POLLEN MORPHOLOGY AND THEIR TAXONOMIC SIGNIFICANCE IN SOME VERBENACEAE

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Abstract

The pollen morphology of 30 species belonging to 16 genera in Verbenaceae is described with a note on its taxonomic significance. The Verbenanceae is an eurypalynous one and shows an array of pollen types differing in nature, number and complexity of apertures and exine ornamentation. These variations are of considerable systematic value. In general, the pollen grains in the family are solitary, 3-zonocolpate or 3-Zonocolporate but dicolpate in *Avicennia, Citharexylvm, Gmelina, Lantana, Petera, Tectona*, or tetracolpate in *Citharexylum, Gmelina, Lantana, Tectona* and *Clerodendrum* or hexacolpate in *Stachytarpheta* have also been encountered.

The grains are -3-zonocolpate in *Clerodendrum, Duranta, Holms-kioldia, Petrea, Premna, Stachytarpheta, Tectona* and *Vitex*; 3-Zonocolporate with faintly-developed endoapertures in *Callicarpa* and *Gmelina* but with distinct lalongate endoapertures in *Avicennia, Citharexylum, Lantana, Phyla, Priva* and *Verbena*.

Although the pollen morphology of Verbenaceae tends to be of a rather diversified type, a number of general evolutionary trends can be recognized: (i) colpate to colporate grains, (ii) small to large size grains, (iii) smooth exine to one with ornamentations, and (iv) spherical to angular forms. Pollen morphology of *Avicennia* supports the inclusion of the genus within Verbenaceae rather than separating it.

Introduction

Verbenaceae is predominantly a tropical family of woody, shrubby, herbaceous and lianas taxa comprizing 75 genera with over 3,000 species (Heywood, 1978) including indigenous and introduced, wild and cultivated. There is a considerable disagreement on the circumscription and delimitation of different taxa at different levels of taxonomic hierarchy and the infrafamilial groupings, within the family. The present work was therefore undertaken to observe the diversity in pollen morphology of different taxa and utilize in refining the circumscription and delimitation of different taxa.

Few studies on Verbenaceae pollen morphology have been completed and those that are available provide descriptions of very few species (Eradtman, 1952; Nair & Rehman, 1962; Rao & Shukla, 1975; Parabia, 1977, Saxena, 1981). In these studies light microscopy was used. Thus to provide detailed and additional information on the pollen morphology and Verbenaceae both light and scanning electron microscopy have been used in the present paper.

Material and Methods

The taxa investigated are listed in Table 1. Voucher materials are deposited in the herbarium of the department of Biosciences, Sardar Patel University, Vallabh Vidyanagar, Gujarat.

Pollen grains were collected from mature anthers of unopened buds to minimize variations, or from herbarium specimens and fixed in glacial acetic acid. Pollen for light micro-

Table 1—Summary of selected pollen

(PE-Prolate, PESP-Prolate spheroidal, SPE-Subprolate, OE-Oblate, OESP-Oblate spheroidal, POE-Perob- bleshwar, Y-Yercadu, GE-Seeds from Germany,

Taxa	Source	Size range (μm)	Size class	Shape Class % (P/E)	Polar view across (μm)
Avicennia Marina (Forsk) Vierh.	G.	12.48—30.16 × 14.56.29.12	ME	PESP (80%) SPE (10%) OE (10%)	18.72—29.12
A. officinalis L.	K.	14.56—30.16 × 19.76—29.12	ME	POE (28.5%) PESP (57.2%) SPE (14.3%)	20.8—29.12
Callicarpa tomentosa (L. Murr.)	M.	30.16—36.4 × 30.16—35.3	ME	OESP (33.3%) PESP (66.7%)	31.2—35.2
Citharexylum subserratum SW.	G.	20.20—29.11 × 21.84—28.60	ME	SPE—(25%) PESP—(75%)	20.2—28.2
Clerodendrum inerme (L.) Gaertn.	G.	59.28—65.52 × 57.2—64.48	LA	PESP (71.4%) SPE (14.3%), PE (14.3%)	57.2—69.68
C. multiflorum O. Ktze.	G.	58.24—63.44 × 48.53—59.28	LA	PESP—(75%) SPE (25%)	45.76—63.44
C. serratum	P.	80.08—96.72 × 79.04—96.72	LA	PESP (80%) SPE (20%)	80.08—95.68
C. indicum (L.) O. Ktze.	K.	83.6—96.72 × 82.16—16.72	LA	SPE (40%) PESP (60%)	84.24—96.72
C. splendens G. Don.	G.	57.2—70.72 × 57.2—68.2	LA	SPE (20%) PESP (80%)	57.2—69.68
C. thomsonae Balf.	K.	62.4—75.92 × 61.36—75.92	LA	PESP (60%) SPE(20%) OESP) (20)	62.4—75.92
C. *Viscosum* Vent.	G.	62.4—71.76 × 62.4—68.64	LA	PESP(60%) SPE(40%)	64.48.71.76
Duronta repens L.	G.	20.8—30.16 18.72—30.16	ME	PESP(71.4%) OESP(14.3×) SPE(14.3%)	22.0—30.16
Gmelina arborea Roxb.	G.	35.36—38.48 × 34.32—36.4	ME	PESP(80%) SPE(20%)	35.36—376.44
G. *Philippensis* Cham.	G.	37.44—41.6 × 36.44—40.56	ME	PESP(72.2%) SPE(9.1%) OESP (18.2%)	36.4—41.6

morphological features of different taxa

late. ME-Medium size. SM-Small, LA-Large, VL-Very Large.G-Gujarat, K-Kerala, P-Poona, M-Maha-
P:Polar axis, E-Equatorial axis).

Apocolpium (μm)	Mescolpium (μm)	Colpi size (μm)	Endocolpium (μm)	Sexine (μm)	Nexine (μm)	Aperture type
14.56—19.76	11.44—13.52	11.44—21.84 × 2.08—3.12	5.2—7.28 × 3.12—4.16	0.78—1.04	.0—1.56	3-Zonocolporate
8.32—11.44	7.28—9.36	12.48—16.64 × 2.08—3.12	3.12—6.2 × 2.08—3.12	1.04—2.5	1.5—2.5	,,
16.64—20.8	6.24—9.36	22.0..26.0 × 2.08—3.12	Faint	1.5—2.08	0.78—1.5	,,
13.52—16.64	5.20—7.28	17.68—22.80 × 0.78—1.04	7.28—9.36 × 0.78—7.5	1.0—1.5	0.78—.04	,,
22.88—32.24	17.68—21.84	36.4—42.64 × 2.08—3.12	—	1-04—2.08	1.5—2.08	3-Zonocolpate
22.00—29.12	13.32—17.68	28.08..37.44 × 2.08—3.12	—	1.00—1.5	1.0—1.04	,,
30.17—37.4	17.68—23.92	75..92–84.24 × 12.48—17.68	—	2.08—3.12	1.04—2.08	,,
34.32—50.6	19.76—26.0	63.44—72.8 × 6.24—9.36	—	1.04—3.12	0.52—0.78	,,
15.2—19.8	11.44—13.2	51.8—r2.6 × 4.46—6.24	—	1.5—2.08	0.78—1.04	,,
18.72—28.6	24.96.26.0	28.08—31.2 × 4.16—6.24	—	1.04—2.08	1.5—2.08	,,
24.96—37.4	20.8—28.08	56.16—65.52 × 5.2—7.28	—	1.04—2.08	0.78—1.2	,,
12.48—15.4	5.2—7.28	15.4—23.92 × 1.04—2.08	—	0.78—1.5	0.78—1.04	,,
16.64—18.72	4.16—7.28	23.92—26.0 × 2.08—3.12	faint	1.8—2.2	1.7—2.08	3-Zonocolporate
19.76—21.84	18.72..20.8	22.08—24.9 × 2.2—3.5	faint	1.0—1.5	1.04—1.5	,,

Contd.

Table 1—(*Contd.*)

1	2	3	4	5	6	7
Holmskiolida sanguinea Retz.		K.	34.2—38.32 × 33.16—36.28	ME	PESP(80%) SPE(20%)	33.16—37 44
Lantana camara var. *aculeata* (L.) Mold		G.	34.32—41.6 × 32.24—41.6	ME	PESP(83.3%) OESP(8.04%) SPE(8.3%)	35.36—39.32
L. Camara var. *hybrida* Mold		G.	32.24—38.48 × 31.2—37.44	ME	SPE(20%) PESP(80%) PESP(80%)	32.24—38.4
L. Camara var. *nivea* Bailey		G.	29.12—36.4 × 26.0—30.16	ME	PESP(66.6%) SPE(33.4%)	27.04—35.6
Petrea volubilis L.		G.	31.2—40.56 × 30.16—40.56	ME	PESP(87.5%) SPE(12.5%)	31.2—40.56
Phyla nodiflora (L.) Greene.		G.	18.6—26.0 × 15.6—25.8	SM	PESP—75% SPE—25% PE—66.7%	18.6—24.9
Premna latifolia Roxb.		K.	13.52—18.7 × 9.36—14.56	SM	EP(66.7%) PESP(33.3%)	10.4—15.6
P. tomentosa		P.	16.64—20.8 × 6.24—11.4	SM	PE(75%) PESP(25%)	8.32—10.48
Priva leptostachya		Y.	41.6—48.88 × 38.48—46.8	ME	PE(83.3%) PESP (16.7%)	39.52—45.84
Stachytarpheta indica (L.) Vahl.		G.	21.84—145.8 × 20.8—145.8	CL	PE(55.5%) SPE(33.3%) PESP(11.2%)	20.8.145.8
Tectona grandis L. F.		G.	24.96—.30.16 × 21.84—29.12	ME	PESP(88.8%) SPE(11.2%)	23.92.29.12
Verbena bipinnatifida Schau.		G.	38.48—43.68 × 30.16—34.32	ME	OESP(83.7%) PESP(16.3%)	32.2—35.6
V. bornariensis L.		GE.	36.4—41.6 × 35.36—40.56	ME	OESP(75%) PESP(25%)	33.36—39.52
V. officinalis L.		G.	37.16—35.36 × 28.08—32.24	ME	OESP(93.5%) PESP(6.5%)	28.08—33.28

Contd.

Table 1—(*Contd.*)

8	9	10	11	12	13	14
18.72—20.8	12.48—14.56	32.24—35.36 × 2.08—3.12	—	0.78—1.30	0.78—1.04	3-Zonocclpate
16.64—19.76	9.36—11.44	24.96—29.12 × 1.C9—2.08	13.48—15.6 × 1.04—3.12	0.78—1.5	1.05—1.5	3-Zonocolpate
12.48—16.64	15.6—18.7	15.6—17.6 × 1.04—3.12	10.4—13.52 × 1.6—3.12	1.04—2.08	1.04—2.08	,,
9.36—12.48	10.4—13.2	11.44—14.5 × 0.78—2.0	9.36..12.48 × 1.04—3.12	0.78—2.0	0.78—2.0	,,
20.8—27.04	29.12—33.28	18.72—22.88 × 1.04—2.08	—	0.78—2.08	1.0—2.08	,,
9.36—15.4	5.2—7.28	12.48—17.68 × 1.04—3.12	6.24—10.4 × 0.78—1.56	0.78—2.04	0.78—1.04	3-Zoncolporate
5.2—7.2	4.16—5.2	10.4—12.48 × 0.78—1.04	—	0.52—0.78	0.52—1.10	3-Zonocolpate
5.2—6.24	4.16—6.2	10.4—12.48 × 0.78—1.04	—	0.78—1.5	0.78—1.04	,,
32.24—35.48	12.48—15.6	30.16—34.32 × 1.04—3.12 2.04—3.12	8.32—11.44 ×	1.04—1.5	0.78—1.3	3-Zonocolporate
14.48—70.72	10.4..55.0	19.76—127.6 × 3.12—33.0	—	3.12—4.4	5.2—6.6	3-Zonocclpate
15.6—17.68	10.4—11.44	18.72—21.84 × 1.04—2.08	—	1.04—2.08	0.78—1.04	,,
20.8—23.92	5.2—7.28	21.63—23.92 × 1.04—3.12	10.4—12.48 × 0.78—2.0	1.04—2.08	0.78—2.0	3-Zonocolporate
24.96—27.04	11.44—13.52	28.08—31.2 × 3.12—4.16	12.48—15.6 × 1.04—2.08	0.78—2.0	1.04—2.08	,,
14.56—17.68	6.24—9.36	20.8—23.92 × 0.78—2.08	11.44—14-56 × 1.04—2.5	0.78—1.04	0.78—1.5	,,

Contd.

Table 1—(*Contd.*)

1	2	3	4	5	6	7
Vitex negundo L.		G.	29.12—31.24 × 16.64—20.8	ME	PE(66.6%) PESP(13.4) SPE(20)	20.8—24.96
V. trifolia L.		G.	23.92—26.0 × 15.6—19.76	ME	PE(85.7%) SPE(14.3%)	20.8—23.92

scopy were prepared by the standard acetolysis method outlined by Erdtman (1952). Material was subsequently mounted in glycerine jelly, observed and photographed with Carl Zeiss photomicroscope-I using Ilford 35 mm film.

For SEM study, both acetolysed and non-acetoloysed pollen grains were used and preparations were made following the procedure by Walker (1974a). The pollen grains mounted on stubs were sputter coated with gold palladium, scanned and photographed with a Cambridge Stereoscan S-4 10, using ORWO NP 22 film.

Dimensional details were obtained on Carl Zeiss microscope using micrometer and all the measurements were made under oil immersion based on an average of 30 readings. The terminology and morphological concepts adopted in the text are that of Erdtman (1952), Reitzma (1970), Nair (1974), Walker and Doyle (1975) and Moore and Webb (1978).

Description

Avicennia L.

Pl. 1, figs. 1, 2 ; Pl. 2, fig. 19

Pollen grains are solitary, isopolar, medium sized. Mostly prolate spheroidal rarely subprolate or oblate. Triangular obtuse in polar view and circular/elliptic in equatorial view. Colpi ends acute, tenuimarginate, 3-zonocolporate, rarely dicolpate, Endocolpium lalongate. Sculpturing reticulate tectate.

Callicarpa L.

Pl. 1, figs. 3, 4, ; Pl. 2, fig. 20 ; Pl. 3, fig. 21

Pollengrains solitary isopolar seldom heteropolar due to parasyncolpate condition (Pl. 1, fig. 4) 3-zonocolporate, rarely tetracolpate grains are observed. Grains are medium sized and vary in shape from oblate spheroidal to prolate spheroidal. Tricircular in polar view, circular/elliptic in equatorial view. Colpi ends acute, tenuimarginate, endocolpium faint. Exine surface reticulate tectate, muri, nonbaculate.

Citharexylum Miller

Pl. 1, fig. 5 ; Pl. 2, fig. 22

Pollen grains are solitary isopolar and medium sized with range in shape from subprolate to prolate spheroidal. Grains are circular in polar view and circular/elliptic in equatorial view 3-Zonocolporate rarely 4-zonocolpate. Colpi crassimarginate margin 1.04-2.08 μm thick. Pores with costa; endocolpium lalongate.

Table 1—(*Contd.*)

8	9	10	11	12	13	14
11.44—13.2	5.2—7.28	22.88—25.9 × 3.12—5.2	—	1.04—2.08	0.78—1.5	3-Zonocolpate
6.24—8.8	5.2—7.28	15.6—18.72 × 1.04—2.08	—	1.04—2.08	0.78—1.5	,,

Clerodendrum L.
Pl. 1, figs. 6-8 ; Pl. 3, figs. 23-26

Pollen grains solitary, isalpolar grains large and prolate spheroidal. Rarely subprolate or prolate grains are also observed. Tricircular in polar view and circular/elliptic in equatorial view. 3-Zonocolpate rarely 4-zonocolpate. Colpi fairly wide, teniumarginate in *C. inerme* and *C. multiflorum*, but crassimarginate in *C. indicum*, *C. serratum* *C. splendens*, *C. viscosum*, margin wavy and spinulose. Exine echinate but echinate tectate in *C. indicum*, *C. thomsonae* and *C. viscosum*. Interechinal area psilate except in *C. indicum* and *C. thomsonae* where it is perforate (Fig. 25).

Duranta L.
Pl. 1, fig. 9 ; Pl. 4, figs. 27, 28

Pollen grains solitary, isopolar, and medium-sized. Grains are prolate spheroidal but rarely oblate spheroidal or subprolate. Tricircular in polar view but circular/elliptic in euqatorial view 3-zonocolpate colpi, tenuimarginate. Exine perforate tectate with wavy surface (Pl. 4, fig. 28).

Gmelina L.
Pl. 1, fig. 10-12; Pl. 4, figs. 29, 30

Pollen grains solitary, isopolar, rarely heteropolar with parasyncolpate condition as in *G. philippensis*. Grains are medium sized and prolate spheroidal, rarely subprolate or oblate spheroidal. Tri-circular in polar view and circular/elliptic in equatorial view, 3-zonocolporate, seldom tetracolporate or dicolpate grains are observed. Colpi ends acute, tenuimarginate, endocolpium faint, exine reticulate semitectate, muri simplybaculate. Each lumina again form reticulation.

Holmskioldia Retz.
Pl. 2, fig. 13 ; Pl. 4, figs. 31, 32

Pollen grains solitary, isopolar and medium sized with a range in size between prolate spheroidal and subprolate. Tricircular in polar view and elliptic in equatorial view. 3-Zonocolpate, colpi tenuimarginate. Exine reticulate tectate, and each lumina again form reticulation.

Lantana L.
Pl. 2, fig. 14 ; Pl. 5, figs. 33-36

Pollen grains solitary, isopolar and medium sized. Grains are mostly prolate spheroidal rarely oblate spheroidal or subprolate. Triangular obtuse in polar view and circular/elliptic in equatorial view. 3-Zonocolporate but seldom di-or tetracolporate grains are observed. Colpi ends acute, tenuimarginate, endocolpium distinct and lalongate. Exine perforate tectate in *L. camara* var. *aculeata* faintly reticulate in *L. camara* var. *hybrida* but psilate in *L. camara* var. *nivea*.

Petrea L.
Pl. 2, fig. 15 ; Pl. 5, fig. 37

Pollen grains solitary, isopolar and medium sized with a variation in shape between prolate spheroidal and subprolate, triangular obtuse in polar view and circular/elliptic in equatorial view, 3-zonocolpate seldom dicolpate grains are observed. Colpi crassimarginate, margin 2.08-3.12 μm thick. Tenuimarginate grains are also found. Exine psilate intectate.

Phyla Lour.

Pollen grains solitary, isopolar and small sized. Shape range between prolate spheroidal to subprolate, triangular obtuse in polar view and circular/elliptic in equatorial view. 3-zonocolporate, Colpi tenuimarginate, endocolpicum lalongate and exine psilate.

Premna L. nom. cons.
Pl. 2, fig. 16

Pollen grains solitary, isopolar and small sized with the shape variation between prolate to prolate spheroidal. Tricircular in polar view and elliptic in equatorial view. 3-zonocolpate, Colpi ends acute, tenuimarginate and exine perforate tectate.
Priva Adans

Pl. 2, fig. 17

Pollen grains solitary, isopolar and medium sized with the shape ranging between prolate and prolate spheroidal. Triangular obtuse in polar view and circular/elliptic in equatorial view 3-zonocolporate. Colpi crassimarginate, margin 1.04-2.08 μm thick, endocolpium lalongate and exine psilate intectate.

Stachytarpheta Vahl. nom cons.
Pl. 5, fig. 38 ; pl. 6, figs. 39, 40

Pollen grains solitary, isolpolar, grains are very large with varying shapes, prolate, subprolate, or prolate spheroidal, circular in polar and equatorial view, 3-zonocolpate, rarely di or hexacolpate grains are also observed. Colpi crassimarginate, margin 1.08-5.5 μm thick and the thickening is due to the merging of the verrucae. Exine verrucate and verrucae are varying in size.

Tectona L. f. nom. cons.
Pl. 2, fig. 11, Pl. 6, figs. 41, 42

Pollen grains solitary, isopolar, medium sized and the shape range from prolate spheroidal to subprolate. Tricircular in polar view and circular/elliptic in equatorial view. Grains are mostly 3-zonocolpate but rarely-3-zonocolporate and tetracolpate grains are also observed. Colpi ends acute, tenuimarginate, exine reticulate, semitectate, lumen smooth and muri nonbaculate.

Verbena L.
Pl. 6, fig. 43

Pollen grains solitary, isopolar and mediu m sized. The shape vary between oblate spheroidal and prolate spheroidal Triangular obtuse in polar view and elliptic acuminate obtuse in equatorial view 3- zonocolporate. Colpi tenuimarginate with acute ends, endocolipium lalongate and exine psilate.

Vitex L.
Pl. 6, fig. 44

Pollen grains solitary, isolpolar and medium sized. They vary in shape between prolate, prolate spheroidal and sub-prolate. Tricircular in polar view and circular/elliptic in equatorial view· Grains 3- zonocolpate, Colpi ends acute, tenuimarginate and exine perforate tectate.

Discussion

The pollen morphological characters as revealed by light and scanning electron microscopy have been extensively used for solving systematic problems and for elucidating evolutionary relationships. (Walker & Doyle, 1975 ; Dickinson & Potter, 1976, Dickinson, 1979 ; Moore & Webb, 1978 ; Argue, 1980 ; Nowicke and Skavarla, 1980; Gadek Martin, 1981; James & Norris, 1981; Simpson & Skavarla, 1981). Pollen morphology of *Citharexylum subserratum*. *Clerodendrum thomsonae*, *Duranta repens*, *Lantana camara* vars. *hybrida* and *Nivea* and *Vitex trifolia* have been investigated for the first time and the rest of the species have been reinvestigated.

Pollen grains in the family Verbenaceae are mostly circular in polar view and predominantly radially symmetrical, 2-3-6, Zonocolpate or 3-Zonocolporate. Endoapertures are absent in *Clerodendrum, Duranta, Holmskioldia, Petrea, Premna, Stachytarpheta, Tectona* and *Vitex* ; Lalongate and ill developed in *Callicarpa, Gmelina;* lalongate and quite distinct in *Avicennia, Citharexylum; Lantana, Phyla, Priva* and *Verbena*. The shape varies as defined by the ratio between length of the polar axis and equatorial axis (P/E) from peroblate to prolate.

Following the circumscription of the pollen grain size classes of Erdtman (1952), the majority of genera studied can be grouped into 4 classes. (i) medium sized (25-50 μm) (ii) Small sized (10-25 μm) (iii) large (50-100 μm) and (iv) very large (100-200 μm). All the species of *Clerodendrum* are characterized by large grains where as those of *Phyla* and *Premna* belong to small size class. *Stachytarpheta* seems to have the largest grains (100-200 μm) among all the taxa investigated and the rest of the taxa have medium sized grains.

The exine thickness and grain size vary substantially within the taxon and hence they are of little taxonomic value. However, the patterns of distribution of pollen size classes appear to be of systematic value in delimiting the genera. For example most of the pollen grains of *Stachytarpheta* are very large which can be easily differentiated from *Phyla* and *Premna* where the grain size is between 10-25 μm. All the species of *Clerodendrum* can be separated from others with its large sized grains.

The outer wall of exine is a unique morphological entity with a structure of its own and it is different from other morphological structures found in plants. Its variability has been used in solving systematic and evolutionary problems (Nair, 1974).

The observations on exine sculpturing are in conformity with those published by earlier workers except in few cases. For example, the exine in *Callicarpa* and *Gmelina* is reticulate but not found to be areolate as reported by Nair and Rehman (1962). Parabia (1977) infact has also described reticulate exine in *Gmelina arborea*. According to Nair and Rehman (1962) the exine in *Citharexylum* is psilate which is not in accordance with the present findings. It is also interesting to note that the exine pattern differs in the 3 varieties of *Lantana camara*. Parabia (1977) recorded pilriae exine in *Phyla nodiflora* which showed only psilate type during the present study. In *Verbena* species including *V. bonariensis* and *V. officinalis* the pollen grains are psilate and not granulate as has been reported by Nair Rehman (1962). The observations based on SEM studies also support light microscopic observations.

The eureticulate, simplibaculate and duplibaculate exine described by Saxena (1981) in *Avicennia marina* and *A. officinalis* is not observed in the present investigation ; nor it is described by earlier workers : Erdtman (1962), Nair and Rehman (1962), Rao and Shukla (1975) and Parabia (1977).

The observations on aperture in different taxa support the previous information but no species with 6-rugate pollen grains has been found in the present study although such grains have been recorded for Verbenanceae by Erdtman (1962). There is no earlier report of 6-Zonocolpate grains in *Stachytarpheta*, which is an additional information.

The pollen grains are solitary in all the genera studied and the tetrads have not been observed in any genus including *Avicennia* for which Parabia (1977) recorded tetrad grains.

Citharexylum, *Callicarpa*, etc. are characterized by the presence of a few 4- zonocolpate besides the predominent 3- zonocolporate grains. Parabia (1977) also reported the presence of a few 3-zonocolporate grains in *Tectona* and *Vitex* besides 3- zonocolpate grains.

The pollen grains of the species of *Clerodendrum*, *Avicennia*, *Premna*, *Gmelina*, *Verbena* and *Vitex* resemble closely with each other (interespecific) in the nature of the aperture and exine stratifications.

Although the pollen morphology of Verbenaceae tends to be of a rather diversified type, a number of general volutionary trends are evident within the family. For exmaple (i) a change in outline from circular to angular (in most of the genera it is almost circular in polar view except *Verbena*, *Lantana*, *Petrea*, *Phyla* and *Priva* where they are angular).

(ii) a change in shape from spherical or subspheroidal to peroblate and prolate (the grains in many taxa are mostly prolate spheroidal but prolate in *Vitex*, *Stachytarpheta*, *Priva* and *Premna* and oblate spheroidal in *Verbena*).

(iii) an increase in size of the grains (a gradation from small sized grains in *Phyla* and *Premna* to medium sized in most of the general to large ones as in *Clerodendrum* and to very large in *Stachytarpheta*.

(iv) a change from colpate to colporate grains with ill developed endoaperturers in *Callicarpa* and *Gmelina* to quite distinct lalongate endoapertures in *Avicennia*, *Citharexylum*, *Lantana*, *Phyla*, *Priva* and *Verbena*.

The transformation from grains without endoapertures to those with well-developed and lalongate endoapertures appears to be a distinct specialization as has been pointed by Dickinson (1979). The presence of a few colpate grains among the dominant colporate ones in *Citharexylum*, *Callicarpa*, etc. and a few colporate grains among the dominant colpate grains in *Tectona* and *Vitex* suggest the connecting link, in the transformation of colpate to colporate condition. Another evolutionary trend is the change from smooth to various exine ornamentations. In *Lantana camara* var. *nivea*, *Petrea*, *Phyla*, *Priva* and *Verbena* the exine is psilate but in others it may be reticulate, perforate, echinate or verrucate. Similar evolutionary trends have been recognized in other families by Van Campo (1966) and Dickinson (1979). The family Verbenaceae has been described as eurypalynous by Erdtman (1952) and the present study confirms this observation.

The systematic position of *Avicennia* has been rather controversial, Bentham and Hooker (1876), Briquet (1897), Melchior (1964), Cronquist (1968) and Takhtajan (1980) retained the genus under the family Verbenaceae either as a subfamily Avicennioideae or tribe Avicennieae. The most recent revision of the genus *Avicennia* is that by Moldenke (1959, 1967) who produces arguments for separating the genus from the Verbenaceae and maintaining a separate family as originally proposed by Endlicher (1843) and followed subsequently by certain other taxonomists. Saxena (1981) supports the treatment of Moldenke (1959, 1967) based on the embryological, anatomical and palynological data available to him. He considered that the duplibaculate character of pollen grains of *Avicennia* distinguished it from the rest of the genera of the family Verbenaceae.

The duplibaculate condition is not located in any species of *Avicennia* during the present study; instead the pollen morphology does not vary much from that of other species. The grains are predominantly 3-zonocolporate with reticulate and nonbaculate exine. The exine ornamentation is similar to *Citharexylum*. The grains are medium-sized among the majority of taxa with medium sized grains and the genus *Avicennia* can well be fit in the subfamily Viticeae along with the other genera.

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Explanation of Plates

Plate 1

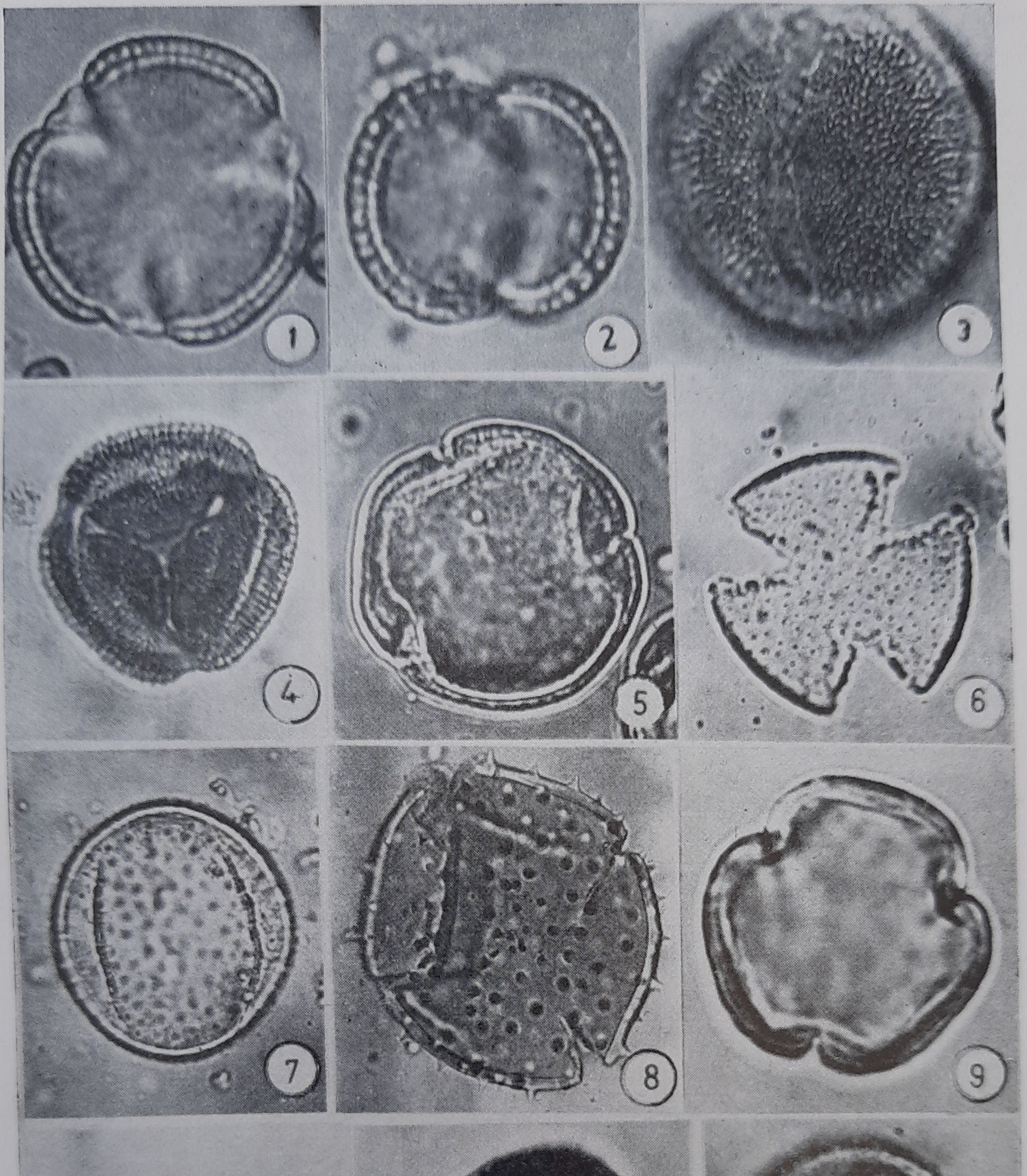
1, 2. *Avicennia marina.* 1. ×1829, 2×1714
3, 4. *Callicarpa tomentosa.* 3. ×1029, 4. ×984
5. *Citharexylum subserratum.* ×984
6. *Clerodendrum viscosum.* ×411
7. *C. splendens.* ×411
8. *C. serratum.* ×389
9. *Duranta repens.* ×984
10. *Gemelina philippensis.* ×1029
11. *G. arborea.* ×1085
12. *G. philippensis.* ×1257

Plate 2

13. *Holmskioldia sanguinea.* ×1029
14. *Lantana camara* var. *culeatata.* ×1257
15. *Petrea volubilis.* ×914
16. *Premna latifolia.* ×2047
17. *Priva leptostachya.* ×914
18. *Tectona grandis.* ×1257
19. *Avicennia marina.* ×2600
20. *Callicarpa tomentosa.* ×2000

Plate 3

21. *Callicarpa tomentosa.* ×10000
22. *Citharexylum subserratum.* ×10000
23, 24. *Clerodendrum thomsonae* 23×1000, 24×6000
25. *C. splendens* ×20000
26. *C. indicum* ×20000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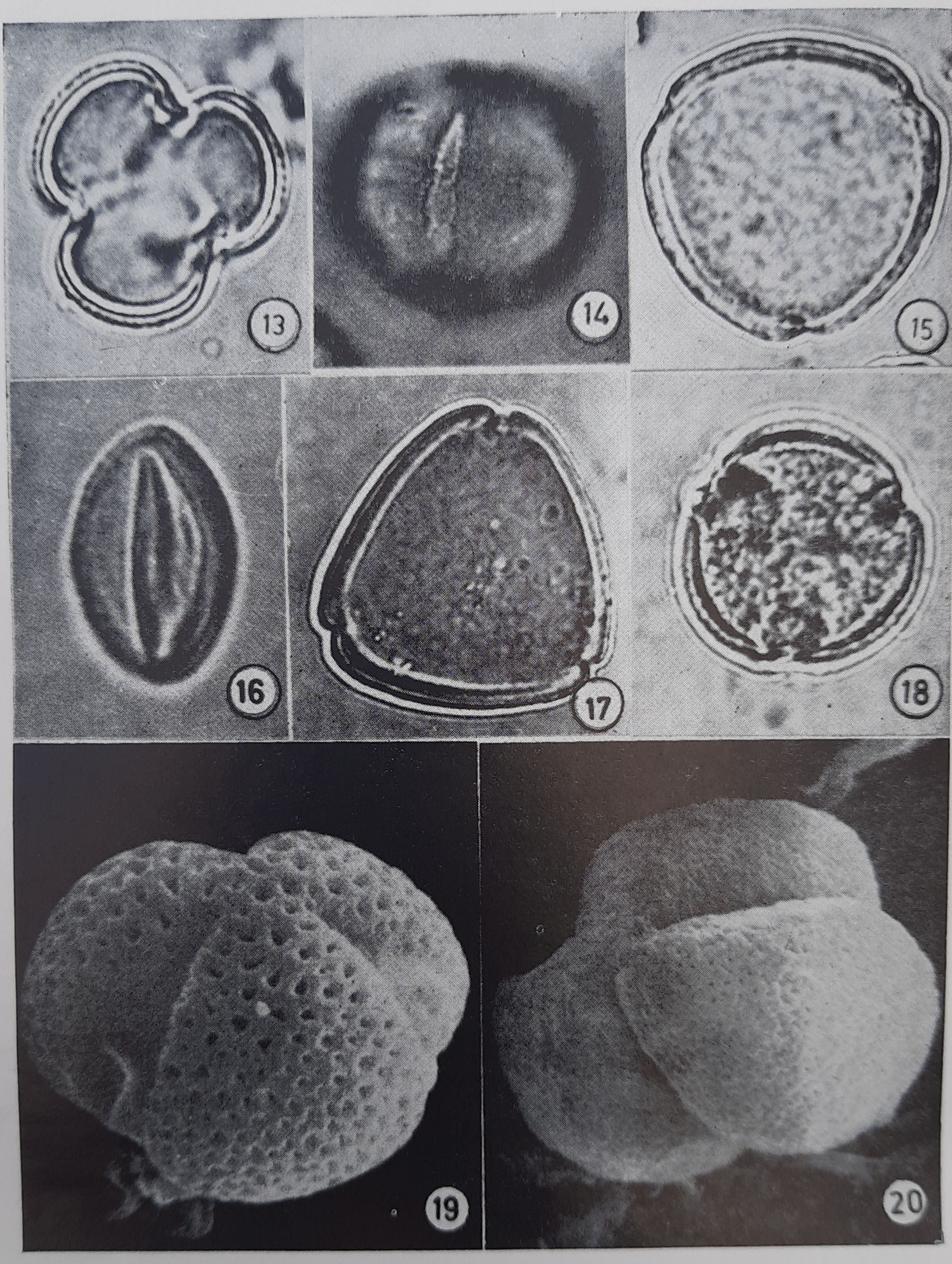
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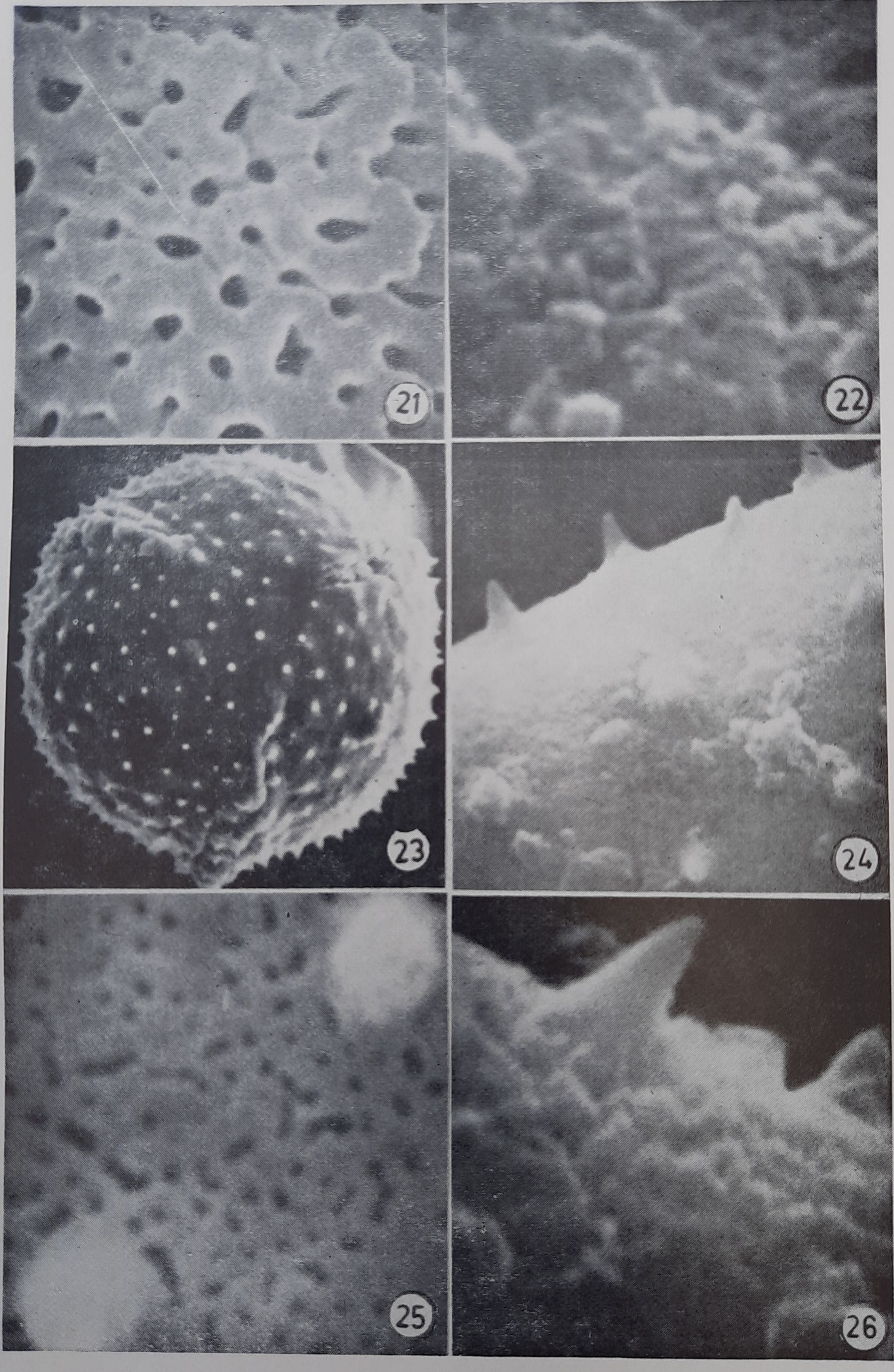
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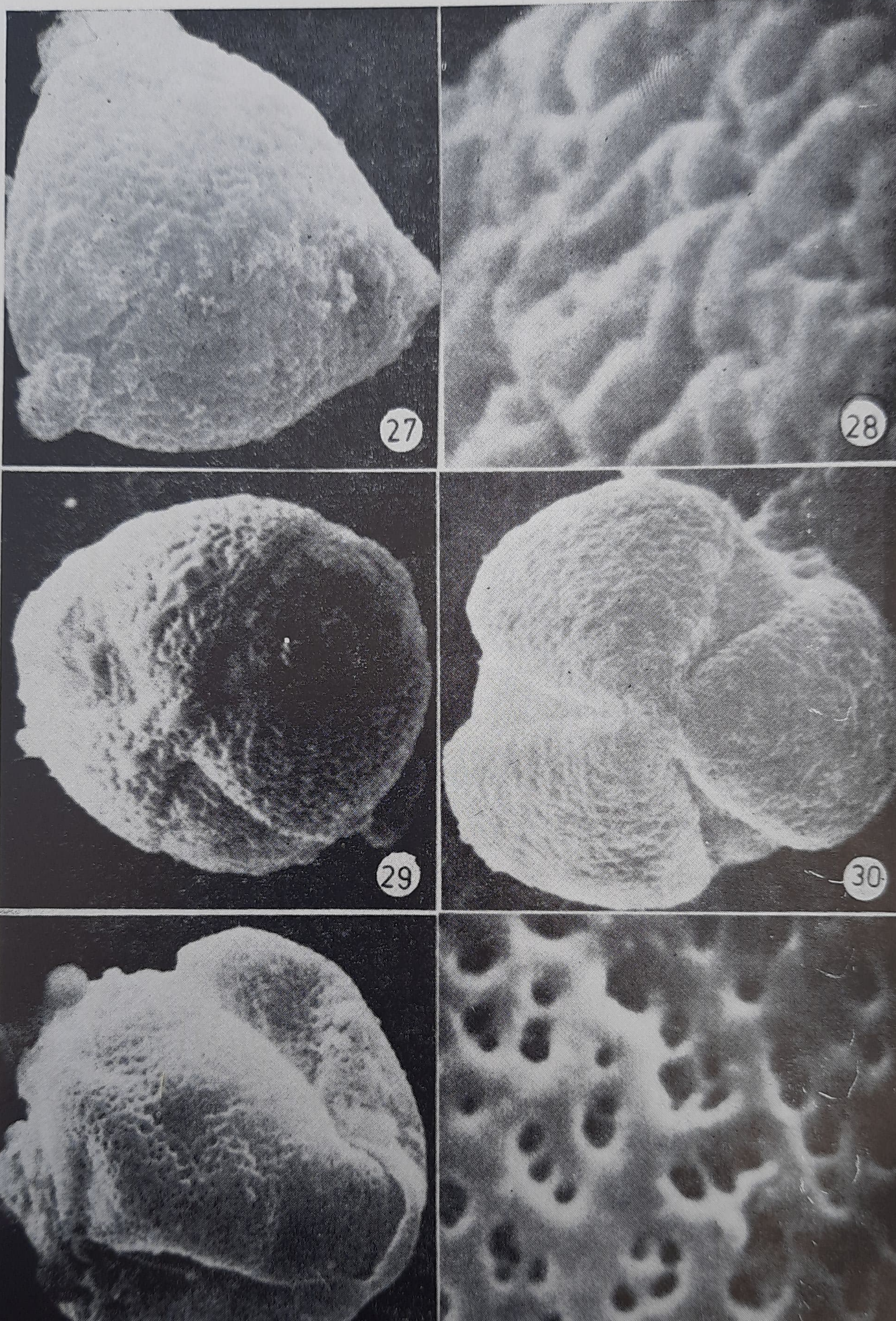
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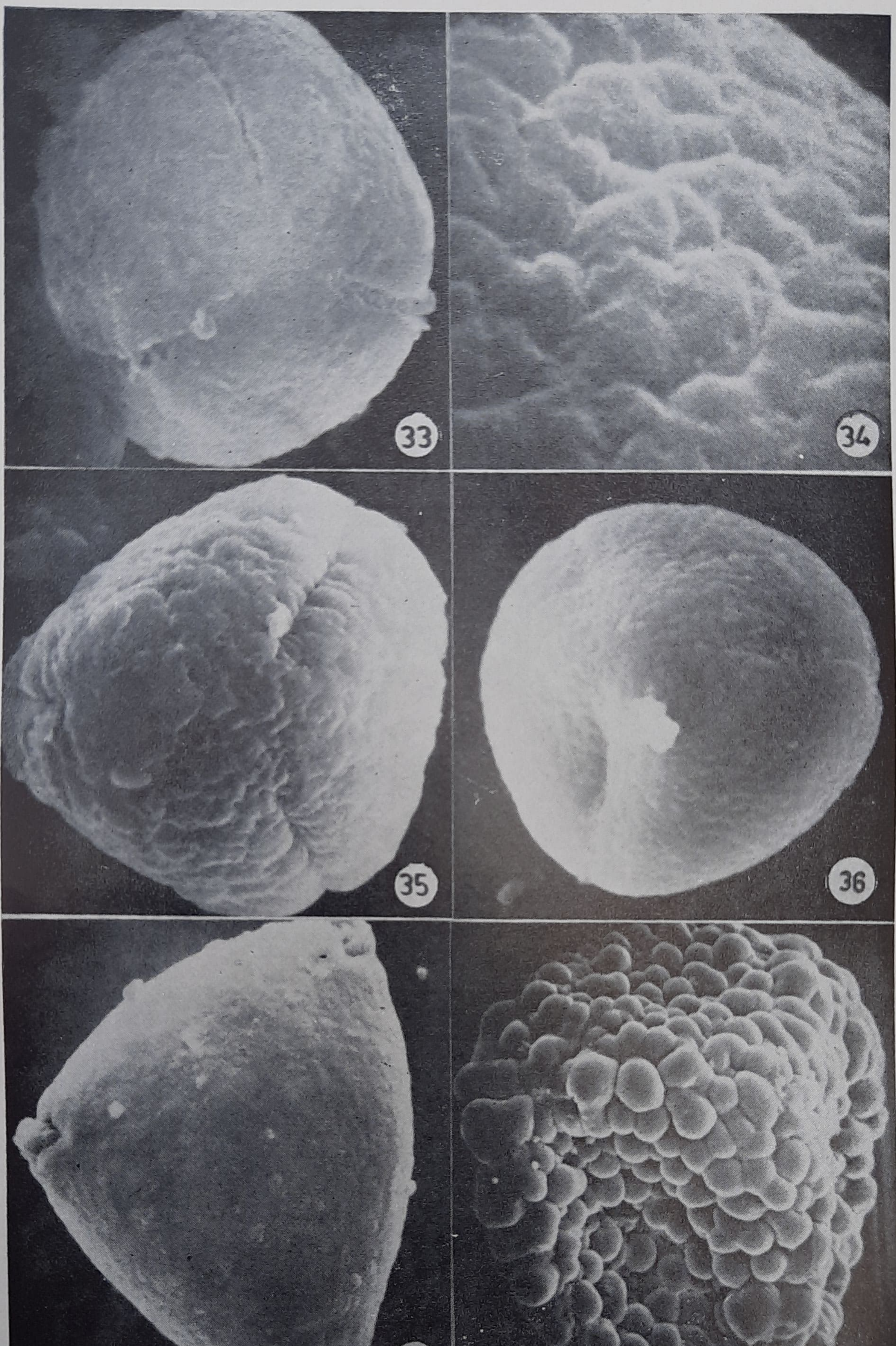
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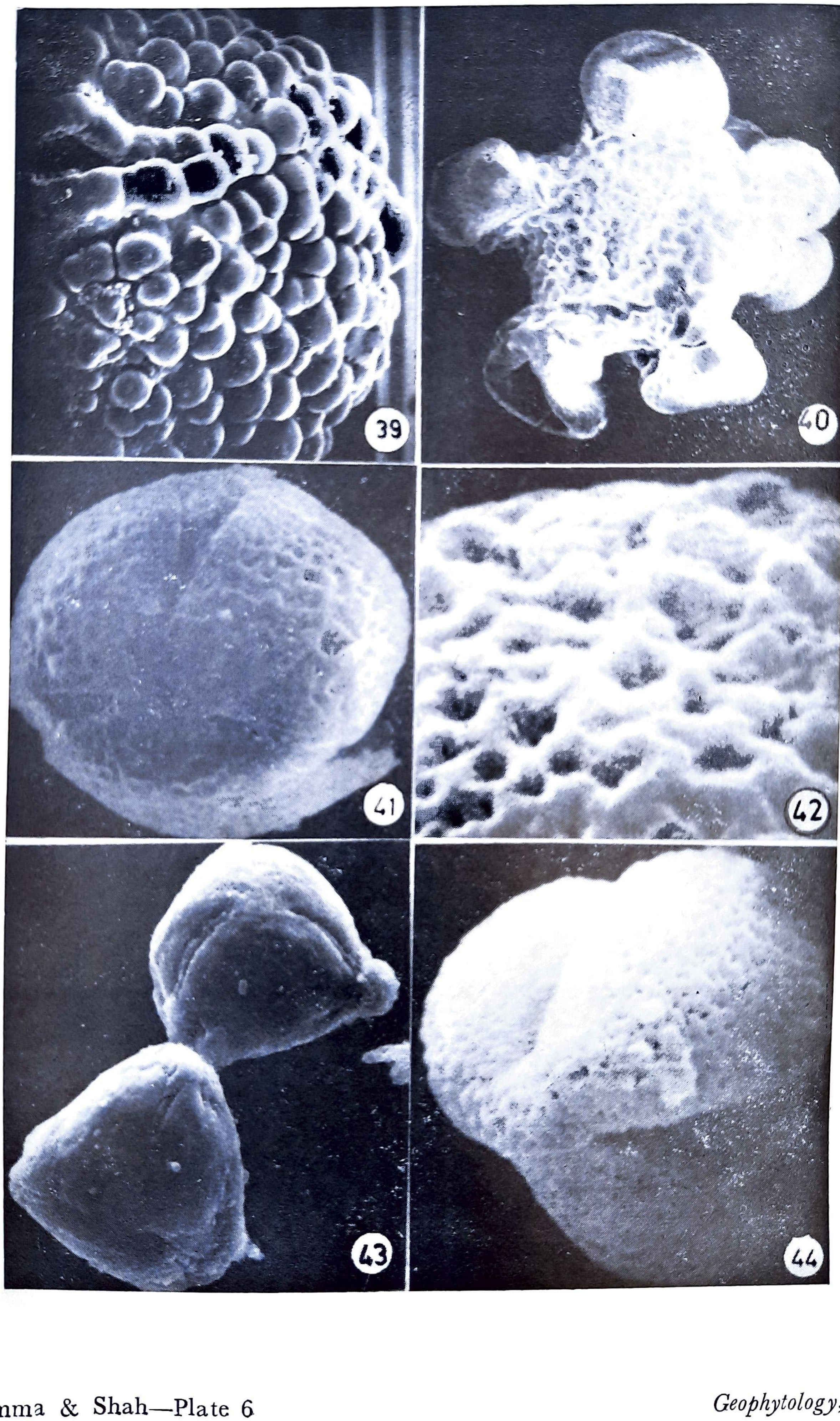
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Plate 4

27, 28. *Duranta repens*. 27. ×2000,28. ×10000
29. *Gmelina arborea*. ×2400
30. *C. philippensis*. ×2000
31, 32. *Holmskioldia sanguinea*. 31. ×2000, 32. ×20000

Plate 5

33, 34. *Lantana camara* var. *aculeata*. 33×2000, 34. ×10000
35. *L. camara* var. *hybrida*. ×2000
36. *L. camara* var. *nivea*. ×2000
37. *Petrea volubilis*. ×2000
38. *Stachytarpheta indica*. × 8900

Plate 6

39, 40. *Stachytarpheta indica*. ×39 × 500, 40.240
41, 42. *Tectona grandis*. 41. ×2000, 42. ×10000
43. *Verbena bipinnatifida*. ×1000
44. *Vitex negundo*. ×5000