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TAXONOMIC STUDIES OF CYPERACEAE (SEDGES) IN SWAT PAKISTAN: USING A MULTIVARIATE APPROACH

NASAR ALI[1], ZAHID ULLAH[1*], AHMAD ALI[1], BUSHRA[1], ZAHEER ABBAS[2] AND AFTAB AHMAD KHAN[1]

[1]Center for Plant Sciences and Biodiversity, University of Swat, Pakistan
[2]Department of Botany, University of Education, Lahore, Dera Ghazi Khan Campus, Pakistan
**Corresponding author's email: zahidmatta@gmail.com; zahidtaxon@uswat.edu.pk*

Abstract

Cyperaceae (sedges) is the seventh largest flowering plant family, forming the dominant component of wetland flora. Taxonomically sedges are a difficult group, due to morphological simplicity, hybridization, polyploidy and species richness. Cyperaceae in district Swat - Pakistan have not been explored previously. The current study revealed 58 species of Cyperaceae belonging to 13 genera. The genus *Carex* was the largest having 15 species. Plant collections were carried out in the entire district from 2014 to 2016 particularly in typical habitats of sedges like wetland, marshes, rice field, along streams and rivers and alpine meadows. Using the collected specimens 84 phenotypic characters were studied using stereomicroscope. Based on these characters morphometric tree was inferred in Minitab16 and SPSS. Our results are in congruence with most phylogenetic studies of the family based on molecular data. In the present study leaf epidermal features of 35 species were observed using light microscopy. The overall results showed that size of stomata, shape of subsidiary cells, shape and wall sinuosity of long cells, presence/absence of intercostal short cells, presence/absence of silica bodies, presence/absence of bulliform cells and presence/absence of papillae represent reliable taxonomic characters. Palynological characters of 35 species were observed under LM. The study showed that pollen in Cyperaceae were pseudomonads. Pollen shapes were obovoidal, triangular or apple shaped with single aperture or four aperturate to polyporate. Based on P/E ratio most of the pollen were oblate-spheroidal to prolate spheroidal, subprolate, spheroidal and suboblate. Equatorial diameter ranged from 16 µm to 37µm while polar axis length ranged from 18.7 µm to 37.3 µm. Exine thickness, polar axis length and sexine sculpturing were found useful diagnostic features. Pollen characters in the family were in most cases uniform and showed variation at the level of subgenus and above. In conclusion systematic studies based multivariate approaches provide a clearer feature of relationship among the taxa studied.

Key words: Cyperaceae, *Carex,* Systematics, Swat, Pakistan, Pollen, Micromorphology.

Abbreviations: A= Absent, AB= Abaxial, CIZ= Costal and intercostal zonation, CS= Cell shape, Fn= Finger like, FWS= flushing with stomata, ICS= Inter stomatal cell, PR= Prickles, SCS= Subsidiary cell shape, SH= Sheath, ST= Stomata, Dom= Dome shaped, P= Present, Con = Conspicuous, WM= Wall Morphology, LC= Long cells, Cos= Costal, Fus= Fusiform, Sur = Surface PP= Papillae, Bu= Bulliforms, Int st=Interstomatal

Introduction

The sedge family *Cyperaceae* comprises of 106 genera and 5387 species (Govaerts *et al*., 2021). It is the third largest family among monocots and seventh largest family of all angiosperms (Simpson *et al*., 2011). In Pakistan it is represented by 22 genera and 179 species (Kukkonen, 2001). They are important ecologically and economically and form dominant vegetation type in wetlands and marshes (Simpson, 1995). The family is characterized by herbs, having trigonous, solid stems, closed leaf sheaths, highly reduced flowers, arranged into spikes or heads, scarious perianth and dry single-seeded achene. Leaf epidermis is provided with smooth silica bodies; dumb-bell shaped stomatal guard cells; pollen grains are pseudomonads, with a single ulcus and 2 or more lateral apertures (APG IV, 2016; Bruhl, 1995; Goetghebeur, 1986).

In the present project multivariate approach was used, incorporating morphometrics, palynology and leaf epidermal micromorphology in order to gain a better insight of the taxonomic and evolutionary relationship of the taxa. Morphological features are still the most useful, reliable and prime source of information in systematic studies (Taia, 2005). These characters provide the basis for practical identification (Judd *et al*., 2015). Although palynology has numerous applications in diverse fields, however it's most fundamental, crucial and valuable utilization is historically nested in solving taxonomic issues in higher plants (Huang, 1972). The remarkable diversity of pollen grains have been used extensively in solving different taxonomic issues like placing taxonomically controversial taxa into their correct position, studying evolutionary relationship between different groups and circumscription of cryptic taxa (Nair, 1980). In *Cyperaceae* the pollens are termed as pseudomonads and it is a synapomorphy for the family *Cyperaceae* (Coan *et al*., 2011). Apart from *Cyperaceae* the occurrence of pseudomonads has also been reported in few species of *Juncaceae*. Micromorphological features of the leaf epidermis provide valuable systematic data in grasses, sedges and rushes. Anatomical and micromorphological characters have been shown to be valuable tools for delimiting taxa and determining relationships in the *Cyperaceae* (Koyama, 1969). No scientific studies exist on the pollen morphology and leaf epidermal micromorphology of the sedges from district Swat. The present studies were therefore carried out to explore the utility of multiple approaches for authentic identification of sedges in order to provide identification guide to biodiversity related researchers.

Material and Methods

Study area, district Swat: Swat district is located, in the northwest corner of Pakistan between 34º 34' to 35º55'N latitude and 72º08' to 72º50'E longitudes. Chitral and Ghizar form the northern boundary of Swat, while Shangla and Kohistan districts are located to the east (Fig. 1). In the south are located Buner and Malakand districts and upper and lower Dir form the western boundary. The area is bestowed with natural beauties of diverse form including aak and conifer forests, alpine meadows, lush green cultivated fields, fruits orchards of various kinds, streams, waterfalls, springs, lakes, rivers, glaciers and high mountain peaks permanently covered with snow. This topographic, geological, climatic and habitat heterogeneity has given rise to equally rich and diverse cultural and economic diversity (Ullah *et al*., 2015).

Taxa sampling and plant specimens: During field exploration standard methodologies recommended by Eymann *et al*., (2010) were adopted. Plant collections were carried out in different areas of the entire district from 2014 to 2016, particularly in typical sedge habitats like wetlands, marshes, rice fields, alpine meadows and along streams and rivers. Preservation and mounting of specimens were done according to the method described in Judd *et al*., (2015) and Eymann *et al*., (2010).

Vouchers specimens were deposited in the Swat University Herbarium (SWAT) Table 5. Specimens were identified with the help of Flora of Pakistan (Kukkonen, 2001) and Flora of China (Dai *et al*., 2010).

Morphology and morphometric studies: In the field magnifying glasses were used for studying specimens. Using the collected specimens from different areas of Swat district all possible phenotypic characters were studied under a stereo microscope (IM-SZ-500, IRMECO Germany) at Swat University Herbarium (SWAT) and were used for morphological descriptions. Descriptions of each species, synonyms, keys for determination, representative specimens, distributions and field photographs were taken for all the species. Terminology and character states are based on Jiménez-Mejías *et al*., (2016) (Table 1). Characters were assigned to appropriate character states and were scored. The final data matrix was analyzed using correlation, neighbor joining and similarity statistics in SPSS and Minitab programs (Fig. 2).

Leaf epidermal micromorphology: For epidermal preparation mid portion of dried leaves were cut up to 2 cm and were placed in a test tube containing 88% lactic acid to soften the leaves for easy scraping. Preparative techniques given in Clarke (1960) and Cotton (1974) were followed. Test tubes with leaf sections were boiled in water bath at 100°C for 60 to 80 minutes. Sharps blades were used to obtain adaxial and abaxial epidermis. To obtain abaxial epidermis adaxial surfaces were scraped leaving abaxial epidermis, similarly, abaxial surfaces were scraped to obtain adaxial epidermis. The prepared slides were observed adjusted under the microscope for studying leaf microscopic features. Microhistological photographs of both epidermal surfaces were taken using 40 x objective lens of microscope, using camera Lucida (Fig. 4). During observation cell width, cell length, size of stomata, number of stomata per unit area, type of stomata shape of stomata, number of rows of long cells, length and width of papillae and length and width of prickles were studied. Costal and intercostal zones were also studied whether it is conspicuous or not (Tables 3, 4). Terminology and description format were adopted after Clifford & Watson (1977) and Ellis (1979).

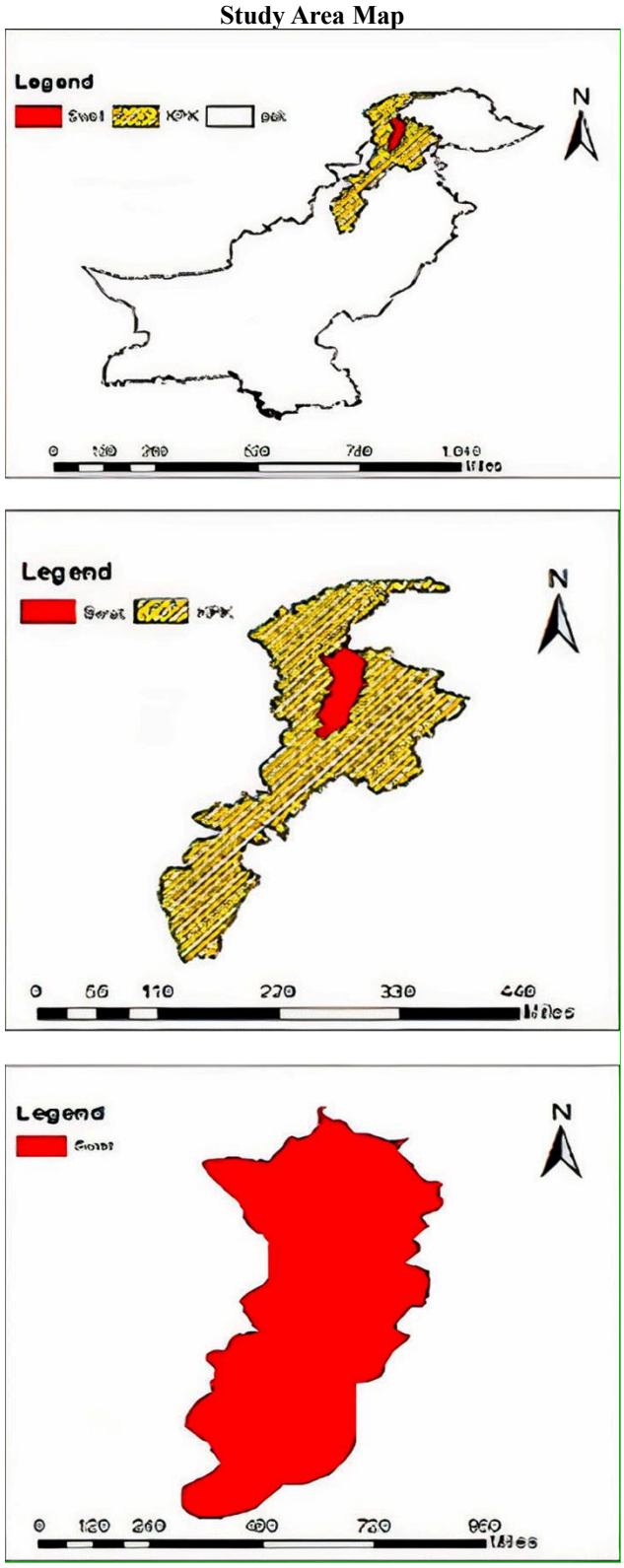

Fig. 1 Map of the study area, district Swat.

Table 1. Characters and character states of the sedges of district Swat.

S. No	Character	Character state
1.	Life form	Annual, perennial
2.	Growth habit	Growing singly, loosely tufted, cespitose
3.	Plant height	Up to 30 cm, 30-70cm, 70-120cm, >120 cm
4.	Rhizome	Present, absent
5.	Rhizome diameter	Up to 2mm, 2-5mm
6.	Rhizome length	Shorter, longer
7.	Stolon	Presence, absence
8.	Rhizome scales	Present, absent
9.	Stem outline	Circular / terete, triangular, more than 3 angles
10.	Stem sides	Concave, convex, straight
11.	Stem diameter	Up to 2mm, 2-6mm, 6-10mm, >10mm
12.	Blade p/a	Present, absent
13.	No. of sheaths	Up to 2, more than 2
14.	Sheath length	Up to 10 mm, 10-25mm, 25-50mm, >5cm
15.	Sheath pubescence	Glabrous, papilose
16.	Sheath colour	Green, yellowish, reddish, brownish, greenish
17.	Sheath mouth	Oblique, straight
18.	Sheath texture	Forming fibres, persistent
19.	Sheath channels	Channeled, not channeled
20.	Leaf length relative to stem	Shorter than stem, equalling to stem, longer than stem
21.	Blade length	Mucro, upto 15 cm, 16-50 cm, >50 cm
22.	Blade width	< 1 mm, 1-3 mm, 4-7 mm, 8-10 mm, >10 mm
23.	Blade surface	Flat, folded, keeled
24.	Blade apex	Acute, attenuate, obtuse, flat
25.	Blade surface (pubescence)	Glabrous, papillose
26.	Blade colour	Grey, green
27.	Ligule	Present, absent
28.	Ligule size	0.1 to 0.3 mm, 0.3 to 0.6 mm, 0.6 to 1mm, > 1mm
29.	Ligule texture	Fringe of hairs, scarious/membranous
30.	Flower	Bisexual, unisexual
31.	Inflorescence	Spike, compound anthelodium, simple anthelodium/headof spikes
32.	Length of inflorescence	To 5 cm, 6-10cm, 11-20 cm, 21-40 cm, >40 cm
33.	No of primary branches	To 3, 4 to 7, > 8
34.	Primary branch length	< 1cm, 1 to 5 cm, 5 to 10, 10 t0 20, >20
35.	Secondry branch size	<1 cm, 1 to 5 cm, 5 to 10, 10 t0 20, >20
36.	Tertiary branch size	<1 cm, 1 to 5 cm, 5 to 10cm, 10 t0 20cm, >20cm
37.	Number of bracts	0 to 3, 3 to 6, more than 6
38.	Bract size	< 1 cm, 1 to 10cm, 10 to 30cm, 30 t0 50cm, > 50cm
39.	Bract foliose/ glume like	Foliose, glume like
40.	Size of lowest bract	Shorter than inflorescence, longer than inflorescence, < 5cm, 5 to 15 cm, 15 to 40, > 40cm
41.	Prophyll	Present, absent

Table 1. (Cont'd.).

S. No	Character	Character state
42.	Prophyll shape	Tubular, glume like
43.	Prophyll size	<5mm, 5 to 20mm, 20 to 40mm, >40mm
44.	Prophyll colour	White, light brown, brown, yellowish
45.	Prophyll bi-nerved/tri-nerves	Binerved, three nerved
46.	Spike sessile/peduculat(stalked)	Pedunculated, sessile, subsessile
47.	Number of spikes	1, 2-30, 30 t0 70, 70 t0 100, more than 100
48.	Spike diameter	<3mm, 3 to 6mm, 6 t0 10 mm, >10
49.	Spike shape	Ovoid, obovoid, cylindrical, ellipsoid, acutish, fusiform, globose
50.	Spike colour	Yellow brown, brown, white, green, purplish
52.	Glume width	<2mm, 2 to 3mm, >3
53.	Glume arrangement	Spirall, digitate, spicate, opposite
54.	Glumes keeled /not keeled	Keeled, not keeled
55.	Glume apex	Round, mucro, truncate, acute, apiculate
56.	Glume surface	Scabrous, smooth, barbed/hairy
57.	Number of glumes / spikes	<10, 10 t0 20, 20 to 40, 40 to 60, > 60
58.	Glume with or without arista	Present, absent
59.	Glume colour	Brown, yellow brown, pale, reddish brown, white
60.	Glume margins	Narrowly scarious, widely scarious, fringed, not fringed
61.	Utricle	Present, absent
62.	Utricle length	<2mm, 2 to 5mm, 5 to 8mm, more than 8mm
63.	Utricle diameter	<0.5mm, 0.5 to 2.5mm, more than 2.5mm
64.	Utricle shape	Ovoid, ellipsoid, planoconvex, fusiform, cylindrical, trigonous, glabrous, obovoid
65.	Utricle colour	Red, yellow brown, light brown, green, yellow, grey, brown
66.	Utricle margins	Scabrous, smooth, setose (with bristle)
67.	Utricle beaked / non beaked	Beaked, not beaked
68.	Utricle nerve	Clearly nerved, nerveless
69.	Beak conical/cylindrical	Cylindrical, conical
70.	Perianth bristles	Present, absent
71.	Perianth bristle number	0, 1 to 3, 3 to 6, more than 6
72.	Bristle length	Half of the length of nut, longer than nut, equalling to nut
73.	Bristle colour	Reddish, brown, colourless
74.	Number of stamens	1, 2, more than 3
75.	Anther size	<1mm, 1 to 3mm, more than 3mm
76.	Number of stigmas	2, 3, more than 3
77.	Nut length	<1 mm, 1 to 3 mm, more than 3mm
78.	Nut diameter	<0.5mm, 0.5 to 1.5mm, >1.5 m
79.	Nut shape	Ovoid, obovoid, lenticular, trigonous, papillose, spherical, obconical, fusiform
80.	Nut surface	Reticulate (vein network), trabeculate, smooth, rugolose, glossy, papilose, puncticulate
81.	Nut apex	Round, conical, apiculate, obtuse
82.	Nut colour	Brown, pale brown, white, yellowish brown, dark brown, grey, blakish brown, yellow
83.	Nut concave/convex	Concave, biconvex, planoconves
84.	Glume shape	Cymbiform, ovate, lanceolate

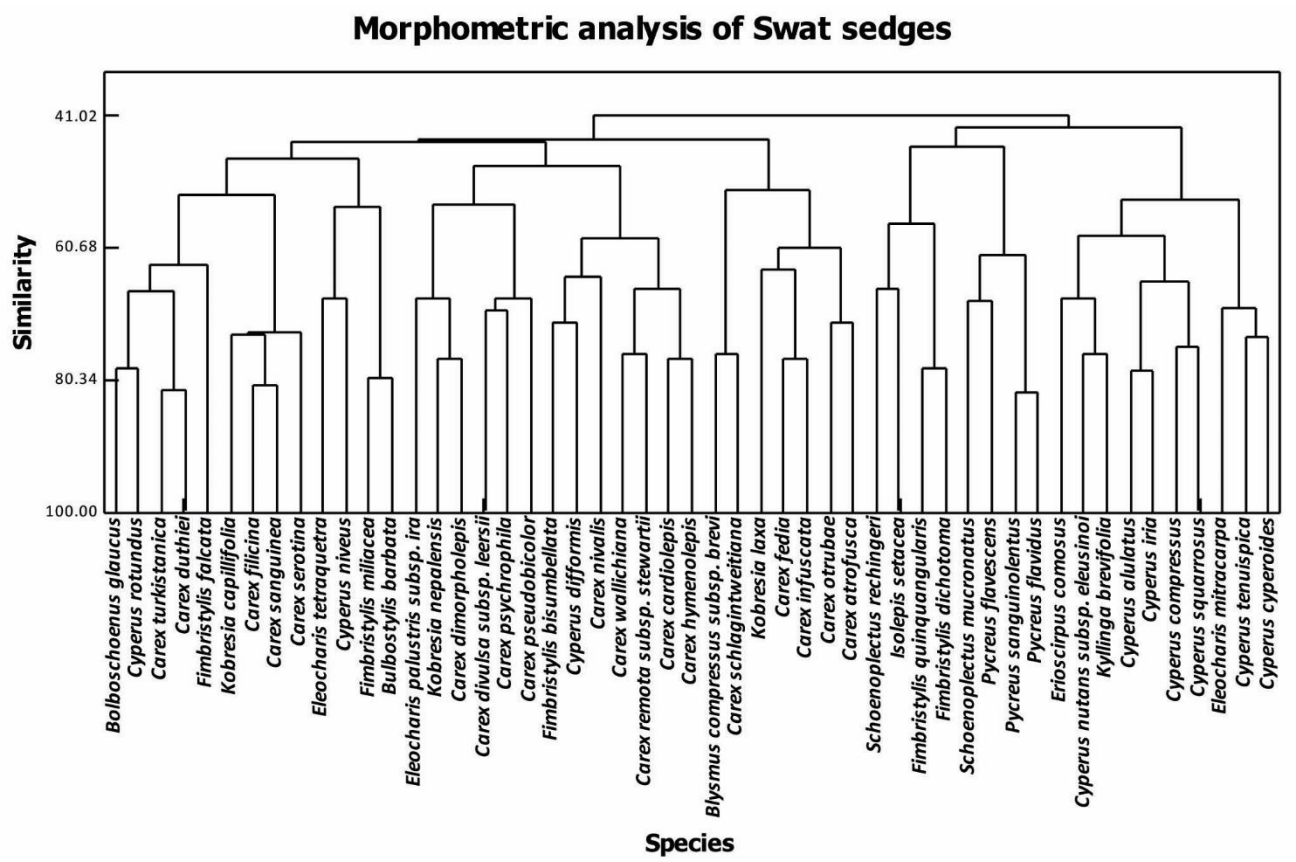

Fig. 2. Morphometric analysis and phenetic tree of the sedges of Swat, Pakistan.

Palynology: Polliniferous materials of each species were isolated from mature flowers. Glycerin jelly was prepared according to modified method following Erdtman (1952). Pollen preparation procedure was followed after Erdtman (1966). Observations of pollen morphology were made using light microscope with 40 x and 100 x (with immersion oil) objective and 10x eye piece. Sexine, nexine and intine were marked in pollen grains. Quantitative measurements were recorded for polar axis length, equatorial axis length, exine thickness, pore diameter, number of colpi and colpi length. Qualitative features such shape, size and pore out line were also recorded (Table 2). Data were statistically analyzed including range, standard deviation and standard error using MS excel. Microphotographs were taken using Orthulux photomicroscope (BM-120, GmbH Germany) in the Center for Plant Sciences and Biodiversity, University of Swat (Fig. 5).

Results and Discussion

Morphology and Morphometric analysis: The present study provides a detailed checklist of 51 taxa of Cyperaceae, belonging to 13 genera, from subfamily Cyperioidae (Table 5). The largest genus *Carex* is represented by 22 species in three subgenera, followed by *Cyperus* with 11 species, *Fimbristylis* with six species, *Eleocharis* with four species, *Kobresia*, *Pycreus*, *Schoenoplectus* with three species each, while *Bolboschoenus, Blysmus, Isolepis, Eriocirpus, Bulbostylis* and *Kyllinga* each are represented by a single species (Fig. 3).

The morphometric analysis was based on 84 morphological characters including both quantitative and qualitative features (Fig. 2). Fifty-one species were included in the final analysis (Fig. 2). Our results are in close congruence with phylogenetic trees obtained from molecular data (Muasya *et al*., 2009; Simpson *et al*., 2007) and morphological data (Hejazi, 2012; Pashirzad, 2014). *Shoenoplectus* formed outgroup to the rest of the species. In molecular analysis of (Muasya *et al*., 2009) *Schoenopletus* is nested in tribe Fuireneae with *Scirpus, Isolepis* and *Fuirena*. The remaining species form two large groups A and B. *Fimbristylis. Bulboschoenus* and *Bulbostylis* form one clade in Simpson *et al*., (2007), but in our study *Fimbristylis* seems paraphyletic on morphological grounds as two species are nested in *Cyperus* clade. *Kobresia* and *Carex* form single monophyletic group on morphological grounds. The most distinctive features seem to be the presence of perigynia, unisexual flowers and features of perigynia. However morphometric data does not support the division of the genus *Carex* into subgenera. Group B further splits into three subgroups. Subgroup B-I contains *Bulbostylis*, three species of *Pycreus* and three species of *Cyperus*. Subgroup B-II is represented by five species of *Cyperus* and one species of *Kyllinga* and *Eriocirpus* each. Subgroup B-III contains nine species including three species of *Fimbristylis* and three species of *Eleocharis,* one species of *Bulbostylis* and *Cyperus niveus*. Here in our study *Cyperus* and *Fimbristylis* both are polyphyletic. Same results were obtained from molecular data by Simpson *et al*., (2007) and Muasya *et al*., (2009). We conclude that morphometric data is extremely valuable in inferring phylogenetic relationships when compared to DNA sequences based phylogeny.

Key to the genera of Cyperaceae (adapted from Flora of Pakistan, and modified accordingly)

1a.	Flowers unisexual	*Carex*
1b.	At least some flowers bisexual	*2*
2a.	Leaf blades absent only basal sheaths present	*Eleocharis*
2b.	Leaf blades more or less developed	*3*
3a.	Inflorescence a single terminal spike	*Eleocharis*
3b.	Inflorescence a multiple spike or anthelodium	*4*
4a.	Spikelets spirally arranged	*Schoenoplectus*
4b.	Spikeletes distichous	*Cyperus*
5a.	Stylopodium well developed	*6*
5b.	Stylopodium absent	*7*
6a.	Stylopodium small and persistent	*Bulbostylis*
6b.	Stylopodium large but deciduous	*Fimbristylous*
7a.	Perianth bristles exceeding glumes	*Erioscirpus*
7b.	Perianth bristles shorter than glumes or absent	*8*
8a.	Perianth bristles present	*Blysmus*
8b.	Perianth bristles absent	*9*
9a.	Inflorescence a multiple spike or anthelodium, spikes with more than 8 glumes	*Pycreus*
9b.	Inflorescences consists of 1-3 heads, spikes with less than 8 glumes	*Kyllinga*

Palynology: Pollen grains in *Cyperaceae* are called pseudomonads, formed by the degradation of tetrads and is a distinguishing character for the family (Kirpes *et al*., 1996; Coan *et al*., 2011). Pollen morphology plays important role in the classification at subfamilial level and sometime at species level (Moar & Wilmshurst, 2003; Koyama, 1961). Important characters include pollen shape, polar axis length, exine thickness and sculpturing and number and type of aperture (Erdtman, 1966; Faegri *et al*., 1989; Wronska-Pilarek *et al*., 2010). These characters have been used to rectify the position of taxonomically contentious taxa (Nair, 1980). Koyama (1961) distinguished apple shaped, spheroidal colporate and spheroidal inaperturate type of pollen grain in *Cyperaceae.*

In the present study 35 species were included belonging to 10 genera *Blysmus, Erioscirpus, Kyllinga Schoenoplectus*, *Eleocharis*, *Fimbristylis*, *Cyperus*, *Pycreus, Kobresia* and *Carex. Carex* is the largest genus in the present study and is represented by 14 species. Minimum polar length (18 µm) was observed for *Carex hymenolepis*. Maximum polar length (44 µm) was observed for *Eleocharis palustris* (Table 2; Fig. 5). Ullah (2014) observed minimum polar length (P) P (25.2 µm) for *Carex cruciata* and maximum P (42.1 µm) for *Carex divulsa.* Meltsov *et al*., (2008) reported that pollen aperture and pollen size are variable and are useful at intraspecific level. Equatorial diameter ranges from 16 µm in *Cyperus tenuispica* to 40 µm in *Schoenoplectus mucronatus, Carex sanguinea, Carex cardiolepis, Eleocharis geniculata* and *Carex pseudocyperus* (Table 2). Equatorial diameter of pollen has no significant role in delimitation of the taxa (Ullah, 2014). Exine thickness ranges from 0.2 µm in *Cyperus iria* to 2.5 µm in *Carex divisa.*

Based on P/E ratio most of the pollens were prolate spheroidal (45%) or oblate spheroidal (25%). In genus *Carex* 57% of the pollen were oblate spheroidal and 35 % were prolate spheroidal (Table 2). These findings are almost similar to Ullah (2104). Wronska-Pilarek *et al*., (2010) observed 38.85% subprolate, 34.9% prolate spheroidal and 6.1% oblate spheroidal pollen grains in Cyperaceae. While Hesse *et al*., (2009) and Moore *et al*., (1991) reported that pollen grain in Cyperaceae are spheroidal or apple shaped. Apple shaped pollen have been reported in *Carex* by Koyama (1961). Faegri *et al*., (1989) reported that pollen in some species of Cyperaceae are pear shaped.

The number of apertures ranges from 1-4 in Cyperaceae. In *Cyperus* 3-4 aperture were observed. This result is in congruence with Huang (1972). In *Fimbristylis* and *Eleocharis* 1-3 apertures were observed. Huang (1972) observed single aperture in both *Fimbristylis* and *Eleocharis.* In *Carex* 3-4 apertures were observedThese findings are similar to Haung (1972) who reported 1-4 apertures in *Carex,* whereas Ullah (2014) observed single aperture in *Carex.* Koyama (1961) reported 1+3 or 1+6 apertures in *Carex* (Fig. 5). The number of apertures is a good diagnostic character to differentiate *Carex* from other genera of the Cyperaceae (Ullah, 2014).

Leaf epidermal anatomy: Leaf epidermal cells show great variation and specialization in different taxa (Prat, 1936) and since the pioneer work of Metcalfe, (1960) and Ellis (1979) extensive data are available on this subject. Leaf epidermal features like panicot type of epidermal cells, cells containing silica bodies, stomatal features, hairs, length and breadth of intercostal cells, trichomes and presence or absence of papillae play an important role in explaining taxonomic and phylogenetic relationship in many taxa (Ogie-Odia *et al*., 2010. Metcalfe & Chalk, 1950; Metcalfe & Gregory, 1964).

In the present study 35 species belonging to 10 genera were observed. These genera include *Blysmus, Erioscirpus, Kyllinga, Schoenoplectus*, *Eleocharis*, *Fimbristylis*, *Cyperus*, *Pycreus, Kobresia* and *Carex. Carex* being largest genus in the present study, is represented by 14 species followed by *Cyperus* represented by 7 species. Our findings reveal that shape, wall morphology of the long cells, presence or absence of papillae, size of stomatal complex, shape of the subsidiary cells and presence or absence of prickles are the most valuable characters for the delimitation of taxa.

Table 2. Quantitative characteristics of pollen grains of Cyperaceae from Swat Pakistan.

S. No.	Name of Taxa	Equatorial view (µm)			Polar view (µm)			Colpi L			Exine thickness			P/E
		Mini-Max	Mean (±SE)	Stdev	Mini-Max	Mean (±SE)	Stdev	Mini-Max	Mean (±SE)	Stdev	Mini-Max	Mean (±Se)	Stdev	
1.	*Blysmus compressus*	32-39	35.5(±1.4)	2.9	33-40	37.3(±1.7)	3.4	12-35	24.3(±5.3)	10.3	0.5-1	0.7(±0.1)	0.2	1.05
2.	*Carex atrofusca*	30-35	32.5(±1)	2.1	28-38	35(±2.3)	4.7	10-22	16.2(±2.2)	4.8	0.7-1	0.8(±1)	0.2	1.07
3.	*Carex cardiolepis*	33-40	36.5(±1.4)	2.9	32-39	35.3(±2)	3.5	12-26	18.2(±2.4)	5.3	0.5-1.3	0.9(±0.2)	0.3	0.96
4.	*Carex divisa*	33-36	34.4(±0.6)	1.3	29-32	30.5(±1.3)	1.3	14-17	15.5(±0.6)	1.3	1.2-2.5	1.8(±0.3)	0.6	0.88
5.	*Carex duthiei*	35-39	36.7(±1.2)	2.1	30-35	32.5(±2.5)	3.5	17-20	18.5(±0.6)	1.3	1.2-2	1.6(±0.2)	0.4	0.89
6.	*Carex filicina*	25-30	27(±1)	2.3	23-31	27.7(±2.4)	4.2	13-15	14(±0.6)	1.2	1-1.5	1.2(±0.1)	0.2	1.02
7.	*Carex hymenolepis*	17-25	21(±1.3)	3.2	18-22	20.3(±0.9	1.7	12-20	17.3(±0.9)	2.7	1-2	1.6(±0.2)	0.4	0.96
8.	*Carex infuscata*	31-39	35.5(±1.7)	3.4	30-40	33.8(±2.2)	4.3	17-26	22(±2.1)	4.2	0-1	1(±0)	0	0.95
9.	*Carex melanantha*	35-38	36.7(±0.9)	1.5	32-35	33(±0.7)	1.4	22-28	25.3(±1.4)	2.8	1-1.5	1.2(±0.1)	0.2	0.89
10.	*Carex otrubae*	29-35	32(±3)	4.2	32-38	34.3(±1.3)	2.6	10-22	16(±2.9)	5.9	0.4-1	0.7(±0.1)	0.3	1.07
11.	*Carex pseudocyperus*	35-40	37.2(±0.9)	1.9	33-39	36.8(±1.3)	2.6	16-26	22.4(±1.3)	3.3	1.2-2.3	1.9(±0.2)	0.5	0.98
12.	*Carex psychrophila*	30-39	35.5(±2)	4	32-40	36.3(±1.8)	3.5	20-27	24.5(±1.6)	3.1	0.6-1	0.8(±0.1)	0.2	1.02
13.	*Carex remota* subsp. *stewartii*	30-36	33.5(±1.3)	2.6	27-32	30.2(±0.7)	1.8	11-17	13.8(±1.1)	2.4	0.5-1	0.8(±0.1)	0.3	0.9
14.	*Carex sanguinea*	33-40	36(±1.5)	2.9	35-40	37(±1.5)	2.6	18-25	21.8(±1.7)	3.3	0.5-1	0.8(±0.1)	0.3	1.02
15.	*Carex schlagintweitiana*	35-39	37(±0.9)	1.8	30-40	35.3(±2.3)	4.6	15-27	22(±2.8)	5.6	0.5-1	0.8(±0.1)	0.3	0.95
16.	*Cyperus alulatus*	20-28	25(±1.5)	3.4	23-31	28(±1.1)	2.8	15-22	18.1(±0.9)	2.4	1-1.2	1(±0)	0.1	1.12
17.	*Cyperus glomeratus*	20-25	22.3(±1.5)	1.5	20-21	20.3(±0.3)	0.6	8-13	10.8(±1.1)	2.2	0.8-1.8	1.3(±0.2)	0.5	0.91
18.	*Cyperus iria*	28-33	30(±1.5)	2.6	25-31	28.3(±1.4)	2.8	11-118	15(±1.2)	2.7	0.2-1.2	1(±0.1)	0.2	0.94
19.	*Cyperus niveus*	21-24	22.5(±0.6)	1.3	21-21	21(±0)	0	8-16	12.3(±1.3)	2.8	0.5-1.2	0.9(±0.1)	0.3	0.93
20.	*Cyperus nutans* subsp. *eleusinoides*	19-26	21.5(±1.3)	3.3	20-26	22.3-(±0.9)	2.3	11-16	14(±1.1)	2.2	1-1.3	1.2(±0.1)	0.2	1.03
21.	*Cyperus rotundus*	25-27	26.3(0.7)	1.2	23-25	24(1)	1.4	13-20	16.5(1)	2.4	1-1.5	1.2(0.1)	0.2	0.91
22.	*Cyperus tenuispica*	16-30	21.8(±2.1)	5.2	19-22	20.3(±0.6)	1.3	8-19	12.2(±1.7)	4.2	0.5-1.5	1(±0.2	0.4	0.934
23.	*Eleocharis geniculata*	32-40	35.7(±2.3)	4	30-32	31(±0.6)	1	20-27	24(±1.5)	2.9	1-1.5	1.2(±0.1)	0.3	0.87
24.	*Eleocharis mitracarpa*	28-36	32.2(±1.5)	3.3	32-35	33.8(±0.8)	1.5	18-25	21.6(±1.2)	2.7	0.6-1.8	1.2(±0.3)	0.5	1.04
25.	*Eleocharis palustris*	30-37	33.8(±1.3)	2.9	30-44	34.9(±1.9)	4.9	15-26	19.8(±1.4)	4	0.7-1	0.9(±0.1)	0.1	1.03
26.	*Erioscirpus comosus*	20-25	22.7(±1.5)	2.5	26-29	27.8(±0.6)	1.3	9-24	13(±1.9)	5.1	0.7-1	0.8(±0.1)	0.2	1.22
27.	*Fambristylis squarrosa*	22-25	24(±0.7)	1.4	23-27	25.3(±1.2)	2.1	8-17	13(±1.4)	3.5	1-1	1(±0)	0	1.05
28.	*Fimbristylis bisumbellata*	24-25	24.7(±0.3)	0.6	24-28	26.3(±1.2)	2.1	12-15	13.7(±0.9)	1.5	1-1	1(±0)	0	1.06
29.	*Fimbristylis dichotoma*	20-32	27.4(±2.1	4.7	27-30	28.5(±1.5)	2.1	8-20	13.4(±2.2)	4.4	0.8-1	1(±0)	0.1	1.04
30.	*Fimbristylis miliacea*	21-30	24.8(±1.9)	3.9	22-31	26(±1.5)	3.3	8-17	12.5(±1.3)	3.6	0.7-1.2	0.9(±0.1)	0.2	1.04
31.	*Kobresia laxa*	23-30	27.2(±1.2)	2.8	28-37	31.9(±1.2)	3.2	10-17	13(±1.1)	2.6	0.5-1	0.8(±0.1)	0.2	1.17
32.	*Kyllinga brevifolia*	22-25	23.5(±0.6)	1.3	22-25	20(±2.6)	4.6	8-15	11.2(±1.3)	2.9	1-1.5	1.3(±0.1)	0.2	0.85
33.	*Pycreus flavidus*	18-24	21.8(±1.3)	2.6	22-24	23(±0.4)	0.8	10-19	15.8(±2)	4	1-1.6	1.3(±0.1)	0.3	1.05
34.	*Schoenoplectus mucronatus*	25-40	31.7(4.4)	7.6	33-35	34(1)	1.4	17-25	22(2.5)	4.4	0.8-1	1(0.1)	0.1	1.07
35.	*Schoenoplectus lacustris*	28-33	30.3(1±1.5	2.5	29-34	31(±0.7)	2	9-17	13.3(±1.3)	3.2	0.8-1	1(±0.1)	0.1	1.02

Where, **P,** Polar; **E**, Equatorial; **P/E,** Polar/equatorial; **Mini,** Minimum; **Max,** Maximum; **SE,** Standard error

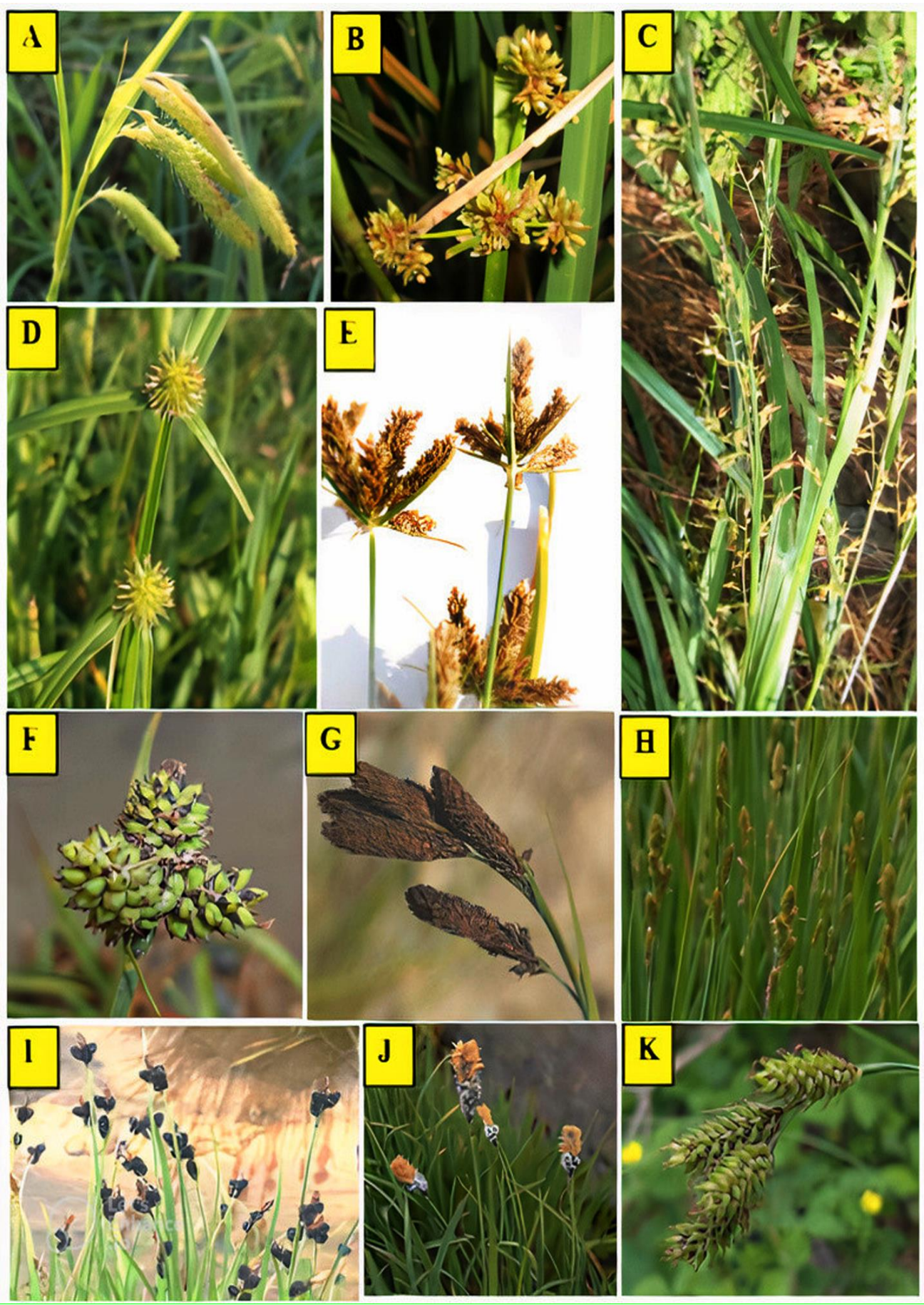

Fig. 3. A. *Carex dimorpholepis,* B. *Cyperus glomeratus,* C. *Carex filicina,* D. *Kyllinga brevifolia,* E. *Cyperus nutans* subsp. *eleusinoides,* F. *Carex infuscata,* G. *Carex nivalis,* H. *Carex divulsa,* I. *Carex infuscata,* J. *Carex melanantha,* K. *Carex psychrophile.*

Table 3. Qualitative features of leaf epidermis in sedges (Cyperaceae) of Swat, Pakistan.

S. No.	Names	Sur	CIZ	Coastal shapes	WM	ST	SCS	PP	ISC	PR
1.	*Blysmus compressus*	AD	Con	LC, Bu, Cos, St, int st, Fus	Sin-Str	P	Dom	P	FWS	A
		AB	Con	LC, Bu, Cos, St, int st	Sin	P	Dom	A	FWS	A
2.	*Carex atrofusca*	AD	Con	LC, Bu, Cos, St	Sin Wv	P	Dom	Fn	FWS	A
		AB	Con	LC, Bu, Cos, St, int st	Sin	P	Dom	Fn	FWS	A
3.	*Carex cardiolepis*	AD	Con	LC, Cos, St, Fus	Sin	P	Dom	P	FWS	P
		AB	Con	LC, Bu, Cos, St, int st	Sin	P	Dom	P	FWS	P
4.	*Carex divisa*	AD	Con	LC, Bu, Cos, St, int st	Sin	P	Dom	FN	FWS	A
		AB	Con	LC, Cos, St, int st, Fus	Sin	P	Dom	P int st	FWS	A
5.	*Carex duthiei*	AD	Con	LC, Bu, Cos	Sin	A	…	….	….	A
		AB	Con	LC, Bu, Cos, St, int st	Sin	P	Dom	A	FWS	A
6.	*Carex filicina*	AD	Con	LC, Bu, Cos	Sin	A		A	FWS	A
		AB	Con	LC, Bu, Cos, St, int st,	Sin	P	Dom	P	FWS	A
7.	*Carex hymenolepis*	AD	Con	LC, Cos, St, Fus	Sin	P	Dom	P	FWS	A
		AB	Con	LC, Bu, Cos, St	Sin	P	Dom	P	FWS	A
8.	*Carex infuscata*	AD	Con	LC, Cos Fus	Sin	A	….	A	…	A
		AB	Con	LC, Bu, Cos, St, int st	Sin	P	Dom	Fn	FWS	A
9.	*Carex melanantha*	AD	Con	LC, Bu, Cos	Sin	A	….	….	….	P
		AB	Con	LC, Bu, Cos, St, int st	Sin	P	Dom	Fn	FWS	A
10.	*Carex otrubae*	AD	Con	LC, Cos, St, int st,	Sin	P	Dom	Fn	FWS	A
		AB	Con	LC, Bu, Cos, St, int st,	Sin	P	Dom	P	FWS	A
11.	*Carex pseudocyperus*	AD	Con	LC, Bu, Cos, St	Sin	P	Dom	A	FWS	A
		AB	Con	LC, Cos, St, int st	Sin	P	Dom	P int st	FWS	A
12.	*Carex psychrophila*	AD	Con	LC, Cos, St, int st, Fus	Sin-Wv	P	Dom	Fn	FWS	A
		AB	Con	LC, Bu, Cos, St, int st	Sin-Wv	P	Dom	Fn	FWS	A
13.	*Carex remota* subsp. *stewarti*	AD	Con	LC, Cos, St, int st, Fus	Sin	P	Dom	Fn	FWS	A
		AB	Con	LC, Bu, Cos, St, int st,	clearly Sin	P	Dom	Fn	FWS	A
14.	*Carex sanguinea*	AD	Con	LC, Bu, Cos, St, int st, Fus	Sin	P	Dom	P	FWS	A
		AB	Con	LC, Bu, Cos, St, int st	Sin	P	Dom	P	FWS	P
15.	*Carex schlagintweitiana*	AD	Con	LC, Cos	Sin	A	…	…	…	P
16.	*Cyperus alulatus*	AB	Con	LC, Bu, Cos, St, int st, Fus	Sin	P	Dom	A	FWS	A
17.	*Cyperus glumeratus*	AD	Con	LC, Bu, Cos, St, int st, Fus	Sin	P	Dom	P	FWS	A
18.	*Cyperus iria*	AB	Con	LC, Bu, Cos, St, int st,	Sin	P	Dom	A	FWS	A
		AD	Con	LC, Bu, Cos, St, int st,	Str-Sin	P	Pa	A	FWS	A
19.	*Cyperus niveus*	AB	Con	LC, Bu, Cos, St, int st, Fus	Sin	P	Pa-Dom	A	FWS	A
		AD	Con	LC, Cos, St, int st,	Str to Sin	P	Dom	p	FWS	A
20.	*Cyperus nutans* subsp. *eleusinoides*	AB	Con	LC, Cos, St, int st,	Sin	P	Dom	P	FWS	A
		AD	Con	LC, Bu, Cos	Sin	A		A	A	A
21.	*Cyperus rotundus*	AB	Con	LC, Bu, Cos, St, int st,	Str-Wv-Sin	P	Dom	P	FWS	A
		AD	Con	LC, Bu, Cos, St, int st, Fus	Sin	P	Dom	A	FWS	A
22.	*Cyperus tenuispica*	AB	Con	LC, Bu, Cos, St, int st	Sin	P	Dom	A	FWS	A
		AD	Con	LC, Bu, Cos, St, int st, Fus	Str to Sin	P	Dom	p	FWS	A
23.	*Eleocharis geniculate*	AB	Con	LC, Bu, Cos, St, int st, Fus	Sin	P	Dom	P	FWS	A
		AD	Con	Bu, Cos, St, int st, Fus	Sin	P	Dom	P	FWS	A
24.	*Eleocharis mitracarpa*	AB	Con	LC, Bu, Cos, St, int st, Fus	Sin	P	Dom	P	FWS	A
		SH	Con	LC, Bu, Cos, St, Fus	Sin	P	Dom	A	A	A
25.	*Eleocharis palustris*	SH	Con	Bu, Cos, St, int st, Fus	Sin	P	Dom	A	Str	A
		SH	Con	LC, Cos, St, int st	Wv, Str	P	Dom	Ps	Str	A
26.	*Erioscirpus comosus*	AD	Con	LC, Bu, Cos	Sin to Wv	A		A		P
		AB	Con	LC, Bu, Cos, St, int st, Fus	Wv, Sin	P	Dom	P	FWS	A
27.	*Fimbristylis squarrosa*	AD	Con	LC, Bu, Cos, St, int st, Fus	Sin/Wv	P	Dom	P	FWS	A
		AB	Con	LC, Bu, Cos, St, int st,	Sin	P	Dom	A	FWS	A
28.	*Fimbristylis bisumbellata*	AD	Con	LC, Cos, St, int st,	Sin	P	Dom	A	FWS	A
		AB	Con	LC, Cos, St, int st,	Sin	P	Dom	P	FWS	A
29.	*Fimbristylis dichotoma*	AD	Con	LC, Cos, St, int st, Fus	Sin	P	Dom	A	FWS	A
30.	*Fimbristylis miliacea*	AB	Con	LC, Bu, Cos, St, int st,	Sin	P	Dom	P	FWS	A
		AD	Con	LC, Cos, St, int st, Fus	Sin	P	Dom	P	FWS	A
31.	*Kobresia laxa*	AB	Con	LC, Bu, Cos, St, int st	Sin	P	Dom	A	FWS	A
		AD	Con	LC, Cos	Sin	A		A	FWS	A
32.	*Kyllinga brevifolia*	AB	Con	LC, Cos, St, int st, Fus	Sin	P	Dom	P	FWS	A
		AD	Con	LC, Bu, Cos, St, int st, Fus	Sin	P	Dom	P	FWS	A
33.	*Pycreus flavidus*	AB	Con	LC, Bu, Cos, St, int st,	Sin	P	Dom	P	FWS	A
		AD	Con	LC, Cos, St, int st, Fus	Sin	P	Dom	P	FWS	A
34.	*Schoenoplectus mucronatus*	AB	Con	LC, Cos, St, int st	Sin	P	Dom	P	FWS	A
		SH	-	fus.	Str	A	..	….	….	A
35.	*Schonoplectus lacustrus*	SH	Con	LC, Bu, Cos, St, int st, Fus	Wv	P	Dom			A

Abbreviations: A=Absent, AB=Abaxial, CIZ=Costal and intercostal zonation, CS=Cell shape, Fn=Finger like, FWS=flushing with stomata, ICS=Inter stomatal cell, PR=Prickles, SCS=Subsidiary cell shape, SH=Sheath, ST=Stomata, Dom=Dome shaped, P=Present, Con =Conspicuous, WM=Wall Morphology, LC=Long cells, Cos=Costal, Fus=Fusiform, Sur =Surface PP=Papillae, Bu=Bulliforms, Int st=Interstomatal

Table 4. Quantitative features of leaf epidermis of sedges (Cyperaceae) form Swat Pakistan.

Names of the taxa		LCL (µm)	LCW (µm)	BuC L (µm)	Cos L (µm)	Cos W (µm)	StL (µm)	StW (µm)
		Min-Max (Mean)±SE)	Min-Max (Mean)±SE)	Min-Max (Mean)±SE)	Min-Max (Mean)±SE)	Min-Max (Mean)±SE)	Min-Max (Mean)±SE)	Min-Max (Mean)±SE)
Blysmus compressus	Ad	70-137.5(113.1)±8.8	15-45(29.5)±3.9	62.5-100(78.5)±3.8	20-87.5(46)±6.9	10-15(12.5)±0.7	37.5-45(40)±0.8	25-27.5(26.8)±0.4
	Ab	62-150(106.9)±10.2	10-15(12.3)±0.7	50-87.5(60.5)±3.6	12.5-100(50.5)±8.7	7.5-17.5(12.2)±1.6	35-42.5(39(±0.9	22.5-27.5(25.3(±0.7
Carex atrofusca	Ad	62.5-125(100)±8	15-27.5(21.3)±1.3	67.5-107.5(91.8)±4.6	37.5-112.5(73.8)±6.2	12.5-20(15.6)±1	37.5-42.5(38.8)±0.6	20-30(24)±1.1
	Ab	50-85(68.1)±4.3	15-25(17.8)±0.9	37.5-87.5(55)±5.3	25-92.5(54)±6.8	10-15(12.8)±0.6	20-37.5(33.8)±1.6	5-30(25)±2.4
Carex cardiolepis	Ad	50-95(73.8)±5.2	17.5-37.5(28.3)±2.4	-	12.5-37.5(27.3)±3.2	12.5-20(15.9)±0.8	32.5-42.5(37.3)±0.9	20-30(24.3)±0.9
	Ab	62.5-10083.4)±4.6	17.5-22.5(19)±0.6	37.5-75(86.3)±7.8	25-50(36)±2.8	10-15(11.9)±0.6	37.5-45(41.3)±0.8	22.5-32.5(28)±1.1
Carex divisa	Ad	50-112.5(86.3)±7.9	20-25(16)±0.6	30-100(67.5)±7.6	37.5-87.5(66.5)±4.7	10-20(14.1)±1.2	35-40(37.5)±0.6	22.5-27.5(25)±0.4
	Ab	62.5-112.5(90)±6	12.5-20(15.3)±0.9	30-75(51.8)±4.6	30-67.5(50.5)±4.1	12.5-17.5(14.49)±0.8	35-42.5(37.5)±0.7	25-37.5(27.8)±1.3
Carex duthiei	Ad	62.5-87.5(75.6)±2.6	20-30(23.8)±0.9	45-75(64)±2.6	50-100(73.3)±5	12.5-17.5(14.7)±0.7	-	-
	Ab	62.5-100(75.6)±4.9	12.5-17.5(14.7)±1.7	50-125(73.5)±7	45-75(58.8)±3.2	12.5-15(13.4)±0.5	47.5-52.5(49)±0.6	25-30(26.3)±0.6
Carex filicina	Ad	107-150(128.3)±4.7	25-37.5(31.4)±1.5	30-155(102.3)±11	25-102.5(61.6)±7.6	10-25(13.6)±1.5	-	-
	Ab	87.5-150(115.9)±8.7	17.5-27.5(22.5)±1.1	57.5-112.5(83.8)±5.9	37.5-80)62(±4.8	7.5-22.5(14.1)±1.8	45-57.5(51.3)±1.4	17.5-25(21.3)±0.7
Carex hymenolepis	Ad	50-87.5(66.9)±5.4	17.5-25(21.5)±1	-	12.5-50(26.5)±4.3	12.5-15(13.4)±0.5	30-52.5(33.8)±2.2	25-27.5(26.8)±0.4
	Ab	50-87.6(66.9)±3.2	10-17.5(13)±1	30-62.5(43)±2.9	12.5-65(37.3)±5.4	12.5-15(12.8)±0.3	32.5-40(35.5)±0.7	17.5-22.5(19.8)±0.6
Carex infuscata	Ad	60-82.5(71.6)±3	20-27.5(24.8)±0.7	-	17.5-55(37)±4	15-20(18.4)±0.8	-	-
	Ab	67.5-10083.4)±3.9	12.5-17.5(15.5)±0.7	30-82.5(60.5)±5.6	25-75(51.5)±4.5	10-15(13.1)±0.8	25-32.5(29.8)±0.8	25-27.5(25.5)±0.3
Carex melanantha	Ad	70-112.5(93.4)5.3	20-30(25.8)±1.1	62.5-105(78)±5.1	55-87.5(72)±3.6	15-20(18.4)±0.7	-	-
	Ab	50-80(65.3)±4	15-22.5(18.3)±0.8	37.5-60(48.3)±2.6	22.5-62.5(39.8)±4.3	10-15(13.1)±0.8	35-47.5(40)±1.2	25-30(26.5)±0.6
Carex otrubae	Ad	95-140115.9)±4.9	15-32.5(27.3)±2.1	-	12.5-47.5(29.8)±3.4	17.5-22.5(20)±0.7	22.5-25(24.5)±0.3	20-30(24)±0.8
	Ab	62.5-112.5(86.9)±5.7	15-20(17.5)±0.7	25-55(38.5)±3.8	25-90(61.8)±7.1	15-20(16.6)±0.8	20-37.5(32)±2.1	20-27.5(24.3)±0.8
Carex pseudocyperus	Ad	75-112.5(94.4)±4.6	15-22.5(19.8)±1	45-100(70.3)±5.5	35-87.5)58.5(±5.6	10-15(11.9)±0.6	37.5-50(46)±1.2	30-37.5(34)±0.7
	Ab	50-95(69.7)±5.8	15-20(19)±0.6	25-67.5(43.8)±4.4	-	-	30-47(37.5)±1.7	27.5-37.5(33.5)±1
Carex psychrophila	Ad	62.5-105(79.9)±5.7	20-30(23)±1	-	5-45(29.5)±4.3	7.5-15(11.9)±0.9	27.5-32.5(29.5)±0.5	20-25(22.8)±0.6
	Ab	35-75(54.1)±4.8	12.5-20(16.3)±0.9	25-55(37.8)±2.7	20-57.5(39.3)±4.3	10-20(15.9)±1.2	27.5-35(31.5)±0.7	25-32.5(29.3)±0.8
Carex remota subsp. *stewartii*	Ad	75-125(109.4)±6.6	15-30(21.8)±1.9		17.5-52.5(34)±3.9	7.5-12.5(10)±0.7	22.5-30(28.3)±0.8	20-37.5(26.5)±1.7
	Ab	62.5-135(95.9)±8.5	12.5-27.5(17.5)±1.7	50-100(74)±5.8	22.5-110(52.8)±9.4	7.5-15(11.6)±0.9	25-32.5(29)±0.9	20-27.5(22)±0.8
Carex sanguinea	Ad	62.5-137.5(104.7)±9.4	10-37.5(20.5)±3	75-125(103.8)5.7	22.5-87.5(55.3)±7	7.5-17.5(12.2)±1.1	32.5-50(39.8)±1.8	22.5-27.5(25.5)±0.5
	Ab	70-112.5(88.4)±5.8	15-35(24.3)±2	60-137.5(86.3)±7.8	17.5-65(39)4.9	12.5-20(15.6)±0.9	45-57.5(51)±1.4	25-40(34.3)±1.3
Carex schlagintweitiana	Ad	45-100(72.2)±6.8	15-22.5(18.8)±0.8	-	22.5-60(39.3)±4.3	12.5-15(13.4)±0.5	-	-
	Ab	45-112.5(71.6)±10.1	12.5-15(13.8)±0.4	37.5-77.5(56.3)±3.3	20-70(44)±4.6	7.5-12.5(10.3)±0.6	30-40(34.5)±0.8	17.5-22.5(20.5)±2.5
Cyperus alulatus	Ad	100-130(113.8)±4	10-37.5(23)±3.3	62.5-125(94.5)±7.5	45-190(90.8)±14.9	12.5-17.5(15.3)±0.6	30-37.5(33.8(±1	22.5-45(31.5)±2.8
Cyperus glomeratus	Ab	50-122.5(87.2)±8.1	12.5-25(17)±1.5	35-87.5(51)±5.1	42.5-100(75.8)±5.8	10-20(15.9)±1.6	37.5-42.5(38.8)±0.7	27.5-37.5(32.3)±1.1
	Ad	125-162.5(142.8)±5.2	25-45(38.8)±1.7	37.5-137.5(80.5)±10.1	37.5-92.5(79)±5.7	10-15(12.5)±0.7	30-40(35.8)±1.1	22.5-35(27)±1.4

Table 4. (Cont'd.).

Names of the taxa		LCL (µm)	LCW (µm)	BuC L (µm)	Cos L (µm)	Cos W (µm)	StL (µm)	StW (µm)
		Min-Max (Mean)±SE)	Min-Max (Mean)±SE)	Min-Max (Mean)±SE)	Min-Max (Mean)±SE)	Min-Max (Mean)±SE)	Min-Max (Mean)±SE)	Min-Max (Mean)±SE)
Cyperus iria	Ab	75-130(104.7)±5.7	15-35(26.8)±2.2	50-87(68.8)±4.1	45-127.5(69.8)±7.9	15-19(16.8)±0.5	6-11(8.5)±0.7	25-47.5(33.8)±2.3
	Ad	142-145(143.8)±1.3	42.5-50(45.8)±2.8	-	62-100(11.5)±19.8	12.5-15(14.2)±0.8	35-40(38.3)±1.7	27.5-30(28.)(±0.8
Cyperus niveus	Ab	77.5-112.5(100)±4.1	17.5-25(22.5)±0.8	-	35-95(75.3)±6.7	7.5-12.5(11.3)±0.7	37.5-40(39)±0.4	20-35(28.3)±1.3
	Ad	62.5-97.5(74.7)±3.6	15-20(17)±0.6	40-62.5(49.3)±2.4	20-57.5(41)±4.23	12.5-15(13.8)±0.5	-	-
Cyperus nutans subsp. *eleusinoides*	Ab	40-50(44.4)±1.3	12.5-15(13.3)±0.4	25-50(34)±2.7	30-50(40.8)±2.1	7.5-132.5(±12	22.5-25(24.3)±0.4	15-22.5(20)±0.7
	Ad	62.5-137.5(96.9)±8.4	12.5-30(20)±1.8	45-100(69.5)±5	-	-	25-35(31)±0.9	20-27.5(23.3)±0.8
Cyperus rotundus	Ab	75-112.5(92.1)±4	12.5-25(19.8)±1.2	50-87.5(67.3)±3.6	25-75(55.8)±5.2	12.5-25(20.6)±1.4	42.5-50(45.5)±0.7	30-40(33.3)±1.2
	Ad	87-237(144)±16.3	20-32.5(26.8)±1.4	100-187.5(136.3)±9.9	62.5-150(104.5)±9.1	17.5-22.5(20.3)±0.6	32.5-40(36.3)±0.7	15-20(18.3)±0.5
Cyperus tenuispica	Ab	67.5-112.5(89.1)±6	10-25(14.8)±1.5	37.5-95(64.5)±5.6	62.5-162.5(99.8)±9.5	10-12.511.3)±0.5	27.5-50(43.3)±2	20-27.5(22.8)±0.9
	Ad	-	-	62.5-125(82.3)±6.9	37.5-100(70.8)±6.2	12.5-17.5(15)±0.7	42.5-55(48.8)±1.3	25-32.5(28.3)±1.1
Eleocharis geniculata	Ab	87.5-125(109.7)±4.5	25-42.5(31.9)±2.2	52.5-11.5(80.3)±7.4	52.5-140(98.8)±9.2	12.5-20(16.6)±1	52.5-67.5(60)±1.3	32.5-42.5(38.5)±0.9
	Sh	30-50(41.4)±2.1	10-12.6(11.1)±0.4	25-56(34.8)±2.8	17.5-42.6(28.8)±2.7	10-12.6(1±0.6	25-36(28.8)±0.9	25-36(27.5)±1.1
Eleocharis mitracarpa	Sh	-	-	100-137.5(115)±3.5	62.5-100(77.3)±3.9	10-12.5(11.30)±0.5	35-40(38.8)±0.6	20-22.5(21.5)±0.4
Eleocharis palustris	Sh	100-262(181.6)±20.7	10-15(12.3)±0.4		30-100(56.5)±7.2	7.5-17.5(10.6) ±1	37.5-42.5(40.3)±0.7	20-22.5(21.5)±0.4
Erioscirpus comosus	Ad	35-57.5(45.9)±2.9	10-20(16.8)±1.2	37.5-65(48)±2.6	20-50(33.3)±3.1	12.5-22.5(15.3)±1.3	-	-
	Ab	50-85(66.6)±4.7	10-20(14.8)±0.9	30-75(46.5)±4.2	20-50(34.3)±2.8	12.5-20(17.5)±0.8	40-50(46)±1.1	25-32.5(28.3)±0.8
Fimbristylis squarrosa	Ad	67.5-150(122.5)±8.7	15-37.5(24.3)±3	42.5-137.5(85.8)±9.1	45-125(82.3)±8	15-22.5(18.4)±1.2	37.5-50(40.5±1.4	22.5-25(23.3)±0.4
	Ab	75-125(105.3)±5.4	17.5-30(23.3)±1.3	37.5-87.5(56.5)±4.8	45-135(95.5)±8.9	12.5-22.5(18.1)±1.3	22.5-30(26.3)±0.9	32.5-37.5(34.5)±0.6
Fimbristylis bisumbellata	Ad	62.5-92.5(81.9)±3.8	17.5-27.5(22.3)±1	-	27.5-77.5(49.3)±5.1	12.5-17.5(15.5)±0.8	30-40(35)±1.1	22.5-27.5(26)±0.6
	Ab	55-82.5(74.7)±3	17.5-22.5(20.5)±0.6	-	30-105(60.8)±8.2	12.5-17.5(14.1)±0.7	30-47.5(42.5)±1.7	25-47.5(33.8)±2.3
Fimbristylis dichotoma	Ad	70-105(89.2)±3.7	22.5-42.5(30.5)±2.4	-	25-62.5(47.8)±0.3	10-22.5(16.6)±1.7	32.5-42.5(38.8)±0.9	20-32.5(27.3)±1.2
Fimbristylis miliacea	Ab	87-142.5(118.8)±6.3	22.5-35(28.3)±1.4	25-127.5(85.8(±9.1	40-125(75)±9.2	10-22.5(15.3)±1.4)	42.5-52.5(47.5)±1.1	22.5-30(26.3)± 0.7
	Ad	62.5-125(93.8)±7.8	17.5-45.5(25.8)±2.7	-	55-90(73)±4.1	10-17.5(12.8)±1	37.5-42.5(39.5)±0.6	20-27.5(24.3)0.8
Kobresia laxa	Ab	62.5-137.5(98.1)±9.2	17.5-2520.5)±0.8	50-80(67.8)±3.6	42.5-100(78)±5.5	10-17.5(13.8)±0.9	47.5-55(50.8)±0.7	25-30(28.5)±0.6
	Ad	50-125(88.4)±9.1	12.5-25.5(18.3)±1.1		20-100(54.5)±8	12.5-20(15.9)±1.2		
Kyllinga brevifolia	Ab	57.5-120(93.1)±7.6	10-20(15)±0.9	55-100(79)±4.3	30-77.5(48.3)±4.4	7.5-15(10.3)±1	27.5-37.5(31.3(±0.9	22.5-35(26)±1.5
	Ad	87.5-137(117.8)±5.4	10-42.5(26.5)±3.4	30-75(57.3)±5	37-105(72.3)±7.5	10-15(13.1)±0.6	27.5-32.5(30)±0.6	17.5-22.5(19.5)±0.5
Pycreus flavidus	Ab	37.5-125(89.1)±11.8	10-22.5(15.3)±1.1	42.5-100(66.5)±5.7	32.5-87.5(66)±6.7	7.5-20(12.8)±1.5	27.5-35(30.8)±0.7	25-27.5(26.5)±0.4
	Ad	10-167(126.9)±8.3	17.5-30(24)±1.7	-	50-97.5(77.8)±5.4	17.5-22.5(20)±0.7	37.5-52.5(47)±1.4	25-40(32)±1.6
Schoenoplectus mucronatus	Ab	95-142(117.8)5.4	15-22(19.8)±0.9	28-115(95)±10.1	-	-	37.5-47.5(41)±1.2	25-30(27.3)±0.7
	Sh	-	-	-	-	-	-	-
Schonoplectus lacustris	Sh	60-100(75)±5.2	17.5-22.5(19.5)±0.6	50-75(64.5)±2.6	45-75(62.5)±3.5	10-12.5(11.6)±0.5	50-52.5(51)±0.4	2.5-27.5(25.5)±0.5

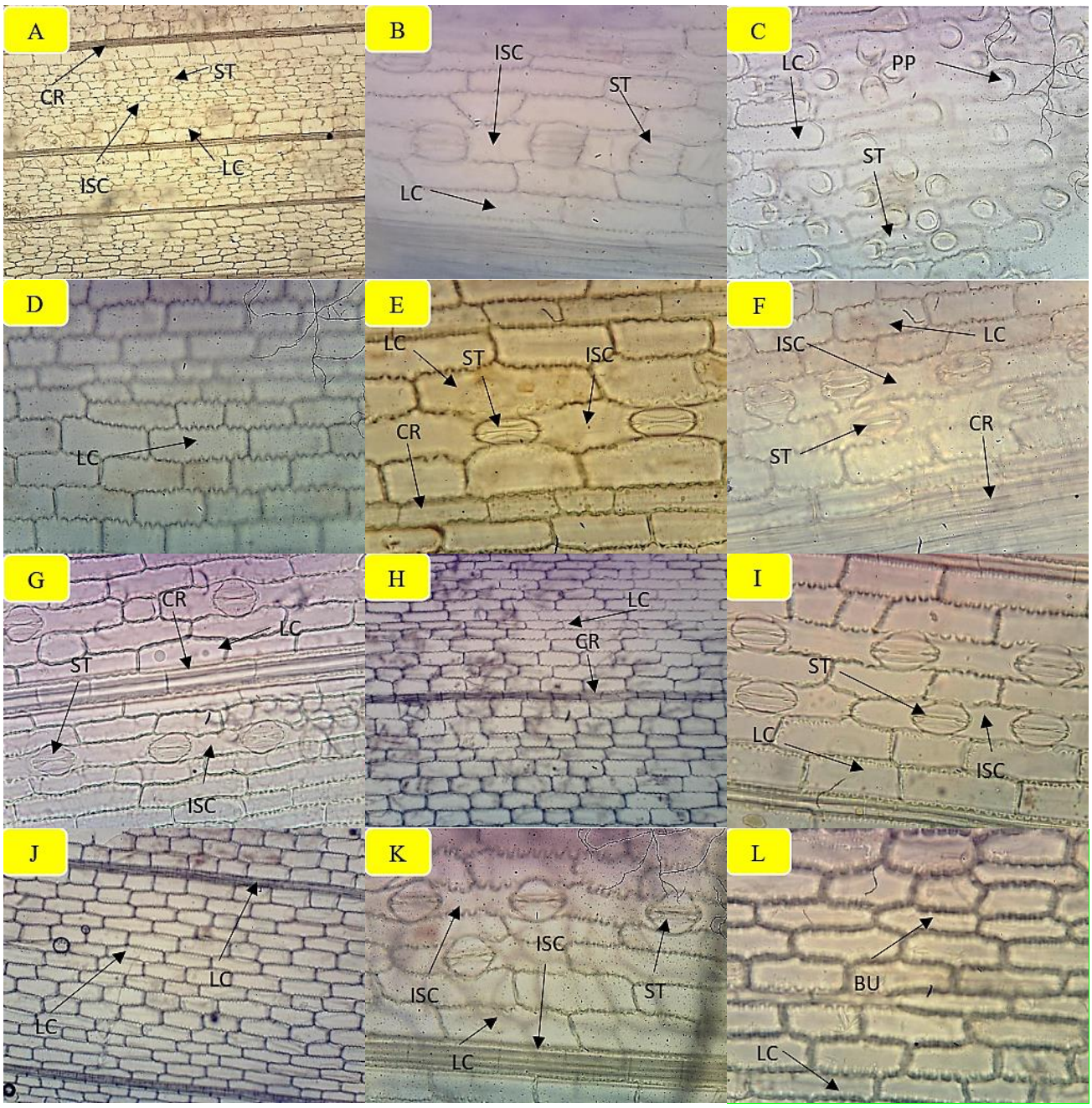

Fig. 4. **A-B**, *Cyperus glumeratus***; C-D,** *Carex infuscata***; E-F,** *Fibristylis dichotoma;* **G-H,** *KyLlinga brevIfolia* **I-J**, *Cyperus iria;* **K-L** *Cyperus nutans.*
Key. ST, stomata; **ICS**, inter stomata cells; **CR**, costal region; **BU,** bulliform cells; **LC,** long cells; **PP,** papillae; **PR,** prickles

In the present study all the species have conspicuous costal and inter-costal zonation except the sheath of *Schoenoplectus mucronatus.* Mostly the walls of mid intercostal cell were sinuous however the adaxial surface of *Cyperus iria*, *Cyperus rotundus* and *Blysmus compressus* showed sinuous to straight wall morphology. The sheath of *Schoenoplectus lacustris* shows wavy wall while in *Schoenoplectus mucronatus* walls were straight (Fig. 4).

Stomata were common on the abaxial surface. Stomata were absent on the adaxial surface of *Cyperus nievus, Carex filicina, Kobresia laxa, Erioscirpus comosus, Carex schlagintweitiana, Carex infuscata, Carex melanantha,* and *Carex duthiei.* Moreover, subsidiary cells were dome shaped (Fig. 4).

The occurrence of papillae is considered to be useful at generic level (Ullah, 2009). Two types of papillae were observed in the present study viz., small round and finger-like. Finger-like papillae were found in species of *Carex.* Metcalfe (1960) has already emphasized the role of papillae in taxonomy. Prickles were not of common occurrence. However, *Erioscirpus comosus, Carex sanguinea, Carex cardiolepis, Carex schlagintweitiana,* and *Carex melanantha* showed the presence of prickles.

The present study showed the absence of trichome, micro-hairs and silica bodies. Though the distinctive silica bodies are reported in Poaceae. Their occurrence and arrangement are very useful in grouping Poaceae (Prat, 1960). The absence of trichome, micro-hairs and silica bodies distinguishes Cyperaceae from Poaceae.

Table 5. List of voucher specimens of Cyperaceae of Swat Pakistan.

Name of the species	Collector	Locality	Voucher number
Bolboschoenus glaucus	Nasar Ali	Shamozai	NA-304
Schoenoplectus rechingeri	Zahid Ullah	Shamozai	NA-11
Schoenoplectus mucronatus	Zahid Ullah	Matta	NA-307
Blysmus compressus subsp. *brevifolius*	Zahid Ullah	Mahodand	NA-309
Isolepis setacea	Nasar Ali	Miandam	NA-331
Erioscirpus comosus	Nasar Ali	Charbagh	NA-427
Eleocharis mitracarpa	Zahid Ullah	Charbagh	NA-310
Eleocharis palustris subsp. *iranica*	Nasar Ali, Rahman Ali	Matta	NA-271
Eleocharis tetraquetra	Zahid Ullah, Aftab Khan	Baghderai	NA-12
Fimbristylis falcata	Nasar Ali	Shamozai	NA-31
Fimbristylis miliacea	Zahid Ullah	Barikot	NA-36
Fimbristylis quinquangularis	Nasar Ali, Zahid Ullah	Barikot	NA-56
Fimbristylis dichotoma	Zahid Ullah	Matta	NA-57
Fimbristylis bisumbellata	Nasar Ali	Matta	NA-81
Bulbostylis barbata	Nasar Ali	Shamozai	NA-90
Cyperus rotundus	Nasar Ali, Zahid Ullah	Kanju	NA-317
Cyperus nutans subsp. *eleusinoides*	Zahid Ullah	Chota Kalam	NA-322
Cyperus alulatus	Zahid Ullah	Matta	NA-335
Cyperus iria	Zahid Ullah	Matta	NA-339
Cyperus compressus	Nasar Ali, Zahid Ullah	Marghuzar	NA-265
Cyperus niveus	Nasar Ali, Zahid Ullah	Kanju	NA-278
Cyperus tenuispica	Nasar Ali	Barikot	NA-254
Cyperus difformis	Nasar Ali, Zahid Ullah	Shakar Dara	NA-255
Cyperus squarrosus	Zahid Ullah	Mingora	NA-41
Cyperus cyperoides	Nasar Ali	Mingora	NA-43
Pycreus sanguinolentus	Nasar Ali, Zahid Ullah	Matta	NA-367
Pycreus flavidus	Nasar Ali	Barikot	NA-393
Pycreus flavescens	Nasar Ali	Hazara	NA-213
Kyllinga brevifolia	Nasar Ali, Zahid Ullah	Matta	NA-332
Kobresia laxa	Nasar Ali	Mankyal	NA-68
Kobresia capillifolia	Nasar Ali	Utror valley	NA-305
Kobresia nepalensis	Nasar Ali, Zahid Ullah	Chukail meadow	NA-321
Carex filicina	Nasar Ali, Zahid Ullah	Miandam	NA-314
Carex sanguinea	Nasar Ali, Zahid Ullah	Miandam	NA-353
Carex otrubae	Nasar Ali, Zahid Ullah	Miandam	NA-377
Carex divulsa subsp. *leersii*	Nasar Ali, Zahid Ullah	Gabral	NA-370
Carex wallichiana	Nasar Ali, Zahid Ullah	Gabin Jabba	NA-369
Carex remota subsp. *stewartii*	Nasar Ali, Zahid Ullah	Kandol lake	NA-341
Carex fedia	Nasar Ali, Zahid Ullah	Miandam	NA-348
Carex serotina	Nasar Ali, Zahid Ullah	Shahi Bagh	NA-312
Carex cardiolepis	Nasar Ali, Zahid Ullah	Lalku	NA-345
Carex schlagintweitiana	Nasar Ali, Zahid Ullah	Malam Jabba	NA-72
Carex hymenolepis	Nasar Ali, Zahid Ullah	Nelawai	NA-405
Carex turkistanica	Nasar Ali, Zahid Ullah	Utror valley	NA-237
Carex psychrophila	Nasar Ali, Zahid Ullah	Miandam	NA-388
Carex atrofusca	Nasar Ali, Zahid Ullah	Mahodand	NA-383
Carex infuscata	Nasar Ali, Zahid Ullah	Miandam	NA-313
Carex duthiei	Nasar Ali, Zahid Ullah	Spin Sar	NA-45
Carex nivalis	Nasar Ali, Zahid Ullah	Kandol lake	NA-401
Carex pseudobicolor	Nasar Ali, Zahid Ullah	Gabral valley	NA-431
Carex dimorpholepis	Nasar Ali, Zahid Ullah	Jarogo banda	NA-366

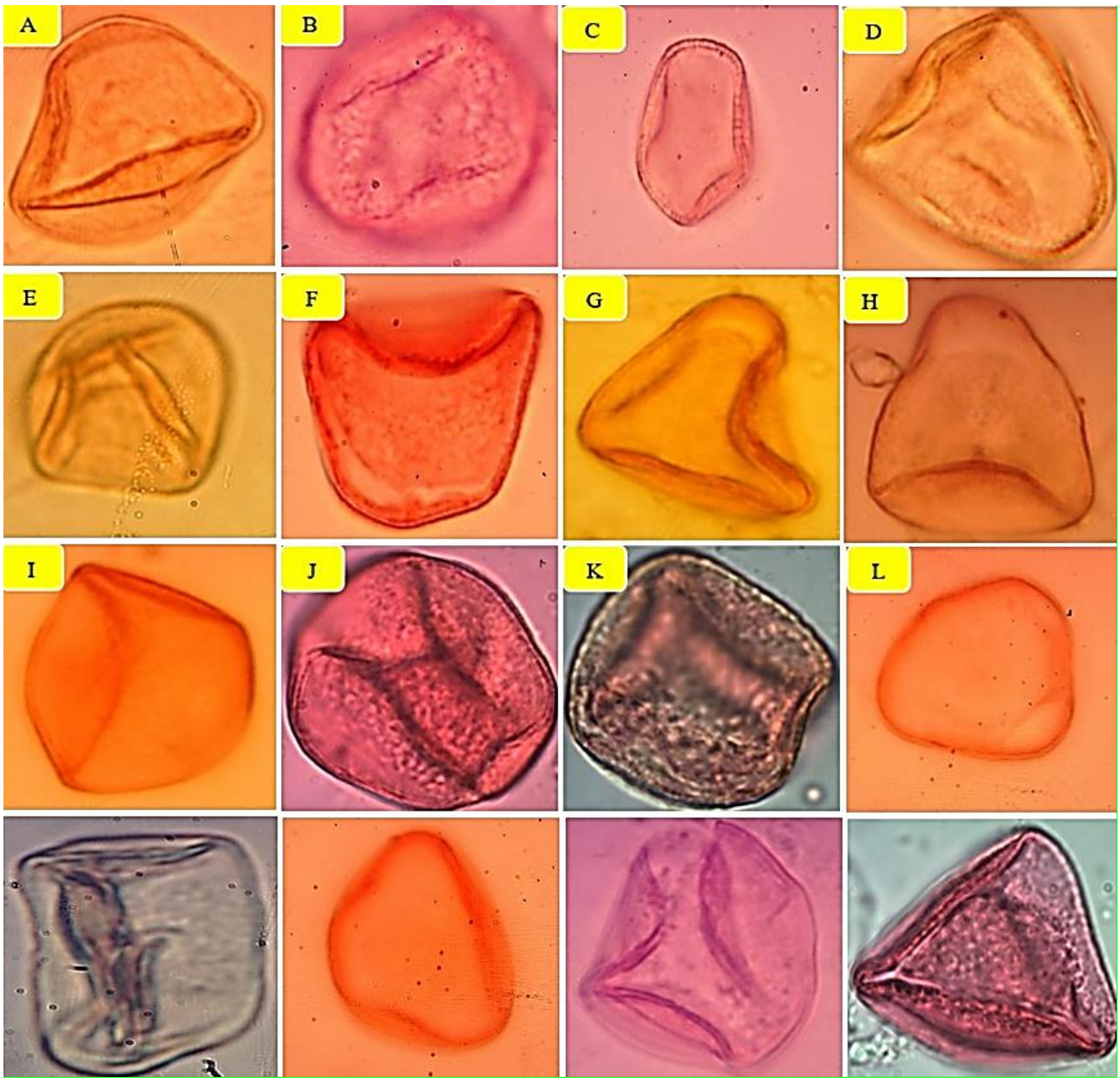

Fig. 5. Diversity of pollens in Cyperaceae. **A**, *Schoenoplectus lacustrus;* **B**, *Cyperus glumeratus;* **C**, *Cyperus tenuispica;* **D**, *Cyperus alulatus;* **E** *Pycreus flavidus;* **F**, *Carex filicina;* **G**, *Carex atrofusca;* **H**, *Carex infuscata;* **I**, *Carex cardiolepis;* **J** *Carex duthiei;* **K**, *Carex melanantha;* **M**, *Carex remota;* **N**, *Carex otrubae;* **O**, *Carex sanguinea;* **P**, *Eleocharis geniculate*.

Conclusion

It is concluded that systematic studies based on multivariate approaches provide clearer picture of relationship among the studied taxa. Further it is suggested that SEM observation of pollen grain and molecular data will also be helpful in taxonomic study of the family.

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