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Pollen morphology of some members of Subfamily Asteroideae (Family-Asteraceae) from West Bengal, India

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ABSTRACT

Asteraceae is the largest family of angiosperms, comprising nearly about 1620 genera and more than 23600 species. In India the family is represented by 900 species belonging to 167 genera. In our present work, the palynomorphological analysis of 31 Indian species belonging to the subfamily Asteroideae has been dealt with. For the present study the polleniferous materials were freshly collected from the Burdwan District of West Bengal, India from their natural habitats while some of them were collected from nurseries. It has been observed that Asteroideae subfamily is strictly eurypalynous. Pollen grains of all the species are spheroidal to oblate-spheroidal and exhibit a great diversity in their spinate and conate surface structures and also in their apertural pattern, ranging from colporate to colporoidate to colpoidorate with variations in their endoaperture.

Key words: Asteraceae, Asteroideae, Palynomorphs, Eurypalynous.

INTRODUCTION

Family Asteraceae of the flowering plant belonging to Order Asterales is the largest family of angiosperms, comprising nearly 1620 genera and more than 23600 species (Stevens 2001) of herbs, shrubs, vines and trees which are cosmopolitan in distribution and are abundant mainly in the arid and sem-arid regions of subtropical and lower temperate latitudes, colonizing a wide variety of habitats. In India the family is represented by 900 sp. belonging to 167 genera (Bisht et al. 2010).

Palynological investigation of the members of Asteraceae has been made from time to time, all over the world, in terms of broad geographical range or detailed studies of specific taxonomic groups. Major palynological researches which worth to be mentioned were made by Wodehouse (1926, 1930, 1935) and Stix (1960) who have studied 235 species and distinguished 49 pollen types. Further analysis of pollen types and exine patterns of Asteraceae sp. were made by Skavarla et al. (1977), Clark et al. (1980) and Bolick (1978). Palynological surveys at the tribal level of classification were carried out in a broader spectrum in many countries within the tribes Lactuceae, Vernoninae, Gnaphaliae, Heleniae, Inulae, Senecionae, Calendulae, Anthemidae, Plucheeae, Gochnatieae, Cynareae by Osman (2006,2011), Qureshi et al. (2008), Bunwong and Chantaramothai (2008) and Telleria et al. (2013). In India, detailed palynological studies of the members of Asteroideae is rather meagre although major palynological studies of the species of Asteraceae were made by Nair (1965), Jain and Nanda (1966), Rao and Shukla (1975) and Srivastava (1976) to name a few.

The classification of the Family Asteraceae, mainly at the subfamily and tribel level, has been worked out and revised by numerous authors from time to time.

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Some of them were discarded while several of them have been accepted and are being followed by many authors. Bentham and Hooker (1873) has divided the family Asteraceae (Compositae) into 11 tribes which are further classified into subtribes, while Panero and Funk (2002) has classified the family into 12 subfamilies and 36 tribes based on comparative DNA sequence data of chloroplast genes. The subfamily, Asteroideae is the largest one which includes more than 70% of the species of the family i.e., 7200 species under 1135 genera worldwide. Robinson (1978, 1983) has further grouped the tribes of the subfamily Asteroideae under 3 supertribes, namely Senecinodae, Asterodae and Helianthodae. List of genera belonging to different tribes as classified by Panero and Funk (2002, 2008) is as follows:

Tribe	**Genera**
Senecionae:	*Cineraria*
Anthemidae:	*Chrrysanthemum*
Asterae:	*Grangea, Brachyscoma, Bellis*
Gnaphalieae:	*Gnaphalium*
Calendulae:	*Calendula, Dimorphotica*
Heliantheae:	*Eluenthera, Eclypta, Lagasceae, Spilanthes, Synedrella,* Tridax, Wedelia, Xanthium, Zinnia, Parthenium, Helianthes, *Enhydra, Rudhbeckia*
Eupatorae:	*Eupatorium, Ageratum, Mikenia*
Inulae:	*Blumea, Sphaeranthes*
Coreopsidae:	*Dahlia, Cosmos, Coreopsis*
Tagetae:	*Tagetes patula*
Plucheeae:	*Plucheeae*

The present work deals with the palynomorphological analysis of 31 Indian species of Asteraceae belonging to the subfamily Asteroideae which are distributed among eleven tribes: Heliantheae, Eupatorae, Inulae, Anthemidae, Coreopsidae, Asterae, Tagetae, Gnaphalieae, Calendulae, Plucheeae and Senecionae, which are further grouped under 3 supertribes namely Helianthodae, Asterodae and Senecionodae.

MATERIAL AND METHODS

The polleniferous materials of thirty-one plant species of Asteraceae were freshly collected from several blocks of Burdwan district of West Bengal. Most of them grow wildly in their natural habitats while some of them are being horticultured. For the present study purpose the pollen grains were acetolysed following the acetolysis method of Erdtman (1952) and were investigated using light field bright microscopy. The acetolysed pollen grains were mounted in glycerine jelly on glass slides with coverslip and were studied under Olympus GB microscope and they were photographed under a Leitz laborlux S (Germany) microscope with Leica DFC 295 digital camera attachment.

OBSERVATION

Micromorphological details of the selected taxa belonging to the subfamily Asteroidae of Asteraceae are as follows:

Ageratum conyzoides (L.) L. (Plate 1, Figs 1-3):

Pollen grains are radially symmetrical, isopolar, oblate spheroidal, P x E 30 x 31µm (incl. spine), amb triangular, planoaperturate, tri-zonocolpoidorate; colpi narrowly elliptic with pointed ends, 17.5 µm in length and 2.4 µm in breadth across the equator, ora more or less circular, 4 µm in diameter, tenuimarginate; exine tegillated, 3.8 µm in thickness (excl. spine), crassisexinous; surface conate, coni 2.2 µm in height and 3.1 µm wide at base, interspinal distance is 4.2 µm.

Bellis perennis L. (Plate 1, Figs 4-6):

Pollen grains are radially symmetrical, isopolar, sub-prolate, P x E 32 x 37 µm, amb sub-triangular, planoaperturate, tri-zonocolpoidorate; colpi faint, broadly elliptic with gradually tapering pointed ends, 19.3 µm in length and 8 µm in breadth across the equator, ora circular, 10.4 µm in diameter at the equator, tenuimarginate; exine tegillate, 2.1 µm in thickness (excl. spine), crassisexinous, surface conate, coni 2.2 µm in height and 2.3 µm wide at base, interspinal distance is 3.3 µm.

Blumea lacera (Burm. f.) DC. (Plate 1, Figs 7-8):

Pollen grains are radially symmetrical, isopolar, oblate spheroidal, P x E 35 x 42 µm (incl. spine), amb triangular, planoaperturate, tri-zonocolporate; colpi

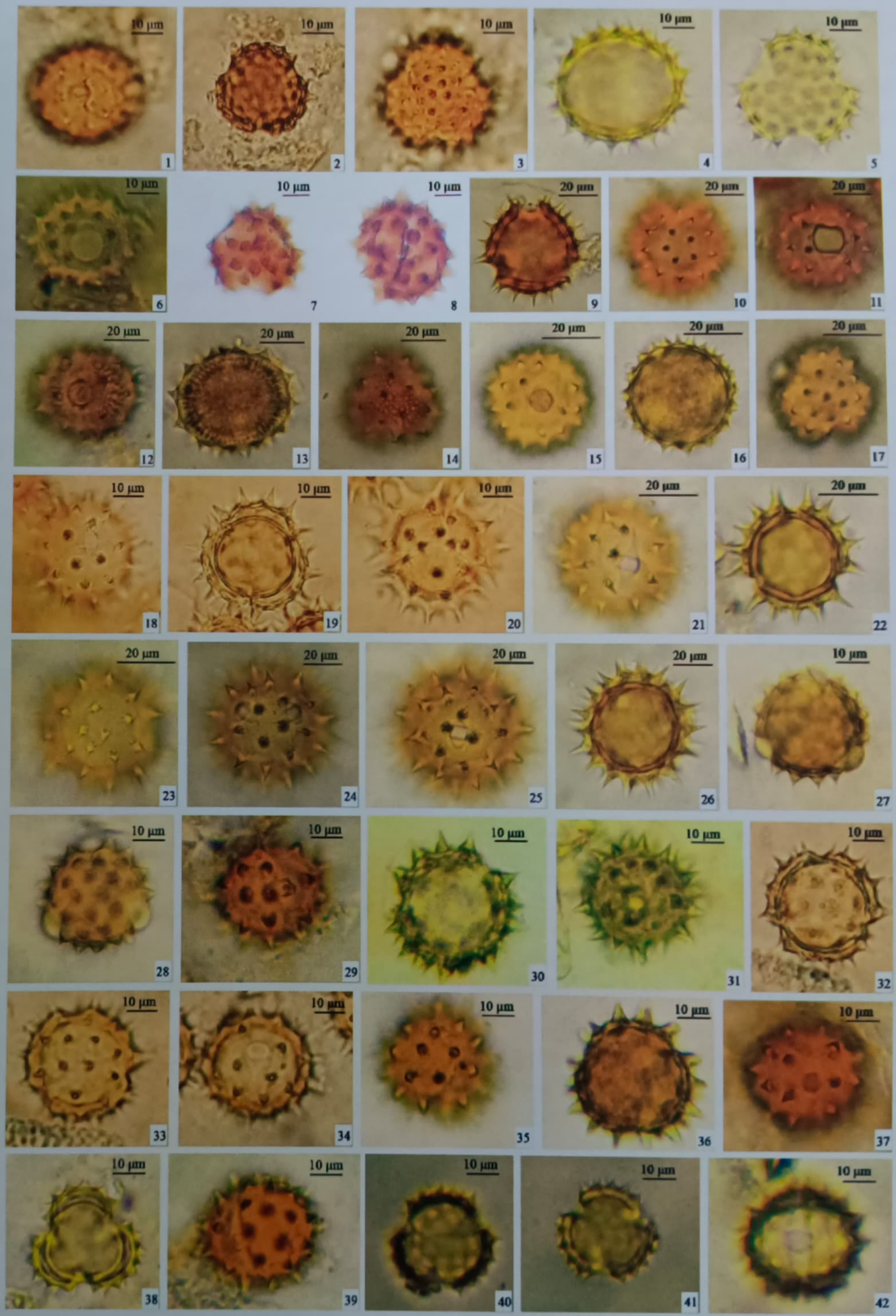

Plate 1

Figs. 1-3 Pollen grains of *Ageratum conyzoides* (L.) L. **Figs. 4-6** *Bellis perennis* L. **Figs. 7-8** *Blumea lacera* (Burm. f.) DC. **Figs. 9-11** *Calendula officinalis* L. **Figs. 12-14** *Chrysanthemum indicum* L. **Figs. 15-17** *Cineraria* X hybrid **Figs. 18-20** *Coreopsis auriculata* L. **Figs. 21-23** *Cosmos bipinnatus* Cav. **Figs. 24-26** *Dahlia* sp. **Figs. 27-29** *Dimorphotheca pluvialis* (L.) Moench **Figs. 30-31** *Eclipta prostrata* (L.) L. **Figs. 32-34** *Eluenthera ruderalis* (Sw.) Sch. Bip. **Figs. 35-37** *Enhydra fluctuens* DC. **Figs. 38-39** *Chromolaena odorata* (L.) King & Rob. **Figs. 40-42** *Gnaphalium polycaulon* Pers.

narrowly elliptic with pointed ends, 21.5 μm in length and 6.4 μm in breadth across the equator, ora more or less circular, 6.3 μm in diameter, tenuimarginate; exine tegillate, 3.1 μm in thickness (excl. spine), crassisexinous; surface spinate, spine 6.4 μm in height and 5.6 μm wide at base with pointed tips, interspinal distance is 3.8 μm.

Calendula officinalis L. (Plate 1, Figs 9-11):

Pollen grains are radially symmetrical, isopolar, oblate-spheroidal to sub-oblate, P x E 56 x 61 μm (spines included), amb triangular-quadrangular, anguloaperturate; tri-tetra-zonocolpoidorate, colpi faint, narrowly elliptic with highly tapering acuminate ends, 9.7 μm in length and 12.4 μm in breadth across the equator, ora broad, lalongately rectangular, 11.2 μm in length along the polar axis and 12.8 μm wide across the equator, crassimarginate, exine tegillated,7.2 μm in thickness (excl. spine), crassisexinous; surface spinate, spines with highly tapering acuminate apex, 9.6 μm in length and 5.6 μm in breadth at the base, interspinal distance is 7.2 μm.

Chrysanthemum indicum L. (Plate 1, Figs 12-14):

Pollen grains are radially symmetrical, isopolar, sub oblate, P x E 41.8 x 48 μm, amb triangular, fossaperturate, trizonocolpoidorate; colpi faint, narrowly elliptic with pointed ends, 24.5 μm in length and 8.1 μm in breadth across the eqiuator, ora circular, 7.7 μm in diameter, tenuimarginate, exine tegillate, 5.2 μm in thickness (excl. spine) with highly developed, distinct, columellae, crassisexinous; surface conate, microreticulate, coni 3.7 μm in length and 6.4 μm in breadth at base, lumina irregularly polygonal, 1.5 μm in diameter, heterobrochate.

Cineraria X hybrid (Plate 1, Figs 15-17):

Pollen grains are radially symmetrical, isopolar, spheroidal to oblate spheroidal, P x E 34 x 35 (incl. spine) in diameter, amb sub-triangular, anguloaperturate, tri-zonocolpoidorate; colpi faint, narrowly elliptic with pointed ends, 23.3 μm in length and 8 μm in breadth across the equator, ora distinctly circular, 7.9 μm in diameter, tenuimarginate, exine tegillate, 3 μm in thickness (excl. spine), crassisexinous; surface conate, coni 2.8 μm in height and 3.8 μm wide at base, interspinal distance is 6.4 μm.

Coreopsis auriculata L. (Plate 1, Figs 18-20):

Pollen grains are radially symmetrical, isopolar, spheroidal, P x E 38 x 39 μm (incl. spine), amb sub-triangular, fossaperturate, tri-zonocolpoidorate; colpoid faint, linear with pointed ends, 24 μm in length and 4.3 μm in breadth across the equator, ora lalongately elliptic with pointed ends, 7.8 μm in diameter, tenuimarginate, exine tegillated, 8.8 μm in thickness (excl. spine), crassisexinous; surface spinate, spine long with highly tapering acuminate apex, spine 7.4 μm in height and 5.6 μm wide at base, interspinal distance is 6.3 μm.

Cosmos bipinnatus Cav. (Plate 1, Figs 21-23):

Pollen grains are radially symmetrical, isopolar, spheroidal, 51 μm in diameter (incl. spine), amb circular, trizonocolporate; colpi short, brevisimmicolpate, narrowly elliptic with highly tapering acuminate ends, 19.3 μm in length and 6.4 μm in breadth across the eqiuator, ora lalongately elliptic with pointed ends, 14.4 μm in diameter across the equator, tenuimarginate, exine tegillate, 5.6 μm in thickness (excl. spine), crassisexinous or sexine is as thick as nexine; surface spinate, spine long and slender with small, conical base, spine 7.7 μm in length and 5.6 μm in breadth at base, interspinal distance is 7.1 μm.

Dahlia sp. (Plate 1, Figs 24-26):

Pollen grains are radially symmetrical, isopolar, spheroidal, 69 μm (incl. spine) in diameter, amb circular, tri-zonocolporate; brevisimmicolpate, colpi short, narrowly elliptic with acute ends, 9.6 μm in length and 5.8 μm in breadth across the equator, ora broadly lalongate with circular ends, 11 μm in diameter across the equator and 6.3 μm along the polar axis, tenuimarginate, exine tegillate, 3.2 μm in thickness (excl. spine), crassisexinous; surface spinate, spine long, slender with highly tapering acuminate apex having conical base, 15.2 μm in height and 9.6 μm wide at base, interspinal distance is 6.1 μm.

Dimorphotheca pluvialis (L.) Moench (Plate1, Figs 27-29):

Pollen grains are radially symmetrical, isopolar, oblate spheroidal, P x E 34.2 x 37.7 μm (incl. spine) in diameter, amb triangular, anguloaperturate, tri-zonocolporoidate; colpi narrowly elliptic with gradually tapering pointed ends, 20 μm in length and 5.6 μm in breadth across the equator, oroid faint, lalongately circular, 6.2 μm in diameter, tenuimarginate, exine tegillate, 2.9 μm in thickness (excl. spine), crassisexinous; surface conate, coni 3.2 μm in height and 3.5 μm wide at base, interspinal distance is 4.7 μm.

Eclipta prostrata (L.) L. (Plate1, Figs 30-31):

Pollen grains are radially symmetrical, isopolar, prolate spheroidal, P x E 44.5 x 43 μm (incl. spine), amb circular, tri-zonocolporate; colpi narrowly elliptic with pointed ends, 24 μm in length and 4.5 μm in breadth across the equator, ora more or less circular, 8 μm in diameter, tenuimarginate, exine tegillate, 5.8μm in thickness (excl. spine), crassisexinous; surface spinate, spine 6 μm in height and 5.3 μm wide at base, interspinal distance is 4.8 μm.

Eluenthera ruderalis (Sw.) Sch. Bip. (Plate 1, Figs 32-34):

Pollen grains are radially symmetrical, isopolar, oblate-spheroidal, P x E 37.6 x 39.8 (incl. spine), amb circular, tri-zonocolporate; colpi narrowly elliptic with acuminate ends, 27.4 μm in length and 5.5 μm in breadth across the equator, ora lalongately elliptic with circular ends, 6.2 μm in diameter at the equator and 4.9 μm in length along the polar axis, tenuimarginate, exine tegillate, 3.7 μm in thickness (excl. spine), crassisexinous; surface spinate, spine 5.8 μm in height and 3.7 μm wide at base, interspinal distance is 8.1 μm.

Enhydra fluctuens DC. (Plate 1, Figs 35-37):

Pollen grains are radially symmetrical, isopolar, sub oblate, P x E 35.4 x 38.6 μm (incl. spine), amb triangular, fossaperturate, trizonocolpoidorate; colpi narrowly elliptic, faint, with pointed ends, 20.9 μm in length and 4.8 μm in breadth across the equator, ora circular, 4.5 μm in diameter, tenuimarginate, exine tegillate, 3.2 μm in thickness (excl. spine), crassisexinous; surface spinate, spines are widely placed, spine 4.7 μm in height and 4.3 μm in breadth across base with truncated or pointed tips, interspinal distance is 7.8 μm.

Chromolaena odorata (L.) King & Rob. (Plate1, Figs 38-39):

Pollen grains are radially symmetrical, isopolar, oblate spheroidal, P x E 39 x 43 μm (incl. spine), amb sub-triangular, fossaperturate, tri-zonocolporate; colpi narrowly elliptic with pointed ends, 15.5 μm in length and 5 μm in breadth across the equator, ora lalongately elliptic with acute ends, 2.5 μm in diameter along the polar axis and 6.8 μm in diameter across the equatorial axis, tenuimarginate, exine tegillate, 3.4 μm in thickness (excl. spine), crassisexinous; surface conate, coni 4.9 μm in height and 6.8 μm in breadth across base with pointed tips, interspinal distance is 7.2 μm.

Gnaphalium polycaulon Pers. (Plate 1, Figs 40-42):

Pollen grains are radially symmetrical, isopolar, oblate spheroidal, P x E 25 x 27.7 μm (incl. spine), amb sub- triangular, fossaperturate, tri-zonocolpoidorate; colpi faint, narrowly elliptic with pointed ends, 18 μm in length and 2.9 μm in breadth across the equator, ora lalongately elliptic with pointed ends, 8 μm in diameter along the equatorial axis and 5 μm in diameter across the polar axis, tenuimarginate, exine tegillate, 5.1 μm in thickness (excl. spine), crassisexinous; surface conate, spines are closely spaced, spine 3.2 μm in height and 3.3 μm wide at base, interspinal distance is 4 μm.

Grangea maderespatona (L.) Poir. (Plate 2, Figs 1-3):

Pollen grains are radially symmetrical, isopolar, oblate- spheroidal, P x E 28 x 32 μm (incl. spine), amb sub-triangular, fossaperturate, tri-zonocolpoidorate; colpi faint, narrowly elliptic with pointed ends, 17 μm in length and 8.2 μm in breadth across the equator, ora more or less circular, 8.1 μm in diameter, tenuimarginate, exine tegillate, 3.2 μm in thickness (excl. spine), crassisexinous; surface conate, spine 5.5μm in height and 5.4 μm wide at base, interspinal distance is 4.4 μm.

Helianthus annuus L. (Plate 2, Figs 4-6):

Pollen grains are radially symmetrical, isopolar, spheroidal, 38 μm (incl. spine) in diameter, amb more or less circular, tri-zonocolpoidorate; colpi faint, narrowly elliptic with abruptly tapering pointed ends, 28.8 µm in length and 3.8µm in breadth at the equator, ora circular, 4.6 µm in diameter, tenuimarginate, exine tegillate, 3.4 µm in thickness (excl. spine), crassisexinous; surface spinate, spine long and slender with highly tapering pointed apex, 8.4 µm in height and 4.5 µm wide at base, interspinal distance is 4.6 µm.

Lagasceae mollis Cav. (Plate 2, Figs 7-8):

Pollen grains are radially symmetrical, isopolar, spheroidal, P x E 28 x 32 µm (incl. spine), amb sub-triangular, tri-zonocolporate; brevisimmicolpate, colpi narrowly elliptic with pointed ends, 17 µm in length and 8.2 µm in breadth across the equator, ora lalongately elliptic with pointed ends, 8.1 µm in diameter, tenuimarginate, exine tegillate, 3.2 µm in thickness (excl. spine), crassisexinous; surface spinate, spine with highly tapering pointed apex, spine 5.5 µm in height and 5.4 µm wide at base, interspinal distance is 4.4 µm.

Mikenia scandens (L.) Willd. (Plate 2, Figs 9-11):

Pollen grains are radially symmetrical, isopolar, oblate spheroidal, P x E 23 x 26 µm (incl. spine), amb sub-triangular, fossaperturate, tri-zonocolporate;colpi narrowly elliptic with pointed ends, 19.5 µm in length and 2.8 µm in breadth across the equator, ora more or less circular, 2.9 µm in diameter, tenuimarginate, exine tegillate, 2.5 µm in thickness (excl. spine), crassisexinous; surface spinate, spine 3.2 µm in height and 2.4 µm wide at base with pointed tips, interspinal distance is 5.6 µm.

Parthenium hysterophorus L. (Plate 2, Figs 12-13):

Pollen grains are radially symmetrical, isopolar, size P x E is 24.1 x 28.9 µm, oblate-spheroidal, amb sub-triangular, trizonocolporate; colpi narrowly elliptic with pointed ends, 16 µm in length and 4.2 µm in breadth across the equator ora more or less circular, 4.5 µm in diameter, tenuimarginate, exine tegillated, 2.5 µm in thickness, crassisexinuous, surface conate, coni 3.3µm in height and 3.4µm wide at base with pointed tips, interspinal distance is 3.6µm.

Pluchea indica (Plate 2, Figs 14-16):

Pollen grains are radially symmetrical, isopolar, oblate-spheroidal, P x E 40 x 42 µm (incl. spine), amb triangular, fossaperturate, tri-zonocolporate; colpi narrowly elliptic with acuminate ends, 28.3 µm in length and 4.2 µm in breadth across the equator, ora lalongately elliptic with pointed ends, 4.8 µm in diameter at the equator and 3.2 µm in length along the polar axis, tenuimarginate, exine tegillate, 4.7µm in thickness (excl. spine), crassisexinous; surface spinate with bulbous base, spine 7.8 µm in height and 5.6 µm wide at base, interspinal distance is 6.7 µm.

Rudbeckia hirta L. (Plate 2, Figs 17-18):

Pollen grains are radially symmetrical, isopolar, spheroidal, P x E 35.2 µm (incl. spine) in diameter, amb circular, tri-zonocolpoidorate; colpi faint, narrowly elliptic with pointed ends, 23.4 µm in length and 3.6 µm in breadth across the equator, ora small, circular, 3.9 µm in diameter, tenuimarginate, exine tegillate, 4 µm in thickness (excl. spine), crassisexinous; surface conate, spine 5.7 µm in height and 4.6 µm wide at base, interspinal distance is 5 µm.

Sphaeranthus indicus L. (Plate 2, Figs 19-20):

Pollen grains are radially symmetrical, isopolar, spheroidal, 23 µm in diameter, amb sub-triangular, fosssaperturate, trizonocolporate; colpi narrowly elliptic with pointed ends, 13 µm in length and 3.4 µm wide across the equator, ora circular, 3.2 µm in diameter, tenuimarginate, exine tegillated, 2.6 µm in thickness (excl. spine), sexine is as thick as nexine, surface conate, spine 3.6µm in height and 3.7µm wide at base, interspinal distance is 4.8 µm.

Acmella paniculata (Wall. Ex DC.) Jansen (Plate 2, Figs 21-23):

Pollen grains are radially symmetrical, isopolar, oblate spheroidal, P x E 38 x 40 µm (incl. spine), amb sub- triangular, fossaperturate, tri-zonocolporate; colpi narrowly elliptic with pointed ends, 22.5 µm in length and 3.4 µm in breadth across the equator, ora lalongately elliptic with pointed ends, 9.3 µm in diameter along the equatorial axis and 1.9 µm in diameter across the polar axis, tenuimarginate, exine tegillate, 4.1 µm in thickness (excl. spine), crassisexinous; surface spinate, spines are closely spaced, spine 6 µm in height and 4.1 µm wide at base, interspinal distance is 3 µm.

Synedrella nodiflora (L.) Gaertn. (Plate 2, Figs 24-26):

Pollen grains are radially symmetrical, isopolar, oblate-spheroidal, P x E 29.3 x 33 µm (incl. spine), amb sub-triangular, fossaperturate, tri-zonocolpoidorate; colpi faint, narrowly elliptic with pointed ends, 19 µm in length and 8.4 µm in breadth across the equator, ora small, circular, 8.2 µm in diameter, tenuimarginate, exine tegillate, 3.4 µm in thickness (excl. spine), crassisexinous; surface conate, spine 5.6µm in height and 5 µm wide at base, interspinal distance is 4.5 µm.

Tagetes erecta L. (Plate 2, Figs 27-29):

Pollen grains are radially symmetrical, isopolar, spheroidal, 48 µm (incl. spine) in diameter, amb circular, tri-zonocolporate; colpi narrowly elliptic with highly tapering acuminate apex, 22.6 µm in length and 10.8 µm in breadth across the equator, ora lalongately oval with pointed ends, 11µm in diameter across the equator and 6.3 µm along the polar axis, tenuimarginate, exine tegillate, 10 µm in thickness (excl. spine), crassisexinous; surface spinate, spine long, slender with highly tapering acuminate apex having conical base, 7 µm in height and 6.5 µm wide at base, interspinal distance is 6.1 µm.

Tridax procumbens (L.) L. (Plate 2, Figs 30-31):

Pollen grains are radially symmetrical, isopolar, spheroidal to oblate spheroidal, 47 µm (incl. spine) in diameter, amb sub-triangular to sub quadrangular, fossaperturate, tri-tetrazonocolporate; colpi narrowly elliptic with pointed ends, 18.5 µm in length and 5 µm in breadth across the equator, ora lalongately elliptic with acute ends, 3.5 µm in diameter along the polar axis and 10.7 µm in diameter across the equatorial axis, tenuimarginate, exine tegillate, 3.8 µm in thickness (excl. spine), crassisexinous; surface spinate, spines are closely placed, spine 6.2 µm in height and 4.3 µm in breadth across base with pointed tips, interspinal distance is 6.9 µm.

Wedellia urticaefolia (Blume) DC. Ex Wight. (Plate 2, Figs 32-33):

Pollen grains are radially symmetrical, isopolar, spheroidal, P x E 34 x 35 µm (incl. spine), amb more or less circular, tri-zonocolporate; colpi narrowly elliptic with pointed ends, 18.6 µm in length and 4.6 µm in breadth across the equator, ora circular, 4.7 µm in diameter across the equator, tenuimarginate, exine tegillate, 3.2 µm in thickness (excl. spine), crassisexinous; surface spinate, spine long and slender with highly tapering pointed apex, 5.8 µm in height and 4.2 µm wide at base, interspinal distance is 4.3 µm.

Xanthium stumarium L. (Plate 2, Figs 34-36):

Pollen grains are radially symmetrical, isopolar, oblate- spheroidal, P x E 30 x 35 µm (incl. spine), amb sub-triangular, fossaperturate, tri-zonocolporoidate; brevicolporate, colpi faint, short, narrowly elliptic with pointed ends, 6.4 µm in length and 3 µm in breadth across the equator, ora small, lolongately elliptic, insconspicuous, 2.9 µm in diameter, tenuimarginate, exine tegillate, 2.4 µm in thickness (excl. spine), crassisexinous; surface conate, spine 2.5. µm in height and 2.3 µm wide at base, interspinal distance is 4.8 µm.

Zinnia hybrid Roem. & Usteri. (Plate 2, Figs 37-38):

Pollen grains are radially symmetrical, isopolar, spheroidal, P x E 30 x 32 µm (incl. spine), amb sub-triangular, tri-tetra-zonocolporate; colpi narrowly elliptic with pointed ends, 17 µm in length and 3µm in breadth across the equator, ora lalongately elliptic with pointed ends, 3.4 µm in diameter across the equator, tenuimarginate, exine tegillate, 3.2 µm in thickness (excl. spine), crassisexinous; surface spinate, spine with highly tapering pointed apex, spine 4.9 µm in height and 3.1 µm wide at base, interspinal distance is 4.5 µm.

Zinnia peruviana (L.) L. (Plate 2, Figs 39-40):

Pollen grains are radially symmetrical, isopolar, spheroidal - oblate spheroidal, P x E 58 x 59 µm (incl. spine), amb triangular, anguloaperturate, tri-zonocolpoidorate, colpi faint, narrowly elliptic with obtuse ends, 32 µm in length and 8.3 µm in breadth across the equator, ora broadly lolongate with circular ends, 7.6 µm in diameter across the equator and 11.4 µm along the polar axis, crassimarginate, exine tegillate, 4.5 µm in thickness (excl. spine), crassisexinous; surface spinate, spine long, slender with small, conical bases, 8 µm in height and 4.1 µm wide at base, interspinal distance is 4.9 µm.

DISCUSSION

The subfamily Asteroidae of the family Asteraceae apparently seems to be a stenopalynous one from the above palynological investigation of the species, as they exhibit similarity in their apertural pattern, being tri to tetra-colporate and surface ornamentation, being spinate to conate. The shape of the grains also ranges from spheroidal to oblate-spheroidal and the size ranges from 28 to 38 µm, except few. On critical analysis of the pollen grains, it can be concluded that the subfamily Asteroidae is strictly a eurypalynous one as they exhibit variations in their colporate apertures, a) being tri-tetrazonocolporate where both the ora and the colpi are distinct, b) colpoidorate where the colpi is faint and not so prominent while the ora is distinctly prominent, e.g., *Ageratum conyzoides, Bellis perennis, Chrysanthemum* sp., c) colporoidate where the colpi is distinct but the ora is insconspicuous, faint, e.g., *Dimorphotheca* sp., *Xanthium* sp. There is also variation in the ora of the pollen grains. Some are lalongate, a) with pointed ends, e.g., *Cosmos* sp., d) circular ends, e.g., *Eluenthera* sp. some are lolongately oval, e.g., *Zinnia* sp. while some are circular, e.g., *Bellis* sp.

Regarding the surface onamentation of the pollen grains, all are either spinate e.g., *Calenduala* sp., *Cosmos* sp., *Blumea* sp., *Dahlia* sp. or conate, e.g., *Ageratum* sp., *Bellis* sp., *Chrysanthemum* sp., *Cineraria* sp., but each species exhibits variation in it, in terms of the base of the spines, some are provided with basal cushions while the rest of the members lack such basal cushions such as *Wedellia* sp., *Synedrella* sp. and *Rudbeckia* sp. The basal cushions are either hemispherical shaped e.g., *Pluchea* sp. or conically notched e.g., *Zinnia peruviana* and *Tagetes erecta*. The interspinal distance also plays a major role in distinguishing these grains. In some grains the spines are closely placed viz., *Parthenium* sp. and *Grangea* sp. while in others the spines are sparsely placed like *Calendula* sp., *Cosmos* sp., *Dahlia* sp. Few grains are exceptionally larger in size ranging from 42-55 µm in diameter like *Zinnia peruviana* and *Tagetes erecta*.

Bentham and Hooker (1873) had placed the genera *Dahlia*, *Coreopsis* and *Cosmos* within the tribe Heliantheae in his book Genera Plantarum. In our present study it has been observed that there is a vivid palynological difference in the pollen grains of these three species from the rest of the members of the tribe Heliantheae, being brevisimmicolpate i.e., colpi is very short and is as long as the underlying endoaperture. So, palynologically it supports the classification of Panero and Funk (2002, 2008) in which the above mentioned three members are grouped into a separate tribe i.e., Coreopsidae.

Tagetes patula has been placed under tribe Helenoidae by Bentham and Hooker (1873), but the pollen grains of *Tagetes* sp. exhibits a striking difference from the rest of the species of tribe Heliantheae by being exceptionally large in size, having very long, slender spines and bearing colporate, lalongate aperture. So, palynologically the classification of Panero and Funk (2002, 2008) is much more acceptable where *Tagetes patula* is put under a separate tribe i.e., Tageteae.

So, according to the present observations, it can be concluded that the classification of Asteroideae at the tribal level by Panero and Funk (2002, 2008) and Funk et al. (2009) is supported palynologically.

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REFERENCES

Bentham G. & Hooker J.D. 1862-1883. Genera Plantarum. 3 vols, Reeve, London.

Bisht V.K., Purohit V., Negi J.S. & Bhandari A.K. 2010. Introduction and advancement in cultivation of Large Cardamom (*Amomum subulatum* Roxb.) in Uttarakhand, India. Research Journal of Agricultural Sciences 1(3): 205-208.

Bolick M.R. 1978. Taxonomic, evalutionary and functional considerations of Composite pollen ultrastructure and sculpture. Plant Systematics and Evolution 130: 209-218.

Bunwong S. & Chantaranothai P. 2008. Pollen morphology of the Tribe Vernonieae (Compositae) in Thailand. The Natural History Journal of Chulalongkorn University 8: 45-55.

Clark W.D., Brown G.K. & Mayes R.M. 1980. Pollen morphology of haplopappus and related genera (Composite-Asterae). American Journal of Botany 67:1391-1396.

Erdtman G. 1952. Pollen morphology and Plant Taxonomy-Angiosperm. Almqvist and Wiksell, Stockholm, pp. 539.

Faegri K. & Iversen J. 1975. Textbook of pollen analysis (5th Edition). Blackwell Scientific Publications, Oxford, pp. 295.

Funk V., Susanna A.S., Tod F. & Robinson H.E. 2009. Classification of Compositae. In: V. Funk, A. Susanna, T. F. Stuessy & R. Bayer (Eds.) Systematics, Evolution and Biogeography of Compositae, International association for Plant Taxonomy, Vienna, Austria, pp. 171-189.

Jain R.K. & Nanda S. 1966. Pollen morphology of some desert plants of Pilani Rajasthan. Palynological Bulletin II & III: 56-69.

Nair P.K.K. 1965. Pollen grains of Western Himalayan Plants, Asia Publishing House, Bombay, pp. 102.

Nair P.K.K. & Lawrence R. 1985. Pollen morphology of Indian Compositae. Today & Tomorrow's Print, Delhi, pp. 182.

Osman A.K.E. 2006. Pollen types of the Egyptian species of tribe Lactuceae (subfamily Cichorioideae-Compositae). Acta Botanica Croatica 2: 161-180.

Osman A.K.E. 2011. Pollen morphology of tribes gnaphalieae, helenieae, plucheeae and senecioneae (subfamily asteroideae) of Compositae from Egypt. American Journal of Plant Sciences 2: 120-133.

Panero J. & Funk V. 2002. Toward a Phylogenetic Subfamilial Classification for the Compositae (Asteraceae). Proceedings of the Biological Society of Washington 115: 909-922.

Panero J. & Funk V. 2008. The value of sampling anomalous taxa in phylogenetic studies: major clade of the Asteraceae revealed. Molecular Phylogenetics and Evolution 47: 757-782.

Qureshi R. & Bhatti G.R. 2008. Ethnobotany of plants used by the Thari people of Nara Desert, Pakistan. Fitoterapia 79: 468-473.

Qureshi S.J., Khan M.A. & Rashid A. 2008. Diameter, exine thickness, and sculpturing in genera *Scorzonera* L., *Sonchus* L. and *Tragopogon* L. of Asteraceae in Pakistan. International Journal of Science and Technology 3(2): 139-149.

Rao A.R. & Shukla P. 1975. Pollen Flora of Upper Gangetic Plain. Today and Tomorrow's Printers and Publishers, New Delhi.

Robinson H. 1978. Compositae-Liabeae. Flora of Ecuador 8: 1-62.

Robinson H. 1983. A generic review of the tribe Liabeae (Asteraceae). Smithsonian Contributions in Botany 54: 1-69.

Serivastava V. 1976. Pollen morphology of *Tagetes* Linn. Palynology 12: 143-147.

Skvarla J.J., Turner B.L., Patel V.C., Tomb A.S. & Thanikaimoni G. 1977. Pollen morphology in the Compositae and in morphologically related families. In: V.H. Heywood, J.B. Harborne & B.L. Turner (Eds.) The biology and the chemistry of the Compositae, Vol. 1, Academic Press, London, New York, San Francisco, pp. 141-265.

Stevens B., Ackerman A.S., Albrecht B.A., Brown A.R., Chlond A., Cuxart J., Duynkerke P.G., Lewellen D.C., Macvean M.K., Neggers R.A.J., Sánchez E., Siebesma A.P. & Stevens D.E. 2001. Simulations of trade wind cumuli under a strong inversion. Journal of Atmospheric Sciences 58: 1870-1891.

Stix E. 1960. Pollenmorfologische Untersuchungen an Compositen. Grana Palynologica 2: 41-126.

Tellería J., Hera D.L. Iván & Pérez-Tris J. 2013. Morphological Variation as a Tool for Monitoring Bird Populations: A Review. Ardeola: revista ibérica de ornitología 60: 191-224.

Wodehouse R.P. 1926. Pollen grain morphology in the classification of the Anthemideae. Bulletin of the Torrey Club 53: 479-485.

Wodehouse R.P. 1930. Pollen grains in identification and classification of plant V. haplopappus and other Astereae: the origin of their furrow configurations. Bulletin of the Torrey Club 57: 21-46.

Wodehouse R.P. 1935. Pollen grains. Their structure, identification and significance in science and medicine, McGraw-Hill, New York, pp. 574.

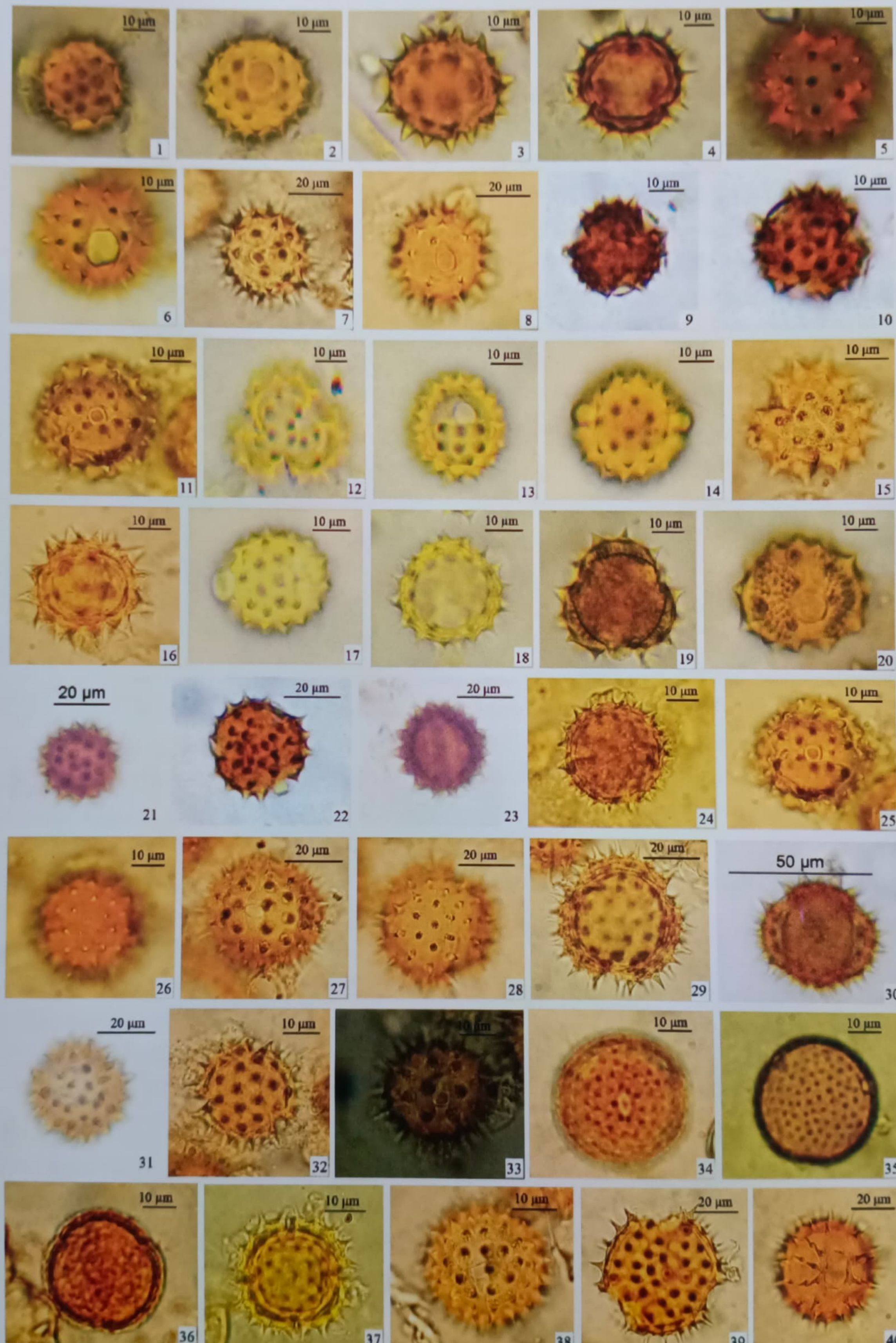

Plate 2

Figs. 1-3 Pollen grains of *Grangea maderespatona* (L.) Poir. **Figs. 4-6** *Helianthus annuus* L. **Figs. 7-8** Lagasceae *mollis* Cav. **Figs. 9-11** *Mikenia scandens* (L.) Willd. **Figs. 12-13** *Parthenium hysterophorus* L. **Figs. 14-16** *Pluchea indica* **Figs. 17-18** *Rudbeckia hirta* L. **Figs. 19-20** *Sphaeranthus indicus* L. **Figs. 21-23** *Acmella paniculata* (Wall. Ex DC.) Jansen **Figs. 24-26** *Synedrella nodiflora* (L.) Gaertn. **Figs. 27-29** *Tagetes erecta* L. **Figs. 30-31** *Tridax procumbens* (L.) L. **Figs. 32-33** *Wedellia urticaefolia* (Blume) DC. Ex Wight. **Figs. 34-36** *Xanthium stumarium* L. **Figs. 37-38** *Zinnia hybrida* Roem. & Usteri. **Figs. 39-40** *Zinnia peruviana* (L.) L.