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Palynological Diversity In Dicotyledonous Species: Morphological And Taxonomic Insights

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Abstract
This study conducted a detailed examination of pollen morphology across 26 species belonging to 24 genera from diverse dicot families in Annamalai Nagar, Chidambaram, Tamil Nadu. The selected species included representatives from families such as Acanthaceae, Apocynaceae, Bignoniaceae, Capparaceae, Caricaceae, Commelinaceae, Cucurbitaceae, Fabaceae, Lamiaceae, Liliaceae, Malpighiaceae, Malvaceae, Moringaceae, Nyctaginaceae, Nymphaeaceae, Oleaceae, Rubiaceae, Rutaceae, and Solanaceae. Pollen grains were collected from various localities and analyzed using light microscopy to assess their morphological characteristics. Key features examined included pollen grain size, shape, symmetry, aperture type, and surface ornamentation. The study focused on identifying and documenting the variations in pollen morphology among these species, which are crucial for taxonomic classification and phylogenetic analyses. The findings contribute valuable insights into the evolutionary relationships and ecological adaptations within these plant families. Moreover, pollen morphology serves as a vital tool in understanding plant reproductive strategies, pollen dispersal mechanisms, and responses to environmental factors. This research underscores the significance of palynological studies in elucidating the diversity and adaptation of flowering plants in local ecosystems, thereby enhancing our broader understanding of plant biology and biodiversity conservation efforts.
Keywords: *Annamalai Nagar, Dicot plants, Palynology, Pollen grains*

1. INTRODUCTION

Hyde and Williams developed the term "palynology" in 1944 to describe the study of pollen grains and spores, emphasizing their outward appearance rather than their interior makeup. The male reproductive organs of flowers create a powdery substance called pollen, which is essential for the sexual reproduction of seed plants. Every pollen grain produces male gametes or sperm cells by acting as a reduced microgametophyte (Bhattacharya, 2014).

The male gametes or sperm cells of flowering plants, referred to as pollen grains, are crucial to their ability to reproduce. Typically formed in the anthers of flowers, these grains explode into the environment and tend to take the form of a fine, powdery dust. They fluctuate greatly in size, shape, and structure among plant species, which reflects adaptations to diverse environmental factors and pollination techniques. (Al-Ghamdi *et al.*, 2021). Pollen grains are essential to plant reproduction and are carried by wind, water, insects, and other vectors, ranging in size from less than 10 to more than 100 micrometers. Their traits—particularly exine micromorphology—are frequently employed in taxonomical and phylogenetic analyses and are useful in identifying evolutionary trends among plant groups. (Barone Lumaga *et al.*, 2020). Palynological analysis is an essential technique in fields ranging from meteorology to archaeology because it provides important insights into previous environments, vegetation changes, and evolutionary processes. (Kelly *et al.*, 2002).

The inner and outer walls of pollen grains, the male gametophytes of flowering plants, are composed of two main concentric layers. The intine, the inner wall, facilitates the pollen tube's germination. The exine, or outside wall, acts as a barrier to keep the pollen grain safe. Pollen characteristics can be grouped by size, shape, polarity, symmetry, aperture type, P/E ratio (polar to equatorial diameter), ornamentation details, and measurements in micrometers (µm).Their characteristics are broken down by Wang and Dobrita (2018). This study explored the pollen morphology of diverse dicotyledonous plant groups in Annamalai Nagar, focusing on their structural variations and taxonomic significance. A total of 26 species belonging to 24 genera across multiple families were systematically collected from various locations in Annamalai Nagar, Chidambaram, Tamil Nadu, to provide a comprehensive understanding of their morphological characteristics.

2. MATERIALS AND METHODS

2.1. Study area

The current field of study Annamalai Nagar is situated on Survey of India (SOI) topo sheet No. 58 M/15, between latitudes 11°20' to 11°25'N and longitudes 79°40' to 79°45'E (Raja Kumar *et al.*, 2016). The taluk headquarters of the Cuddalore district in Tamil Nadu is Annamalai Nagar Township, which is situated east of Chidambaram. The campus, which covers around 1000 acres, is located north of the Coleroon River, which empties into the Bay of Bengal. (Chidambaram *et al.*, 2009). The district experiences a hot, tropical environment, with March through May marking the height of the summer season. The southwest monsoon season will have modest rainfall, while the northeast monsoon season will see the most rainfall. January through February is considered a cool winter. Rainfall typically ranges between 1150 and 1250 mm per year (Aswini *et al.*, 2024) (Fig.1).

2.2. Plant collection

The 26 plants were collected from Annamalai Nagar during the flowering season. The collected plants were identified by K.M. Matthew, 1991 (An Excursion Flora of Central Tamil Nadu, India) and Gamble flora, 2014 (Flora of the Presidency of Madras).

2.3 Sample preparation

Flower buds were taken straight from the plants before anthesis. Separated the anthers with some forceps in a sterile condition. 5 ml of 70% ethanol was added, smashed with a glass rod, and sieved in glass centrifuge tubes. The pellets were preserved after the samples were centrifuged for five minutes. 5 ml of glacial acetic acid was added, and after 5 minutes of centrifugation, the pellets were preserved. Five milliliters of acetolysis mixture (9:1 mixture of sulfuric acid and acetic anhydride) were added, heated for seven to ten minutes at 100° C, centrifuged, and the pellets were preserved (Erdtman, 1960). 5 ml of glacial acetic acid was added once more, and the pellets were preserved after centrifugation. To get rid of extra chemicals, the samples were centrifuged and serially cleaned at least three times.

For microscopic analysis, the materials were placed on microscope slides in glycerine jelly, covered with cover slips, and sealed with paraffin wax. An Olympus Light microscope equipped with an Optika camera was used to observe the pollen morphology, which included pollen type, size class, and shape class, as well as measurements of polar and equatorial diameter (µm), aperture, symmetry, polarity, and ornamentation (Table 2). The images were captured at a 40x magnification. A 40x lens was used to measure the quantitative and qualitative data, and 10 pollen grains were measured for each pollen feature in order to get precise results. The figures had a 20µm scale affixed. For every pollen grain of the taxa that were gathered, the morphological traits were noted. The measurements of the polar and equatorial diameter (µm), aperture, P/E ratio, pollen unit, shape class, size class, and ornamentation were recorded (Table 2).

2.4 Measurement

The tool Graph Pad Prism was used to evaluate the variations and quantitative data in polar and equatorial diameter (Fig. 2) and also heatmap was used to show the relationship among the studied pollen grains (Fig. 3). Pie diagrams illustrates the count of habit, pollen unit, shape class, size class, aperture and exine sculpturing of the studied species (in %) (Figs. 4, 5, 6, 7, 8 and 9). The measurement of polar and equatorial diameter (µm) was determined by counting 10 grains of each taxon (n=10). Arithmetic mean and range of both polar and equatorial diameters were noted (Table 3). The shape class is indicated by the P/E ratio.

P/E Ratio = Polar axis/Equatorial diameter × 100

3. RESULTS

The Table 1 includes the generic descriptions of 26 plant species from 19 different families. In addition to their scientific name, common name, Tamil name, habit, flowering season, and pollinator, members of the family comprise trees, shrubs, climbers, and aquatic plants. Using a light microscope, the micromorphological traits of the species were examined. From the taxa gathered, the following were discussed: pollen unit, shape classes, size class, measurement of polar and equatorial diameter (µm), P/E ratio, aperture, and ornamentation (Table 2). The pollen micro-morphological properties of taxa in polar and equatorial diameter (µm) are quantitatively analyzed in Table 3. The plant morphology and pollen morphology of the studied plants were discussed below.

Plant and pollen morphology of *Abutilon grandifolium* (willd.) Sweet

A fast-growing perennial shrub (2–5m) native to South America, found in tropical and subtropical regions. It has large, velvety, heart-shaped leaves (5–15 cm) with serrated edges. Bright yellow, bell-shaped flowers (4–5 cm) bloom in warmer months. Small, segmented capsule fruits contain dark kidney-shaped seeds, dispersed by wind or animals. Its fibrous root system aids in rapid spread and establishment. The pollen grains of *A. grandifolium* are very large, spheroidal, with an average diameter of 68.2 µm in polar view and 67.6 µm in equatorial view. The polar/equatorial (P/E) ratio is 100, indicating a nearly perfect spherical shape. The pollen grains are pantoporate, possessing numerous circular to slightly oval pores evenly distributed across the exine. The exine is less than 3 µm thick and exhibits echinate with a thick tectum, covered in spinules. The large size of the pollen and the spinulose decorations suggest that the plant has changed to make it stickier for pollinators, which makes cross-pollination more effective (Table 2, 3 & Figure 10-a, b).

Plant and pollen morphology of *Allamanda cathartica* L.

A sprawling shrub native to Tropical America, commonly found in coastal plains. It has whorled, broadly oblong leaves (8–12 cm long, 3–5 cm wide) and terminal cymes. The golden-yellow, funnel-shaped corolla (6–9 cm) has overlapping lobes. Enclosed stamens have sagittate anthers, and the ovary is bilocular. The fruit is a spiny, (sub) globose drupe, about 4 cm in diameter. The pollen grains of *A. cathartica* are large and sub-prolate in shape, with a polar axis measuring 49.4 µm and an equatorial diameter of 58.4 µm, giving them a P/E ratio of 118. These grains are known for their 3-colporate apertures, which means they have three long colpi with separate pores that help pollen germinate. The exine is relatively thin, measuring approximately 1.5–2 µm in thickness. The tectum is well-developed, providing structural integrity and contributing to the uniformity of the pollen sculpturing. The ornamentation is psilate, meaning it lacks significant surface projections, resulting in a smooth or faintly textured appearance (Table 2, 3 & Figure 10-c, d).

Plant and pollen morphology of *Barleria cristata* L.

A subshrub (1.5–2m) native to the Himalayas, India, Burma, East Asia, and the Philippines, found in coastal plains up to 900m. It has elliptic-oblong to lanceolate leaves (8–12 cm) and flowers in lax cymes (1–4 per group). The purplish-pink, violet, or white corolla is about 4 cm across. The calyx lobes dry to scarious, with spinous and ciliate outer lobes. It has two hairy stamens, three staminodes, and an ovary with four ovules. Flowering occurs from December to February, with fruiting from January onward. *B. cristata* pollen grains are small and shaped like a prolate-spheroidal disc. They are about 20.4 µm across the equator and 21.8 µm across the polar axis, giving them a P/E ratio of 106. They exhibit 3 or 4 colporate apertures, which are elongated furrows with pore-like structures that facilitate pollen germination. The exine is relatively thin, ranging from 1.8 to 2.5 µm in thickness, and demonstrates a finely reticulate to microreticulate surface pattern. The tectum is continuous and well-developed, providing structural integrity and protection (Table 2, 3 & Figure 10-e, f).

Plant and pollen morphology of *Carica papaya* L.

It is a dioecious, soft-wooded tree with abundant latex, native to Tropical America and widely cultivated in tropical and subtropical regions. It has deeply 7-lobed, 20–30 cm wide leaves. Greenish-yellow unisexual flowers bloom from November to March, with male inflorescences reaching 1m and female flowers about 3 cm across. The ovary is single-celled with five parietal placentas. Its ovoid-oblong berry turns yellow when ripe, fruiting year-round. It can be found from coastal plains up to 1300 m elevation. *C. papaya* pollen is usually medium-sized and prolate-spheroidal, measuring about 24.4 µm in polar view and 26.6

μm in equatorial view. It has a P/E ratio of 1.09, which means it has a slightly longer shape along the polar axis. It is tricolporate, which means it has three clearly defined colpi with pores that help pollen germinate and tubes grow, which is necessary for fertilization to work. The exine decoration is psilate, which means it has a smooth surface with little shaping. This may help the pollen travel more easily and work with certain pollination mechanisms (Table 2, 3 & Figure 10-g, h).

Plant and pollen morphology of *Citrus limon* L.

A small evergreen tree or shrub (3–6m) native to Northeast India, Myanmar, and China, widely cultivated for its tart, aromatic fruits. It has glossy, dark green, elliptical leaves with a lemon scent. Small, fragrant white flowers with a purple tint bloom year-round in warm climates. The oval to oblong yellow fruits (5–10 cm) have a textured rind and juicy, acidic pulp. Seeds are small, oval, and pale, with some seedless varieties. It has a shallow root system and it needs well-drained soil. *C. limon* pollen is usually small and prolate-spheroidal. It measures about 22.1 μm in polar view and 22.4 μm in equatorial view, and has a P/E ratio of 1.01, which means it has a nearly spherical shape with some stretching along the polar axis. It possesses 3 or 4 colporate apertures, which facilitate pollen germination and tube formation, enhancing fertilization efficiency. The exine decoration is reticulate, with a net-like pattern that helps pollen stick to the plant and interact with pollinators, which helps the plant spread. The elongate shape of the pollen grains plays a role in structural stability and adaptability to different pollination mechanisms (Table 2, 3 & Figure 10-i, j).

Plant and pollen morphology of *Citrus medica* L.

It is a slow-growing evergreen shrub or small tree (2–5 m) native to Northeast India, China, and Myanmar. It has irregular, spiny branches and large, leathery, citrus-scented leaves. Fragrant white to purple-tinged flowers bloom seasonally. The fruit is large, oval to oblong, with a thick, rough, aromatic yellow rind and minimal pulp or juice. Few seeds, sometimes seedless, and a shallow root system need well-drained soil. Spread globally through ancient trade routes. The pollen of *C. medica* (citron) is typically small and spheroidal, with dimensions of 21.2 μm in polar view and 21 μm in equatorial view, resulting in a P/E ratio of 1.00, indicating an almost spherical shape. There are three or four colpi on each pollen grain, and each one has a hole in it. These holes help the pollen grains germinate and form pollen tubes. The exine is reticulate, characterized by a net-like sculpturing pattern that enhances pollen adhesion and interaction with pollinators. A clear outer layer called the exine layer protects the pollen and helps it stay alive and spread (Table 2, 3 & Figure 10-k, l).

Plant and pollen morphology of *Cleome gynandra* L.

A viscid, foul-smelling annual herb (up to 80 cm) native to Sri Lanka, India, East and Southeast Asia, and Malaysia, now widely introduced in the New World. It has 3–5-foliolate leaves with obovate leaflets and pink or white flowers (2.5 cm) with four petals and six stamens. The terete, striate, glandular capsule contains numerous cleft seeds. It can be found in wastelands, roadsides, and cultivated fields at an elevation of 500–900 m. Flowering and fruiting occur year-round. *C. gynandra* pollen is usually small and prolate-spheroidal. It measures 13.4 μm in polar view and 14.6 μm in equatorial view, and its P/E ratio of 1.08 shows that it has a slightly longer shape. It is tricolporate, possessing three distinct colpi with pores, which are crucial for germination and pollen tube formation and facilitating successful fertilization. The exine is psilate, meaning it has a smooth surface without ornamentation, which may contribute to reduced adhesion and ease of dispersal (Table 2, 3 & Figure 10-m, n).

Plant and pollen morphology of *Coccinea grandis* L.

A dioecious vine native to North Tropical Africa, Asia, Malaysia, Australia, and Fiji, now introduced to the West Indies and Tropical South America. It has 5-angled or deeply 5-lobed leaves (2–7.5 cm) and simple tendrils. White, campanulate male flowers (1.5 cm) and larger female flowers (2.5 cm) bloom from December to March. The fruit is a blood-red, ovoid-oblong berry (5 × 2.5 cm) with granular seeds. Found in thickets and wastelands up to 500m elevation, it is a semi-wild, extensive creeper with a deeply grooved woody stem. Fruiting occurs year-round. The pollen from *C. grandis* is medium-sized and sub-prolate. It is about 33.8 μm long along the polar axis and 40.6 μm long along the equatorial axis, and its P/E ratio is 1.20, which means it has a slightly longer shape along the polar axis. It is tricolporate, which means it has three clearly defined colpi with pores that help pollen germinate and tubes grow, which is necessary for fertilization to work. The exine decoration is reticulate, with a net-like pattern that makes it easier for pollinators to stick to the pollen and interact with the flower. This design probably helps with pollination (Table 2, 3, & Figure 10-o, p).

Plant and pollen morphology of *Commelina benghalensis* L.

A perennial plant native to Africa, India, East Asia, and Malesia, found in thickets, scrub jungles, roadside puddles, and cultivated lands up to 1100m. It has ovate to oblong-ovate leaves (2.5–5 cm) and pubescent, funnel-shaped spathes (1.5 cm). The blue flowers (8 mm) have broadly ovate petals, with cleistogamous flowers on the rootstock. The ellipsoid, three-celled capsule contains five distinct seeds. It thrives in diverse habitats from coastal regions to highlands. *C. benghalensis* pollen is usually prolate-spheroidal, measuring 37.6 µm in polar view and 36 µm in equatorial view. Its P/E ratio of 1.04 shows that it has a slightly longer shape. It is monosulcate, referring to a type of pollen aperture characterized by a single, elongated furrow (sulcus) on the surface of the pollen grain. This sulcus serves as the site for pollen tube emergence during germination. The exine is psilate, meaning it has a smooth surface without ornamentation, which may contribute to reduced adhesion and ease of dispersal (Table 2, 3 & Figure 11-a, b).

Plant and pollen morphology of *Crinum americanum* L.

This perennial aquatic flowering plant is native to the southeastern U.S., Mexico, the Caribbean, and Central America. It grows 60–90 cm tall with long, strap-like leaves in a rosette. Large, fragrant white flowers with thin, curved petals bloom from spring to fall. Each cluster has 6–10 blossoms, especially fragrant at night. It produces floating green seed capsules and has a bulbous root system adapted to wetlands. It can be found in swamps, marshes, and along riverbanks. The pollen of *C. americanum* is typically large and prolate-spheroidal, measuring 53.1 µm in polar view and 54.6 µm in equatorial view, with a P/E ratio of 1.03, indicating a nearly spherical shape with slight elongation. It is Colpate refers to a type of elongated furrows or grooves called colpi on the surface of the pollen grain. During germination, the pollen tube emerges from this sulcus. This sulcus serves as the site for pollen tube emergence during germination. It possesses a granulate exine ornamentation, characterized by a finely textured, grainy surface that may aid in pollen adhesion and interaction with pollinators. The moderately thick outer exine layer (Table 2, 3 & Figure 11-c, d).

Plant and pollen morphology of *Cucurbita pepo* L

An annual trailing or bushy vine native to North America, specifically Mexico and the southern U.S. It has broad, lobed, rough-textured leaves and tendrils for climbing. Large, bright yellow to orange funnel-shaped flowers are monoecious. Fruits vary in size, shape, and color, including pumpkins, zucchinis, and gourds, with many seeds inside. The flat, oval, cream-colored seeds are nutrient-rich. It has a shallow but extensive root system. The pollen of *C. pepo* is very large and prolate-spheroidal, measuring 111.8 µm in polar view and 110 µm in equatorial view, with a P/E ratio of 1.01, indicating an almost spherical shape with a slight elongation. It is pantoporate, meaning it has multiple pores evenly distributed across the surface, a trait that enhances pollen tube emergence from various points, improving fertilization efficiency. The outer layer is echinate, which means it has sharp spines (echinae) all over it. These spines help the exine stick to pollinators, mostly bees, so the pollen can be transferred successfully (Table 2, 3 & Figure 11- e, f).

Plant and pollen morphology of *Datura metal* L.

A subshrub (up to 80 cm) native to tropical and subtropical Asia and Africa, found in hilly regions up to 1500m, as well as plains and coastal areas. It has elliptic to angulate leaves (10–18 cm) with an unequally truncate base and often lobed margins. The white corolla, sometimes tinged with purple, is about 7 cm across with five lanceolate teeth. The capsule (4 cm) has short, stout, sometimes forked spines. Flowering and fruiting occur year-round. The pollen from *D. metel* is usually medium-sized and prolate-spheroidal. It is 48 µm across the equator and 46.8 µm across the polar view, and its P/E ratio of 1.02 indicates a nearly spherical shape with slight elongation. It is tricolporate, possessing three distinct colpi (elongated furrows) that serve as apertures for pollen tube emergence, playing a crucial role in successful fertilization. The exine is striate, meaning it has a finely grooved or striated surface pattern, which may enhance pollen adhesion to pollinators and aid in dispersal (Table 2, 3 & Figure 11-g, h).

Plant and pollen morphology of *Gardenia jasminoides* J.Ellis

It is a fragrant evergreen shrub that ranges in height from 1 to 2 meters and is native to China, Taiwan, and Japan. It thrives in warm, humid forests and subtropical regions. It has dark green, glossy, leathery elliptical leaves (5–10 cm). Large, white, waxy, highly fragrant flowers bloom from late spring to summer, sometimes year-round in warm climates. Small, orange to reddish-brown berry-like fruits contain seeds. It has a fibrous root system and prefers well-drained soil. The pollen from G. *jasminoides* is usually medium-sized and prolate-spheroidal. It is 39.6 µm in polar view and 40.4 µm in equatorial view, and its P/E ratio of 1.02 shows that it is almost spherical with some stretching. It possesses 3 or 4 porate apertures, which serve as crucial exit points for pollen tube emergence and enhance fertilization efficiency. The exine is foveolate, which means it has a surface texture that looks like pits. This may help pollen stick to pollinators and give the structure support (Table 2, 3 & Figure 11-i, j).

Plant and pollen morphology of *Ixora coccinea* L.

This tropical evergreen shrub, measuring 1.5–2 m, is native to South Asia, which includes India, Sri Lanka, and Bangladesh. It has dark green, glossy, leathery elliptical leaves (5–10 cm). Small, tubular, star-shaped flowers bloom year-round in dense clusters, in red, orange, pink, or yellow. The plant produces small, round, dark purple to black berries that attract birds. It has a fibrous root system and thrives in tropical and subtropical forests, coastal, and lowland regions. *I. coccinea* pollen is usually medium-sized and sub-prolate. It is 23.2 µm long in polar view and 29 µm long in equatorial view, and its P/E ratio of 1.24 shows that it has a slightly elongated shape. It is tricolporate, which means it has three colpi, each with its set of pores. These pores allow the pollen tubes to come out, which ensures fertilization. The exine ornamentation is psilate, exhibiting a smooth surface devoid of significant sculpturing (Table 2, 3 & Figure 11-k, l).

Plant and pollen morphology of *Lagenaria siceraria* (Molina) Standl.

A monoecious vine native to tropical America and Asia, cultivated in warm regions worldwide. It has suborbicular, angular or shortly 3-lobed leaves (7–10 × 10–12 cm) with a biglandular petiole and 2-fid tendrils. Large, solitary flowers have a narrow-campanulate calyx and five white oblong-obovate petals (4 × 2 cm). Male flowers have three stamens with coalescent anthers, while female flowers have a densely villous ovary with numerous horizontal ovules. Bottle gourd pollen is usually big and prolate-spheroidal, measuring 53.4 µm in polar view and 58.4 µm in equatorial view. It has a P/E ratio of 1.09, which means it is almost spherical but slightly longer than it is wide. It is tricolporate, which means it has three colpi, each with its set of pores. These pores allow pollen tubes to emerge and help the fertilization process. The exine is foveolate, characterized by a surface with depressions or pits, which may aid in pollen adhesion to pollinators and enhance dispersal efficiency (Table 2, 3 & Figure 11-m, n).

Plant and pollen morphology of *Malpighia emarginata* DC.

A tropical evergreen shrub or small tree (2–6m) known for its bright red, vitamin C-rich fruits. It has dark green, glossy, oval to oblong leaves with smooth or slightly wavy edges. Small, pink to lavender flowers bloom in clusters year-round. The cherry-like fruits (1–2 cm) have juicy, tart pulp and contain 2–3 small, rigid seeds. With a shallow root system, it is well-adapted to dry conditions. The pollen of M. *emarginata* is characterized as medium-sized, prolate-spheroidal grains measuring approximately 24.2 µm in polar view and 24.4 µm in equatorial view, with a P/E ratio of 1.03, indicating a nearly spheroidal shape. The grains are pantoporate, meaning they possess multiple, evenly distributed pores, a feature that may facilitate effective pollen dispersal. The exine ornamentation is psilate, exhibiting a smooth surface devoid of significant sculpturing (Table 2, 3 & Figure 11-o, p).

Plant and pollen morphology of *Mirabilis jalapa* L.

A bushy, herbaceous perennial (1–1.5m) known for its fragrant, multicolored flowers that open in the late afternoon and close in the morning. It has opposite, ovate to lance-shaped, bright green leaves. The trumpet-shaped flowers come in pink, yellow, red, white, or variegated combinations, sometimes on the same plant. It produces small, round, black, wrinkled seeds. Thick, tuberous roots help it survive dry conditions. The pollen of M. *jalapa* is medium-sized and prolate-spheroidal, measuring approximately 26.8 µm in polar view and 26.4 µm in equatorial view, with a P/E ratio of 1.01, indicating a nearly spherical shape. It possesses three colporate apertures, a characteristic feature that facilitates pollen germination and tube growth. The exine ornamentation is psilate, displaying a smooth surface with minimal sculpturing, which may be associated with specific pollination strategies (Table 2, 3 & Figure 12-a, b).

Plant and pollen morphology of *Moringa oleifera* L.

A fast-growing, drought-resistant deciduous tree (10–12m) with a straight or slightly drooping trunk and an open, umbrella-shaped canopy. It has feathery, compound leaves with bright green oval leaflets. Small, fragrant, creamy-white flowers grow in clusters and bloom year-round in warm climates. The long, slender, green pods (30–50 cm) resemble drumsticks and contain round, dark brown seeds with wing-like structures. Native to the Himalayan foothills of India and Pakistan, it thrives in tropical and subtropical regions and is valued for its nutritional, medicinal, and economic benefits. The pollen of *M. oleifera* is medium-sized and prolate-spheroidal, measuring approximately 27.8 µm in polar view and 26.2 µm in equatorial view, with a P/E ratio of 1.06, indicating a slightly elongated shape along the polar axis. It possesses three colporate apertures, which facilitate pollen germination and tube growth, aiding in fertilization. The exine ornamentation is psilate, characterized by a smooth surface with minimal sculpturing, which may influence pollen dispersal and adherence to pollinators (Table 2, 3 & Figure 12-c, d).

Plant and pollen morphology of *Nyctanthes arbor-tristis* L.

A shrub growing up to 4 meters tall, with four-angled branchlets and simple, obovate, seven-nerved leaves (5–8 × 3–5 cm). The bisexual flowers are arranged in 3-chotomous cymes, with a salver-shaped corolla (2.5 cm across) featuring an orange tube and 5–7 white, twisted lobes. It has two included stamens and a bilocular ovary with a single ovule per locule. The obovoid, compressed capsule (2 × 1.2 cm) has a thick epicarp and orbicular seeds. A fragrant garden shrub, it flowers year-round in plains and is native to India and the subtropical Himalayas. The pollen of *N. arbor-tristis* is large and prolate-spheroidal, measuring approximately 44.6 µm in polar view and 41.6 µm in equatorial view, with a P/E ratio of 1.07, indicating a slightly elongated shape along the polar axis. It possesses three colporate apertures, a common feature that facilitates efficient pollen tube formation and fertilization. The exine ornamentation is reticulate, characterized by a net-like pattern that enhances pollen adhesion and interaction with pollinators (Table 2, 3 & Figure 12-e, f).

Plant and pollen morphology of *Nymphaeae alba* L.

A perennial aquatic plant with floating leaves and elegant white flowers, it thrives in still or slow-moving freshwater bodies. The large, rounded, leathery leaves (15–30 cm in diameter) have a notched base, with a dark green upper surface and often a reddish underside. Its fragrant, white flowers (10–20 cm in diameter) feature bright yellow stamens, opening during the day and closing at night. Anchored by thick, fleshy rhizomes in muddy bottoms, it produces underwater capsules containing numerous seeds. Native to Europe, North Africa, and parts of Asia. The pollen of *N. alba* is medium-sized and sub-prolate, measuring approximately 25.2 µm in polar view and 32.4 µm in equatorial view, with a P/E ratio of 1.28, indicating a slightly elongated shape along the polar axis. It possesses three colporate apertures, which are well-defined furrows with pores that facilitate efficient pollen germination and tube formation. The exine ornamentation is psilate, characterized by a smooth surface with minimal sculpturing, which may reduce resistance during pollen dispersal and enhance compatibility with specific pollination mechanisms (Table 2, 3 & Figure 12-g, h).

Plant and pollen morphology of *Pseuderanthemum carruthersi* Seem.

An ornamental evergreen shrub, valued for its striking foliage and attractive flowers. It grows quickly, reaching 1.5–2 meters (5–7 feet) in height, with large, lance-shaped, glossy leaves in deep green, purple, maroon, or variegated patterns. The small, tubular flowers are typically purple, pink, or lilac with darker markings, appearing in loose clusters. It has a fibrous root system and thrives in warm tropical and subtropical climates but is sensitive to frost. Widely cultivated and naturalized in tropical regions worldwide, including Southeast Asia, the Caribbean, and parts of Central and South America. The pollen of *P. carruthersii* is medium-sized and prolate-spheroidal, measuring approximately 34.2 µm in polar view and 34.8 µm in equatorial view, with a P/E ratio of 1.01, indicating a nearly spherical shape. It possesses three colporate apertures, which play a crucial role in pollen germination and fertilization by facilitating pollen tube growth. The exine ornamentation is reticulate, characterized by a net-like pattern that enhances pollen adhesion and interaction with pollinators (Table 2, 3 & Figure 12-i, j).

Plant and pollen morphology of *Senna alata* L.

A robust shrub growing up to 2 meters tall, with compound leaves (3–50 cm) consisting of 8–14 pairs of leaflets. The lower leaflets are oblong-elliptic, while the upper ones are broadly obovate (5–12 × 2.5–8 cm). It produces showy, orange flowers in racemes up to 30 cm long, blooming from November to February. The pods are oblong (15 × 1.5 cm) with two longitudinal crenulated wings, containing numerous seeds. Common in plains, especially near watercourses and cultivated lands, it is valued for its medicinal properties. Native to South America, it is now widely distributed in tropical regions worldwide. The pollen of *S. alata* is medium-sized and spheroidal, measuring approximately 24.2 µm in polar view and 24.4 µm in equatorial view, with a P/E ratio of 1.00, indicating an almost perfectly spherical shape. It possesses three colporate apertures, which facilitate pollen germination and tube growth, aiding in fertilization. The exine ornamentation is psilate, characterized by a smooth surface with minimal sculpturing, which may influence pollen dispersal and adherence to pollinators (Table 2, 3 & Figure 12-k, l).

Plant and pollen morphology of *Solanum torvum* Sw.

A spiny shrub growing up to 2.5–4 meters tall, with scattered prickles and sinuate leaves (8–15 × 6–12 cm), sparsely pubescent above and densely so below. It produces extra-axillary corymbose comes with a peduncle up to 5 cm long. The white corolla is about 2.5 cm across, with acute lobes, and the fruit is a small, green, globose berry (1 cm in diameter) with smooth seeds. Common in hilly areas above 700 meters, it flowers from February–April and August–November, with fruiting year-round. Native to the West Indies, it is now widely naturalized. The pollen of *S. torvum* is small and prolate-spheroidal, measuring approximately 20.6 µm in polar view and 20.2 µm in equatorial view, with a P/E ratio of 1.01, indicating a nearly spherical shape with slight elongation along the polar axis. It possesses three colporate apertures, which facilitate pollen germination and tube growth, essential for successful fertilization. The exine ornamentation is psilate, exhibiting a smooth surface with minimal sculpturing, which may play a role in pollen dispersal efficiency and compatibility with pollinators (Table 2, 3 & Figure 12-m, n).

Plant and pollen morphology of *Solanum trilobatum* L.

An armed, climbing undershrub with ovate-angular, sinuate leaves (3–7.5 × 2–6 cm), covered in prickles on both sides. It bears extra-axillary racemes with a peduncle up to 6 cm long. The purple corolla, about 3.5 cm across, has acute-apiculate lobes, while the calyx is cup-shaped with prickly, recurved lobes. The fruit is a small, green globose berry (1 cm in diameter) with white spots and circular, slightly pitted seeds. Found mainly in coastal plains, it flowers from December to March, with fruiting in February. Native to the Peninsula, Malay Peninsula, and Malacca. The pollen of *S. trilobatum* is small and prolate-spheroidal, measuring approximately 22 µm in polar view and 21 µm in equatorial view, with a P/E ratio of 1.04, indicating a slightly elongated shape along the polar axis. It possesses three colporate apertures, which aid in pollen germination and tube formation, facilitating fertilization. The exine ornamentation is psilate, characterized by a smooth surface with minimal sculpturing, which may influence pollen dispersal and interactions with pollinators (Table 2, 3 & Figure 12-o, p).

Plant and pollen morphology of *Tecoma stans* L.

An evergreen shrub or small tree growing up to 6 meters, with opposite, odd-pinnate leaves comprising 5–11 ovate-lanceolate leaflets (4–10 × 2–2.5 cm). It bears showy panicles of bright yellow, bell-shaped flowers (3 cm across) with a campanulate calyx featuring five teeth. The fruit is a long, linear capsule (10–24 cm) containing numerous two-winged seeds. Common in plains and hills, it often grows in wastelands and near temples. Flowering occurs from December to February in plains and year-round in hills, with fruiting throughout the year. Native to South Florida, the West Indies, and South America, it is widely cultivated in India. The pollen of *T. stans* is medium-sized and prolate-spheroidal, measuring approximately 33.6 µm in polar view and 35.8 µm in equatorial view, with a P/E ratio of 1.06, indicating a slightly elongated shape along the polar axis. It possesses three colporate apertures, which are well-defined furrows with pores that facilitate pollen germination and tube formation, aiding in fertilization. The exine ornamentation is psilate, characterized by a smooth surface with minimal sculpturing, which may influence pollen dispersal efficiency and compatibility with pollinators (Table 2, 3 & Figure 13-a, b).

Plant and pollen morphology of *Volkameria inermis* L.

A shrub growing up to 1.5 (3) meters, with obovate to suborbicular leaves (1.5–3(5) × 1.5–2(3) cm). It produces axillary cymes with a peduncle up to 3 cm long. The white corolla, adorned with pink lines, is 2 cm across, with a cup-shaped calyx and four red stamens. The fruit is a small, globose drupe (0.6 cm in diameter). Common in plains, especially near coastal areas, it grows along fences and in wastelands.

Flowering occurs from January to April, with fruiting year-round. Native to coastal India and Sri Lanka, it has naturalized in East and Southeast Asia and Australia. The pollen of *V. inermis* is medium-sized and prolate-spheroidal, measuring approximately 28.2 µm in polar view and 25.6 µm in equatorial view, with a P/E ratio of 1.10, indicating a moderately elongated shape along the polar axis. It possesses three colporate apertures, which are well-defined furrows with pores that facilitate efficient pollen germination and tube formation, playing a crucial role in fertilization. The exine ornamentation is psilate, characterized by a smooth surface with minimal sculpturing, which may enhance pollen dispersal efficiency and influence pollination mechanisms (Table 2, 3 & Figure 13-c, d).

Among the 26 collected samples, the majority were shrubs, followed by herbs, trees, and climbers, indicating that shrubs were the most dominant growth form in the selected dicotyledonous species. Pollen morphological analysis revealed significant variation in pollen units, shapes, sizes, apertures, and exine sculpturing. The dominant pollen type was monads, meaning the pollen grains were dispersed as single units rather than in clusters. The prevalent shape observed was prolate spheroidal, where the grains were slightly elongated along the polar axis but still nearly spherical. This shape is commonly associated with improved aerodynamics and pollinator adherence. The pollen grains were generally small in size, which could enhance dispersal efficiency, especially in wind-pollinated species. The aperture type was predominantly tricolporate, characterized by three elongated furrows (colpi) combined with three circular pores, which facilitate pollen tube emergence and ensure reproductive success in diverse environmental conditions. The exine sculpturing was primarily psilate, meaning the outer pollen wall had a smooth surface with minimal ornamentation, a feature often linked to wind pollination as it reduces resistance and prevents adhesion.

DISCUSSION

This article examines the morphology of pollen from a few angiospermic plants in Annamalai Nagar. The current investigation examined the pollen morphology of the following species, namely *B. cristata* and *P. carrutherssi* (Acanthaceae), *A. cathartica* (Apocynaceae), *T. stans* (Bignoniaceae), *C. gynandra* (Capparaceae), *C. papaya* (Caricaceae), *C. benghalensis* (Commelinaceae), *C. grandis*, *C. pepo*, and *L. siceraria* (Cucurbitaceae), *S. alata* (Fabaceae), *V. inermis* (Lamiaceae), *C. americanum* (Liliaceae), *M. emarginata* (Malpighiaceae), *A. grandifolium* (Malvaceae), *M. oleifera* (Moringaceae), *M. jalapa* (Nyctaginaceae), *N. alba* (Nymphaeaceae), *N. arbor-tristis* (Oleaceae), *I. coccinea*, *G. jasminoides* (Rubiaceae), *C. limon* and *C. medica* (Rutaceae), *D. metel*, *S. torvum*, and *S. trilobatum* (Solanaceae).

The following species among those under study exhibit tricolporate pollen grains: *A. grandifolium*, *C. gynandra*, *C. papaya*, and *A. cathartica*, *C. grandis*, *D. metel* , *I. coccinea*, *L. siceraria*, *M. jalapa*, *M. oleifera*, *P. carruthersii*, *S. alata*, *S. torvum*, *S. trilobatum*, and *V. inermis*. These taxa were found to have tricolpate pollen grains – *N. arbor-tristis*, *N. alba* and *T. stans*. From the following taxa, three to four colporate pollen grains were found – *B. cristata*, *C. limon*, *C. medica* and *G. jasminoides*. The taxa *C. pepo* and *M. emarginata* are known to produce pantoporate pollen grains. *C. benghalensis* and *C. americanum* were monosulcate pollen grains. The study ornamentation from the pollen grains shows that reticulate ornamentation was observed in *B. cristata*, *C. limon*, *C. medica*, C. grandis, *N. arbor-tristis*, *P. carruthersii.* Psilate ornamentation were observed in the following taxa *A. cathartica*, *C. papaya*, *C. gynandra*, *C. benghalensis*, *I. coccinea*, *M. emarginata*, *M. jalapa*, *M. oleifera*, *N. alba*, *S. alata*, *S. torvum*, *S. trilobatum*, *T. stans* and *V. inermis*. Granulate pollen grains were observed in *C. americanum*. Echinate pollen grains were observed in *C. pepo*. Striate pollen grains were observed in *D. metel*. Foveolate pollen grains were observed in *G. jasminoides* and *L. siceraria*.

Based on the size of the pollen grain the following types were observed - small (1-25µm), medium (25-50 µm), large (50-70 µm) and very large (70-100 µm). Small pollen grains were observed from *B. cristata*, *C. limon*, *C. medica*, *C. gynandra*, *S. torvum, S. trilobatum.* Medium sized pollen grains were observed from *C. papay*, C. grandis, *C. benghalensis*, *D. metel*, *G. jasminoides*, *I. coccinea*, *M. emarginata*, *M. jalapa*, *M. oleifera*, *N. alba*, *P. carruthersii*, *S. alata*, *T. stans*, and *V. inermis* .

Large pollen grains were observed in *A. cathartica*, *C. americanum*, *L. siceraria* and *N. arbor-tristis*. Very large pollen grains were observed in *A. grandifolium*. Among the taxa studied pollen grains of *G. jasminoides* shows tetrads. But all other taxa show monads, normally the pollen of leguminosae members shows tetrad pollen grains compared to other taxa. Shape of the pollen grain also vary with taxa. Spheroidal shape pollen found in *A. grandifolium* and *S. torvum*. Prolate spheroidal found in *B.rleria cristata*, *C. papaya*, *C. limon*, *C. gynandra*, *C. benghalensis*, *C. americanum*, *C. pepo*, *D. metel*, *G. jasminoides*, *L. siceraria*, *M. emarginata*, *M. jalapa*, *M. oleifera*, *N. alba*, *P. carruthersii*, *S. torvum*, *S. trilobatum*, *T. stans* and *V. inermis*. Majority of the taxa shows this type of pollen grain. Sub-prolate pollen grains were observed in *A. cathartica*, *I. coccinea*, and *N. alba*. From the study it is observed that Malvaceae pollen grains shows echinate pollen type (Christensen, 1986). The presence study also coincides with study of pollen morphological studies on some angiospermic taxa of Annamalai Nagar. From the observation it is found that Rutaceae members (*C. limon* and *C. medica*) shows small pollen grains (Garralla and Mautino 2021). The present study coincides with study of pollen morphological studies on some angiospermic taxa of Annamalai Nagar. Generally, monosulcate pollen grains were observed in monocots. It is also observed in the present study (*C. benghalensis* and *C. americanum*) (Furness and Rudall 2001). The monocot taxa studied in the present study were also shows monosulcate pollen grains.

CONCLUSION

The data on pollen grains from various plant species reveal a broad spectrum of sizes, shapes, and surface characteristics that are critical for plant identification and classification. The pollen grains range from very small (13.4 µm) in *C. gynandra* to very large (111.8 µm) in *C. pepo*. The grains exhibit various shapes, predominantly prolate-spheroidal or sub-prolate, with some spheroidal forms observed. The P/E ratios, which indicate the degree of elongation, vary from 100 (nearly spherical) to 128 (highly elongated), highlighting the diversity in grain morphology. Surface ornamentation of the pollen grains includes psilate (smooth), reticulate (net-like), echinate (spiny), granulate (granular), foveolate (pitted), and striate (striped) patterns. Different species also exhibit different colporate types, such as 3-colporate, 4-colporate, monosulcate (single furrow), and pantoporate (multiple pores). The diversity in pollen grain morphology and surface ornamentation observed among these plant species underscores the complexity and adaptability of plant reproductive strategies. The variations in size, shape, and surface features are not merely aesthetic but serve functional roles in pollination and plant identification. Understanding these characteristics is essential for accurate plant classification and can aid in botanical studies, ecological research, and agricultural practices. The observed patterns suggest that pollen grains have evolved a range of adaptations to meet specific ecological needs and enhance reproductive success.

In conclusion, the studied pollen samples exhibited a high degree of morphological variability, reflecting their adaptive significance in different pollination mechanisms. The dominance of monads, prolate spheroidal shape, small size, tricolporate aperture, and psilate exine suggests evolutionary adaptations for efficient pollen dispersal and reproductive success, contributing to the ecological diversity and survival of these dicotyledonous species.

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Conflict of Interest : The authors declared that they have no conflict of interest.

Table 1: A list of plants gathered from several families that display common characteristics.

S. No.	Collected taxa	Family	Common name	Habit	Flowering period	Pollinator
1.	*Abutilon grandifolium* (willd.) Sweet	Malvaceae	Hairy Indian Mallow	Shrub	Apr-Sep	Insects
2.	*Allamanda cathartica* L.	Apocynaceae	Golden trumpet	Shrub	May-Sep	Bees
3.	*Barleria cristata* L.	Acanthaceae	Porcupine Flower	Shrub	Nov-Jan	Insects & Butterflies
4.	*Carica papaya* L.	Caricaceae	Papaya	Tree	Feb-May	Bees
5.	*Citrus limon* L.	Rutaceae	Lemon	Tree	Jun-Aug	Bees & Birds
6.	*Citrus medica* L.	Rutaceae	Citron	Tree	Apr-May	Bees
7.	*Cleome gynandra* L.	Capparaceae	African cabbage	Herb	Jul-Aug	Insects
8.	*Coccinea grandis* L.	Cucurbitaceae	Ivy Gourd	Climber	Aug-Sep	Bees
9.	*Commelina benghalensis* L.	Commelinaceae	Dayflower	Herb	Jul-Aug	Bees & Butterflies
10.	*Crinum americanum* L.	Liliaceae	Florida crinum lily	Herb	Jun-Nov	Insects
11.	*Cucurbita pepo* L.	Cucurbitaceae	Pumpkin	Climber	Jul-Aug	Bees
12.	*Datura metel* L.	Solanaceae	Devils Weed	Shrub	Jun-Jul	Insects
13.	*Gardenia jasminoides* J.Ellis	Rubiaceae	Cap jasmine	Shrub	May-Sep	Bees & Birds
14.	*Ixora coccinea* L.	Rubiaceae	Jungle geranium	Shrub	Throughout	Butterflies
15.	*Lagenaria siceraria* (Molina) Standl.	Cucurbitaceae	Bottle Gourd	Climber	Jul-Aug	Bees
16.	*Malpighia emarginata* DC	Malpighiaceae	Barbados cherry	Shrub	Apr-Nov	Insects
17.	*Mirabilis jalapa* L.	Nyctaginaceae	Four o" clock flower	Herb	Jun-Oct	Bees
18.	*Moringa oleifera* L.	Moringaceae	Drumstick tree	Tree	Jul-Aug	Bees
19.	*Nyctanthes arbor-tristis* L.	Oleaceae	Night Blooming Jasmine	Shrub	Aug-Dec	Bees
20.	*Nymphaea alba* L.	Nymphaeaceae	White water lily	Herb	Jun-Sep	Insects
21.	*Pseuderanthemum carrutherssi* Seem.	Acanthaceae	Purple False Eranthemum	Shrub	May-Sep	Butterflies
22.	*Sena alata* L.	Fabaceae	Candle bush	Shrub	Sep-Dec	Bees
23.	*Solanum torvum* Sw.	Solanaceae	Turkey Berry	Shrub	Aug-Nov	Insects
24.	*Solanum trilobatum* L.	Solanaceae	Purple fruited pea egg plant	Shrub	Jan-Aug	Bees
25.	*Tecoma stans* L.	Bignoniaceae	Golden Bells	Shrub	May-Oct	Birds
26.	*Volkameria inermis* L.	Lamiaceae	Seashore Tube flower	Shrub	Nov-Dec	Butterflies

Table 2: Pollen micro morphological properties of the examined taxa of various distinct families.

S. No.	Plant taxa	Pollen unit	Shape classes	Size classes	Aperture	Ornamentation
1.	*A. grandifolium*	Monad	Spheroidal	Very large	3 colporate	Echinate
2.	*A. cathartica*	Monad	Sub-prolate	Large	3 colporate	Psilate
3.	*B. cristata*	Monad	Prolate-spheroidal	Small	3-4 colporate	Reticulate
4.	*C. papaya*	Monad	Prolate-spheroidal	Medium	3 colporate	Psilate

5.	*C. limon*	Monad	Prolate-spheroidal	Small	3-4 colporate	Reticulate
6.	*C. medica*	Monad	Spheroidal	Small	3-4 colporate	Reticulate
7.	*C. gynandra*	Monad	Prolate-spheroidal	Small	3 colporate	Psilate
8.	*C. grandis*	Monad	Sub-prolate	Medium	3 colporate	Reticulate
9.	*C. benghalensis*	Monad	Prolate-spheroidal	Medium	Monosulcate	Psilate
10.	*C. americanum*	Monad	Prolate-spheroidal	Large	Colpate	Granulate
11.	*C. pepo*	Monad	Prolate-spheroidal	Very large	Pantoporate	Echinate
12.	*D. metel*	Monad	Prolate-spheroidal	Medium	3 colporate	Striate
13.	*G. jasminoides*	Tetrad	Prolate-spheroidal	Medium	3-4 porate	Foveolate
14.	*I. coccinea*	Monad	Sub-prolate	Medium	3 colporate	Psilate
15.	*L. siceraria*	Monad	Prolate-spheroidal	Large	3 colporate	Foveolate
16.	*M. emarginata*	Monad	Prolate-spheroidal	Medium	Pantoporate	Psilate
17.	*M. jalapa*	Monad	Prolate-spheroidal	Medium	3 colporate	Psilate
18.	*M. oleifera*	Monad	Prolate-spheroidal	Medium	3 colporate	Psilate
19.	*N. arbor-tristis*	Monad	Prolate-spheroidal	Large	3 colpate	Reticulate
20.	*N. alba*	Monad	Sub-prolate	Medium	3 colpate	Psilate
21.	*P. carrutherssi*	Monad	Prolate-spheroidal	Medium	3 colporate	Reticulate
22.	*S. alata*	Monad	Spheroidal	Medium	3 colporate	Psilate
23.	*S. torvum*	Monad	Prolate-spheroidal	Small	3 colporate	Psilate
24.	*S. trilobatum*	Monad	Prolate-spheroidal	Small	3 colporate	Psilate
25.	*T. stans*	Monad	Prolate-spheroidal	Medium	3 colpate	Psilate
26.	*V. inermis*	Monad	Prolate-spheroidal	Medium	3 colporate	Psilate

Table 3: Pollen micromorphological characteristics of species in polar and equatorial diameters (μm): a quantitative study. n=10 [R= range; X= Arithmetic mean (μm) and n= number of pollen grain measured (μm).

S. No.	Plant taxa	Polar axis (μm) (R) x	Equatorial axis (μm) (R) x	P/E ratio
1.	*A. grandifolium*	(66-72) 68.2	(65-71) 67.6	100
2.	*A. cathartica*	(44-57) 49.4	(50-65) 58.4	118
3.	*B. cristata*	(20-21) 20.4	(19-23) 21.8	106
4.	*C. papaya*	(23-26) 24.4	(23-29) 26.6	109
5.	*C. limon*	(21-23) 22.1	(22-24) 22.4	101
6.	*C. medica*	(20-23) 21.2	(18-23) 21	100
7.	*C. gynandra*	(13-14) 13.4	(14-16) 14.6	108
8.	*C. grandis*	(31-35) 33.8	(36-43) 40.6	120
9.	*C. benghalensis*	(34-38) 37.6	(32-41) 36	104
10.	*C. americanum*	(49-57) 53.1	(46-58) 54.6	108
11.	*C. pepo*	(93-149) 111.8	(102-125) 110	101
12.	*D. metel*	(47-49) 48	(46-48) 46.8	102
13.	*G. jasminoides*	(28-44) 39.6	(38-46) 40.4	102
14.	*I. coccinea*	(20-25) 23.2	(27-31) 29	124

15.	*L. siceraria*	(51-57) 53.4	(51-63) 58.4	109
16.	*M. emarginata*	(23-25) 24.2	(22-28) 24.4	103
17.	*M. jalapa*	(26-28) 26.8	(25-28) 26.4	101
18.	*M. oleifera*	(27-28) 27.8	(22-28) 26.2	106
19.	*N. arbor-tristis*	(41-49) 44.6	(37-45) 41.6	107
20.	*N. alba*	(22-28) 25.2	(27-35) 32.4	128
21.	*P. carrutherssi*	(30-41) 34.2	(33-37) 34.8	101
22.	*S. alata*	(23-25) 24.2	(22-28) 24.4	100
23.	*S. torvum*	(20-21) 20.6	(18-23) 20.2	101
24.	*S. trilobatum*	(21-23) 22	(20-22) 21	104
25.	*T. stans*	(31-35) 33.6	(34-38) 35.8	106
26.	*V. inermis*	(24-31) 28.2	(19-29) 25.6	110

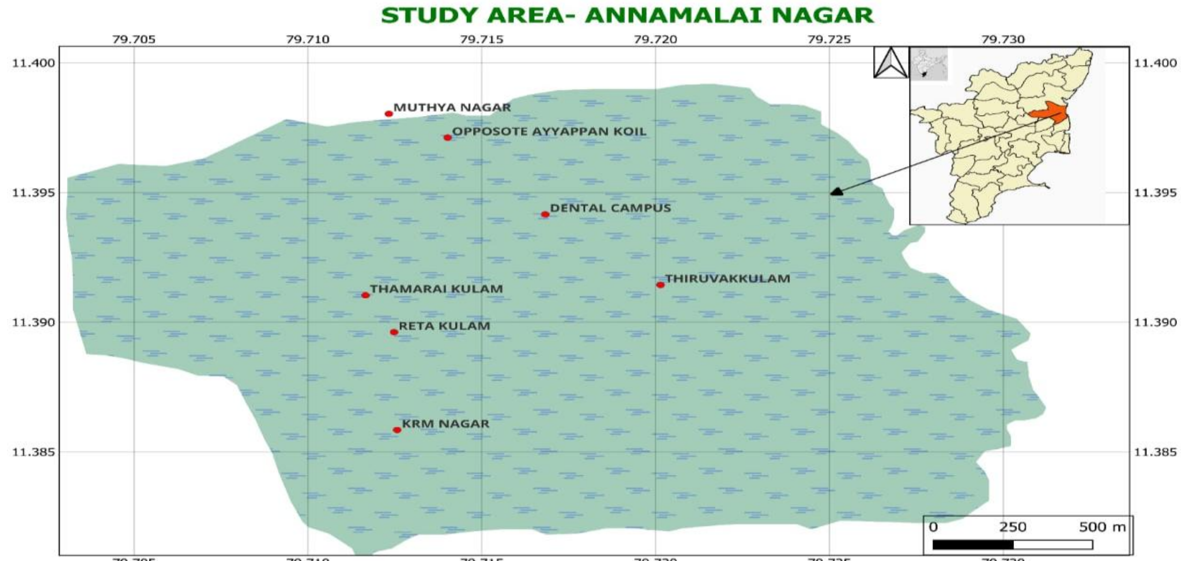

Figure 1: Map of the investigation location in Annamalai Nagar, Chidambaram, Tamil Nadu.

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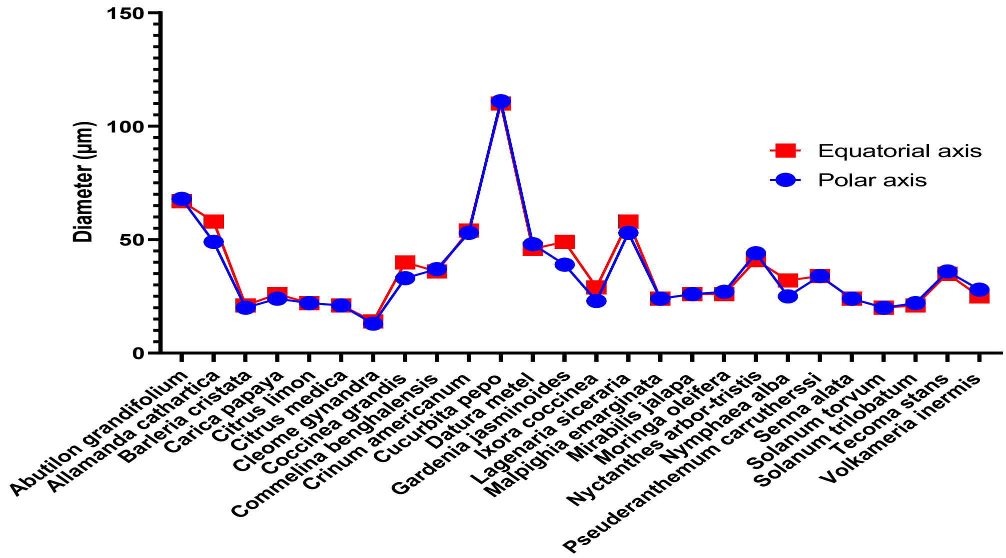

Figure 2: Variations in polar and equatorial diameters of the selected taxa.

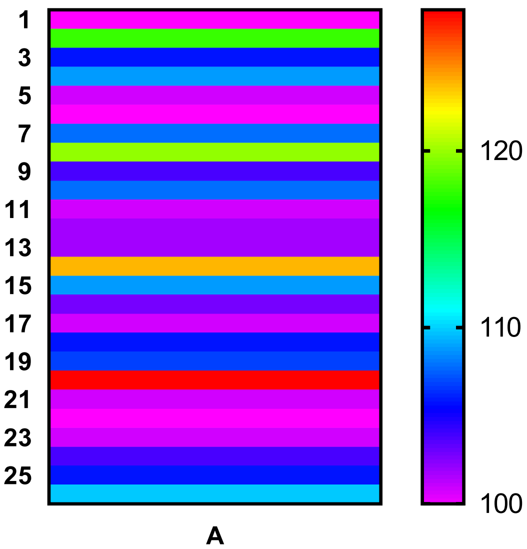

Figure 3: Heatmap illustrating the relationships between pollen grain P/E ratios

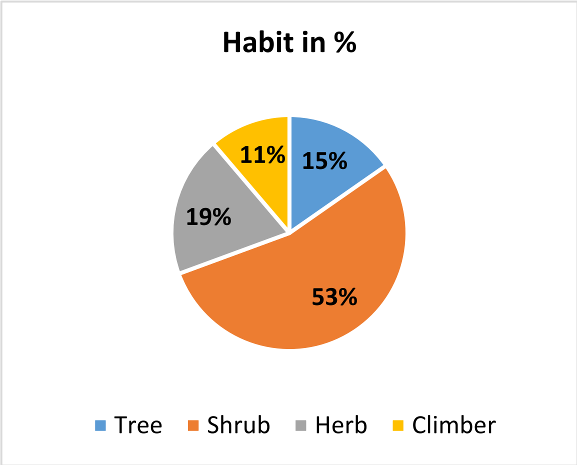

Figure 4: Pie chart shows the habit (in %) of the studied species.

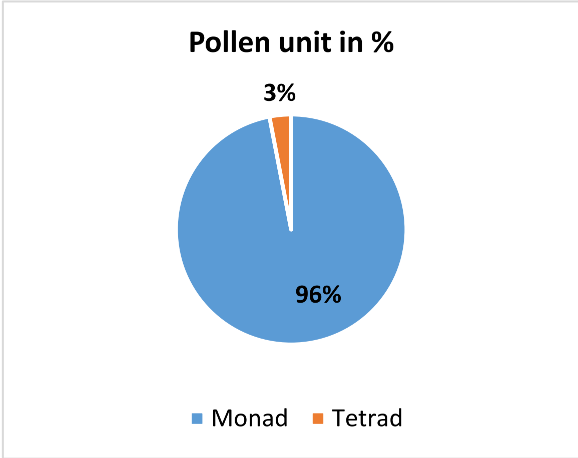

Figure 5: Pie chart shows the unit of pollen grain (in %) among the studied species.

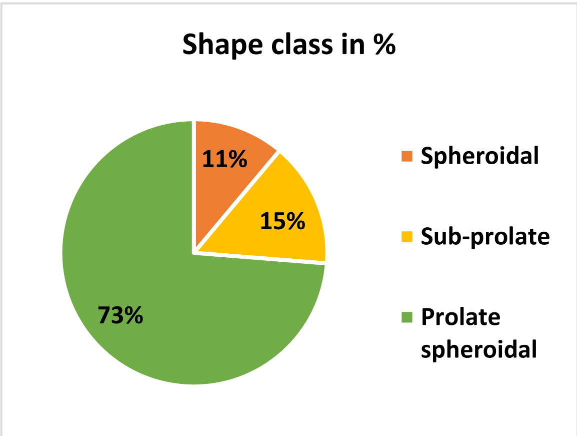

Figure 6: Pie chart shows the shape class of pollen grain (in %) among the studied species.

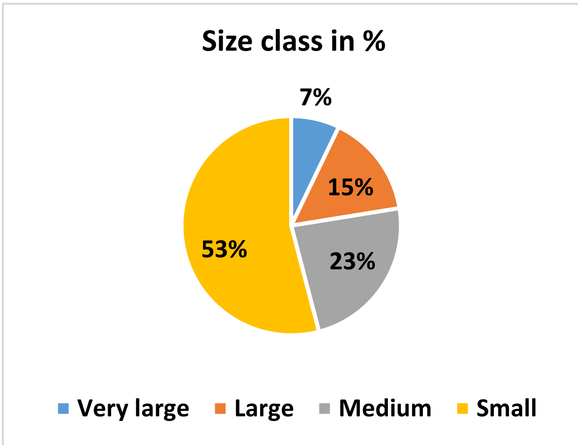

Figure 7: Pie chart shows the size class of pollen grain (in %) among the studied species.

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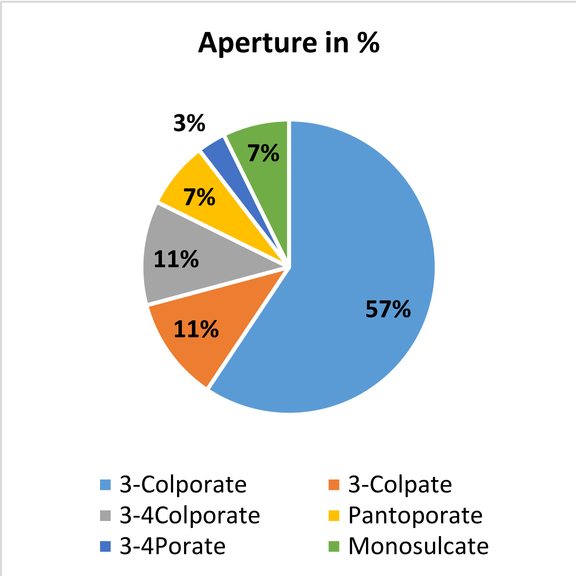

Figure 8: Pie chart shows the aperture of pollen grain (in %) among the studied species.

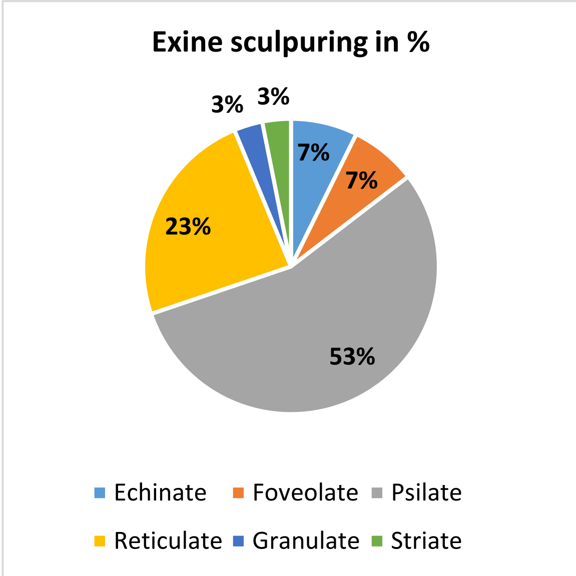

Figure 9: Pie chart shows the exine characters of pollen grain (in %) among the studied species.

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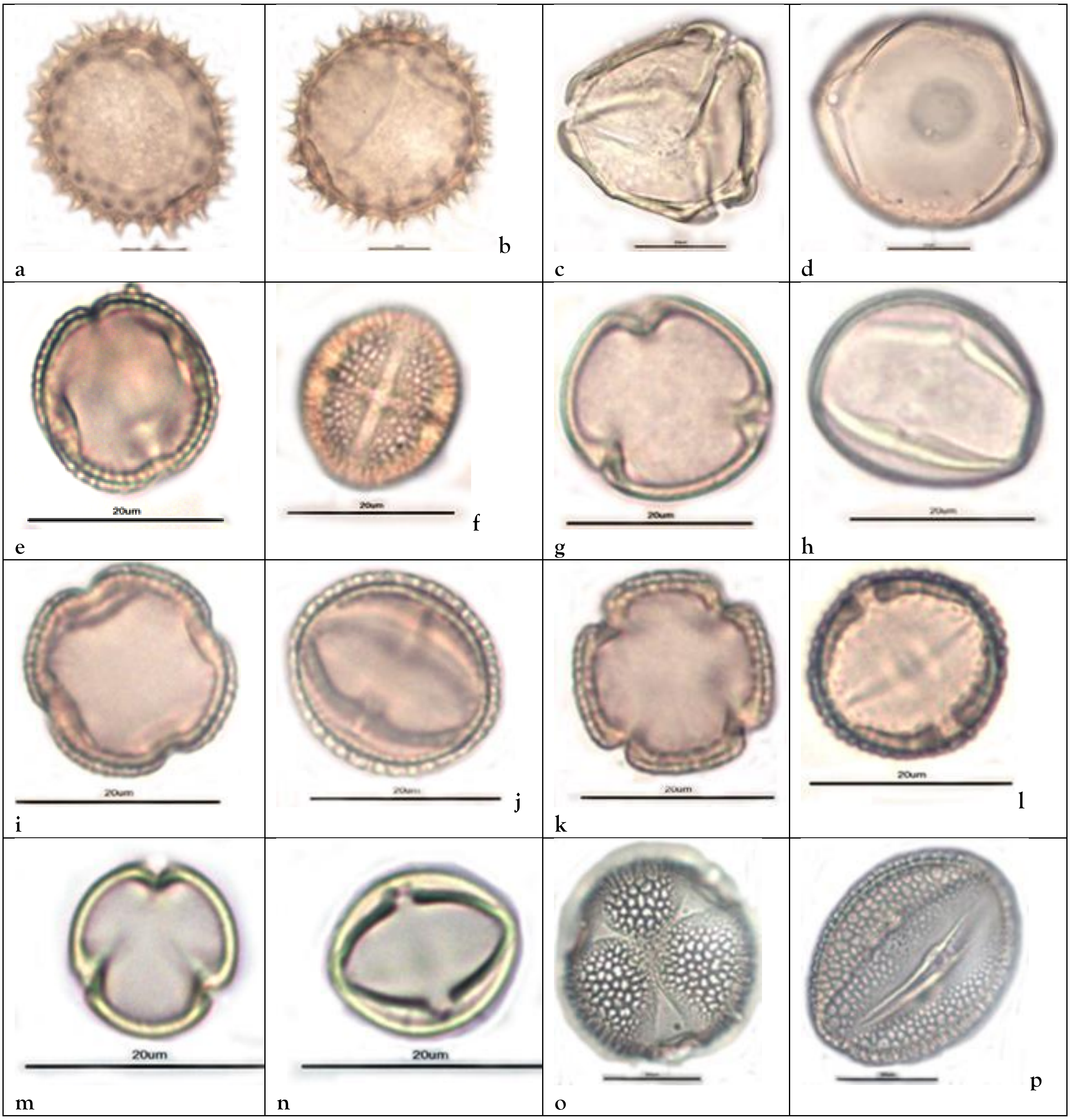

Figure 10: a- *A. grandifolium* Polar view, b- Equatorial view. c- *A. cathartica* Polar view, d- Equatorial view. e- *B. cristata* Polar view, f- Equatorial view. g- *C. papaya* Polar view, h- Equatorial view. i- *C. limon* Polar view, j- Equatorial view. k- *C. medica* Polar view, l- Equatorial view. m- *C. gynandra* Polar view, n- Equatorial view. o- *C. grandis* Polar view, p- Equatorial view.

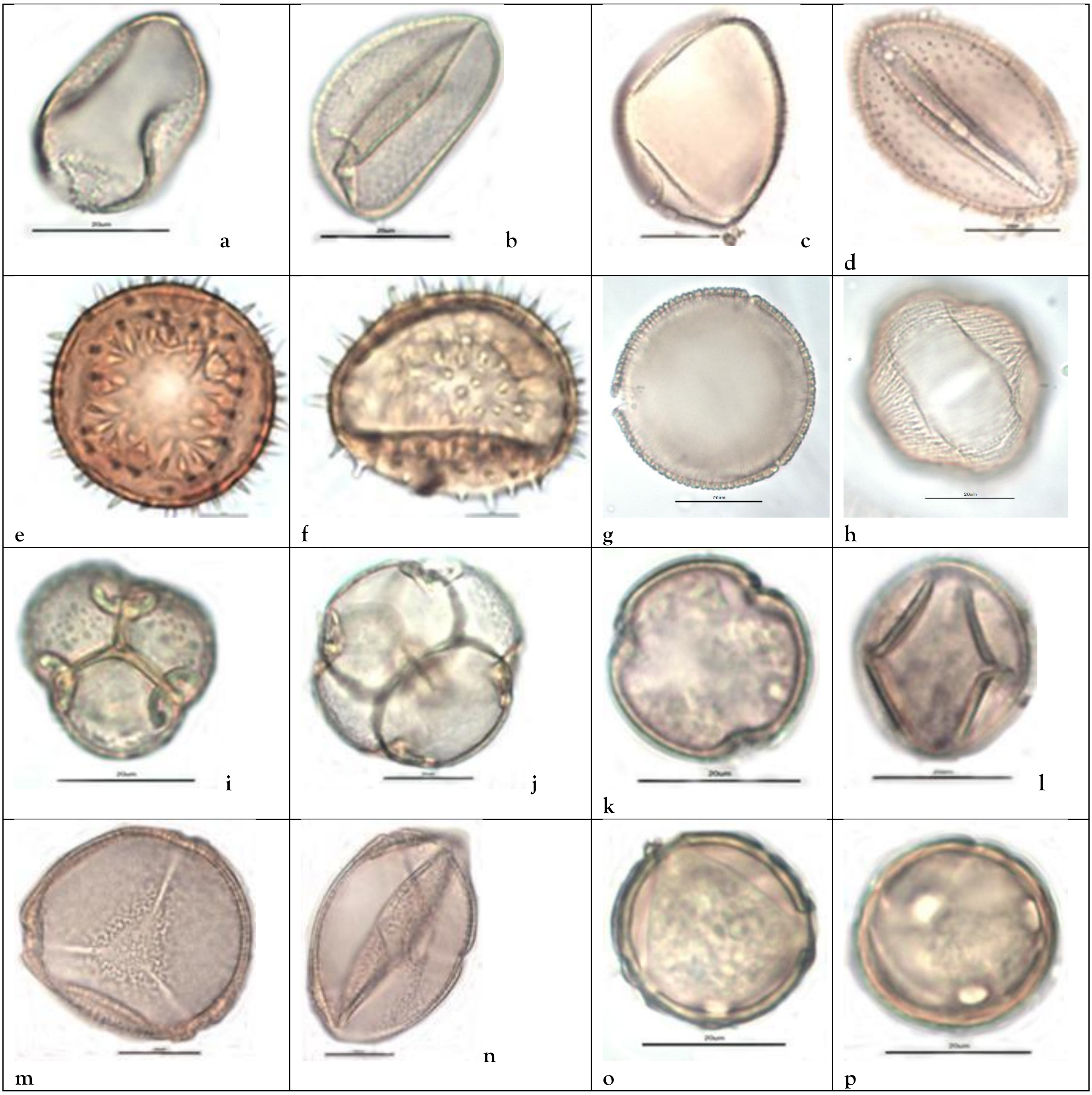

Figure 11: a- *C. benghalensis* Polar view, b- Equatorial view. c- *C. americanum* Polar view, d- Equatorial view. e- *C. pepo* Polar view, f- Equatorial view. g- *D. metel* Polar view, h- Equatorial view. i- G. *jasminoides* Polar view, j- Equatorial view. k- *I. coccinea* Polar view, l- Equatorial view. m- *L. siceraria* Polar view, n- Equatorial view. o- *M. emarginata* Polar view, p- Equatorial view.

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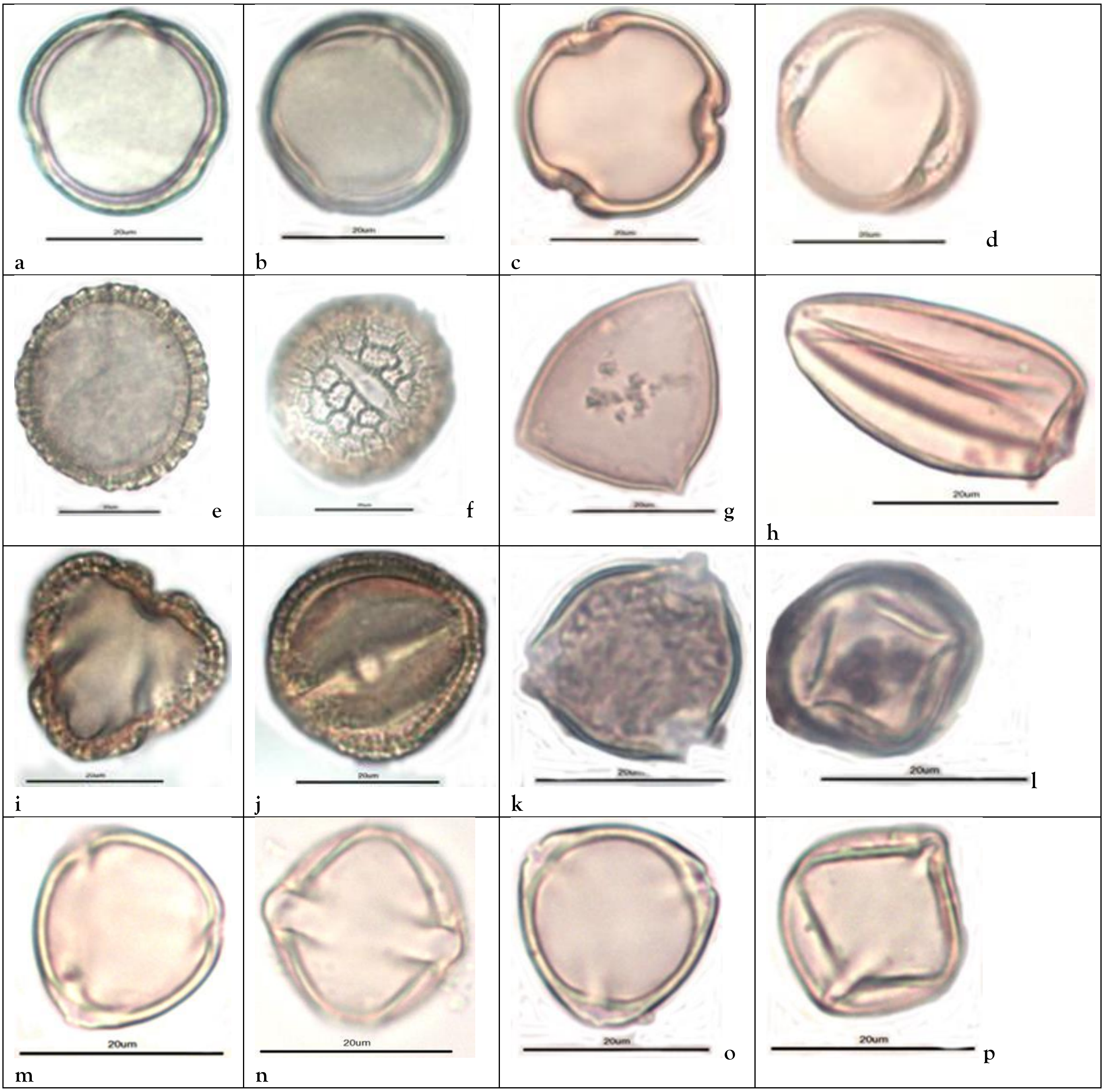

Figure 12: a- *M. jalapa* Polar view, b- Equatorial view. c- *M. oleifera* Polar view, d- Equatorial view. e- *N. arbor-tristis* Polar view, f- Equatorial view. g- *N. alba* Polar view, h- Equatorial view. i- *P. carrutherssi* Polar view, j- Equatorial view. k- *S. alata* Polar view, l- Equatorial view. m- *S. torvum* Polar view, n- Equatorial view. o- *S. trilobatum* Polar view, p- Equatorial view.

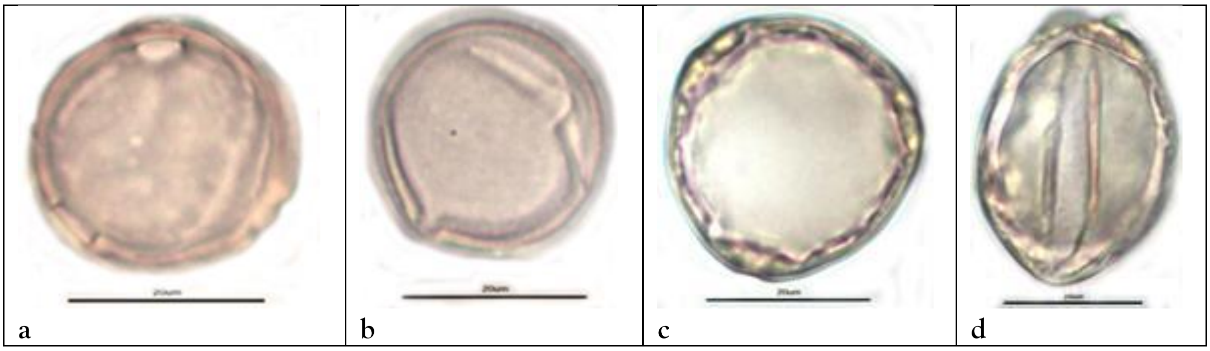

Figure 13: a- *T. stans* Polar view, b- Equatorial view. c- *V. inermis* Polar view, d- Equatorial view.

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