

## POLLEN FLORA OF PAKISTAN -LXIX. POACEAE

ANJUM PERVEEN AND MUHAMMAD QAISER\*

Department of Botany, University of Karachi, Karachi, Pakistan; \*University of Karachi, Karachi –Pakistan;  
Corresponding author's e-mail: anjum\_tahir@hotmail

### Abstract

Pollen morphology of 54 species belonging to 30 genera of the family Poaceae from Pakistan has been investigated using light and scanning electron microscope. It is a stenopalynous family. Pollen grains are mostly spheroidal, monoporate, rarely diporate, ± circular, pore small, operculate, non-operculate, annulate or non-annulate, tectum areolate to scabrate. On the basis of exine ornamentations 5 distinct pollen types are recognized. Palynology does not correspond with tribal and generic classification. However, palynology is significantly helpful at the specific level.

### Introduction

Poaceae is one of the largest families of flowering plants. It consist of c. 620 and 8000 species. It is widely distributed in all the regions of the world. It is divided into number of subfamilies viz., Festucoideae, Panicoideae, Eragrostoideae, Bambusoideae, Oryzoideae and Arundinoideae (Mabberley, 2008). The family is represented by 158 genera and 492 species in Pakistan (Cope, 1982).

Poaceae is a very homogeneous taxon and a readily field recognized family, by having rounded stem usually hollow internodes, leaves 2-ranked, sheath open or sometimes closed, ligule usually present, each flower (floret) of spikelet typically contained two bracts (lemma and palea), perianth of 0-3 lodicules, stamens usually three, fruit grain or caryopsis. The grass family is of great economic importance than any other families of flowering plants having major and minor cereals viz., rice, wheat, corn, barley, millet, rye and oat. Similar to floral morphology, palynology of the family is also remarkably uniform. Pollen morphology of various members of the family Poaceae have been studied by different workers from time to time. Andersen & Bertelsen (1972) studied some members of Poaceae by scanning electron microscope. Page (1975) divided areolate tectum type in two groups on the basis of granules proximity i.e., widely space type and closely space type. Kohler & Lange (1979) distinguished cereal pollen from grass pollen by light and scanning electron microscope. Linder & Ferguson (1985) examined the pollen morphology and phylogeny of the order Restionales and Poales. Siddiqui & Qaiser (1988) also examined pollen morphology of the family Poaceae from Karachi. Pollen morphology of 60 species of family Poaceae from Venezuelan mountain have been examined by Salgado-Labouriau & Rinaldi (1990). Skvarla *et al.*, (2003) investigated annulus-pore relationship in Poaceae pollen. Pollen morphology of 75 species and 42 genera of Chloroideae has been studied by Liu *et al.*, (2004). Ozler *et al.*, (2009) studied the pollen morphology of the genus *Agropyron* from Turkey.

There are two reports on the pollen morphology of Poaceae from Pakistan. Siddiqui & Qaiser (1988) studied the pollen of 60 species from the Karachi, Sindh and Perveen (2006) investigated pollen morphology of 22

species of the family Poaceae from Pakistan. Out of 492 species only 82 species are palynologically investigated. In view of the enormous size of the family the present study is undertaken. Pollen morphology of 54 species of family Poaceae representing 30 genera belonging to 10 tribes has been examined by light and scanning electron microscope.

### Materials and Methods

Polleniferous material was obtained from Karachi University Herbarium (KUH) or collected from the field. The list of voucher specimens is deposited in KUH. The pollen grains were prepared for light microscope (LM) by the standard methods described by Erdtman (1952) and scanning microscopy (SEM). For light microscopy, the pollen grains were mounted in unstained glycerin jelly and observations were made with a Nikon Type-2 microscope, under (E40, 0.65) 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 adhesive cello tape and coated with gold in a sputtering chamber (Ion-sputter JFC-1100). Coating was restricted to 150 A. The S.E.M examination was carried out on a Jeol microscope JSM-6380 A. The measurements were based on 15-20 readings from each specimen. Pollen diameter, pore diameter and exine thickness were measured (Tables 1-5).

The terminology used is in accordance with Erdtman (1952); Rowley (1960), Kremp (1965); Faegri & Iversen (1964); Andersen & Bertelsen (1972) and Moore & Webb (1978).

**General description of Poaceae pollen:** Pollen grains apolar, medium, rarely large size, 18.7-72 µm in diameter, spheroidal, monoporate sometimes diporate, rarely triporate, operculate to non-operculate, annulate to non-annulate or reduce annulus, generally sexine as thick as nexine often thicker or some time thinner than nexine. Tectum usually areolate-scabrate, rarely areolate cum scabrate. In areolate tectum, scabrae fine-large in size, grouped in 2-40 on regular or irregular areolae. On the basis of exine ornamentation family has been divided into five pollen types.

### Key to the pollen types

1. Tectum scabrate ..... Type-V
- Tectum areolate or areolate cum scabrate ..... 2
2. Tectum areolate cum scabrate ..... Type-IV
- Tectum areolate ..... 3
3. Areolate with coarse scabrae ..... Type-III
- Areolate with fine-medium scabrae ..... 4
4. Areolate with fine or diffused scabrae ..... Type-I
- Areolate with medium scabrae, not diffused ..... Type-II



Table 2. General pollen characters of species found in Pollen type-II.

Name of taxa	Pollen diameter in µm	Aperture	Annulus	Operculum	Annulus thickness in µm	Pore diameter in µm	Exine thickness in µm	Tectum
<i>Aeluropus littoralis</i> (Gouan) Parl.	22.50 (24.55±0.5) 29.70	Monoporate	+	++	1.25 (1.33±0.91) 1.50	0.60 (2.75±0.19) 2.75		Areolate, scabrae medium, in groups of 2-10, widely distributed on medium size ± regular areolae
<i>Aeluropus macrostachyus</i> Hack.	25.0 (26.62±0.08) 32.50	Monoporate	+	+	1.75 (1.94±0.05) 1.25	2.51 (3.25±0.15) 4.11	1.1 (1.92±1.51) 2.51	Areolate, scabrae medium in groups of 2-10, medianly distributed medium sized areolate
<i>Eragrostis tremula</i> Hochst. ex Steud.	22.5 (25.03±2.0) 27.50	Monoporate	+	+	1.25 (1.37±0.68) 1.50	3.0 (3.89±0.68) .75	c. 1.5	Areolate, scabrae medium in groups of 2-8, widely distributed on medium size large irregular areolae.
<i>Festuca alatanica</i> (St-Yves) Rozhev.	22.5 (26.64±0.80) 31.25	Monoporate	+	+	5.25 (6.96±0.38) 7.51	2.75 (3.18±0.2) 5.10	0.50 (0.78±0.08)	Areolate, scabrae medium, in groups of 4-15, widely distributed on medium sized irregular areolae
<i>Festuca hartmannii</i> (Markgr.-Dammenb.) Alexeev	25.40 (29.5±0.74) 37.25	Monoporate	+	+	2.50 (2.57±0.04) 2.75	2.75 (3.69±0.20) 5.0	0.50 (1.26±0.05) 1.0	Areolate, scabrae medium, in groups of 2-9, closely distributed on small sized irregular areolae
<i>Festuca kashmiriana</i> Stapf	29.50 (32.43±0.12) 38.50	Monoporate-diporate & triporate	+	+	5.10 (6.47±0.34) 7.50	2.25 (2.95±0.12) 3.75	-	Areolate, scabrae medium, in groups of 3-8, closely distributed on small sized irregular areolae.
<i>Leymus secalinus</i> (Georgi) Tzvele	33.25 (38.39±0.96) 49.75	Monoporate-diporate	+	+	c. 2.75	2.75 (4.23±) 6.25	1.0 (1.15±0.28) 1.50	Scabrae, scabrae medium, widely distributed on subsillate surface
<i>Opismenus undulatifolius</i> (Ard.) Roem. & Schult.	22.50 (24.65±0.34) 27.50	Monoporate-diporate	+	+	1.10 (1.5±0.49) 2.90	0.75 (1.25±0.16) 1.33	2.51 (2.9±0.1) 3.75	Areolate scabrae medium in groups of 2, widely distributed on medium size ± irregular areole.
<i>Parapholis incurva</i> (L.) C. E. Hubbard	30.11 (30.69±0.35) 32.75	Monoporate	+	+	c. 7.75	3.75 (5.25±0.45) 7.25	0.75 (1.25±6.43) 7.43	Areolate scabrae medium in groups of 308, widely distributed on medium sized areolae
<i>Pennisetum lanatum</i> Klotz	29.50 (35.33±85) 47.75	Monoporate-diporate	+	-	-	2.75 (7.20±1.76) 8.75	1.0 (1.27±0.04) 1.50	Areolate, scabrae medium, in groups of 2-8, medianly distributed on small sized areolae.
<i>Sporobolus ioclados</i> (Nees) ex Trin) Nees	17.75 (20.13±6.31) 22.51	Monoporate	+	+	2.11 (2.18±0.06) 2.25	2.25 (2.5±0.08) 3.50	0.750 (1.15±0.03) 1.25	Areolate scabrae medium in groups of 2-20 medianly distributed on medium size irregular areolae.
<i>Stipa splendens</i> Trin.	23.75 (25.97±0.29) 27.50	Monoporate	+	-	-	2.50 (2.89±0.09) 4.0	1.0 (1.14±0.04) 1.50	Areolate, scabrae medium 2-8, closely distributed on medium size irregular areolae

Table 3. General pollen characters of species found in Pollen type-III.

Name of taxa	Pollen diameter in µm	Aperture	Annulus	Operculum	Annulus thickness in µm	Pore diameter in µm	Exine thickness in µm	Tectum
<i>Agrostis stolonifera</i> L.	19.15 (23.11±0.79) 24.00	Monoporate-diporate	+	+	3.15 (5.06±0.23) 6.25	1.25 (1.57±0.17) 2.25	0.75 (0.89±0.04) 1.25	Areolate, scabrae coarse 2-8 small size areolae
<i>Agrostis vinealis</i> Schreb.	18.50 (21.25±0.31) 22.75	Monoporate-diporate	+	+	5.11 (6.20±0.26) 7.50	2.25 (2.53±0.03) 2.55	0.5 (0.96±0.12) 1.25	Areolate, scabrae coarse, widely distributed on medium sized irregular areolae, incision clear
<i>Festuca arundinacea</i> Schreb.	30.35 (33.59±0.76) 37.90	Monoporate	+	+	1.25 (2.39±0.10) 2.50	2.50 (3.91±0.22) 5.0	0.25 (0.40±0.04) 0.05	Areolate, scabrae coarse in groups of 2-8 medianly distributed on small size areolae
<i>Trisetum spicatum</i> (L.) Richt.	26.25 (28.9±0.52) 35.10	Monoporate-diporate	+	+	-	1.01 (1.33±0.2) 1.15	2.75 (2.95±0.087) 3.75	Areolate, scabrae coarse, in groups of 4-12, medianly distributed on medium size irregular areolae

Table 4. General pollen characters of species found in Pollen type-IV.

Name of taxa	Pollen diameter in $\mu\text{m}$	Aperture	Annulus	Operculum	Annulus thickness in $\mu\text{m}$	Pore diameter in $\mu\text{m}$	Exine thickness in $\mu\text{m}$	Tectum
<i>Elymus dahuricus</i> Turcz. ex Griseb.	40.01 (49.33 $\pm$ 1.19) 55.11	Monoporate	+	-	10 (11.01 $\pm$ 0.32) 13.0	3.75 (6.54 $\pm$ 0.31) 7.75	0.25 (1.60 $\pm$ 0.18) 1.87	Areolate cum scabrae coarse, medially distributed on subsilate surface
<i>Elymus longe-aristatus</i> subsp. <i>candiculatus</i> (Nevski) Tzvelev	35.0 (39.22 $\pm$ 0.43) 42.50	Monoporate	+	+	6.25 (7.95 $\pm$ 0.43) 10.11	2.51 (2.37 $\pm$ 0.14) 0.5	0.25 (0.36 $\pm$ 0.04) 0.5	Areolate cum scabrae, scabrae coarse, widely distributed on subsilate surface
<i>Elymus nutans</i> Griseb.	40.0 (44.47 $\pm$ 1.28) 53.75	Monoporate	+	+	7.75 (8.95 $\pm$ 0.26) 10.01	2.75 (4.16 $\pm$ 0.24) 5.0	0.25 (0.46 $\pm$ 0.13) 0.5	Areolate cum scabrae, scabrae fine, closely distributed on small size areolae
<i>Elymus semicostatus</i> (Nees ex Steud.) Held.	37.50 (39.55 $\pm$ 0.54) 45.0	Monoporate	+	+	2.25 (2.95 $\pm$ 0.13) 3.11	2.75 (4.21 $\pm$ 0.26) 5.11	c.1.5	Areolate cum scabrae, scabrae fine, closely distributed on small size areolae
<i>Eremopyrum distans</i> (C. Koch) Nevski	35.11 (35.62 $\pm$ 0.54) 37.75	Monoporate-diporate	+	+	-	5.25	1.0 (1.17 $\pm$ 0.11) 1.25	Areolate cum scabrae scabrae coarse
<i>Eudalopsis binata</i> (Retz.) C. E. Hubbard	25.01 (27.20 $\pm$ 0.35) 37.75	Monoporate-diporate	+	+	5.22 (6.40 $\pm$ 0.26) 7.25	5.11 (6.40 $\pm$ 0.05) 1.51	0.51 (0.75 $\pm$ 0.05) 1.51	Areolate cum scabrae
<i>Helictotrichon virescens</i> (Nees ex Steud.) Henr.	22.50 (31.52 $\pm$ 0.56) 33.70	Monoporate-diporate	+	+	5.0 (5.5 $\pm$ 0.79) 7.50	2.11 (2.6 $\pm$ 0.16) 3.13	0.5 (0.72 $\pm$ 0.11) 1.25	Areolate cum scabrae medium, widely distributed on subsilate surface
<i>Hemardia persica</i> (Boiss.) C. E. Hubbard	30.25 (3.25 $\pm$ 2.91) 36.25	Monoporate	+	+	5.11 (7.85 $\pm$ 1.02) 10.11	2.75 (2.84 $\pm$ 0.44)	c.2.75	Areolate-cum-scabrae
<i>Melica persica</i> Kunth	25.11 (29.69 $\pm$ 0.60) 33.75	Monoporate	+	+	c.0.5	2.25 (3.21 $\pm$ 0.37) 4.75	1.25 (1.43 $\pm$ 0.08) 2.11	Areolate cum scabrae closely distributed on subsilate surface
<i>Phleum alpinum</i> L.	33.75 (35.44 $\pm$ 0.53) 42.75	Monoporate-diporate	+	+	2.50 (2.66 $\pm$ 0.04) 2.75	2.75 (4 $\pm$ 0.19) 5.0	0.25 (0.75 $\pm$ 0.051) 0.25	Areolate cum scabrae scabrae coarse, closely distributed on small size irregular areolae
<i>Tripogon purpurascens</i> Duthie	20.0 (21.5 $\pm$ 0.38) 23.0	Monoporate-diporate	+	+	c. 1.6	2.50 (2.91 $\pm$ 0.17) 3.75	0.75 (1.45 $\pm$ 0.20) 1.75	Areolate cum scabrae, scabrae coarse, widely distributed on small size areolae.

Table 5. General pollen characters of species found in Pollen type-V.

Name of taxa	Pollen diameter in $\mu\text{m}$	Aperture	Annulus	Operculum	Annulus thickness in $\mu\text{m}$	Pore diameter in $\mu\text{m}$	Exine thickness in $\mu\text{m}$	Tectum
<i>Elymus hispidus</i> (Opiz) Meld.	37.50 (45.42 $\pm$ 0.93) 55.01	Monoporate-diporate	+	+	2.75 (3.16 $\pm$ 0.15) 4.75	3.11 (5.13 $\pm$ 0.17) 7.25	c. 0.5	Scabrae, scabrae medium
<i>Hordeum murinum</i> L.	29.55 (32.52 $\pm$ 0.60) 36.25	Monoporate	+	+	c.2.25	3.11 (4.45 $\pm$ 0.37) 5.25	0.5 (0.75,84 $\pm$ 0.44) 1.11	Scabrae coarse closely distributed on sub-psilate surface
<i>Lolium rigidum</i> Gaud.	21.25 (25.44 $\pm$ 0.09) 28.75	Monoporate-diporate	+	+	1.75 (2.25 $\pm$ 0.17) 2.75	2.25 (2.72 $\pm$ 0.19) 3.75	0.75 (0.94 $\pm$ 0.05) 1.25	Scabrae, scabrae medium
<i>Piptatherum gracile</i> Mez	22.5 (23.75 $\pm$ 0.32) 26.25	Monoporate	+	+	4.75 (5.55 $\pm$ 0.20) 2.25	2.25 (2.71 $\pm$ 0.28) 4.11	0.75 (0.95 $\pm$ 0.09) 1.25	Scabrae, scabrae coarse, widely distributed on sub-psilate surface
<i>Piptatherum muaroi</i> (Stapf) Mez	23.75 (27.5 $\pm$ 0.38) 29.75	Monoporate-diporate	+	+	5.02 (5.7 $\pm$ 0.18) 7.50	2.25 (2.86 $\pm$ 0.62) 3.75	1.25 (1.42 $\pm$ 0.61) 1.50	Scabrae, scabrae coarse, medianly distributed on sub-psilate surface
<i>Stipa jacquemontii</i> Jaub. & Spach.	23.57 (27.3 $\pm$ 1.39) 28.50	Monoporate	+	+	0.5 (2.12 $\pm$ 0.55) 3.0	2.75 (3.5 $\pm$ 0.70) 7.0	0.75 (1.43 $\pm$ 0.41) 2.25	Scabrae, scabrae coarse medianly distributed on sub-psilate surface

**Description of pollen types**

**Type-I:** Areolate with minute or fine scabrae-type (Fig. 1 A-F Fig. 2A-C).

**Size:** 18.5-46  $\mu\text{m}$  in diameter.

Spheroidal, monoporate-diporate, operculate to non-operculate, annulate to non-annulate, often annulus reduced, annulus 1-5.1  $\mu\text{m}$  thick, 4-10.11  $\mu\text{m}$  in diameter. Pore 0.31-3.95  $\mu\text{m}$  in diameter. Exine 0.71-3.61  $\mu\text{m}$  thick, sexine as thick as nexine or thicker or thinner than nexine. Tectum areolate, scabrae minute or fine some times diffused in groups of 2-25, closely-medianly distributed on small-large areolae.

**Species included:** *Agrostis gigantea* Roth, *Agrostis munroana* Aitch. & Hemsl., *Agrostis viridis* Gouan, *Bothriochloa ischaemum* (L.) Keng, *Capillepedium parviflorum* (R.Br.) Stapf, *Digitaria sanguinalis* (L.) Scop., *Digitaria stricta* Roth ex Roem. & Schult., *Festuca rubra* L., *Hyparrhenia hirta* (L.) Stapf, *Hyalopoa nutans* (Stapf.) Alexeev, *Ischaemum molle* Hook. f., *Ischaemum rugosum* Salisb., *Koeleria macrantha* (Ledeb.) Schult., *Lolium temulentum* L., *Oplismenus compositus* (L.) P. Beauv., *Pennisetum flaccidum* Griseb., *Phacelurus speciosus* (Stud.) C.F. Hubbard., *Piptatherum aequiglume* (Duthie ex Hook. f.) Rozhev., *Sporobolus diander* (Retz.) P. Beauv., *Sporobolus kentrophyllus* (K. Schum.) W.D. Clayton and *Sporobolus tremulus* (Willd.) Kunth

**Type-II:** Areolate with medium scabrae-type (Fig. 2D-F; Fig. 3A).

**Size:** 17.3-50.99  $\mu\text{m}$  diameter.

Spheroidal, monoporate-diporate, operculate-non-operculate, annulate to non-annulate, sometimes annulus reduced, annulus 0.85-4.11  $\mu\text{m}$  thick 3-7.81  $\mu\text{m}$  in diameter. Pore 1-4.32  $\mu\text{m}$  in diameter. Exine 0.33-3.49  $\mu\text{m}$  thick, sexine as thick as thick or slightly thicker or thinner than nexine. Tectum areolate, scabrae medium size, in groups of 2-25, closely-widely distributed on small-large regular or irregular areolae.

**Species included:** *Aeluropus littoralis* (Gouan) Parl., *Aeluropus macrostachyus* Hack., *Eragrostis termula* Hochst. ex Steud., *Festuca alata* (St-Yves) Rozhev., *Festuca hartmannii* (Markgr.-Dannenb.) Alexeev, *Festuca kashmiriana* Stapf, *Leymus secalinus* (Georgi) Tzvelev, *Oplismenus undulatifolius* (Ard.) Roem. & Schult., *Parapholis incurva* (L.) C. E. Hubbard, *Pennisetum lanatum* Klotzsch, *Sporobolus ioclados* (Nees ex Trin) Nees and *Stipa splendens* Trin

**Type-III:** Areolate with coarse scabrae-type.

**Size:** 18.3-40  $\mu\text{m}$  in diameter.

Spheroidal, monoporate-diporate, rarely triporate, operculate to non-operculate, annulate sometimes annulus reduced, annulus 1.05-3.91  $\mu\text{m}$  thick, 4.2-7.81  $\mu\text{m}$  in diameter. Pore 2.11-3.96 in diameter. Exine 0.35-2.99  $\mu\text{m}$  thick, sexine thicker than or as thick as nexine rarely thinner than nexine. Tectum areolate with coarse scabrae, in groups of 2-20 closely-widely distributed on small-large regular or irregular areolae.

**Species included:** *Agrostis stolonifera* L., *Agrostis vinealis* Schreb., *Festuca arundinacea* Schreb. *Trisetum spicatum* (L.) Rich.

**Type-IV:** Areolate cum scabrata-type (Fig. 3B-E).

**Size:** 20.2-56.5  $\mu\text{m}$  in diameter.

Spheroidal, monoporate-diporate, rarely triporate, operculate to non-operculate or indistinct operculum, annulate, often with reduce annulus, annulus 0.71-4.14  $\mu\text{m}$  thick, 4.76-8.61  $\mu\text{m}$  in diameter. Pore 0.71-4.94  $\mu\text{m}$  in diameter. Exine 0.35-1.43  $\mu\text{m}$  thick, sexine as thick as nexine often slightly thicker than nexine. Tectum areolate-cum-scabrata, scabrae medium-coarse often minute in groups of 8-40, mostly widely or sometimes closely distributed on large regular or irregular areolae.

**Species included:** *Elymus dahuricus* Turcz. ex Griseb., *Elymus longe-aristatus* (Boiss.) Tzvelev subsp. *canaliculatus* (Nevski) Tzvelev, *Elymus nutans* Griseb., *Elymus semicostatus* (Nees ex Steud.) Meld., *Eremopyrum distans* (C. Koch) Nevski, *Eulaliopsis binata* (Retz.) C. E. Hubbard, *Helictotrichon virescens* (Nees ex Steud.) Henr., *Henrardia persica* (Boiss.) C. E. Hubbard, *Melica persica* Kunth, *Phleum alpinum* L. and *Tripogon purpurascens* Duthie.

**Type-V:** Scabrata type (Fig. 3F)

**Size:** 21.11-56.15  $\mu\text{m}$  in diameter.

Spheroidal, monoporate-diporate, rarely triporate, operculate to non-operculate, annulate, annulus 1.12-4.58  $\mu\text{m}$  thick, 3.41-11.79  $\mu\text{m}$  in diameter. Pore 1.43-8.59  $\mu\text{m}$  diameter. Exine 0.35-2.9  $\mu\text{m}$  thick, sexine as thick as nexine often slightly thicker or thinner than nexine. Tectum scabrata, fine-coarse scabrae, closely-widely distributed on smooth surface.

**Species included:** *Elymus hispidus* (Opiz) Meld., *Lolium rigidum* Gaud., *Hordeum murinum* L., *Piptatherum gracile* Mez., *Piptatherum munroi* (Stapf) Mez., and *Stipa jacquemontii* Jaub. & Spach.

**Discussion**

Poaceae is a stenopalynous family. The pollen grains are generally apolar, monoporate-diporate rarely triporate. Tectum is generally areolate, areolate cum scabrata, or simply scabrata. Similar type of tectum are also observed in the other members of the family Poaceae by Faegri & Iversen (1964) and Andersen & Bertelsen (1972). According to Thanikaimoni (1985), Poaceae pollen were evolved from monosulcate-monoporate to operculate. Skvarla *et al.*, (2003) reported non-annulated pollen in the genus *Parian*. Baser *et al.*, (2009) reported monoporate, heteropolar, prolate-spheroidal and operculate-annulate pollen, with mixed scabrata type exine and insular type in the genus *Eremopyrum*. Ozeler *et al.*, (2009) reported monoporate, rarely dioporate, pollen having scabrata groups of exine, scabrae density, size and other pollen characters, such as annulus, operculum diameter are important characters for delimiting the taxa.

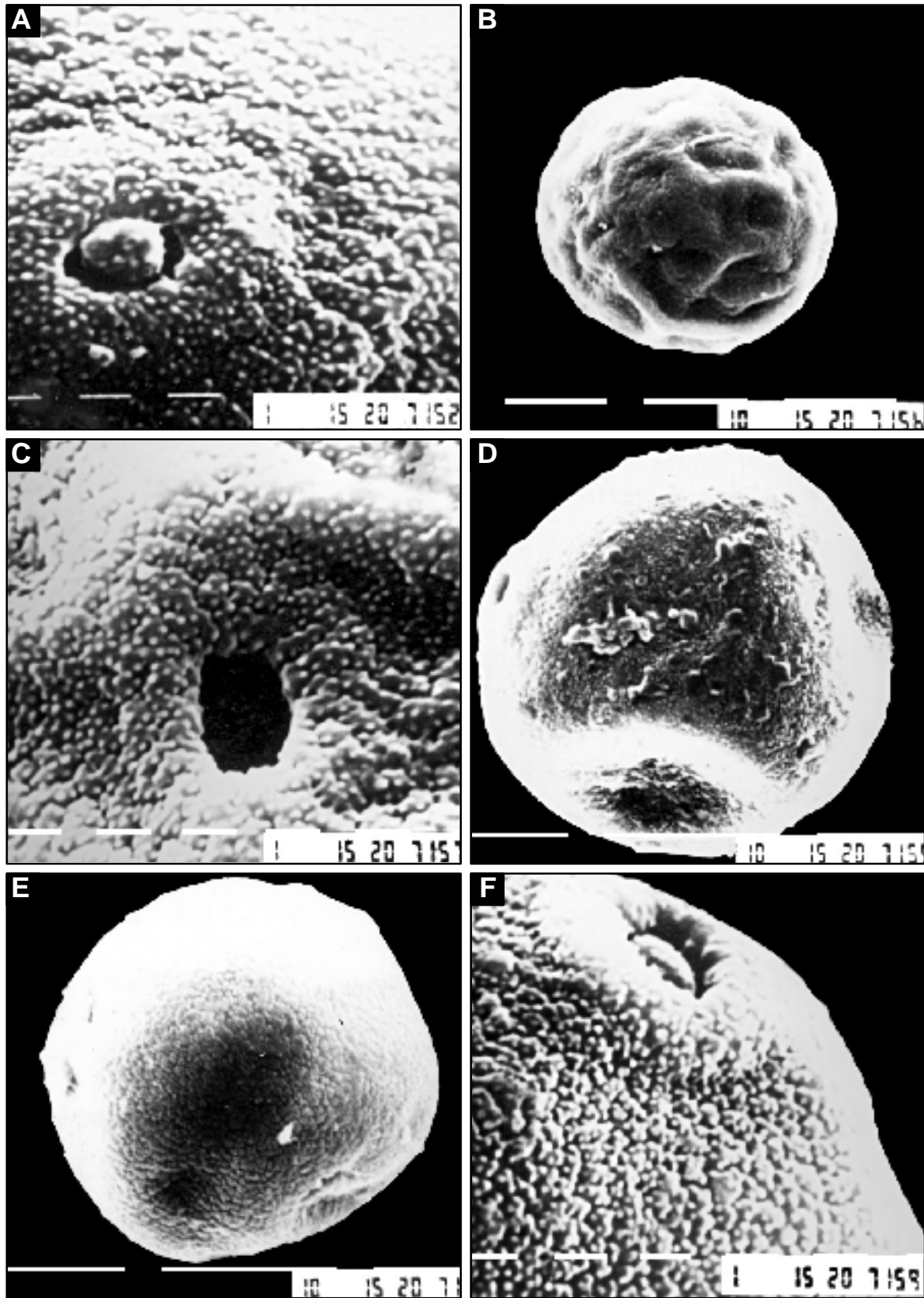


Fig. 1. Scanning Electron micrographs of pollen grains. *Agrostis munroana*: A, Exine pattern., *Bothriochloa ischaemum*: B, Pollen grain; C, Exine pattern.; D, Pollen grain; *Digitaria stricta*: E, Pollen grain, F, Exine pattern.

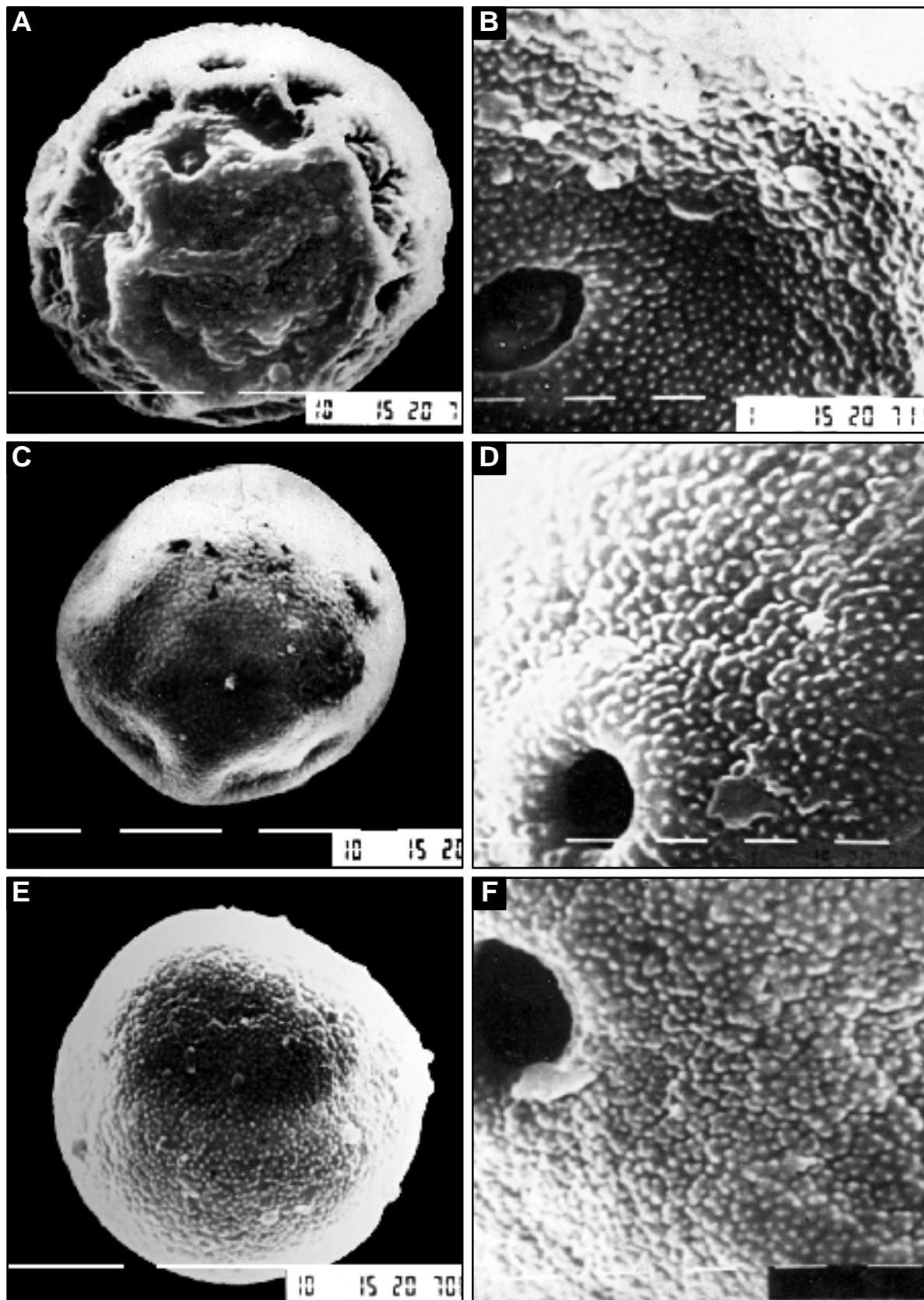


Fig. 2. Scanning Electron micrographs of pollen grains. *Koeleria macrantha*: A, Pollen grain; B, Exine pattern., *Pennisetum flaccidum*: C, Pollen grain; *Aeluropus macrostachyus*: D, Exine pattern.; E, Pollen grain: *Festuca kashmiriana*., F, Exine pattern.

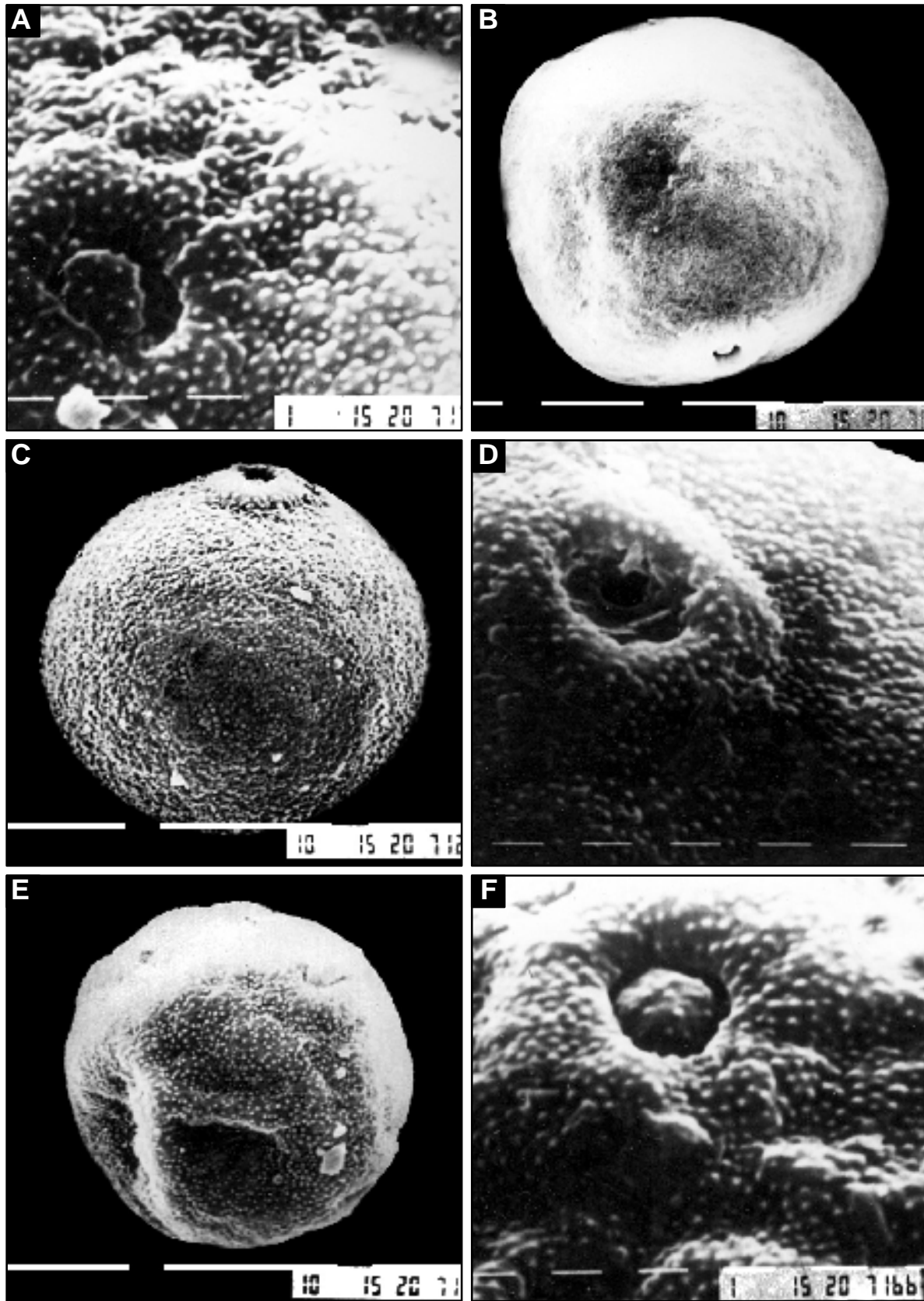


Fig. 3. Scanning Electron micrographs of pollen grains.: *Festuca alatavica*: A, Exine pattern., *Elymus longe-aristatus*: B, Pollen grain. *Phleum alpinum* C, Pollen grain. *Melica persica*: D, Exine pattern, E, Pollen grain. *Elymus hispidus*: F, Exine pattern.



Pollen grains are medium, rarely large sized 15.7-72 um in diameter, mostly, spheroidal operculate to non-operculate, annulate to non-annulate or with reduced annulus, generally sexine thinner or thicker than nexine, often as thick as nexine. Pollen grains are normally monoporate, however, diporate or triporate grains are also found within the same species. Erdtman (1952) and Chaturvedi. (1971) reported 0-7 pores in Triticale. The two types of grains (mono and diporate) within the same species are the results of polyploidy (highest percentage of polyploid has been reported in the family Poaceae among the angiosperms (Stebbins, 1949) similarly, due to polyploidy size of the grains is also varied and within the same species large size double diporate grains also occur as compared to normal diporate grains. In this contention it might be possible that, chromosome at anaphase do not segregate normally. During meiotic division, and ultimately large sized grains are formed Muller (1979) pointed out that level of polyploidy may express itself directly in pollen sized higher the level than larger the grain size. Double-diporate grains in the family Poaceae have also been reported by Siddiqui & Qaiser (1988). In the present investigation, doubled diporate grains are found in *Festuca rubra* L., *Sporobolus tremulus* (Willd.) Kunth, *Trisetum spicatum* (L.) Richt. and *Tripogon purpurascens* Duthie.

Similar to other pollen characters (apertural type, size, shape and polarity) tectum of the family are also uniform and generally areolate-scabrate and rarely scabrate to areolate cum scabrate tectum is observed. However on the basis of tectal surface 5 pollen types are recognized. Type -I is characterized by its areolate tectum with fine scabrae, scabrae in groups of 2-20 closely medianly distributed on medium-small irregular areolae. Majority of the species fall within this pollen type (see pollen type). Pollen Type-II is readily recognized by its areolate tectum with medium scabrae, in groups of 2-20 scabrae, closely widely distributed on medium-large size regular or irregular areolae 12 species are included in this type. Type-III is delimited by having areolate tectum with coarse scabrae. Type-IV is distinguished by having areolate-cum scabrate tectum, scabrae coarse, rarely fine-medium distributed closely-widely on large irregular areolae. Pollen type-V is characterized by scabrate tectum, scabrae are coarse to fine. Six species are included in this type. Perveen (2006) also divided 22 species of family Poaceae into five pollen types based on exine pattern. Liu *et al.*, (2004) examined 57 species of subfamily Chloroideae and recognized 5 pollen types on the basis of annulus, exine thickness and exine ornamentation.

### Pollen morphology and taxonomy

#### Tribe: Aeluropodeae

Within this tribe two species are included viz., *Aeluropus littoralis* (Gouan) Parl., *Aeluropus macrostachyus* Hack. These species are characterized by areolate with medium scabrate tectum. However, these species are easily separated on the basis of annulus thickening and pore diameter (Table 1).

#### Tribe: Eragrostideae.

Within this tribe two species i.e., *Eragrostis termula* Hochst. ex Steud., and *Tripogon purpurascens* Duthie, are examined. *Eragrostis termula* is easily recognized by areolate with medium scabrate tectum whereas, *Tripogon purpurascens* Duthie is characterized by areolate cum scabrate tectum i.e., pollen type-IV.

#### Tribe: Meliceae

Within this tribe a single species i.e., *Melica persica* Kunth is examined. This species is characterized by areolate cum scabrate tectum i.e., pollen type-IV.

#### Tribe: Paniceae

From this tribe 3 genera were investigated i.e., *Pennisetum* (*Pennisetum lanatum* Klotzsch, *P. flaccidum*), *Oplismenus* (*Oplismenus compositus* (L.) P. Beauv. *Oplismenus undulatifoliosus* (Ard.) Roem. & Schult.) and *Digitaria* (*Digitaria sanguinalis* (L.) Scop. *Digitaria stricta* Roth ex Roem. & Schult., Four species such as, *Pennisetum flaccidum* Griseb., *Digitaria sanguinalis* (L.) Scop. *Digitaria stricta* Roth ex Roem. Schult., and *Oplismenus compositus* (L.) P. Beauv. , are easily delimited by having areolate with fine scabrate exine (pollen type-I), whereas *Pennisetum lanatum* and *Oplismenus undulatifoliosus* (Ard.) Roem. & Schult are easily recognized by pollen type-II areolate with medium scabrate exine.

#### Tribe: Andropogoneae

Seven genera are examined from this tribe each representing a single species (except *Ischaemum*) namely, *Bothriochloa ischaemum* (L.) Keng, *Hyparrhenia hirta* (L.) Stapf, *Parapholis incurva* (L.) C. E. Hubbard *Phacelurus speciosus* (Steud.) C. E. Hubbard, *Capillepedium parviflorum* (R. Br.) Stapf. And *Eulaliopsis binata* (Retz.) C. E. Hubbard, distributed in two pollen types i.e., I, II. Seven species like, *Bothriochloa ischaemum* (L.) Keng, *Hyparrhenia hirta* (L.) Stapf, *Capillepedium parviflorum* (R. Br.) Stapf, *Hyparrhenia hirta* (L.) Stapf, *Ischaemum molle* Hook. f. *Ischaemum rugosum* Salisb. and *Phacelurus speciosus* (Steud.) C. E. Hubbard, recognized by areolate with fine scabrate tectum, whereas *Parapholis incurva* (L.) C. E. Hubbard has areolate with medium scabrate tectum. However, these genera are further delimited on the basis of other pollen characters.

#### Tribe: Aveneae

This tribe includes 2 pollen types i.e., I, III and IV. Ten species viz., *Agrostis gigantea* Roth, *Agrostis munroana* Aitch. & Hemsl., *Agrostis stolonifera* L., *Agrostis viridis* Gouan, *Agrostis vinealis* Schreb., *Henrardia persica* (Boiss.) C. F. Hubbard, *Helictrichon virescens* (Nees ex Steud.) Henr., *Koeleria macrantha* (Ledeb) Schult., *Phleum alpinum* L., and *Trisetum spicatum* (L.) Richt. are included belonging to six genera

namely, *Agrostis*, *Helictotrichon*, *Henrardia*, *Koelaria*, *Phleum* and *Trisetum*. However, these genera are further delimited on the basis of other pollen characters.

#### **Trib:** Sporoboleae

Species of this tribe are distributed in two pollen types, I and II. Three species of *Sporobolus* such as *Sporobolus diander* (Retz.) P. Beauv., *Sporobolus kentrophyllus* (K. Schum.) W. D. Clayton *Sporobolus tremulus* (Willd.) Kunth have included in pollen type-I, which is recognized by areolate with fine scabrate exine. Whereas, *Sporobolus ioclados* (Nees ex Trin) Nees is easily delimited by having areolate with medium scabrae pollen type-II. However, these species are easily delimited on the basis of pollen grains diameter (Table 1).

#### **Tribe:** Stipeae

From this tribe two genera have been examined i.e., *Piptatherum* (*Piptatherum aequiglume* (Duthie ex Hook. f.) Rozhev., *Piptatherum gracile* Mez and *Piptatherum munroi* (Stapf) Mez and *Stipa* (*Stipa splendens* Trin., and *Stipa jacquemonti* Jaub & Spach. These species are distributed in three pollen types I, II and V.

#### **Tribe:** Triticeae

Three genera of this tribe are distributed into two pollen types viz., pollen type-I areolate with fine scabrate and areolate cum scabrate pollen type-II. *Elymus* (*Elymus dahuricus* Turcz. ex Briseb. *E. hispidus* (Opiz) Meld, *Elymus longe-aristatus* subsp. *canaliculatus* (Nevski) Tzvelev

*Elymus nutans* Griseb., *Elymus semicostatus* (Nees ex Steud.) Meld and *Eremopyrus distans* (C. Koch) Nevski), are easily recognized by having areolate cum scabrate tectum. In *Leymus secalinus* (Georgi) Tzvelev, tectum is characterized by areolate cum scabrate tectum.

#### **Tribe:** Poeae

This tribe has 10 species viz. *Festuca alata* (St-Yves) Rozhev *Festuca gigantea* (L.) Vill., *Festuca hartmannii* (Markgr.-Dannenb.) Alexeev, *Festuca arundinacea* Schreb., *Festuca kashmiriana* Stapf, *Festuca rubra* L. *Hyalopoa nutans* (Stapf) Alexeev, *Hyparrhenia hirta* (L.) Stapf, *Lolium rigidum* Gaud, *Lolium termulentum* L., these species are distributed in Pollen type-I, II, III and V but mostly in pollen types-I and II.

#### **Conclusion**

Palynology of the family Poaceae do not support the tribal and generic classification. The 5 pollen types recognized in the present study are quite heterogeneous. Genera of different tribes and the different species of the same genus fall in different pollen type. Pollen type-I accommodates the species of tribes Aveneae and

Andropogoneae. On the other hand some species of the tribe Aveneae are found in pollen type-IV, in which exine is scabrate. However, palynology is significantly helpful at specific level. Pollen morphology also confirms stenopalynous nature of the family Poaceae.

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