

POLLEN MORPHOLOGY OF THE FAMILY LABIATAE FROM PAKISTAN

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Abstract

Pollen morphology of 79 species representing 27 genera of the family Labiatae from Pakistan have been examined by light and scanning electron microscope. Labiatae is a eurypalynous family. Pollen grains are generally free, radially symmetrical, isopolar, mostly colpate (3-8), rarely colpporate. Shape of pollen grains are prolate-spheroidal to oblate-spheroidal or sub-oblate. Sexine may be thicker or thinner than nexine. Reticulate tectum is the most common type. Other tectum types *viz.* rugulate, foveolate, striate and fossulate are also found. Shape, aperture types and exine ornamentation are found to be more significant pollen characters where seven distinct pollen types *viz.* *Elsholtzia densa* - type, *Marrubium marrubiastrum* - type, *Nepeta laevigata* - type, *Scutellaria prostrata* - type, *Salvia aegyptiaca* - type, *Stachys parviflora* - type and *Teucrium scordium* - type are recognized. The pollen morphology of the family Labiatae does not support the infra familial classification but at the species level it is quite helpful in delimitation of various taxa.

Introduction

The family Labiatae is cosmopolitan in distribution with two major centers of occurrence Mediterranean and Central Asian regions, represented by c. 200 genera and 3200 species (Willis, 1973, Mabberley, 1987). It is represented in Pakistan by 60 genera and 212 species. Several plants of mint family are used as pot herbs and spices such as sege (*Salvia officinalis*), spearmint (*Mentha spicata*), peppermint (*Mentha piperita*), basil (*Clinopodium vulgare*). The family is also known for its ornamental plants.

The family Labiatae has little character difference. In addition to this sexual dimorphism especially gynodioecium is quite frequent phenomenon, and in some genera this combined with hybridization and phenotypic plasticity, often offer difficulties while delimiting species and sometimes even genera.

Number of investigations on pollen morphology have been carried out on particular genera or on geographic groups of taxa belonging to various subfamilies and tribes of Labiatae (Waterman, 1960; Emboden, 1965; Soursa, 1966; Matas-Methem, 1966; Nabli, 1972; Bennel, 1983; Afzal-Rafli, 1983, Abu-Asab & Cantino, 1989; Harley *et al.*, 1992). In few cases attempts have also been made to correlate palynological data with phylogeny and evolutionary tendencies in some tribes such as Ajugeae (Abu-Asab & Cantino, 1992; 1993). The pollen of this large family with over 150 genera are either completely unexplored or partly examined. No information is available on the pollen morphology of various taxa of Labiatae occurring in Pakistan.

Pollen morphology of 79 species representing 27 genera from Pakistan has been investigated in the present investigation. The purpose of the current investigation is two fold, first to provide palynological information about various taxa of Pakistan, secondly to find additional micromorphological characters in this intricate family.

Materials and Methods

Pollen samples were obtained from the herbarium specimens of Karachi University Herbarium (KUH) or from fresh samples collected from the field. The list of voucher specimens is deposited in KUH. The pollen grains were prepared for light (LM) and scanning microscopies (SEM) by the standard methods described by Erdtman (1952). For light microscopy, the pollen grains were mounted in unstained glycerin jelly and observations were made with a Nikon Type-2 microscope, under E40, (0.45) and oil immersion (E100, 1.25), using 10x eye piece. For SEM studies, pollen grains suspended in a drop of water were directly transferred with a fine pipette to a metallic stub using double sided cellotape and coated with gold in a sputtering chamber (Ionsputter JFC-1100). Coating was restricted to 150A. The SEM examination was carried out on a Jeol microscope JSM-T200. The measurements are based on 15-20 readings from each specimen. Polar length, equatorial diameter, colpus length, and exine thickness were measured (Table 1-5).

The terminology used is in accordance with Erdtman (1952), Faegri & Iversen (1964), Kremp (1965) and Walker & Doyle (1976).

Observations

General pollen characters of the family Labiatae: Pollen grains usually radially symmetrical, isopolar, prolate-spheroidal to oblate-spheroidal or sub-oblate to sub-prolate. Mostly 3-8 colpate, rarely colporate, trilobed, fossaperturate, colpal membrane psilate to sub-psilate, or granulated, often perforated. Sexine thicker or thinner than nexine. Tectum generally finely to coarsely reticulate, with perforated luminae, perforations variable in numbers rarely rugulate - reticulate or striate-rugulate, or often sub-psilate. The following 7 pollen types are recognized on the basis of aperture, tectum type and shape of pollen grains I: *Elsholtzia densa* - type, II: *Marrubium marrubiastrum* - type, III: *Nepeta laevigata* - type, IV: *Salvia aegyptiaca* - type, V: *Scutellaria prostrata* - type VI: *Stachys parviflora* - type, VIII: *Teucrium scordum* - type.

Key to the pollen types

1. + Pollen grains colpate 2
 - Pollen grains colporate VI: *Stachys parviflora* - type
2. + Pollen grains 3-colpate, rarely 4-colpate 3
 - Pollen grains 6-8 colpate 5
3. + Tectum medium - coarsely-reticulate with perforated lumina
 V: *Scutellaria prostrata* - type
 - Tectum not as above 4
4. + Tectum verrucate VIII: *Teucrium scordum* - type
 - Tectum rugulate-reticulate II: *Marrubium marrubiastrum* - type
5. + Tectum psilate I: *Elsholtzia densa* - type
 - Tectum other than psilate 6
6. + Pollen grains prolate-spheroidal to prolate III: *Nepeta laevigata* - type
 - Pollen grains oblate-spheroidal to sub-oblate IV: *Salvia aegyptiaca* - type

Table 1. General pollen characters of species found in the pollen type *Marrubium marrubiastrum*.

Name of taxa	Shape	P/E ratio	Polar length (P) µm	Equatorial length (L) µm	Tectum type
<i>Marrubium anisodon</i> C. Koch.	Ob-Sp	0.83	22.75-24.5 (23.62 ± 0.87)	27.5-28.75 (28.12 ± 0.61)	F-R
<i>M. marrubiastrum</i> (Steph.) Hedge	Pr-Sp	1.06	22.5-28.75 (25.45 ± 0.65)	22.5-27.6 (23.5 ± 0.58)	Foss.
<i>Orostegia aucheri</i> Boiss.	Pr-Sp		24.7-27.5 (26.44 ± 0.38)	22.5-26.5 (24.4 ± 0.33)	R - Rug
<i>Phlomis cashmeriana</i> Royle ex Benth.	Sub-Pr		27.5-41.25 (32.71 ± 0.9)	22.5-30 (26.5 ± 0.95)	Rug
<i>Teucrium royleanum</i> Wall. ex Benth.	Sub-Pr		27.25-35 (31.5 ± 0.42)	25-27.75 (26.27 ± 0.35)	Rug-R

Abbreviations: C-R= Coarsely reticulate, M-R = Medium reticulate, F-R = finely reticulate, Rug = Rugulate, Foss = Fossulate, R = Reticulate, Pr-Sp = Prolate-spheroidal, Sub-pr = sub-prolate, Pr = Prolate, Ob-Sp = Oblate-spheroidal, Sub-ob= Sub-oblate.

Table 2. General pollen characters of species found in pollen type *Nepeta laevigata*.

Name of taxa	Shape	P/E ratio	Polar length (P) μm	Equatorial diameter (E) μm	Colpus length (L) μm	Tectum
<i>Nepeta glutinosa</i> Benth.	Pr-Sp	1.06	27.15-41.2 (36.7 \pm 0.34)	29.5-37.5 (34.35 \pm 0.76)	25-37.5 (33.26 \pm 0.86)	C-R
<i>N. raphanorhiza</i> Benth.	Pr-Sp	1.05	22.7-30 (27.06 \pm 0.53)	22.5-81.25 (25.64 \pm 0.51)	20-25.5 (26.5 \pm 0.09)	C-R
<i>N. paulsenii</i> Briquet	Sub-Pr	1.29	25-32 (28.25 \pm 0.42)	19.7-34.5 (21.3 \pm 0.6)	22.5-27.5 (24.2 \pm 0.6)	C-R
<i>N. laevigata</i> (D. Don) Hand. - Mazz.	Pr-Sp	1.11	22.5-34.75 (29.5 \pm 1.97)	22.75-32.5 (28.8 \pm 1.55)	20.25-28.75 (25.29 \pm 0.46)	C-R
<i>N. nervosa</i> Royle ex Benth.	Pr-Sp	1.01	27.7-31.25 (30.9 \pm 0.38)	12.5-32.5 (30.34 \pm 0.39)	25-30 (27.08 \pm 0.91)	C-R
<i>N. connata</i> Royle ex Benth.	Pr-Sp	1.04	12-40.35 (33.8 \pm 1.09)	27.5-36.35 (32.5 \pm 0.9)	26.5-31.25 (27.9 \pm 0.7)	C-R
<i>N. linearis</i> Royle ex Benth.	Pr-Sp	1.10	25-34.74 (28.9 \pm 0.57)	22.75-28.75 (26.07 \pm 0.52)	22.5-27.5 (25.1 \pm 0.52)	C-R
<i>N. gowaniana</i> (Wall. ex Benth.)	Pr-Sp	1.12	29-45.25 (41.21 \pm 1.25)	31.5-40 (36.65 \pm 0.7)	32.5-42.5 (37.5 \pm 0.95)	R-Rug
<i>N. erecta</i> (Royle ex Benth.) Benth.	Sub-Sp	1.16	40.25-47.5 (44.8 \pm 0.82)	37.5-45.5 (38.5 \pm 2.5)	37.5-42.5 (40.25 \pm 0.68)	C-R
<i>N. clarkei</i> Hook.f.	Pr-Sp	1.71	35-47.5 (39.87 \pm 1.07)	29.5-37.5 (34.03 \pm 0.32)	32.5 (34.37 \pm 37.5)	C-R
<i>N. floccosa</i> Benth.	Sp-Sp	1.18	22.5-28.75 (25.8 \pm 0.5)	17.75-28.9 (21.85 \pm 0.65)	17.5-25 (22.6 \pm 0.5)	C-R
<i>N. cataria</i> L.	Pr-Sp	1.01	27.5-32.5 (30.8 \pm 0.5)	27.25-34.75 (30.35 \pm 0.7)	22.5-30 (26.26 \pm 0.64)	C-R
<i>N. leucolaena</i> Benth. ex Hook.f.	Pr-Sp	1.04	27.5-35 (32.19 \pm 0.5)	25-39 (30.95 \pm 0.52)	25-31.25 (28.51 \pm 0.45)	C-R

Table 2 (Cont'd.)

Name of taxa	Shape	P/E ratio	Polar length (P) μm	Equatorial diameter (E) μm	Colpus length (L) μm	Tectum
<i>N. griffithii</i> Hedge	Pr-Sp	1.01	22.5-25.25 (24.7 \pm 0.55)	20-27.25 (24.11 \pm 1.13)	17.5-22.5 (20.87 \pm 0.65)	C-R
<i>N. distans</i> Royle ex Benth.	Pr-Sp	1.99	21.25-25.5 (24.4 \pm 0.4)	18-27.5 (22.5 \pm 0.56)	17.5-25 (21.3 \pm 0.44)	C-R
<i>N. hindostana</i> (Roth.) Hainas	Pr-Sp	1.04	27.5-31.25 (29.63 \pm 0.04)	23.75-31.25 (26.7 \pm 0.66)	25-12.68 (25.5 \pm 0.29)	C-R
<i>N. saturooides</i> Boiss.	Pr-Sp	1.01	22.5-32.5 (30.5 \pm 0.41)	25.5-32.5 (30.25 \pm 0.7)	25-3 (28.3 \pm 0.85)	C-R
<i>Prunella vulgaris</i> L.	Pr-Sp	1.13	27.7-40 (34.8 \pm 1.48)	25-33.75 (30.7 \pm 1.43)	25-35 (30.03 \pm 1.42)	C-R
<i>Phlomis spectabilis</i> Falc. ex Benth.	Pr-Sp	1.07	26.25 (30.11 \pm 0.33) 32.5	23.5 (27.9 \pm 0.48) 32.5	25-31.25 (27.14 \pm 0.33)	C-R
<i>Saliva hians</i> Royle ex Benth.	Pr-Sp	1.07	18-42.5 (33.05 \pm 1.56)	35-42.5 (40 \pm 1.58)	32.5-37.5 (36 \pm 1.02)	M-R
<i>Ziziphora tenuior</i> L.	Pr-Sp	1.01	28.75-35 (31.0 \pm 0.81)	25-33.75 (30.89 \pm 1.08)	22.5-30 (24.8 \pm 0.96)	C-R
<i>Micromeria biflora</i> (Buch.-Ham ex Dom) Benth.	Sub-Pr	1.20	28.75-35 (33.4 \pm 1.18)	26.6-30 (27.7 \pm 0.73)	25-30 (29 \pm 1.0)	C-R
<i>Meniha longifolia</i> (L.) L.	Pr-Sp	1.02	25-35 (-29.11 \pm 0.64)	18-22.5 (28.29 \pm 0.83)	21.25-36.25 (24.26 \pm 0.53)	M-R
<i>M. royleana</i> Benth.	Sub-Pr	1.21	22.5 (21.85 \pm 1.02) 30.25	18.75 (21.9 \pm 1.02) 30.25	17.75-22.5 (22.33 \pm 0.91)	M-R
<i>M. spicata</i> L.	Pr-Sp	1.08	25-30 (27.5 \pm 0.71)	21.2-30 (25.7 \pm 1.32)	21.2-25.5 (23.03 \pm 0.51)	M-R

Table 3. General pollen characters of species found in pollen type *Salvia aegyptiaca*.

Name of taxa	Shape	P/E ratio	Polar length (P) μm	Equatorial diameter (E) μm	Colpus length (L) μm	Tectum
<i>Marrubium vulgare</i> L.	Ob-Sp	0.83	22.5-24.5 (23.12 \pm 0.61)	27.5-28.75 (28.1 \pm 0.6)	c. 17.5	C-R
<i>Nepeta podostachys</i> Benth.	Ob-Sp	0.93	25-30 (27.7 \pm 0.57)	25-32.5 (29.58 \pm 0.86)	22.5-28.75 (25.79 \pm 0.54)	C-R
<i>N. bracteata</i> Benth.	Ob-Sp	0.96	27.5-41.25 (35.6 \pm 1.85)	27.5-48 (36.97 \pm 2.96)	27.5-37.5 (28.9 \pm 2.0)	C-R
<i>N. eriosphaera</i> Rech.f. et Koeie	Ob-Sp	0.95	23-31.25 (26.-- \pm 0.49)	23.76-37.25 (27.78 \pm 0.47)	20-27.5 (22.2 \pm 0.72)	CR-I
<i>Dracocephalum stamineum</i> Kar. & Kir.	Ob-Sp	0.96	27.5-37.5 (30.7 \pm 0.99)	25-35 (30.88 \pm 1.04)	25-30 (26.13 \pm 0.73)	CP
<i>D. nutans</i> L.	Ob-Sp	0.95	31.5-30.5 (33.55 \pm 0.75)	32.5-40 (35 \pm 1.31)	27.5-31.35 (29.3 \pm 0.76)	C-R
<i>Salvia cabulica</i> Benth.	Ob-Sp	0.99	35 (40.48 \pm 0.81) 50	35 (40.5 \pm 0.76) 47.75	30-40 (35 \pm 0.95)	C-R
<i>S. bucharica</i> M. Pop.	Ob-Sp	0.89	12.2-36.25 (29.3 \pm 1.02)	27.5-37.25 (30.2 \pm 1.83)	21.2-27.5 (24.7 \pm 0.52)	C-R
<i>S. plebeia</i> R. Br.	Ob-Sp	0.93	--.5-35 (26.9 \pm 0.--)	25-30.5 (26.6 \pm 1.48)	20-30 (24.7 \pm 0.73)	C-R
<i>S. lanata</i> Roxburgh	Ob-Sp	0.99	35.7 (36.7 \pm 0.74) 31.5	35.2 (36.8 \pm 0.88) 37.75	32.5	C-R
<i>S. macrosiphon</i> Boiss.	Ob-Sp	0.88	35-52.7 (41.6 \pm 1.47)	43.7-55 (47.1 \pm 1.35)	30-50 (36.0 \pm 1.50)	C-R
<i>S. moocroftiana</i> Wall ex Benth.	Ob-Sp	0.91	37.5 (38.87 \pm 1.17) 25	37.5 (42.37 \pm 0.61) 48.75	25-40 (34.25 \pm 0.69)	C-R
<i>Salvia aegyptiaca</i> L.	Ob-Sp	0.97	21.25-36.25 (29.37 \pm 1.02)	27.5-37.75 (30.22 \pm 1.82)	21.55-27.5 (24.0 \pm 0.52)	M-R

Table 3 (Cont'd.)

Name of taxa	Shape	P/E ratio	Polar length (P) μm	Equatorial diameter (E) μm	Colpus length (L) μm	Tectum
<i>S. nubicola</i> Wall ex Sweet	Sub-Ob	0.85	22.5-38.1 (35.13 \pm 0.39)	32.5-45 (41.5 \pm 0.75)	27.5-32.5 (29.6 \pm 0.38)	C-R
<i>Perovskia atriplicifolia</i> Benth.	Ob-Sp	0.98	28.75-37.6 (32.15 \pm 0.91)	27.5-31.5 (32.5 \pm 1.13)	22.5-35 (27.18 \pm 1.29)	M-R
<i>Ziziphora clinopodioides</i> Lam.	Ob-Sp	0.95	25.25 (26.93 \pm 0.34)	25-32.5 (28.34 \pm 0.32)	20-22.5 (23.39 \pm 0.33)	M-R
<i>Melissa officinalis</i> L.	Ob-Sp	0.97	31.25-38.15 (33.85 \pm 0.68)	25-37.5 (34.63 \pm 0.96)	20.25-35 (28.8 \pm 0.80)	M-R
<i>Calamintha hydaspidis</i> (Falconer ex Benth.) Hedge	Sub-Ob	0.85	22.5-32.5 (31.4 \pm 1.86)	32.5-38.75 (36.6 \pm 0.81)	27.5-30 (28.5 \pm 0.61)	R
<i>Clinopodium vulgare</i> L.	Sub-Ob	0.86	32.5-38.7 (33.7 \pm 1.24)	35.2-41.25 (38 \pm 1.01)	27.5-32.5 (29.2 \pm 0.92)	F-R
<i>C. umbrosum</i> (M. Bieb.) C. Koch.	Ob-Sp	0.99	26.2-24.75 (29.58 \pm 1.44)	26.2-32.75 (29.4 \pm 0.98)	22.5-30 (26.6 \pm 1.23)	M-R
<i>Origanum vulgare</i> L.	Ob-Sp	0.93	25 (27.63 \pm 0.67)	27.2-22.5 (29.5 \pm 0.69)	20-27.5 (21.6 \pm 1.36)	C-R
<i>Thymus linearis</i> Benth.	Ob-Sp	0.94	27.5-35 (28.0 \pm 0.51)	18-35 (30.8 \pm 1.42)	18-35 (30.67 \pm 1.42)	C-R
<i>Elsholtzia ciliata</i> (Thunb.) Hyllander	Ob-Sp	0.96	17.5-25.5 (21.6 \pm 1.02)	17.5-25 (22.3 \pm 1.17)	15.25-21.25 (18.15 \pm 0.76)	R-Rug
<i>Isodon coetsa</i> (Buch. Ham. ex D. Don) Kudo	Ob-Sp	1.01	22.5-35 (31.84 \pm 0.56)	21.25-30.25 (26.95 \pm 0.57)	22.5-31.25 (26.9 \pm 0.49)	C-R
<i>I. rugosus</i> (Wall. ex Benth.) Codd	Pr-Sp	1.04	27.5-37.5 (30.75 \pm 1.75)	21.5-32.75 (29.4 \pm 1.84)	22.5-32.5 (25.5 \pm 2.3)	C-R
<i>Ocimum americanum</i> L.	Ob-Sp	0.67	37.5-42.5 (39.2 \pm 0.55)	55-60.05 (57.9 \pm 1.02)	22.5-30.5 (28.5 \pm 0.74)	C-R

Table 4. General pollen characters of species found in pollen type *Scutellaria prostrata*.

Name of taxa	Shape	P/E ratio	Polar length (P) μm	Equatorial diameter (E) μm	Colpus length (L) μm	Tectum
<i>Scutellaria grossa</i> Wall. ex Benth.	Sub-Pr	1.17	17.5-22.5 (19.8 \pm 0.28)	13.57-20 (16.9 \pm 0.29)	15-20 (17.5 \pm 0.19)	C-R
<i>S. petiolata</i> Hemsley et Lace	Sub-Pr	1.22	17.5-21.65 (19.3 \pm 0.44)	13.15-17.5 (15.8 \pm 0.31)	15-20 (16.63 \pm 0.52)	C-R
<i>S. linearis</i> Benth.	Pr-Sp	1.01	15-20 (17.5 \pm 0.30)	14.7-20 (17.38 \pm 0.25)	14.5-17.75 (15.5 \pm 0.13)	M-R
<i>S. multicaulis</i> Boiss.	Ob-Sp	0.90	16.5-17.5 (16.48 \pm 0.22)	15.5-20 (18.31 \pm 0.26)	12.5-17.25 (14.03 \pm 0.33)	M-R
<i>S. edelbergii</i> Rech.f.	Ob-Sp	0.90	15-17.5 (16.3 \pm 0.25)	16.25-22.5 (17.9 \pm 0.25)	12.5-17.5 (14.47 \pm 0.36)	C-R
<i>S. chamaedrifolia</i> Hedge et Paton	Pr-Sp	1.02	17.5-25.25 (18.5 \pm 0.42)	17.5-20 (18.03 \pm 0.2)	15-20 (17.12 \pm 0.39)	C-R
<i>S. prostrata</i> Jacq ex Benth.	Pr-Sp	1.02	17.5-35 (21.0 \pm 0.94)	17.5-22.5 (20.5 \pm 0.48)	15-20 (17.66 \pm 0.49)	C-R
<i>S. lacei</i> Hedge et Paton	Ob-Sp	0.97	12.5-18.7 (17.6 \pm 0.28)	16.2-19.7 (17.92 \pm 0.18)	12.7-17.5 (15.02 \pm 0.36)	M-R
<i>S. heydei</i> Hook.f.	Pr-Sp	1.01	22.5-25 (23.5 \pm 0.36)	22.0-26.25 (23.7 \pm 0.69)	18.75-22.5 (20.62 \pm 0.42)	C-R
<i>S. stocksii</i> Boiss.	Pr-Sp	1.02	17.5-20.5 (19.16 \pm 0.29)	16.25-20.25 (18.7 \pm 0.39)	15.2-11.75 (16.78 \pm 0.28)	M-R
<i>Phlomis stewartii</i> Hook.f.	Ob-Sp	0.96	15-35 (30.5 \pm 1.78)	28.75-33.75 (31.7 \pm 0.84)	25-30.25 (28.36 \pm 0.95)	M-R
<i>P. bracteosa</i> Roylia ex Benth.	Sub-Pr	1.17	22.5-37.5 (33.47 \pm 0.52)	20-32.51 (28.47 \pm 0.68)	20-35 (32.04 \pm 3.32)	F-R
<i>Craniotome furcata</i> (Link.) O. Kuntze	Sub-Pr	1.14	19.7-22.5 (21.0 \pm 0.25)	14.5-19.75 (18.40 \pm 1.37)	16.3-20 (18.28 \pm 0.33)	R

Table 5. General pollen characters of species found in pollen type *Stachys parviflora*.

Name of taxa	Shape	P/E ratio	Polar length (P) µm	Equatorial length (L) µm	Tectum type
<i>Ajuga bracteosa</i> Wall. ex Benth.	Pr	1.35	31.5-36.25 (34.05 ± 0.44)	21.2-30 (25.04 ± 0.58)	F-R
<i>A. parviflora</i> Benth.	Ob-Sp	0.914	22.5-30.2 (26.6 ± 0.75)	20-35 (29.36 ± 1.23)	R-Rug
<i>Stachys flocosa</i> Benth.	Pr-Sp	1.05	22.5-26.25 (24.8 ± 0.22)	20-25 (23.61 ± 23.6)	M-R
<i>S. parviflora</i> Benth.	Ob-Sp	0.94	25-30.25 (27.5 ± 0.41)	25.1-31.25 (29.30 ± 0.37)	M-R
<i>S. tibetica</i> Vatke	Pr-Sp	1.01	25-27.5 (25.59 ± 0.19)	25-28.25 (25.39 ± 0.13)	Rug

I: *Elsholtzia densa* – type (Fig. 1. A, B).

Pollen class: 6-colpate, 6-zonocolpate.

P/E ratio: 0.91

Aperture: Ectoaperture-colpus not sunken long margin irregular, end acute Endoaperture: absent.

Exine: Sexine thicker than nexine.

Ornamentation: Tectum psilate.

Outline: Equatorial view elliptic, polar view oblate, 6-lobed.

Measurements: Polar axis (P) 15 (18.75±1.25) 21.25 μm , colpus length 7.5 (15.3±0.31) 16.25 μm , colpal membrane granulated, mesocolpium 5 (5.4±0.61) μm , P.A.I. 3.73.

Species included: *Elsholtzia densa* Lab.

II: *Marrubium marrubiastrum* - type (Fig. 1. C, D).

Pollen class: 3-colpate, trizonocolpate.

P/E ratio: 0.93-1.20.

Aperture: Ectoaperture-colpus long, sunken, narrow, end acute, endoaperture absent.

Exine: Sexine thinner or thicker than sexine or as thick as nexine.

Ornamentation: Rugulate-reticulate or fossulate-foveolate.

Outline: Equatorial view elliptic, pole side slightly rounded, polar view trilobed, with aperture on the angles of the outline of the grain in polar view.

Measurements: Polar axis (P) 22.5 (43.1 ± 0.61) 41.2 μm , equatorial diameter (E) 22.5 (40.6 ± 0.1) 36.25 μm , mesocolpium 1.25 (20. ± 0.12) 27.5 μm , colpus 17.5 (36.7 ± 0.25) 37.5 μm , apocolpium 1.5 (2.75 ± 0.11) 2.5 μm , exine 1.25 (3 ± 0.37) 3.5 μm thick.

Species included: *Marrubium marrubiastrum* (Steph.) Hedge, *M. anisodon* C. Koch., *Phlomis cashmeriana* Royle ex Benth., *Ostostegia aucheri* Boiss and *Teucrium royleanum* Wall. ex Benth.

Key to the species

1. + Pollen grains sub-prolate *Phlomis cashmerianum*
 - Pollen grains oblate-spheroidal to prolate-spheroidal 2
2. + Tectum reticulate-rugulate *Ostostegia aucheri*
 - Tectum fossulate-foveolate 3
3. + Pollen grains prolate-spheroidal *Marrubium marrubiastrum*
 - Pollen grains oblate-spheroidal *Marrubium anisodon*

III: *Nepeta laevigata* – type (Fig. 1. E, F; Fig. 2 A-F; Fig. 3. A-D).

Pollen class: 6-colpate, 6-zonocolpate.

P/E ratio: 1.01-1.29

Shape: Prolate-spheroidal to sub-prolate.

Aperture: Ectoaperture-colpus not sunken, long margin irregular, end acute, endoaperture absent.

Exine: Sexine thicker or thinner than nexine or as thick as nexine.

Ornamentation: Tectum medium coarsely reticulate, with regular or irregular pattern of muri, lumina 0.1-1.33 μm in diameter.

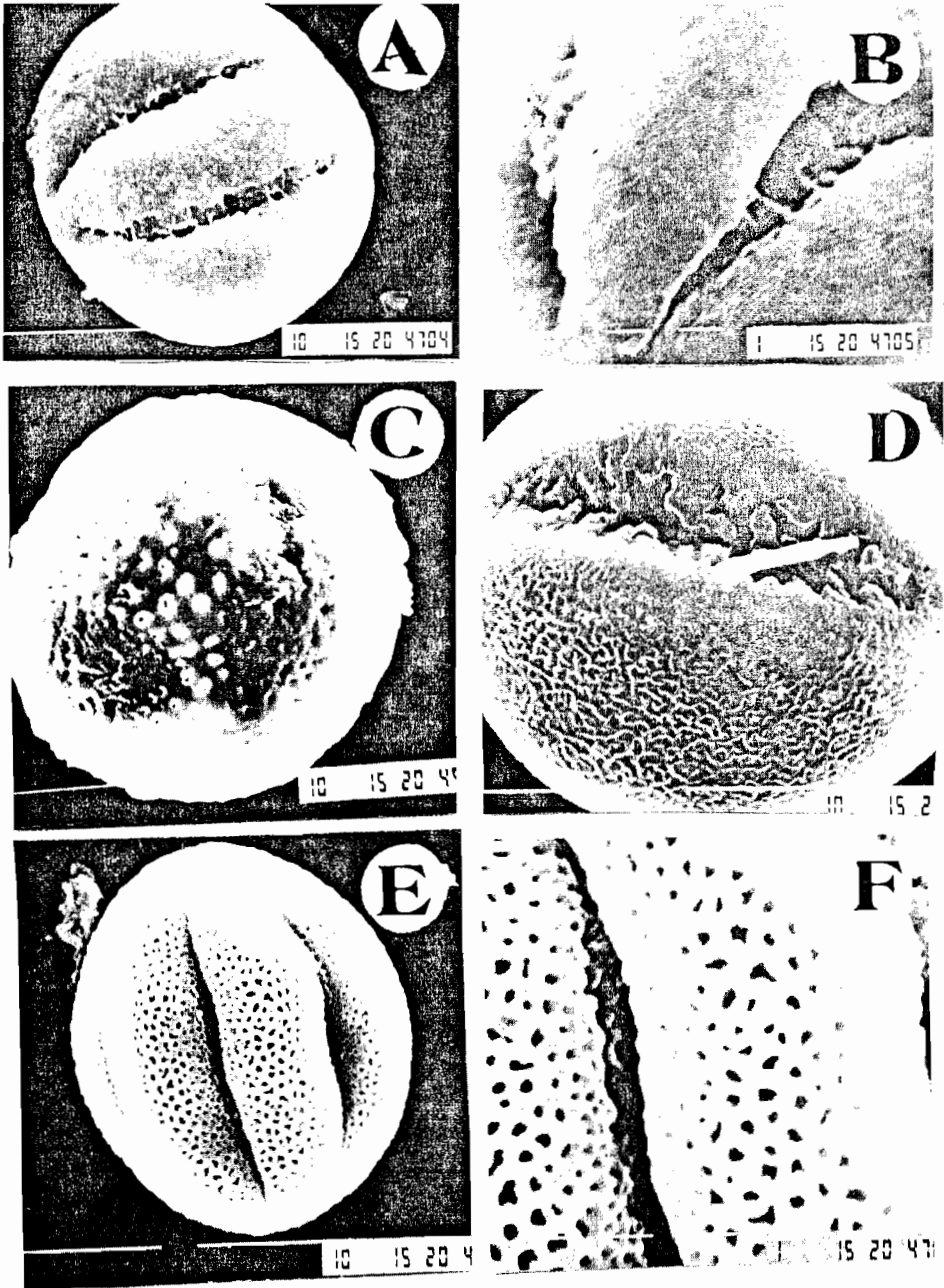


Fig. 1. Scanning micrographs: *Elsholtzia densa*: A. Pollen grains; B. Exine pattern. *Phlomis cashmeriana*: C. Equatorial view, D. equatorial view. *Mentha longifolia*: E. equatorial view; F. Exine pattern. (Scale bar = A, C, D & E = 10 μ m; B & F= 1 μ m).

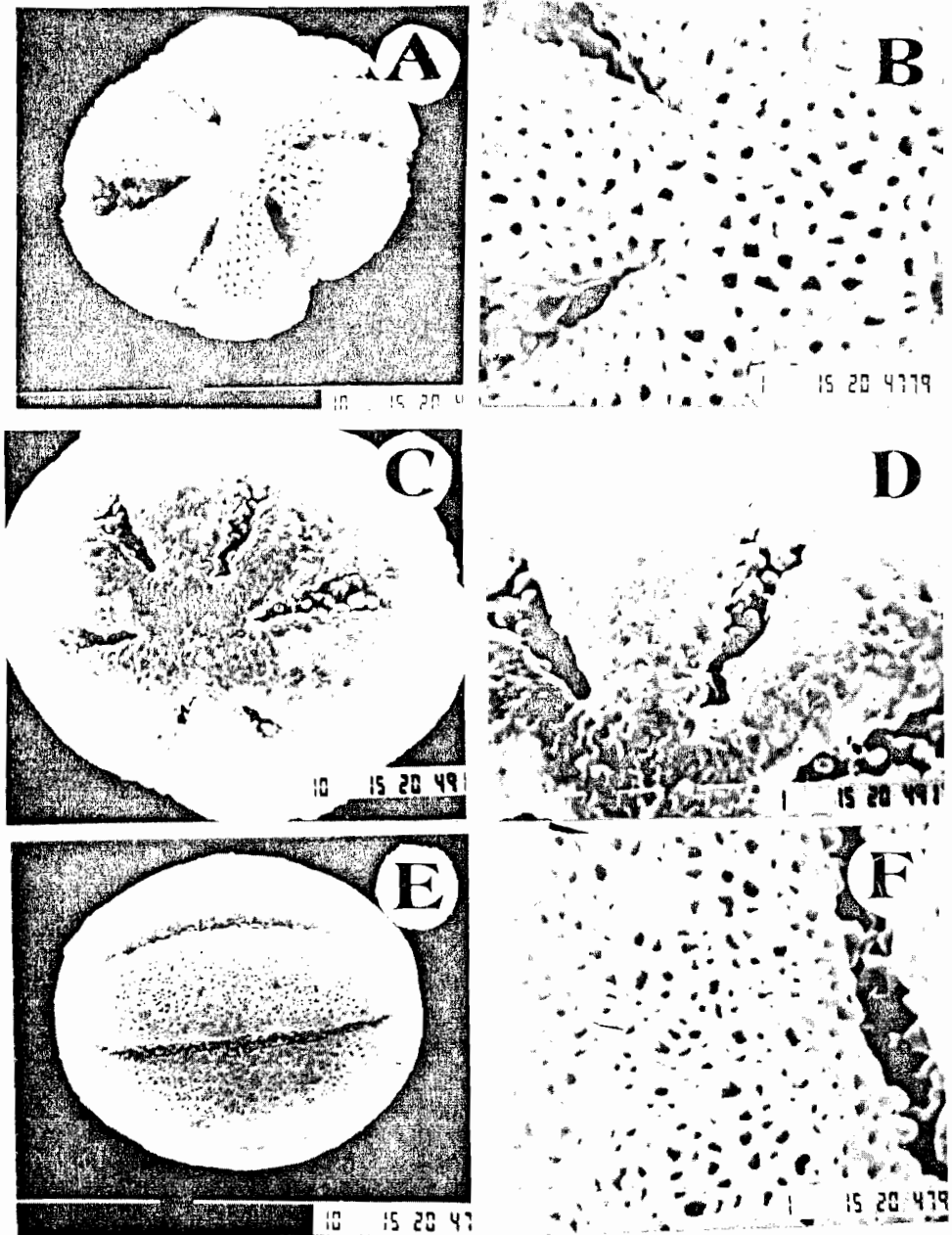


Fig. 2. Scanning micrographs: *Mentha royleana*: A. Pollen grains; B. Exine pattern. *Nepeta flaccosa*: C. polar view, D. exine pattern. *N. glutinosa*: E. equatorial view; F. Exine pattern. (Scale bar = A, C, E = 10 μ m; B, D & F = 1 μ m).

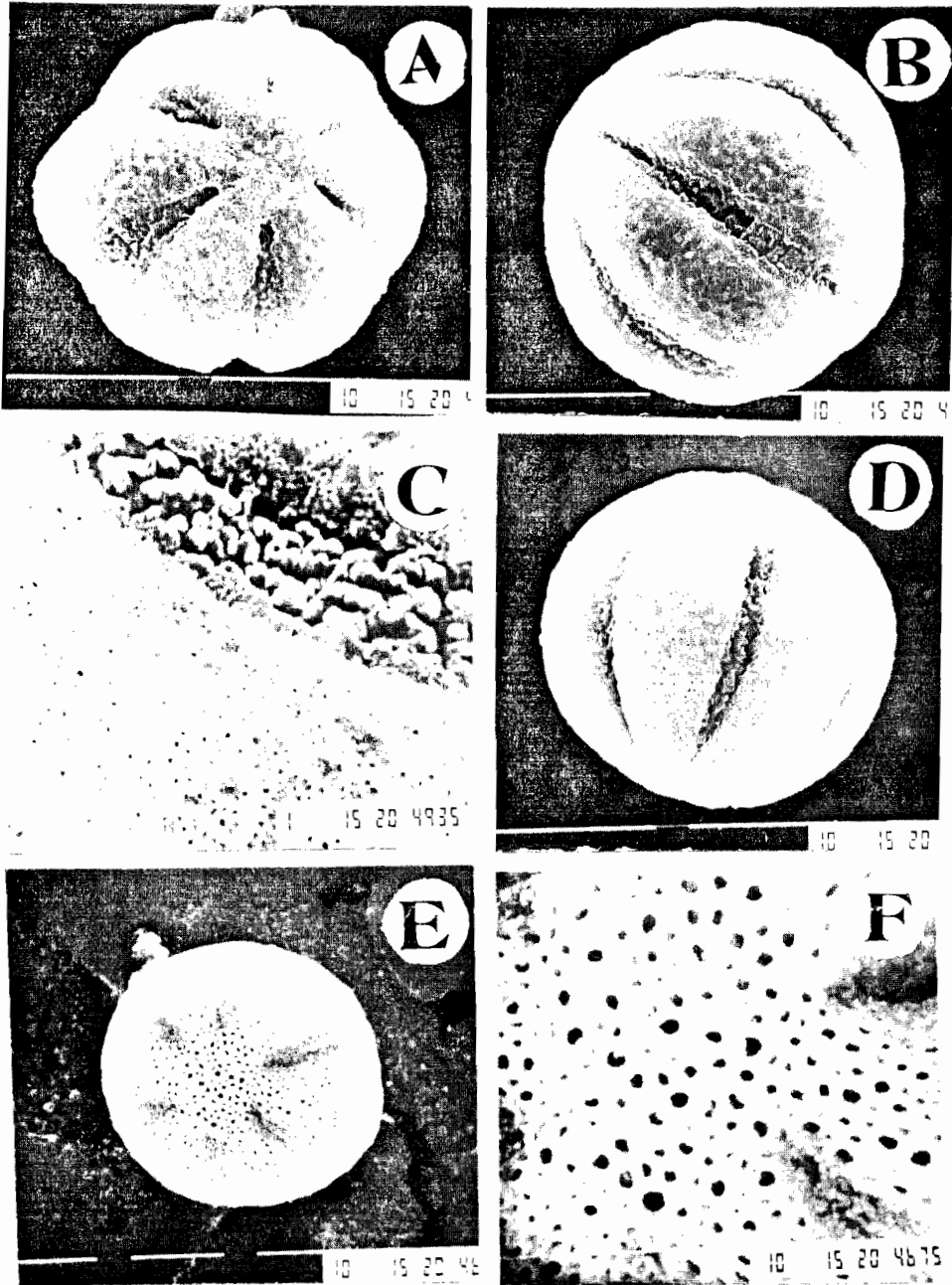


Fig. 3. Scanning micrographs: *Nepeta hindostana*: A. Polar view; B. Equatorial view; C. Exine pattern. *N. distans*: D. Equatorial view, *Calamintha hydaspidis*: E. equatorial view; F. Exine pattern. (Scale bar = A, B, D-F = 10 μ m; C = 1 μ m).

Outline: Equatorial view elliptic, polar view oblate, 6-lobed.

Measurements: Polar axis (P) 12 (29.5±1.25) 47.5 µm, colpus length 17.5 (30±0.31) 42.5 µm, colpal membrane granulated, mesocolpium 7.5 (12.5±1.11) µm, apocolpium 2.5 (5±0.11) 7.5 µm, exine 0.5(1.37±1.11) 2.25, P.A.I. 3.23.

Species included: *Micromeria biflora*, *Mentha longifolia* *M. royleana*, *M. spicata*, *Nepeta paulesnii*, *Nepeta leucolaena*, *N. griffithii*, *N. distans*, *N. hindostana*, *N. saturooides*, *N. glutinosa*, *N. raphanorhiza*, *N. paucifolia*, *N. laevigata*, *N. nervosa*, *N. connata*, *N. linearis*, *N. govaniana*, *N. erecta*, *N. clarkei*, *N. flaccosa*, *N. cataria*, *Phlomis spectabilis*, *Prunella vulgaris*, *Salvia hains* and *Ziziphora tenuior*.

Key to the species and species groups

1. + Pollen sub-prolate subtype- *Mentha royleana*
 (*Micromeria biflora*, *Mentha royleana*, *Nepeta paulesnii*)
 - Pollen grain prolate-spheroidal 2
2. + Tectum medium reticulate *Mentha longifolia*
 - Tectum coarsely reticulate subtype *Phlomis spectabilis* (*Nepeta leucolaena*, *N. griffithii*, *N. distans*, *N. hindostana*, *N. saturooides*, *Prunella vulgaris*, *Salvia hains*, *Ziziphora tenuior*, *Mentha spicata*, *N. glutinosa*, *N. raphanorhiza*, *N. paucifolia*, *N. laevigata*, *N. nervosa*, *N. connata*, *N. linearis*, *N. govaniana*, *N. erecta*, *N. clarkii*, *N. flaccosa*, *N. cataria*)

IV: *Salvia aegyptiaca* – type (Fig. 2. E, F; Fig. 4 A-F; Fig. 5. A-F; Fig. 6. A-D).

Pollen class: 6-colpate, 6-zonocolpate.

P/E ratio: 0.85-1.01.

Shape: Oblate-spheroidal to sub-oblate

Aperture: Ectoaperture-colpus not sunken, long margin irregular, end acute, endoaperture absent.

Exine: Sexine thicker or thinner than nexine.

Ornamentation: Tectum finely to coarsely reticulate, lumina more or less regular pattern of muri 0.01-1.6 µm in diameter, often striate.

Outline: Equatorial view elliptic, polar view oblate, 6-lobed.

Measurements: Polar axis (P) 17.5 (31.25 ± 1.25) 45.2 µm, colpus length 15.25 (32.6 ± 0.31) 50.25 µm long, colpal membrane granulated, mesocolpium 7.5 (20 ± 1.61) 32.5 µm, apocolpium 0.75 (6.66 ± 1.43) 12.5 µm, exine 0.25 (1.25 ± 1.11) 2.25 µm, thick, P.A.I. 3.73.

Species included: *Calamintha hydaspidis*, *Clinopodium umbrosum*, *C. vulgare*, *Dracocephalum stamineum*, *Elsholtzia ciliata*, *Isodon coetsa*, *I. rugosus*, *Marrubium vulgare*, *Melissa officinalis* *Nepeta eriosphaera*, *N. podostachys*, *N. bracteata*, *Ocimum americanum*, *Origanum vulgare*, *Salvia bucharia*, *S. plebeia*, *S. lanata*, *S. macrosiphon*, *S. moorcroftiana*, *S. aegyptiaca*, *S. nubicola*, *Thymus linearis*, *Perovskia atriplicifolia* and *Ziziphora clinopodioides*.

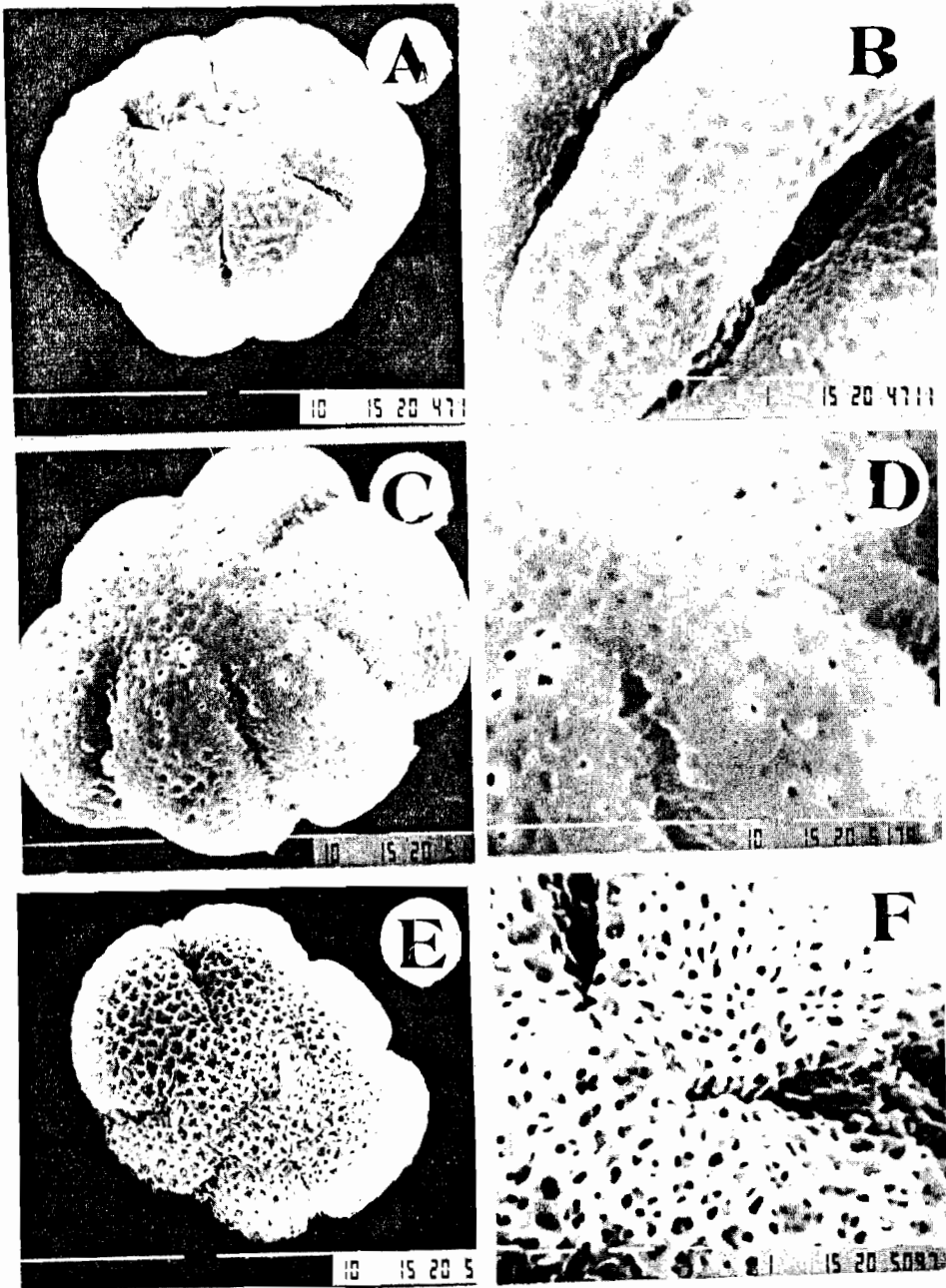


Fig. 4. Scanning micrographs: *Elsholtzia ciliata*: A. Polar view; B. Exine pattern. *Perovskia atriplicifolia*: C. Polar view; D. Exine pattern. *Salvia plebeia*: E. Polar view; F. Exine pattern. (Scale bar = A, C, D & E = 10 μ m; B & F = 1 μ m).

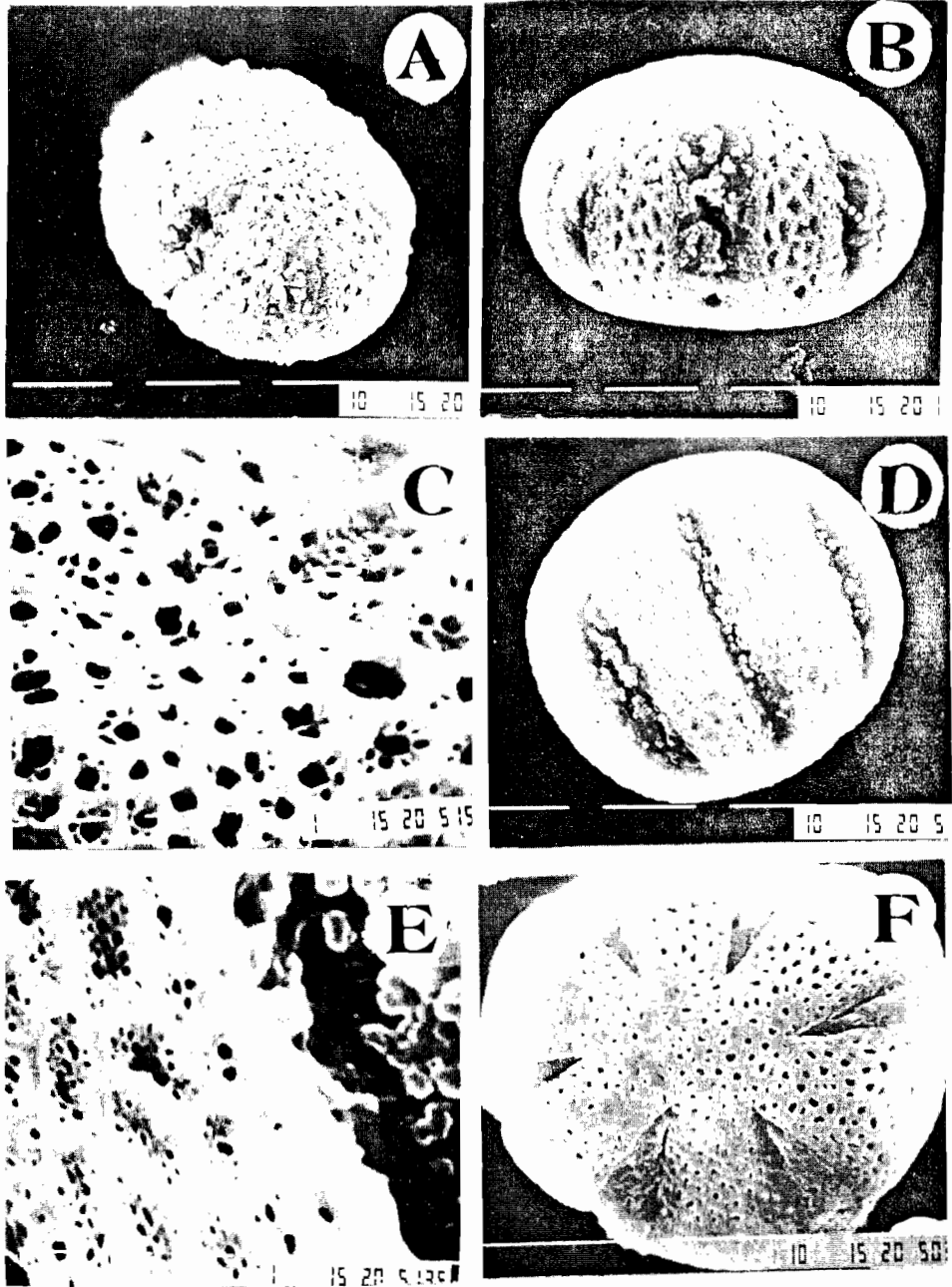


Fig. 5. Scanning micrographs: *Salvia macrosiphon*: A. Polar view; B. Equatorial view; C. Exine pattern. *S. moorcroftiana*: D. Equatorial view; E. Exine pattern. *Perovskia atriplicifolia*: F. Polar view. (Scale bar = A, B, D & F = 10 μm ; C, E = 1 μm).

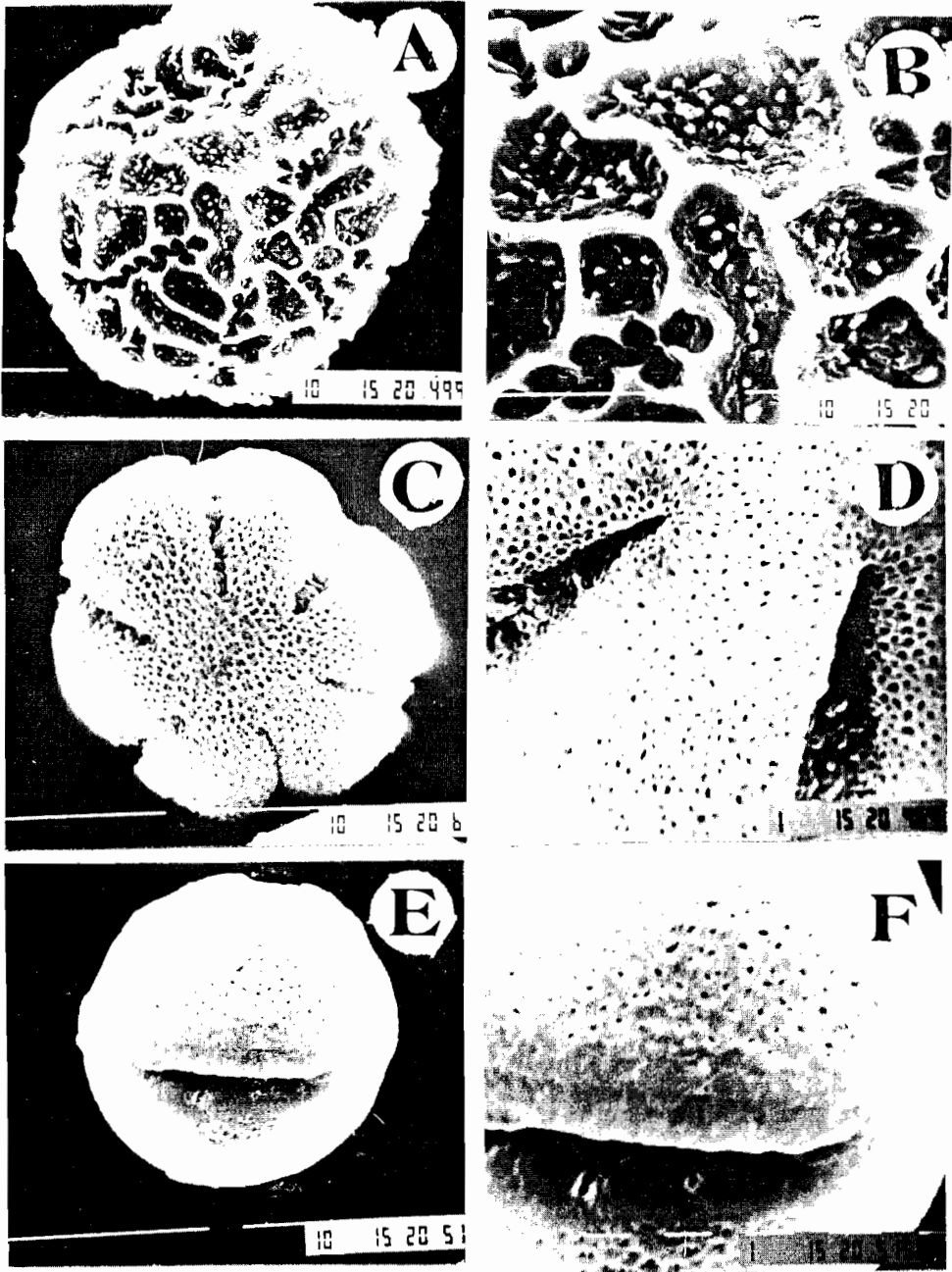


Fig. 6. Scanning micrographs: *Ocimum tenuiflorum*: A. Polar view; B. Exine pattern. *Ziziphora clinopodioides*: C. Polar view; D. Exine pattern. *Scutellaria lacei*: E. Equatorial view; F. Exine pattern. (Scale bar = A-C & E = 10 μ m; D & F = 1 μ m).

Key to the species and species groups

1. + Tectum striate *Nepeta eriosphaera*
 - Tectum finely to coarsely reticulate 2
2. + Tectum finely reticulate *Clinopodium umbrosum*
 - Tectum medium-coarsely reticulate 3
3. + Tectum medium reticulate subtype-
Perovskia atriplicifolia (*Salvia nubicola*, *Perovskia atriplicifolia*, *Ziziphora clinopodioides*, *Melissa officinalis*, *Calamintha hydaspidis*, *Organum vulgare*)
 - Tectum coarsely reticulate subtype – *Isodon coetsa* (*Marrubium vulgare*, *Nepeta podostachys*, *N. bracteata*, *Dracocephalum stamineum*, *S. bucharia*, *S. plebeia*, *S. lanata*, *S. macrosiphon*, *S. moorcroftiana*, *S. aegyptiaca*, *Thymus linearis*, *Elsholtzia ciliata*, *Isodon coetsa*, *Ocimum tenuiflorum*, *Clinopodium vulgare* and *Isodon rugosus*)

V: *Scutellaria prostrata* type (Fig. 6. E, F; Fig. 7. A, B).

Pollen class: 3-zonocolpate.

P/E ratio: 0.9-1.22.

Apertures: Ectoapertures-colpus long, sunken, narrow, margins sub-psilate end actue endoaperture absent.

Exine: Sexine thicker or thinner than nexine.

Ornamentation: Tectum medium, coarsely reticulate with regular or irregular pattern of muri, lumena, 0.1-1 μm in diameter, perforations 0.016-0.3 μm in diameter.

Outline: Equatorial view elliptic, isopolar, polar view trilobed with aperture on the angles of the outline of the grains in polar view.

Measurements: Polar axis (P) 15 (26.2 \pm 0.22) 33.7 μm , colpus length 12.5 (17.4 \pm 0.11) 22.5 μm , mesocolpium 10 (22.5 \pm 0.11) 22.5 μm , apocolpium 0.25-2.55 μm , exine 0.2 (1.22 \pm 0.11) 2.25 μm thick.

Species included: *Craniotome furcata* (Link) O. Kuntze., *Scutellaria grossa* Wall ex Benth., *S. petiolata* Hemsley et Lacey., *S. linearis* Benth., *S. multicaulis* Boiss. *S. edelbergii* Rechii., *S. chamaedrifolia* Hedge et Paton, *S. prostrata* Jacq., ex Benth., *S. lacei* Hedge et Paton, *S. hedyei* Hook. J., *S. stocksii* Boiss., *Phlomis stewartii* Hook. J., *P. bracteosa* Royle ex Benth.

VI: *Stachys parviflora* type (Fig. 7. C, D).

Pollen class: 3-zonocolporate.

P/E ratio: 0.01-1.35.

Apertures: Ectoaperture-colpus not sunken, long, narrow, margin irregular, end acute. Endoaperture oval circular or la-longate.

Exine: Sexine thicker than nexine or slightly thinner than nexine.

Ornamentation: Tectum finely, medium, reticulate, rarely reticulate-rugulate.

Outline: Equatorial view elliptic, pole side rounded, polar view trilobed, with apertures on the angles of the outline of the grain in polar view.

Measurements: Polar axis (P) 22.5 (29.2 \pm 0.11) 36 μm , equatorial view 20 (27.5 \pm 0.12) 35 μm , P/E ratio: 0.91-1.35, colpus length 17.5 (26.2 \pm 0.11) 35 μm , mesocolpium 12.5 (16.5 \pm 1.1) 19.5 μm , apocolpium 0.2 (2.61 \pm 0.11) 5 μm , exine 1.25 (17.5 \pm 0.2) 2.25 μm thick.

Species included: *Ajuga parviflora* Benth., *A. bracteosa* Wall ex Benth., *Stachys floccosa* Benth., *S. tibetica* Vatke. *S. parviflora* Benth.

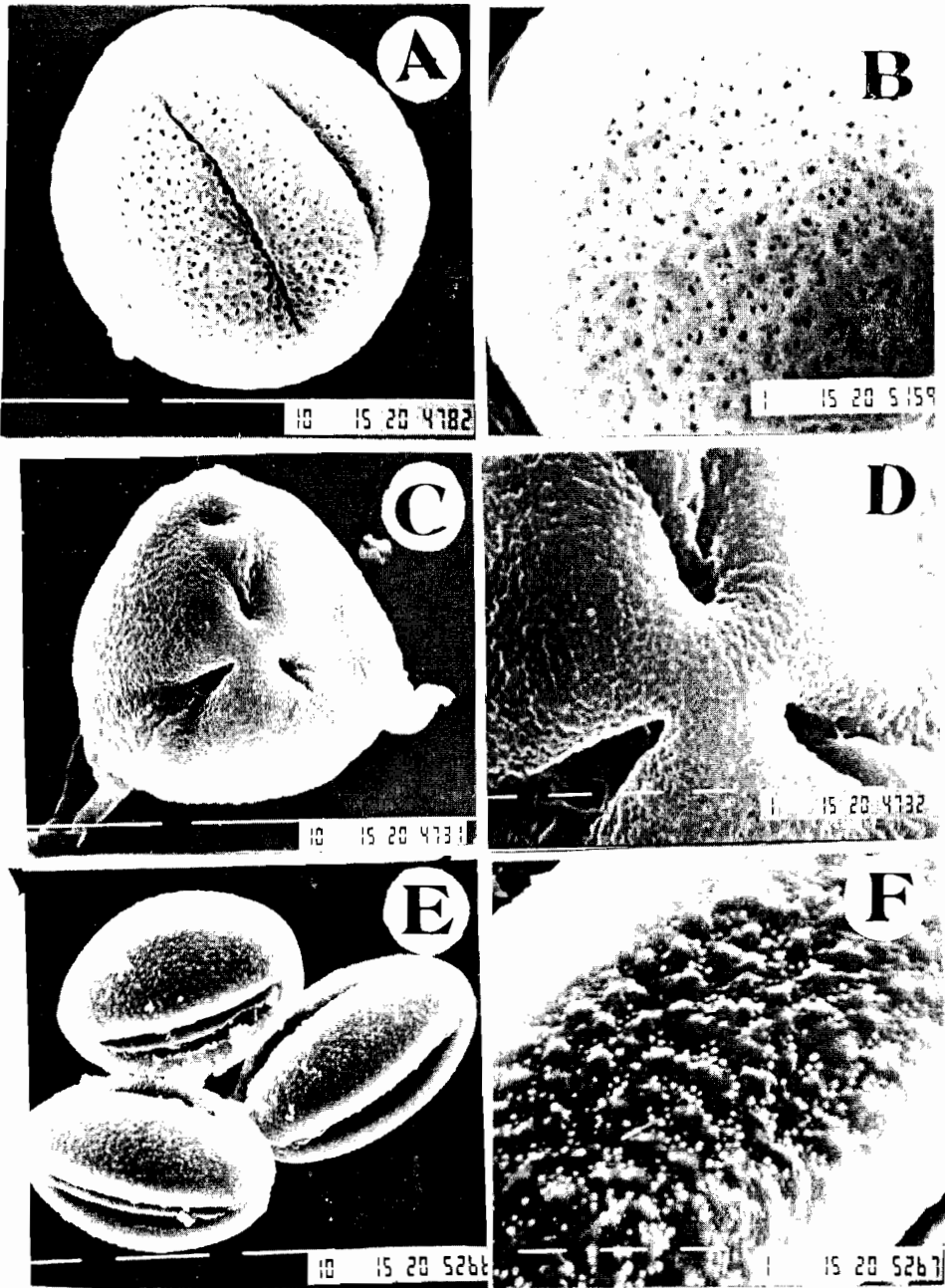


Fig. 7. Scanning micrographs: *Scutellaria multicaulis*: A. Polar view; B. Exine pattern. *Ajuga breacteosa*: C. Polar view; D. Exine pattern: *Teucrium scordium*: E. Equatorial view; F. Exine pattern. (Scale bar = A, C & E = 10 μ m; B, D & F = 1 μ m).

Key to the species and groups

- 1. + Pollen grains sub-prolate 2
- Pollen grains oblate-spheroidal to prolate-spheroidal 3
- 2. + Colpi 20.35 μm long, polar length 22.5- 37.5 μm *Phlomis bracteosa*
- Colpi 15.3-20 μm long, polar length 17.7-22.5 μm *Cranitome furcata*-group (*Cranitome furcata*, *Scutellaria grossa*, *S. petiolate*)
- 3. + Pollen grains oblate-spheroidal 4
- Pollen grains prolate-spheroidal 6
- 4. + Polar length 25-35 μm *Phlomis stewartii*
- Polar length 12.5-18.7 μm 5
- 5. + Tectum coarsely reticulate *Scutellaria edelbergii*
- Tectum medium-reticulate *Scutellaria multicaulis*-group (*Scutellaria multicaulis*, *S. lacei*)
- 6. + Tectum coarsely reticulate *S. chamaedrifolia*
- Tectum medium reticulate *Scutellaria linearis*-group (*Scutellaria linearis*, *S. stocksii*)

Key to the species and groups of *Stachys parviflora*-type

- 1. + Pollen prolate-spheroidal to prolate 2
- Pollen oblate-spheroidal 3
- 2. + Polar length of pollen grain 31-37 μm *Ajuga bracteosa*
- Polar length 22-26.23 μm *Stachys floccosa*
- 3. + Tectum medium reticulate-rugulate *Ajuga parviflora*
- Tectum medium reticulate *Stachys parviflora*

VII: *Teucrium scordium* – type (Fig. 7. E, F).

Pollen class: 3-zonocolpate.

P/E ratio: 1.26

Apertures: Ectoapertures-colpus long, sunken, narrow, margins sub-psilate, end actue, endoaperture absent.

Exine: Sexine thicker than nexine.

Ornamentation: Tectum verrucate with fine scabrae.

Outline: Equatorial view elliptic, isopolar, polar view trilobed with aperture on the angles of the outline of the grains.

Measurements: Polar axis (P) 27 (31.2 \pm 0.22) 47.7 μm , colpus length 22.5 (25.4 \pm 1.07) 30 μm , mesocolpium 18 (20.0 \pm 0.49) 2255 μm , apocolpium 1.25 (1.75 \pm 0.18) 2.5 μm , exine 1.25 (1.88 \pm 0.08) 2.25 μm thick.

Species included: *Teucrium scordium*

Discussion

Labiatae is an eurypalynous family (Erdtman, 1952). Pollen grains are usually radially symmetrical, isopolar, oblate-spheroidal to prolate-spheroidal or sub-prolate to sub-oblate. Mostly colpate (colpi 3-6) rarely colporate, colpal membrane finely-coarsely granulated. Tectum is mostly reticulate (coarse-fine). In addition to this, various grades of rugulate-reticulate, fossulate-rugulate often sub-psilate or striate tectum are also found. However, colpate pollen with reticulate tectum are more frequently found within the family. Most striking variation is found in the shape, apertural types and tectal surface. On the basis of shape, aperture and tectum types 7 distinct pollen types viz. *Elsholtzia densa* type, *Marrubium marrubiastrum* - type, *Scutellaria prostrata* - type, *Stachys parviflora* type, *Nepeta laevigata* - type *Salvia aegyptiaca* - type and *Teucrium scordium* - type are recognized. Pollen type-I: *Elsholtzia densa* - type is characterized by its subpsilate tectum. Only one species is included in this pollen type (*Elsholtzia densa*). Pollen type - II: *Marrubium marrubiastrum* is recognized by its 3-colpate pollen with reticulate-rugulate tectum. It comprises of 4 species, this pollen type is further divided into subtypes on the basis of tectal types and shape class (see key to the species). Pollen type-III *Nepeta laevigata* is easily delimited by having 6-colpate pollen with prolate-spheroidal to sub-prolate pollen. It comprises of 25 species, distributed in 7 genera belonging to subfamily Lamioideae. Although, the species of this pollen type are fairly uniform in their pollen character but on the basis of pollen shape these species can be divided into two subtypes viz. *Nepeta griffithii* - subtype (Prolate-spheroidal) and *Mentha reyleana* - subtype (sub-prolate pollen), (see Account of pollen types). Pollen grains of *Nepeta laevigata* - type closely resemble to *Salvia aegyptica* - type. But the latter type differs in shape.

Pollen type - IV: *Salvia aegyptiaca* is characterized by 6-colpate with oblate-spheroidal to sub-oblate pollen. Majority of the species i.e., 27 species are distributed in 12 genera belonging to two subfamilies i.e., Lamioideae and Ocimoideae (*Ocimum*). This pollen type is quite similar and it is very difficult to characterize the genera and species on the basis of pollen characters. However, these characters are significant enough to separate into two subtypes i.e. subtype - *Perovskia atriplicifolia* and subtype - *Isodon coetsa*. *Perovskia atriplicifolia* - subtype is characterized by fine-medium reticulate tectum this subtype includes: *Perovskia atriplicifolia*., *Salvia nubicola* *Ziziphora clinopodioides*, *Melissa officinalis*, *Calamintha hydaspidis*, *Organum vulgare*. In Subtype *Isodon coetsa* tectum is coarsely reticulate. It comprises of 17 species such as, *Marrubium vulgare*, *Nepeta podostachys*, *N. bracteata*, *Dracocephalum stamineum*, *S. bucharia*, *S. plebeia*, *S. lanata*, *S. macrosiphon*, *S. moorcroftiana*, *S. aegyptiaca*, *Thymus linearis*, *Elsholtzia ciliata*, *Isodon coetsa*, *Ocium tenuiflorum*, *Clinopodium umbrosum*, *C. vulgare* and *Isodon rugosus* (see key to the species and species groups).

Scutellaria prostrata - type is easily delimited by its 3-colpate pollen with reticulate tectum. 12 species are included belonging to subfamily Scutellarioideae and few species from subfamily Lamioideae (*Craniotome furcata* (Link) O. Kuntze, *Phlomis stewartii* Hook. J., *P. bracteosa* Royle ex Benth.). These species are further divided on the basis of pollen shape, pollen size, colpi length (see key to the species).

Pollen type - VI: *Stachys parviflora* is recognized by its 3-colporate. Two genera are included namely *Ajuga* and *Stachys* with reticulate-rugulate tectum 4 species are included in this pollen type, these species are further divided on the basis of tectal types and shape class (see key to the species). Pollen type-VII: *Teucrium scordium* - type is characterized

by its verrucate tectum. Only single species is included in this pollen type (*Tecurium scordium*). With a few exception most of the genera belonging to different tribes and subtribes fall with in the same pollen type, likewise the species of the same genus are also distributed in two or even three different pollen types. For instance *Nepeta* species are accommodated in *Nepeta laevigata* type and *Salvia aegyptiaca* type, similarly species of *Phlomis* are placed in three different pollen types- *Nepeta laevigata* pollen type, *Scutellaria prostrata* pollen type and *Marrubium marubiastrum* pollen type. It is therefore evident from the foregoing discussion that the pollen types do not correspond with the infrafamilial classification. Similar observations have also been made by Nabli (1976), Bennel (1983) while dealing with the pollen morphology of different genera of Labiatae. However, on the other hand pollen characters tend to be of more value not only in grouping the species but also in their delimitation, for instance several *Nepeta* and *Salvia* species can be delimited on the basis of pollen characters. It is therefore concluded that the pollen morphology in Labiatae plays a significant role in species grouping and identification rather than establishing affinities between genera and tribes.

Acknowledgement

Financial support provided by the National Scientific Research Development Board (NSRDB), University Grants Commission, Pakistan is gratefully acknowledged. We are also grateful to the Director of M.A.H. Qadri, Biological Research Centre, University of Karachi for providing facilities of scanning electron microscope.

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