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Pollen Morphology and Variability Among Indian Cultivars of *Chrysanthemum morifolium* and Comparative Analysis with Genera of the Asteraceae Family

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Abstract:

This study investigates the pollen morphology of 134 *Chrysanthemum morifolium* Ramat cultivars through scanning electron microscopy (SEM). Chrysanthemum, a globally significant cut-flower crop, is renowned for its ornamental and medicinal properties. Morphology of a pollen grain, a microscopic flower structure known for being reproductive unit of higher plants was put forth for Scanning Electron Microscopy analysis that revealed diverse Chrysanthemum pollen traits, including shape, size, spine length, spine rows between colpi, ornamentation, and aperture type. Comparative analysis with 14 genera from daisy family, the PalDat database further explains uniqueness of Chrysanthemum in Asteraceae. Statistical analyses, employing cluster and principal component analyses, classify Chrysanthemum cultivars based on their pollen morphological characters. Significant cultivars exhibit distinct outgroups, suggestive of geographic and environmental impacts on evolution. The study suggests the significance of pollen characters, such as length, form index, and equatorial diameter in taxonomy and classification. This study contributes considerations into Chrysanthemum pollen morphology, enhancing knowledge of intrageneric relationships. The conclusions feature the importance of SEM techniques in identifying species based on palynomorphological traits. Future research, encompassing morphological, karyological, and molecular aspects, is recommended for a complete taxonomy of the Chrysanthemum genus.

Keywords: Pollen morphology; Palynology; Scanning electron microscope; PCA; Asteraceae; Cluster analysis.

Introduction:

Chrysanthemum (*Chrysanthemum morifolium* Ramat), a member of the Asteraceae family with a high ornamental value is one of the ten most popular traditional flowers in India and one of the four most popular cut flowers in the world; therefore, it is a commercially important species that occupies a large share of the global market of cut-flower production (Higuchi, 2018); reportedly, the second largest floriculture crop in the world after roses (Spaargaren and Geest, 2018). The term ‘chrysanthemum’ comes from the Greek ‘krus anthemon’, which means gold flower, and was initially used in China (Eisa, et al., 2022). The history of the Chrysanthemum-group, a branch of the Asteraceae family, reveals its importance as a system for studying speciation influenced by ecogeographical gradients and diverse macrohabitats in East Asia. Despite ongoing debates about its circumscription and monophyly, the group is characterized by features such as solitary flower heads or corymbose synflorescences, radiate or disciform capitula, and echinate Anthemis-type pollen grains (Shen et al., 2021). There exists a wide variety of chrysanthemum cultivars globally, which are dicotyledonous herbaceous annual or perennial plants, showcasing significant diversity in both morphology and popularity. These flowers are praised worldwide not only for their unique aesthetic characteristics, vibrant colors, and complex structures but also receive substantial recognition for their therapeutic and medicinal properties. (Hadizadeh et al., 2022).

Pollen grain is a microscopic structure of flower containing the microgametophytes of flowering plants, which produces the male gametes. Pollen characteristics have been extensively studied, including its origin, morphology, and physiology. Its role is also studied in DNA identification, flower pollination, germination, and fertilization. Their adaptation to distinct pollination strategies results in observable anatomical variations, as detailed by Halbritter et al (2018). The current investigation into pollen has played a crucial role in enhancing the knowledge of plant classification, taxonomy and biodiversity.

Morphological study of pollen grain is very useful in paleoecology, paleontology, and archeology, which includes traits such as wall morphology, polarity, symmetry, shape, and size are crucial parameters in this regard. In recent years, scanning electron microscopy (SEM) has emerged as a powerful technique for evaluating the morphology of pollen grains across different species (Parakhia, 2017). The exploration of pollen morphology, demonstrated in Moore et al.'s (1991) study on the systematics of the Asteraceae family and its genera and species, has been helpful in advancing the understanding of evolution and systematics that help identify past plant assemblages and environmental changes, making them useful in plant taxonomy. However, using pollen morphology for taxonomy is challenging and should be combined with other characteristics. Traditional methods for flowering plant biodiversity classification involve examining observable traits like floral morphology, leaf structure, and growth habits. Recent molecular tools such as DNA barcoding, RAPD, AFLP, microsatellites, and SNPs offer efficient means for categorization, addressing evolutionary questions beyond traditional methods, each with its strengths and limitations in detecting genetic differences at specific taxonomic levels (Arif et al, 2010). Over the past two decades, several studies have considered variations in pollen characteristics among different cultivars (Messora et al., 2017). Yet, there is an uncertainty regarding the evolutionary processes that have led to the diverse shapes of pollen found in flowering plants. Key knowledge gaps exist concerning the relationship between pollen morphology and factors such as genetics, environment, pollination ecology, and the evolution of pollinators (Kriebel et al., 2017; Mander et al., 2020). Despite studies showing that genome size does not predict pollen size well, little research has been done on how genome size or events like whole-genome duplication relate to the evolution of pollen morphology. This study builds upon a similar concept that pollen grain morphology can serve as a meaningful criterion for distinguishing cultivars and exploring biodiversity in flowering plants (Jardine, 2022).

Pollen morphology plays an important role in discriminating and describing intraspecific as well as interspecific diversity for species. Modern taxonomies are seen to be relied on palynology for precise differentiation and classification of closely related taxa and thereby palynology is regarded as one of the most effective tools for achieving identifications and defining the boundaries of plant groups (Khan et al., 2012). Though the causes of variation in pollen morphology are largely unknown, the evolutionary implications of differences in pollen morphology depend on the relative importance of environmental and genetic controls for pollen structure variation (Sahli et al, 2023). For instance, this diversity may be important for pollen grain survival in a variety of environmental conditions. Pollen grains' ability to accommodate volume changes during dehydration and hydration is affected by pollen size, number of apertures, wall ornamentation, and thickness (Ejsmond et al., 2011; Matamoro-Vidal et al., 2016). According to Matamoro-Vidal et al., (2016), aperturate pollens with thin exine walls and crotonoid ornamentation are more flexible and may retain their integrity better under intense desiccation stress. Plants in hotter environments tend to produce larger pollens with a lower surface-to-volume ratio, which could be used to reduce the rate of water loss. Different findings suggest that the relationships between ornamentation type and pollination system are taxonomic (Ferguson, 1985; Sannier et al., 2009; van der Ham et al., 2010).

The study of pollen morphology provides the information on genetic identity and parentage of genotypes which is important for the exploration of germplasms aimed at maximizing the use of genetic diversity (Adedeji and Akinniyi, 2015). Although there has been a broad research on the morphology and pollen characteristics of Asteraceae, the daisy family over the years, there remains a lack of specific information regarding the palynology of numerous subfamily members. The current study is aimed to address this gap by conducting thorough palynological examinations of 134 Chrysanthemum cultivars using scanning electron microscopy. This research serves to observe and describe the pollen morphology variations and enhance the identification of Chrysanthemum cultivars through their palynological attributes. The pollen morphology of species from various genera within the Asteraceae family was comparatively examined, utilizing data present in the PalDat database. Moreover, the pollen morphological information sourced from PalDat for the different genera was compared with the morphological data obtained for 134 Chrysanthemum cultivars through SEM analysis. While several genera within the Asteraceae family have undergone palynological research, as documented and deposited in PalDat database, a thorough examination of Chrysanthemum genus pollen remains absent. This gap in systematic research is yet to be addressed.

Material and Methods:

Sample collection:

In this study, a total of one hundred and thirty-four *C. morifolium* cultivars, each possessing high ornamental value, had been selected for analysis. In addition to this, another species, *C. coronarium* was also studied for its pollen morphology. The selected Indian cultivars are collected and maintained at ICAR-Directorate of Floricultural Research (DFR) in Pune. The pollens were precisely collected at the stage of anthesis using sterile forceps to maintain sample integrity. Various chrysanthemum cultivars that were subjected to examination and analysis can be found enlisted in Table 1, providing a reference for further investigation.

Scanning electron microscopic studies:

The pollens were acetolysed using the method described by Erdtman (1966) during the sample preparation for SEM with slight modifications for further experimentation. The samples were air dried and sputtered with gold before being examined under a scanning electron microscope (SEM). Qualitative attributes, such as the shape of pollen in both polar and equatorial views, pollen class, exine, ornamentation, pollen size, polarity and aperture type were examined using scanning electron microscopes. On the other hand, quantitative characteristics, including polar length, equatorial diameter, exine thickness, spine length, and spine rows between colpi were measured. The shape of pollen was determined using methods described by Erdtman (1945), characterizing pollen shape based on the equatorial view, by calculating the P/E ratio, ratio of the polar axis to the equatorial diameter (P: E) as shown in the following equation, and Form Index (FI) = P/E × 100; where, P: Polar axis, E: Equatorial diameter (Erdtman, 1966). Shape classes and relations between polar axis (P) and equatorial axis (E) of grains in equatorial view when one of the apertures lies exactly at the center.

Statistical analysis:

Pollen measurement data were calculated from at least 10 grains per sample. Measurements and analysis of scanning electron microscope images carried out by using Fiji win64 software. Two analyses were conducted using StatistiXL software, a data analysis package (Coutinho et al., 2021). Cluster analysis (CA) was performed using the average taxonomic distance, specifically the Euclidean distance matrix, and the UPGMA clustering method, as implemented in StatistiXL software in MS Excel. Here, we investigated the relations among Chrysanthemum cultivars on the basis of similarity by employing Hierarchical Cluster Analysis (HCA) with the assistance of pollen morphology data. HCA was conducted to explore how these cultivars could be grouped based on the observed dissimilarities in their characteristics. Multivariate ordination analysis of the pollen characteristics from 134 cultivars were subjected to numerical analysis, including techniques such as principal component analysis (PCA) in addition to cluster analysis.

Database screening and data collection:

The morphometric data included in PalDat database (https://www.paldat.org/; accessed on 12 September, 2023, was obtained for species from 14 various genera within the Asteraceae family, which had also been subjected to SEM analysis, summarized in table 2. Data collected was compared for their pollen morphological features with Chrysanthemum cultivars as considered in this study.

Multivariate analysis of Asteraceae family members:

The pollen morphological data obtained via PalDat database for various Asteraceae members were compared to the data obtained via SEM in present study. The methodology for multivariate analysis was based on study by Marinho et al. (2018) where principal component analysis (PCA) was conducted on the pollen data to validate if species could be classified. The variance was extracted using the variance/covariance (centered) matrix and coordinates in a distance-based scatter plot. The results are plotted in a two-dimensional graph of the first two principal components. Hierarchical cluster analysis (HCA) was also performed to verify that pollen traits could differentiate and thereby group plants of Asteraceae family members. The HCA dendrogram was created using Ward's method on the squared Euclidean distance measure and linkage method. Statistical analysis was carried out using StatistiXL in MS Excel.

Results and Discussion:

Scanning electron microscopic studies:

In the study of morphology of Chrysanthemum pollen grains, several key features were examined (table 1). Figure 1 represents microscopic (SEM) views of pollen grains from different cultivars. All the pollen grains exhibited radial symmetry, with shapes ranging from oblate and prolate-spheroidal in equatorial view to circular lobate in polar view. The examination of 134 cultivars of Chrysanthemum gives the revelation that there is a great range of variation of polar length 24.86 - 43.6 μm out of which the maximum pollen size 43.60 μm was in Punjab Gold variety in polar view while the minimum size 24.86 μm in IAH Red. Similarly, the maximum pollen size 44.08 μm (equatorial diameter) was recorded in Punjab Gold cultivar in equatorial view and minimum size 25.99 μm in Cherabu cultivar. Wodehouse (1935) reported pollen diameter range from 24.2 to 34.2 μm in Chrysanthemum species which gives support to the present findings. The polar-to-equatorial diameter (P/E) ratio varied between different species, indicating differences in pollen shape. All the studied Chrysanthemum pollen grains showed tetrahedral tetrad polarity with P/E ratio within the range of 0.9 – 1.1. Predominantly, the presence of spines on the pollen grains was a distinctive characteristic, with pyramidal-shaped spines that were commonly conical and had a broad base at the bottom and a blunt to sharp apical portion.

The exine surface in some Chrysanthemum species appeared granulated, and the intine was thinner than the exine. These species have somewhat aggregated and granulated columella. The exine thickness varied between 2.1 μm to 5 μm among different Chrysanthemum cultivars, with Red Gold having the thickest exine and Ravi, Pink Cloud, and DFR-C-6 sharing the thinnest. Similar findings were obtained in the studies of Huang (1972) which reported that exine was 2.0–2.5μm thick in four species of Chrysanthemum from Taiwan and in the studies by Meo and Khan (2006) the exine thickness observed was in the range of 4.1−7.9 μm in Chrysanthemum cultivars studied in Pakistan. Pollen ornamentation was observed through SEM, revealing variations in exine sculpturing. Chrysanthemum pollen grains presented features like caveat, echinate, and varying spine lengths, distinguishing different cultivars.

The pollen grains were tricolporate with apertures that either being lacunate or non-lacunate, and the apertural membrane was echinate. Similar observations were reported for medicinal plant species of Asteraceae (Compositae) from flora of Kaghan Valley studied by Khan et al. (2012). The number of spine rows between colpi ranged from 3 to 6 in Chrysanthemum species, providing a useful character for species differentiation within the genus and showing the taxonomic potential of these features. These results align with the study reported by Meo & Khan (2006) where the pollen morphology of 7 Chrysanthemum species (Compositae – Anthemideae) from Pakistan was considered. This variation in the number of spine rows between colpi demonstrates a correlation between these features and enhances the taxonomic potential for segregating species within the genus.

Among the 134 Chrysanthemum cultivars analysed, PAU-55, Bidhan Gold, Bidhan Shwet, Bidhan Sabita, Bidhan Rajat, Bidhan Neeta, and Bidhan Agnishikha are photosensitive cultivars with an average spine length of 5 μm and form indices ranging from 92 to 109. On the other hand, the photo-insensitive cultivars, including Bidhan Tarun, Mother Teresa, Vanity Pink, Autumn Joy, ACC - 2, Aparajita, IAH Red, and Royal Purple, feature spines with lengths ranging from 5 to 6 μm and occurred in spheroidal shapes that are prolate to oblate when viewed from an equatorial perspective. Spine length varied among the cultivars, ranging from 4.19 μm to 13.42 μm which resembled with the study reported by Wodehouse (1935) where Chrysanthemum species apparently showed pollen spine about 2.3 to 8.1 μm long. The morphometric data thus obtained was further analysed.

Statistical analysis:

As multivariate analysis, the hierarchical cluster analysis was performed using StatistiXL, with Euclidean distance as the similarity measure and Wards linkage as algorithm. As a result, it was observed in the dendrogram that the cultivars were divided into two initial clusters divided cultivars in 2 basic distinct groups A and B based on their overall similarity in characteristics with a squared Euclidean distance of 3381.234, which were further categorized into 3 clusters each (Figure 2). The Chrysanthemum cultivars were primarily partitioned into 2 groups based on the number of spine rows between colpi; group A showed presence of 3-4 spine rows while group B were observed to have 5-6 spine rows between colpi. Notably, cultivars such as Kundan, Bidhan Gold, Vanity pink, Bidhan Tarun, Liliput, Pusa Century, and PAU-55 were observed to form distinct smaller outgroups at comparatively greater distances. The more substantial clusters were in close proximity to each other and comprised the majority of members, with 44 and 45 individual cultivars, respectively. The differentiation or variation observed in Chrysanthemum cultivars could be correlated with geographic and environmental factors (Hao et. al., 2022). PCA was employed to ascertain if the morphological pollen data facilitated the grouping of cultivars. The first two principal components (PCs) with eigenvalues exceeding one were depicted. These findings were visualized in a two-dimensional plot of the initial and secondary principal components. The eigenvalues, representing the highest character variation, were graphed on a two-dimensional scatter plot using the first two principal component axes (PCA1, PCA2). Figure 3 shows the same for the pollen morphological data of Chrysanthemum cultivars obtained using scanning electron microscopy. Notably, the first two principal component axes are of significance, collectively explaining 93.084% of the variance, with the first accounting for 69.911% and the second for 23.174%. According to the biplot, the morphological characters pollen length, form index, and equatorial diameter were the most significant variables.

Database screening and data collection:

PalDat provided pollen morphological data for 14 genera in Asteraceae family including *Artemisia vulgaris, Helenium autumnale, Inula Britannica, Solidago virgaurea, Calendula officinalis,* *Leucanthemum vulgare, Bellis perennis, Leucanthemopsis alpine, Doronicum columna, Tanacetum parthenium, Achillea clavennae, Anthemis tinctoria, Bidens pilosa,* and *Senecio abrotanifolius.* Table 2 provides morphological information about all these plant genera within the family Asteraceae, with a focus on their pollen characteristics including details such as the size, shape, and aperture type of the pollen grains. In the Asteraceae family, most species are observed to have spheroidal pollen grains with colporate or tricolporate apertures, demonstrating a consistency in these characteristics. While there is variation in size, with some species having small-sized pollen (10-25 µm) and others possessing medium-sized pollen (26-50 µm), this manner shows a strong homogeneity in pollen traits within the family observed in most of these species, are shared by Chrysanthemum's pollen, despite its larger size.

Multivariate analysis of Asteraceae family members:

Multivariate analysis methods like PCA and HCA were utilized to study data structure, identify similarities, and detect outliers. Principle Component Analysis, represented as a visualization approach, while HCA served as an agglomerative algorithm, both widely employed for their efficiency in data analysis (Granato et al., 2018) were used here for the morphometric data obtained through SEM and from PalDat Database. When PCA was carried out for Asteraceae family members for their morphological characters, it was observed that the first principal component (PC1), representing 72.510% of the variance, seems to signify overall size, with larger grains on the right and smaller on the left and second principal component (PC2) with 26.627% variance captures shape differences, with elongated grains at the top and rounder at the bottom (Fig. 4). The vector rows indicate the direction and magnitude of the original morphological variables, according to which the longer arrows like Polar Length and Equatorial Diameter correlate positively with PC1, while Form Index correlates negatively with PC2. It revealed that size and elongation/roundness were the major factors those contributed to the variance. The spread of points indicates diversity, with some cultivars tightly clustered (less diverse) and others like *Solidago virgaurea* more diffuse (more diverse). PC1 played a crucial role, differentiating varieties by traits like polar length, equatorial diameter, and P/E ratios. Some taxa, including *Artemisia vulgaris* and *Achillea clavennae*, clustered together due to similar pollen size and rounded shape, while *Chrysanthemum morifolium* cultivars showed separation based on elongation and protrusion. PC2, though less dominant, contributed to distinctions in aperture numbers. HCA revealed similarity relationships amongst the Asteraceae members, based on pollen morphological data. Overall, the hierarchy showed morphological relationships from trait similarities and differences among Asteraceae family members- ranging from predominant separation of certain genera to sub-clusters distinguishing even close cultivars (Figure 5). The dendrogram contained two primary clusters, further subdivided into about five main sub-groupings. Within the sub-clusters, genera like *Bellis perennis, Inula britannica, Leucanthemum alpina* were clustered closely, indicating similarity in floral traits. On the other hand, tighter sub-groupings were emerged of the Chrysanthemum cultivars of our interest where *C. morifolium* - Dark Red showing similar traits with *Solidago virgaurea* were clustered together with a squared Euclidean distance of 141.276; *C. morifolium* – Ravi was clustered with *Calendula officinalis* independently with a squared Euclidean distance of 23.719; *C. morifolium* - DFR-C1 exhibiting similar traits with *Senecio abrotanifolius* were placed together in another cluster with a squared Euclidean distance of 13.936 while *C. morifolium* - Punjab Gold cultivar was seen as an outgroup individually showing characteristics comparatively distinguishing. *Helenium autumnale, Leucanthemum vulgare, Doronicum columnae, Tanacetum parthenium, Anthemis tinctoria, Bidens pilosa,* and *Chrysanthemum coronarium* were observed to cluster together because of their similar P/E ratios displaying *C. coronarium* distinguished from *C. morifolium* in its morphological traits yet similar to the other Asteraceae family members in the group. The Chrysanthemum variants were shared the most similarity, diverging last on the vertical axis. Their late merging was reflected finer-scale morphological variations between the cultivated types. Besides, genera *Artemisia vulgaris* and *Achillea clavennae* sharing a common characteristic of having a higher P/E ratio and, accordingly, a higher Form Index showed a squared Euclidean distance of 15.369, clustering together and diverging from the rest of the groups earlier. This suggests a more distinct morphology compared to others. Thus, when compared to other Asteraceae family members, morphological variables like P/E ratio, equatorial diameter provide continuous quantitative differences. The study on morphological, cytological, and physiological features of ripe pollen by Pacini & Franchi (2020) disclosed correlations among the traits (shape, size, and dispersal units), the female counterpart, and environmental factors. Despite their shared reproductive function, diverse morphological and physiological characteristics were observed during dispersal. Analyzing factors such as pollen grain types, shape, size, and dispersal units contributed to a slight understanding of complex interactions influencing plant reproduction. The importance of studying the diversity in plant shapes and forms was elaborated by Jardine et al. (2022); it was suggested that understanding morphological differences among plants is crucial for biodiversity research, complementing traditional diversity metrics and the differences were distributed across space and time, zooming in on specific plant parts like pollen and flower will be more useful.

As a result, pollen morphological characters studied for Chrysanthemum pollen that are size, shape, type, spine, ornamentation and echini feature result to be informative and contribute to a better understanding of their intergeneric relationships. The importance of SEM techniques for identifying examined species using palynomorphological traits is further clarified. Based on the foundational information provided by pollen morphological data, it was revealed that the varieties could be studied for their biodiversity.

Conclusion

Analysis of pollen morphology in 134 different types of Chrysanthemum flowers was conducted using scanning electron microscopy. Detailed observations were made on characteristics like shape, spine length, ornamentation, and aperture type of the pollen grains using Scanning Electron Microscopy, accentuating the significance of SEM techniques in identifying species based on pollen features. Multivariate analyses, including hierarchical clustering and principal component analysis for the morphometric data, were used to categorize the cultivars based on these pollen traits. Among *C. morifolium* cultivars, "Punjab Gold" was distinguished by its larger pollen size, "IAH Red" with the equatorial diameter of 25.14 µm; "Kundan" having a spine length of 13.42 µm, distinguishing it from other analyzed cultivars in terms of longer spines. Different clusters were discerned, signifying that potential environmental influences had contributed to the observed variation or biodiversity. On the basis of data obtained through PalDat database, different Asteraceae members were compared for their pollen morphology and the distinction of pollen morphology as a reliable tool for classification was noted. Studying pollen morphology is crucial for understanding various aspects of plant biology, including reproduction, biodiversity assessment, ecological interactions, and plant adaptation to their environment. Understandings from pollen morphology research have practical applications in agriculture and horticulture as well.

Figure legends:

Fig 1: 1A: Polar view of Pollen grain of Pusa Century; 2A: Equatorial view of pollen grain of Pusa Century. And 3A: 15X magnification view of spinulous exine of Pusa Century; 1B: Polar view of Pollen grain of Pusa Kesari; 2B: Equatorial view of pollen grain of Pusa Kesari. And 3B: 15X magnification view of spinulous exine of Pusa Kesari; 1C: Polar view of Pollen grain of Pusa Shwet; 2A: Equatorial view of pollen grain of Pusa Shwet. And 3A: 15X magnification view of spinulous exine of Pusa Shwet; 1D: Polar view of Pollen grain of Pusa Guldasta; 2D: Equatorial view of pollen grain of Pusa Guldasta and 3D: 15X magnification view of spinulous exine of Pusa Guldasta.

Fig. 2 Dendrogram obtained on Hierarchical Cluster Analysis as the multivariate analysis for 134 Chrysanthemum cultivars.

Fig. 3 Scatter plot as a result of Principal Component Analysis (PCA) as multivariate ordination analysis using pollen morphological data.

Fig. 4 Principal Component Analysis (PCA) for pollen morphological data obtained from PalDat database in comparison with representative Chrysanthemum cultivars where HA - *Helenium autumnale*, AV - *Artemisia vulgaris*, HA - *Helenium autumnale*, IB - *Inula britannica*, SV - *Solidago virgaurea*, CO - *Calendula officinalis*, LV - *Leucanthemum vulgare*, BP - *Bellis perennis*, LA - *Leucanthemopsis alpine*, DC - *Doronicum columnae*, TP - *Tanacetum parthenium*, AC - *Achillea clavennae*, AT - *Anthemis tinctoria*, BPi - *Bidens pilosa*, SA - *Senecio abrotanifolius,* CC - *Chrysanthemum coronarium, and* CM - *Chrysanthemum morifolium*

Fig. 5 Dendrogram representing cluster analysis of selected Asteraceae members for morphological characters of pollen grains.

Table Legends:

Table 1. Morphometric data of pollen grains in equatorial view of *Chrysanthemum morifolium* cultivars obtained on SEM analysis (n = 134) represented as arithmetic mean ± standard deviation; P/E ratio–polar:equatorial diameter ratio.

Table 2. Description of the pollen morphology of members of Asteraceae family as obtained from PalDat Database.

CRediT authorship contribution statement:

Patil SA: Methodology, Formal analysis, Writing-original draft Nimbalkar Mansinghraj: Methodology, Formal analysis, review and editing and data analysis. Kulkarni AJ: Writing - original draft Writing review and editing and data analysis Jadhav PR: Formal analysis, Writing-editing Pagariaya MC: Methodology, data analysis and editing of draft Saha TN: Resources. Mahesh M: Validation and editing. Magdum A: Validation and editing; Kapil S: Validation and editing; KV Prasad: Resources, Supervision. Dixit GB: Resources, Supervision; Kawar PG: Methodology, Formal analysis, Writing-review and final editing; Supervision.

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Declaration of Competing Interest

All the authors listed have agreed with the submission and declared no conflict of interest.

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Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) used chat.opeanai.com in order to proof read the contents of manuscript. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

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(a) Palynological studies of the plants growing in Punjab.

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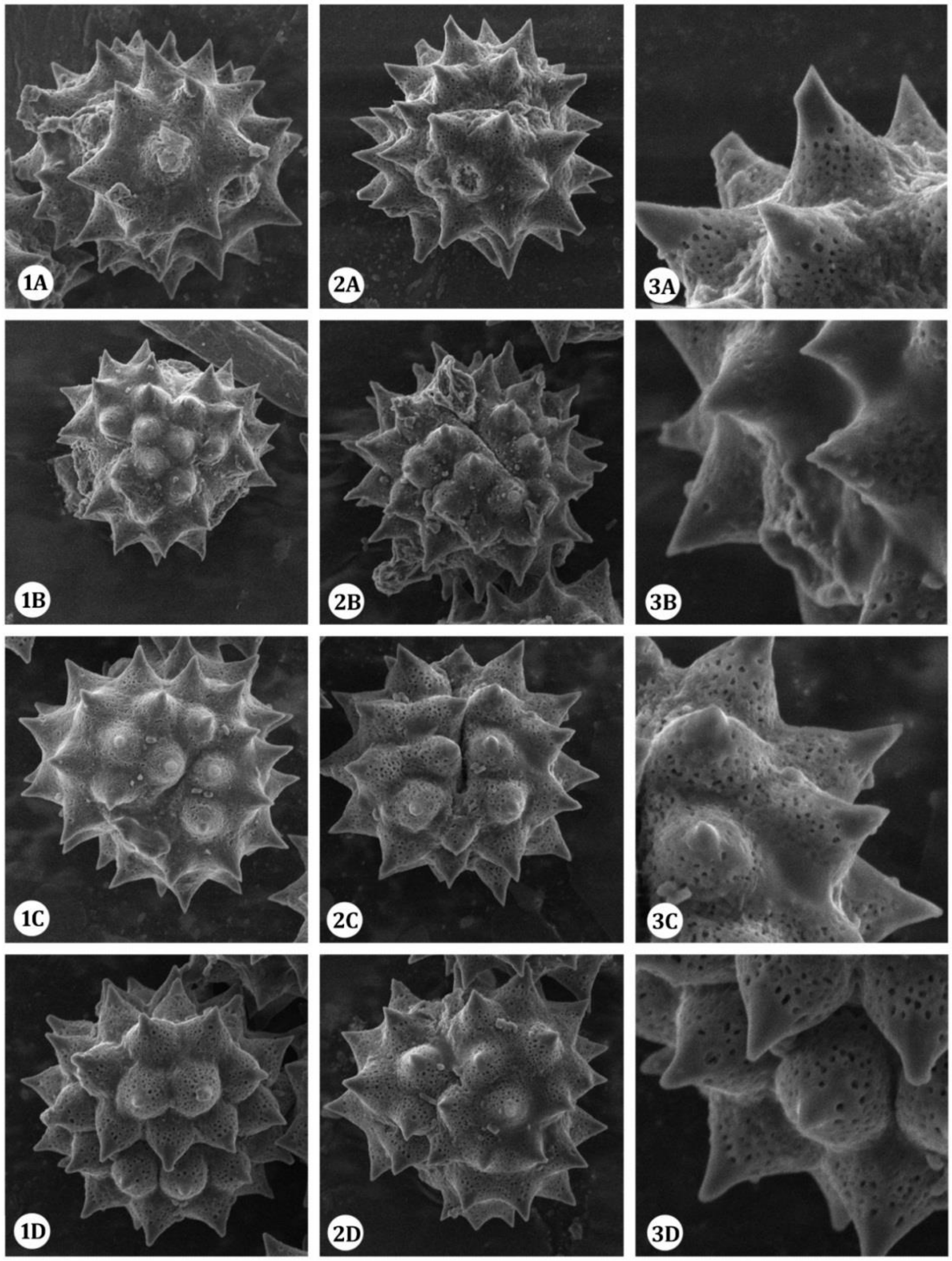

Fig 1: 1A: Polar view of Pollen grain of Pusa Century; 2A: Equatorial view of pollen grain of Pusa Century. And 3A: 15X magnification view of spinulous exine of Pusa Century; 1B: Polar view of Pollen grain of Pusa Kesari; 2B: Equatorial view of pollen grain of Pusa Kesari. And 3B: 15X magnification view of spinulous exine of Pusa Kesari; 1C: Polar view of Pollen grain of Pusa Shwet; 2A: Equatorial view of pollen grain of Pusa Shwet. And 3A: 15X magnification view of spinulous exine of Pusa Shwet; 1D: Polar view of Pollen grain of Pusa Guldasta; 2D: Equatorial view of pollen grain of Pusa Guldasta and 3D: 15X magnification view of spinulous exine of Pusa Guldasta.

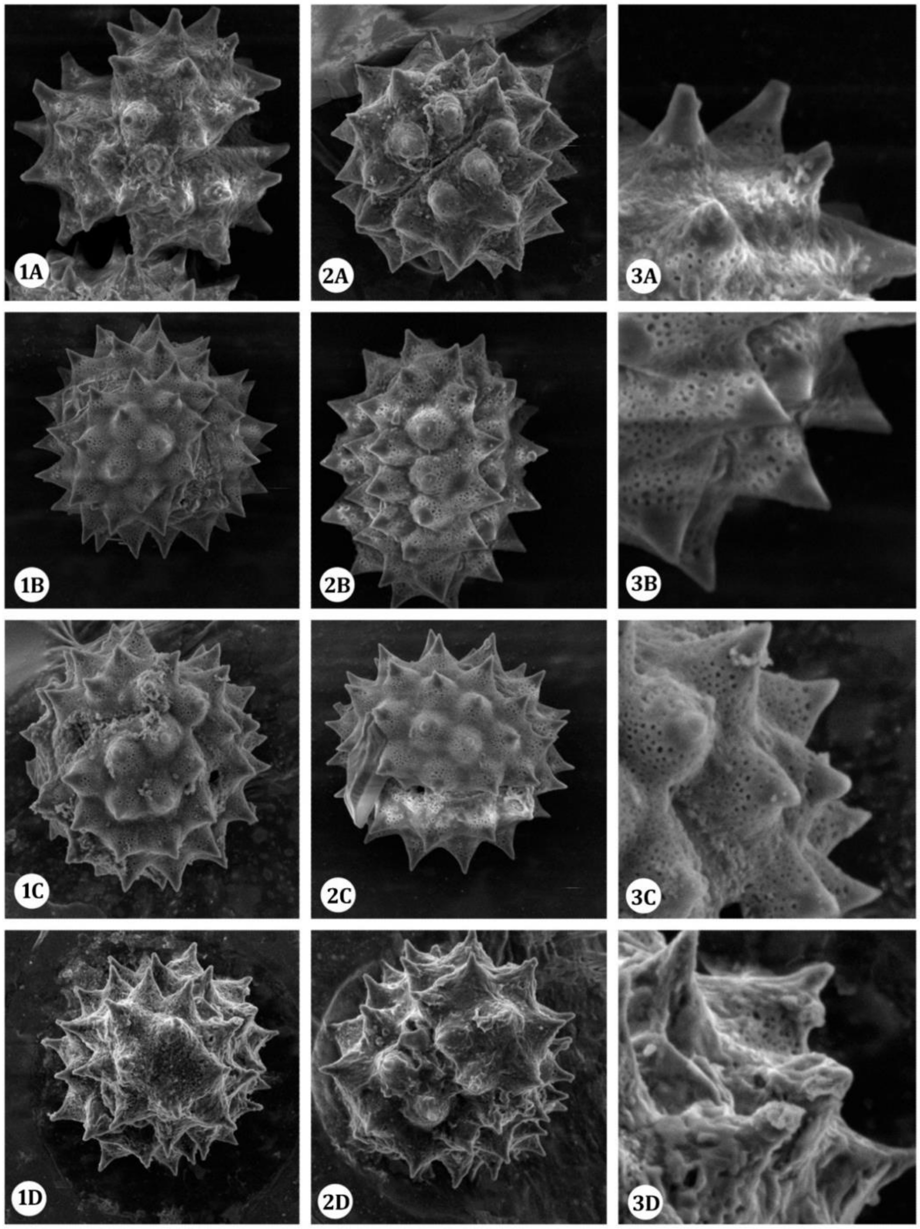

Fig 1: 1A: Polar view of Pollen grain of Pusa Aditya; 2A: Equatorial view of pollen grain of Pusa Aditya. And 3A: 15X magnification view of spinulous exine of Pusa Aditya; 1B: Polar view of Pollen grain of Pusa Chitraksha; 2B: Equatorial view of pollen grain of Pusa Chitraksha. And 3B: 15X magnification view of spinulous exine of Pusa Chitraksha; 1C: Polar view of Pollen grain of Pusa Sona; 2A: Equatorial view of pollen grain of Pusa Sona. And 3A: 15X magnification view of spinulous exine of Pusa Sona; 1D: Polar view of Pollen grain of PAU-35; 2D: Equatorial view of pollen grain of PAU-35 and 3D: 15X magnification view of spinulous exine of PAU-35.

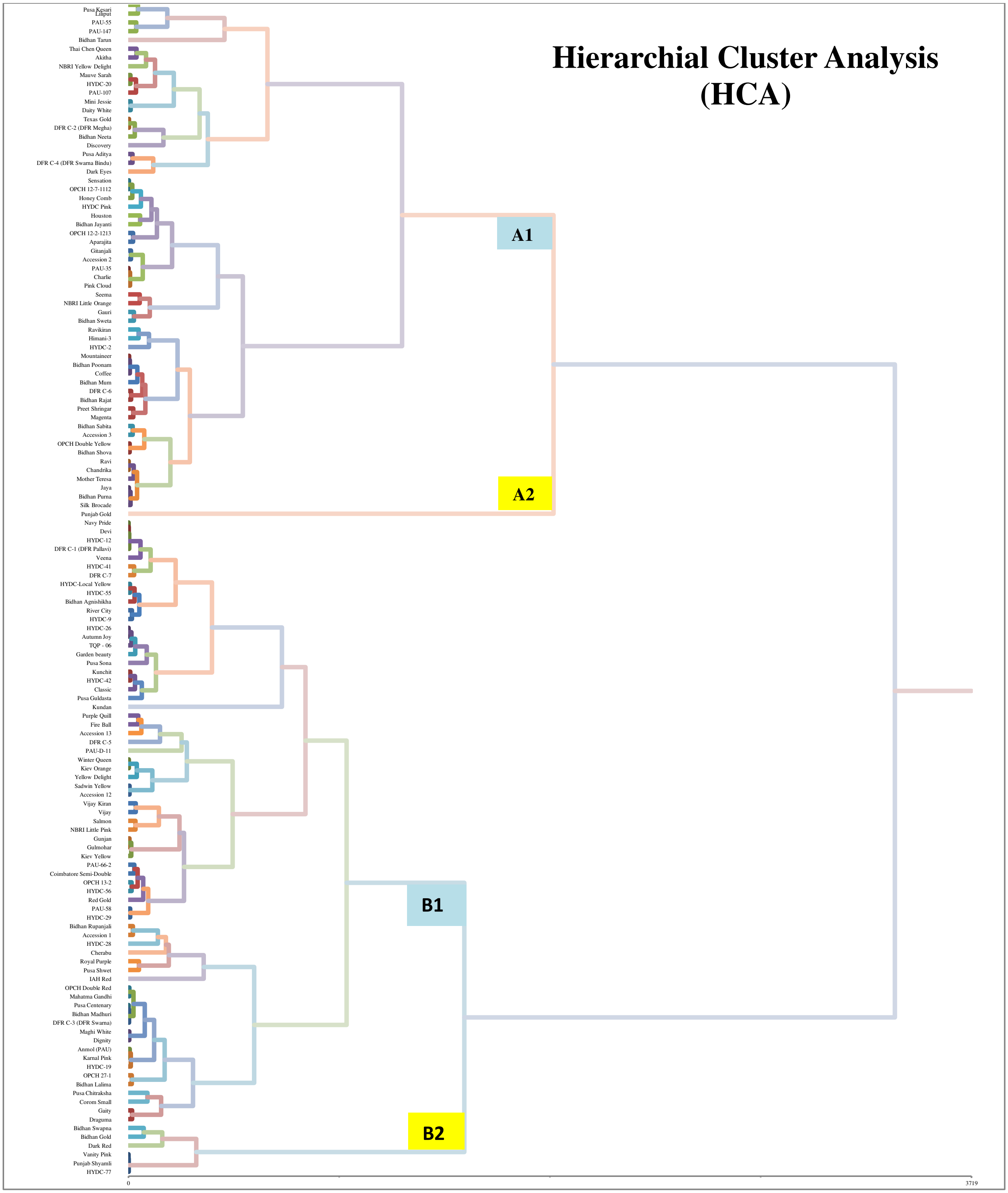

Fig. 2 Dendrogram obtained on Hierarchical Cluster Analysis as the multivariate analysis for 134 Chrysanthemum cultivars.

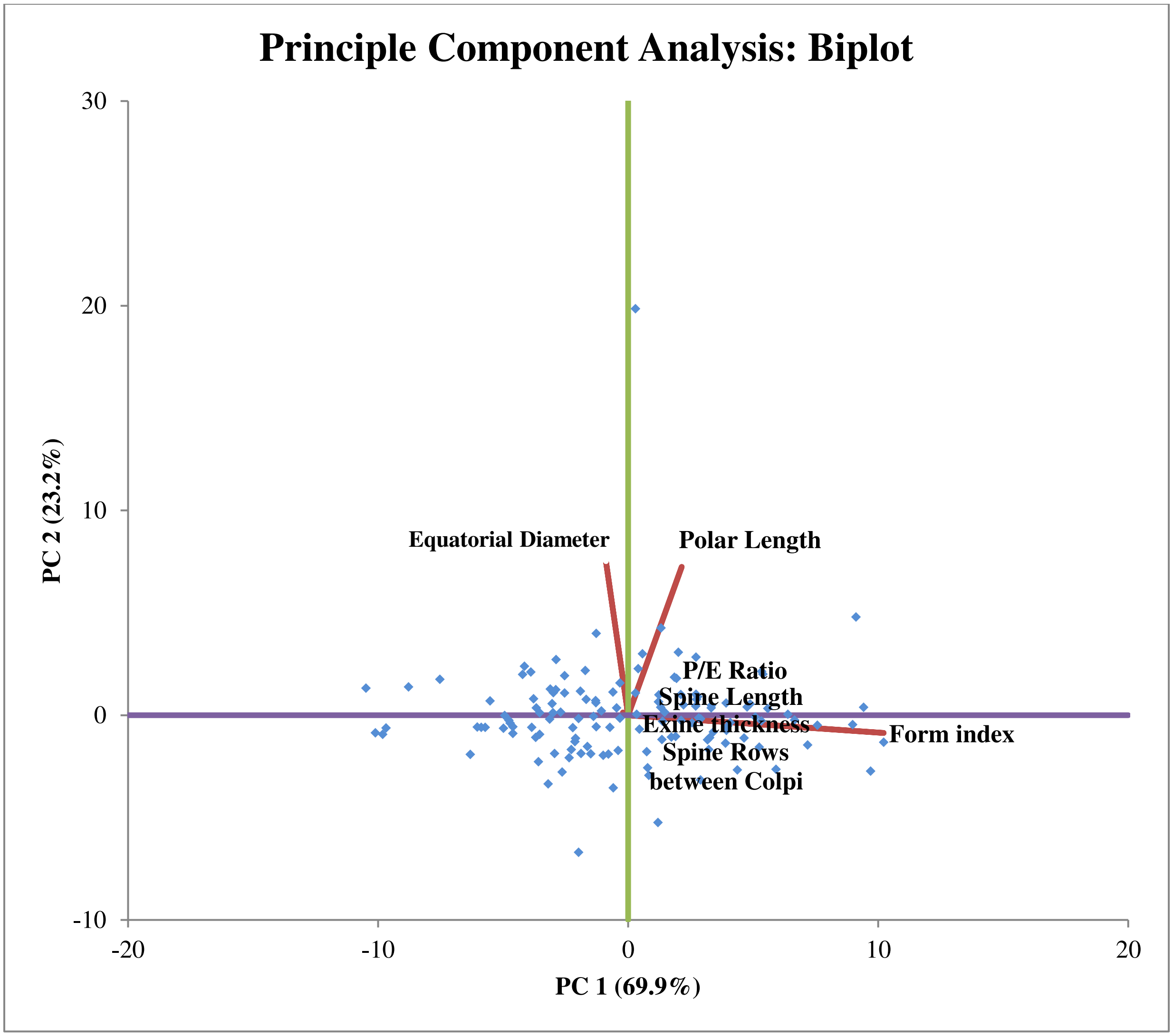

Fig. 3 Scatter plot as a result of Principal Component Analysis (PCA) as multivariate ordination analysis using pollen morphological data.

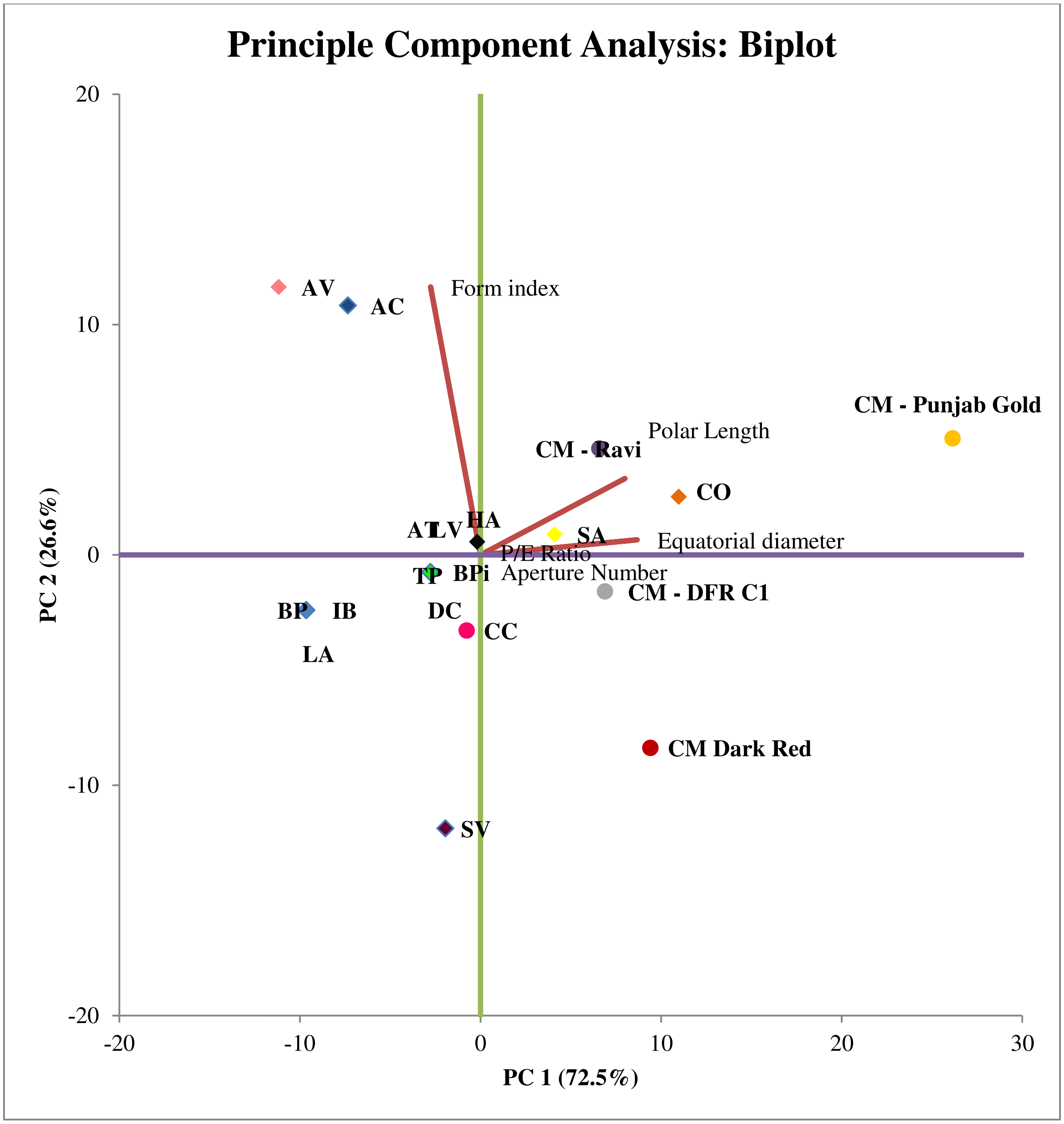

Fig. 4 Principal Component Analysis (PCA) for pollen morphological data obtained from PalDat database in comparison with representative Chrysanthemum cultivars where HA - *Helenium autumnale*, AV - *Artemisia vulgaris*, HA - *Helenium autumnale*, IB - *Inula britannica*, SV - *Solidago virgaurea*, CO - *Calendula officinalis*, LV - *Leucanthemum vulgare*, BP - *Bellis perennis*, LA - *Leucanthemopsis alpine*, DC - *Doronicum columnae*, TP - *Tanacetum parthenium*, AC - *Achillea clavennae*, AT - *Anthemis tinctoria*, BPi - *Bidens pilosa*, SA - *Senecio abrotanifolius, CC* - *Chrysanthemum coronarium, and* CM - *Chrysanthemum morifolium*

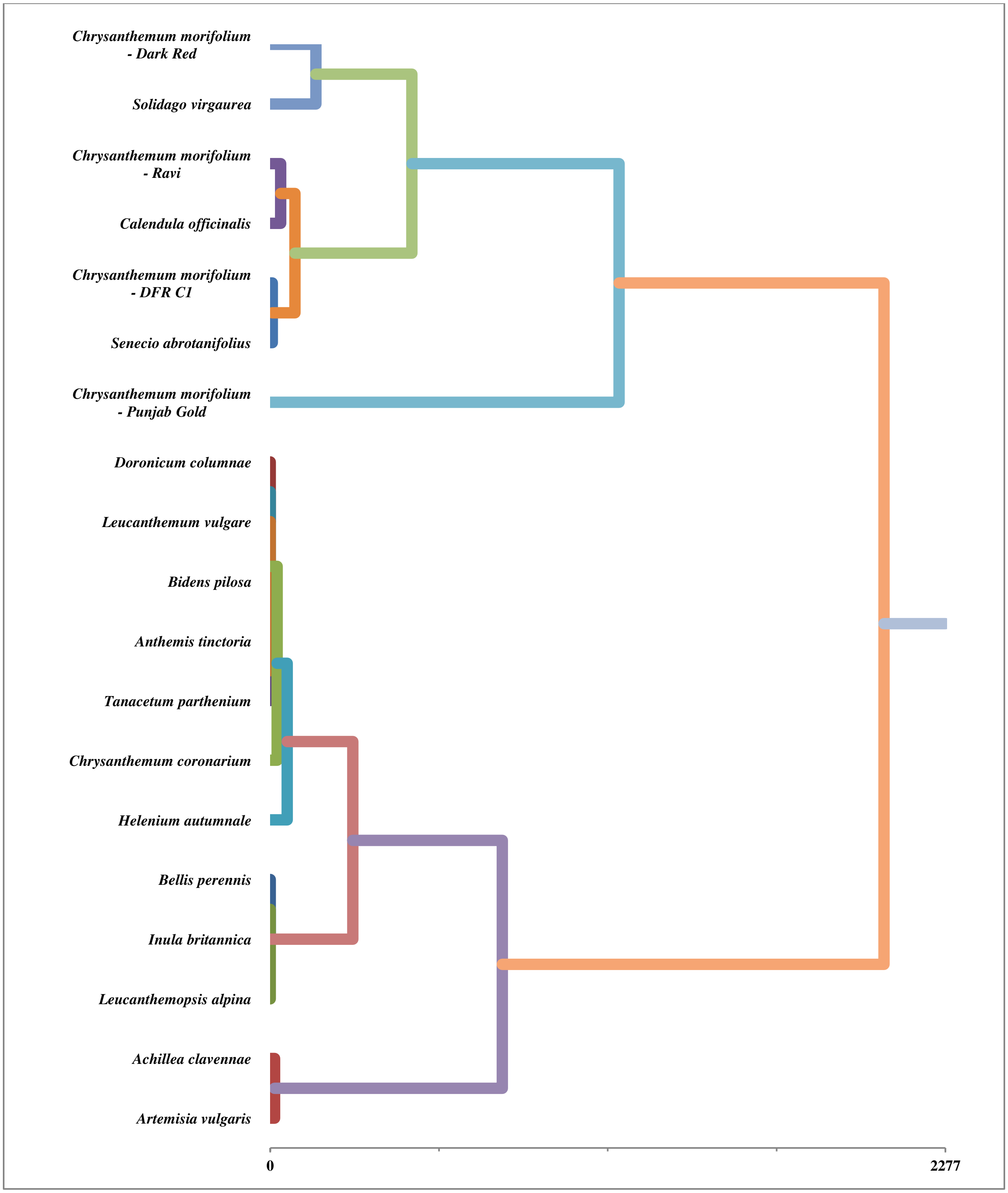

Fig. 5 Dendrogram representing cluster analysis of selected Asteraceae members for morphological characters of pollen grains.

Table 1. Morphometric data of pollen grains in equatorial view of *Chrysanthemum morifolium* cultivars obtained on SEM analysis (n = 134) represented as arithmetic mean ± standard deviation; P/E ratio– polar:equatorial diameter ratio.

Chrysanthemum Varieties	Polar Length	Equatorial diameter	P/E Ratio	Form index	Exine thickness	Spine Length	Spine rows between colpi	Shape in Equatorial view
1. Accession 1	28.80 ± 3.46	28.48 ± 3.99	1.01 ± 0.17	101.12 ± 13.15	3.11 ± 0.44	5.13 ± 0.87	4.0 ± 0.7	Oblate Spheroidal
2. Accession 12	30.10 ± 3.61	30.99 ± 4.34	0.97 ± 0.16	97.13 ± 12.63	4.31 ± 0.60	5.28 ± 0.90	5.0 ± 0.9	Prolate Spheroidal
3. Accession 13	31.04 ± 4.35	31.55 ± 3.47	0.98 ± 0.19	98.38 ± 6.89	2.28 ± 0.32	6.57 ± 0.79	4.0 ± 0.5	Oblate Spheroidal
4. Accession 2	29.49 ± 8.88	29.27 ± 9.07	1.01 ± 0.01	100.75 ± 97.86	3.18 ± 0.14	5.83 ± 0.31	5.0 ± 0.3	Oblate Spheroidal
5. Accession 3	31.11 ± 1.56	29.91 ± 3.29	1.04 ± 0.03	104.02 ± 8.32	3.32 ± 0.56	4.53 ± 0.59	4.0 ± 0.1	Prolate Spheroidal
6. Akitha	30.86 ± 4.01	29.34 ± 3.81	1.05 ± 0.14	105.19 ± 13.67	2.26 ± 0.29	6.46 ± 0.84	4.0 ± 0.5	Oblate Spheroidal
7. Anmol (PAU)	28.32 ± 4.25	28.48 ± 3.14	0.99 ± 0.11	99.43 ± 12.93	2.57 ± 0.50	5.01 ± 0.85	5.0 ± 0.9	Oblate Spheroidal
8. Aparajita	31.54 ± 3.70	30.92 ± 4.11	1.02 ± 0.18	101.98 ± 13.67	3.53 ± 0.32	5.91 ± 1.10	4.0 ± 0.7	Oblate Spheroidal
9. Autumn Joy	28.63 ± 6.76	29.93 ± 7.28	0.96 ± 0.01	95.68 ± 92.92	3.24 ± 0.06	5.51 ± 0.32	5.0 ± 0.3	Prolate Spheroidal
10. Bidhan Agnishikha	28.52 ± 3.78	29.77 ± 4.33	0.96 ± 0.17	95.81 ± 13.26	3.73 ± 0.49	6.93 ± 1.00	5.0 ± 0.7	Prolate Spheroidal
11. Bidhan Gold	29.46 ± 8.40	31.75 ± 9.45	0.93 ± 0.01	92.78 ± 88.89	2.50 ± 0.09	5.05 ± 0.35	6.0 ± 0.3	Oblate Spheroidal
12. Bidhan Jayanti	30.38 ± 3.94	29.93 ± 4.33	1.02 ± 0.18	101.51 ± 13.80	3.92 ± 0.47	6.14 ± 0.89	6.0 ± 0.7	Oblate Spheroidal
13. Bidhan Lalima	29.53 ± 3.54	29.86 ± 4.45	0.99 ± 0.16	98.91 ± 12.06	3.30 ± 0.35	4.83 ± 0.86	6.0 ± 1.1	Prolate Spheroidal
14. Bidhan Madhuri	28.55 ± 3.65	29.06 ± 4.19	0.98 ± 0.17	98.27 ± 13.20	2.56 ± 0.55	5.63 ± 1.04	5.0 ± 1.1	Prolate Spheroidal
15. Bidhan Mum	29.65 ± 3.54	28.66 ± 4.18	1.03 ± 0.17	103.45 ± 12.86	3.04 ± 0.46	6.00 ± 0.82	6.0 ± 1.1	Oblate Spheroidal
16. Bidhan Neeta	31.05 ± 3.43	28.83 ± 4.07	1.08 ± 0.17	107.69 ± 12.78	3.40 ± 0.36	5.78 ± 0.96	5.0 ± 0.9	Oblate Spheroidal
17. Bidhan Poonam	30.14 ± 3.56	28.94 ± 4.01	1.04 ± 0.18	104.16 ± 13.45	3.50 ± 0.43	6.16 ± 1.02	5.0 ± 1.1	Prolate Spheroidal
18. Bidhan Purna	30.80 ± 3.73	29.78 ± 4.04	1.03 ± 0.18	103.44 ± 14.00	2.35 ± 0.48	5.70 ± 0.98	5.0 ± 0.9	Prolate Spheroidal
19. Bidhan Rajat	30.45 ± 4.42	29.20 ± 3.49	1.04 ± 0.10	104.26 ± 12.06	2.86 ± 0.26	5.64 ± 0.86	5.0 ± 1.1	Prolate Spheroidal
20. Bidhan Rupanjali	28.01 ± 3.70	27.65 ± 4.17	1.01 ± 0.18	101.29 ± 13.45	2.62 ± 0.33	5.51 ± 0.97	4.0 ± 0.9	Prolate Spheroidal
21. Bidhan Sabita	30.33 ± 4.55	29.11 ± 3.21	1.04 ± 0.11	104.19 ± 13.54	3.50 ± 0.50	5.17 ± 0.88	4.0 ± 0.7	Prolate Spheroidal
22. Bidhan Shova	30.38 ± 3.36	29.50 ± 3.87	1.03 ± 0.17	103.00 ± 13.17	2.54 ± 0.37	4.87 ± 0.94	4.0 ± 0.0	Prolate Spheroidal
23. Bidhan Sweta	32.42 ± 4.42	31.59 ± 3.49	1.03 ± 0.10	102.64 ± 12.06	2.38 ± 0.50	5.14 ± 0.86	5.0 ± 1.1	Prolate Spheroidal
24. Bidhan Swapna	28.95 ± 3.47	31.61 ± 4.43	0.92 ± 0.16	91.59 ± 11.91	3.40 ± 0.50	5.99 ± 1.02	5.0 ± 0.9	Prolate Spheroidal

25.	Bidhan Tarun	35.15 ± 5.27	32.34 ± 3.56	1.09 ± 0.12	108.69 ± 14.13	2.43 ± 0.50	6.21 ± 1.06	6.0 ± 1.1	Prolate Spheroidal
26.	Chandrika	30.68 ± 4.60	29.97 ± 3.30	1.02 ± 0.11	102.35 ± 13.31	2.42 ± 0.50	5.96 ± 1.01	5.0 ± 0.9	Oblate Spheroidal
27.	Charlie	30.28 ± 4.54	29.79 ± 3.28	1.02 ± 0.11	101.65 ± 13.22	2.58 ± 0.50	5.17 ± 0.88	5.0 ± 0.9	Prolate Spheroidal
28.	Cherabu	26.48 ± 3.97	25.99 ± 2.86	1.02 ± 0.11	101.86 ± 13.24	3.23 ± 0.50	5.00 ± 0.85	4.0 ± 0.7	Oblate Spheroidal
29.	Classic	28.27 ± 4.24	29.89 ± 3.29	0.95 ± 0.10	94.58 ± 12.30	3.59 ± 0.50	5.06 ± 0.86	4.0 ± 0.7	Oblate Spheroidal
30.	Coffee	29.70 ± 4.45	28.51 ± 3.14	1.04 ± 0.11	104.18 ± 13.54	3.59 ± 0.50	5.47 ± 0.93	5.0 ± 0.9	Prolate Spheroidal
31.	Coimbatore Semi-Double	30.11 ± 4.52	30.82 ± 3.39	0.98 ± 0.11	97.69 ± 12.70	3.48 ± 0.50	5.55 ± 0.94	4.0 ± 0.7	Oblate Spheroidal
32.	Corom Small	27.58 ± 2.09	28.50 ± 3.14	0.97 ± 0.09	97.00 ± 8.73	2.64 ± 2.38	6.88 ± 1.95	5.0 ± 1.1	Oblate Spheroidal
33.	Daity White	32.46 ± 4.87	30.83 ± 3.39	1.05 ± 0.12	105.29 ± 13.69	3.44 ± 0.50	5.28 ± 0.90	6.0 ± 1.1	Prolate Spheroidal
34.	Dark Eyes	28.88 ± 3.47	27.56 ± 3.86	1.05 ± 0.18	104.78 ± 13.62	4.85 ± 0.68	5.41 ± 0.92	4.0 ± 0.7	Prolate Spheroidal
35.	Dark Red	28.53 ± 3.42	31.72 ± 4.44	0.90 ± 0.15	89.94 ± 11.69	2.91 ± 0.41	4.19 ± 0.71	6.0 ± 1.1	Oblate Spheroidal
36.	Devi	29.63 ± 3.56	30.47 ± 4.27	0.97 ± 0.16	97.24 ± 12.64	3.00 ± 0.42	5.12 ± 0.87	5.0 ± 0.9	Oblate Spheroidal
37.	DFR C-7	28.39 ± 3.41	29.35 ± 4.11	0.97 ± 0.16	96.74 ± 12.58	3.68 ± 0.51	5.19 ± 0.88	4.0 ± 0.7	Oblate Spheroidal
38.	DFR C-2 (DFR Megha)	31.05 ± 3.73	29.08 ± 4.07	1.07 ± 0.18	106.77 ± 13.88	3.33 ± 0.47	5.90 ± 1.00	5.0 ± 0.9	Oblate Spheroidal
39.	DFR C-1 (DFR Pallavi)	29.10 ± 3.49	29.93 ± 4.19	0.97 ± 0.16	97.21 ± 12.64	3.17 ± 0.44	5.37 ± 0.91	5.0 ± 0.9	Prolate Spheroidal
40.	DFR C-3 (DFR Swarna)	28.26 ± 3.39	28.78 ± 4.03	0.98 ± 0.17	98.16 ± 12.76	2.63 ± 0.37	5.09 ± 0.87	5.0 ± 0.9	Oblate Spheroidal
41.	DFR C-4 (DFR Swarna Bindu)	29.85 ± 3.58	28.30 ± 3.96	1.05 ± 0.18	105.49 ± 13.71	2.72 ± 0.38	5.39 ± 0.92	4.0 ± 0.7	Oblate Spheroidal
42.	DFR C-5	32.36 ± 3.88	32.80 ± 4.59	0.99 ± 0.17	98.69 ± 12.83	3.48 ± 0.49	4.92 ± 0.84	5.0 ± 0.9	Prolate Spheroidal
43.	DFR C-6	30.00 ± 4.20	28.95 ± 3.18	1.04 ± 0.20	103.62 ± 7.25	2.06 ± 0.29	5.48 ± 0.66	5.0 ± 0.7	Prolate Spheroidal
44.	Dignity	28.25 ± 4.24	28.55 ± 3.14	0.99 ± 0.11	98.95 ± 12.86	3.03 ± 0.00	5.10 ± 0.87	6.0 ± 1.1	Prolate Spheroidal
45.	Discovery	30.26 ± 4.54	28.17 ± 3.10	1.07 ± 0.12	107.40 ± 13.96	3.76 ± 0.00	8.23 ± 1.40	5.0 ± 0.9	Prolate Spheroidal
46.	Draguma	27.95 ± 4.19	28.49 ± 3.13	0.98 ± 0.11	98.14 ± 12.76	4.42 ± 0.57	5.43 ± 0.92	5.0 ± 0.9	Prolate Spheroidal
47.	Fire Ball	31.15 ± 4.67	32.04 ± 3.52	0.97 ± 0.11	97.22 ± 12.64	3.49 ± 0.00	5.57 ± 0.95	4.0 ± 0.72	Prolate Spheroidal
48.	Gaity	27.44 ± 4.12	28.02 ± 3.08	0.98 ± 0.11	97.92 ± 12.73	4.46 ± 0.00	5.46 ± 0.93	4.0 ± 0.65	Oblate Spheroidal
49.	Garden beauty	28.38 ± 4.26	29.74 ± 3.27	0.96 ± 0.11	95.46 ± 12.41	3.97 ± 0.36	5.68 ± 0.97	6.0 ± 0.9	Prolate Spheroidal
50.	Gauri	32.43 ± 4.86	31.81 ± 3.50	1.02 ± 0.11	101.96 ± 13.26	3.542 ± 0.18	5.22 ± 0.89	5.0 ± 0.9	Prolate Spheroidal

51.	Gitanjali	29.32 ± 4.40	28.84 ± 3.17	1.02 ± 0.11	101.66 ± 13.22	2.65 ± 0.00	5.92 ± 1.01	5.0 ± 0.0	Oblate Spheroidal
52.	Gulmohar	29.70 ± 4.16	29.71 ± 3.27	1.00 ± 0.19	99.97 ± 7.00	4.69 ± 0.00	4.70 ± 0.56	5.0 ± 0.0	Oblate Spheroidal
53.	Gunjan	29.30 ± 4.10	29.42 ± 3.24	1.00 ± 0.19	99.61 ± 6.97	4.47 ± 0.00	5.30 ± 0.64	5.0 ± 0.9	Prolate Spheroidal
54.	Himani-3	29.52 ± 4.43	28.88 ± 3.18	1.02 ± 0.11	102.21 ± 13.29	4.285 ± 0.47	7.12 ± 1.21	5.0 ± 0.0	Oblate Spheroidal
55.	Honey Comb	30.68 ± 4.60	30.54 ± 3.36	1.00 ± 0.11	100.44 ± 13.06	3.18 ± 0.00	6.02 ± 1.02	5.0 ± 0.0	Oblate Spheroidal
56.	Houston	31.53 ± 4.73	30.94 ± 3.40	1.02 ± 0.11	101.90 ± 13.25	2.99 ± 0.39	5.89 ± 1.00	6.0 ± 1.0	Prolate Spheroidal
57.	HYDC-12	29.42 ± 4.41	30.14 ± 3.32	0.98 ± 0.11	97.60 ± 12.69	2.75 ± 0.25	4.94 ± 0.84	5.0 ± 1.0	Prolate Spheroidal
58.	HYDC-19	28.40 ± 4.26	28.51 ± 3.14	1.00 ± 0.11	99.62 ± 12.95	2.24 ± 0.00	6.07 ± 1.03	5.0 ± 0.9	Oblate Spheroidal
59.	HYDC-2	29.38 ± 4.41	28.38 ± 3.12	1.04 ± 0.11	103.53 ± 13.46	3.22 ± 0.00	6.70 ± 1.14	3.0 ± 0.0	Oblate Spheroidal
60.	HYDC-20	31.12 ± 4.36	29.68 ± 3.26	1.05 ± 0.20	104.86 ± 7.34	3.53 ± 0.49	5.32 ± 0.64	5.0 ± 0.9	Prolate Spheroidal
61.	HYDC-26	28.32 ± 4.25	29.55 ± 3.25	0.96 ± 0.11	95.83 ± 12.46	3.24 ± 0.50	5.28 ± 0.90	5.0 ± 0.9	Prolate Spheroidal
62.	HYDC-28	28.24 ± 4.24	27.33 ± 3.01	1.03 ± 0.11	103.33 ± 13.43	2.47 ± 0.50	5.66 ± 0.96	5.0 ± 0.65	Prolate Spheroidal
63.	HYDC-29	29.37 ± 4.41	29.87 ± 3.29	0.98 ± 0.11	98.32 ± 12.78	3.25 ± 0.50	6.12 ± 1.04	4.0 ± 0.0	Oblate Spheroidal
64.	HYDC-41	28.52 ± 4.28	29.45 ± 3.24	0.97 ± 0.11	96.85 ± 12.59	2.33 ± 0.50	5.37 ± 0.91	4.0 ± 0.72	Oblate Spheroidal
65.	HYDC-42	28.23 ± 4.23	29.90 ± 3.29	0.94 ± 0.10	94.40 ± 12.27	2.66 ± 0.50	5.73 ± 0.97	5.0 ± 0.9	Oblate Spheroidal
66.	HYDC-55	28.67 ± 4.30	29.70 ± 3.27	0.96 ± 0.04	96.24 ± 3.92	2.85 ± 0.50	6.05 ± 0.91	5.0 ± 0.9	Oblate Spheroidal
67.	HYDC-56	30.29 ± 4.63	30.81 ± 3.28	0.98 ± 0.11	98.31 ± 13.45	4.41 ± 0.50	6.20 ± 1.01	4.0 ± 0.9	Prolate Spheroidal
68.	HYDC-77	27.45 ± 3.84	30.21 ± 3.32	0.91 ± 0.17	90.87 ± 6.36	3.49 ± 0.49	6.08 ± 0.73	4.0 ± 0.52	Oblate Spheroidal
69.	HYDC-9	29.20 ± 4.38	30.16 ± 3.32	0.97 ± 0.11	96.79 ± 12.58	3.20 ± 0.50	6.75 ± 1.15	6.0 ± 0	Prolate Spheroidal
70.	HYDC-Local Yellow	28.71 ± 4.31	30.03 ± 3.30	0.96 ± 0.11	95.62 ± 12.43	2.91 ± 0.50	6.25 ± 1.06	5.0 ± 0.9	Oblate Spheroidal
71.	IAH Red	24.86 ± 3.73	25.14 ± 2.77	0.99 ± 0.11	98.85 ± 12.85	2.46 ± 0.50	5.21 ± 0.89	5.0 ± 0.9	Oblate Spheroidal
72.	Jaya	30.89 ± 4.63	29.85 ± 3.28	1.03 ± 0.11	103.46 ± 13.45	2.99 ± 0.50	5.93 ± 1.01	6.0 ± 1.08	Prolate Spheroidal
73.	Karnal Pink	28.60 ± 4.29	28.60 ± 3.15	1.00 ± 0.11	100.00 ± 13.00	2.98 ± 0.50	5.51 ± 0.94	5.0 ± 0.9	Oblate Spheroidal
74.	Kiev Orange	30.50 ± 4.27	31.67 ± 3.48	0.96 ± 0.18	96.30 ± 6.74	3.54 ± 0.50	5.32 ± 0.64	5.0 ± 1	Oblate Spheroidal
75.	Kiev Yellow	30.01 ± 4.20	30.07 ± 3.31	1.00 ± 0.19	99.80 ± 6.99	4.87 ± 0.50	5.65 ± 0.68	6.0 ± 0.78	Prolate Spheroidal
76.	Kunchit	28.29 ± 3.96	29.86 ± 3.28	0.95 ± 0.18	94.73 ± 6.63	3.62 ± 0.51	5.51 ± 0.66	5.0 ± 0.65	Prolate Spheroidal
77.	Kundan	27.94 ± 4.19	28.65 ± 3.15	0.98 ± 0.11	97.52 ± 12.68	2.98 ± 0.50	13.42 ± 2.28	6.0 ± 1.08	Oblate Spheroidal
78.	Liliput	29.84 ± 4.48	27.14 ± 2.99	1.10 ± 0.12	109.96 ± 14.30	2.84 ± 0.50	5.49 ± 0.93	5.0 ± 0.65	Oblate Spheroidal
79.	Magenta	30.14 ± 4.52	29.32 ± 3.23	1.03 ± 0.11	102.77 ± 13.36	3.07 ± 0.50	5.73 ± 0.98	4.0 ± 0.52	Prolate Spheroidal
80.	Maghi White	28.18 ± 3.95	28.59 ± 3.14	0.99 ± 0.19	98.57 ± 6.90	3.13 ± 0.44	5.81 ± 0.70	5.0 ± 0.65	Prolate Spheroidal

81.	Mahatma Gandhi	29.00 ± 3.19	29.54 ± 3.25	0.98 ± 0.11	98.14 ± 14.72	3.19 ± 0.50	5.72 ± 0.86	4.0 ± 0.52	Oblate Spheroidal
82.	Mauve Sarah	30.75 ± 4.61	29.15 ± 3.21	1.05 ± 0.12	105.49 ± 13.71	3.96 ± 0.50	4.98 ± 0.85	6.0 ± 0.78	Oblate Spheroidal
83.	Mini Jessie	32.39 ± 4.86	30.74 ± 3.39	1.05 ± 0.12	105.34 ± 13.69	3.76 ± 0.50	5.07 ± 0.86	4.0 ± 0.52	Oblate Spheroidal
84.	Mother Teresa	31.13 ± 4.67	30.28 ± 3.33	1.03 ± 0.11	102.79 ± 13.36	2.27 ± 0.50	6.02 ± 1.02	4.0 ± 0.52	Oblate Spheroidal
85.	Mountaineer	29.76 ± 4.46	28.74 ± 3.16	1.04 ± 0.11	103.54 ± 13.46	3.76 ± 0.50	6.05 ± 1.03	5.0 ± 0.9	Oblate Spheroidal
86.	Navy Pride	29.34 ± 1.47	30.15 ± 3.32	0.97 ± 0.03	97.00 ± 2.91	3.26 ± 0.50	4.91 ± 0.64	4.0 ± 0.52	Oblate Spheroidal
87.	NBRI Little Orange	33.09 ± 4.63	32.71 ± 3.60	1.01 ± 0.19	101.16 ± 7.08	2.36 ± 0.33	6.21 ± 0.75	5.0 ± 0	Prolate Spheroidal
88.	NBRI Little Pink	30.09 ± 4.21	30.42 ± 3.35	0.99 ± 0.19	98.92 ± 6.92	2.84 ± 0.40	6.64 ± 0.80	4.0 ± 0.72	Oblate Spheroidal
89.	NBRI Yellow Delight	31.22 ± 4.68	29.74 ± 3.27	1.05 ± 0.12	104.98 ± 13.65	3.72 ± 0.50	6.62 ± 1.13	4.0 ± 0.72	Oblate Spheroidal
90.	OPCH Double Red	28.66 ± 4.01	29.16 ± 3.21	0.98 ± 0.19	98.29 ± 6.88	3.22 ± 0.45	5.04 ± 0.60	4.0 ± 0.72	Prolate Spheroidal
91.	OPCH 12-2-1213	31.03 ± 4.34	30.36 ± 3.34	1.02 ± 0.19	102.20 ± 7.15	2.57 ± 0.36	5.49 ± 0.66	4.0 ± 0.52	Prolate Spheroidal
92.	OPCH 12-7-1112	30.57 ± 4.28	30.16 ± 3.32	1.01 ± 0.19	101.37 ± 7.10	2.80 ± 0.39	6.10 ± 0.73	5.0 ± 0.9	Oblate Spheroidal
93.	OPCH 13-2	30.07 ± 4.21	30.51 ± 3.36	0.99 ± 0.19	98.55 ± 6.90	3.60 ± 0.50	6.99 ± 0.84	5.0 ± 0.9	Prolate Spheroidal
94.	OPCH 27-1	29.58 ± 4.14	29.72 ± 3.27	1.00 ± 0.19	99.54 ± 6.97	2.27 ± 0.32	4.90 ± 0.59	5.0 ± 0.65	Oblate Spheroidal
95.	OPCH Double Yellow	31.00 ± 4.34	30.14 ± 3.32	1.03 ± 0.20	102.84 ± 7.20	2.52 ± 0.35	4.82 ± 0.58	5.0 ± 0.9	Prolate Spheroidal
96.	Punjab Shyamli	27.22 ± 3.81	29.99 ± 3.30	0.91 ± 0.17	90.76 ± 6.35	3.46 ± 0.48	5.77 ± 0.69	4.0 ± 0.72	Prolate Spheroidal
97.	PAU-107	30.02 ± 4.50	28.62 ± 3.15	1.05 ± 0.12	104.89 ± 13.64	4.09 ± 0.50	5.01 ± 0.85	5.0 ± 0	Oblate Spheroidal
98.	PAU-147	31.37 ± 4.39	28.76 ± 3.16	1.09 ± 0.21	109.06 ± 7.63	3.59 ± 0.50	5.76 ± 0.69	6.0 ± 1.08	Oblate Spheroidal
99.	PAU-35	29.95 ± 4.49	29.48 ± 5.01	1.02 ± 0.15	101.60 ± 15.24	2.56 ± 0.50	5.46 ± 0.82	5.0 ± 0.9	Prolate Spheroidal
100.	PAU-55	32.07 ± 4.81	29.32 ± 3.23	1.09 ± 0.12	109.39 ± 14.22	2.40 ± 0.50	5.84 ± 0.99	5.0 ± 0.65	Prolate Spheroidal
101.	PAU-58	29.24 ± 4.39	29.52 ± 3.25	0.99 ± 0.11	99.04 ± 12.88	2.78 ± 0.50	6.51 ± 1.11	6.0 ± 1.08	Prolate Spheroidal
102.	PAU-66-2	30.04 ± 4.51	30.36 ± 3.34	0.99 ± 0.11	98.95 ± 12.86	3.72 ± 0.50	5.46 ± 0.93	5.0 ± 0	Oblate Spheroidal
103.	PAU-D-11	30.13 ± 4.22	30.96 ± 3.41	0.97 ± 0.18	97.30 ± 6.81	2.33 ± 0.33	8.71 ± 1.05	5.0 ± 0.9	Oblate Spheroidal
104.	Pink Cloud	30.13 ± 4.52	29.45 ± 3.24	1.02 ± 0.11	102.31 ± 13.30	2.08 ± 0.00	5.38 ± 0.91	4.0 ± 0.72	Oblate Spheroidal
105.	Preet Shringar	30.34 ± 4.55	29.43 ± 3.24	1.03 ± 0.11	103.10 ± 13.40	3.80 ± 0.00	4.69 ± 0.80	4.0 ± 0.64	Oblate Spheroidal
106.	Punjab Gold	43.60 ± 6.10	44.08 ± 4.85	0.99 ± 0.19	98.91 ± 6.92	3.27 ± 0.46	5.81 ± 0.70	5.0 ± 0.9	Prolate Spheroidal
107.	Purple Quill	30.66 ± 4.60	31.41 ± 3.46	0.98 ± 0.11	97.62 ± 12.69	3.48 ± 0.00	6.59 ± 1.12	6.0 ± 1.08	Prolate Spheroidal
108.	Pusa Aditya	29.21 ± 4.38	27.49 ± 3.03	1.06 ± 0.12	106.25 ± 13.81	3.48 ± 0.00	5.26 ± 0.89	5.0 ± 0.9	Oblate Spheroidal

109. Pusa Centenary	28.49 ± 1.42	28.84 ± 3.17	0.99 ± 0.03	99.00 ± 2.97	3.48 ± 0.00	5.48 ± 0.71	6.0 ± 1.08	Oblate Spheroidal
110. Pusa Chitraksha	26.90 ± 4.03	27.62 ± 3.04	0.97 ± 0.11	97.40 ± 12.66	3.48 ± 0.00	4.91 ± 0.83	5.0 ± 0.9	Prolate Spheroidal
111. Pusa Guldasta	27.28 ± 4.09	28.95 ± 3.19	0.94 ± 0.10	94.23 ± 12.25	3.48 ± 0.00	5.51 ± 0.94	5.0 ± 0.9	Prolate Spheroidal
112. Pusa Kesari	30.97 ± 4.34	28.07 ± 3.09	1.10 ± 0.21	110.33 ± 7.72	2.20 ± 0.00	5.14 ± 0.62	5.0 ± 0	Prolate Spheroidal
113. Pusa Shwet	27.28 ± 4.09	27.29 ± 3.00	1.00 ± 0.11	99.96 ± 12.99	2.73 ± 0.00	4.93 ± 0.84	5.0 ± 0.9	Oblate Spheroidal
114. Pusa Sona	29.21 ± 4.38	30.80 ± 4.63	0.95 ± 0.10	94.81 ± 7.58	2.73 ± 0.00	4.42 ± 0.49	5.0 ± 0	Oblate Spheroidal
115. Ravi	30.74 ± 4.61	29.90 ± 3.29	1.03 ± 0.11	102.83 ± 13.37	2.05 ± 0.00	5.88 ± 1.00	5.0 ± 0	Oblate Spheroidal
116. Ravikiran	29.49 ± 4.42	28.91 ± 3.18	1.02 ± 0.11	102.03 ± 13.26	3.66 ± 0.00	5.92 ± 1.01	4.0 ± 0	Prolate Spheroidal
117. Red Gold	29.80 ± 3.28	30.03 ± 5.11	0.99 ± 0.12	99.22 ± 14.88	4.98 ± 0.50	6.40 ± 0.51	4.0 ± 0	Oblate Spheroidal
118. River City	29.35 ± 4.40	30.37 ± 3.34	0.97 ± 0.11	96.64 ± 12.56	3.30 ± 0.50	6.12 ± 1.04	5.0 ± 0	Oblate Spheroidal
119. Royal Purple	28.23 ± 4.23	27.89 ± 3.07	1.01 ± 0.11	101.22 ± 13.16	2.62 ± 0.50	5.18 ± 0.88	5.0 ± 0	Prolate Spheroidal
120. Sadwin Yellow	30.00 ± 4.50	30.84 ± 3.39	0.97 ± 0.11	97.28 ± 12.65	4.76 ± 0.50	6.01 ± 1.02	4.0 ± 0	Prolate Spheroidal
121. Salmon	30.50 ± 4.57	30.63 ± 3.37	1.00 ± 0.11	99.57 ± 12.94	3.40 ± 0.50	7.03 ± 1.19	5.0 ± 0	Prolate Spheroidal
122. Seema	32.08 ± 4.81	31.90 ± 3.51	1.01 ± 0.11	100.55 ± 13.07	2.64 ± 0.50	5.69 ± 0.97	6.0 ± 0	Prolate Spheroidal
123. Sensation	30.82 ± 4.62	30.41 ± 3.35	1.01 ± 0.11	101.35 ± 13.18	2.41 ± 0.50	5.65 ± 0.96	5.0 ± 0.9	Prolate Spheroidal
124. Silk Brocade	31.08 ± 4.66	30.21 ± 3.93	1.00 ± 0.15	102.88 ± 8.23	2.75 ± 0.50	5.27 ± 0.79	5.0 ± 0.0	Oblate Spheroidal
125. Texas Gold	31.19 ± 4.68	29.29 ± 3.22	1.07 ± 0.12	106.47 ± 13.84	3.05 ± 0.50	6.40 ± 1.09	5.0 ± 0.9	Oblate Spheroidal
126. Thai Chen Queen	31.24 ± 1.56	29.57 ± 3.29	1.06 ± 0.03	106.00 ± 3.12	2.66 ± 0.56	5.58 ± 0.84	5.0 ± 0.0	Prolate Spheroidal
127. TQP - 06	28.84 ± 3.75	30.21 ± 3.93	0.96 ± 0.00	95.45 ± 0.00	4.04 ± 0.50	5.44 ± 0.82	5.0 ± 0.0	Prolate Spheroidal
128. Vanity Pink	27.20 ± 4.08	30.07 ± 3.31	0.90 ± 0.10	90.47 ± 11.76	3.55 ± 0.50	5.66 ± 0.96	4.0 ± 0.0	Prolate Spheroidal
129. Veena	29.66 ± 4.45	30.74 ± 3.38	0.96 ± 0.11	96.49 ± 12.55	2.73 ± 0.50	5.03 ± 0.86	4.0 ± 0.0	Prolate Spheroidal
130. Vijay	31.52 ± 4.73	31.38 ± 3.45	1.00 ± 0.11	100.47 ± 13.06	4.00 ± 0.50	6.51 ± 1.11	5.0 ± 0.0	Oblate Spheroidal
131. Vijay Kiran	30.88 ± 3.40	30.93 ± 5.26	1.00 ± 0.12	99.84 ± 14.98	4.93 ± 0.50	5.89 ± 0.47	5.0 ± 0.0	Oblate Spheroidal
132. HYDC Pink	29.99 ± 3.30	29.82 ± 5.07	1.01 ± 0.12	100.57 ± 15.09	3.06 ± 0.50	6.46 ± 0.52	4.0 ± 0.0	Oblate Spheroidal
133. Winter Queen	30.64 ± 3.37	31.91 ± 5.42	0.96 ± 0.12	96.01 ± 14.40	3.06 ± 0.50	5.51 ± 0.44	5.0 ± 0.0	Prolate Spheroidal
134. Yellow Delight	30.33 ± 3.34	31.59 ± 5.37	0.96 ± 0.12	96.00 ± 14.40	4.03 ± 0.40	5.04 ± 0.40	6.0 ± 0.0	Oblate Spheroidal

Table 2. Description of the pollen morphology of members of Asteraceae family as obtained from PalDat Database.

Organism	Pollen Shape	Polar Length	Equatorial Diameter	P/E Ratio	Form Index	Aperture Number	Aperture Type
Artemisia vulgaris	Spheroidal	16-20	16-20	1.14	113.89	3	Colporus
Helenium autumnale	Spheroidal	-	-	-	-	3	Colporus
Inula britannica	Spheroidal	16-20	16-20	1.00	100.00	3	Colporus
Solidago virgaurea	Spheroidal	16-20	21-25	0.89	89.13	3	Colporus
Calendula officinalis	Spheroidal	31-35	31-35	1.00	100.00	3	Colporus
Leucanthemum vulgare	Spheroidal	16-20	21-25	1.00	100.00	3	Colporus
Bellis perennis	Spheroidal	16-20	16-20	1.00	100.00	3	Colporus
Leucanthemopsis alpina	Spheroidal	16-20	16-20	1.00	100.00	3	Colporus
Doronicum columnae	Spheroidal	21-25	21-25	1.00	100.00	3	Colporus
Tanacetum parthenium	Spheroidal	21-25	21-25	1.00	100.00	3	Colporus
Achillea clavennae	Spheroidal	21-25	16-20	1.12	112.20	3	Colporus
Anthemis tinctoria	Spheroidal	16-20	21-25	1.00	100.00	3	Colporus
Bidens pilosa	Spheroidal	-	21-25	1.00	100.00	3	Colporus
Senecio abrotanifolius	Spheroidal	21-25	26-30	1.00	100.00	3	Colporus
Chrysanthemum coronarium	Spheroidal	20.08-27.15	20.2-28.4	1.00	100.00	4	Colporus
***Chrysanthemum morifolium* - Ravi**	Spheroidal	26.13-35.35	26.6 - 33.2	1.03	103.00	5	Colporus
***Chrysanthemum morifolium* - Punjab Gold**	Spheroidal	37.5-49.7	39.2 - 48.9	0.99	99.00	6	Colporus
***Chrysanthemum morifolium* - DFR C1**	Spheroidal	25.61-32.59	25.7 - 34.1	0.97	97.00	7	Colporus
***Chrysanthemum morifolium* - Dark Red**	Spheroidal	25.11- 31.95	27.3 - 36.2	0.90	90.00	8	Colporus