

Pollen Flora of Pakistan - VIII *Leguminosae* (Subfamily: *Papilionoideae*)

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Abstract: The pollen morphology of 157 species, representing 37 genera, of the subfamily *Papilionoideae* from Pakistan have been examined using light and scanning electron microscopy. *Papilionoideae* is a eurypalynous subfamily. The pollen grains are generally free, radially symmetrical, isopolar, mostly tricolporate, rarely colpate or porate. The shape is commonly prolate to sub-prolate, or prolate-spheroidal, less commonly to oblate-spheroidal or sub-oblate, often perprolate. The ora is commonly la-longate or circular, rarely lolongate. Colpal membrane is psilate to sub-psilate or granulated, often scabrate. The sexine is thicker than or as thick as the nexine. A reticulate tectum type is the most common. However, other tectum types i.e., rugulate, foveolate, striate and areolate tectum, are also found in a considerable number of taxa. The delimitation of genera on the basis of pollen characteristics is difficult. However, shape, apertural types and ornamentation were found to be more significant pollen characters. On the basis of these characters 10 distinct pollen type were recognized, namely, *Alysicarpus monilifer*-type, *Astragalus affghanus* - type, *Colutea armata* - type, *Dumasia villosa* - type, *Ebenus stellata* - type, *Onobrychis stewartii* - type, *Rhynchosia minima* - type, *Securigera securidaca* - type, *Taverniera lappacea* - type and *Vigna trilobata* - type.

These palynological findings correlate quite well with tribal classification, and most of the tribes were easily recognized palynologically.

Key Words: Pollen morphology, *Leguminosae: Papilionoideae*, Pakistan.

Pakistan'ın Polen Florası - VIII *Leguminosae* (Altfamilya: *Papilionoideae*)

Özet: *Papilionoideae* altfamilyasının Pakistan'da bulunan 37 cinsine dahil 157 türün polen morfolojileri ışık ve elektron mikroskopları ile incelenmiştir. *Papilionoideae* atfamilyası öripalinoz özellik göstermektedir. Polenler tek, radyal simetrik, izopolar, çoğunlukla trikolporat, nadiren kolpat ya da porattır. Şekilleri genellikle prolat ile subprolat ya da prolat-sferoid, nadiren oblat-sferoid ya da sub-oblat, çoğunlukla perprolattır. Ora la-longat ya da dairesel, nadiren lo-longattır. Kolpus membranı psilat ile sub-psilat ya da granüllü, çoğunlukla skabrattır. Sekzin nezdinden daha kalın ya da onunla aynı kalınlıktadır. En yaygın tectum tipi retikülatır. Bununla birlikte, pek çok taksonda rugulat, foveolat, striat ve aerolat gibi diğer tectum tiplerine de rastlanmıştır. Cinsleri polen karakterlerine göre ayırmak güçtür. Ancak, şekli apertür tipleri ve ekzin süslenmelerinin daha belirgin ayırt edici karakterler oldukları belirlenmiştir. Bu karakterlere bağlı olarak 10 polen tipi ayırt edilmiştir. Bunlar *Alysicarpus monilifer* - tip, *Astragalus affghanus* - tip, *Colutea armata* - tip, *Dumasia villosa* - tip, *Ebenus stellata* - tip, *Onobrychis stewartii* - tip, *Rhynchosia minima* - tip, *Securigera securidaca* - tip, *Taverniera lappacea* - tip ve *Vigna trilobata* - tip.

Mevcut palinolojik bulgular tribusların sınıflandırılması ile uyum içindedir ve tribuslar palinolojik olarak kolayca ayırt edilmektedir.

Anahtar Sözcükler: Polen morfolojileri, *Leguminosae: Papilionoideae*, Pakistan.

Introduction

Leguminosae is one of the largest families of flowering plant after the *Compositae* and *Orchidaceae* with c. 657 genera and 16400 species, and is cosmopolitan in distribution, mostly in tropical areas (1, 2). Within this family more than 50% of the species belong to the subfamily *Papilionoideae*, i.e., 480 genera and

12000 species (1, 3). In Pakistan, it is represented by 90 genera and 435 species (4).

Papilionoideae has been divided into a number of tribes i.e., 33 tribes by Hutchinson (5), 11 tribes by Bentham and Hooker (6) and 24 tribes by Polhill & Raven (7).

The subfamily *Papilionoideae* contains mostly trees,

Tribes	I	II	III	IV	V	VI	VII	VIII	IX	X
1. Sophoreae										
Shophora	-	2	-	-	-	-	1	-	-	-
2. Milletieae										
Tephrosia	1	2	1	-	-	-	3	-	-	-
3. Robinieae										
Sesbania	-	-	1	-	-	-	-	-	-	-
4. Indigofereae										
Indigofera	7	-	2	-	-	-	4	-	-	-
5. Desmodieae										
Alysicarpus	3	1	1	-	-	-	1	-	-	-
Desmodium	-	2	-	-	-	-	-	-	-	-
Campylotropis	-	1	-	-	-	-	-	-	-	-
Lespedeza	-	-	-	-	-	-	1	-	-	-
6. Phaseoleae										
Pueraria	-	1	-	-	-	-	-	-	-	-
Dumasia	-	-	-	1	-	-	-	-	-	-
Vigna	-	-	-	-	-	-	-	-	-	2
Flemingia	1	-	-	-	-	-	-	-	-	-
Rhynchosia	-	-	-	-	-	-	5	-	-	-
Atylosia	-	1	-	-	-	-	-	1	-	-
7. Psoraleae										
Psoralea	-	-	-	-	-	-	1	-	-	-
8. Galegeae										
Colutea	-	1	1	-	-	-	-	-	-	-
Caragana	-	1	-	-	-	-	-	-	-	-
Chesneya	-	1	-	-	-	-	1	-	-	-
Astragalus	-	46	-	-	-	-	1	-	-	-
Oxytropis	-	3	-	-	-	-	-	-	-	-
Alhagi	-	-	-	-	-	-	1	-	-	-
Glycyrrhiza	2	-	-	-	-	-	-	-	-	-
9. Hedysareae										
Taverniera	-	-	-	-	-	-	-	-	4	-
Onobrychis	-	-	-	-	-	-	5	-	2	-
Ebenus	-	-	-	-	1	-	-	-	-	-
10. Loteae										
Lotus	2	-	2	-	-	-	-	-	-	-
Securigera	-	-	-	-	-	-	-	1	-	-
11. Coronilleae										
Hippocrepis	-	-	-	-	-	-	-	1	-	-
12. Vicieae										
Vicia	-	3	-	-	-	-	-	-	-	-
Lathyrus	-	2	3	-	-	-	-	-	-	-
13. Trifolieae										
Ononis	-	1	-	-	-	-	-	-	-	-
Melilotus	-	2	-	-	-	-	-	-	-	-
Trigonella	-	3	-	-	-	-	-	-	-	-
Medicago	-	1	2	-	-	-	-	-	-	-
Trifolium	-	2	2	-	-	-	-	-	-	-
14. Cicereae										
Cicer	-	-	-	-	-	-	1	-	-	-
15. Crotalarieae										
Crotalaria	-	4	-	-	-	-	-	-	-	-
Lotonains	-	-	-	-	-	-	1	-	-	-
16. Genisteae										
Argyrolobium	-	-	-	-	-	-	1	-	-	-

Table 1. Distribution of pollen types within Polhil & Raven's (1981) tribal classification

Abbrerations used in Table 2-6

Ob-sp = oblate-spheroidal, Sb-ob = sub-oblate, P-sp = Prolate - spheroidal, Pr = prolate, F-rg = finely rugulate, Fs = fossulate, Fs-rg = fossulate-rugulate, Rg = rugulate, Rg-r= Rugulate - reticulate, St-rg = striate - rugulate, Sb-p = sub-psilate, Rg-fs = rugulate-fossulate, Ds-rg = Densely rugulate, Ar-fp = areolate finely punctate, ±rg = more or less rugulate, Fv = Foveolate, Fv-fs = Foveolate - fossulate, Fv-M = Foveolate mesocolpium, Pt-p Punctate pole, MRt = Medium reticulate, FRt = Finely reticulate, Rt = Reticulate, CrRt = Coarsely reticulate.

Table 2. General pollen characteristics of different species of the *Alysicarpus monilifer*-type

No. taxa	Shape	P/E ratio	Polar length (P) in μm	Equatorial Diameter (E) in μm	Colpus length (C)	Mesocolpium in μm	Apocolpium in μm	Exine thickness μm	Tectum
1.	Ob-sp	0.95	41.28(43.39 \pm 0.0) 46.67	35.9(46.75 \pm 1.26) 50.27	28.7(31.95 \pm 0.60) 35.9	32.3(37.6 \pm 1.21) 43.0	7.18(10.4 \pm 0.94) 10.7	2.87(3.19 \pm 0.01) 3.6	F-rg
2.	Sb-ob	0.85	39.9(46.09 \pm 1.45) 53.38	43.2(53.84 \pm 2.43) 66.6	19.9(20.4 \pm 0.16) 20.3	36.6(41.02 \pm 0.77) 49.9	13.3(17.0 \pm 0.76) 19.9	2.97(4.04 \pm 0.19) 4.32	Fs
3.	Ob-sp	0.98	49.9(59.44 \pm 3.13) 69.0	57.2(60.0 \pm 0.25) 63.4	39.9(41.9 \pm 1.33) 46.6	36.6(46.3 \pm 1.94) 69.9	13.3(18.31 \pm 2.36) 26.6	2.99(3.64 \pm .08) 3.90	Fs-rg
4.	P-sp	1.03	23.3(23.9 \pm 2.3) 26.6	20.3(23.10 \pm 0.16) 24.9	16.6(20.15 \pm 0.25) 23.3	16.6(18.06 \pm 0.41) 23.3	1.66(3.35 \pm 0.43) 3.66	1.66(1.80 \pm 0.10) 2.99	Fs
5.	Ob-sp	0.98	39.9(43.43 \pm 2.6) 52.9	36.9(43.6 \pm 0.63) 46.6	35.3(37.6 \pm 0.54) 46.6	29.9(31.51 \pm 1.94) 36.6	3.33(4.32 \pm 0.24) 6.60	1.33(1.94 \pm 0.12) 2.99	Rg-
6.	Ob-sp	0.93	24.3(25.6 \pm 0.44) 26.64	23.3(26.1 \pm 0.56) 26.9	19.6(21.9 \pm 0.56) 24.9	17.3(20.7 \pm 0.85) 26.6	3.33(4.32 \pm 1.68) 6.66	1.66(1.78 \pm 0.36) 2.33	Rg-r
7.	P-sp	1.07	29.6(30.5 \pm 0.36) 33.6	26.6(30.02 \pm 0.46) 33.6	20.3(23.0 \pm 0.31) 26.6	23.3(2.7 \pm 0.48) 29.9	3.99(7.29 \pm 0.45) 8.32	1.33(2.47 \pm 0.10) 3.66	St-rg
8.	P-sp	1.10	29.9(32.7 \pm 0.80) 36.6	26.6(29.5 \pm 0.14) 33.6	19.6(23.27 \pm 0.56) 29.6	24.9(25.7 \pm 0.85) 26.9	6.66(8.32 \pm 1.66) 8.32	0.66(1.52 \pm 0.34) 3.66	Rg-
9.	Ob-sp	0.98	25.1(28.3 \pm 0.95) 32.23	30.5(32.5 \pm 0.56) 35.91	17.9(18.7 \pm 0.52) 21.53	17.9(20.2 \pm 0.37) 25.12	3.61(5.09 \pm 0.61) 7.18	1.43(2.23 \pm 0.23) 3.23	sb-p
10.	Sb-ob	0.82	26.6(32.1 \pm 0.41) 35.3	32.3(37.6 \pm 0.71) 41.21	17.9(18.3 \pm 0.3) 21.5	25.4(29.4 \pm 0.71) 32.3	7.18(8.4 \pm 0.35) 10.7	0.71(1.48 \pm 0.4) 2.5	Rg-fs
11.	Sb-sp	0.78	28.7(34.0 \pm 1.18) 35.9	36.6(43.2 \pm 0.86) 48.27	21(23.8 \pm 0.75) 28.7	28.7(31.5 \pm 0.5) 35.0	8.97(12.70 \pm 0.82) 17.91	3.23(3.51 \pm 0.04) 3.54	Ds-rg
12.	Sb-ob	0.81	19.70(23.6 \pm 0.55) 25.13	25(29.0 \pm 0.58) 32.32	14.3(18.3 \pm 0.97) 21.51	17.9(19.3 \pm 0.52) 21.5	3.59(5.18 \pm 0.31) 7.18	0.35(0.9 \pm 0.11) 1.43	Ar-fp
13.	Sb-ob	0.79	21.5(23.8 \pm 0.44) 25.13	26.6(29.9 \pm 9.59) 33.3	14.3(16.5 \pm 0.52) 17.36	17.9(19.21 \pm 0.53) 21.54	7.18(9.08 \pm 0.49) 10.1	0.78(1.32 \pm 0.16) 1.79	Rg
14.	Ob-sb	0.97	25.1(26.7 \pm 0.45) 23.5.9	23.3(27.3 \pm 0.65) 48.4	17.5(21.18 \pm 0.58) 28.7	17.9(19.20 \pm 0.52) 1.9	7.18(9.33 \pm 0.49) 10.7	1.43(1.54 \pm 0.06) 3.23	\pm rg
16.	P-sb	1.03	24.4(28.1 \pm 0.1) 38.1	23.1(27.1 \pm 0.2) 33.1	29.9(32.5 \pm 0.82) 36.9	26.6(30.3 \pm 0.48) 33.3	3.33(4.9 \pm 0.05) 6.06	1.33(2.63 \pm 0.34) 2.60	Fv
17.	P-sp	1.10	16.6(19.5 \pm 0.18) 19.9	16.6(17.50 \pm 0.24) 16.9	13.3(16.6 \pm 0.23) 16.36	9.94(13.1 \pm 0.65) 3.66	0.33(366 \pm 0.10) 0.99	0.33(0.77 \pm 0.33) 0.99	Fv-fs
18.	Ob-sp	0.94	25.1(26.17 \pm 0.41) 28.7	25.1(27.5 \pm 0.43) 28.0	21.5(22.0 \pm 0.33) 23.3	17.9(20.5 \pm 0.51) 21.5	3.50(4.19 \pm 0.33) 7.18	0.72(1.14 \pm 0.15) 1.79	Fv-M pt-p

Species (1-18)

1) *Alysicarpus monilifer*, 2) *A. scariosus*, 3) *A. longifolius*, 4) *Desmodium laxiflorum*, 5) *D. motorium*, 6) *Flemingia semialata*, 7) *Glycyrrhiza triphylla*, 8) *G. glabra*, 9) *Indigofera argentea*, 10) *I. cordifolia*, 11) *I. linifolia*, 12) *I. oblongifolia*, 13) *I. sessiliflora*, 14) *I. hochstetteri*, 15) *I. linnaei*, 16) *Lotus makranicus*, 17) *Lotus schimperii*, 18) *Tephrosia subtriflora*

shrubs, herbs and sometimes lianas, often with root nodules containing nitrogen-fixing bacteria and frequently with non-protein amino-acids in the seeds. The leaves are mostly pinnately compound (rarely palmate), bipinnate, unifoliate, trifoliate or simple. The flowers are bisexual, irregular and usually in the raceme. The fruit is generally a legume, sometimes indehiscent, rarely a lomentum breaking into one-seeded segments.

A number of authors have studied the pollen morphology of the members of the subfamily *Papilionoideae*: Mahler (8), Verdcourt (9), Stainier (10), Graham & Tomb (11), Ferguson (12-14); Ferguson and Skvarla (15-17), Ferguson and Strachan (18), Poole (19), Polhill (20), Kavanag et al. (21), Stainer and Hervat (22) and Stirton (23). However, Papilionoids distributed in Pakistan have not been fully explored palynologically. Only Khan and Memon (24) have worked on some of its members using light microscopy. Thus the present study was carried out to provide palynological information on 157 species representing 37 genera, belonging to 16 tribes (7) distributed in Pakistan (Table 1).

Materials and Methods

Pollen samples were obtained from Karachi University Herbarium (KUH), or collected during field work. The list of voucher specimens is deposited at KUH. The pollen grains were prepared for light (LM) and scanning microscopy (SEM) using the standard methods described by Erdtman (25). For light microscopy, the pollen grains were mounted on unstained glycerine jelly and observations were made with a Nikon Type-2 microscope, under (E40, 0.65) and oil immersion (E100, 1.25) using a 10 eye piece. For SEM studies, the pollen grains were suspended in a drop of water and directly transferred with a fine pipette to a metallic stub using double-sided adhesive tape and coated with gold in a sputtering chamber (Ionsputter JFC-1100). The coating was restricted to 150Å. The S.E.M examination was carried out with a Jeol JSM-T200 microscope. The measurements were based on 15-20 readings from each specimen. Pollen diameter, polar axis (P) and equatorial diameter (E), colpi length, apocolpium, mesocolpium and exine thickness were measured (Tables 2-6).

The terminology used is that of Erdtman (25),

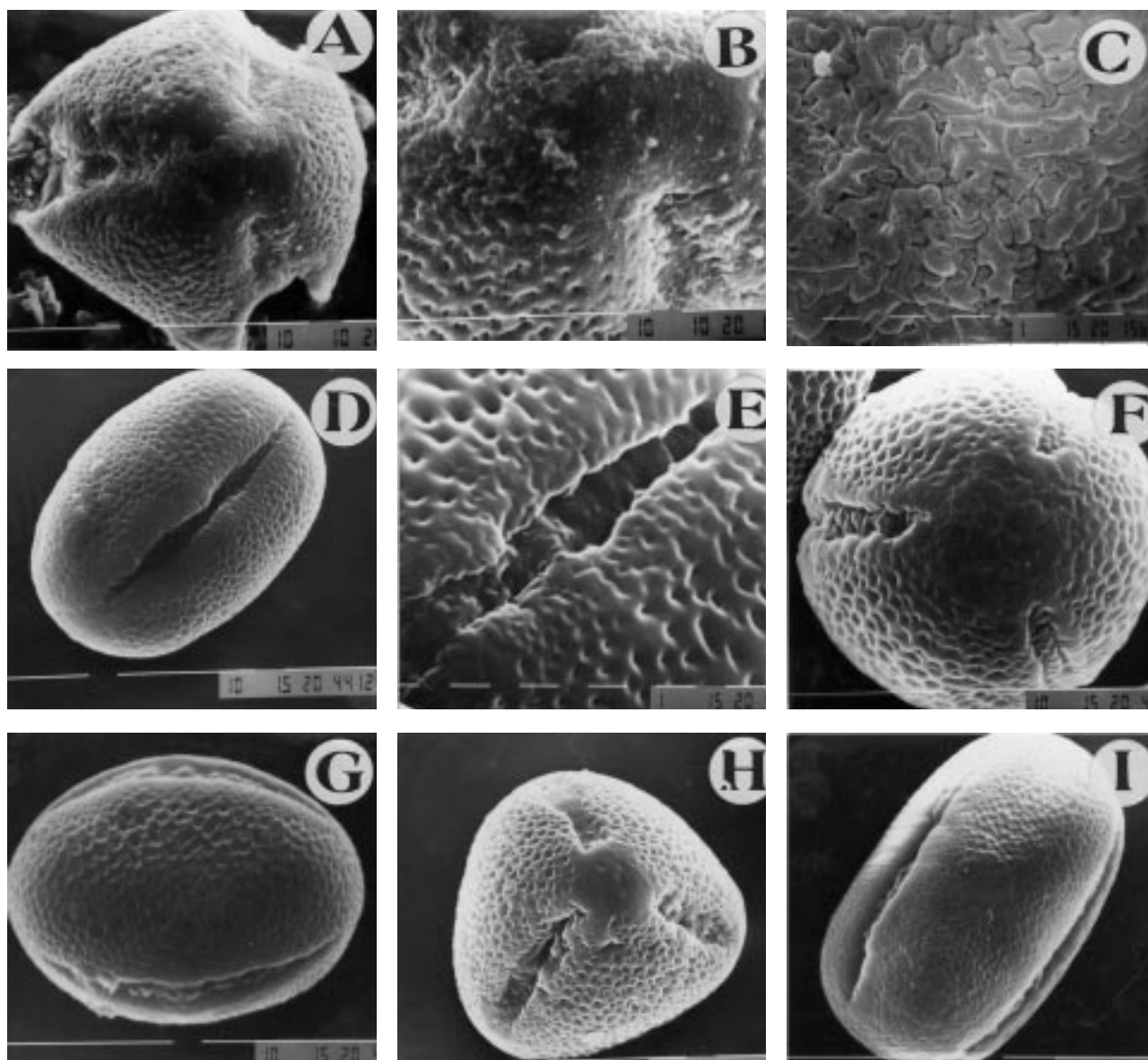


Figure 1. —Scanning Electron micrographs of pollen grains. *Tephrosia subtriflora*: A, Polar view; B, Exine pattern. *Indigofera hochstetteri*: C, Exine pattern. *Astragalus affghanus*: D, Equatorial view; E, Exine pattern. *A. augans*: F, polar view. *A. amherstianus*: G, Equatorial view. *A. alitschuri*: H, Polar view; I, Equatorial view; Scale bar= A, B, D, F-I = 10 μ m; C & E = 1 μ m.

Kremp (26), Faegri & Iversen (27) and Walker & Doyle (28).

Observation

General Pollen Characteristics of the sub-family Papilionoideae

Pollen grains usually radially symmetrical, isopolar, prolate to sub-prolate, or sub-oblate to oblate-spheroidal, rarely prolate-spheroidal, tricolporate, rarely

colpate or porate; generally triangular or trilobed in polar view. Colpal membrane psilate to sub-psilate or granulate often scabrate; ora commonly la-longate or circular, rarely lo-longate. Sexine thicker or thinner than nexine or as thick as nexine. Tectum generally finely to coarsely reticulate. In addition, rugulate, rugulose-fossulate, fossulate-rugulate, occasionally breached by puncta or perforations, often rough scabrate or subpsilate tectum. In most of the species ornamentation \pm psilate or sub-psilate towards colpus forming distinct colpal margins.

Key to the pollen types

1. + Pollen grains porate _____2
 – Pollen grains colpate or colporate _____ 3
2. + Pollen grains prolate, tectum rugulate
 _____IV. *Dumasia villosa*-type
 – Pollen grains sub-oblate to oblate-spheroidal,
 tectum reticulate
 _____ X. *Vigna trilobata*-type
3. + Pollen grains colpate _____4
 – Pollen grains colporate _____6
4. + Pollen grains proprolate,
 P/E ratio more than 200
 _____VI. *Onobrychis stewartii*-type
 – Pollen grains prolate, P/E ratio less than 200
 _____5
5. + Polar length 33 - 39.9 μm
 _____V. *Ebenus stellate*-type
 – Polar length less than 33 μm
 _____IX. *Taverniera lappacea*-type
6. + Pollen grains prolate to sub-prolate _____7
 – Pollen grains oblate-spheroidal to prolate-
 spheroidal _____9
7. + Tectum reticulate or striate type _____8
 – Tectum fossulate-rugulate or foveolate-rugulate
 _____III. *Colutea armata*-type
8. + Tectum reticulate
 _____II. *Astragalus affghanus*-type
 – Tectum striate or striate-rugulate
 _____VIII. *Securigera securidaea*-type
9. + Tectum reticulate often reticulate rugulate
 _____VII. *Rhynchosia minima*-type
 – Tectum other than reticulate
 _____I. *Alysicarpus monilifer*-type

Pollen type-I: *Alysicarpus monilifer*-type (Fig.1 A-C; Fig.7 A & F).

Pollen class: Tricolporate, zonoaperturate.

P/E ratio: Subtransverse to semierect, rarely semi-transverse.

Shape: Oblate-spheroidal to prolate-spheroidal, rarely oblate.

Apertures: Ectoaperture-colpi medium, narrow with acute ends. Endoaperture la-longate, \pm circular in shape, often with operculum.

Exine: Sexine thicker than nexine, rarely thinner than nexine, often as thick as nexine.

Ornamentation: Tectum mostly fossulate-rugulate or rugulate-fossulate, rarely sub-psilate or areolate; most of the taxa have distinct colpal margin.

Measurements: Polar length (P) 16.6 (39.4 \pm 0.13) 69.9 μm , Equatorial diameter (E) 16.6 (38.5 \pm 1.41) 63.27 μm , colpus 13.3 (29.25 \pm 1.94) 46.6 μm long. Mesocolpium 9.94 (29.6 \pm 0.22) 69.9 μm . Apocolpium 7.18 (10.98 \pm 0.36) 26.6 μm . Exine 0.33 (2.02 \pm 0.19) 3.99 μm thick. P/E ratio: 0.75-1.10 (Table-2).

Key to the species and species groups

1. + Pollen grains sub-oblate _____2
 – Pollen grains oblate-spheroidal to prolate-
 spheroidal _____6
2. + Mesocolpium 36.6 - 49.9 μm _____
 _____ *Alysicarpus scariosus*
 – Mesocolpium 28.8 - 35.9 μm _____3
3. + Tectum sub-psilate to areolate _____4
 – Tectum not as above _____5
4. + Tectum sub-psilate
 _____ *Indigofera argentea*
 – Tectum \pm areolate _____ *Indigofera oblongifolia*
5. + Polar length 21.5 - 25.1 μm
 _____ *Indigofera sessiliflora*
 – Polar length 26.6 - 48.27 μm
 _____ *I. cordifolia*-group
 (*Indigofera cordifolia* Heyne ex Roth, *I. linnaei*
 Ali, *I. linifolia* (L.) Retz.)
6. + Polar length 39.9 - 69.0 μm _____ 7
 – Polar length 16.6 - 39.9 μm _____ 9
7. + Apocolpium 13.3 - 26.6 μm
 _____ *Alysicarpus longifolia*
 – Apocolpium 3.33 - 10.7 μm _____8

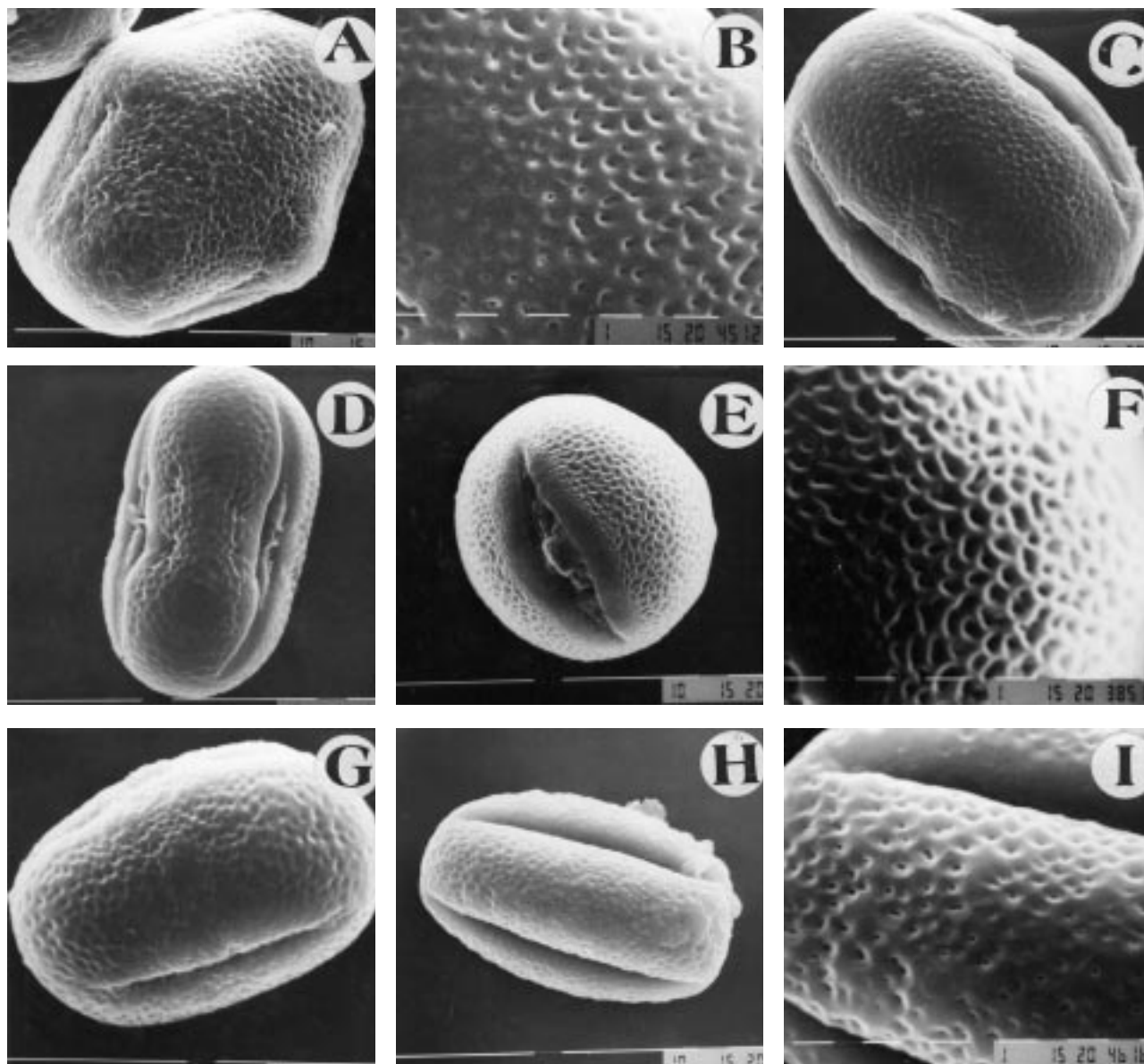


Figure 2. —Scanning Electron micrographs of pollen grains. *Astragalus bervisopus*: A, Equatorial view; B, Exine pattern. *A. kahiricus*: C, Equatorial view. *Crotalaria juncea*: D, Equatorial view. *Campylotropis meeboldii*: E, Equatorial view; F, Exine pattern. *Oxytropis lapponica*: G, Equatorial view. *Pueraria tuberosa*: H, equatorial view; I, Exine pattern. Scale bar = A, C, D, E, G & H = 10 μ m; B, E & I = 1 μ m.

- | | | | |
|--|-------------------------------------|--|--------------------------------------|
| 8. + Exine 2.87 - 3.6 μ m | _____ <i>Alysicarpus monilifera</i> | 11. + Apocolpium 3.33 - 6.66 μ m | _____ <i>Flemingia semialata</i> |
| - Exine 1.33 - 2.99 μ m | _____ <i>Desmodium motorium</i> | - Apocolpium 7.18 - 10.77 μ m | _____ <i>Indigofera hochstetteri</i> |
| 9. + Pollen grains oblate-spheroidal | _____ 10 | 12. + Polar length 16.6 - 19.9 μ m | _____ <i>Lotus schimperii</i> |
| - Pollen grains prolate - spheroidal | _____ 12 | - Polar length 23.3 - 36.6 μ m | _____ 13 |
| 10. + Tectum foveolate | _____ <i>Tephrosia subtriflora</i> | | |
| - Tectum rugulate or rugulate-reticulate | _____ 11 | | |

13. + Tectum fossulate-foveolate —————14
 – Tectum not as above —————15
14. + Colpi 16 - 23 µm long
 —————*Desmodium laxiflorum*
 – Colpi 29.6 - 39.9 µm long
 —————*Lotus makranicus*
15. + Tectum striate-rugulate
 —————*Glycyrrhiza triphylla*
 – Tectum rugulate - reticulate
 —————*Glycyrrhiza glabra*

Pollen type-II: *Astragalus affghanus*-type
 (Fig.1D-I; Fig.2 A-I; Fig.3 A-E)

Pollen class: Tricolporate, zonoaperturate.

P/E ratio: Erect to semierect, rarely pererect.

Shape: Prolate, sub-prolate rarely perprolate.

Apertures: Ectoapertures - long, narrow, not sunken, colpi with acute ends. Endoapertures - circular or rectangular, lo-longate or la - longate.

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

Ornamentation: Tectum generally medium reticulate, rarely coarsely or fine reticulum, often reticulate - fossulate or reticulate-rugulate.

Outline: Triangular or trilobed in polar view, elliptic in equatorial view.

Measurements: Polar length (P) 14.98 (28.55 ± 0.32) 46.2 µm; equatorial diameter (E) 12.6 (22.5 ± 0.64) 24 µm. Colpus 13.3 (28.05 ± 0.46) 60.2 µm long. Mesocolpium 6.66 (22.5 0.77) 36.6 µm. Apocolpium 1.65 (4.32 ± 0.72) 5.38 µm. Exine 0.33 (2.28 ± 0.10) 6.66 µm thick.

Key to the species groups

1. + Tectum reticulate - fossulate or reticulate - rugulate —————*Vicia monantha*-group
 – Tectum fine - coarsely reticulate —————2
2. + Tectum finely reticulate
 —————*Oxytropis microphylla*-group
 – Tectum medium - coarsely reticulate —————3

3. + Tectum medium reticulate
 —————*Astragalus stocksii*-group
 – Tectum coarsely reticulate
 —————*Crotalaria medicaginea*-group

The species included in the *Vicia monantha* - group: *Vicia monantha* Retz., *V. hirsuta* (L.) S.E. Gray, *V. tenuifolia* Roth, *Lathyrus aphaca* L., *L. erectus* Lagasca, *Trigonella hamosa* L., *Medicago orbicularis* (L.) Bart., *Melilotus messarensis* (L.) All, *Trigonella pubescens* Edgew. ex Baker, and *Trifolium resupinatum* L.

The species included in the *Oxytropis microphylla* - group: *Astragalus stewartii* Baker, *Astragalus dipogon* Bunge, *A. peduncularis* Royle ex Benth., *A. bakaliensis* Bunge, *A. coluteocarpus* Boiss., *Colutea nepalensis* Sims, *Caragana ambigua* Stocks, *Chesneya acaulis* (Baker) Popov, *Desmodium elegans* DC., *O. lapponica* (Wall.) Gay, *O. mollis* Royle ex Benth., *Trifolium dubium*, Sibth, *Melilotus officinalis* (L.) Pall., *Sophora mollis* (Royle) Baker, *S. secundiflora* (Ortega) DC., *Tephrosia purpurea* (L.) Pers., *Tephrosia shamimii* Ali and *Trigonella gharuensis* Rech. f.

The species included in the *Astragalus stocksii*-group: *A. chlorostachys* Lindl., *A. graveolens* Bunch. - Ham. ex Benth., *A. kuramensis* Baker, *A. himalayanus* Klotzch, *A. tibetanus* Benth e. Bunge, *A. auganus* Bunge, *A. gilgitensis* Ali, *A. grahamianus* Royle ex Benth., *A. bicuspis* Fisch, *A. anisacanthus* Boiss., *A. congestus* Baker, *A. kahircus* DC., *A. nivalis* Kar. & Kir, *A. breviscapus* Fedtsch., *A. trichocarpus* Grah. ex Benth., *A. koschukensis* Boiss., *A. stocksii* Bunge, *A. amherstianus* Royle ex Benth., *A. scorpiurus* Bunge, *A. neubauerianus* Sirj. & Rech. f., *A. schimperi* Boiss., *A. leucocephalus* Grah., ex Benth., *A. contortuplicatus* L., *A. ammophilus* Kar., *A. corrugatus* Bertol., *A. webbianus* Grah ex Benth., *A. retamocarpus* Boiss. & Hohen., *A. strictus* Grah ex Benth., *A. albovillosus* Kitamura, *A. affghanus* Boiss., *A. pyrrhotrichus* Boiss., *A. rhizanthus* Royle ex Benth., *A. squarrosus* Bunge, *A. khalifatensis* Ali, *A. sykesiae* N.D. Simpson, *A. brahuicus* Bunge, *A. alitschuri* O. Fedtsch., *A. subuliformis* DC., *A. xanthoxiphidiopsis* Rech. f., and *A. pseudo-becki* Sirj. & Rech. f., *Astragalus zanskarensis* Benth. ex Bunge, *Alysicarpus ovalifolius* (Schumacher) J. Leonard, *Campylotropis meeboldii* (Schindler) Schindler, *Crotalaria albida* Heyne ex Roth, *C. juncea* L., *Pueraria tuberosa* (Roxb. e Willd.) DC., *Ononis antiquorum* L., *Trigonella gracilis* Benth., and *Trifolium resupinatum* L.

The species included in the *Crotalaria medicaginea*-

Table 3. General pollen characteristics of different species of the *Colutea armata*-type

No. of taxa	Polar Length μm	Equatorial diameter μm	F/E ratio	colpus length in μm	Mesocolpium in μm	Apocolpium in μm	Exine thickness in μm	Tectum
1.	35.9(38.7 \pm 0.11) 43.08	25.1(32.6 \pm 0.2) 37.6	1.18	17.2(27.6 \pm 0.97) 35.9	3.6(5.38 \pm 1.03) 32.31	1.8(2.18 \pm 0.94) 7.18	Fs-rg 2.87	
2.	26.9(28.2 \pm 0.60) 32.36	17.3(21.7 \pm 0.93) 28.3	1.30	16.6(21.8 \pm 0.54) 20.1	16.6(19.4 \pm 0.58) 23.31	4.9(5.87 \pm 0.24) 6.32	0.66(0.71 \pm 0.03) 0.99	Fv-rg
3.	23.3(27.3 \pm 0.48) 31.9	21.5(23.7 \pm 0.64) 28.7	1.15	14.4(18.8 \pm 1.93) 25.13	17.9(23.1 \pm 1.87) 28.7	7.18(7.71 \pm 0.59) 10.77	1.07(1.50 \pm 0.06) 2.13	Fs
4.	24.7(29.2 \pm 0.24) 32.3	21.5(24.0 \pm 0.21) 28.1	1.21	14.4(21.0 \pm 6.25) 25.12	17.9(20.6 \pm 0.32) 21.5	5.38(7.06 \pm 0.22) 8.97	1.75(2.22 \pm 0.13) 2.87	sb-pt
5.	328.2(41.2 \pm 0.46) 48.9	23.3(25.4 \pm 0.27) 26.6	1.61	26.2(31.6 \pm 0.70) 39.9	16.6(17.0 \pm 0.26) 19.92	4.99(6.32 \pm 0.11) 6.66	0.66(0.72 \pm 0.36) 0.99	Rg-rt
6.	42.3(43.7 \pm 0.65) 48.28	26.6(29.6 \pm 0.5) 30.1	1.49	36.6(40.1 \pm 0.69) 43.2	16.6(19.3 \pm 2.4) 23.3	c.6.66	0.66(0.85 \pm 0.06) 1.66	Rg-fs
7.	37.5(40.4 \pm 0.46) 42.25	25.1(26.4 \pm 0.29) 27.5	1.51	25.1(29.9 \pm 0.71) 32.5	c.17.5	c.5	1.25(1.74 \pm 0.45)	Rg-rt 1.75
8.	33.1(36.0 \pm 0.25) 39.62	21.6(24.0 \pm 0.25) 24.22	1.49	23.3(23.0 \pm 0.35) 26.14	c 16.48	c.8.32	0.66(0.99 \pm 0.12) 1.66	Fs
9.	13.3(17.2 \pm 0.34) 19.9	9.91(11.9 \pm 0.19) 13.3	1.44	9.99(12.8 \pm 0.30) 16.6	6.66(8.2 \pm 0.37) 11.6	0.66(2.02 \pm 0.17) 3.33	0.33(0.60 \pm 0.14) 0.69	Fs-rg
10.	16.1(18.8 \pm 0.29) 21.03	14.3(15.8 \pm 0.21) 16.81	1.18	14.1(15.2 \pm 0.28) 16.81	10.0(10.2 \pm 0.60) 11.21	2.94(3.36 \pm 0.58) 3.92	1.26(1.35 \pm 0.02) 1.41	Fv-fs
11.	25.1(28.6 \pm 0.64) 32.32	17.9(21.8 \pm 0.57) 25.13	1.30	17.1(21.0 \pm 0.77) 23.32	14.3(16.9 \pm 0.91) 17.9	4.31(6.10 \pm 0.44) 2.18	1.43(1.69 \pm 0.05) 1.79	Rg-fs
12.	26.9(28.2 \pm 0.39) 29.07	19.5(21.7 \pm 0.41) 23.22	1.39	14.5(19.9 \pm 1.07) 21.39	16.5(21.6 \pm 2.14) 25.13	c.4.32	0.35(0.5 \pm 0.09) 0.72	Fs
13.	28.7(31.4 \pm 0.63) 36.63	17.9(20.7 \pm 0.38) 23.33	1.51	21.5(22.7 \pm 1.08) 23.33	c.14.36	c.2.27	1.43(1.73 \pm 0.03) 1.29	Rg-rt
14.	30.3(32.9 \pm 0.47) 37.8	25.2(27.6 \pm 0.42) 30.81	1.19	25.2(28.1 \pm 1.11) 30.3	14.11(15.6 \pm 0.64) 18.21	3.61(4.17 \pm 0.61) 4.91	1.41(1.50 \pm 0.08) 2.21	Fv-rt
15.	25.1(24.9 \pm 0.47) 34.10	18.3(21.4 \pm 0.33) 26.9	1.35	21.5(24.6 \pm 0.61) 32.31	11.1(15.4 \pm 0.51) 17.7	3.59(5.20 \pm 0.41) 5.37	1.43(1.65 \pm 0.04) 2.15	Rg
16.	49.9(51.2 \pm 0.32) 55.61	35.9(40.1 \pm 0.42) 43.06	1.27	35.9(40.8 \pm 0.52) 46.6	25.1(30.8 \pm 1.30) 35.4	10.7(11.1 \pm 0.35) 11.4	0.73(1.56 \pm 0.20) 2.51	Rg
17.	21.2(22.9 \pm 0.41) 29.43	14.3(18.1 \pm 0.35) 21.89	1.26	14.4(17.1 \pm 0.59) 25.13	10.7(14.3 \pm 0.24) 17.9	c.3.59	1.07(1.27 \pm 0.08) 1.79	Rg-rt

Species (1-17)

1) *Alysicarpus heterophyllus*, 2) *Colutea armata*, 3) *Indigofera caerulea*, 4) *Indigofera intricata*, 5) *Lathyrus emodii*, 6) *L. cicera*, 7) *L. humilis*, 8) *L. pratensis*, 9) *Lotus corniculata*, 10) *L. garcinii*, 11) *Medicago lupulina*, 12) *M. polymorpha*, 13) *Sesbania concolor*, 14) *Tephrosia uniflora*, 15) *Trifolium repens*, 16) *T. incarnatum*, 17) *Trigonella comiculata*

group: *Crotalaria medicaginea* Lamk, *C. burhia* Buch.-Ham. ex Benth., and *Atylosia scarabaeoides* (L.) Baker.

Pollen type-III: *Colutea armata*-type (Fig.3 F-I; Fig.4 A & B; Fig.7 G - J).

Pollen class: Tricolporate, zonoaperturate.

P/E ratio: Erect or semierect.

Shape: Prolate to sub - prolate.

Apertures: Ectoaperture-colpus long, narrow, acute ends. Endoaperture-ora \pm circular in shape, la-longate or lo-longate.

Exine: Sexine thicker or thinner than nexine.

Ornamentation: Tectum mostly rugulate-fossulate or fossulate-rugulate, rarely fossulate or fossulate-reticulate; most of the species have distinct colpal margins.

Measurements: Polar length (P) 21.6 (34.5 \pm 0.19) 55.1 μm . Equatorial diameter (E) 9.99 (25.1 \pm 0.11) 43.0 μm , colpus length 9.9 (26.4 \pm 0.50) 40.6 μm . Mesocolpium 6.66 (19.9 \pm 0.54) 35.9 μm . Apocolpium 0.66 (6.64 \pm 0.4) 11.48 μm . Exine 0.33 (1.34 \pm 0.06) 2.87 μm thick (Table-3).

Key to the species and species groups

1. + Polar length - 21 - 43 μm _____ 2
 - Polar length less than 21 μm
 _____ *Lotus garcini-group*
 (*Lotus corniculata* L., *L. garcinii* DC.)
2. + Pollen grains with distinct colpal margins _____ 3
 - Pollen grains without distinct colpal margins _____ 6
- 3 + Apocolpium 10.7 - 11.5 μm
 _____ *Trifolium incarnatum*
 - Apocolpium less than 10.7 μm _____ 4
4. + Colpus length 36.6 - 43.2 μm
 _____ *Lathyrus cicera*
 - Colpus length 14 - 34 μm _____ 5
5. + Tectum rugulate or rugulate-reticulate
 _____ *Sesbania concolor group*
 (*Lathyrus emodi* (wall ex Fritsch) Ali, *L. humilis*)

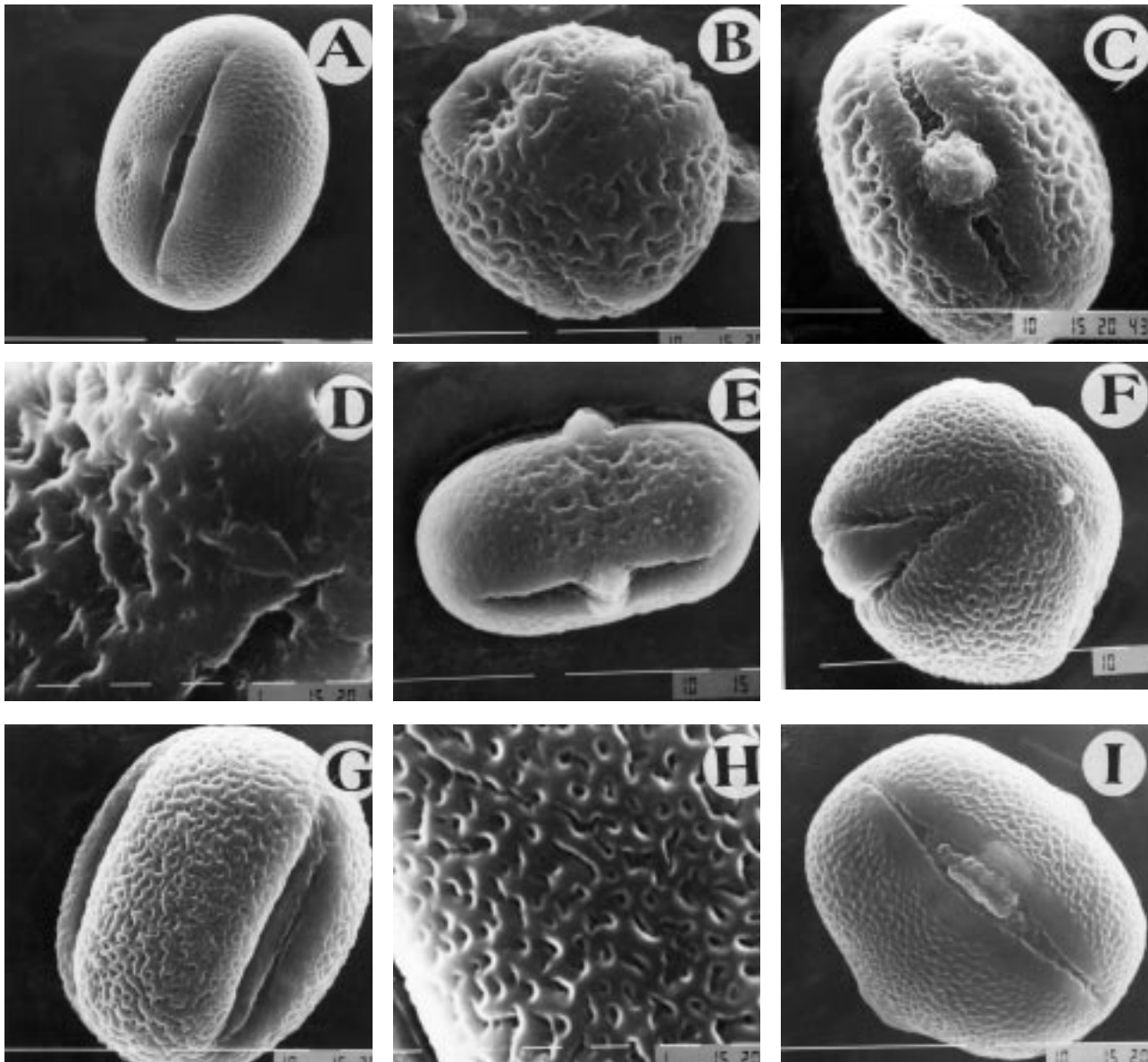


Figure 3. –Scanning Electron micrographs of pollen grains. *Sophora secundiflora*: A, Equatorial view. *Vicia monantha*: B, polar view; C, Equatorial view; D, Exine pattern. *V. hirsuta*: E, Equatorial view. *Sesbania concolor*: F, polar view; G, Equatorial view; H, Exine pattern. *Trigonella corniculata*: I, Equatorial view. Scale bar = A-C, E-G & I = 10 µm; D & H = 1 µm.

(Ser.) Fisher ex Sprangel, *Trifolium repens* L.,
Trigonella corniculata L., *Sesbania concolor* Gillett)

– Tectum fossulate or fossulate-rugulate

—————*Medicago polymorpha*-group

(*Colutea armata* Hemsley L., *Medicago lupulina* L., *M. polymorpha* L.)

+ Tectum sub-psilate-scabrate

—————*Indigofera intricata*

– Tectum not as above —————7

7. + Tectum foveolate-reticulate

—————*Tephrosia uniflora*

– Tectum fossulate or fossulate-rugulate ———8

8. + Polar length 23.3 - 31.9 µm

—————*Indigofera caerulea*

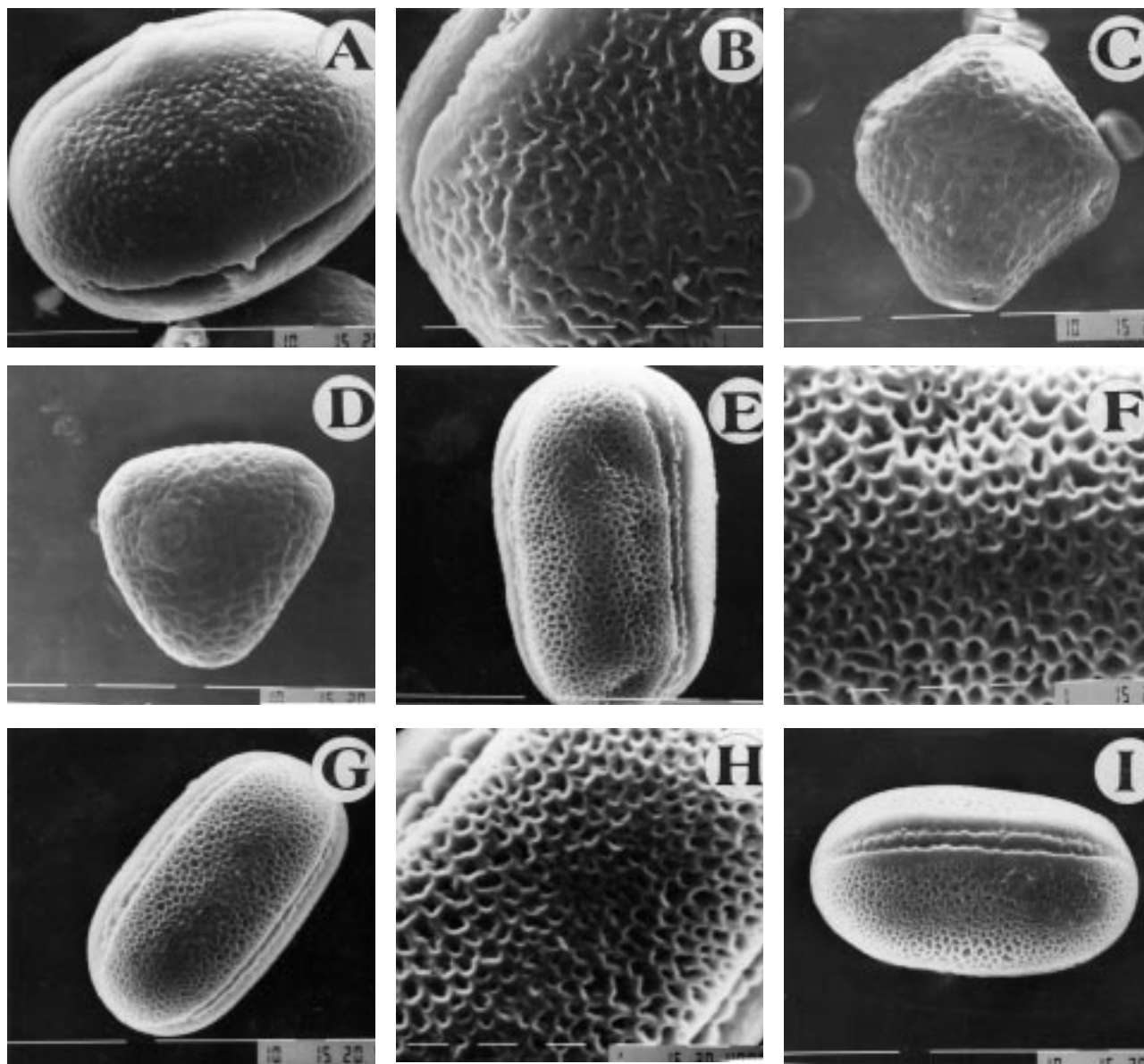


Figure 4. –Scanning Electron micrographs of pollen grains. *Lathyrus cicera*: A, Equatorial view. *Trigonella corniculata*: B, Exine pattern. *Dumasia villosa*: C & D, polar view. *Ebenus stellata*: E, Equatorial view; F, Exine pattern. *Onobrychis corniculata*: G, Equatorial view; H, Exine pattern. *O. stewartii*: I, Equatorial view. Scale bar = A, C - E, G, I = 10 μ m; B, F & H = 1 μ m.

– Polar length 35.9 – 43.08 μ m

—————*Alysicarpus heterophyllus*

Pollen type-IV: *Dumasia stellata*-type (Fig.4 C & D).

Pollen class: Triporate, zonoaperturate.

P/E ratio: Semi-erect.

Shape: sub-prolate.

Apertures: Circular with annulus.

Exine: Sexine thicker than nexine.

Ornamentation: Rugulate.

Outline: Trilobed-triangular in polar view, elliptic in equatorial view.

Measurements: P 39.9 (41. 48) 43.2 μ m; and equatorial diameter E 36.6 (39.8) 44.9 μ m. Pore di-

Table 4. General pollen characteristics of different species of the *Rhynchosia minima*-type

No. taxa	Shape	P/E ratio	Polar length (P) in μm	Equatorial Diameter (E) in μm	Colpus length (C) in μm	Mesolocpium in μm	Apocolpium in μm	Exine thickness μm	Tectum
1.	Psp	1.04	14.02(15.02 \pm 0.17) 16.80	12.06(13.09 \pm 0.28) 15.11	11.09(13.0 \pm 0.28) 14.23	7.01(8.8 \pm 0.4) 9.81	C.3.5	0.7(0.74 \pm 0.05) 1.26	MRt
2.	Sb-ob	0.80	21.05(24.06 \pm 0.20) 28.36	21.05(30.06 \pm 0.142) 35.9	17.09(18.03 \pm 0.58) 21.13	21.5(22.02 \pm 0.47) 25.12	7.18(07.50 \pm 0.32) 10.41	0.78(01.07 \pm 0.04) 1.79	FRt
3.	P-sp	1.04	17.01(18.21 \pm 0.42) 21.2	15.04(17.05 \pm 0.24) 19.6	11.02(18.05 \pm 0.39) 15.4	12.06(13.07 \pm 0.21) 11.11	3.05(4.35 \pm 0.05) 4.21	0.98(01.31 \pm 0.04) 1.54	MRt
4.	P-sp	0.92	29.09(32.03 \pm 0.33) 33.09	33.03(35.07 \pm 0.34) 36.06	16.06(21.32 \pm 0.60) 26.06	23.03(25.03 \pm 0.41) 29.09	6.66(09.86 \pm 0.16) 11.32	1.66(21.87 \pm 0.09) 03.33	Rt
5.	P-sp	1.12	23.03(25.09 \pm 0.54) 28.6	19.06(20.00 \pm 0.63) 26.6	16.06(20.02 \pm 0.63) 23.3	16.06(18.69 \pm 0.69) 19.9	3.99(4.65 \pm 0.33) 4.99	0.66(0.91 \pm 0.13) 1.66	Mrt
6.	P-sp	1.04	23.03(26.06 \pm 0.04) 28.07	25.01(25.37 \pm 0.45) 28.07	17.09(21.38 \pm 0.58) 25.13	17.04(20.05 \pm 0.58) 25.13	3.59(5.30 \pm 0.58) 07.18	0.71(1.28 \pm 05.09) 01.07	FRt
7.	P-sp	1.07	32.03(34.02 \pm 0.36) 36.02	28.04(31.08 \pm 0.56) 35.09	25.01(28.19 \pm 0.06) 34.01	21.05(24.08 \pm 0.53) 28.7	4.30(6.68 \pm 0.15) 10.79	0.71(1.72 \pm 0.48) 01.79	FRt
8.	P-sp	0.96	23.03(26.12 \pm 0.55) 29.07	25.03(27.02 \pm 0.55) 32.03	14.36(16.95 \pm 1.41) 17.09	17.09(21.09 \pm 0.39) 25.01	3.59(05.42 \pm 0.36) 01.18	1.79(02.33 \pm 0.57) 02.87	FRt
9.	P-sp	1.12	28.07(31.05 \pm 0.34) 34.1	25.01(27.09 \pm 0.19) 28.7	21.05(24.06 \pm 0.33) 25.13	17.09(20.06 \pm 0.32) 25.13	3.59(4.52 \pm 0.29) 07.18	1.43(1.61 \pm 0.01) 01.79	FRt
10.	P-sp	1.08	21.13(23.11 \pm 0.31) 23.8	15.04(21.03 \pm 0.86) 25.2	17.09(19.15 \pm 1.97) 21.54	17.95(20.05 \pm 0.21) 21.54	8.97(10.04 \pm 0.27) 10.77	2.87(3.26 \pm 0.08) 3.59	CrRt
11.	P-sp	1.05	19.3(23.07 \pm 0.31) 24.7	18.03(22.02 \pm 01.04) 39.0	16.06(19.05 \pm 0.23) 19.9	13.03(15.06 \pm 0.36) 16.9	3.99(4.19 \pm 0.11) 4.99	0.99(1.57 \pm 0.05) 1.99	CrRt
12.	P-sp	1.09	19.09(20.07 \pm 0.48) 23.06	16.6(18.09 \pm 0.91) 19.09	16.6(17.62 \pm 0.58) 19.09	13.3(17.62 \pm 0.5) 16.06	3.33(4.16 \pm 0.51) 06.66	0.22(0.81 \pm 0.6) 01.33	FRt
13.	Ob-sp	0.98	25.13(26.07 \pm 0.06) 30.5	21.54(27.02 \pm 0.8) 32.51	18.8(19.6 \pm 0.51) 21.51	12.6(14.07 \pm 1.21) 18.2	C.4.2	0.98(01.54 \pm 0.98) 2.12	FRt
14.	Sb-ob	0.83	18.21(21.35 \pm 8.46) 25.21	1.01(25.48 \pm) 28.32	15.41(18.01 \pm 0.41) 18.21	15.41(11.71 \pm 0.41) 18.21	8.41(9.23 \pm 0.37) 9.81	12.06(1.53 \pm) 2.11	CrRt
15.	P-sp	1.09	25.01(28.49 \pm 0.73) 32.31	17.9(25.09 \pm 01.09) 32.31	17.09(21.9 \pm 0.29) 25.13	17.09(22.75 \pm 0.35) 25.13	3.59(4.45 \pm 0.52) 08.92	1.07(1.72 \pm 0.04) 02.15	CrRt
16.	Sb-ob	0.82	19.61(23.40 \pm 0.47) 25.21	23.8(26.30 \pm 0.12) 32.31	11.21(15.21 \pm 0.1) 18.21	14.61(20.54 \pm 0.34) 21.41	6.31(7.77 \pm 0.34) 09.81	1.41(1.71 \pm 0.11) 12.12	CrRt
17.	Ob-sp	0.96	28.07(33.46 \pm 0.35) 35.3	32.0(34.05 \pm 0.49) 36.10	21.1(25.95 \pm 0.35) 28.70	21.54(25.07 \pm 0.50) 32.31	3.59(4.74 \pm 0.31) 7.18	0.15(2.20 \pm 0.01) 3.32	Fv-fs
18.	P-sp	1.05	21.54(23.92 \pm 0.35) 25.84	07.95(22.06 \pm 0.45) 25.12	10.77(16.03 \pm 0.51) 18.30	14.03(17.7 \pm 0.31) 18.31	3.54(6.32 \pm 2.36) 07.58	1.43(1.77 \pm 0.4) 02.15	CrRt
19.	P-sp	1.02	21.25(23.17 \pm 0.24) 33.03	20.0(22.54 \pm 0.32) 25.05	17.05(19.9 \pm 0.33) 22.05	17.07(19.05 \pm 0.37) 22.05	2.05(3.43 \pm 0.27) 05.00	1.25(11.88 \pm 0.42) 02.25	FRt
20.	Sb-ob	0.81	21.54(22.0 \pm 0.32) 23.33	25.13(27.01 \pm 0.64) 30.57	14.7(17.23 \pm 0.48) 17.95	17.9(20.92 \pm 0.35) 25.13	3.58(4.38 \pm 0.43) 07.18	0.77(1.75 \pm 0.84) 02.15	Rt-rg
21.	P-sp	1.14	21.54(24.59 \pm 0.90) 28.07	17.09(21.52 \pm 0.24) 23.33	17.09(19.37 \pm 0.047) 25.13	14.36(17.09 \pm 0.29) 19.36	1.79(4.30 \pm 0.29) 07.17	1.07(01.06 \pm 0.04) 01.79	FRt
22.	P-sp	1.08	21.18(25.06 \pm 0.49) 32.18	19.09(23.06 \pm 0.44) 29.0	17.09(20.01 \pm 0.72) 26.4	14.36(19.16 \pm 0.83) 21.54	3.59(05.89 \pm 0.64) 7.18	01.44(01.75 \pm 0.08) 1.79	MRt

Species (1-18)

1) *Alhagi maurorum*, 2) *Astragalus fatmensis*, 3) *Argyrolobium roseum*, 4) *Atylosia mollis*, 5) *Cicer macranthum*, 6) *Chesneya parviflora*, 7) *Indigofera hebeptala*, 8) *I. trifoliata*, 9) *I. heterantha*, 10) *Indigofera articulata*, 11) *Lespedeza juncea*, 12) *Lotononis platycarpus*, 13) *Psoralea plicata*, 14) *Rhynchosia pulverulanta*, 15) *Rhynchosia pseudo-cajan*, 16) *R. minima*, 17) *R. rothii*, 18) *R. schimperii*, 19) *Sophora alopecuroides*, 20) *Tephrosia strigosa*, 21) *T. falciformis* 22) *Tephrosia apollinea*

ameter 3.94 (5.74) 7.53 μm . Mesopodium 26.6 (35.5 \pm 6.62) 39.9 μm . Apopodium 9.99 (16.24 \pm 0.29) 16.65 μm . Exine 2.99 (3.17 \pm 0.036) 3.33 μm thick.

Pollen type-V: *Ebenus stellata* - type (Fig.4 E & F).

Pollen class: Tricolpate, zonoaperturate.

P/E ratio: Erect.

Shape: Prolate.

Apertures: Ectoaperture - colpus long, narrow, not sunken, colpal membrane sub-psilate. Endo-

aperture absent, colpi ends acute.

Exine: Thick, sexine thinner than nexine.

Ornamentation: Tectum medium reticulate, with \pm irregular pattern of muri, luminae 0.33 - 1 μm in diameter.

Outline: Equatorial view-elliptic, polar view trilobed, with apertures on the angle, sides convex.

Measurements: Polar axis P 33.3 (35.32) 39.9 μm ; and equatorial diameter E 16.6 (18.8 \pm 0.38) 19.9 μm . Colpi 29.9 (31.76 \pm 0.52) 36.6 μm long.

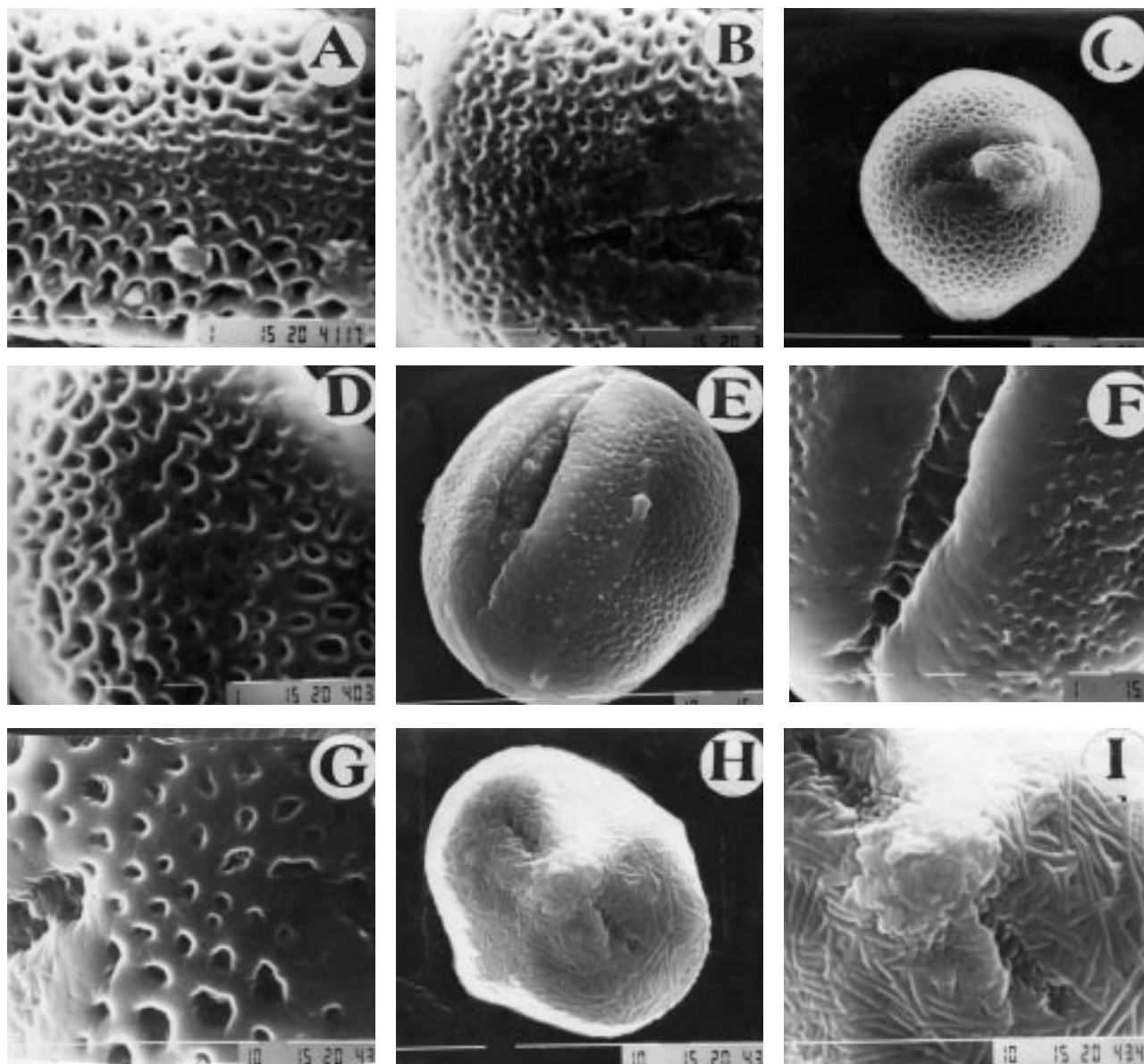


Figure 5. –Scanning Electron micrographs of pollen grains. *Onobrychis stewartii*: A, Exine pattern. *Cicer macrantha*: B, Exine pattern. *Lespedeza juncea*: C, Equatorial view; D, Exine pattern. *Tephrosia filiciformis*: E, Equatorial view; F, Exine pattern. *Rhynchosia rothii*: G, Exine pattern. *Securigera securidaca*: H, Equatorial view; I, Exine pattern. Scale bar = A, B, D & F = 1 μ m; C, E, G-H = 10 μ m.

Mesocolpium c.16 μ m. Exine 0.66 (0.71 \pm 0.22) 0.99 μ m thick.

Pollen type - VI: *Onobrychis stewartii*-type (Fig.4 G-I; Fig.5 A).

Pollen class: Tricolpate, zonoapreturate.

P/E ratio: Pererect.

Shape: Perprolate.

Apertures: Ectoaperture-colpus long, narrow, not sunken, colpi ends acute, colpal membrane sub-psilate to psilate, sometimes colpi operculated. Endoaperture absent.

Exine: Exine medium, sexine thicker or thinner than nexine.

Ornamentation: Tectum finely-medium reticulate; luminae gradually reducing in size towards colpus

No. Length in of taxa	Breadth in μm	Colpus length in μm	Exine thickness in μm
1. 33.3(38.3 \pm 0.56) 42.9	13.3(13.86 \pm 0.56) 14.9	26.6(13.16 \pm 0.62) 39.9	0.33(0.58 \pm 0.62) 0.66
2. 26.6(31.87 \pm 0.51) 33.9	13.3(14.8 \pm 0.22) 33.8	26.6(33.16 \pm 0.0) 39.9	0.33(0.66 \pm 0.35) 0.90
3. 31.6(38.05 \pm 1.56) 46.2	13.3(15.30 \pm 0.29) 16.55	24.9(34.02 \pm 0.87) 39.96	0.33(0.63 \pm 0.019) 0.66
4. 23.9(31.1 \pm 0.42) 33.3	13.3(15.79 \pm 0.25) 19.9	23.3(27.9 \pm 0.46) 31.6	0.33(0.56 \pm 0.03) 0.66
5. 20.3(22.1 \pm 0.07) 33.3	8.32(10.5 \pm 0.18) 13.3	17.3(18.3 \pm 0.66) 13.9	0.33(0.52 \pm 0.03) 0.66

Table 5. General pollen characteristics of different species of the *Onobrychis stewartii*-type

Species (1-5)

1) *Onobrychis tavernierifolia*, 2) *O. dealbata*, 3) *O. stewartii*, 4) *O. cornuta*, 5) *O. microntha*

forming distinct colpal margins; lumina variable in size and shape, 0.61-1 μm in diameter.

Outline: Trilobed, with apertures on the angles in polar view. Equatorial view narrow elliptic, sides convex.

Measurements: Polar length (P) 20.3 (33.7 \pm 0.11) 42.9 μm , and equatorial diameter (E) 8.32 (12.1 \pm 0.25) 33.6 μm . Colpi length 17.3 (33.6 \pm 0.11) 39.9 μm . Mesocolpium 6.66 (8.11 \pm 0.11) 10.3 μm . Apocolpium 0.33 (0.77 \pm 0.21) 1.09 μm . Exine 0.33 (0.61 \pm 0.03) 0.90 μm thick (Table-4).

Key to the species and species groups

- + Colpus length 13.3 - 17.3 μm
 - *Onobrychis micrantha*
- Colpus length 23 - 39.9 μm
 - *Onobrychis tavernierifolia*-group
(O. dealbata stocks, O. stewartii Baker, O. cornata (L.) Desv., O. tavernierifolia stocks ex Boiss)

Pollen type - VII: *Rhynchosia minima* - type (Fig.5 B-G; Fig.7 K & L).

Pollen class: Tricolporate, zonoaperturate.

P/E ratio: Sub-transverse to semi-transverse rarely semi-erect.

Apertures: Ectoaperture - colpi medium, narrow with acute ends. Endoapertures la-longate \pm circular in shape, often with operculum.

Exine: Tectum generally finely-coarsely reticulate rarely reticulate-rugulate; luminae size gradually reducing towards colpus forming distinct colpal margins.

Measurements: Polar length (P) 14.2 (24.7 \pm 0.17) 26.2 μm , and equatorial diameter (E) 21.1 (22.8 \pm 0.29) 35.9 μm , colpi 11.9 (20 \pm 0.28) 34.1 μm long. Mesocolpium 17.95 (22.65 \pm 0.69) 28.7 μm . Apocolpium 3.5 (6.69 \pm 0.5) 11.9 μm . Exine 0.71 (1.78 \pm 0.13) 3.95 μm thick, P/E ratio: 0.81-1.12 (Table-5).

Key to the species

- 1. + Pollen grains sub-oblate —————2
– Pollen grains oblate-spheroidal to prolate-spheroidal —————3
- 2. + Apocolpium 3.8 - 7.18 μm
————— *Tephrosia strigosa*
– Apocolpium 7.18 - 10.4 μm
————— *Rhynchosia pulverulanta*-group
(*Astragalus fatmensis* Hochst. ex Blatter, *Rhynchosia minima* (L.) DC. and *R. pulverulanta* stocks)
- 3. + Polar length 14-16.8 μm
————— *Alhagi maurorum*
– Polar length 19.2-35.3 μm —————4
- 4. + Pollen grains oblate-spheroidal —————5
– Pollen grains prolate-spheroidal —————6
- 5. + Colpi without distinct colpal margins
————— *Indigofera trifoliata*
– Colpi with distinct colpal margins
————— *Psoralea plicata*-group
(*Atylosia mollis* Benth, *Rhynchosia rothii* Benth. ex Aitch., *Psoralea plicata* Delile)

No.Length in of taxa	Breadth in μm	Colpus length in μm	Exine thickness in μm
1. 16.8(17.8 \pm 0.20) 19.6	9.8(10.6 \pm 0.22) 11.2	12.6(13.1 \pm 0.13) 14	0.84(1.26 \pm 0.06) 14
2. 18.2(20.29 \pm 0.46) 23.1	11.2(12.4 \pm 0.2) 14	15.4(17.15 \pm 0.50) 19.6	0.7(1.17 \pm 0.63) 1.4
3. 21.54(22.24 \pm 0.8) 23.33	10.77(13.9 \pm 0.25) 15.07	17.95(19.40 \pm 0.34) 21.89	0.72(1.34 \pm 0.09) 1.79
4. 17.95(18.36 \pm 0.23) 21.54	8.97(11.05 \pm 0.2) 14.36	11.48(15.68 \pm 5.19) 17.95	0.71(1.20 \pm 0.11) 3.59
5. 23.9(29.57 \pm 0.42) 33.3	16.3(16.9 \pm 1.11) 17.64	16.6(2.49 \pm 0.09) 29.9	0.66(2.82 \pm 0.29) 3.33
6. 24.9(27.2 \pm 0.41) 30.3	13.3(13.9 \pm 0.24) 16.6	19.9(23.1 \pm 0.7) 26.07	0.66(0.68 \pm 0.64) 0.99

Table 6. General pollen characteristics of different species of the *Taverniera lappaceae*-type

Species (1-6)

1) *Taverniera cunefolia*, 2) *T. lappacea*, 3) *T. sparteae*, 4) *T. glabra*, 5) *Onobrychis nummularia*, 6) *O. laxiflora*

+ Mesocolpium c. 12.6 μm —————7

– Mesocolpium 14.3 - 28.7 μm

—————*Lotononis platycarpus*-group

(*Cicer macranthum* M. Pop., *Indigofera heterantha* Wall, ex Brandis, *I. hebetata* Benth. ex Baker Chesneya parviflora Jaub. spach, *Lespedeza juncea* (L.f.) Pers., *Lotononis platycarpus* (Viv.) Pic-Serm., *Rhynchosia schimperii* Hochst. ex Boiss, *R. pseudo - cajan* Camb., *Sophora alopecuroides* L., *Tephrosia falciformis* Ramaswami, *T. apollinea* (De-lile & Link))

7. + Colpi 11.2 - 15.4 μm long

—————*Argyrolobium roseum*

– Colpi 18.8 - 21.5 μm long

—————*Indigofera articulata*

Pollen type - VIII: *Securigera securidaca*-type (Fig.5 H & I).

Pollen class: Tricolporate, zonoaperturate.

P/E ratio: Erect to sub-erect.

Apertures: Ectoaperture - colpus long, narrow, not sunken; colpal membrane granulated, colpi ends acute.

Endoaperture: Ora circular, la-longate.

Exine: Thin, sexine thicker than nexine.

Ornamentation: Tectum striate or striate-rugulate.

Measurements: Polar length P 16.6 (18.5 \pm 0.18) 19.9 μm , equatorial diameter E 13.3 (16.59 \pm 0.24) 19.9 μm . Colpi length 12.8 (15.6 \pm 0.2) 16.9 μm . P/E ratio: 1.26 - 1.36. Mesocolpium 16.15 (17.2 \pm 0.52) 18.3 μm . Apocolpium c.8.91 μm . Exine 0.6 (0.75 \pm 0.11) 1.42 μm thick.

Pollen type - IX: *Taverniera lappaceae* (Fig.6 A-D).

Pollen class: Tricolpate, zonoaperturate.

P/E ratio: Erect.

Shape: Prolate.

Apertures: Ectoaperture-colpus long, narrow, not sunken, colpi ends acute, colpal membrane sub-psilate to psilate sometimes colpi operculated. Endoaperture absent.

Exine: Thick, sexine thicker or thinner than nexine.

Ornamentation: Tectum finely-medium reticulate, luminae gradually reducing in size towards colpus forming distinct colpal margins; lumina variable in size and shape, 0.33-1 μm in diameter.

Outline: Trilobed, with apertures on the angles in polar view. Equatorial view narrow elliptic, sides convex.

Measurements: Polar length (P) 16.8 (23.7 \pm 0.11) 23.9 μm , and Equatorial diameter (E) 8.97 (14.1 \pm 0.21) 14.36 μm . Colpi length 11.4 (20.6 \pm 0.11) 29.9 μm . Mesocolpium 5.81 (10.8 \pm 0.52) 14.2 μm . Apocolpium 1.71 (3.71 \pm 0.52) 14.33 μm . Exine 0.71 (1.26 \pm 0.09) 3.59 μm thick (Table 6).

Key to the species group

+ Polar length 23.9 - 33.3 μm

—————*Onobrychis laxiflora*-group

(*Onobrychis laxiflora* Baker, *O. nummularia* Stocks)

– Polar length 16.6 - 23.3 μm

—————*Taverniera cunefolia*-group

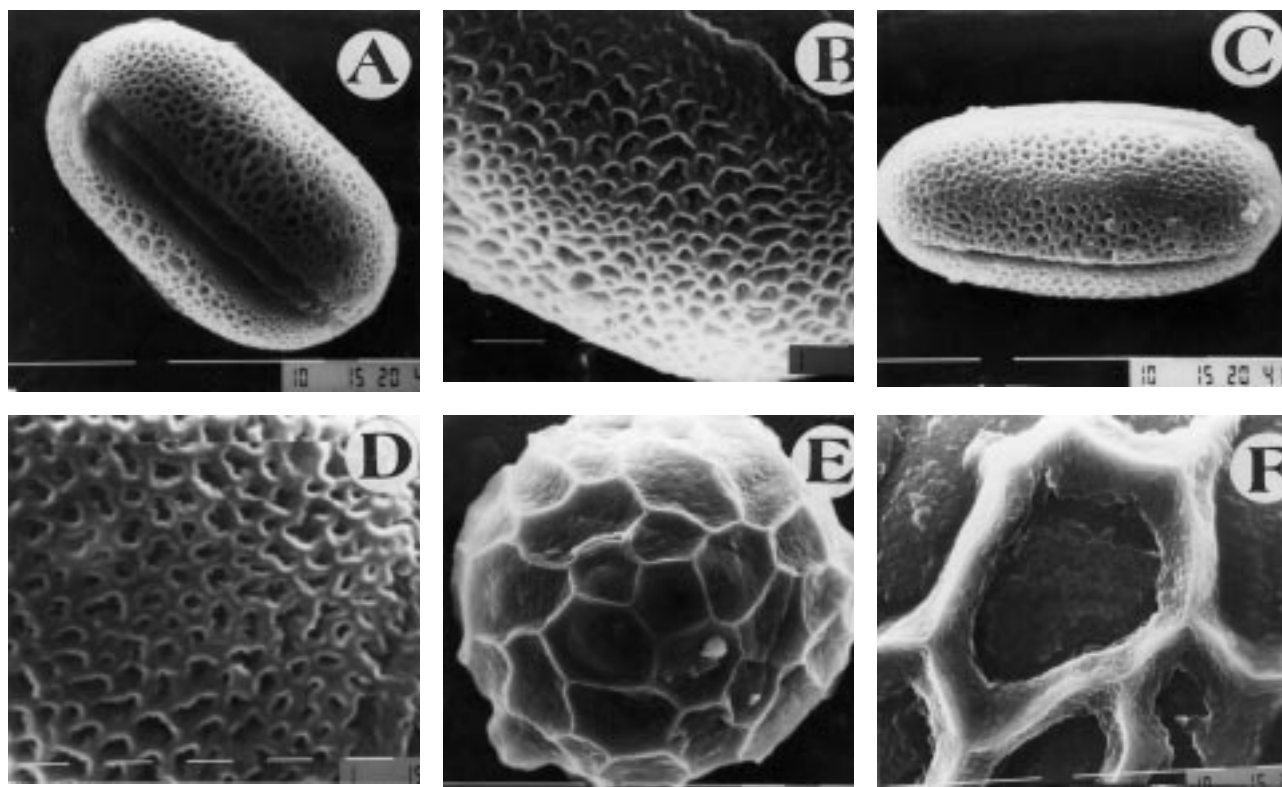


Figure 6. —Scanning Electron micrographs of pollen grains. *Taverinera glabra*: A, Equatorial view; B, Exine pattern. *T. spartea*: C, Equatorial view; D, Exine pattern. *Vigna trilobata*: E, polar view, F, Exine pattern. Scale bar = A, C, E & F = 10 μ m; B & D = 1 μ m.

(*T. cunefolia* (Roth) Arn., *T. lappaceae* (ForssK.) DC., *T. spartea* (Burm.f.)DC., *T. glabra* Boiss)

Pollen type - X: *Vigna trilobata*-type (Fig.6 E & F).

Pollen class: Triporate, zonoaperturate.

P/E ratio: Sub-transverse to semi-transverse.

Shape: Sub-obate to oblate-spheroidal.

Apertures: Pore circular, with distinct margins or annulus.

Exine: Thick, sexine thicker than nexine.

Ornamentation: Tectum very coarsely reticulate with sub-psilate; luminae variable in shape and size, 3.83-15.5 μ m in diameter, muri thin.

Outline: Polar view \pm triangular, equatorial view elliptic.

Measurements: Polar view P 23.3 (43.99) 68.21 μ m, and equatorial diameter E 28 (60.2 \pm 1.1) 71.8 μ m. Pore diameter 3.1 (9.1 \pm 1.2) 10.77 μ m. Exine thickness 1.79-5.39 μ m thick.

Key to the species

- + Polar length 23.3 - 31.95 μ m *Vigna trilobata*
 - Polar length 50.26 - 68.4 μ m — *V. vexillata*

Results and Discussion

Papilionoideae is \pm eurypalynous in nature (25). Within the subfamily, the delimitation of the genera on the basis of pollen characteristics is less marked. However, palynology is significant at the tribal and subtribal levels. Ferguson & Skvarla (16) described the pollen morphology of the subfamily *Papilionoideae* in relation to tribal classification.

Striking variations were found in shape, apertural types and exine patterns. The pollen grains are generally free, radially symmetrical, isopolar, usually tri-colporate, rarely colpate or porate. The shape is commonly sub-prolate to prolate, or prolate-spheroidal to oblate-spheroidal. The tectum is mostly reticulate (coarse - fine). In addition to this, various grades of fossulate, fossulate to foveolate, fossulate-rugulate often sub-psilate or areolate tectum types are also

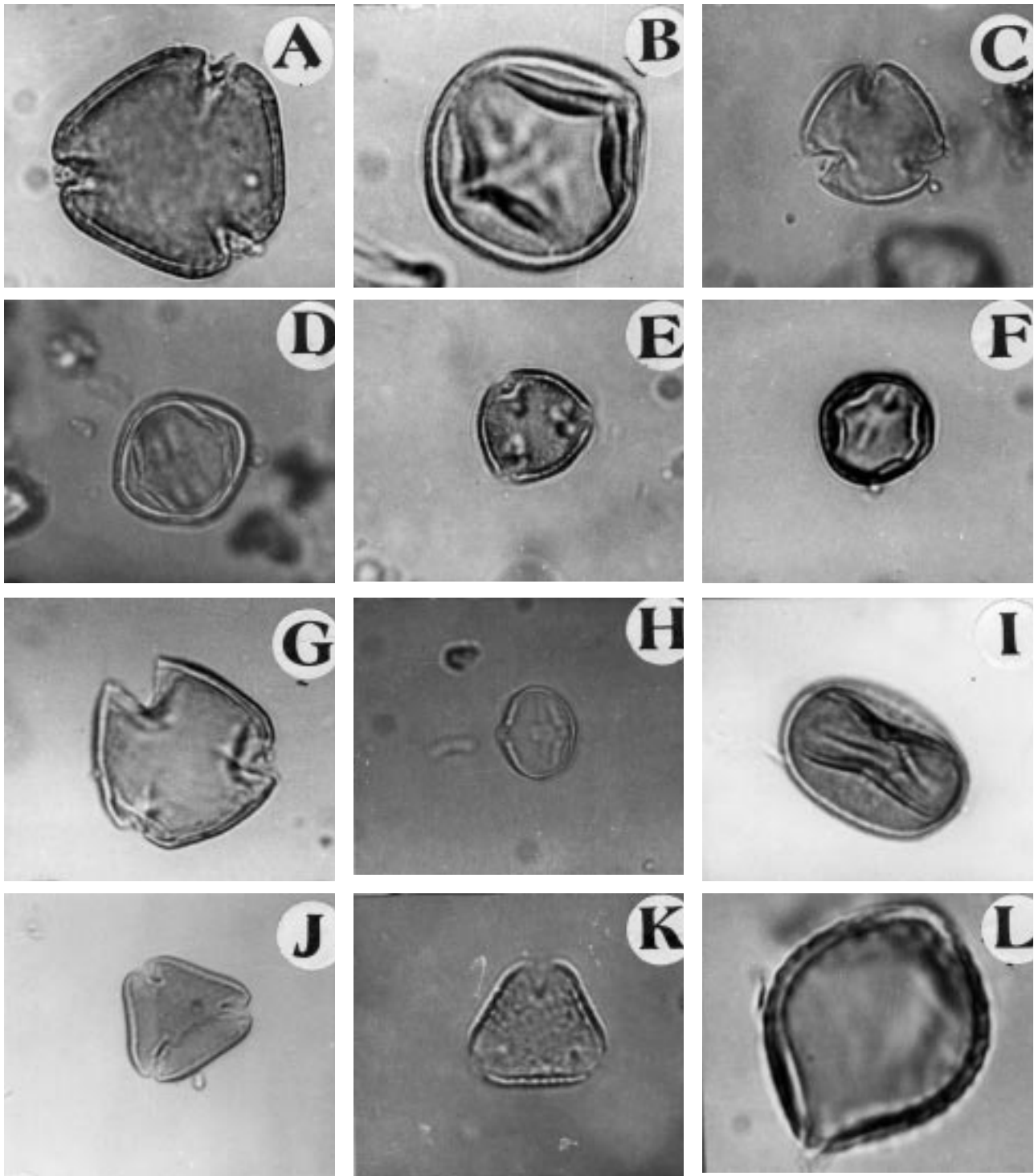


Figure 7. —Light micrographs of pollen grains. *Alysicarpus monilifer*: A, polar view; B, Equatorial view. *Indigofera argenta*: C, polar view; D, Equatorial view. *I. hochstleri*: E, polar view; F, Equatorial view. *Alysicarpus heterophyllus*: G, polar view. *Lotus garcnii*: H, Equatorial view. *Medicago lupulina*: I, Equatorial view. *M. polymorpha*: J, polar view. *Rhynchosia minima*: K, polar view; L, Equatorial view. All figs = 400X

found. However, tricolporate pollen grains with reticulate tectum are more frequently found within this subfamily (more than 70% of the studied taxa, Table 1).

On the basis of shape, apertural types and exine patterns 10 distinct pollen types were recognized, namely, Pollen type-I: *Alysicarpus monilifer*-type, Pollen type-II, Pollen type III, Pollen type-IV: *Dumasia villosa*-type, Pollen type-V: *Ebenus stellate*-type, Pollen type-VI: *Onobrychis stewartii*-type, Pollen type-VII: *Rhynchosia minima*-type, Pollen type-VIII: *Securigera securidaea*-type, Pollen type-IX: *Taverniera lappacea*-type Pollen type-X: *Vigna trilobata*-type.

Pollen type 1 is easily distinguished by its sub-transverse to semi-transverse rarely semi-erect P/E ratio. The tectum is fossulate-rugulate or rugulate to fossulate rarely sub-psilate or areolate. Pollen type 1 comprises 18 species, distributed in 7 genera, belonging to 6 tribes. This pollen type is quite heterogeneous. However, pollen characteristics are helpful at the specific level (see the key to the species). Most of the species of this type belong to the tribe *Indigoferae* (*Indigofera* L.). The species of the genus *Indigofera* L., show a wide variety of tectum types, ranging from rugulate, rugulate-fossulate, rugulate-reticulate, areolate to almost smooth. Similar types of variation in the tectum of the genus *Indigofera* L., were also reported by Vishnu-Mittre & Sharma (29). Bonnefille (30) and Ferguson and Skvarla (16).

Pollen type II is the largest of all the 10 pollen types, with 90 species belonging to 20 genera distributed in 7 tribes (Table 1). Pollen type II is characterized by an erect or pererect P/E ratio. The reticulate tectum ranges from fine to coarse reticulum, with regular or irregular patterns of muri. In most of the species, the luminae are gradually reduced in size, forming \pm distinct subsilate to psilate colpal margins. Pollen type II is more frequent in the tribe *Galegeae* (*Colutea* L., *Astragalus* L., *Oxytropis* DC., *Caragana* Lam.). Ferguson & Skvarla (16) also reported similar types of pollen in the tribe *Galegeae*. However, species of other tribes, such as *Crotalariaeae* (*Crotalaria* L.), *Milletieae* (*Tephrosia* Pers.), *Diocleae* (*Pueraria* L.), *Vicieae* (*Vicia* L., *Lathyrus* L.), *Trifolieae* (*Ononis* L., *Melilotus* Mill., *Medicago* L., *Trigonella* L., *Trifolium* L.), *Desmodieae* (*Campylotropis* Bung, *Alysicarpus* Desv. and *Desmodium* Desv.) are also included in pollen type II, although the species of pollen type II are fairly uniform in their pollen characteristics. On the basis of luminae pattern Pollen type can be divided into 4 dis-

tinct groups, *Vicia monantha* – group (rugulate - reticulate), *Oxytropis microphylla*-group (finely reticulate), *Astragalus stocksii* - group (medium reticulate) and *Crotalaria medicaginea* – group (coarsely reticulate) (see the account of the pollen type).

Pollen type III is usually recognized due to its erect –to– per-erect P/E ratio with rugulate-reticulate, rugulate-fossulate or fossulate-rugulate tectum. A psilate-scabrate type of tectum is rarely found. This pollen type is found in 15 species, distributed in 7 different tribes, *Desmodieae* (*Alysicarpus* Desv.), *Galegeae* (*Colutea*), *Indigoferae* (*Indigofera* L.) *Vicieae* (*Lathyrus* L.), *Robinieae* (*Sesbania* Adanson), *Loteae* (*Lotus* L.) and *Trifolieae* (*Trifolium* L., *Trigonella* L., *Medicago* L., *Melilotus* Mill.). Although the species of pollen type III belong to 7 different tribes, their palynology suggests a close relationship between these tribes. In addition, pollen type III is \pm similar to pollen type II, though they differ in terms of tectal surface. In the latter type, a reticulate tectum is common. Pollen type III is \pm uniform and it is very difficult to characterize the genera and species on the basis of pollen characteristics (Table 3). However, these characteristics are significant enough to separate 3 species and 4 groups (see the key to the species and species groups).

The pollen type IV is restricted to the genus *Dumasia* DC., belonging to the tribe *Phaseoleae*. This pollen type is easily distinguished by its prolate, triporate, zonoaperturate pollen with a rugulate tectum. Ferguson & Skvarla (16) described triangular pollen in *Dumasia* DC., (tribe *Phaseoleae*) with a very short polar view and complex apertures on the angles comprising pairs of pores linked by a colpal zone.

Pollen type V is easily delimited due to its colpate, prolate pollen, with a polar length of more than 33 μm (34 - 39.9 μm) It is found in the genus *Ebenus* L. (*Hedysareae*).

Pollen type V closely resembles pollen type IX, but the latter type differs in its polar length, which is less than 33 μm .

Pollen type V closely resembles pollen type IX, but the latter type differs in its polar length, which is less than 33 μm .

Pollen type VI is easily recognized by its pererect P/E ratio. However, other characteristics of this pollen type are similar to pollen type V (tricolpate grains with a reticulate tectum) and pollen type IX. Pollen types V, VI and IX belong to the same tribe i.e., *Hedysareae* (*Ebenus* L., *Onobrychis* Mill., *Taverniera* DC.).

Only a single genus, *Onobrychis* has this pollen type.

The distinctive feature of pollen type VII is the reticulate tectum with a sub-transverse to sub-erect, rarely semi-erect P/E ratio. There are 12 genera in this pollen type, distributed among 10 tribes, namely, *Sophoreae* (*Sophora* L.), *Crotalariaeae* (*Crotalaria* L.), *Millettiae* (*Tephrosia* Pres.), *Indigofereae* (*Indigofera* L.), *Galegeae* (*Alhagi* Adan., *Astragalus* L. and *Chesneya* Lindl. (ex Endl.)), *Phaseoleae* (*Rhynchosia* Lour.) *Vicieae* (*Cicer* L.) *Desmodieae* (*Lespedeza* Mich.), *Genisteae* (*Argyrolobium* Eckl. & Zeyh.) and *Psoraleeae* (*Psoralea* L.). The pollen characteristics of this type are fairly uniform. Various species of this pollen type are difficult to differentiate because the margins between species are too narrow to enable a key to the species to be made (see Table 5). However, on the basis of shape, size, colpi length and mesocolpium, 5 species and 3 species groups were distinguished (see the key to the species and species groups). In this pollen type the genus *Psoralea* (*Psoraleeae*) has relatively specialized pollen compared to other species and species groups by having well differentiated margo colpi and very distinct pores in the colpi (16).

Pollen type VIII is characterized by its striate or striate-rugulate tectum. This pollen type is found in two genera, *Securigera* DC. (*Loteae*) and *Hippocrepis* L. (*Coronilleae*), each representing a single species. Although these genera are similar in tectal surface, they differ in grain shape (see the key to the genera).

Pollen type IX is easily delimited by its prolate, 3-colpate pollen with reticulate tectum. Pollen type IX is similar to pollen type V but there is little difference in terms of polar length. All the species (5 species representing two genera *Taverniera* DC. and *Onobrychis* Mill. characteristics) of pollen type IX are similar in pollen characteristics and it is difficult to differentiate

them on the basis of pollen characteristics (see the key to the species).

Pollen type X is specific to the genus *Vigna* (tribe, *Phaseoleae*). This pollen type is characterized by porate pollen with coarsely reticulate tectum (9; 10). It is \pm similar to pollen type V because both types have porate and zono-aperturate pollen. However, the latter type differs in tectal surface and grain shape (prolate pollen with rugulate tectum). Two species of *Vigna* can easily be separated on the basis of polar length key to the species).

With few exceptions, the ten pollen types recognized correspond closely to Polhill & Raven's (7) tribal classification and most of the tribes are easily distinguished palynologically, for examples pollen types I, III and VII. These types are more common in the tribes Enddl. *Indigofereae* and *Desmodieae*, whereas pollen type II is predominantly found in the tribe *Galegeae* (*Astragalus* L., *Colutea* L., *Chesneya* Lindl. ex Edl.), *Caragana* L., *Oxytropis* DC. and more frequently in the genus *Astragalus* L. Similarly, pollen types IV and X are restricted to the tribe *Phaseoleae* (except *Flemingia* Ait. f., *Pueraria* DC., *Rhynchosia* Lour.) in the subtribe *Erythrinae* *Dumasia* DC. and subtribe *Phaseolinae* (*Vigna* Savi.) respectively. Pollen types V, VI and IX are easily recognized by the colpate pollen found in the members of the tribe *Hedysareae* (Ebenus L., *Onobrychis* Mill, *Taverniera* DC.).

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