, gradually tapering toward apex with blunt tips.

Previous studies have described the pollen of *Lantana camara* having different characteristics. *(Zafar et al*., 2022) identified it as tricolporate, medium-sized, round, and scabrate. (Basarkar and Technology, 2017) explained *L. camara* pollen were tricolporate, elliptical, triangular, and psilate. Whereas current findings described *L. camara* grains were oblate-spheroidal, round, medium, iso-polar, monad, tricolpate, sunken and perforated colpi with scabrate exine. Past studies on pollen data of *Malvastrum coromandelianum* shown large, oblate-spheroidal in shape, with multiple pores, and a surface covered in spines and small spinules. (Cheema, 2018; Zafar *et al*., 2022). We observed *M. coromandelianum* grains were prolate- spheroidal, round, large, iso-polar and monad. Exine is echinate with regular spines that are broad and bulbous at base and blunt tip apex.

Previous research identified pollinic features of *Parthenium hysterophorus* as small, circular, and oblate in shape. It was perforate and echinate, with three colpi visible on its surface (Attique *et al*., 2022; Basarkar and Technology, 2017; Nabila *et al*., 2022). However, this study described *P. hysterophorus* pollen were observed prolate-spheroidal, round, small, iso-polar, monad and tricolpate. Echinate and perforated exine having regular, spines that consist perforated bulbous base and pointed apex. Earlier study was identified the pollen of *Physalis angulata* were psilate, oblate-spheroidal or prolate in shape, with four or three colpi (Bhat *et al*., 2018). The present work represent pollen of *P. angulata* were as prolate-spheroidal, spherical, medium and iso-polar.

According to Bahadur *et al*. (2022) the pollen of *Ricinus communis* were oblate-spheroidal in shape, with two colpi visible on its surface, echinate exine, covered in small spines. We described in this study pollen of *R. communis* were observed sub-oblate, triangular, medium, iso-polar. Tricolpate, sunken and slit like apertures with fastigium cavity visible while exine surface is scabrate to perforate.

Nabila *et al*. (2022) elaborate *Taraxacum officinale* grains were monad, with six colpi visible on its surface exine is echinate, covered in small spines. In polar view, the shape of the pollen is circular to semi-angular, while in equatorial view, it is also circular to semi-angular. In our finding grains of *T. officinale* were prolate-spheroidal, triangular, medium size, iso-polar, monad and having tricolporate, bulged and circular apertures. Echinate exine consisting of pointed spines with broader base and acute tips. Past studies have reported that the pollen grains of *Tribulus terrestris* were oblate-spheroidal in shape have multiple pores, including both polyporate and pantoporate types and feature a reticulated exine (Thakur *et al*., 2020). Whereas current observation explained pollen of *T. terrestris* were oblate-spheroidal, round, medium-large, a polar and monad. Cristate-reticulate exine with slightly wavy margins.

Kumar *et al*. (2020) described the pollen of *Trichodesma indicum* was tricolporate, with a sub-prolate shape and a small size. The colpi are longicolpate that are elongated in shape. The pollen surface features obscurely reticulate sculpturing. While in our results pollen of is *T. indicum* were examined prolate- spheroidal, triangular, small, iso-polar, and tetrad. Colpi are bulged, micro-granulate, three in number with fastigium cavity visible

(Perveen and Qaiser, 2007) reported that the grains of *Verbena officinalis* were oblate-spheroidal in shape, striate-regulate exine sculpturing and has three colpi. However, grains pollen of *V. officinalis* were observed sub-oblate, triangular, medium-large, heteropolar, monad, tri or tetracolpate, sunken and slit like colpi with microscabrate exine in present work. The pollen of *Zephyranthes carinata* were described previously round and has a textured surface with ridges and furrows that form hexagonal or pentagonal shapes. This texture is due to the muri on the exine, which gives it an ornamental appearance. (Bahadur *et al*., 2018). Present study interprets the pollen of *Z. carinata* were oval, large, iso-polar, monad, prolate and oval. Colpi are nonvisible while exine sculpturing is cristate-foveolate.

Thus, the study of pollen morphology can offer valuable tools for the identification of different plant species. Further, these palynological method can be applied in comparative and taxonomic studies to provide important insights into evolutionary relationships and accurate classification of different angiosperms grouping.

## Conclusions

Pollen morphological traits from selected flora of the Lesser Himalayas, such as pollen shape, size, type, aperture orientation, and exine sculpturing were significant for accurate species identification. Exine stratification were visualized as echinate, cristate-reticulate, granulate, punctate, scabrate, rugulate-perforate, striate-rugulate, verrucate, cristate-foveolate patterns. Pollen types observed were tricolporate, tricolpate, polyporate. Major shapes observed in polar view were spherical, round, triangular, tetragonal while prolate-spheroidal, spherical, oblate-spheroidal, prolate and sub-oblate in equatorial view. Palynomorphs with the highest mesocolpium distance were measured in *Cascabela thevetia* (87.05 µm). Whereas exine thickness was noted maximum for *Ipomoea carnea* (3.55 µm). Colpi size was calculated largest for *Convolvulus arvensis* (20.4 µm). The variations in morpho pollinic features highlights the diversity of species found in Lesser Himalaya and this knowledge of pollen flora description was helpful to resolve systematics and correct identification of problematic taxa.

## Authors' Contributions

KK: Contributed to the conceptualization of the study, data collection, and analysis. MZ: Provided guidance throughout the research process, contributed to the writing and revision of the manuscript. MA: Participated in data analysis and interpretation. MSA: Contributed to literature review and manuscript writing. MSE: Funding, Provided expertise in a specific aspect of the research methodology. TM: Contributed to data interpretation and statistical analysis. AY: Involved in data collection and organization. SI: Contributed to the discussion section of the manuscript. DS: Provided critical feedback and revisions to the manuscript. NN: Participated in the design of the study and data interpretation. HFE: Contributed to the conceptualization and design of the study. IM: Participated in data collection and analysis. MSdeO: Involved in manuscript preparation and formatting. SM: Provided expertise in a specific area of the research topic. VF: Contributed to the overall supervision and coordination of the research project. All authors read and approved the final manuscript.

**Ethical approval** (for researches involving animals or humans)

Not applicable.

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## Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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